DELAWARE SOLID WASTE AUTHORITY

prepared for:

Delaware Solid Waste Authority
1128 S. Bradford Street
Dover, Delaware 19903

Volume 15:
Hydrogeologic Assessment Reports III

Cherry Island Landfill Expansion Project
Wilmington, Delaware

prepared by:

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HYDROGEOLOGIC ASSESSMENT REPORTS III:

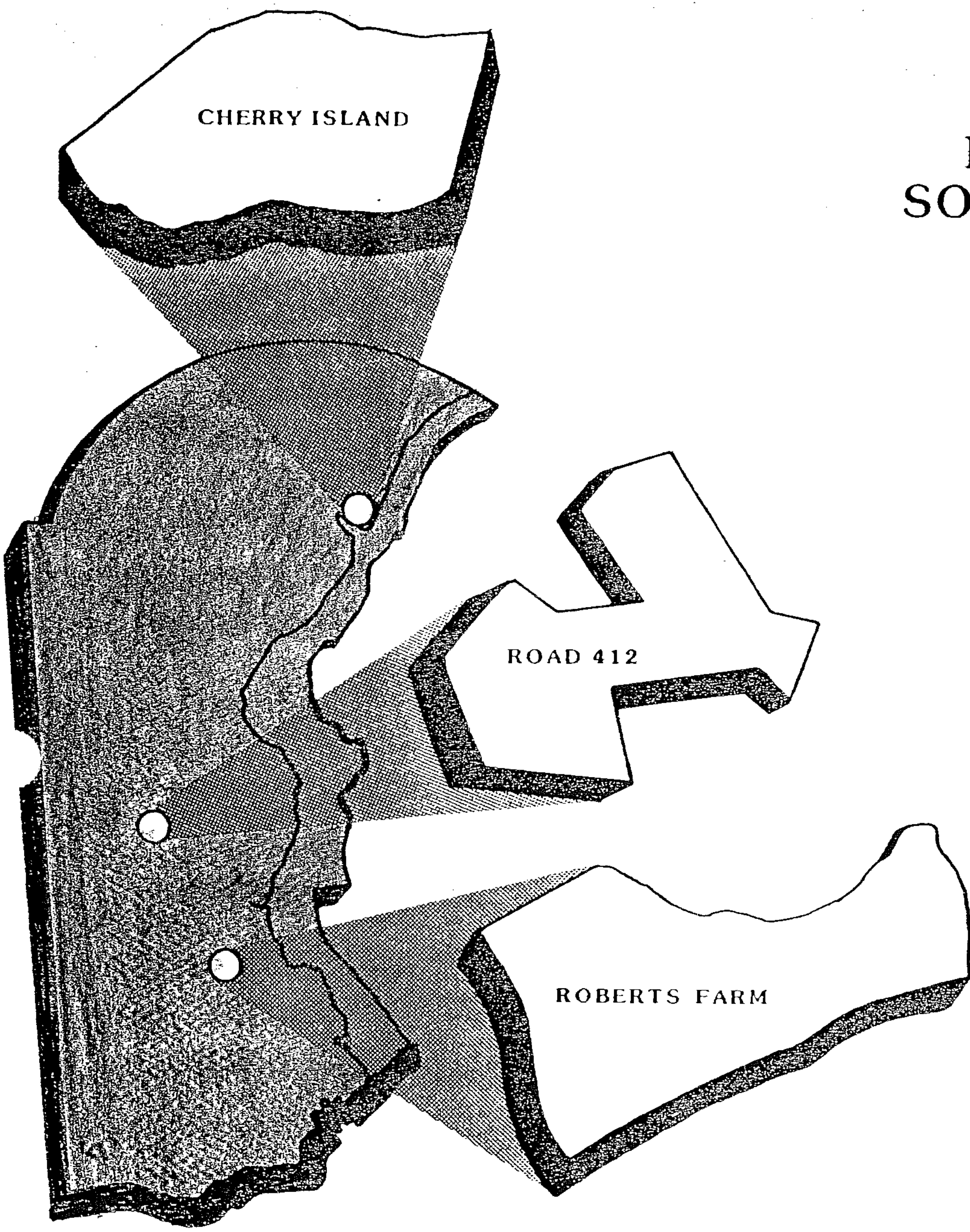
1. Gilbert Associates, "Site Suitability Study for the Northern Solid Waste Facility," prepared for the Delaware Solid Waste Authority, January 1982.

2. Gilbert Associates, "Site Suitability Study for the Northern Solid Waste Facility – Supplemental Report, Responses to Agency Comments" prepared for the Delaware Solid Waste Authority, February 1982.

3. Roy F. Weston, Inc., "Northern Solid Waste Management Center – Cherry Island Landfill, Phase V Disposal Area, Hydrogeologic, Geotechnical and Landfill Capping Report," prepared for the Delaware Solid Waste Authority, March 1995.

1. Gilbert Associates, "Site Suitability Study for the Northern Solid Waste Facility," prepared for the Delaware Solid Waste Authority, January 1982.

SITE SUITABILITY STUDY



for the

NORTHERN SOLID WASTE FACILITY

DELAWARE SOLID WASTE AUTHORITY

Gilbert/Commonwealth
ENGINEERS/CONSULTANTS Reading PA / Jackson [illegible]

SITE SUITABILITY STUDY
FOR THE
NORTHERN SOLID WASTE FACILITY
NEW CASTLE COUNTY, DELAWARE

JANUARY 1982

DELAWARE SOLID WASTE AUTHORITY
DOVER, DELAWARE

GILBERT/COMMONWEALTH
ENGINEERS/CONSULTANTS
READING, PA/JACKSON, MI

ACKNOWLEDGEMENTS

This report entitled "Site Suitability Study for the Northern Solid Waste Facility" was prepared by Gilbert Associates, Inc., Reading, Pa. on behalf of the Delaware Solid Waste Authority. The report is a culmination of months of concerted effort both by Gilbert Associates personnel assigned to the project and by members of the Authority's Staff and Board of Directors.

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- State of Delaware, Department of Natural Resources & Environmental Control, Division of Environmental Control:
  - Water Resources Section
  - Wetlands Section
  - Solid Waste Section

- State of Delaware, Department of Natural Resources & Environmental Control, Division of Fish and Wildlife
- State of Delaware, Department of Transportation, Division of Highways
- State of Delaware, Division of Historical and Cultural Affairs
- New Castle County Department of Planning
- Water Resources Agency for New Castle County
- Wilmington Metropolitan Area Planning Coordinating Council
- City of Wilmington, Planning Division
- Delaware Geological Survey

SITE SUITABILITY STUDY
FOR THE
NORTHERN SOLID WASTE FACILITY
NEW CASTLE COUNTY, DELAWARE

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1.0 EXECUTIVE SUMMARY

1.1 INTRODUCTION

In January 1981, Gilbert Associates, Inc., was retained by the Delaware Solid Waste Authority to obtain factual information on five candidate sites pre-selected by the Delaware Solid Waste Authority for the location of the proposed Northern Solid Waste Facility (NSWF), a sanitary landfill. In February 1981, Gilbert Associates completed this assignment and presented to the Delaware Solid Waste Authority a report entitled "Site Information on Candidate Sites of Proposed Northern Solid Waste Facility." The information contained within that report, along with other information received from the public during the public comment period, enabled the Authority to reduce the number of sites to three in March 1981.

In April 1981, the Delaware Solid Waste Authority authorized Gilbert Associates to investigate in more detail the three sites which were chosen for further consideration. These three sites were:

- o Cherry Island
- o Road 412
- o Roberts Farm

The location of each site is shown in Figure 1.0-1.

This investigation by Gilbert Associates has culminated in a report which will provide the Authority with the details and information needed to rank the sites for the NSWF which is an integral part of the Authority's program to provide effective, efficient, and environmentally sound solid waste management for New Castle County. Combined with the solid waste and sewage sludge processing facilities under construction at Pigeon Point, New Castle County soon will have one of the most advanced solid waste management systems in the nation.

This Executive Summary is an overview of the findings of the investigation mentioned above. It provides general information regarding the study methodology and the characteristics of each of the candidate sites. The Summary Matrix, Table 1.2-1, presents in a tabular form pertinent information about each of the candidate sites.

1.2 STUDY METHODOLOGY

The three candidate disposal sites were evaluated by a team of scientists and engineers. Their study methodology incorporated siting criteria developed as a consequence of over 6 months' worth of public meetings and hearings conducted under the auspices of the Delaware Solid Waste Authority, to solicit input from both the public and private sectors; existing Delaware Department of Natural Resources and Environmental Control regulations; applicable United States Environmental Protection Agency regulations; and other applicable State or Federal guidelines. Each site is described in terms of area, location, and pertinent physical features. The pertinent considerations used in the analysis of each site included:

- o Engineering Considerations
- o Environmental Considerations
- o Transportation Considerations
- o Regulatory Considerations
- o Cost (Economic) Considerations

The engineering considerations dealt with:

- o geology/hydrogeology
- o hydrology (drainage)

- flood plains/wetlands/streams
- estimated site capacity/longevity
- cover material needs
- screening

Environmental considerations of importance were:

- ecology (existing flora and fauna)
- land use
- zoning
- demography
- cultural, recreational, and natural areas
- historic sites
- aesthetics

Transportation considerations included reviews of:

- highway access
- rail access
- waterway access

Regulatory considerations of significance having potential impact upon the analysis of each site were:

- Delaware regulations for solid waste disposal
- Federal regulations developed under the Resource Conservation and Recovery Act (RCRA) dealing with floodplain siting, endangered species, wetlands, and groundwater
- Federal Aviation Administration criteria

Cost considerations were:

- estimated landfill development costs
- estimated landfill operational costs
- estimated hauling costs

24. 5,068,400
25. 5,341,500
26. 5,620,000
27. 5,904,000
28. 6,193,600
29. 6,488,800

28.35 30.171

TABLE 1.2-1
SUMMARY MATRIX CANDIDATE SITES FOR NSWF

	ROAD 412 (29659 T/A)	ROBERTS FARM (25091 T/A)	CHERRY ISLAND (24844 T/A)
1. Total Area of Properties (Acres)	259	720	350
2. Potential for Expansion	Yes (South)	Yes (South)	Yes (West)
3. Estimated Acreage for Expansion	90	80	150
4. % of Total Area - Flood Plains/Wetland	None	36%	None
5. % of Total Area - Prime Farmland	65%	60%	None
6. % of Total Area - Woodland	None	6%	None
7. Estimated Usable Area (Acres)	171 (7.125)	202 (8.4167)	215* (8.6)
8. Estimated Site Life (Years)	24	24	25
9. Est. One-Way Mileage From DRP	19.5	27.6	3.4
10. Est. Population within 300 Yds. of Site	50	16	None
11. Historic Properties on Site	2	3	None
12. Historic Properties within 300 Yds. of Site	2	2	None
13. Current Zoning	R-2 (Agricul. and Gen. Purp.)	R-2 (Agricul. and Gen. Purp.)	Light Mfg. and Gen. Mfg.
14. Proposed Future Land Use	Post 1985 Indus. Development	Post 1985 Coastal Zone Industrial Development	Light and Heavy Industry; Multi-use Park
15. Public Utilities Potentially Available	None	Yes (Sewer)	Yes (Water and Sewer)
16. Critical Habitat of Endangered/Threatened Species	None	None	None
17. Distance from Nearest Railroad	1.5 Miles	4.0 Miles	0.1 Miles
18. Distance from Nearest Airport	2.4 Miles	7.2 Miles	4.7 Miles
19. No. of Aquifers within Surficial 200'	4	3	2
20. Aquifer Subcrop Area	Yes	No	No
21. Natural Resource Protection Area	No	No	No
22. Major Groundwater Flow Directions	SE-NE	S-N	S
23. Flow Towards Wells	SE (NO) - NE (YES)	S (NO) - N (NO)	NO
24. Soil Thickness in Useable Area	4'-27'	4'-27'	Dredge Spoil Deposits are ~ 35' deep
25. Suitability of On-Site Soils for Cover Material	Soils Suitable	Soils Suitable	Not Suitable unless dewatered
26. Estimated Quantity of Cover Soils to be Imported for Operation of Site	None	232,000 c.y.	2,731,000 c.y
27. Screening Needed	Yes	Yes	No
28. Estimated Capital Needed for Start-up	$3,476,500	$4,693,500	$17,559,000** ($ 4,758,000)***
29. Highway Improvement Costs	$ 960,000	$1,050,000	None
30. Estimated 1st Year Operating Cost	$1,190,000	$1,185,000	$1,956,000
31. Estimated 1st Year Hauling Cost	$1,526,000	$1,959,000	$ 663,000
32. Initial Year Total Tonnage Cost (For wastes hauled to and landfilled at the NSWF)	$20.35/Ton	$23.90/Ton	$29.06/Ton** ($19.88/ton)***
33. Total Project Cost Over 20-Year Planning Period	$186,416,000	$222,662,000	$281,163,000** ($194,272,000)***

* Area represented by the Edgemoor dredge disposal site
** Alternative 1 - Lined facility with leachate collection
*** Alternative 2 - Unlined facility with leachate collection

78,256 70,978 165,000 1/way mi

1,040,152 1,102,287 903,590 /acre

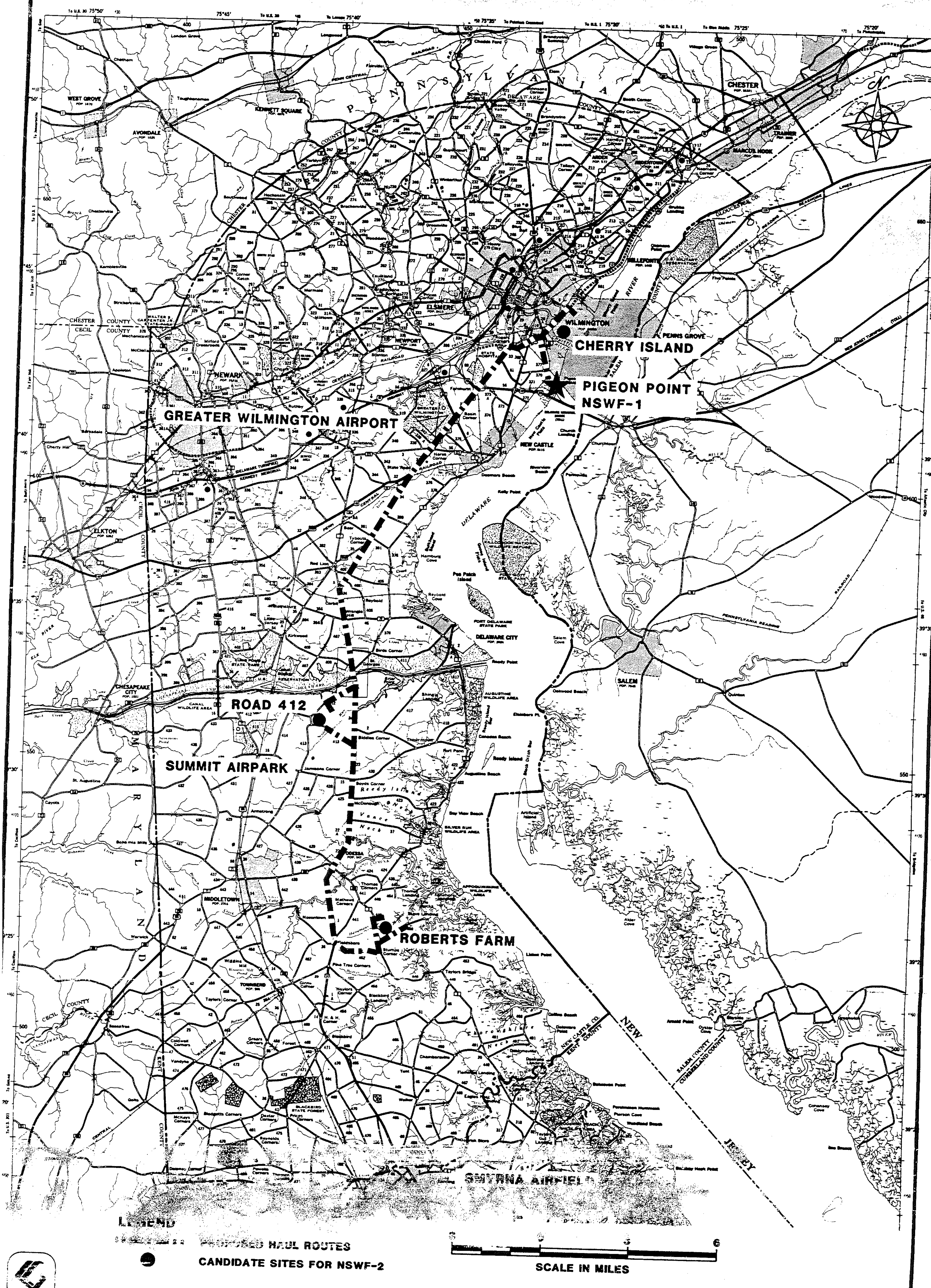


FIGURE 1.0-1
SITE LOCATION MAP

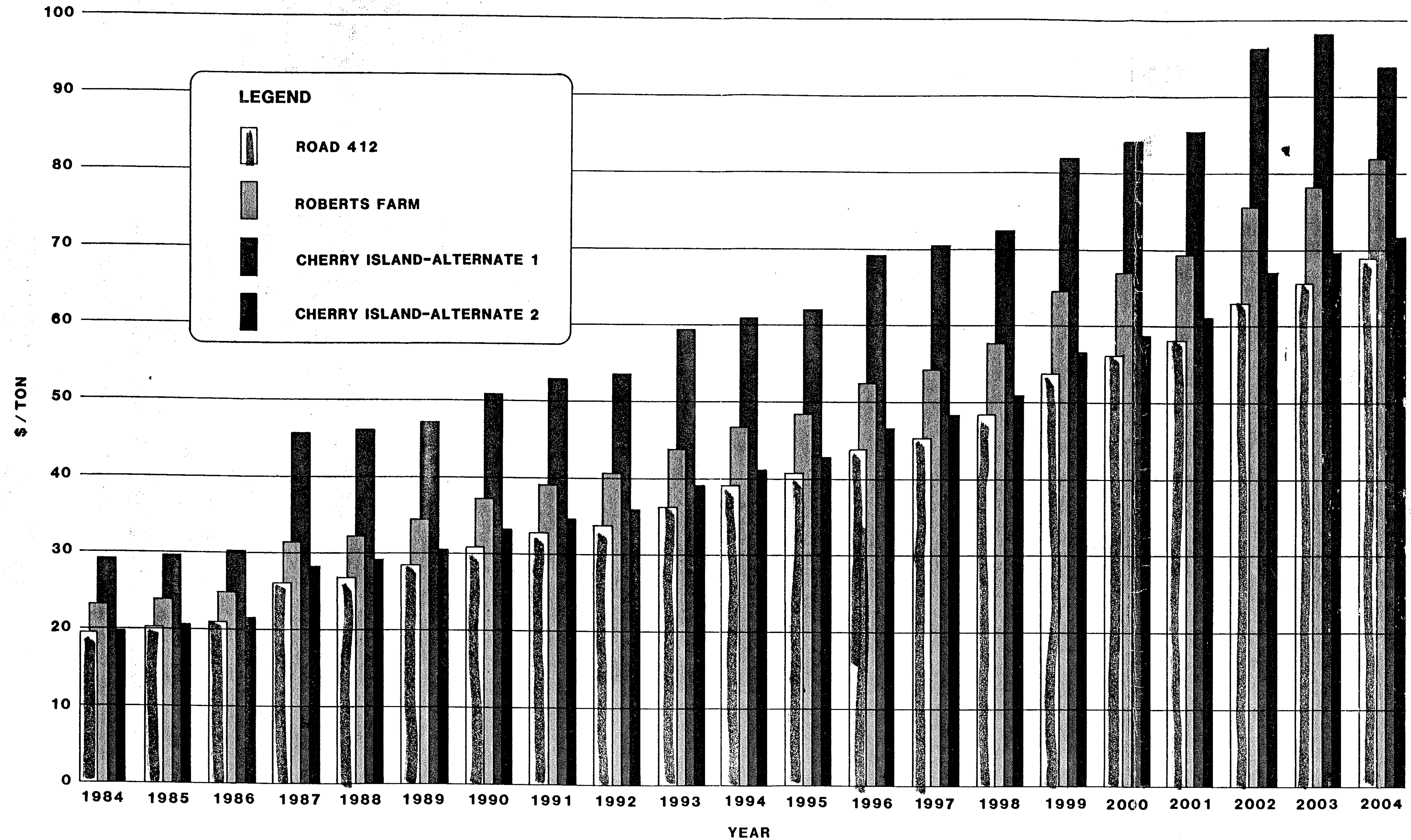


FIGURE 1.0-2
ANNUAL COST COMPARISON
($ / TON OF WASTE LANDFILLED)

Solid waste generation rates utilized in the economic analyses and for determining site lives were based upon data provided by the Delaware Solid Waste Authority. The anticipated waste generation for the initial, tenth, and 20th years of the project are as follows:

Year	Total Waste Stream (tons)	Yearly Total of Wastes to be Landfilled (tons)	Cumulative Wastes Landfilled (tons)
1	380,000	159,000	159,000
10	419,000	198,000	1,784,000
20	468,000	247,000	4,029,000

1.3 ROAD 412

The Road 412 site encompasses approximately 260 acres of primarily open farmland located about 5.5 miles north of Odessa, Delaware, and less than a mile south of the C & D Canal. The elevation* of the site varies from 24 feet to more than 77 feet, with the majority of the site at elevation 50 or greater. Little upgradient runoff flows onto the site which is situated on the northeast extremity of a ridge. Drainage of surface runoff from the site is of more critical importance at this site, but can be controlled with a variety of engineering measures such as berms, swales, diversion ditches, sedimentation basins, and other velocity reduction techniques.

The Road 412 site is situated in the Coastal Plain Physiographic Province and is underlain by a thick sequence of sediments containing four aquifers within the top 200 feet. These aquifers are the Pleistocene water table aquifer and the subcropping Mount Laurel aquifer, the Englishtown confined aquifer, and the Magothy confined aquifer.

*Datum: Mean Sea Level

The Pleistocene water table aquifer and the subcropping Mount Laurel aquifer can be treated as one. It is variable across the site and flow directions are numerous. If the liner and leachate collection system were to fail and no corrective actions were taken, contamination could enter the aquifer. The flow of the contaminated water also would be multi-directional and, if no corrective actions were taken, surface water contamination of Scott Run could occur. Geologic data pertaining to use of the water table aquifer in the Road 412 area indicates 20 domestic wells may be present.

The Englishtown aquifer is a principal source of water to residents located south of the C & D Canal. This aquifer is confined by the Marshalltown Formation at the Road 412 site. The water yielding properties of the aquifer are fair to poor and potentiometric surface data indicates that vertical seepage of leachate to the aquifer is possible should a liner and leachate collection system fail and no corrective actions are taken. Flow within the aquifer is towards the northeast.

The Magothy aquifer is confined by the Merchantville Formation and has poor water yielding properties based on its limited thickness and silty nature. Potentiometric surface data also indicates that vertical seepage of leachate to this aquifer is possible should a landfill liner and leachate collection system fail and no corrective actions are taken. Flow within the aquifer is towards the southeast or away from the residential Magothy wells in the area.

Useable thicknesses of soil for cover materials are variable across the site ranging from 4 feet to 27 feet. These soils are suitable for use as daily or final cover materials.

[redacted]. Considering the above limiting condition and the property line setback of 200 feet established by the Authority, it is estimated that approximately 171 of the estimated total 260 acres are usable for landfilling purposes.

Allowing for a nominal 40 feet landfill height above the existing grade, the estimated service life of this candidate site is approximately 24 years. It appears that sufficient cover materials for the routine operation of the landfill as well as sufficient materials for protective cover for a synthetic membrane liner are available on site. See Figure 1.3-1.

Screening of the site, particularly along Road 412, would probably be necessary.

Since, at any one time, landfilling will be confined to a small portion (20-30 acres) of lands presently under cultivation and will not infringe upon any wooded areas or marshy areas adjacent to the site, the effects of a landfill facility upon the existing wildlife habitat are expected to be minor. They primarily will consist of increased levels of activity and noise in those portions of the site being filled or utilized as stockpile and/or borrow areas for the storage and/or acquisition of cover materials. Since the site would ultimately be returned to open space uses, its value for wildlife is not expected to be diminished from the current situation.

The site is adjacent to the Chesapeake and Delaware Canal Wildlife Area. It is expected that the wildlife, especially whitetail deer, would occasionally move south of Road 412 to feed in the cultivated areas of the site. Other than its use as a feeding area, the site presents little in the way of wildlife habitat because of its extensively cultivated condition.

No permanent streams are on site. However, Scott Run flows in a northeasterly direction just beyond the site. No information on water quality or fish population for Scott Run is available.

Although it is reported that bald eagles or peregrine falcons could be sighted on occasion at the Road 412 Site, this site is not located near any known historic or existing bald eagle nesting sites.

The Road 412 site is located in the Middletown-Odessa-Townsend Planning District. The site currently is zoned R-2 (Agricultural and General Purpose). Approximately 65% of the total area is classified as prime farmland (Class I and Class II soils). The proposed site is located entirely within an area designated as Post-1985 Industrial Development. The exception to this are two very small areas associated with tributaries to Scott Run and the C & D Canal which have been designated as Resource Protection.

It is estimated that about 50 persons reside within the 16 dwellings situated within 300 yards of the Road 412 site, assuming a population density of 3.12 persons per household as derived from county census data. Other than the C & D Canal Wildlife Area north of the site, no cultural, recreational, or natural areas are within 300 yards of the proposed boundaries of the site.

There are no National Register Historic Sites in the vicinity of the site. However, the site contains two structures and there are two structures located within 300 yards of the site which have been identified by the State Division of Historical and Cultural Affairs as having unique architectural significance.

The total one-way mileage to the Road 412 Site from Pigeon Point is 19.5 miles. U.S. Route 13 comprises 15.6 miles of this. The conditions of the roads along the suggested haul route (See

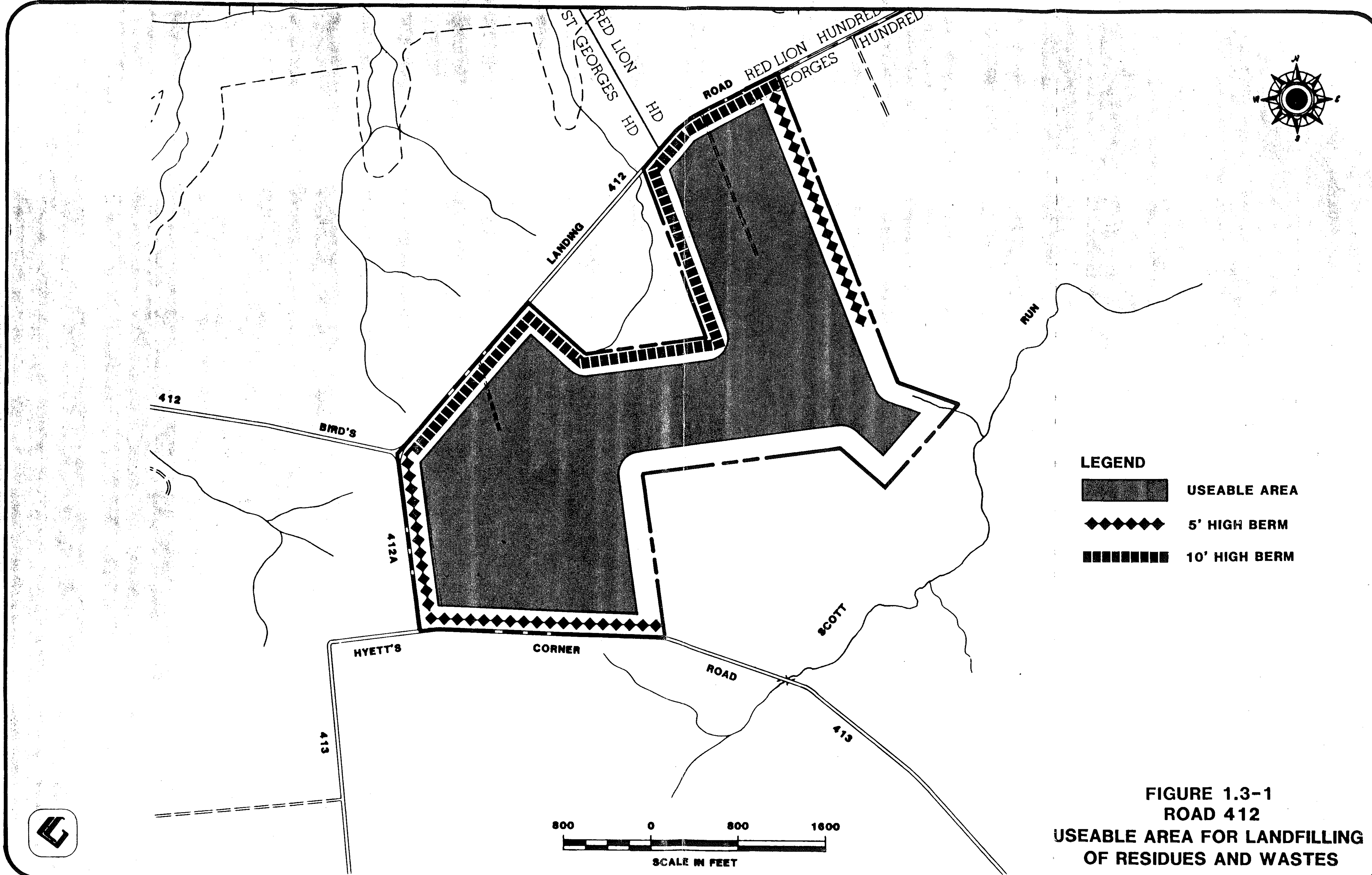


FIGURE 1.3-1
ROAD 412
USEABLE AREA FOR LANDFILLING
OF RESIDUES AND WASTES

Figure 1.0-1) are good to excellent with the exception of State Roads 412 and 413. These would be considered to be in fair condition and would have to be upgraded from their respective intersections with U.S. 13 to termination at the site in order to satisfactorily handle the increased traffic associated with the development of a landfill at this site.

Both rail access and waterway access (barging) were considered but determined not to be practical as alternative methods of transportation.

Start-up capital cost for landfill development at this site is estimated at approximately $3.5 million (1984 dollars). Initial year operating expenses are estimated at approximately $1.2 million (1984 dollars). Initial year hauling costs are estimated at approximately $1.5 million (1984 dollars).

Figure 1.0-2 presents projected total tonnage costs on an as landfilled basis for each year of the 20-year planning period. On an as landfilled basis, the initial year total tonnage cost for facilities construction and operation and waste hauling is estimated at $20.35/ton.

1.4 ROBERTS FARM

The Roberts Farm site comprises approximately 720 acres of a mixture of open farmland, marshland, and open water located about 2.5 miles southeast of Odessa. Elevations* at the site vary from 2 feet or less to more than 54 feet. The site is divided into two parts by Hangman's Run. Existing drainage patterns of surface runoff are toward this stream; [redacted]ies. However, drainage from certain upgradient properties will have to be intercepted and diverted around the disposal area.

*Datum: Mean Sea Level

This site is situated in the Coastal Plain Physiographic Province and is underlain by a thick sequence of sediments containing three aquifers within the top 200 feet. These aquifers are the Pleistocene water table aquifer, the Rancocas confined aquifer, and the Mount Laurel confined aquifer.

The Pleistocene water table aquifer is variable across the site and is not extensively utilized for well supplies. Flow within the aquifer is towards Hangman's Run. Accordingly, if the landfill liner and leachate collection system should fail, and no corrective action is taken, this aquifer could become contaminated. This could then subsequently cause some surface water contamination of Hangman's Run. However, this would not jeopardize surrounding wells since they are all situated upgradient.

The Rancocas aquifer is a principal water supply aquifer in the area. It is confined by the Calvert Formation and/or semi-confined by clayey Pleistocene materials where the Calvert Formation has been eroded away. The potentiometric surfaces of the Rancocas and the water table aquifer indicate that vertical seepage of leachate would be possible if the liner and leachate collection system fail and no corrective action is taken. The flow within the aquifer is southward or away from the Route 9 residential development.

Useable thicknesses of soil for cover materials are variable across the site ranging from 1 foot to 27 feet. These soils are suitable for use as daily or final cover materials.

The limiting conditions at this site are:

- 100 year flood plain
- State of Delaware Wetlands
- On-site or adjacent streams

Considering the above limiting conditions and DSWA established property line setbacks of 200 feet, it is estimated that the Roberts Farm Site contains approximately 202 acres which would be suitable for landfilling.

Allowing for a nominal height of the refuse deposit above the existing grade of 40 feet, the estimated service life of this candidate site is approximately 24 years. It appears that sufficient cover material would be available on site for the routine operation of a landfill. See Figure 1.4-1.

Screening of the site, particularly parallel to Route 9, would be necessary.

Since landfilling will not occur on the wetlands portion of the site and the useable areas identified are presently cultivated, the effects of a landfill operation on the existing wildlife habitat are expected to be minor. They will primarily consist of increased levels of activity and noise in and around the small portions of the site (20 to 30 acres) being filled or utilized as borrow areas to obtain cover material. Since the disposal area would ultimately be returned to open space uses, its value for wildlife is not expected to be diminished from the current situation.

Because of its proximity to the coastal marshes, the site's wildlife resources are primarily waterfowl. The dam on Hangman's Run prevents access to the pond by marine and brackish water fish. As a result, the pond should be capable of supporting the same freshwater species as are found within the upper Appoquinimink, namely carps, minnows, pikes, suckers, catfish, killifish, sticklebacks, and sunfish.

With respect to endangered and threatened species, although historically bald eagles have been known to nest, feed, and migrate through the vicinity of Roberts Farm, the site and its immediate vicinity are not presently used for nesting by bald eagles. Historically, the closest nesting sites were identified as Cedar Swamp and Blackbird Landing, both of which are 2.5 miles away or more from this candidate landfill site. Of the five presently active nest sites, the closest to Roberts Farm is at Bombay Hook.

Roberts Farm is located within the Middletown-Odessa-Townsend Planning District. The site currently is zoned as R-2 (Agricultural and General Purpose). Approximately 60% of the total site acreage is classified as prime farmland (Class I and Class II soils). Major portions of the site have been designated either as "stream valley, flood plain, and marshland protection" (primarily along Hangman's Run and its tributaries) or "Post-1985 Coastal Zone Industrial Development" with only small, selective portions designated for agricultural use.

It is estimated that about 16 people reside in the 5 dwellings situated within 300 yards of the site, assuming a population density of 3.12 persons per household as derived from county census data.

The site is part of an area designated as a Natural Vista from Route 9 which itself has been designated a Scenic Highway by the State of Delaware. There are no National Register Historic Places in the vicinity of the Roberts Farm Site. However, the site contains three structures and there are two structures located within 300 yards of the site which have been identified by the State Division of Historical and Cultural Affairs as having unique architectural significance.

The total one-way mileage to Roberts Farm from Pigeon Point is 27.6 miles. U.S. Route 13 comprises 22.5 miles of this. The conditions of the roads along the suggested haul route (See

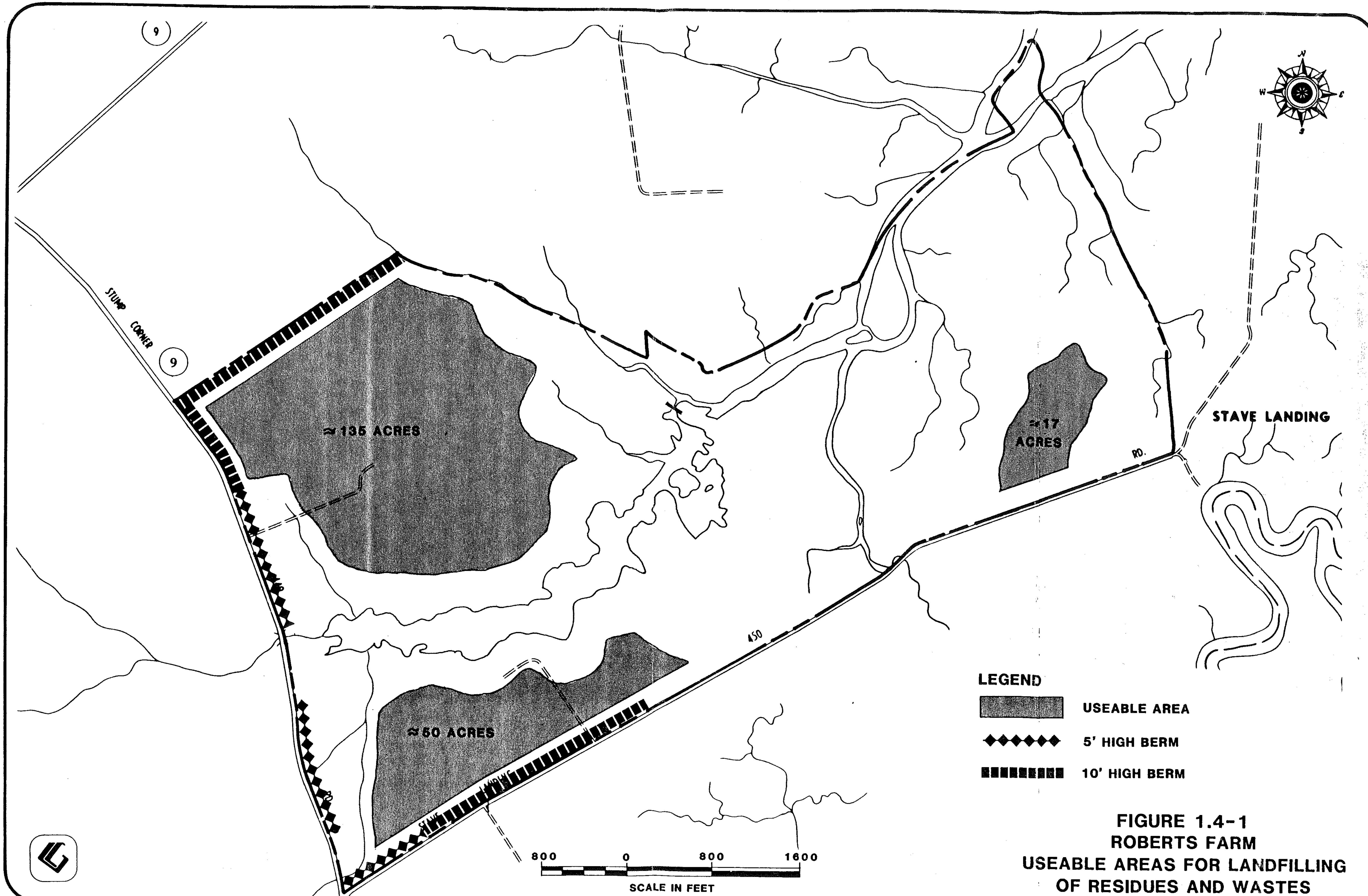


FIGURE 1.4-1
ROBERTS FARM
USEABLE AREAS FOR LANDFILLING
OF RESIDUES AND WASTES

Figure 1.0-1) are good to excellent with the exception of State Road 452 which is considered to be in fair condition. This road would have to be upgraded from its intersection with U.S. 13 to its intersection with Delaware Route 9 to enable it to satisfactorily handle the increased traffic associated with the development of a landfill at this site.

Both rail access and waterway access (barging) were considered but determined not to be practical alternatives.

Start-up capital cost for landfill development at this site is estimated at approximately $4.7 million (1984 dollars). Initial year operating expenses are estimated at approximately $1.2 million (1984 dollars). Initial year hauling costs are estimated at approximately $2.0 million (1984 dollars).

Figure 1.0-2 presents projected total tonnage costs on an as landfilled basis for each year of the 20-year planning period. On an as landfilled basis, the initial year total tonnage cost for facility construction and operation and waste hauling is estimated at $23.90/ton.

1.5 CHERRY ISLAND

The Cherry Island site comprises approximately 350 acres of open land located at the confluence of the Christina and Delaware Rivers in the City of Wilmington, Delaware. Most of the area under consideration for use as a landfill site is land reclaimed with dredge spoils. The site continues to be used by the U.S. Army Corps of Engineers for disposal of materials dredged from the river channels serving the Port of Wilmington. Elevations* at the site vary from about 4 feet at the river's edge to a maximum of 50 feet at a point on the dike defining the

*Datum: Mean Sea Level

"Edgemoor" dredge disposal area. Little upgradient runoff flows onto the site. Drainage of surface runoff from the site is of more critical importance here and can be controlled with a variety of engineered measures.

The Cherry Island site is situated in the Coastal Plain Physiographic Province of Delaware and is underlain by a thick sequence of materials which include dredge spoil, Recent estuarine deposits, the Columbia formation and the Potomac formation. The latter two formations are utilized for groundwater supplies in New Castle County

A perched water table exists on Cherry Island at or very near the surface. The level of this water table is expected to decline upon cessation of dredging operations; however, this decline will be very slow considering the permeabilities of the dredge spoil materials. The presence of the perched water table precludes placement of refuse in excavated pits or trenches. Leachate generated from the landfill, absent control measures, could seep into the perched water table, and such seepage could move downward to the Columbia Formation and then laterally toward both the Delaware and Christina Rivers.

The Pleistocene water table aquifer or Columbia formation underlies the site and is confined due to the presence of overlying estuarine and dredge spoil materials. Movement of groundwater in the formation is southward or towards the Christina River. There are no water table aquifer wells within the general area of Cherry Island.

The Potomac formation is the deepest and oldest unconsolidated deposit underlying the site. The formation serves as a principal source of groundwater in New Castle County. Data collected during the installation of the monitoring wells in the Potomac formation on Cherry Island indicate that the water yielding properties of the formation at Cherry Island are poor. Potentiometric surface data indicates that vertical seepage of leachate is possible should the liner and/or leachate collection system fail and no corrective action is taken. Flow in the sandy zones occurring within the formation is southward. There are no Potomac wells within the general area of Cherry Island.

Based on tests and reported grain size analyses of the dredge spoil materials, these materials at first glance appear suitable for use as cover materials. However, excessive moisture contents create a workability problem such that adequate compaction of the dredge spoil materials cannot be accomplished without first reducing the moisture content through excavating, aerating and stockpiling of the spoil. The presence of a perched water table may also limit the volume of drege spoil for cover, since materials obtained at depth will require additional drying time.

The dredge spoil materials and underlying estuarine deposits are very soft and settlement sensitive. Estimates of settlements indicate that consolidation of 3 to 5 feet will occur under a 40-foot high refuse deposit. This creates two landfilling scenerios for this site: Alternative 1: Site Preloading followed by the Installation of a Membrane Type Liner and Leachate Collection System; and Altenative 2: No Site Pre-loading or Membrane Liner with the Installation of a Leachate Collection System. [redacted]

The most significant limiting condition at this site is: on-site or adjacent streams. However, the 200-foot property line setback established by the Authority encompasses the 100-foot stream setback at all points for this site. All of the 350 acres, less the area associated with the property line setback, would be useable. For the purposes of this study, it was assumed that only the eastern portion of the site, identified by the Corps of Engineers as the "Edgemoor" Area, would be utilized and a total of 215 acres was estimated to be available for disposal. See Figure 1.5-1.

Allowing for a nominal refuse deposit height of 40 feet above the existing grade at the Cherry Island site, the estimated service life of this candidate site would be approximately 25 years. Considering that at some time in the future the adjacent "Wilmington" dredge disposal area to the west also could be utilized, the total life of this site would be significantly increased. The use of dredge spoils for cover material is not deemed practical, and it was assumed [redacted]

Screening of this site is considered impractical. There are no residential areas within 300 yards of the site, and Interstate I-495 skirting the site on the west is elevated.

The western area of the site contains spoil from recent dredging operations and supports virtually no vegetation. The eastern portion is being colonized by plants through natural selection. Species are representative of types characteristic of waste deposits. The only significantly vegetated areas occur outside the perimeter dikes. Because of the extensively disturbed character of this site, there is very little habitat suitable for wildlife other than small populations of mammals such as mice, shrews, raccoons, or rabbits. Water fowl would not use the site to any extent other than as a resting area because of lack of feeding areas on the site. Also, the number of fish species found in the Delaware and Christina River at Cherry Island are relatively limited. Water quality is described as marginal, being heavily affected by the highly urbanized and industrialized sections upstream. With regard to endangered and threatened

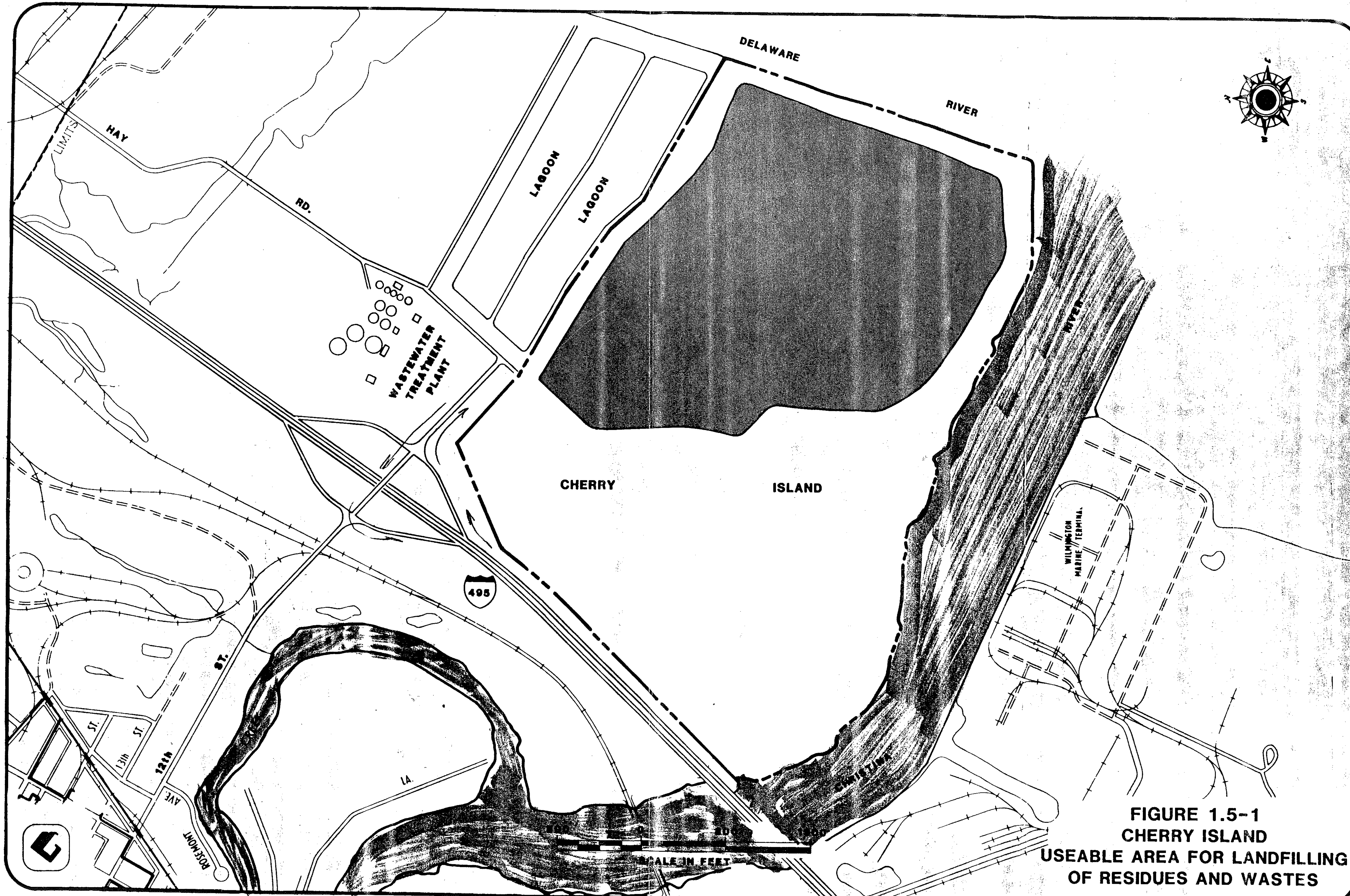


FIGURE 1.5-1
CHERRY ISLAND
USEABLE AREA FOR LANDFILLING
OF RESIDUES AND WASTES

species, the site is not located near any known historic or existing bald eagle nesting sites. According to an official of the Delaware Division of Fish and Wildlife, the shortnose sturgeon, however, almost certainly utilize the Delaware River near Cherry Island as a migratory route during spring and fall. Because of low dissolved oxygen, they are most likely not present near the site during summer.

Because of the existing condition of the site, use of the site for a landfill is not expected to disturb any wildlife habitat. Whatever wildlife exists within the fringes of the site are already exposed to levels of noise and activity from the dredging operations, traffic on I-495, and surrounding industries and utilities which should not be significantly different from that associated with landfilling.

The Wilmington Planning Commission has recommended various portions of Cherry Island to be set aside for light or heavy industry and a multi-use park. However, portions of the area originally proposed for the park appear to have been encroached upon by the Wilmington Area Wastewater Treatment Plant.

The proposed site contains no prime agricultural soils. There are no dwellings within 300 yards of the site, nor are there any cultural, recreational, or natural areas or historic sites within 300 yards of the proposed site.

The total one-way mileage to the Cherry Island Site from the DRP at Pigeon Point is 3.4 miles. Interstate 495 comprises the major portion of the mileage. The conditions of the roads are good to excellent. It appears that no roads would require upgrading.

Both rail access and waterway access were considered but determined not to be practical alternative transportation modes.

that cover major portions of the State of Delaware and which could include all or some of the proposed sites (personal communication, Mr. H. Lloyd Alexander, Jr., Endangered Species Coordinator). Critical habitat, as defined by the Endangered Species Act of 1973, has not been designated for these species (personal communication, Mr. Paul Nickerson, Endangered Species Specialist, USDI, 1980).

"No formal studies are available on the historical use of the proposed sites by endangered species," (personal communication, Mr. H. Lloyd Alexander, Jr.). However, at least four pairs of eagles were known to nest in New Castle County before the early 1960's (Abbott, 1978). By 1977, no eagle nesting activity occurred in the County. Both bald eagles and peregrine falcons are found in the study area during migration and occasionally at other times. "It is possible" that both "could occasionally be sighted in migration at any of the proposed sites" (personal communication, Mr. H. Lloyd Alexander, Jr.).

The shortnose sturgeon historically has been taken from the Delaware River in small numbers by commercial fishermen. The species has been found as far upstream as Trenton, New Jersey (Tyrawski, 1979). Two specimens were taken between Bordentown and Trenton in 1971. Within the past two years, two specimens were found at the intake system of the Salem Nuclear Generating Station (personal communication with Mr. H. Lloyd Alexander, Jr.).

Although little is known of the spawning habits and early life history of shortnose sturgeon, they are probably similar to those of the more common Atlantic sturgeon. Adults are migratory, remaining at sea for part of the time, and returning to the parent stream in April to June to spawn. Spawning occurs "in the middle reaches of large tidal rivers..." (Scott and Crossman, 1973). It is unlikely that sturgeon would travel far upstream in small tributary streams.

4. After review of the public comments, the Staff will recommend to the Board the priority ranking of the sites.

5. At a public meeting, the Board of Directors will establish the priority ranking of the sites.

6. The Staff will submit the highest ranked site to the Department of Natural Resources and Environmental Control (DNREC) for site suitability approval.

7. If this site is not approved, the second highest ranked site will be submitted to DNREC for site suitability approval.

8. If this site is not approved, the third highest ranked site will be submitted to DNREC for site suitability approval.

9. When site suitability approval is received from DNREC, and when agreement has been reached upon purchase of the site, the Staff will authorize the Engineers to proceed with design of the site.

10. The design will be submitted with a permit application for the site.

11. Upon receipt of design approval and permit, bids for construction of the landfill facility will be issued.

12. Upon execution of the Contract Documents with the successful low bidder, a "Notice to Proceed" with construction will be issued and construction of the NSWF will begin.

2.0 SCOPE

The purpose of Gilbert's investigation of Cherry Island, Road 412, and Roberts Farm was to build upon information presented in an earlier report (dated February 1981). The information presented in the earlier report was obtained primarily from interviews with public officials, review of published data made available by various County, State, and Federal agencies, and observations made during field visits to each candidate site by Gilbert personnel. The earlier information has been augmented with site specific data acquired from sub-surface exploration programs, aerial photographic surveys, and ecological surveys. Additional information regarding property ownership, property boundaries, and property values was provided by the Delaware Solid Waste Authority. Return visits were made to many governmental agencies, and additional governmental agencies or departments were contacted or visited to secure additional published data. Involved in this data base augmentation program was a team of scientists and engineers including, among others, personnel experienced in the following disciplines: hydrogeology, geology, environmental engineering, environmental planning, terrestrial ecology, and aquatic ecology.

3.0 STUDY METHODOLOGY

This Section presents an overview of pertinent considerations which are discussed in more detail (as they relate specifically to each site) in Sections 4 thru 6. It also provides information on methods and references employed and/or consulted, as part of the detailed site investigations.

3.1 SITE DESCRIPTION

The site descriptions give the size of each site (acres) and provide information regarding the location of the site. Described in general terms are the features of the property and surrounding properties, such as whether the land is wooded or open, whether it has any distinguishing characteristic or landmark, whether it is farmland that is actively farmed or that is fallow, and whether it is near public water and/or sewer services. Roads, highways, railroads, and power transmission lines are noted. The information presented is based upon observations made during visits to each site, and the study of maps and aerial photographs.

3.2 ENGINEERING CONSIDERATIONS

3.2.1 Geology/Hydrogeology

The geotechnical appraisal of each proposed site is based on published reports obtained from State and Federal Geology and Soils Agencies, maps prepared by the Delaware Geological Survey and United States Geological Survey, data obtained from a subsurface exploration and monitoring well installation program, laboratory analyses of selected soil and water samples and geophysical logs prepared by the Delaware Geological Survey. Specific items addressed in the geotechnical appraisal of each site include regional stratigraphy, site stratigraphy, hydrogeology, aquifer systems and soil and sediment data.

In preparing the physiography and area geology of each site, County wide reports and maps published by the Delaware Geological Survey were utilized. Detailed descriptions of the surficial soil units were obtained from the New Castle County Soil Survey published by the United States Department of Agriculture-Soil Conservation Service. Underlying sediment descriptions were based on samples obtained from the monitoring well installation program and the geophysical logging performed by the Delaware Geologic Survey. Representative soil samples obtained during the monitoring well construction program were tested for grain size distribution. Conclusions regarding the suitability of on-site soils for cover materials were based upon these laboratory testing results.

The detailed description of the hydrogeology of each site is based on the installed monitoring wells, subsequent water level readings and the geophysical logs prepared by the Delaware Geological Survey. Supportive maps showing potentiometric surfaces are based on actual water level data and interpretative groundwater flow directions were determined through the utilization of standard hydrogeologic criteria. Predictive data relative to impact assessments are based on classical hydrogeologic equations, actual field water level data, measured geologic sections and hydraulic values published by the Delaware Geological Survey.

3.2.2 Hydrology

The intent of this sub-section is to provide a description of the drainage characteristics of each site. Combined with following sections on "Flood Plains", "Wetlands", and "Streams", it also provides information with regard to surface water features on, adjacent to, or near the site. The topography or relief of each site is described in terms of elevation differences. Diversion of upgradient runoff from adjacent properties is discussed, as well as control of runoff from the site with regard to downgradient properties. Erosion control measures considered appropriate for the site, primarily based on the relief of the site, also are mentioned. The information presented is based upon the study of USGS topographic maps, site specific topographic maps, aerial photographs, and observations made during site visits.

3.2.3 Flood Plains

Shown on a figure developed for each candidate site, where applicable, are the limits of the 100-year flood plain where it encroaches upon the site. This information was developed by the United States Housing and Urban Development as part of the Flood Insurance Studies for New Castle County and the City of Wilmington. It was made available by the New Castle County Department of Planning and the City of Wilmington, Planning Division. The areas defined to be within the 100-year flood plain are shown in a shaded pattern. In accordance with the site selection criteria developed by the Authority, disposal areas are shown not to encroach upon the 100-year flood plain.

3.2.4 Wetlands

As appropriate, maps have been developed for each candidate site which show the extent of State of Delaware Wetlands as defined by the Delaware Wetlands Acts. These wetlands incorporate only certain tidal or salt water estuaries which are identified on aerial maps published by the Wetlands Section of the Delaware Department of Natural Resources and Environmental Control (DNREC). In accordance with the Delaware Solid Waste Authority's site selection criteria, disposal areas are shown to encroach no closer than 100 yards (300 feet) of the edge of State of Delaware Wetlands.

The U.S. Army Corps of Engineers was contacted with regard to what would be considered fresh-water wetlands at the candidate sites.

Generally the Corps of Engineers has jurisdiction only where the stream flow is greater than 5 cubic ft. per second. As applicable, maps are presented in the environmental assessment of each site which show what would be considered to be "wetlands" by the Corps of Engineers' under that agencies definition of wetlands*. Encroachment upon such areas are precluded by the site selection criteria developed by the Authority wherein the edge of the disposal area should be no closer than 100 ft. to other bodies of water such as ponds, lakes, creeks, swamps, and marshes. This is based upon the State of Delaware Solid Waste Disposal Regulations, Section 6.03(g)1.

3.2.5 Streams and Other Bodies of Water

Also identified on the wetlands maps are streams and impoundments. In accordance with the site selection criteria developed by the Authority, disposal areas are shown to encroach no closer than 100 feet of the edge of these bodies of water. The 100 feet criterion is based upon the State of Delaware Solid Waste Disposal Regulations, Section 6.03(g)1.

3.2.6 Site Capacity/Longevity

The volumes of wastes which can be accommodated at any of the three land disposal sites and the resultant longevity (site life) estimated for each is dependent upon many factors. Some of these factors such as general population trends and waste generation trends within the service area, in-place refuse densities, and

*Those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamp, marshes, bogs, and similar areas.

refuse to cover ratios are non-site specific. Site specific factors which are dependent upon government regulations or guidelines and site location, configuration, topography, and geology are: buffer zones and allowable depths of the refuse deposit below and above the existing grade. Discussions on non-site specific factors are detailed within this section. Site specific factors are described in general in this section, and in more detail in the corresponding sub-section for each candidate site.

3.2.6.1 Refuse Quantities

For the 20+ year planning period being considered, refuse quantities are expected to increase in direct proportion to the projected increase in population for New Castle County. Based upon recent trends, per capita refuse generation rates are not expected to increase. The New Castle County population figures for the following years reflect an average annual population increase of approximately 1.1%.*

1980	-	399,002 (Census)
1990	-	445,100 (Projection)
2000	-	496,100 (Projection)

Therefore, the starting year refuse generation estimate provided by the Delaware Solid Waste Authority (which is shown below) will be increased at 1.1% per year.

*Population projection based upon data obtained from the New Castle County Department of Planning.

The staff of the Delaware Solid Waste Authority provided the following information regarding refuse generation for New Castle County:

Beginning year refuse generation:	380,000 tons
Processable portion*:	-260,000 tons
Non-processable (to be landfilled):	120,000 tons
Residues from processing (approx. 10%):	+ 26,000 tons
Total residues and non-processables:	146,000 tons

To this is added another 13,000 tons (5%) of processable wastes resulting from scheduled and non-scheduled facility outages giving a beginning year total of 159,000 tons.

The yearly increase in materials to be landfilled is shown in Table 3.2-1. This estimate is based upon processing 1000 TPD for the duration of the planning period. This is a conservative approach since it does not take into account the possibility of expanding plant capacity by adding additional processing units (physical plant expansion potential) or by increasing hours of operation.

3.2.6.2 Refuse Densities

The weighted average in-place density of the above wastes is estimated at 1250 lbs/c.y. (0.625 tons/c.y.). This value was used for determining volumes and site lives for the three candidate sites discussed in subsequent sections of this report. The weighted average in-place density was derived from a consideration of the three types of waste which will be landfilled at the NSWF: 1) unprocessed mixed municipal refuse; 2) residues from the DRP; and 3) non-processable materials.

*Processable materials are defined as the solid waste which can be accepted and processed by the equipment integral to the Delaware Reclamation Project (DRP) at Pigeon Point.

In-place densities of landfilled mixed municipal refuse vary from 700 lbs/c.y. to 1200 lbs/c.y. depending upon the type of compaction equipment used and the characteristics of the waste. For the purposes of this study a 1000 lbs/c.y. in-place density was assumed. This is recognized as a reasonable in-place density for planning purposes where a specially built landfill compactor will be utilized on the landfill. Measurements made by the Authority's Contract Operator at Pigeon Point have verified this value.

The in-place density of residue from the DRP will vary with moisture content and particle size. For the purposes of this study, it has been assumed to approximate that of cinders which is about 1450 lbs/c.y.

The in-place density of the non-processable fraction of the waste stream which includes, among other materials, construction and demolition debris (broken concrete, blocks, bricks, structural timber), logs, stumps, matresses, bedsprings and rugs was estimated at 1300 lbs/c.y.

3.2.6.3 Cover Material Needs

For estimating cover material requirements at each site it was assumed that the landfill will be operated as an "area fill". In accordance with DNREC regulations, cover material (soil) will have to be applied at the end of each working day. Completed areas will have to be covered with 2 feet of cover material as soon after completion as possible. Consequently, a refuse to cover soil ratio of 3:1 (by volume) was utilized in the calculations.

TABLE 3.2-1
YEARLY INCREASE IN MATERIALS TO BE LANDFILLED

Year	Total Waste Stream (tons)	Yearly Total of Wastes to be Landfilled (tons)	Cumulative Wastes Landfill (tons)
1 (1984)	380,000	159,000	159,000
2	384,180	163,200	322,200
3	388,406	167,400	489,600
4	392,678	171,700	661,300
5	396,997	176,000	837,300
6	401,364	180,400	1,017,700
7	405,779	184,800	1,202,500
8	410,243	189,200	1,391,700
9	414,756	193,800	1,585,500
10	419,318	198,300	1,783,800
11	423,930	202,900	1,986,700
12	428,593	207,600	2,194,300
13	433,308	212,300	2,406,600
14	438,074	217,100	2,623,700
15	442,893	221,900	2,845,600
16	447,765	226,800	3,072,400
17	452,690	231,700	3,304,100
18	457,670	236,700	3,540,800
19	462,704	241,700	3,782,500
20	467,794	246,800	4,029,300
21	472,940	251,900	4,281,200
22	478,142	257,100	4,538,300
23	483,402	262,400	4,800,700
24	488,719	267,700	5,068,400
25	494,095	273,100	5,341,500
26	499,530	278,500	5,620,000
27	505,025	284,000	5,904,000
28	510,580	289,600	6,193,600
29	516,196	295,200	6,488,800
30	521,874	300,900	6,789,700

3.2.6.4 Buffer Zones

Site boundaries coincide with property lines as such information was provided by the Authority. Disposal area boundaries are shown to be set back a minimum of 200 feet from all property lines to create a buffer zone to help isolate the landfill from adjacent properties. Disposal area boundaries also are defined by the

100-year flood plain, a 100 yard buffer from the edge of State of Delaware Wetlands, and a 100 feet buffer from all other bodies of water. Where two or more of these limiting conditions overlap, the condition requiring the greatest distance (widest buffer zone) prevails.

3.2.6.5 Slopes

Disposal area finished sideslopes of 33% (approximately a 3:1 length to height ratio) were assumed. The finished grades of the top of the disposal areas were assumed to reflect existing slopes.

3.2.6.6 Average Depth of Refuse Deposit

A nominal height of 40 feet above the existing grade was used to determine site volumes. This represents the total depth of the landfill including cover material and wastes. Where an opportunity appears to exist to landfill wastes below the existing grade it is so indicated in the individual site write-ups.

Disregarding sideslopes, a site landfilled to an average depth of 40 feet would require the following number of acres for the 20 year planning period:

W_D - 0.625 tons/c.y.
20 - year tonnage: 4,029,300 tons
V_R = 4,029,300 tons @ 0.625 tons/c.y. = 6,446,880 c.y.
V_C = @ 3:1 refuse to cover ratio = 2,148,960 c.y.
$V_T = V_R + V_C$
V_T = 6,446,880 + 2,148,960 = 8,595,840 c.y.
$A(40)$ = 8,595,840 c.y. x 27 ft^3/c.y. = 232,087,680 ft^3/40 ft
= 5,802,192 ft^2
= 133.2 acres

W_D = Weighted Density
V_R = Volume of Refuse

V_C = Volume of Cover Material

V_T = Total Disposal Area Volume

$A(40)$ = Area in acres at an average landfill depth of 40 feet

3.2.7 Screening of Sites

As feasible for each site, along those portions of the property where landfill operations may be visible to passersby or to neighboring landowners from their dwellings, a 5 to 10 ft. high grassed berm should be incorporated in the design. It was assumed that the berms would have a crest 10 ft. wide and 2:1 sideslopes, and will be constructed within the property line buffer zone. Additional screening, if deemed of benefit, can be achieved by landscaping the berms with rapid growing shrubbery or trees.

3.3 ENVIRONMENTAL CONSIDERATIONS

3.3.1 Ecology

The objectives of the ecological portion of the study were: 1) to define ecological baseline conditions at the sites; 2) to compare the sites with surrounding areas; and 3) to define potential project impacts. The proximity of coastal wetlands, endangered species habitat, and wildlife areas were of special concern.

Information was obtained by reviewing literature, contacting and visiting state agencies, walking each site, and driving through surrounding areas. The type of information sought for each site included: 1) species present (including migratory species), 2) habitat types, 3) vegetation community types and percent coverage of each, 4) endangered species likely to be on or near the site, and exact location of their habitat in relation to each site; 5) economically valuable species found on or near the site, 6) location of nearest wildlife and public hunting areas, and 7) description of surrounding areas in relation to each site.

Standard references as well as locally-performed studies were consulted (these are cited in the text). The Delaware Department of Natural Resources and Environmental Control (DNREC) was contacted by telephone and letter; the Division of Environmental Control supplied information on water quality and wetlands. The Division of Fish and Wildlife supplied information on fisheries, hunting, and wildlife areas, and endangered species, particularly bald eagles. A local expert was consulted for information on the shortnose sturgeon.

The DNREC's wetlands maps were consulted, and checked against information obtained during the site visits. Vegetation mapping was accomplished by using a combination of USGS topographic maps, recent (1981) aerial photographs, and information obtained during the site visits.

The following information on endangered and threatened species applies to all sites evaluated, and is presented here.

Information was sought regarding the presence of Federal or state-designated endangered or threatened species. The type of information sought included: (1) Which endangered or threatened species, if any, presently have ranges that include any of the sites?; (2) Which endangered or threatened species have historically occurred on or near the sites?; (3) Which of these species have recently been seen on or near any of the sites?; and (4) What use have endangered or threatened species made (or are making) of the sites for nesting, feeding, and migration?

Initially, the 1980 official Federal list of endangered and threatened species published by the U.S. Department of the Interior (USDI, 1980) was consulted to determine which of the listed species are protected in Delaware. Another USDI publication, the "Endangered Species Technical Bulletin" (1978) was reviewed for information on raptor (birds of prey) distribution. Literature supplied by the State of Delaware concerning endangered species also was reviewed. In addition, requests were made to the following offices (either by telephone or letter) for information on endangered and threatened species of Delaware:

1. U.S. Fish and Wildlife Office for Region 5 - Endangered Species Specialist;

2. Delaware Department of Natural Resources and Environmental Control, Division of Fish and Wildlife - Endangered Species Coordinator; and

3. U.S. Fish and Wildlife Bald Eagle Recovery Plan Leader for the Delmarva Region.

Also, the National Wildlife Federation's Raptor Information Center was contacted and asked for information from their annual winter raptor survey. This survey includes information on eagle sightings in New Castle County, Delaware.

Information obtained that is applicable to the entire study area is summarized here. Site-specific information is presented in the following sections of this report.

The State of Delaware recognizes the Federal list of endangered species. The state has no additional list of its own. Of the endangered and threatened species listed by USDI (1980) for the United States, three occur in Delaware. The bald eagle (*Haliaeetus leucocephalus*) is listed as endangered in the "conterminus" U.S. (except that it is designated as threatened in five mid-western and western states). The American peregrine falcon (*Falco peregrinus anatum*) is endangered throughout the U.S. The shortnose sturgeon (*Acipenser brevirostrum*) is endangered along the entire Atlantic coast. These three species have ranges that cover major portions of the State of Delaware and which could include all or some of the proposed sites (personal communication, Mr. H. Lloyd Alexander, Jr., Endangered Species Coordinator). Critical habitat, as defined by the Endangered Species Act of 1973, has not been designated for these species (personal communication, Mr. Paul Nickerson, Endangered Species Specialist, USDI, 1980).

"No formal studies are available on the historical use of the proposed sites by endangered species," (personal communication, Mr. H. Lloyd Alexander, Jr.). However, at least four pairs of eagles were known to nest in New Castle County before the early 1960's (Abbott, 1978). By 1977, no eagle nesting activity occurred in the County. Both bald eagles and peregrine falcons are found in the study area during migration and occasionally at other times. "It is possible" that both "could occasionally be sighted in migration at any of the proposed sites" (personal communication, Mr. H. Lloyd Alexander, Jr.).

The shortnose sturgeon historically has been taken from the Delaware River in small numbers by commercial fishermen. The species has been found as far upstream as Trenton, New Jersey (Tyrawski, 1979). Two specimens were taken between Bordentown and Trenton in 1971. Within the past two years, two specimens were found at the intake system of the Salem Nuclear Generating Station (personal communication with Mr. H. Lloyd Alexander, Jr.).

Although little is known of the spawning habits and early life history of shortnose sturgeon, they are probably similar to those of the more common Atlantic sturgeon. Adults are migratory, remaining at sea for part of the time, and returning to the parent stream in April to June to spawn. Spawning occurs "in the middle reaches of large tidal rivers..." (Scott and Crossman, 1973). It is unlikely that sturgeon would travel far upstream in small tributary streams.

3.3.2 Land Use

3.3.2.1 Future Land Use

The New Castle County Department of Planning, prepared nine District Studies which refined the County's General Comprehensive Development Plan and provided a detailed analysis of land use recommendations, while at the same time serving to update the County's overall Plan. These Planning District Plans, which recommended development in 1985, were used for future land use discussions for the Road 412 and Roberts Farm sites.

The City of Wilmington's Report and Recommendations on Cherry Island and adjacent areas, a supplement to the City's Comprehensive Development Plans, was used as the basis for discussions of land development recommendations for the Cherry Island site.

The New Castle County Department of Planning is presently in the process of revising the County's Comprehensive Plan. Preliminary recommendations for the Road 412, Roberts Farm and Cherry Island sites are described as appropriate, in the subsequent sections.

The County's and City's plans do not address the need nor the location of landfill sites as part of the land use planning process. Therefore, in all cases, identified sites cannot be found to be compatible with such land use plans.

Coastal Zone Protection Areas, as delineated on the New Castle County Department of Planning's Planning District Plans, are areas regulated by the Delaware Coastal Zone Act, Chapter 70, Title 7, and referred to in that Act as the Coastal Strip. The Coastal Zone Act prohibits heavy industry and bulk product transfer facilities from locating in the Coastal Strip and subjects manufacturing and processing facilities to a permit to ensure protection of coastal resources. The Coastal Zone Act, however, does not appear to apply to a sanitary landfill facility (personal and written communication with John Sherman, Delaware Coastal Management Program).

3.3.2.2 Farm Land Classification

Prime agricultural soils information was obtained from the Soil Survey of New Castle County, Delaware, prepared by the U.S. Department of Agriculture, Soil Conservation Service.

The soil survey identified and classified all soil found in the County and grouped soils by capability, depending on suitability of the soils for field crop production. The groups are classified according to the limitations of the soils when used for field crops, their risk of damage, and their response to treatment. Classifications range from Class I (few limitations) to Class VIII (limitations that preclude their use for commercial plants). The prime agricultural soils (Class I and Class II) are defined as follows by the Soil Conservation Service:

Class I - Soils that have few limitations which restrict their use.

Class II - Soils that have moderate limitations that reduce the choice of plants or which require moderate conservation practices.

Subclasses are further used to define soil groups within soil classes:

1. Main limitation is the risk of erosion unless close-growing plant cover is maintained.

2. Water in or on the soil interferes with plant growth or cultivation.

Capability units (Arabic numbers) are also used within subclasses to indicate that soils are suitable to the same crops and pasture plants, require similar management, and have similar productivity and other responses to management techniques.

Generally, the proposed landfill operation follows the process where refuse and other waste material is spread on the ground and compacted. At the end of each working day, all solid waste delivered to the site during the day is covered with compacted soil. At the completion of the life of the landfill, a final layer of cover soil is placed on top of the landfill.

Preparation for the proposed landfill will entail the removal and stockpiling of the top 6" to 12" of existing soil. At completion of an area, it will be covered with 12" to 18" of random fill material on top of which will be placed 6" to 12" of the stockpiled "top soil". The completed landfill thus would have a final cover with the top 6" to 12" consisting of the native "top soil" which existed on the site prior to the landfill operation. As a result, prime agricultural soils (Class I and Class II) existing on the site should not be lost, and portions of the site could be placed back into productive agricultural use upon exhausting the landfill site. Little information is available concerning agricultural productivity of soils over landfills, however, examples do exist of continued use of completed landfill sites for agricultural purposes. The York County Solid Waste and Refuse Authority sanitary landfill in Stewartstown, Pa. has recently experienced some promising results on approximately 40 acres of completed landfill planted with grain and clover.

3.3.3 Zoning

Zoning restriction for each site was obtained from current zoning regulations. Road 412 and Roberts Farm come under the New Castle County Zoning Code and the permitted uses and minimum lot area requirements discussed reflect those requirements contained in the County Code. The Cherry Island site is under the zoning jurisdiction of the City of Wilmington. Zoning regulations concerning permitted uses and area requirements for this site are, therefore, governed by the City's requirements.

3.3.4 Demography

Information pertaining to the population residing within 300 yards of site boundaries was obtained through a house count conducted during field visits to the proposed sites. Field information was verified and augmented by review of recent aerial photography of each site obtained from Real Estate Data, Inc., dated April 1980.

All dwellings (trailers, permanent and seasonal residences) were included in the house count so as to produce a "worst case" scenario for resident population estimates. However, on-site dwellings were not included in the total since it was assumed that such dwellings would be vacated and become part of the landfill facilities.

The estimated population for each site is the product of the number of dwellings multiplied by the estimated population per dwelling. The estimated population per dwelling was obtained from the Preliminary Census of Population and Housing for the specific County areas where the sites are located. It was assumed that all housing units enumerated were permanent residences since preliminary census findings did not distinguish between permanent and seasonal or occupied and vacant structures. The census area's total population was divided by the number of housing units enumerated in that area, resulting in an estimate of population per housing unit.

3.3.5 Cultural, Recreational and Natural Areas

Cultural and recreational areas located within 300 yards of a proposed site boundary were identified during a field survey conducted by Gilbert's staff. In addition, the New Castle County's Department of Parks and Recreation Inventory of County, City and State Parks was used to supplement field findings.

Natural Areas and Natural Vistas within 300 yards of site boundaries were obtained from "Delaware's Outstanding Natural Areas and Their Preservation," a 1978 publication prepared by Lorraine N. Fleming.

Natural Areas are defined as tracts of land and/or areas which possess unique natural values, i.e., unusual marshes, forests, and geological areas, areas of unique archeological significance, or habitat for rare and endangered plants and animals. Natural Vistas are unique or unusually attractive views of Delaware's natural scenery.

3.3.6 Historic Sites

3.3.6.1 National

The National Register of Historic Places was consulted to determine and identify any sites of national importance located within 300 yards of the proposed landfill site boundaries.

3.3.6.2 State

State historic sites, architectural and archaeological significant buildings or areas, as identified by the State Division of Historical and Cultural Affairs, Bureau of Archaeology and Historic Preservation, are discussed if such historic sites were found to be within 300 yards of the proposed site boundary.

3.3.7 Aesthetics

Aesthetics, during construction and operation and at completion of all operations, are discussed for each site, based on a subjective evaluation, since what is aesthetically pleasing varies from person to person and cannot be easily quantified.

However, aesthetic description based on the visibility of each site (the viewing area), the number of people that could view it, and the potential disruption of the visual characteristics of nearby areas can be evaluated on a relative basis.

In the discussion of aesthetics and potential disruptions it should be kept in mind that, at any given time, only a small fraction of the site (roughly 20 to 30 acres), will be disturbed. Also, operation of the landfill will entail that at the end of each working day, all solid waste delivered to the site will be covered with soil.

3.4 TRANSPORTATION CONSIDERATIONS

3.4.1 Highway Access

Highway access to the candidate sites was considered to be the most logical transportation alternative. For each site several highway routing alternatives were evaluated. Only what is considered to be the best practical route is shown in Figure 1.0-1. For the suggested access to each site, a table is presented which lists: the road by name and/or number; the mileage on that road, the most recent Delaware Department of Transportation traffic count(s); the number of dwelling units along the route; the classification of the road (heavy, medium, or light duty as designated on the USGS 7.5 minute quadrangle map of the area); and, any limitations with regard to roadway width, grades, curves, and structures such as bridges and underpasses. A total one-way mileage along the suggested haul route from the DRP at Pigeon Point is provided for each site.

Information on traffic counts, bridge limitations, and road limitations was obtained from interviews or correspondence with officials of the Delaware Department of Transportation in Dover, Delaware.

In general, the light duty roads described in following sections of this report are lightly travelled rural roads, approximately 18' wide, and designed by the Department of Transportation to be capable of handling legal loads for the anticipated traffic densities. From a practical standpoint, the Authority should consider that such roads would have to be upgraded to withstand the day-in, day-out traffic pressure to which they would be subjected if utilized as an access route to the proposed NSWF. Similarly, the Authority should consider that it would be necessary to upgrade any single-lane stream crossings along these access routes.

3.4.2 Rail Access

Although highway access was considered to be the prime means by which the residues and non-processed wastes would be hauled to the candidate landfill sites, the possibility of rail access to each site was considered. Distances are given to the nearest rail line.

3.4.3 Waterway Access

As with rail access, the possibility of waterway access (barging of wastes) to each site was considered. Distances to the nearest navigable waterway are given for each site.

3.4.4 Discussion of Waste Transport Alternatives

For each site a discussion of waterway, rail, and highway access to the site is made. The comparison is general in nature but indicates facilities required, additional permitting which may be necessary, intergovernmental or interagency agreements which may be required, and advantages/disadvantages associated with each system.

3.5 REGULATORY CONSIDERATIONS

3.5.1 State Regulations for Solid Waste Disposal

The State of Delaware, "Delaware Solid Waste Disposal Regulation" dated August 1974 is the regulation under which DNREC issues permits for sanitary landfills within the state. The most pertinent criteria are found on page 11 of the Regulation under Paragraph (8), Operational Requirements, Ground and Surface Water Protection.

1. Operational Requirements

   a. Ground and surface water protection. All leachate shall be collected and treated so as to provide a degree of removal of pollutants reflecting the application of a practicable level of technology. All disposal areas and leachate collection ditches and ponds shall be lined with an impermeable liner. A synthetic impermeable liner shall be installed unless the applicant can prove to the satisfaction of the Department that a natural soil liner is impermeable. All treated leachate shall be disposed of in accordance with the Department's Regulations Governing the Control of Water Pollution. The Department may consider various systems for collecting, treating and recycling leachate as the state of the art technology develops. Wells or other monitoring devices shall be installed and maintained to determine the initial characterization of the water quality and directions of groundwater flow and to detect changes in these conditions during the operation of

> the landfill. At least three feet of separation between refuse deposits and the estimated yearly high groundwater table level shall be maintained. The refuse fill shall be kept a minimum of 100 feet from all surface waters. Operations shall be planned and conducted so rainwater is drained off the fill or disposal area at all times. Standing water shall not be allowed on the fill at any time. The completed fill shall have a minimum slope of 2% to facilitate surface drainage and a maximum slope that precludes erosion.

Of these requirements, the most important with regard to facility siting studies are the need to line each site, to collect and treat leachate, to maintain a vertical buffer of at least three (3) feet between the refuse deposit and the seasonal high groundwater table, and to maintain a minimum distance of 100 feet from all surface waters (construed to include freshwater marshes, swamps, bogs, rivers, lakes, creeks, and ponds).

3.5.2 Local Regulations

As best as can be determined, there appears to be no County or City regulations governing the siting and/or operation of sanitary landfills within their respective jurisdictions which are more restrictive than the applicable State and Federal regulations or requirements, or the Delaware Solid Waste Authority's own site selection criteria.

3.5.3 Federal Regulations

With regard to Category C, Statutory and Regulatory Requirements of the "Landfill Site Selection Criteria" developed by the Delaware Solid Waste Authority, the following comments are made pertaining to USEPA sanitary landfill siting requirements as developed under the Resource Conservation and Recovery Act (RCRA).

3.5.3.1 Floodplain Siting

Although the Authority's flood plain siting criterion prohibits the location of a disposal site within the 100 year flood plain, the criterion adopted by EPA does not prohibit siting of facilities in flood plains. The regulation* reads:

> "Facilities or practices in flood plains shall not restrict the flow of the base flood, reduce the temporary water storage capacity of the flood plain, or result in washout of solid waste, so as to pose a hazard to human life, wildlife, or land or water resources." In commenting upon the regulation, EPA made the following statement: "The disposal facility or practice should seek to avoid washout of solid waste, rather than necessarily prevent inundation of the waste..."

Therefore, although generally it would be advisable to avoid siting in a flood plain if there are alternative sites available, other advantages associated with the "flood plain site" may far outweigh this disadvantage, and the "flood plain site" should not be summarily dismissed.

3.5.3.2 Endangered Species

With regard to endangered species, the criterion adopted by EPA does not unequivocally preclude siting in a critical habitat area. The regulation states that:

1. Facilities or practices shall not cause or contribute to the taking of any endangered or threatened species of plants, fish, or wildlife;

2. The facility or practice shall not result in the destruction or adverse modification of the critical habitat of endangered or threatened species as identified in 50 CFR Part17.

*Federal Register/Vol. 44, No. 179/Thursday, September 13, 1979 Criteria for Classification of Solid Waste Disposal Facilities and Practices.

In relation to destruction of habitat, EPA clarifies that:

> "...Where 'critical' habitats of threatened or endangered species have been identified by the Department of the Interior, it is unacceptable under the Act for solid waste disposal activities to destroy or adversely modify such habitats. In setting this criterion, EPA is not precluding all disposal in a critical habitat area. Only when such disposal appreciably diminishes the likelihood of the survival and recovery of threatened or endangered species using the habitat does a violation occur..."

Although approval of disposal plans by the Office of Endangered Species of the Department of Interior is not required, the Office should be consulted if a critical habitat area is being considered for siting a disposal facility.

3.5.3.3 Wetlands

The EPA criterion regarding wetlands has been included under the Surface Waters section of the referenced Federal Register. It appears somewhat ambiguous concerning requirements precluding siting of disposal facilities in wetlands since it links violations to point and non-point source discharges to the waters of such wetlands. National Pollutant Discharge Elimination System (NPDES) permits (administered by DNREC) are required for point sources such as those from a sedimentation basin or leachate treatment facility. Non-point source discharges must be in consonance with State and area-wide water quality management planning programs under Section 208 of the Clean Water Act. Generally, it appears that facilities are not to be located in wetlands unless permits are obtained under provisions of Section 402 and/or 404 of the Clean Water Act. Efforts have been made to insure that the useable areas identified for each site do not infringe upon wetlands as such are defined by the Corps of Engineers.

3.5.3.4 Groundwater

The EPA Groundwater criteria stipulate:

1. A facility or practice shall not contaminate an underground drinking water source beyond the solid waste boundary or beyond an alternative boundary specified in accordance with paragraph b. of this section.

2. Only a State with a solid waste management plan approved by the Administrator pursuant to Section 4007 of the Act may establish an alternative boundary to be used in lieu of the solid waste boundary. A State may specify such a boundary only if it finds that such a change would not result in contamination of groundwater which may be needed or used for human consumption.

Adhering to the State requirements which are cited in Section 3.5.1 will result in a facility which will be designed to preclude the contamination of groundwater. The State of Delaware's requirement for all new land disposal facilities to be lined is more stringent than EPA's criteria. EPA does not require that a site be lined if it can be demonstrated that no adverse impact on the environment will result from a natural renovation site.

3.5.3.5 Federal Aviation Administration Criteria

Airport locations in Delaware were checked in the Aircraft Owners and Pilots Association publication entitled "AOPA's Airports USA." The distance from the center of each proposed site to the nearest airport was measured, using USGS 7-1/2 minute quadrangle maps.

The Federal Aviation Administration (FAA) has published criteria for the location of landfill sites in the vicinity of commercial airports. If the wastes to be landfilled pose a potential attractant to birds, the landfill must be located a minimum distance of 10,000 feet from the runway of an airport handling turbojet aircraft; for airports handling piston driven aircraft the distance requirement is 5,000 feet.

Three airports are of concern relative to this study. They are:

1. Greater Wilmington Airport (three asphalt runways 7,000 feet, 7,165 feet and 5,004 feet in length); 10,000 feet restriction; County (public) owned/public use facility.

2. Summit Airport (one asphalt runway 4,500 feet and one turf runway 2,385 feet); 5,000 feet restriction; privately owned/public use facility.

3. Smyrna (one turf runway 2,600 feet); 5,000 feet restriction; privately owned/public use facility.

A telephone interview with an official of the Delaware Department of Transportation revealed that there were no plans for expansion at any of these airports which would have an impact upon any of the three candidate sites. With regard to new facilities in the planning stages there was a 3,000 feet airstrip proposed west of Townsend near the Maryland border. This facility would be a privately owned/public use facility. None of the existing airports or the proposed airfield would have an impact upon any of the three candidate sites.

3.6 COST CONSIDERATIONS

Costs to construct and operate a sanitary landfill for the disposal of the residues, processable materials, and overages from the Delaware Reclamation Project in accordance with governing Federal and State regulations are broken-down into two categories: capital costs, which are associated with the construction of the site, purchase of equipment, purchase of land, engineering fees, and legal fees; and, operating costs, which are associated with such items as labor, fuel, utilities, cover material procurement, laboratory analyses, and groundskeeping.

The acquisition and construction of the NSWF will be financed by revenue bonds. An interest rate of 9.6% was utilized in the financial calculations for amortization of start-up capital over the 20-year project life. Projected future capital needs are amortized at 12% interest. An annual inflation rate of 9% was assumed for both capital costs and operating costs.

3.6.1 Estimated Landfill Development Costs

Landfill development costs have been separated into "one-time" costs and "recurring" costs. The "one-time" costs are those associated with the initial development and permitting of the site. The costs are amortized over the 20 year planning period of the project or a shorter period as is applicable. This includes construction of administrative facilities, primary access roads, installation of utilities, fencing, landscaping (screening), land purchase, equipment purchase, and engineering and legal fees associated with permitting of the site. The "recurring" costs are those associated with the periodic development of lined disposal areas. With the exception of the first area developed, the costs were amortized over the life of each area. This includes contractor costs and engineering fees and legal fees associated with the design and construction of each phase of the landfill. The development costs are shown in a table and an annual cost of capital has been derived for each year of the planning period.

3.6.2 Estimated Landfill Operational Costs

Annual operating costs have been developed to complement the annual cost of capital. This, too, will be shown in a table for each year of the planning period. Included in this will be the annual cost of importing cover material for those candidate sites for which this is found to be necessary. Excluding the costs associated with the importation of cover material, the annual operating costs should be about the same for each candidate site.

3.6.3 Estimated Hauling Costs

Computed separately will be the annual cost for hauling the solid wastes to each candidate landfill site, using Pigeon Point as the point of origin for all wastes and hauling over the routes previously identified. These costs also will be shown in a table for each year of the planning period. In this analysis the motorized equipment shall be assumed to have a useful life of five years, trailers will be assumed to have a useful life of seven years and the equipment amortized accordingly. The construction of a transfer station (loading facility) at Pigeon Point will not enter into this analysis since it would be common to all of the scenarios.

4.0 ROAD 412

4.1 SITE DESCRIPTION

4.1.1 Location

The proposed Road 412 site is located in the southern part of New Castle County immediately south of the Chesapeake and Delaware Canal and approximately 5.5 miles north of Odessa. From Figure 4.2-1 it can be seen that the site is situated approximately 2000 feet south of the Canal and 3500 feet west of U.S. 13.

4.1.2 Size and Features

This site comprises two parcels of land which together total approximately 259 ± acres. See Figure 4.2-2. Virtually all of the site is undulating, but gently sloping, open farmland.

4.1.3 Boundaries/Description of Adjacent Lands

The Road 412 site is bounded on the west by Road 412A with farmland just beyond. It is bounded on the south by Hyetts Corner Road (Road 413) and/or adjacent farmlands; on the east by adjacent farmlands with Scott Run and associated woodland just beyond; and on the north by Bird's Landing Road (Road 412) and adjacent farmlands incorporating some residential development. No significant residential development appears to have occurred in the area, however, since the USGS St. Georges quadrangle map was last photorevised in 1970. Reportedly, a small industrial landfill is located along Road 412 approximately 7600 feet west of the site.

TABLE 4.2-2

ROAD 412 SITE

WATER LEVEL DATA

Well No.	Ground Surface Elev. (ft.)	Top of PVC Casing Elev. (ft.)	Depth to* Water Level (ft.)	Elev. of** G.W. (ft.)
P-1	73.0	75.1	32.9	42.2
P-2	73.5	75.7	30.9	44.8
P-3	74.5	76.3	35.4	40.9
P-4	61.5	63.5	28.9	34.6
P-5	51.0	52.5	23.1	29.4
P-6	42.5	44.4	16.1	28.3
P-7	39.5	41.4	20.8	20.6
P-8	47.0	49.2	14.8	34.4
E-1	68.5	71.0	52.8	18.2
E-2	61.5	63.9	53.0	10.9
E-3	47.0	48.5	27.9	20.6
M-1	73.0	75.3	81.3	-6.0
M-2	51.0	52.4	58.0	-5.6
M-3	47.0	48.8	59.1	-10.3

*As Measured From Top of PVC Casing

**Elev. of G.W. = Elev. Top of PVC Casing - Depth to Water Level

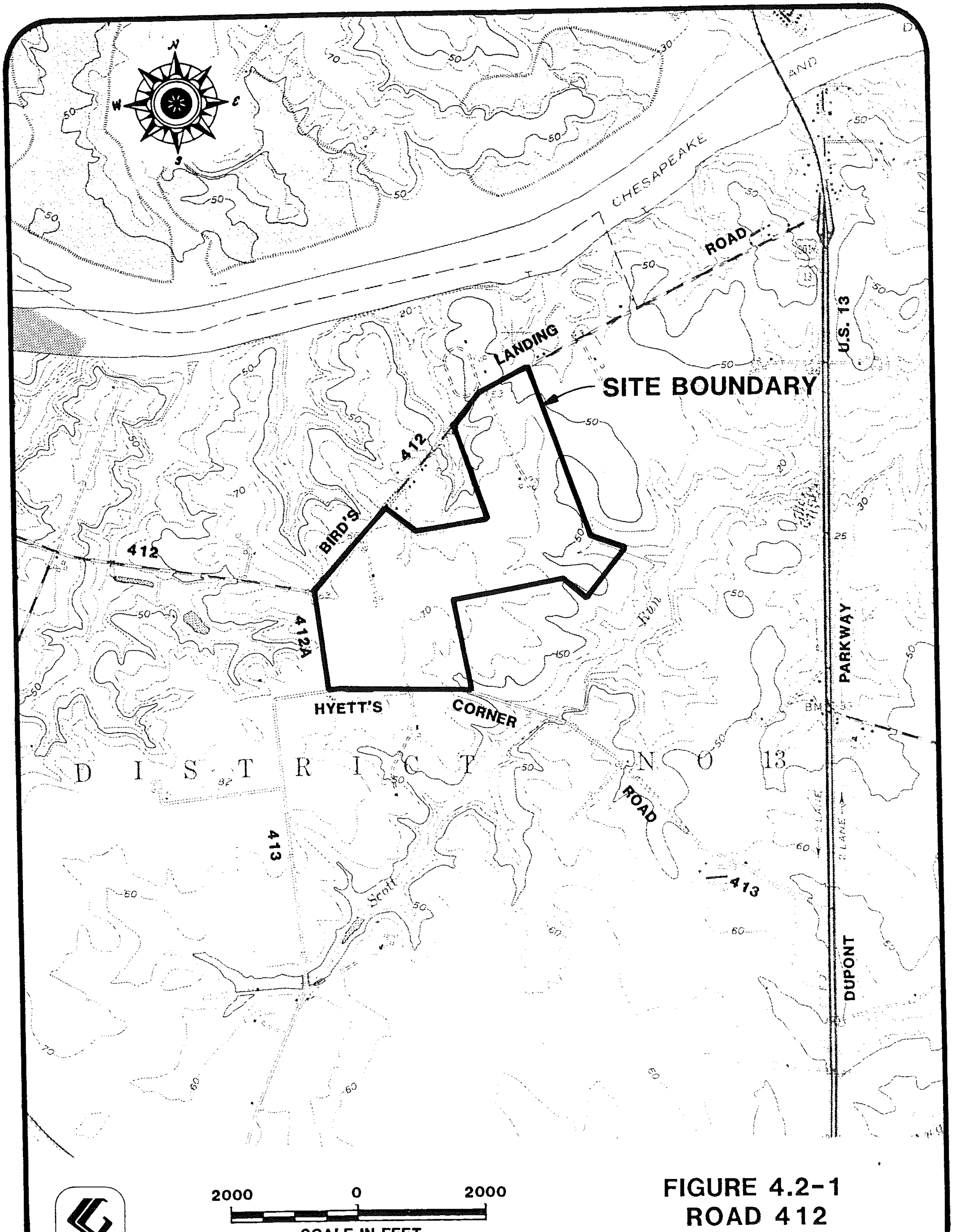


FIGURE 4.2-1
ROAD 412
LOCATION MAP

The Coastal Plain Province is comprised of a wedge of unconsolidated materials which consists of gravels, sands, silts and clays. This wedge of materials, which overlies the crystalline basement is thinnest at the Piedmont/Coastal Plain boundary and gradually thickens in a general southeastern direction towards the Continental Shelf. As reported by Sundstrom and Pickett, 1971, the thickness of the Coastal Plain sediments in New Castle County varies from 0 feet near Newark and Wilmington to approximately 2300 feet near the Smyrna River which serves as the southern boundary of the County. At the Road 412 site, the Coastal Plain sediments are approximately 750 feet thick. These sediments range in age from lower Cretaceous (135 million years) to Pleistocene (1 million years) and comprise numerous geologic formations. The oldest and deepest formation underlying the region of the Road 412 site is the Potomac formation. This formation lies at a depth of approximately 175 feet and extends to the crystalline basement. The Potomac formation typically consists of variegated red, gray, purple, yellow and white lignitic silt and clay which contains interbedded white, gray and rust brown quartz sand and some gravel. The Potomac formation is of lower Cretaceous age and is unconformably overlain by the Magothy formation. The upper Cretaceous age Magothy formation lies at a depth of approximately 160 feet and consists of white to buff, well sorted quartz sand with beds of gray and black clayey silt. As reported by Sundstrom and Pickett, 1971, the Magothy is discontinuous along strike and in some areas absent due to doming of the crystalline basement or erosion.

The Merchantville formation unconformably overlies the Magothy formation and is also upper Cretaceous in age. This formation is dark gray to dark blue in color and consists of sandy silt to silty fine sand. The formation occurs at a depth of approximately 100 to 140 feet in the region of the Road 412 site and is not considered an aquifer. The Merchantville formation is the oldest formation in the Matawan Group. In addition to the Merchantville formation, this group consists of a middle Englishtown formation unit and a upper Marshalltown formation unit. These middle and upper Matawan Group units overlie the Merchantville formation and consists of light gray and rust brown, well sorted fine sand (Englishtown formation) and dark greenish gray massive, highly glauconitic, very silty fine sand (Marshalltown formation). In the general area of the Road 412 site the Marshalltown formation and Englishtown formation lie at a depth of approximately 50 to 80 feet, respectively. The Englishtown is reported to be a minor aquifer in Delaware. The Marshalltown formation is not considered an aquifer.

Overlying the Marshalltown formation and subcropping the surficial Pleistocene age Columbia formation, the Mount Laurel formation has been mapped. The Mount Laurel formation, which is also called the Monmouth formation consists of gray to greenish red brown glauconitic fine to medium quartz sand with some silt. The surficial Columbia formation consists typically of orange, tan, and yellow medium to coarse sands and gravel. As indicated on Figure 4.2-1, the Columbia formation (Pleistocene sediments) form an undulating topography at the Road 412 site. In reference to the figure, the Road 412 site varies in elevation* from a maximum of approximately 70 $\pm$ feet to a minimum elevation of approximately 20 $\pm$ feet. Drainage of the site is provided by the Chesapeake and Delaware Canal to the north and by Scott Run to the south and east.

4.2.1.3 Subsurface Exploration Program

The subsurface exploration and monitoring well installation program for the Road 412 site was undertaken during the period

*Datum: Mean Sea Level

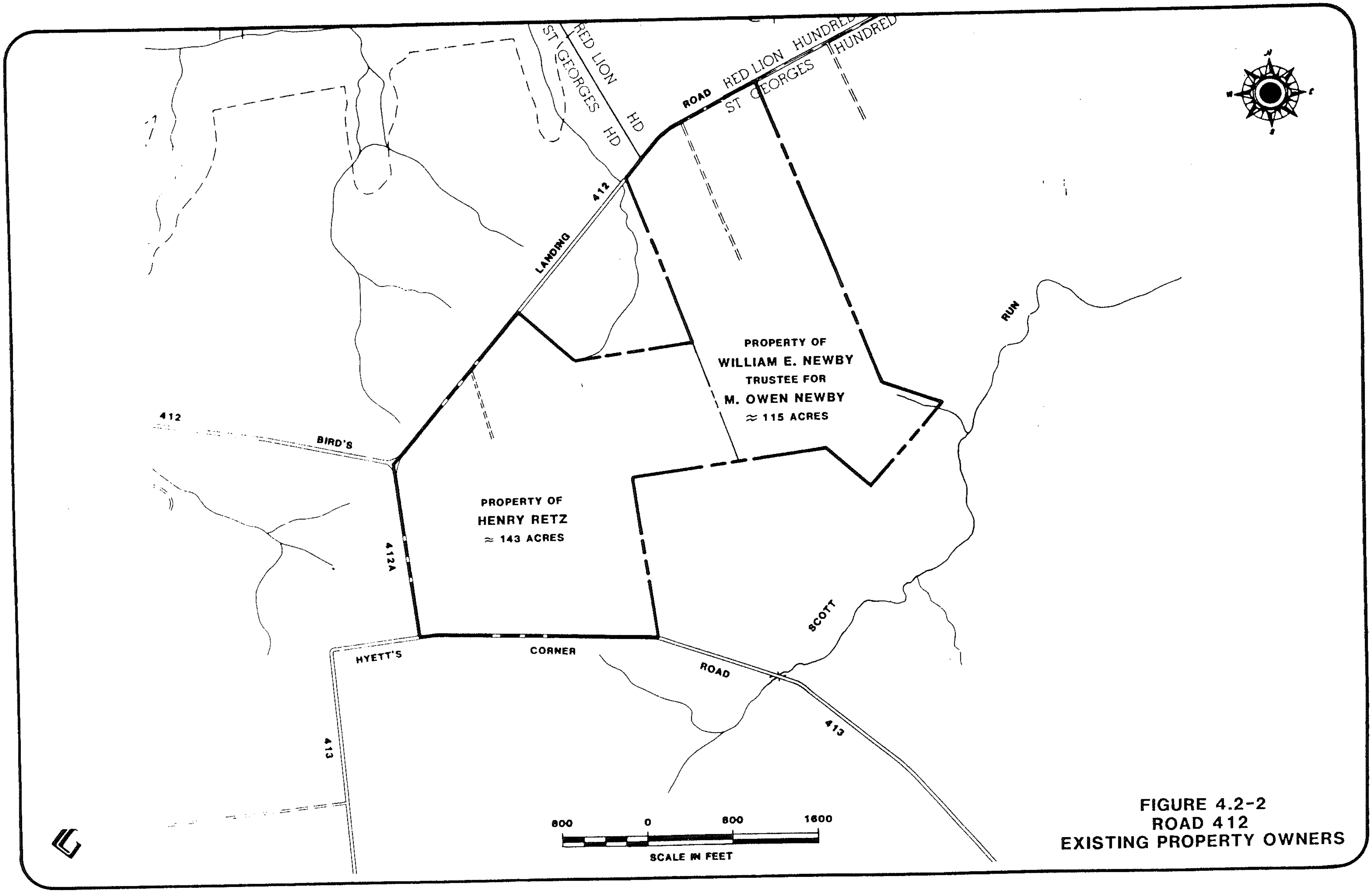


FIGURE 4.2-2
ROAD 412
EXISTING PROPERTY OWNERS

extending from July 14, 1981 through July 22, 1981. Delmarva Drilling Company, Inc. of Bridgeville, Delaware and Middletown Well Drilling Company of Odessa, Delaware (subcontractor to Delmarva Drilling Company, Inc.) were contracted to perform the monitoring well installations. In total, eight Pleistocene/Mount Laurel wells, three Englishtown wells and three Magothy wells were constructed. Drilling equipment consisted of Failing Model 1250 rotary rigs.

Field Procedures

As previously indicated, a total of eight Pleistocene/Mount Laurel wells were constructed during the monitoring well installation program. The locations of these wells, which are designated P-1 through P-8, are shown on Figure 4.2-3. The monitoring wells were constructed for the purpose of identifying the types and thicknesses of the various sediments comprising the Pleistocene and the subcropping Mount Laurel formations. In addition, the wells were constructed for the purpose of determining groundwater elevations, flow directions and water quality data.

In determining the types and thicknesses of the sediments, samples from each well bore were collected and logged at five foot intervals. In order to determine groundwater elevations and flow directions, 4-inch diameter polyvinyl chloride (PVC) pipe with 5 foot long PVC screen sections were installed in each well. The PVC screen had a number 16 slot opening size. This screen was gravel packed with No. 2 Morie gravel after installation. After development of the water in each monitoring well, the annular space between the well bore and the PVC casing was sealed with bentonite grout from the top of the gravel pack to within 2 feet of the surface. A 6-inch diameter steel protector casing with a locking cap was installed and the steel casing was set in concrete grout at a depth of approximately 2 feet. The Pleistocene/Mount Laurel monitoring wells were monitored during the course of the subsurface exploration program and a complete set of water level elevations was obtained on July 28, 1981. The geologic logs of the eight Pleistocene/Mount Laurel wells are included in Appendix A of this section.

In order to determine the characteristics of the uppermost confined aquifer and potentiometric surface data, three wells were constructed in the Englishtown formation. The Englishtown wells are shown on Figure 4.2-3 and are designated E-1 through E-3. The geologic logs of the wells are included in Appendix A of this section. The Englishtown wells were constructed in identical fashion to the previously described Pleistocene/Mount Laurel wells. However, a ten foot long, rather than five foot long, screen section was utilized.

Three deep monitoring wells were installed in the Magothy formation. These wells are designated M-1 through M-3 on Figure 4.2-3. Well M-2 was the first well drilled at the site and served as the data base for the remaining well construction. Upon drilling completion and drill tool removal, the Delaware Geological Survey performed gamma ray logging of the well. Differential single point electric logging was also attempted but problems with lowering the probe into the open well bore precluded this activity. After completion of logging, the various formations comprising the site were identified. Construction of the deep wells included the installation of ten-foot long 4-inch diameter PVC screen sections and casing, gravel packing, development, bentonite sealing and installation of steel protector casing set in cement grout. The geologic and geophysical logs of the Magothy wells are included in Appendix 4A and 4B, respectively.

USDA Soil Descriptions

According to the United States Department of Agriculture - Soil Conservation Service publication entitled, "Soil Survey - New

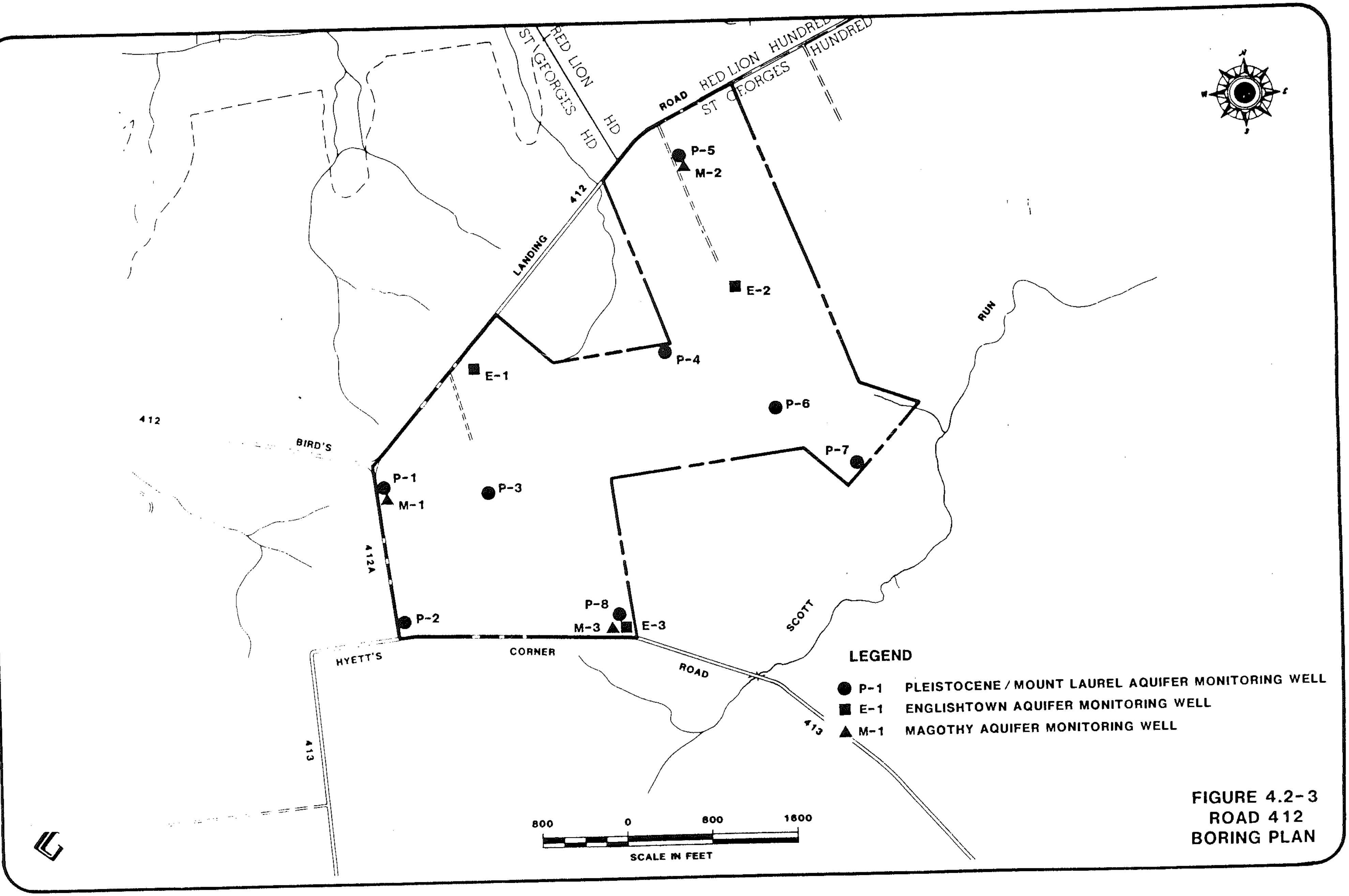


FIGURE 4.2-3
ROAD 412
BORING PLAN

Castle County, Delaware", several soil series surficially blanket the Road 412 site. As shown on Figure 4.2.4, two units of the Matapeake soil series and one unit of the Woodstown soil series are indicated. As published in the above reference, descriptions of the soils follow:

MeB2 - Matapeake silt loam, 2 to 5 percent slopes, moderately eroded: The soil forming this unit is described as deep, well-drained soil that occurs on uplands of the Coastal Plain. The surface layer consists of brown silt loam which is underlain by a thin layer of yellow brown silt loam followed by brown silty clay loam. The soil has a high available moisture capacity and is suited to practically all uses. Engineering properties of the soil indicate that the unit typically has a pH of 4.5 to 5.5, has a permeability ranging from 0.2 to 6.3 inches per-hour and has a low to moderate shrink swell potential. This unit blankets approximately 70 percent of the site.

MeC2 - Matapeake silt loam, 5 to 10 percent slopes, moderately eroded: This soil is like the MeB2 unit above but is slightly more eroded. This unit blankets approximately 25 percent of the site.

WsA - Woodstown loam, 0 to 2 percent slopes: This soil consists of deep, moderately well drained materials occupying uplands of the Coastal Plain. In profile, the surface layer is brown loam, which is underlain by yellowish brown loam or fine sandy loam. Beneath this subsurface layer the soil typically consists of yellowish-brown sandy clay loam. Impeded drainage and seasonal wetness are the main limitations of use. The Woodstown unit blankets approximately 5 percent of the site.

Sediment Description

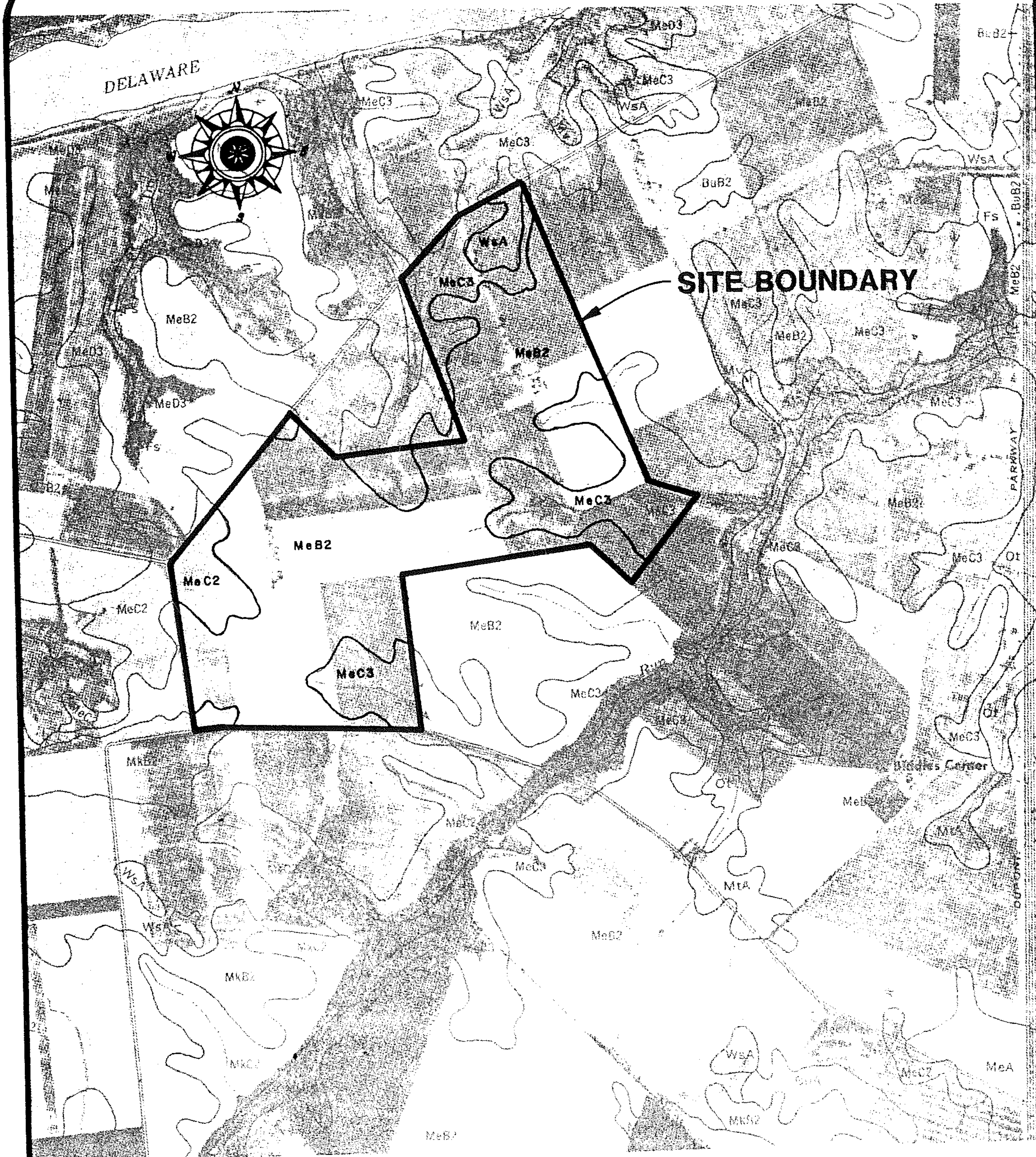
Based on the results of the subsurface exploration and monitoring well installation program, Figures 4.2.5A and 4.2.5B which are geologic cross-sections of the Road 412 site, have been developed. In reference to these figures, the Coastal Plain sediments, which underlie the above defined soil units, are quite variable and comprise numerous geologic formations some of which serve as groundwater aquifers in New Castle County.

The Pleistocene sediments consist of predominantly brown to rust brown fine to coarse sand with layers of clayey gravel and silty sand. The thickness of the Pleistocene sediments varies from 30 feet to 55 feet (see logs M-2 & M-1).

Subcropping the Pleistocene sediments, the Mount Laurel formation was penetrated by the E-series and M-series monitoring wells. As evidenced by these borings, the Mount Laurel formation was approximately 20-24 feet thick and consisted of light gray to greenish gray clayey sand, silty sand, and sandy clayey silt.

As shown on Figures 4.2-5A and 4.2-5B, the Marshalltown formation directly underlies the Mount Laurel formation and confines the lower Englishtown formation. The Marshalltown formation ranged in thickness from 24 to 32 feet and consisted of greenish gray clayey silt, silty clay, silty sand with some clay and sandy clay with some silt. The Englishtown formation, which is a confined aquifer at the Road 412 site, ranged in thickness from 12 to 36 feet and consisted predominantly of dark gray silty sand.

Underlying the Englishtown formation and overlying the Magothy formation, the Merchantville formation was penetrated by the Magothy monitoring wells. Samples logged from these wells (see logs M-1 through M-3) indicate that the Merchantville formation consists predominantly of dark green-gray silty clay to clayey silt. The formation ranged in thickness from 36 feet at the M-1 location to 67 feet at the M-3 location where gamma logging of the monitoring well was conducted.

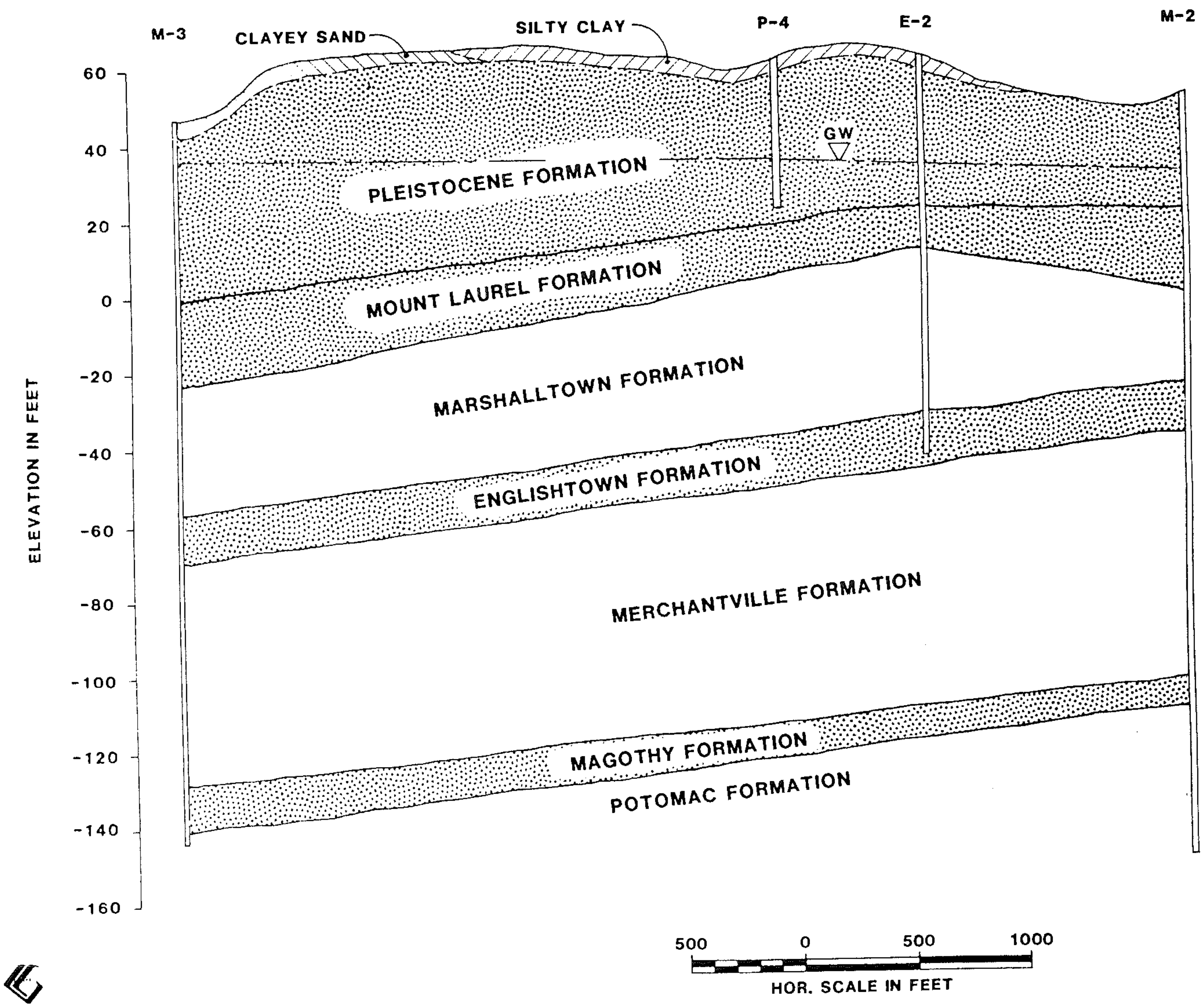


REFERENCE: SOIL SURVEY OF NEW CASTLE COUNTY, DELAWARE,
USDA, SOIL CONSERVATION SERVICE, 1970

0 1/4 1/2 3/4

SCALE IN MILES

FIGURE 4.2-4
ROAD 412
SOILS MAP



PLEISTOCENE FORMATION:
PREDOMINANTLY BROWN TO RUST BROWN SILTY SAND, SOME MICACEOUS SANDS AND GRAVELS

MOUNT LAUREL FORMATION:
GREEN GRAY SILTY SANDS, SOME CLAYEY SANDS MICACEOUS, SOME GLAUCONITE, ZONES OF SHELL FRAGMEMTS

MARSHALLTOWN FORMATION:
GREEN GRAY SANDY SILTY CLAY WITH SOME FINE SAND SEAMS, TRACE OF SHELL FRAGMENTS

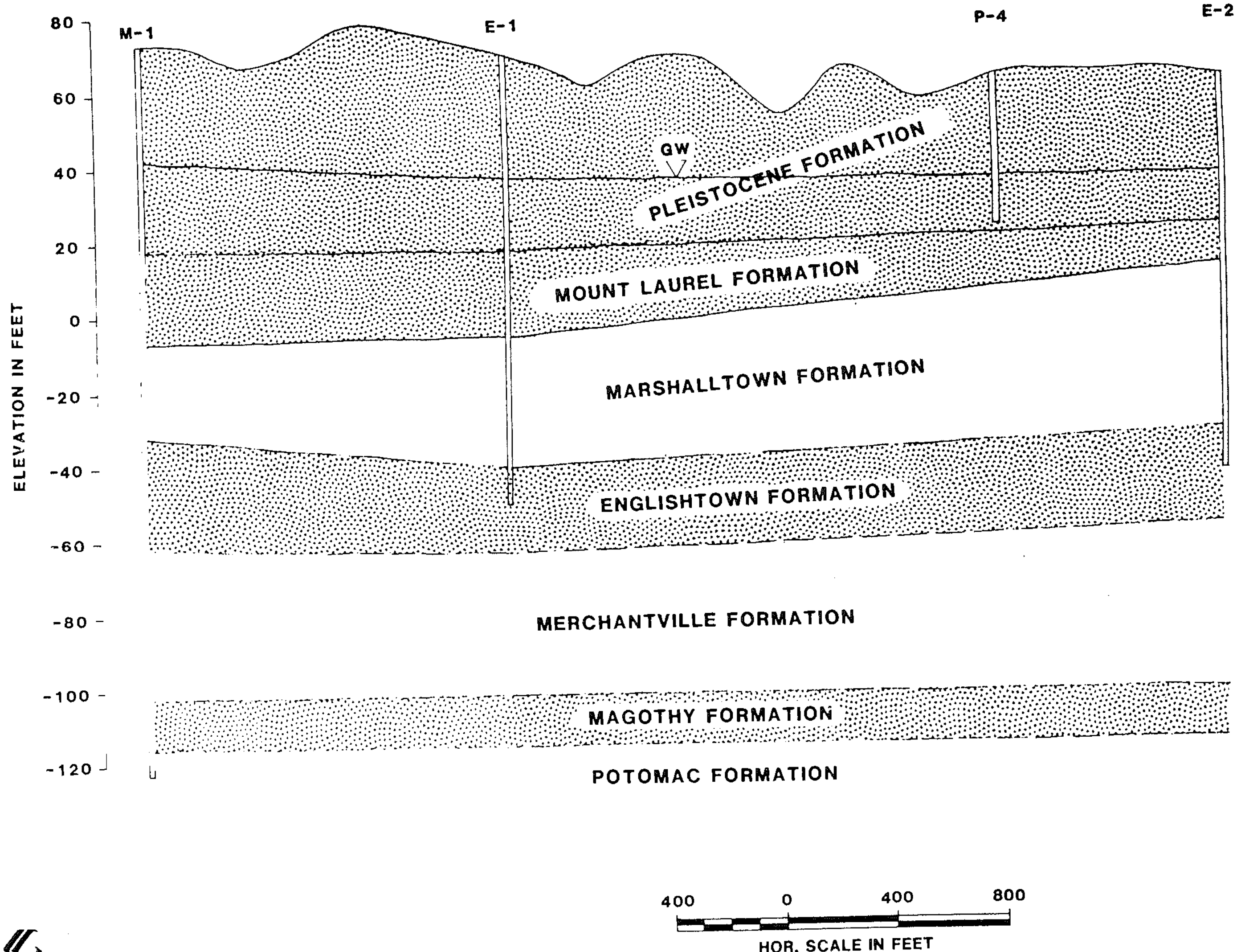
ENGLISHTOWN FORMATION:
GREEN GRAY SILTY FINE SAND, SOME SHELL FRAGMENTS, SLIGHTLY MICACEOUS

MERCHANTVILLE FORMATION:
DARK GREEN GRAY TO GRAY SILTY CLAY TO CLAYEY SILT, SOME GLAUCONITE, MICACEOUS, FEW SHELL FRAGMENTS

MAGOTHY FORMATION:
LIGHT GREEN GRAY SILTY FINE SAND, SAND IS SUGARY WHEN WASHED, AT M-2 SAND IS CLAYEY SILT

POTOMAC FORMATION:
CREAM, RED, GREEN SILTY CLAY

FIGURE 4.2-5A
ROAD 412
GEOLOGIC CROSS SECTION



PLEISTOCENE FORMATION:
PREDOMINANTLY BROWN TO RUST BROWN SILTY SAND, SOME MICACEOUS SANDS AND GRAVELS

MOUNT LAUREL FORMATION:
GREEN GRAY SILTY SANDS, SOME CLAYEY SANDS MICACEOUS, SOME GLAUCONITE, ZONES OF SHELL FRAGMEMTS

MARSHALLTOWN FORMATION:
GREEN GRAY SANDY SILTY CLAY WITH SOME FINE SAND SEAMS, TRACE OF SHELL FRAGMENTS

ENGLISHTOWN FORMATION:
GREEN GRAY SILTY FINE SAND, SOME SHELL FRAGMENTS, SLIGHTLY MICACEOUS

MERCHANTVILLE FORMATION:
DARK GREEN GRAY TO GRAY SILTY CLAY TO CLAYEY SILT, SOME GLAUCONITE, MICACEOUS, FEW SHELL FRAGMENTS

MAGOTHY FORMATION:
LIGHT GREEN GRAY SILTY FINE SAND, SAND IS SUGARY WHEN WASHED, AT M-2 SAND IS CLAYEY SILT

POTOMAC FORMATION:
CREAM, RED, GREEN SILTY CLAY

FIGURE 4.2-5B
ROAD 412
GEOLOGIC CROSS SECTION

Beneath the Merchantville formation, the Magothy formation or aquifer was penetrated. At the Road 412 site this aquifer averaged a thickness of 12 feet and consisted of green gray clayey sandy silt to silty sand with the sand being sugary. Based on topographic information, the top of the Magothy aquifer varies from elevation -102 to -126 feet across the site.

The Potomac formation was the deepest Coastal Plain formation penetrated at the Road 412 site. This formation varied from 161 to 175 feet below the surface and consisted of gray, red and cream sandy clay. This formation extends downward to the crystalline basement.

4.2.1.4 Suitability of Insitu Materials for Cover

In order to determine the suitability of the insitu materials occurring above the water table for use as cover materials, representative soil samples were collected and submitted for laboratory testing of grain size distribution. This testing included hydrometer testing of the sediments passing through the No. 200 sieve size. The testing results and gradation curves are included in Appendix 4C of this section.

Daily and Final Cover

Ideally, cover materials should be of such character that they can be compacted to minimize percolation of water through the cover, will not crack excessively when dry, and are free of large objects and putrescible materials. Cover materials should consist of stockpiled soils obtained from excavations at the site. In general, the bulk of materials excavated on site will consist of soils comprising the surficial 5 to 20 feet.

The results of the grain size analyses are summarized on Table 4.2-1. Review of the table indicates that the soils

TABLE 4.2-1

ROAD 412 SITE
GRAIN SIZE ANALYSES

Well No.	Depth (ft)	Cumulative Percent Retained — Sieve Sizes 4	10	18	30	50	100	200	Classification	USCS*
E-2	5	6.6	6.6	8.5	17.6	40.6	49.8	54.0	silt and sand	SM-ML
P-2	5	3.6	5.1	6.7	9.6	22.4	32.1	36.4	sandy clayey silt	ML
P-3	5	0	0.9	0.9	2.8	10.2	17.4	22.5	sandy clayey silt	ML-CL
P-5	5	0	1.1	8.6	35.7	80.4	93.2	94.8	fine to medium sand	SP
P-6	5	0	0.8	4.5	17.9	73.9	91.7	93.7	fine to medium sand	SP-SM
P-7	5	0	0	1.0	5.3	21.5	30.6	33.9	sandy silt	ML
P-7	10	0.7	7.9	27.6	53.6	79.7	86.3	88.3	silty fine to coarse sand	SM-SP
P-8	5	15.9	18.8	23.9	30.8	49.0	61.5	69.7	silty sand and some gravel	SM

*Unified Soil Classification System

comprising the surficial 5 to 10 feet of the Road 412 site vary from silty sand and gravel (P-8, 5 feet) to sandy silty clay (P-3, 5 feet).

In general, most of the soils on the site are suitable for use as daily and final cover material for the routine operation of the landfill. They contain fairly significant amounts of fines (materials passing No. 200 sieve) which will facilitate compaction and reduce percolation of precipitation. However, in several cases (P-2, 5 feet and P-7, 5 feet) the percentages of fines represent more than half of the size fraction. These particular soils may have a tendency to crack when dry. If excessive cracking is noted, blending of these soils with other on-site soils during placement over the refuse will preclude this from occurring.

<u>Protective Cover for Liner</u>

Based on the grain size analyses the on-site soils are free of aggregate, rocks or solid materials greater than 2-inches in diameter and have a sufficient quantity of fines which would allow their use for protective cover material for the liner.

4.2.1.5 Hydrogeology

As defined in the following sections of this report, data pertinent to the hydrogeologic regime of the Road 412 site is presented.

<u>Aquifer Discussion</u>

As evidenced through the construction of a series of monitoring wells on the Road 412 site, four groundwater aquifers comprise the surficial 200 feet of the Coastal Plain sediments. These aquifers, namely the Pleistocene and subcropping Mount Laurel water table aquifer, the Englishtown confined aquifer and the Magothy confined aquifer vary in their hydraulic properties, water yielding capabilities and their local use. A hydrogeologic description of these aquifers follows:

Pleistocene/Mount Laurel Water Table Aquifer - The Pleistocene water table aquifer blankets all of New Castle County south of the "fall line" and typically consists of medium to coarse sands and gravel. In New Castle County, the aquifer has a transmissivity in the range of 16,000 to 100,000 gallons per day per foot, has a storage coefficient of 0.12 to 0.15, and an average specific capacity of 14.8 gallons per minute per foot of drawdown. (Sundstrom and Pickett, 1971). In the area of the Road 412 site, the Pleistocene sediments have limited saturated thicknesses, are subcropped by the Mount Laurel aquifer and both formations act as one hydrogeologic unit. The Mount Laurel aquifer is a minor aquifer of fair to poor water yielding properties and is unimportant in terms of large individual supplies, but is of importance from the Chesapeake and Delaware Canal southward for rural residential supplies (Sundstrom, Pickett, Varrin, 1975). Although the Mount Laurel aquifer has a low transmissivity of 1,500 gallons per day per foot, the aquifer, when coupled with the overlying Pleistocene sediments which have limited saturated thickness, is capable of yielding adequate residential supplies and is utilized as such in the Road 412 site area.

Englishtown Aquifer - This aquifer is considered a minor aquifer of fair to poor water yielding properties and is unimportant in terms of large individual supplies, but is of importance from the Chesapeake and Delaware Canal southward for rural residential supplies. The aquifer reportedly has a low transmissivity of 1,800 gallons per day per foot and may be utilized by some residents of the Road 412 site area. Using the 1,800 gallons per foot transmissivity value and an average aquifer thickness across the Road 412 site of 20 feet, the hydraulic conductivity of the

Englishtown aquifer is estimated to be in the range of 4 x 10^{-3} cm/sec. In the area of the Road 412 site and as previously indicated on Figures 4.2-5A and 4.2-5B, the Englishtown aquifer is confined from the Mount Laurel aquifer by the Marshalltown formation. This formation is approximately 24 to 34 feet thick on site and had an estimated permeability of 1 x 10^{-4} to 1 x 10^{-5} cm/sec.

Magothy Aquifer - This aquifer is confined by the overlying Merchantville formation and is the deepest aquifer penetrated on site. The Merchantville formation is not an aquifer and ranges in thickness from 35 to 55 feet at the Road 412 site. The Merchantville formation consists of silty clay to clayey silt and has an estimated permeability of 1 x 10^{-7} cm/sec. The underlying Magothy aquifer is relatively thin across the Road 412 site and consisted of predominantly silty sand. Although limited data is available, the Magothy aquifer reportedly has a transmissivity of 4,000 gallons per day per foot and a storage coefficient of .00006 which indicates relatively tight confinement (Sundstrom and Pickett, 1971). Based on the very silty nature of the Magothy aquifer on the Road 412 site, the hydraulic conductivity of the aquifer is estimated to be in the range of 5 x 10^{-3} cm/sec. The Magothy aquifer also is a source of water to residents in the Road 412 area.

Aquifer Monitoring

In constructing the Pleistocene/Mount Laurel monitoring wells, four-inch diameter PVC casings containing 5-foot long screen sections were installed in each well. The standpipes were utilized to obtain data pertinent to the phreatic surface of the water table aquifer and to determine groundwater flow directions. Further, the wells were used to obtain representative groundwater samples.

Similarly, four-inch diameter PVC casings containing 10-foot long PVC screen sections were installed in the Englishtown and Magothy wells. These standpipes were utilized to obtain data pertinent to the potentiometric surface of the confined aquifers and to obtain representative groundwater samples.

During the course of the investigation program, water level readings were taken of the completed wells and a complete set of water level readings was obtained on July 28, 1981, after drilling completion. The water level data obtained on July 28, 1981 is summarized in Table 4.2-2.

Potentiometric Surfaces and Groundwater Flow

Based on the water level data presented in Table 4.2-2, one potentiometric surface map of the Pleistocene/Mount Laurel water table aquifer and two potentiometric surface maps of the Englishtown and Magothy confined aquifers have been prepared. These maps appear as Figures 4.2-6 through 4.2-8 of this report.

Figure 4.2-6 represents the potentiometric surface of the Pleistocene Mount Laurel water table aquifer. In reference to the figure, the groundwater table at the Road 412 site is quite variable. In general the water table has the highest elevation (P-2, 44.8 feet) in the southwest portion of the site and the lowest elevation (P-7, 20.6 feet) in the southeast portion of the site near Scott Run. Based on the potentiometric surface map, several groundwater divides occur on site and groundwater flows in several directions with the dominant flow patterns being towards the southeast and northeast. Review of Table 4.2-2 indicates that the shallowest depth to water occurred at monitoring well P-8 (12.6 feet) and that the maximum depth to water was measured at monitoring well P-3 (33.6 feet).

TABLE 4.2-2

ROAD 412 SITE

WATER LEVEL DATA

Well No.	Ground Surface Elev. (ft.)	Top of PVC Casing Elev. (ft.)	Depth to* Water Level (ft.)	Elev. of** G.W. (ft.)
P-1	73.0	75.1	32.9	42.2
P-2	73.5	75.7	30.9	44.8
P-3	74.5	76.3	35.4	40.9
P-4	61.5	63.5	28.9	34.6
P-5	51.0	52.5	23.1	29.4
P-6	42.5	44.4	16.1	28.3
P-7	39.5	41.4	20.8	20.6
P-8	47.0	49.2	14.8	34.4
E-1	68.5	71.0	52.8	18.2
E-2	61.5	63.9	53.0	10.9
E-3	47.0	48.5	27.9	20.6
M-1	73.0	75.3	81.3	-6.0
M-2	51.0	52.4	58.0	-5.6
M-3	47.0	48.8	59.1	-10.3

*As Measured From Top of PVC Casing

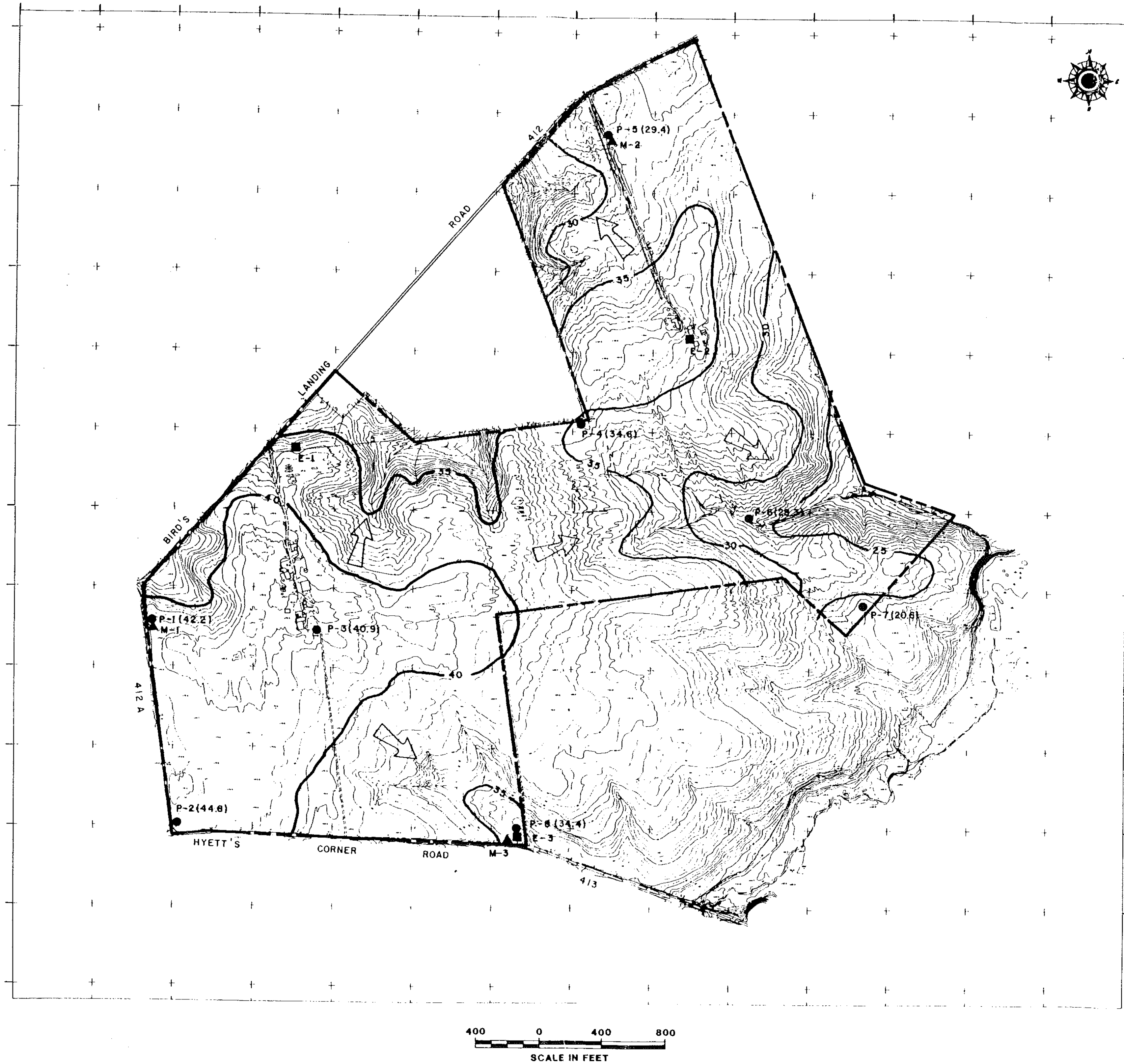
**Elev. of G.W. = Elev. Top of PVC Casing - Depth to Water Level

Figure 4.2-6 represents the potentiometric surface of the Englishtown Aquifer. This surface varies from elevation 24 feet, in the extreme southwest corner of the site, to elevation 8 feet in the extreme northeast corner of the site. Groundwater flow within the confined aquifer, is towards the northeast. Comparison of the potentiometric surface maps of the Pleistocene/Mount Laurel water table aquifer and the Englishtown aquifer indicates that the potentiometric surface of the Englishtown aquifer is lower across the entire site than the potentiometric surface of the Pleistocene/Mount Laurel aquifer. Accordingly, potential downward movement of contaminants is possible.

Figure 4.2-8 represents the potentiometric surface of the Magothy Aquifer. In reference to this figure, the potentiometric surface varies from elevation -6 feet near the Road 412 border of the site to elevation -11 feet near Scott Run. Based on these elevations, groundwater flow within the Magothy aquifer is towards the southeast. Comparison of both Figures 4.2-6 and 4.2-7 with Figure 4.2-8 indicates that the potentiometric surface of the Magothy aquifer is lower than either the water table aquifer or the Englishtown aquifer. Accordingly, potential downward movement of contaminants is possible.

Water Table Fluctuations

Because the Delaware Solid Waste Disposal Regulation requires that at least 3 feet of separation between refuse deposits and the yearly high groundwater table be maintained, an estimate of the seasonal high water table at the Road 412 site has been prepared using data published by the United States Geological Survey (see Adams and Boggess, 1964). In this publication, which has been prepared for the St. Georges area of Delaware, is a hydrograph showing the average depth to groundwater for an eleven year period (1950-1961) for 13 water table wells in Delaware. In addition, actual water level fluctuations for wells on and surrounding the



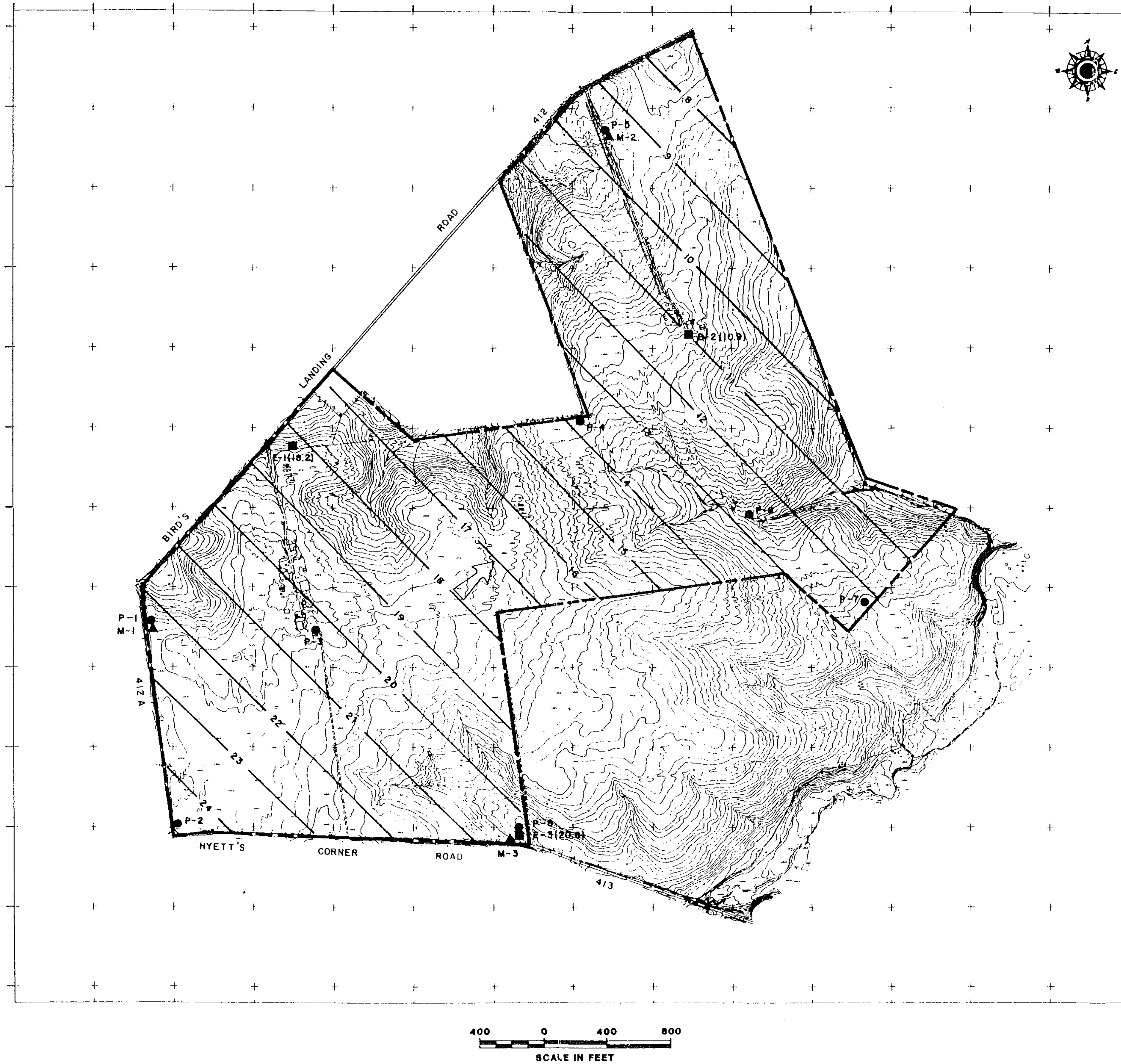
BORING NUMBER	GROUND SURFACE ELEVATION	GROUNDWATER ELEVATION *
P-1	73.0	42.2
P-2	73.5	44.8
P-3	74.5	40.9
P-4	61.5	34.6
P-5	51.0	29.4
P-6	42.5	28.3
P-7	39.5	20.6
P-8	47.0	34.4
E-1	68.5	18.2
E-2	61.5	10.9
E-3	47.0	20.6
M-1	73.0	-6.0
M-2	51.0	-5.6
M-3	47.0	-10.3

* GROUNDWATER LEVELS MEASURED 7/28/81

LEGEND

- ● P-1 — PLEISTOCENE / MOUNT LAUREL AQUIFER MONITORING WELL
- ■ E-1 — ENGLISHTOWN AQUIFER MONITORING WELL
- ▲ M-1 — MAGOTHY AQUIFER MONITORING WELL
- (20.6) — ELEVATION OF GROUNDWATER AT PLEISTOCENE / MOUNT LAUREL MONITORING WELL
- —35— — POTENTIOMETRIC SURFACE
- ⇦ — DIRECTION OF GROUNDWATER FLOW

FIGURE 4.2-6
ROAD 412
POTENTIOMETRIC SURFACE MAP
PLEISTOCENE / MOUNT LAUREL
WATER TABLE AQUIFER



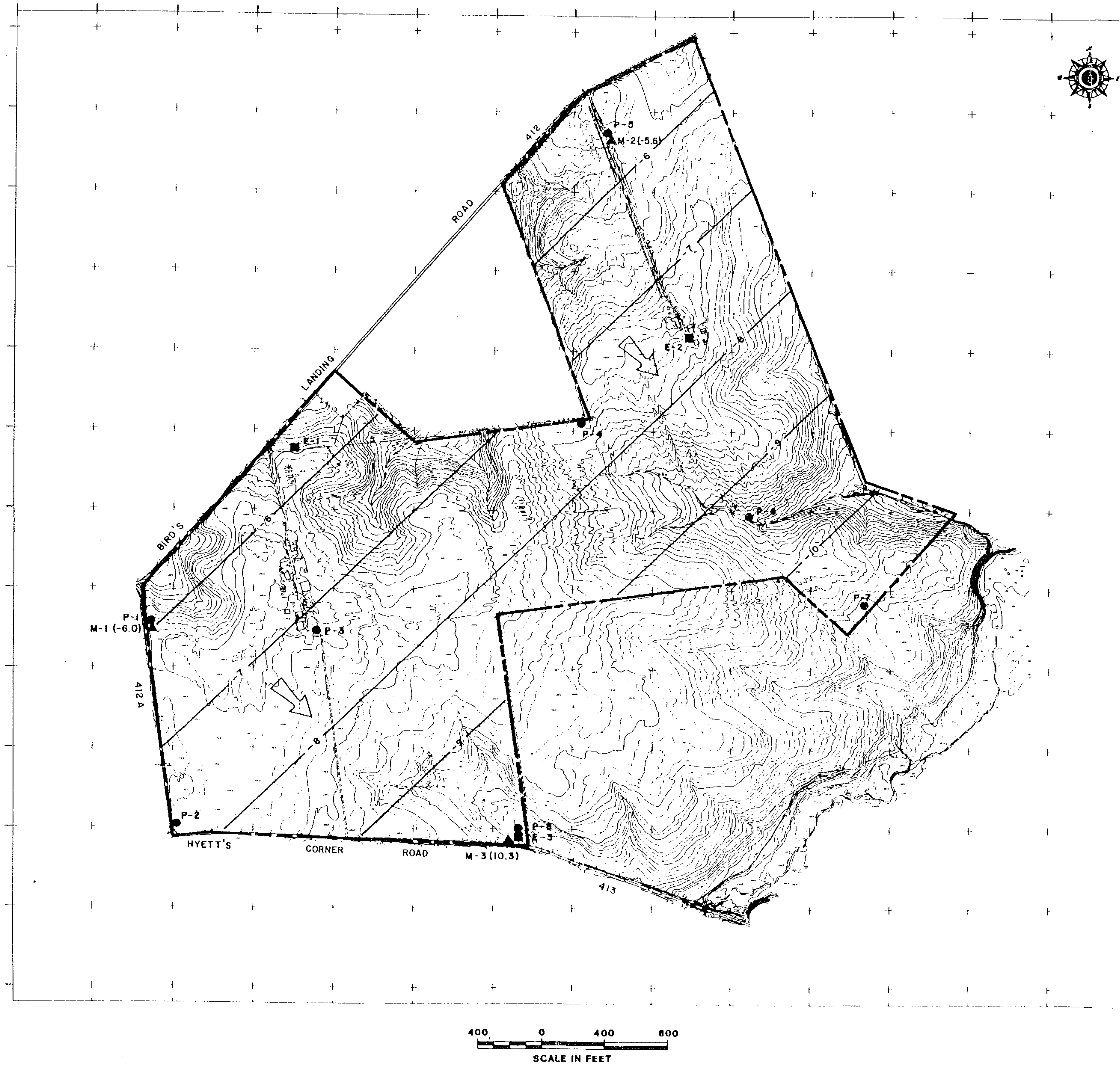
BORING NUMBER	GROUND SURFACE ELEVATION	GROUNDWATER ELEVATION *
P-1	73.0	42.2
P-2	73.5	44.8
P-3	74.5	40.9
P-4	61.5	34.6
P-5	51.0	29.4
P-6	42.5	28.3
P-7	39.5	20.6
P-8	47.0	34.4
E-1	68.5	18.2
E-2	61.5	10.9
E-3	47.0	20.6
M-1	73.0	-6.0
M-2	51.0	-5.6
M-3	47.0	-10.3

* GROUNDWATER LEVELS MEASURED 7/28/81

LEGEND

- ● P-1 PLEISTOCENE / MOUNT LAUREL AQUIFER MONITORING WELL
- ■ E-1 ENGLISHTOWN AQUIFER MONITORING WELL
- ▲ M-1 MAGOTHY AQUIFER MONITORING WELL
- (10.9) ELEVATION OF GROUNDWATER AT ENGLISHTOWN MONITORING WELL
- —14— POTENTIOMETRIC SURFACE
- ⇦ DIRECTION OF GROUNDWATER FLOW

FIGURE 4.2-7
ROAD 412
POTENTIOMETRIC SURFACE MAP
ENGLISHTOWN AQUIFER



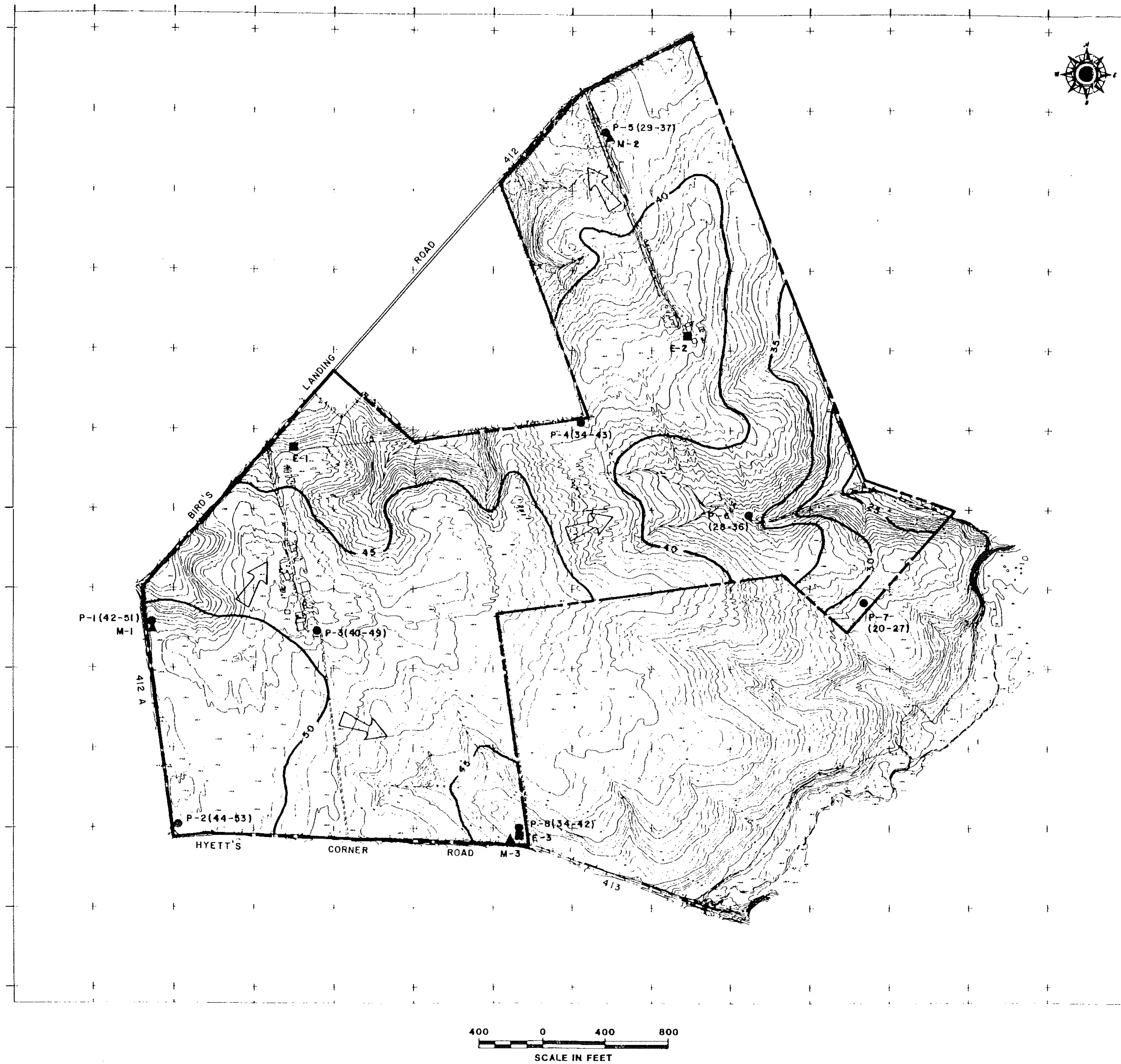
BORING NUMBER	GROUND SURFACE ELEVATION	GROUNDWATER ELEVATION *
P-1	73.0	42.2
P-2	73.5	44.8
P-3	74.5	40.9
P-4	61.5	34.6
P-5	51.0	29.4
P-6	42.5	28.3
P-7	39.5	20.6
P-8	47.0	34.4
E-1	68.5	18.2
E-2	61.5	10.9
E-3	47.0	20.6
M-1	73.0	-6.0
M-2	51.0	-5.6
M-3	47.0	-10.3

* GROUNDWATER LEVELS MEASURED 7/28/81

LEGEND

- ● P-1 PLEISTOCENE / MOUNT LAUREL AQUIFER MONITORING WELL
- ■ E-1 ENGLISHTOWN AQUIFER MONITORING WELL
- ▲ M-1 MAGOTHY AQUIFER MONITORING WELL
- (-6.0) ELEVATION OF GROUNDWATER AT MAGOTHY MONITORING WELL
- —-8— POTENTIOMETRIC SURFACE
- ⇦ DIRECTION OF GROUNDWATER FLOW

FIGURE 4.2-8
ROAD 412
POTENTIOMETRIC SURFACE MAP
MAGOTHY AQUIFER



BORING NUMBER	GROUND SURFACE ELEVATION	GROUNDWATER ELEVATION *
P-1	73.0	42.2
P-2	73.5	44.8
P-3	74.5	40.9
P-4	61.5	34.6
P-5	51.0	29.4
P-6	42.5	28.3
P-7	39.5	20.6
P-8	47.0	34.4
E-1	68.5	18.2
E-2	61.5	10.9
E-3	47.0	20.6
M-1	73.0	-6.0
M-2	51.0	-5.6
M-3	47.0	-10.3

* GROUNDWATER LEVELS MEASURED 7/28/81

LEGEND

- ● P-1 PLEISTOCENE / MOUNT LAUREL AQUIFER MONITORING WELL
- ■ E-1 ENGLISHTOWN AQUIFER MONITORING WELL
- ▲ M-1 MAGOTHY AQUIFER MONITORING WELL
- (30-35) ESTIMATED RANGE OF ALTITUDE OF WATER TABLE
- —35— SEASONAL HIGH ELEVATION OF WATER TABLE
- ⇦ DIRECTION OF GROUNDWATER FLOW

FIGURE 4.2-9
ROAD 412
SEASONAL HIGH WATER TABLE MAP

Road 412 site are shown on the report map. The hydrograph indicates that the seasonal low water level is typically in July or August. Accordingly, the water levels listed on Table 4.2-2 are considered to be seasonal low levels since they were recorded in July. The fluctuations shown on the report map indicate that the water levels on the Road 412 site should rise as much as 9 feet, in the western portion of the site, and 7 feet in the southeastern portion of the site. This rise will be gradual and the highest levels should occur in early spring.

Using this data, Figure 4.2-9 has been developed. This figure shows the estimated seasonal high water levels of the Road 412 site. Further, this figure, along with the detailed topographic map of the site, can be utilized to estimate the permissible depths of excavation for any part of the proposed site.

Groundwater Quality

After construction of the monitoring wells, one representative groundwater sample was obtained from each aquifer underlying the surficial 200 feet of the Road 412 site. These samples were obtained on July 28, 1981 through the utilization of a 2-inch diameter stainless steel bailer and the samples were submitted for laboratory testing the same day. All samples were filtered prior to testing using a .45 micron filter. The results of the chemical analyses performed on the samples are summarized on Table 4.2-3 of this report. Also listed on the table are allowable constituent limits for drinking water for the State of Delaware.

Review of Table 4.2-3 indicates that groundwater occurring in all three aquifers is of excellent quality and meets with Delaware drinking water requirements with one minor exception.

TABLE 4.2-3
ROAD 412 SITE
WATER QUALITY ANALYSES

Chemical Constituent	Pleistocene Well P-8	Englishtown Well E-2	Magothy Well M-3	Delaware Limit *
Alkalinity mg/l	61	136	87	-
Arsenic mg/l	<0.002	<0.002	<0.002	0.05
Chloride mg/l	6	3	6	250
Chromium mg/l	0.01	0.013	<0.01	0.05
Conductivity μmhos	194	297	275	-
Copper mg/l	0.011	0.011	0.01	1.0
Hardness mg/l	74	140	110	-
Iron mg/l	0.01	0.025	0.022	0.3
Lead mg/l	<0.04	<0.04	<0.04	0.05
Manganese mg/l	0.054	0.046	<0.006	0.05
Mercury ug/l	<0.05	<0.05	<0.05	2.00
Nickel mg/l	<0.01	<0.01	<0.01	-
Nitrates N mg/l	2.98	<1.0	1.0	10
Nitrites mg/l	<0.005	<0.005	0.02	-
N. Ammonia mg/l	0.11	0.06	0.17	-
N. Kjeldhahl mg/l	0.56	0.336	1.01	-
pH	6.8	7.7	7.2	-
Diss. Solids mg/l	100	155	144	500
Selenium mg/l	<0.002	<0.002	<0.002	0.10
Sulfate mg/l	12.8	11.6	41.1	250
TOC mg/l	46.9	16.3	69.4	-

* mg/l, unless otherwise noted

The groundwater sample from Well P-8 slightly exceeds the limit for manganese (0.05 vs. 0.054). All three samples have high Total Organic Carbon (TOC) levels. This is attributed to the solvent used in cementing the PVC casing lengths together.

Local Water Use

Information pertaining to groundwater use in the Road 412 area has been obtained from data contained within Delmarva Power & Light Company's Preliminary Safety Analysis Report of the Summit Nuclear Power Plant Site. Additional data was obtained from discussions with well drilling contractors. Both the drilling contractor discussions and the report data indicate that the Pleistocene (Columbia)/Mount Laurel, Englishtown, and Magothy aquifers are all utilized by the residents of the Road 412 site area.

In reference to Figure 4.2-10, the locations of wells situated within a one-mile radius of the center of the Road 412 site are shown. Data pertinent to these wells are summarized on Table 4.2-4. In reference to the table, approximately 20 residential wells are situated near the Road 412 site and eighteen of the twenty wells derive their supplies from the Englishtown aquifer.

Interviews with Delmarva Drilling Company indicate that the Magothy aquifer is also utilized in the Road 412 area. Logs obtained from two Magothy wells situated in the Road 412 area are summarized below. However, because the exact location of the wells are unknown, the Magothy wells do not appear on Figure 4.2-10 and are not shown on Table 4.2-4.

Location	Date Drilled	Depth	Yield	Specific Capacity	Static Water Level
East of Road 412 Site	3/20/81	189 feet	11 gpm	0.10	55 feet
North of Road 412 Site	5/23/78	190 feet	15-20 gpm	0.37	60 feet

TABLE 4.2-4

Road 412 Site
Well Data

Well No.	Well Depth (Ft.)	Aquifer Utilized
1	40	Columbia
2	60	Columbia/Mt. Laurel
3	42	Columbia/Mt. Laurel
4	40	Columbia
5	42	Columbia
6	40	Columbia/Mt. Laurel
7	126	Englishtown
8	40	Columbia/Mt. Laurel
9	40	Columbia/Mt. Laurel
10	35	Columbia/Mt. Laurel
11	35	Columbia/Mt. Laurel
12	28	Columbia/Mt. Laurel
13	40	Columbia/Mt. Laurel
14	25	Columbia/Mt. Laurel
15	50	Columbia/Mt. Laurel
16	--	Columbia
17	50	Columbia/Mt. Laurel
18	120	Englishtown
19	40	Columbia
20	40	(not reported)

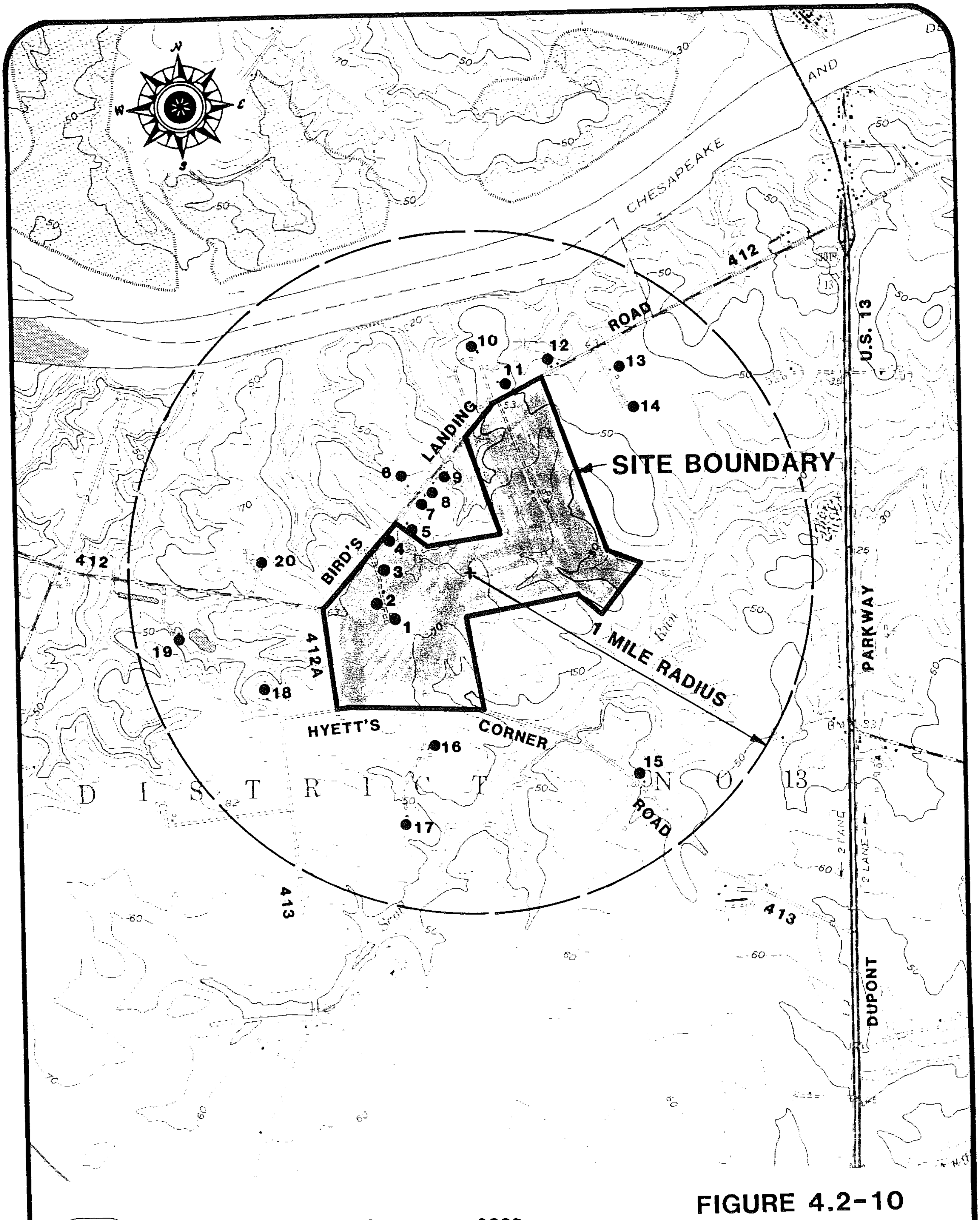


FIGURE 4.2-10
ROAD 412
WELL LOCATIONS

Potential Impacts

In the construction of any solid waste disposal facility, potential impacts upon both the geologic and hydrogeologic regimes exist. These impacts include potential contamination of the water table aquifer and subsequently downgradient shallow wells and/or surface water supplies; and potential contamination of deeper, confined aquifers and subsequently downgradient municipal or residential wells. Based on the physical and interpretative data developed through the subsurface exploration and monitoring well construction program, these impacts are discussed below. It should be noted that based on the geologic properties of the Road 412 site, a solid waste disposal facility incorporating lined disposal areas and a leachate collection system will be required in order to comply with state regulations. Further it should be noted that a lined landfill with a leachate collection system greatly prohibits, if not precludes, contamination of groundwater from leachate.

Using Darcey's Law (Q=KIA), the amount of vertical seepage of leachate that could occur at the Road 412 Site has been calculated for a "worst case" situation in which the site is presumed to be unlined. In estimating the amount of seepage that could occur in this situation, a hydraulic conductivity of 1×10^{-7} cm/sec was utilized for the Marshalltown formation. An area of 171 acres, or the total area to be filled with refuse, was utilized for an area of vertical inflow. An average vertical hydraulic gradient was used as calculated from the gradients determined for the three Englishtown monitoring wells and the three Magothy monitoring wells.

For the Englishtown aquifer the results of the calculation indicate that approximately 3817 gpd (22 gpd/acre) of seepage can occur at the Road 412 site. As leachate seeps vertically downward, natural renovation will occur through cation exchange.

Further, as the seepage enters the Englishtown aquifer, it will be diluted with groundwater flowing within the aquifer. This dilution ratio has been calculated to be 7.25:1. If diluted leachate enters the Englishtown aquifer, the resulting leachate plume would flow northeastward.

Similarily, the amount of seepage that could enter the Magothy aquifer also has been calculated using the entire useable portion of the site as a vertical inflow area. The results of this calculation indicate that 4550 gpd or 26.6 gpd/acre could occur and that a dilution ratio of slightly greater than one to one exists. The dilution ratios in both aquifers are relatively small. This is due to the limited thicknesses of the aquifers and their generally poor water yielding properties.

At the Road 412 site, if leachate were to escape the liner or collection system <u>and no corrective actions were taken</u>, the leachate would percolate downward and could eventually reach the water table aquifer. As discussed in previous sections of this report, groundwater flow in the Pleistocene/Mount Laurel water table aquifer is multidirectional with the dominant direction being east-southeast or towards Scott Run. Accordingly, if leachate were to escape <u>and corrective actions were not taken</u>, there would be a possibility that Scott Run could be impacted. Similarly there would be a possibility that the quality of surrounding water table wells, also could be impacted. Geologic literature pertaining to local groundwater use indicates that there are at least 18 water table wells in the Road 412 area.

4.2.1.6 Geotechnical Summary

The Road 412 site is situated in the Coastal Plain Physiographic Province of Delaware and is underlain by a thick sequence of unconsolidated sediments which contain three minor aquifers within the surficial two hundred feet. Monitoring wells have been constructed in these aquifers and representative soil and water samples have been collected and submitted for laboratory analyses. Based on the laboratory analyses and in conjunction with other data and calculations developed during the construction of the Pleistocene/Mount Laurel, Englishtown and Magothy aquifer monitoring wells, the following geotechncial conclusions are presented:

1. Useable thicknesses of soil for cover materials are variable across the site and range from 20 to 25 feet in the western portion of the site, to 14 to 18 feet in the northeastern portion of the site, and to 6 to 12 feet in the southeastern portion of the site. These soils are suitable for use as daily or final cover materials.

2. Based on the above thicknesses of soil, it may be possible to obtain all daily and final cover materials on site.

3. The Pleistocene/Mount Laurel water table aquifer is variable across the site and flow directions are numerous. If contamination were to enter the aquifer and no corrective actions were taken, surface water contamination of Scott Run could occur. Geologic data pertaining to use of the water table aquifer in the Road 412 area indicates approximately eighteen wells are present within a one mile radius of the center of the site.

4. The Englishtown aquifer is a principal source of water to residents located south of the Chesapeake and Delaware Canal. This aquifer is confined by the Marshalltown formation at the Road 412 site. The water yielding properties of the aquifer are fair to poor and potentiometric surface data indicates that vertical seepage of leachate is possible should the

liner and leachate collection system fail and no corrective actions are taken. Flow within the aquifer is towards the northeast.

5. The Magothy aquifer is confined by the Merchantville formation and has poor water yielding properties based on its limited thickness and silty nature. Potentiometric surface data indicates that vertical seepage of leachate is possible should the liner and leachate collection system fail and no corrective actions are taken. Flow within the aquifer is towards the southeast or away from the residential Magothy wells in the area.

4.2.2 Hydrology

4.2.2.1 Topography

Elevations* on the Road 412 site vary from a low of 24 feet in the northwest corner of the "Newby" property to a high of 77 feet approximately 300 feet west of the existing farmhouse, barn, and out buildings on the Retz property. The majority of the site (81%) is at an elevation greater than 50 feet. The lower elevations (less than 50 feet) are predominantly on the "Newby" property and are concentrated in the north near Road 412 and in the southwest approaching Scott Run. A significant amount (57%) of the lower lying areas are incorporated within the 200' property line buffer zone.

*Datum: Mean Sea Level

4.2.2.2 Runoff Control

Little upgradient runoff flows onto the Road 412 site from neighboring properties since:

1. The site is situated on the northeast extremity of a ridge (elevation 70 feet or greater) which extends from the Road 412 site in a southwesterly direction to Mt. Pleasant, a distance of approximately 12,000 ft. About 3,000 ft. of this ridge lies within the site boundaries; and

2. Ditches associated with Road 412A and Road 413 act as intercepts on the west and south, respectively.

A small tributary to Scott Run encroaches upon and drains a portion of the eastern part of the site. Scott Run, which flows in a northeasterly direction, is approximately 350' southeast of the site at its closest point.

Drainage of surface runoff from precipitation falling upon the site can be effectively controlled with berms, diversion ditches, and swales. The configuration of the site and its topography is such that sedimentation basins or other suitable velocity reduction techniques will be needed to control surface runoff flows and drainage onto downgradient properties. These facilities can be integrated with existing drainage ditches and culverts parallel to or crossing beneath Roads 412, 412A, and 413.

4.2.3 <u>Flood Plain Limits</u>

The Road 412 site, in its entirety, is outside the 100-year flood plain associated with Scott Run. Therefore, the 100-year flood plain criterion does not affect this site.

4.2.4 Wetlands

The State of Delaware Wetlands associated with Scott Run (as designated by DNREC) terminate at a point approximately 900 feet east of U.S. Route 13. Therefore, adherence to the wetlands criterion will not have an impact upon this site.

However, since areas defined as State of Delaware Wetlands are limited to salt water or brackish wetlands, the Authority felt that it was encumbent upon it to insure that wastes also are not deposited within wetland areas as such are defined by the Corps of Engineers. A visit to this candidate site was arranged and a survey of the site was undertaken on May 29, 1981 by a representative of the Corps of Engineers Philadelphia Office and a representative of the DNREC Wetland Section. Although the Authority would have to petition the Corps of Engineers for a determination of jurisdiction as it regards Scott Run, the Corps representative indicated that adhering to the DNREC requirement of maintaining a minimum 100' wide buffer between the edge of the disposal area and the edge of any pond, stream, or marsh (as well as adhering to the other buffer zone criteria) should preclude encroachment upon the wetlands associated with this site.

4.2.5 Streams

In accordance with the State of Delaware's Solid Waste Regulation, a minimum of 100' must be maintained between the edge of the disposal area and the edge of a body of water. Scott Run is more than 100 feet beyond the southeast boundary of the site. As a result, it has no direct impact upon the site. However, the headwaters of a small tributary to Scott Run and a small tributary to the Chesapeake and Delaware Canal, does encroach upon this candidate site as shown in Figure 4.2-11. Figure 4.2-11 also shows the area which would be excluded for landfilling based upon this criterion.

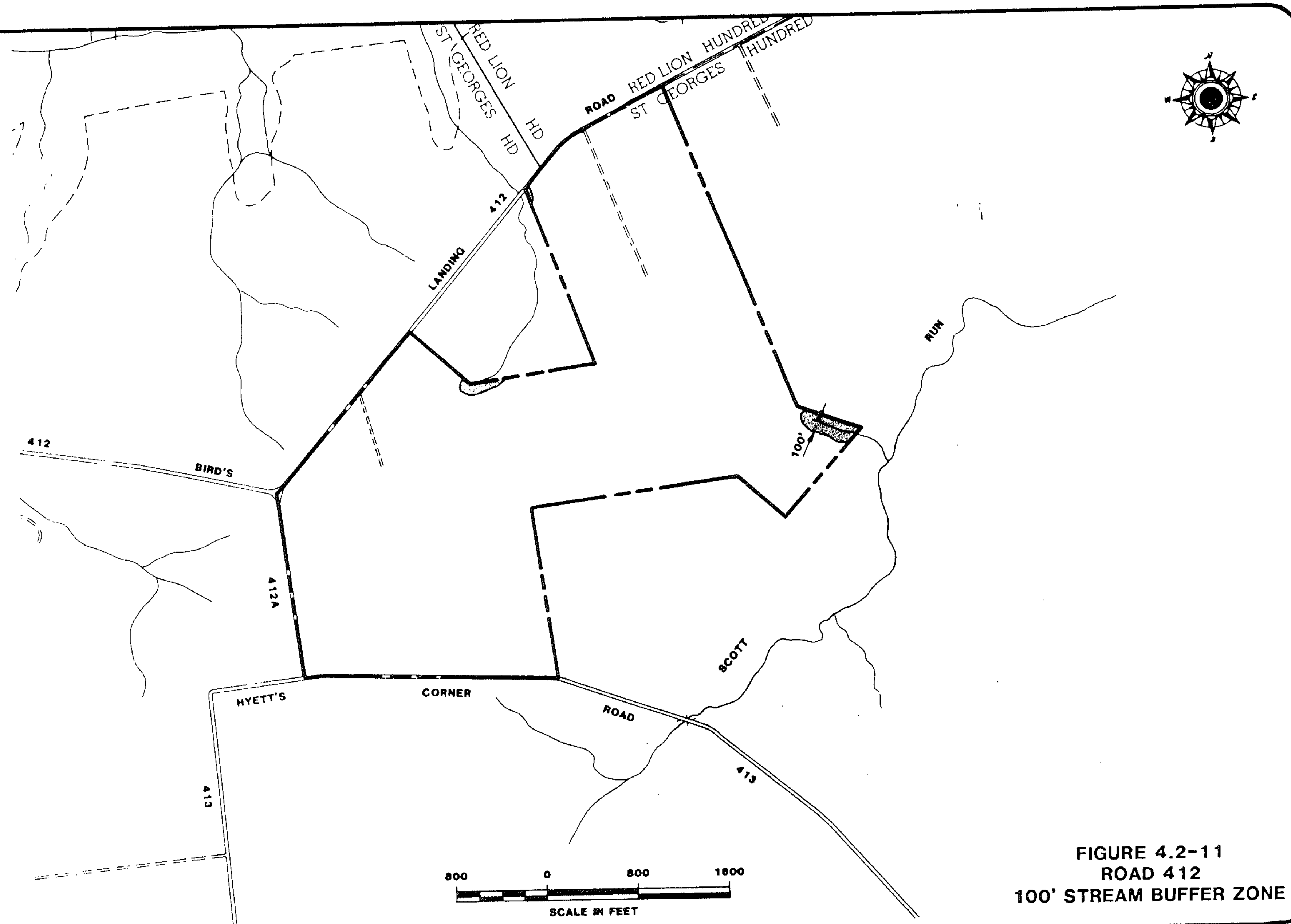


FIGURE 4.2-11
ROAD 412
100' STREAM BUFFER ZONE

4.2.6 <u>Property Line Setbacks</u>

The property line setback established by the Delaware Solid Waste Authority for this site is 200 feet. Therefore, there will be a minimum 200 feet buffer zone around the perimeter of the site in which no wastes will be landfilled. The area excluded for landfilling (approximately 88 acres) by adhering to this criterion is illustrated in Figure 4.2-12. Excluding the 200 feet from landfilling does not necessarily preclude the use of this buffer zone area for other purposes such as service or access roads, support facilities, or borrow areas.

It should be noted here that consideration should be given by the Authority to the acquisition of the land separating this candidate site from Scotts Run. This land currently is owned by Delmarva Power and Light. Although it may appear that all that this accomplishes is to increase the usable disposal area, what it actually provides is flexibility. It provides additional possibilities for gaining access to the disposal areas. Most importantly, however, the limits (edge) of the disposal areas can be shifted to coincide with the drainage divides thereby reducing the potential impacts on the Pleistocene/Mount Laurel water table aquifer in some portions of the site.

4.2.7 <u>Site Capacity</u>

4.2.7.1 Useable Area

It is estimated that of the total 259 $\pm$ acres of the Road 412 site, 66% or approximately 171 acres are useable for landfilling. This is illustrated in Figure 4.2-13 which is a composite of Figures 4.2-11 and 4.2-12.

4.2.7.2 Estimated Depth of Refuse Deposits Below Existing Grade

Utilizing the "Seasonal High Water Table Map", Figure 4.2-9, as a guide, it is estimated that soil depths* for the site range from 4 feet in the southeast corner of the Newby parcel, to a maximum of 27 feet (at two points) in the northwest corner of the Retz parcel. Taking into account the 3 feet of vertical buffer required between the seasonal high water table and the base of the refuse deposit (which has been assumed to be the soil/liner interface), excavation depths range between 1 foot and 24 feet, respectively, at the points mentioned above. Since there will be 2 feet of protective cover soil placed over the liner prior to the landfilling of any wastes, the depth of wastes placed below the existing grades would range up to 22 feet. The average depth of excavation is estimated at 13 feet. Therefore, the average depth of the landfill (refuse deposit) below the existing grade is estimated at 11 feet.

4.2.7.3 Height of Refuse Deposit Above Existing Grade

It has been assumed that the nominal height of the landfill above the existing grade will be approximately 40 feet. It also has been assumed that the top surface of the fill will be graded to conform to the existing site contours.

4.2.7.4 Estimated Site Volume/Longevity

Of the 171 acres considered as useable, approximately 15% should be reserved for leachate storage and/or treatment facilities. The following table, Table 4.2-5, summarizes for the Road 412 site the estimated volume, estimated capacity, estimated life, cover material availability, and cover material requirements.

*Soil depth is defined as the depth of soils to a limiting condition which, in this case, is the seasonal high groundwater table.

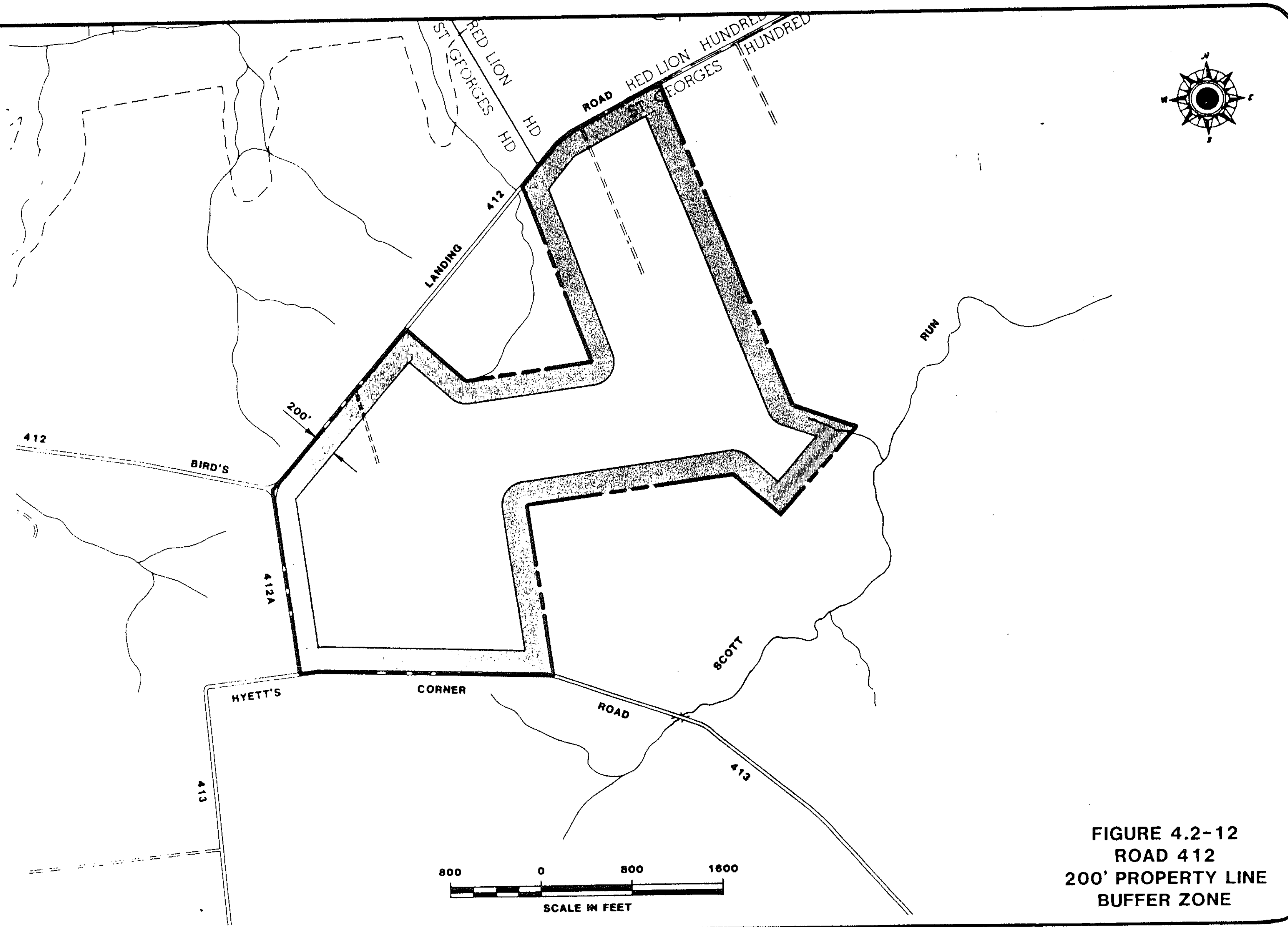


FIGURE 4.2-12
ROAD 412
200' PROPERTY LINE
BUFFER ZONE

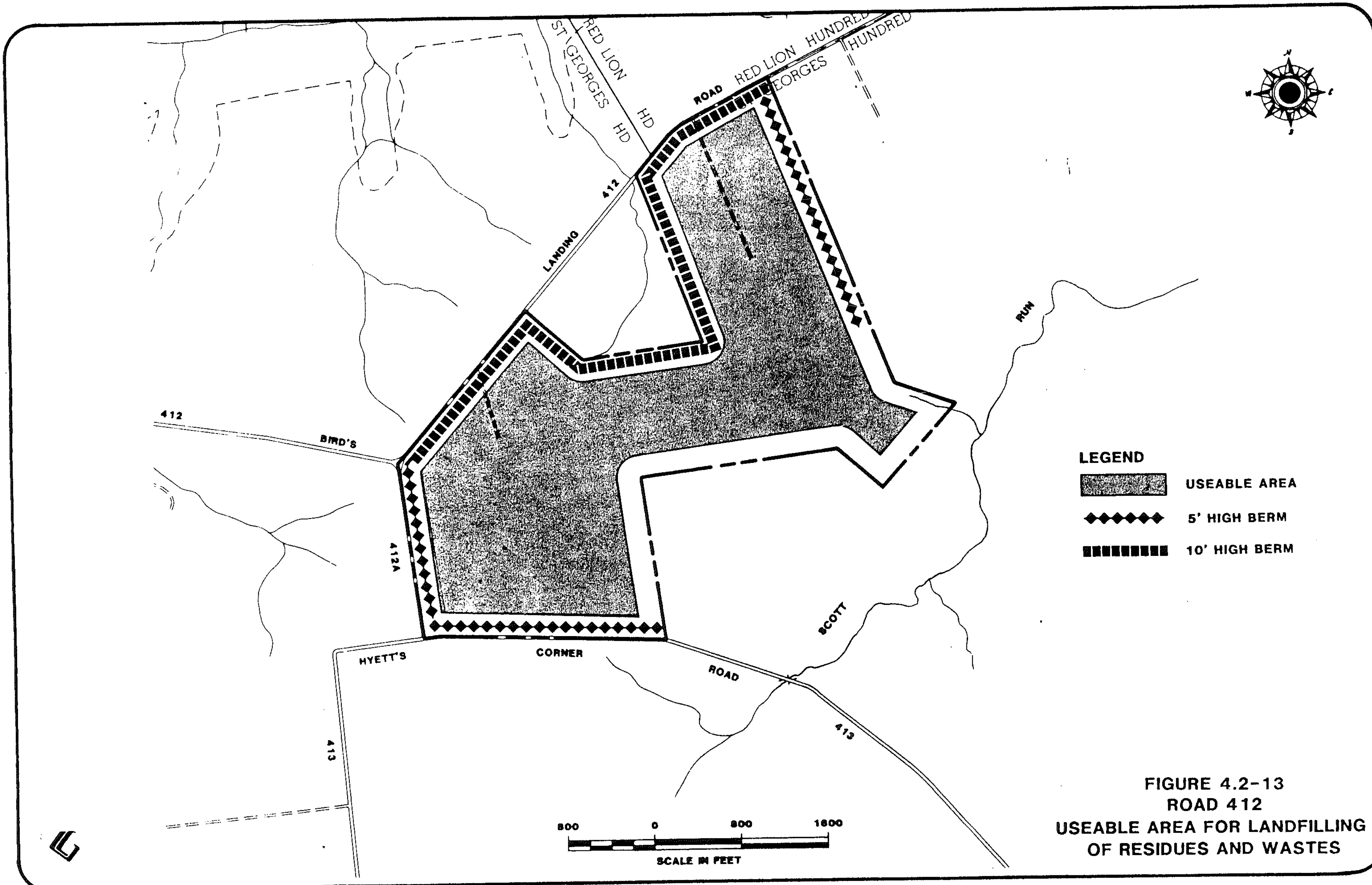


FIGURE 4.2-13
ROAD 412
USEABLE AREA FOR LANDFILLING
OF RESIDUES AND WASTES

If the total capacity in tons (5,079,000) shown in Table 4.2-5 is compared to the cumulative tonnage column of Table 3.2-1, it can be seen that the estimated life of this candidate landfill site is just over 24 years. This is somewhat lower than that estimated using the 10th year tonnage (middle of the 20 year planning/ period) as an average.

4.2.7.5 Estimated Cover Material Requirements and Availability

As can be seen from Table 4.2-5, it appears that there will be a surplus of approximately 353,000 c.y. of cover material over the life of the project. If earthmoving activities are managed prudently, this surplus could be utilized for protective cover for the liner. Approximately 58,400 c.y. of protective cover material are estimated to be needed for each phase of disposal area development. Therefore, the surplus would carry the Authority through the first six phases of development. This means that protective cover material only would have to be imported for the last 21+ acres developed. The capital needs schedule shown on the left side of Table 4.5-4 reflects this. These factors and others will be addressed in the construction cost estimates and operating cost estimates developed later on in this report.

Generally the on-site soils are suitable for daily and final cover as discussed in Section 4.2.1.4. However, at times, a soil material may be encountered which would require some crude blending with other on-site soils to create a more acceptable cover material. This would have to be accomplished as part of the routine operation of the landfill.

4.2.7.6 Potential On-Site Borrow Areas

To preclude the importation of protective cover material for use during the construction of the last disposal area of the phased development program, it may be possible to use the buffer zones as

TABLE 4.2-5
SUMMARY TABLE FOR ROAD 412

Acres For Landfilling	Acres[1] For Leachate Storage	Total Volume of Disposal Area (c.y.)	Volume Of Refuse (c.y.)	Volume Of Cover[4] (c.y.)	Cover Material Available (c.y.)	Capacity[2] in Tons (@0.625 tons/(c.y.)	Estimated Life at 10th yr. Tonnage Rate (198300)	Average Excavation Depth (Ft.)
146	25	10,835,000[3]	8,126,000	2,709,000	3,062,000	5,079,000	25.6 years	13

1. Area reserved for leachate storage and/or treatment facilities incorporates space needed for berms, access roads, and service roads for such facilities.
2. In-place density estimated at 1250 lbs/c.y. which is equivalent to 0.625 tons/c.y.
3. Volume and tonnage figures are rounded off to nearest thousand.
4. "Cover" refers to the materials needed for daily and final covering of the refuse.

a source for obtaining borrow materials. For instance, those buffer zones which are not proposed to incorporate screening berms may be designated as potential borrow areas. For the purposes of this report, however, a conservative approach has been taken. The cost estimates developed in subsequent paragraphs, and as alluded to above, will not incorporate this possibility.

4.2.8 Screening of Sites

Screening of the site should be accomplished by landscaping with a combination of earth berms and plantings. As shown on Figure 4.2-13, the berms which are proposed for construction within the northern buffer zone should be about 10 feet high, with a 10 foot wide crest, and 2:1 sideslopes. They would be constructed from soils excavated within the buffer zone and seeded with appropriate native grasses. A lower berm, approximately 5 high should be appropriate for incorporation within the buffer zones parallel to Road 412A, Road 413, and the eastern boundary of the Road 412 site.

The screening capability of all of the berms can be augmented with the planting of appropriate fast growing trees or shrubs.

4.3 ENVIRONMENTAL CONSIDERATIONS

4.3.1 Ecology

4.3.1.1 Terrestrial Communities

Vegetation: The Road 412 site is in an area of rather intensive cultivation where significant woodland areas generally occur along streams or on land to steep to cultivate. The only significant woodland on or near the site is located along Scott Run. This is a rather wet woods containing red maple, white ash, sycamore, willow, tulip tree, and black cherry. The herbaceous flora is also characteristic of riparian woods and contains jewelweed, skunk cabbage, false nettle, and Virginia creeper. This woodland would be classified as broad-leaved deciduous forested wetland according to the Fish and Wildlife Service classification (Cowardian et al., 1979). A small area of open water is located beyond the extreme southeastern corner of the site. Because there are some trees in this open area it would still be classified as a forested wetland. This woodland would not be affected by landfill operations. In fact, it creates an excellent buffer southeast of the site. (As indicated earlier, the State of Delaware Wetlands associated with Scott Run terminate approximately 900 feet east of U.S. Route 13 which is approximately 3,500 feet east of the site boundary.)

Other trees (primarily maple and oaks with some hickories) are scattered along the fence lines separating individual fields. At the time of the site visits in June 1981, corn was growing in the eastern and western portions of the site, while wheat was growing in the central portion.

Beyond the northern boundary of the site is a small residential area and woodland. These woods are located along a small, intermittant stream flowing into the Chesapeake and Delaware Canal, and are very similar to the woods along Scott Run.

Wildlife: The site is adjacent to the Chesapeake and Delaware Canal Wildlife Area. This area includes the entire length of the canal and portions of Lums Pond State Park north of the Canal. The wooded or abandoned portions of this area would provide habitat for a number of wildlife species. No mammals were observed during the site visit, but studies conducted in support of the proposed Summit Power Station (U.S. Atomic Energy Commission, 1974) listed the species in Table 4.3-1 as occurring onsite. The proposed Summit Power Station site is adjacent to the western boundary of the Road 412 site.

It is expected that the wildlife of the Chesapeake and Delaware Canal Wildlife Area, especially the whitetail deer, would at least occassionally move south of Road 412 to feed in the cultivated areas of the site. Other than its use as a feeding area, the site presents little in the way of wildlife habitat because of its extensively cultivated condition.

"The C & D Canal Area, particularly Scotts Run, does experience significant waterfowl use. Mallards, black ducks, blue-winged teal, green-winged teal, pintails, wood ducks and Canada geese frequent the area. Several duck blind sites in Scotts Run provide good quality waterfowl hunting." (Personal communication with Mr. H. Lloyd Alexander) The avianfauna is diverse because of the variety of habitats provided by the pattern of woods and fields. Table 4.3-2 lists the birds observed onsite during the site visit in June 1981. Approximately 168 species of birds were observed on the Summit Power Station site (Ichthyological Associates, Inc., 1976). Red-winged blackbird, common grackle, and brown-headed cowbird were the most abundant species. Bobwhite and ring-necked pheasants were the most abundant game birds.

4.3.1.2 Aquatic Communities

<u>Physical Description</u>

The Road 412 site drains into the Chesapeake and Delaware Canal (Canal) about one quarter mile to the north, and Scotts Run, a Canal tributary, which flows just beyond the site's southeastern border. No permanent streams are onsite. The Canal, which is 15.7 miles long, connects the upper Chesapeake Bay (Elk River) with the Delaware River. The Canal is about 450 feet wide, and 35 feet deep, and has a tidal amplitude of 5.5 feet at Reedy Point, Delaware (Delaware DNREC, 1980, and Kernehan et al., 1975). The tidal flow of about 57,120 cfs has a net movement from the

TABLE 4.3-1

MAMMALS OBSERVED IN THE VICINITY OF THE ROAD 412 SITE*

Common Name	Scientific Name
Oppossum	*Didelphis marsupialis*
Shorttail shrew	*Blarina brevicauda*
Little brown myotis	*Myotis lucifugus*
Raccoon	*Procyon lotor*
Longtail weasel	*Mustela frenata*
Striped skunk	*Mephitis mephitis*
Red fox	*Vulpes fulva*
Gray fox	*Urocyon cinereoargenteus*
Woodchuck	*Marmota monax*
Gray squirrel	*Sciurus carolinensis*
Southern flying squirrel	*Glaucomys volans*
Beaver	*Castor canadensis*
White-footed mouse	*Peromyscus leucopus*
Muskrat	*Ondatra zibethica*
Norway rat	*Rattus norvegicus*
House mouse	*Mus musculus*
Meadow jumping mouse	*Zapas hudsonius*
Eastern cottontail	*Sylvilagus floridanus*
Whitetail deer	*Odocoileus virginianus*

*U.S. Atomic Energy Commission, 1974

upper Chesapeake to the Delaware River, resulting in low salinities.

The canal has a U-shaped cross section, and its substrate is sand, gravel and mud (Kernehan et al., 1975a). Scott's Run is one of its larger tributaries.

Scott's Run appears to originate about 1.5 miles to the southwest of the site, and flows in a northeasterly direction past the site. It is well shaded by mature trees for much of its length. Near the site, it is about ten to 12 feet wide and contains pools from

TABLE 4.3-2

BIRD SPECIES OF THE ROAD 412 SITE

Common Name	Scientific Name
Great blue heron	*Ardea herodias*
Mourning dove	*Zenaida macroura*
Black-capped chickadee	*Parus atricapillus*
Mockingbird	*Mimus polyglottos*
Wood thrush	*Hylocichla mustelina*
Red-winged blackbird	*Agelaius phoeniceus*
Common grackle	*Quiscalus quiscula*
Cardinal	*Cardinalis cardinalis*
Indigo bunting	*Passerina cyanea*
Song sparrow	*Melospiza melodia*

two to three feet deep. The bottom is mud and rubble. During the site visit in June of 1981, the flow appeared low.

Water Quality

The salinity of the Chesapeake and Delaware Canal decreases from east to west because of the net inflow of predominantly fresh water from Elk River. Salinity is generally highest in late summer and lowest in mid-winter (Bason et al., 1976).

Water quality of the Canal is presently "excellent" (Delaware DNREC, 1980). Although Bason et al. (1976) indicated a summer dissolved oxygen (DO) sag prior to 1976, DO values are presently within state and federal standards, as are fecal coliform levels. This may be attributed partly to the upgrading of Chesapeake City's Sewage treatment plant (Delaware DNREC, 1980). Water quality parameters measured by the state are listed on Table 4.3-3.

The Canal has been classified as a water quality limited segment, "due to its vulnerability to rapid deterioration from even minor pollution sources" (Delaware DEC, 1980). Designated uses are: industrial water supply, secondary contact recreation, maintenance and propagation of fish, aquatic life and wildlife, navigation, drainage, and anadromous fish passage.

Water quality data for Scott's Run are not available. With the exception of salinity, water quality is most likely similar to that of the Canal. The entire drainage area is rural, and no point sources of pollution are apparent along Scott's Run.

A total of 67 species of fish were taken from 1972 through 1975 during the survey of the Canal performed for the Summit Power Station (Bason et al., 1976). These are listed in Table 4.3-4, on which the most abundant species are indicated. Overall, the bay anchovy was the most abundant species. With some exceptions, peak numbers of these species were usually taken between June and October. Migratory species found in the Canal include blueback herring, alewife, and Atlantic menhaden.

Table 4.3-3

Water Quality of the C & D Canal for October 1978 - September 1979 (at River Mile 4.50 - St. Georges)

Parameter	Concentration (mg/l unless otherwise indicated)* Maximum	Median	Minimum	State Criteria for C&D Canal	U.S EPA Quality Criteria for Water**
Dissolved oxygen	13.1	10.9	6.7	not<5-daily average not<4	5.0
BOD (5-day)	4.9	2.6	<2.4	-	-
Color (unit)	92	26	15	-	75
pH (unit)	8.2	7.5	7.4	6.5-8.5	6.5-9.0
Turbidity (unit)	85	35	10	-	-
Alkalinity	46.0	37.0	16.0	not<20	≥20 (for fresh water)
Acidity	5.0	3.0	0.0	shall not exceed alkalinity by 20	-
Hardness	2600	165	13	-	-
Chloride	2600	340	14	-	-
Total Nitrogen	1.3	0.8	<0.50	-	-
Organic Nitrogen	1.1	0.6	0.1	-	-
Ammonia Nitrogen	0.70	0.15	<0.10	-	-
Nitrite Nitrogen	0.06	0.02	<0.01	-	-
Nitrate Nitrogen	1.70	1.23	0.65	-	-
Total Phosphate	0.95	0.30	<0.10	-	0.10
Total Coliform (#/100ml)	4100	720	100	-	-
Fecal Coliform (#/100ml)	390	20	< 10	200	200 (for bathing waters)
Fecal Strep. (#/100ml)	370	90	20	-	-

* Source: Delaware DNREC, 1980

** Source: U.S. EPA (1976)

The Canal and adjacent waters serve as spawning and nursery areas for a number of species. It was reported (Kernehan et al., 1975a,b) that the most abundant species found in the egg and larval stages in 1975 were striped bass, river herring spp., white perch, bay anchovy, naked goby, and American eel. There appeared to be a relationship between currents in the Canal, and distribution of eggs and larvae.

Kernehan et al., (1981) stated that "The most important spawning and nursery ground for Atlantic Coast striped bass (Morone saxatilis) are in the Chesapeake Bay and its tributaries. One of the most important spawning and nursery areas of the Chesapeake system is the upper bay - lower Elk River - Chesapeake and Delaware Canal Complexes". Spawning is concentrated in the upper Chesapeake Bay and the western portion of the Canal. Spawning during the period studied occurred from mid April to mid June. Although previous studies indicated that the Canal was the most important spawning area, high numbers of eggs, and larvae found in the upper Chesapeake Bay during this study indicate that the upper bay south of Turkey Point is a much more important spawning and nursery ground than the C & D Canal" (Kernehan et al., 1981). Water temperatures and flow during spawning are probably the critical factors to development of strong year classes. Rapid changes in water temperature during relatively short, critical time periods can drastically affect the size of an entire year class.

Scott's Run is not tidal in the vicinity of the site. It was not included in the Canal studies performed for Summit Station. No information on the fishes of Scott's Run is available.

The Canal is, in itself, somewhat unique in the area because it is a manmade system, and is affected by the tides and water quality of both the Chesapeake Bay and Delaware River. The fish community it supports does not appear to be unusual for the area.

Table 4.3-4

Fishes Collected in the Chesapeake and Delaware Canal and Adjacent Waters from 1972 through 1975

Common Name	Scientific Name	Most Abundant Species*	Ichthyoplankton found in 1974-75
Lampreys	Petromyzontidae		
Least brook lamprey	Lampetra aepyptera		
Sea lamprey	Petromyzon marinus		
Freshwater eels	Anguillidae		
American eel	Anguilla rostrata	x	x
Herrrings	Clupeidae		
Blueback herring	Alosa aestivalis	x	x
Hickory shad	Alosa mediocris	x	x
Alewife	Alosa pseudoharengus	x	x
American shad	Alosa sapidissima	x	x
Atlantic menhaden	Brevoortia tyrannus	x	x
Gizzard shad	Dorosoma cepedianum	x	x
Anchovies	Engraulidae		
Striped anchovy	Anchoa hepsetus*		
Bay anchovy	Anchoa mitchilli	x	x
Mudminnows	Umbridae		
Eastern mudminnow	Umbra pygmaea		
Pikes	Esocidae		
Redfin pickerel	Esox americanus		x
Chain pickerel	Esox niger		
Minnows and Carp	Cyprindae		
Goldfish	Carassius auratus		
Carp	Cyprinus carpio		x
Silvery minnow	Hybognathus nuchalis		x
Golden shiner	Notemigonus crysoleucas	x	x
Satinfin shiner	Notropis analostanus		
Spottail shiner	Notropis hudsonius*	x	x
Rosyface shiner	Notropis rubellus*		
Fallfish	Semotilus corporalis*		
Suckers	Catostomidae.		
Quillback	Carpiodes cyprinus		
White sucker	Catostomus commersoni		x
Creek chubsucker	Erimyzon oblongus		x
Shorthead redhorse	Moxostoma macrolepidotum		

Table 4.3-4 (Cont'd)

Common Name	Scientific Name	Most Abundant Species*	Ichthyoplankton found in 1974-75
Freshwater catfishes	Ictaluridae		
White catfish	Ictalurus catus		
Brown bullhead	Ictalurus nebulosus	x	
Channel catfish	Ictalurus punctatus		x
Tadpole madton	Notorus gyrinus		
Pirate perches	Aphredoderidae		
Pirate perch	Apphredoderus sayanus*		
Codfishes	Gadidae		
Silver hake	Merluccius bilinearis*		
Red hake	Urophycis chuss*		
Spotted hake	Urophycis regius*		
Cusk-eels	Ophidiidae		
Striped cusk-eel	Rissola marginata		
Needlefishes	Belonidae		
Atlantic needlefish	Strongylura marina		
Killifishes	Cyprinodontidae		
Sheepshead minnow	Cyprinodon variegatus		
Banded killifish	Fundulus diaphanus	x	
Mummichog	Fundulus heteroclitus	x	x
Striped killifish	Fundulus majalis		
Silversides	Atherinidae		
Rough silverside	Membras martinica		x
Tidewater silverside	Memidia beryllina	x	x
Atlantic silverside	Menidia menidia	x	x
Sticklebacks	Gasterosteidae		
Fourspine stickleback	Apeltes quadracus		
Threespine stickleback	Casterosteus aculeatus		
Pipefishes	Syngnathidae		
Northern pipefish	Syngnathus fuscus		
Temperature basses	Percichthyidae		
White perch	Morone americana	x	x
Striped bass	Morone saxatilis	x	x

Table 4.3-4 (Cont'd)

Common Name	Scientific Name	Most Abundant Species*	Ichthyoplankton found in 1974-75
Sunfishes	Centrarchidae		
Blackbanded sunfish	*Enneacanthus chaetodon*		
Bluespotted sunfish	*Enneacanthus gloriosus*		
Banded sunfish	*Enneacanthus obesus*		
Redbreast sunfish	*Lepomis auritus*		
Pumpkinseed	*Lepomis gibbosus*		x
Warmouth	*Lepomis gulosus*		x
Bluegill	*Lepomis macrochirus*	x	x
Smallmouth bass	*Micropterus dolomieui**		
Largemouth bass	*Micropterus salmoides*		
White crappie	*Pomoxis annularis*		x
Black crappie	*Pomoxis nigromaculatus*		
Perches	Pecidae		
Tessellated darter	*Etheostoma olmstedi*		x
Yellow perch	*Perca flavescens*		x
Shield darter	*Percina peltata*		
Blue fishes	Pomatomidae		
Bluefish	*Pomatomus saltatrix*	x	
Jacks and Pompanos	Carangidae		
Crevalle jack	*Caranx hippos*		
Drums	Sciaenidae		
Silver perch	*Bairdiella chrysura*		
Weakfish	*Cynoscion regalis*	x	x
Spot	*Leiostomus xanthurus*	x	x
Atlantic croaker	*Micropogon undulatus*	x	x
Black drum	*Pogonias cromis**	x	x
Gobies	Gobiidae		
Naked goby	*Gobiosoma bosci*	x	x
Butterfishes	Stromateidae		
Butterfish	*Peprilus triacanthus**		
Lefteye Flounders	Bothidae		
Summer flounder	*Paralichthys dentatus**		x
Righteye Flounders	Pleuronectidae		
Winter flounder	*Pseudopleuronectes Americanus**		x
Soles	Soleidae		
Hogchoker	*Trinectes maculatus*	x	x

* captured in a variety of gear
Source: Bason et al., (1976), Kernehan et al. (1975a), and Kernehan et al, (1975b)

4.3.1.3 Special Considerations

Endangered and Threatened Species

"It is possible that bald eagles or peregrine falcons could occasionaly be sighted in migration at any of the proposed sites" (personal communication with Mr. H. Lloyd Alexander, Jr.) However, the Road 412 site is not located near any known historic or existing bald eagle nesting sites.

Brundage (1981) reported that the presence of shortnose sturgeon in the Chesapeake and Delaware Canal has not been documented despite intensive sampling related to the proposed Summit Power Station. The species has been found both in the Delaware River near the Canal, and in the upper Chesapeake Bay. The Canal may be used as a migratory route, but it is "highly unlikely" that the sturgeon use it for spawning or nursery (Brundage, 1981).

Wetlands: The woodland along Scott Run would be classified as a broad-leaved deciduous forested wetland according to the U.S. Fish and Wildlife Service classification system (cowardin et al., 1979). This woodland is located beyond the site boundary and is further protected by the 200 ft. property line buffer discussed in an earlier section of the report. The wetland area for Scott Run designated by the State of Delaware terminates at a point approximately 900 feet east of U.S. Route 13. Consequently, landfill operations will not adversely affect State of Delaware Wetlands.

Economically and Recreationally Important Species: The site is located adjacent to the Chesapeake and Delaware Canal Wildlife Area. This area encompasses approximately 5,700 acres and extends along both sides of the canal across the entire width of the state. North of the Canal it includes Lums Pond State Park. Both small game (including waterfowl) and deer are hunted in the area.

The area was used by 4,600 licensed hunters in 1977 and by 4,500 in 1978 (H. Lloyd Alexander, personal communication).

The Canal supports a sport fishery, as well as serving as a spawning and nursery area for some sport species. In 1978, the state's boat fishing pressure on the Canal was 0.6 percent of the statewide pressure. Compare this to Delaware Bay's which was 35.4 percent (Miller, 1980). In contrast, the Canal is important within the state for shore fishing, providing 13.7 percent of the state's total effort in 1978. Species of fish that have been taken in the Canal that most likely contribute to the sport fishery include weakfish, Atlantic croaker, bluefish, spot, white perch, striped bass, and black drum. Blue crab is also found in the Canal.

There "is presently a shortage of access boat ramps to the canal" (DNREC, 1980). The public boat ramp closest to the site is located on the Delaware River at Delaware City (Delaware Highways Official Map). Several fishing piers are open to the public along the Canal.

A popular freshwater fishery exists in Lum's Pond, which is north of the Canal to the northwest of the Road 412 site. This fishery is primarily for sunfish species (Miller, 1978).

4.3.1.4 Project Impacts

The entire area that would be used for landfill is presently under cultivation or occupied by farm houses and other farm buildings. No wildlife habitat that is unique in the region will be disturbed if the site is used for a landfill. Construction activities will disturb the soil, and could temporarily increase turbidity and sedimentation in Scott's Run, and possibly locally in the Canal. An adequate erosion and sedimentation control plan would minimize, if not preclude, this from occurring.

Actual use of the landfill will involve stripping and stockpiling the topsoil, excavation of the disposal area, and lining the area to be filled with an impermeable liner. No more than about 20 acres of disposal area will be in use at any one time; and no more than about 30 acres will be in some stage of use or preparation at any one time.

Effects of landfill operation on adjacent wildlife habitats are expected to be minor, consisting mainly of increased levels of activity and noise. The site's ultimate value for wildlife is not expected to be diminished.

The landfill will be lined and graded so that all leachate will flow to a central collection point. The leachate could be hauled offsite for treatment, in which case no effluent will be discharged to adjacent waterways. If the leachate is treated onsite, treatment, must be adequate for the discharge to meet NPDES requirements.

4.3.2 Land Use

4.3.2.1 Future Land Use

The site is located in the Middletown-Odessa-Townsend Planning District and the plan for this district was prepared by the New Castle County Department of Planning on May 15, 1973.

The Planning District is the largest of the nine districts in the County, bounded on the north by the Chesapeake and Delaware Canal; on the west by the Maryland-Delaware State Line; on the south by the County Line; and on the east by the Delaware River.

The proposed site is located entirely in an area designated as Post-1985 Industrial Development. The exceptions to this recommendation are those areas adjacent to the two small onsite tributaries which have been designated Resource Protection.

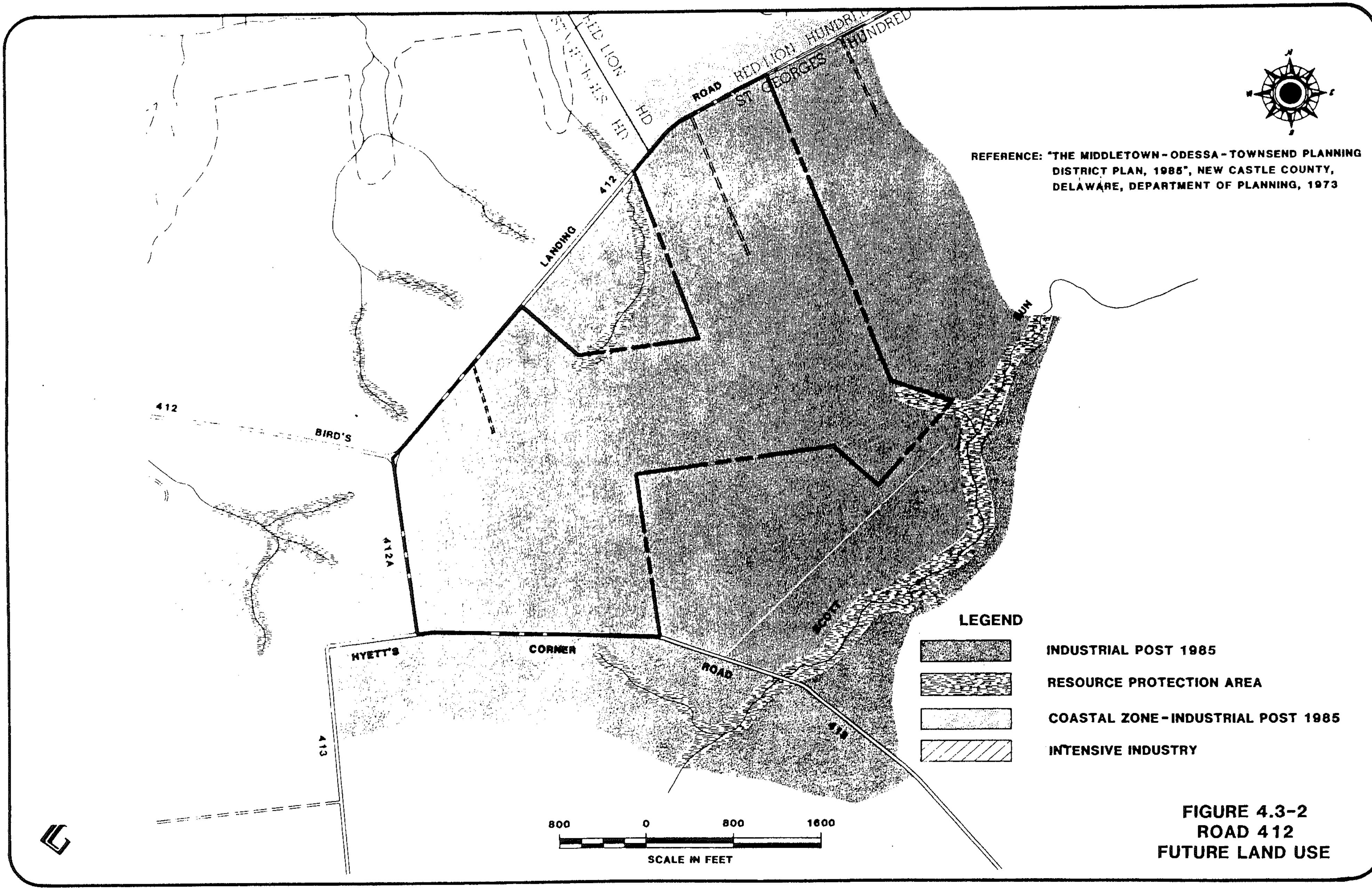


FIGURE 4.3-2
ROAD 412
FUTURE LAND USE

The County Department of Planning Comprehensive Plan update is recommending that the area the site is located in continue to be designated for industrial development.

4.3.3.2 Farm Land Classification

The proposed Road 412 site contains approximately 259 acres of land. Prime agricultural land (Class I and Class II soils) accounts for 169 acres or 65.3 percent of the proposed site total.

The Class II soils found on the site include the following:

Symbol	Soil Name	Capability
MeB	Matapeake silt loam (2-5% slope)	IIe-4
MkB	Matapeake silt loam (silty substratum 2-5% slope)	IIe-4
WsA	Woodstown loam (0-2% slope)	IIw-1

New Castle County contains an estimated 279,680 acres of land, 111, 532 acres of which (approximately 39.90 percent of the total) are prime agricultural land. The Road 412 site contains less than 1/6 of 1 percent (~0.15%) of all Class I and Class II soils found in the County.

The estimated average yields per acre of principal crops, based on good conservation practices of the prime agricultural soils found on the site, are as follows:

	Bushels				
Soil	Corn	Oats	Wheat	Irish Potatoes	Soybeans
MeB	115	60	60	650	40
MkB	120	60	45	675	45
WsA	90	50	40	-	45

4.3.3 Zoning

The site has been designated an an R-2 (Agricultural and General Purpose) District by the New Castle County Zoning Code. The R-2 District permits single-family residences, mobile homes, churches, schools, police and fire stations, libraries, museums and art galleries, country clubs, agricultural uses, professional offices, and parks and playgrounds.

In addition, commercial greenhouses, hospitals, aviation facilities, cemeteries, amusement parks, camps, riding clubs, social and fraternal organizations, veterinary hospitals and kennels, tourist homes, armories, and other utility or public service structures are permitted by special exception.

The minimum lot area for any dwelling or permitted non-residential use is one-half acre (21,780 sq. ft.) with a minimum lot width of 75 feet.

In 1974, 377 acres owned by Delmarva Power and Light (DP&L) west of the proposed Road 412 site and adjacent to Road 413 was rezoned from R-2 to M-2. In 1979 and additional 505 acres also were proposed to be rezoned from R-2 to M-2 for DP&L. The 1974 rezoning was for the accomodation of a nuclear powerplant, while the most recent proposal for rezoning is limited to a fossil fuel generating facility by voluntary offer of DP&L.

4.3.4 Demography

There are 16 dwellings located within 300 yards of the proposed site boundary. The 1980 Preliminary Census of Population and Housing identified the entire Middletown-Odessa Division as having 13,181 people and 4,440 housing units. Excluding the towns of Middletown, Odessa, Townsend and Smyrna, the Division had a population of 9,506 and 3,051 housing units, or 3.12 residents per

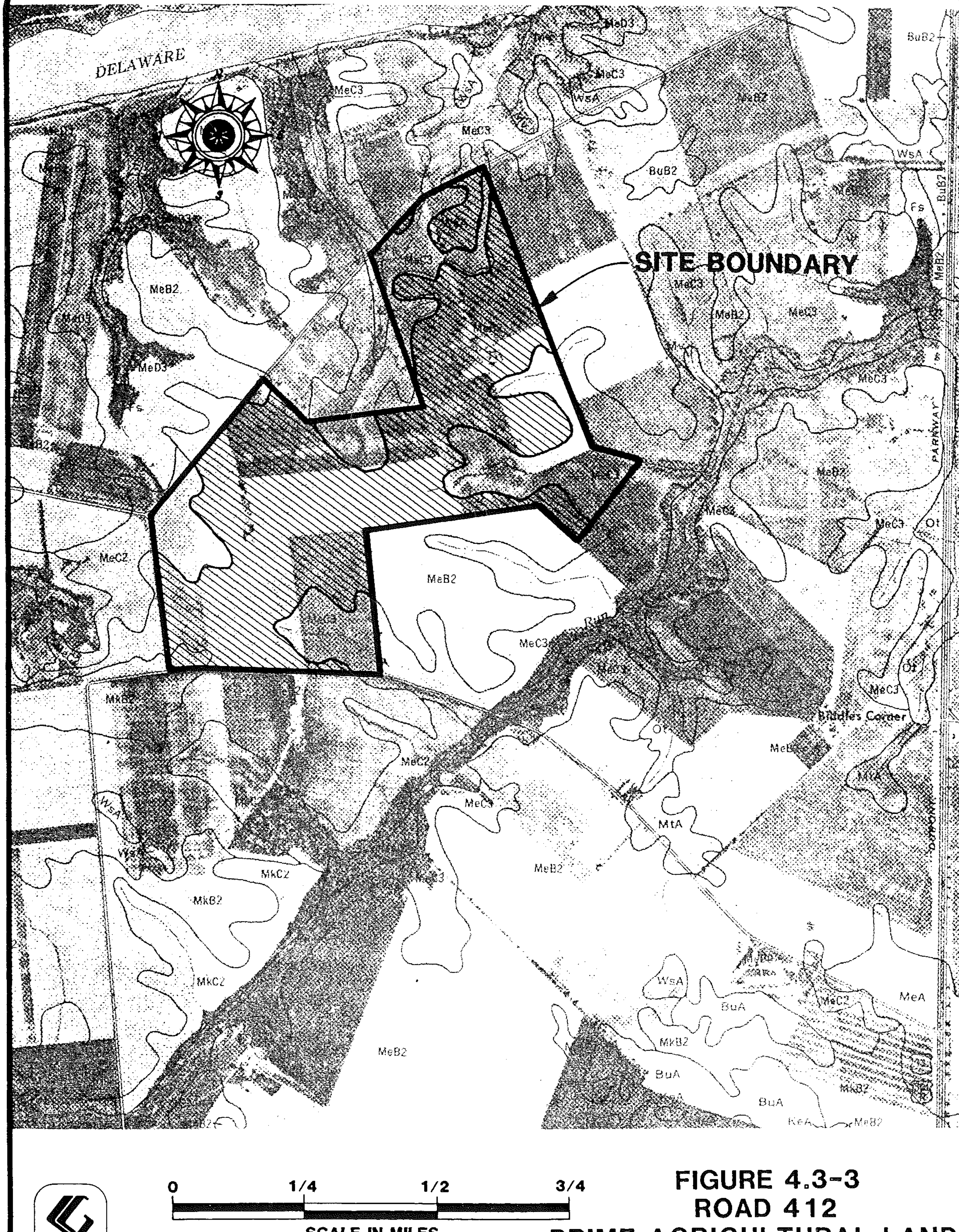
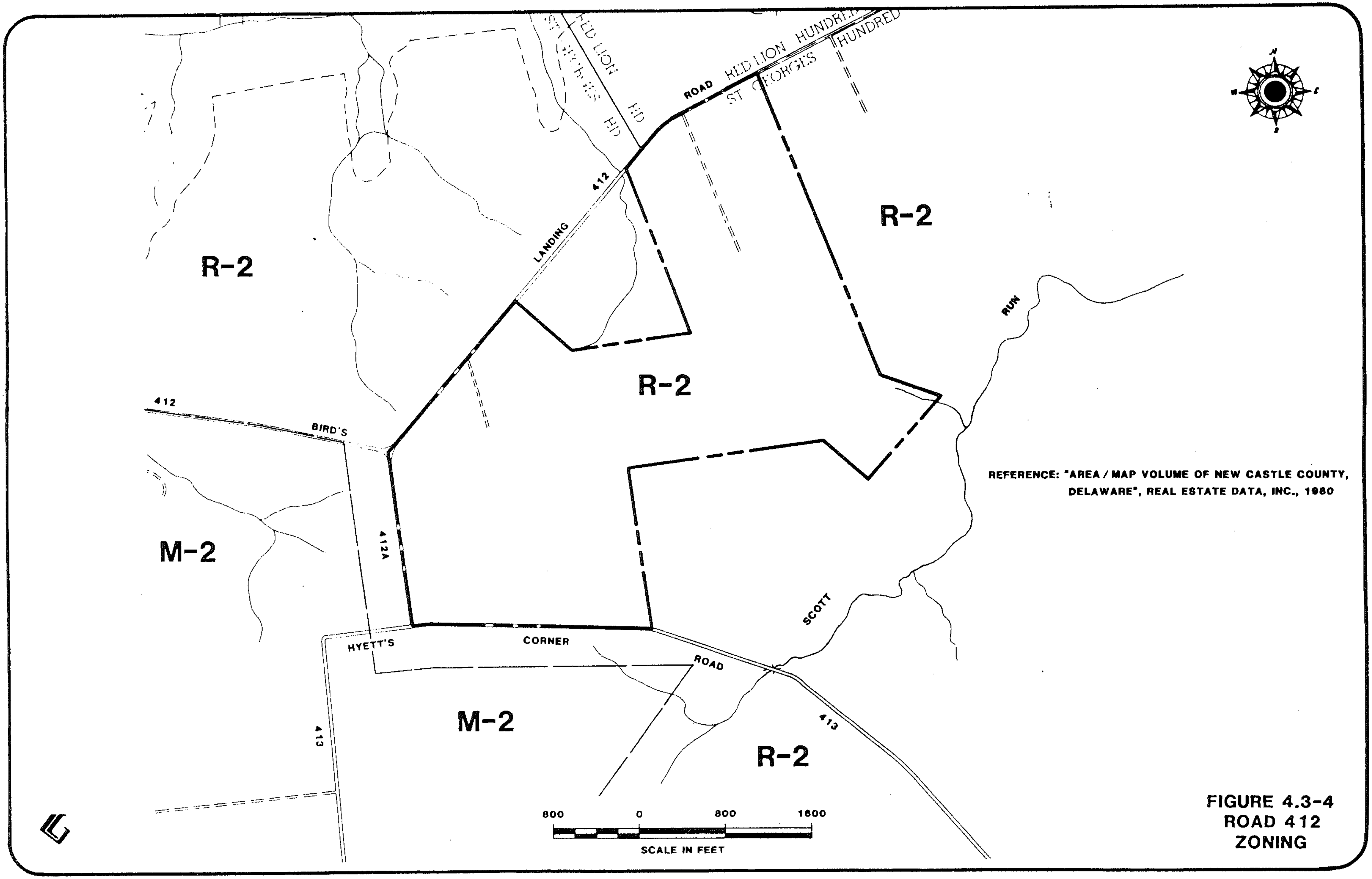


FIGURE 4.3-3
ROAD 412
PRIME AGRICULTURAL LAND



REFERENCE: "AREA / MAP VOLUME OF NEW CASTLE COUNTY, DELAWARE", REAL ESTATE DATA, INC., 1980

FIGURE 4.3-4
ROAD 412
ZONING

housing unit, assuming that all dwellings are permanent and occupied.

Based on this estimate of 3.12 persons per housing unit, it is estimated that 50 persons reside within 300 yards of the proposed Road 412 site boundary.

4.3.5 Cultural, Recreational and Natural Areas

With the possible exception of the Chesapeake and Delaware Canal Wildlife Area north of the site, there are no cultural, recreational or natural areas within 300 yards of the proposed site boundary.

4.3.6 Historic Sites

There are no historic sites, as listed in the National Register of Historic Places, in the vicinity of the proposed site. The site does, however, contain two structures, the J. P. Hudson House (N-5192) and the L. N. McWhorter House (N-5194) which have been identified by the Division of Historical and Cultural Affairs as having unique architectural characteristics.

N-5192: J.P. Hudson House. This is a mid-19th century house and farm building complex. The house demonstrates the modest vernacular architectural style of the period. At the present time **it has not been assessed for its National** Register eligibility.

N-5194: L.N. McWhorter House, "Mount Hope". This mid to late 19th century structure exhibited similar architectural detailing to "Grandview." This structure is vacant and its condition is deteriorating. Much of the interior architectural detailing has been removed. **This structure would not be** eligible for National **Register Listing**.

In addition, the J.P. Hudson House, "Grandview", and the T. McWhorter House are located within 300 yards of the proposed site boundaries.

N-5193: J.P. Hudson House, "Grandview". This mid to third quarter 19th century structure, supposedly incorporates an earlier construction element of unknown age. This structure exhibits typical modest architectural detailing of the period. At present, it has not been assessed for its National Register eligibility.

N-5197: T. McWhorter House: This mid 19th century 2-story Italianate architectural style house, which underwent modest renovations in the late 19th century, and the outbuildings, appear to be eligible for National Register listing.

4.3.7 Aesthetics

The proposed Road 412 site is located adjacent to Road 412 (Bird's Landing Road), Road 413 (Hyetts Corner Road) and Road 412A. The site is clearly visible from these roads and from adjacent areas. However, these three peripheral roads are used primarily by local residents. Although the site can be seen from the St. George's Bridge, its distance from the bridge (about 1.0 mile), the average rate of speed of vehicles crossing the bridge, and the obstructed view created by the structural elements of the bridge, do not create a situation of high visibility.

The site can be screened from the view of motorists travelling the local roads by a combination of berms and plantings, thus reducing the aesthetic impact that the landfill operation may produce.

The site should not significantly affect the character of the surrounding area upon completion of all operations even though it will be raised above existing elevations at the end of its useful life. Although proper management of the site could permit the

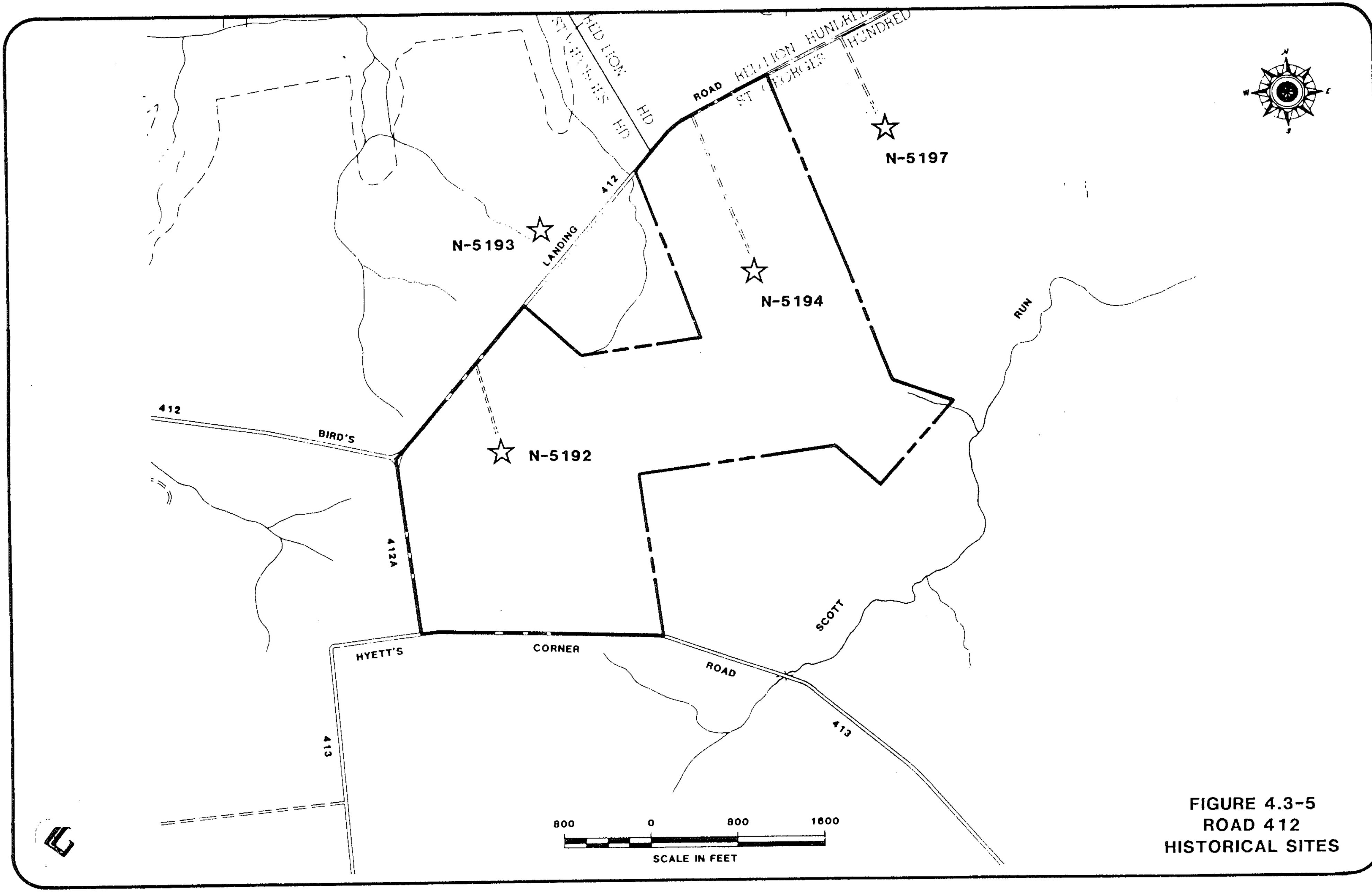


FIGURE 4.3-5
ROAD 412
HISTORICAL SITES

resumption of certain agricultural operations (thus re-establishing the agricultural character of the area) the site probably will be reserved for open space use upon completion of landfilling.

4.4 TRANSPORTATION CONSIDERATIONS

4.4.1 Highway Access

Although the Road 412 site can be approached from various directions using either U.S. Route 13 or State Route 896, the suggested highway access would be as shown on Figures 1.0-1 and 4.4-1 and as delineated in Table 4.4-1.

Using Road 413 (Hyett's Corner Road) to gain access to the site rather than Road 412 (Bird's Landing Road) will take advantage of a recently upgraded intersection at the juncture of Road 413 and U.S. Route 13. Also the least number of residences are found along this route (three, as compared to ten along Road 412). A disadvantage associated with this route is that an existing narrow bridge over Scott Run must be crossed. This bridge has a posted limit of 10 tons. It would have to be upgraded or completely replaced to handle the truck traffic associated with the hauling of wastes to this site.

Truck traffic leaving the site to return to the DRP can be routed over Road 413 to return to U.S. 13 and thence to Pigeon Point. To get to the north-bound lanes of U.S. 13, however, two south bound lanes of traffic would have to be crossed before merging with the north bound lanes. As an alternative, there is the potential to set up a "one-way" traffic pattern at this site using Road 412 for outbound traffic. It would require the "empty" trucks to travel beneath the St. Georges Bridge. This would allow merging directly into the northbound lanes just at the foot of the bridge thus eliminating the confrontation with southbound traffic.

TABLE 4.4-1
ROAD 412
PROPOSED HAUL ROUTE DATA

NAME/ROAD #	MILES	HOUSES ALONG ROUTE	CLASSIFICATION	LIMITATIONS	TOTAL AADT*	TRUCK AADT	% ** INCREASE AADT	% ** INCREASE TRUCK AADT
Pigeon Point Road (State Road 377)	1.1	2	Heavy Duty (Collector)	None	2300	161	4.3	62
State Road 359	0.4	0	Heavy Duty (Collector)	None	3650	1095	2.7	9.1
Interstate 495	1.1	0	Heavy Duty (Interstate)	None	33307	4996	0.3	2.0
U.S. Route 13	15.6	80	Heavy Duty (Principal Arterial)	None	None of U.S. 40 46654	6224	0.2	1.6
					South of U.S. 40 22416	3837	0.4	2.6
State Road 413	1.3	3/85	Light Duty (Secondary)	Bridge over Scott Run; 10-ton posted limit.	180	27	27	285
Total one-way mileage:	19.5							

* AADT - Annual Average Daily Traffic as reported by DELDOT.

** Based upon: 10th year tonnage estimate; 260 working days/year; and 15 tons payload per truck, approximately 50 truck loads of waste per day would be hauled to the disposal site; therefore, traffic counts should be increased by 100 to reflect impact of the hauling operation.

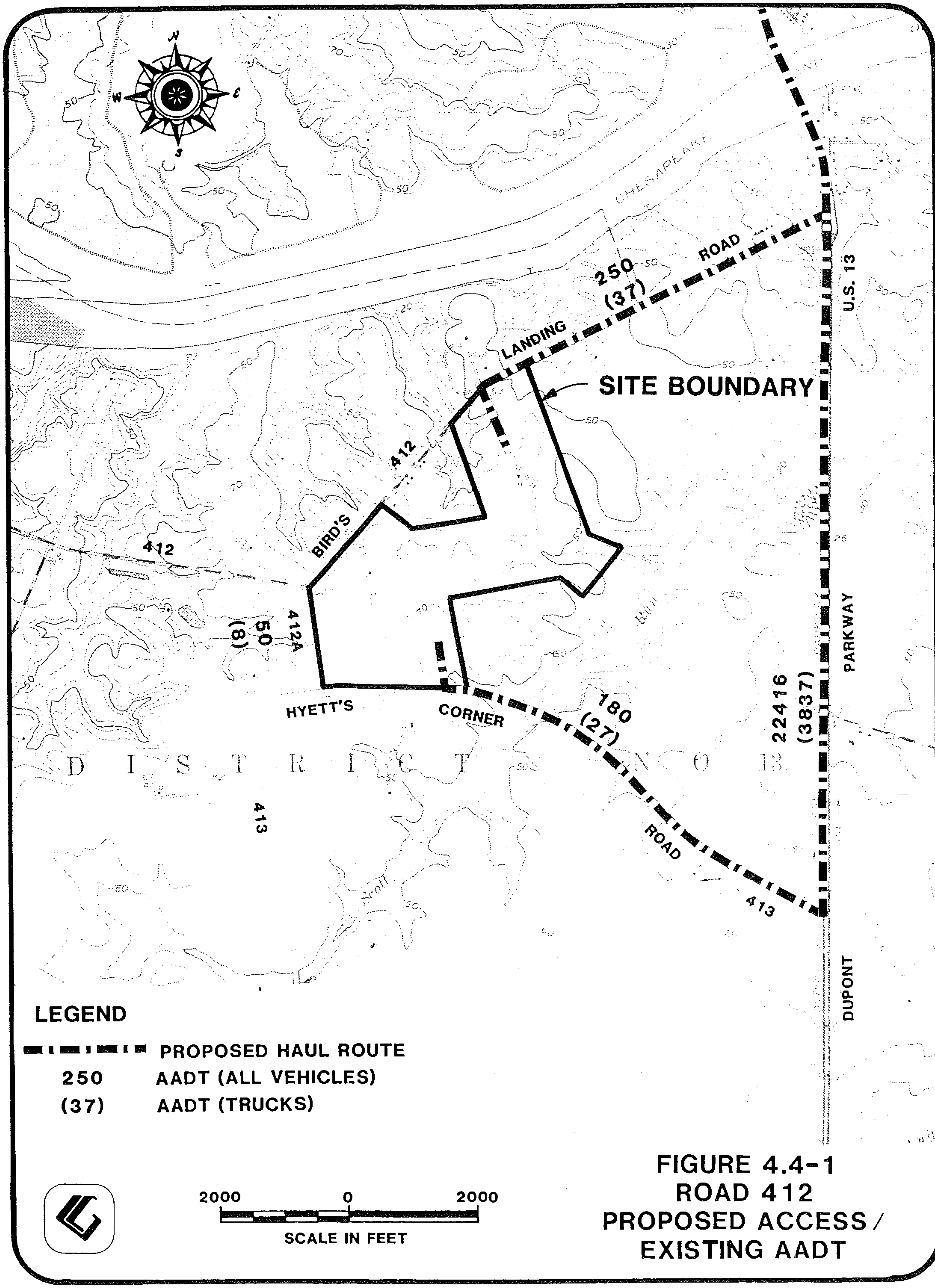


FIGURE 4.4-1
ROAD 412
PROPOSED ACCESS / EXISTING AADT

If easements for an access corridor could be negotiated on property between the site and U.S. Route 13, there is a potential for direct access from U.S. 13. Construction of such a new access road, however, would involve a new stream crossing over Scott Run.

Should this site ultimately be selected for the NSWF, these access and egress alternatives should be investigated in detail. For the purposes of this study it will be assumed that access from U.S. Route 13 will be via Road 413, Hyett's Corner Road, and egress from the site will be via Road 412.

The anticipated truck traffic volume associated with hauling the wastes from Pigeon Point to any of the sites (assuming an average net load of 15 tons per truck, the 10th year waste generation rate and hauling 260 days/year) is an average of about 50 truck loads per day. This means an increase of 100 in the truck count along any portion of the haul route. Table 4.4.2 shows the effect of this on the different segments of the suggested haul route for which traffic counts are available. If, however, a one-way traffic pattern can be established using Road 412 for the return trip to Pigeon Point, the increase in the truck count due to the landfill's presence would be cut to about 50 per day for Road 413 and would increase truck counts by 50 per day along a portion of Road 412.

The conditions of the roads along the suggested route are good to excellent with the exception of State Roads 412 and 413 which would probably be considered to be in fair condition. For purposes of the economic investigation discussed in Section 4.4.6, it will be assumed that these roads would have to be upgraded from the intersection with Route 13 to the site. Intersection improvements at U.S. Route 13 and Road 413 have recently been made by DELDOT. As it regards restrictions or limitations along the route, the only structure of significance would be the bridge over Scott Run which has to be traversed to gain access to the site. DELDOT has a 10-ton posted limit for this bridge.

4.4.2 Rail Access

The nearest rail line to this site is approximately 1.5 miles to the west. Consequently hauling wastes to the site by rail would require at a minimum the construction of a 1.5 mile spur, rights of way acquisition, switching facilities, and two grade crossings and related traffic control facilities: one across Road 414 and one across Road 412A. At least two streams also would have to be crossed.

Special loading facilities would be required at Pigeon Point along with a small yard to accommodate empty (spare) rail cars. Since it is anticipated that it would take the better part of the day, if not the whole day, to make a round trip, at least one set of spare cars would be needed. To load and unload the mix of wastes anticipated, anything from residue to mattresses (and other awkward items), special rail cars and unique unloading facilities would be required. However, the rail cars could not be maneuvered to the working face, therefore a certain number of transfer trailer type vehicles would be required to move the wastes from the unloading facility to the working face of the landfill.

Special railcars and associated handling facilities could be avoided if transfer trailers were hauled "piggy-back" to the site. However, to handle one day's waste at the average tonnage rate, more than 50 trailers would be needed for each set of rail cars. Assuming two trailers to a flat car, at least 25 rail road flat cars would be needed along with trackage and space to store and shift the units as necessary. As an alternative to "piggy-backing" transfer trailers, the use of specially modified freight containers can be employed for transfer of refuse. This would be similar to a system currently employed by the city of London, England and recently considered by Philadelphia, Pa. Although this may reduce, somewhat, the number of flat cars needed to haul one day's waste, it will have no effect on the other facilities necessary for a rail haul system.

Logistical problems with regard to manning the locomotives also may be cumbersome from the standpoint of current union requirements.

The rail haul alternative, in terms of susceptibility to weather, probably would be the most reliable. Since there is only one track route to the site, however, flexibility is poor should there be a breakdown such as a derailment along the route. The derailment would have to be cleared and track repaired before the system could function again. On the other hand, if a portion of a highway haul route is blocked, a temporary alternative routing can be readily initiated.

4.4.3 Waterway Access (Barging)

The closest navigable water to the site is the Chesapeake and Delaware Canal which is 2000 feet north of the site across Road 412. Proceeding with such a venture would require construction of marine terminal facilities for loading at Pigeon Point and marine terminal facilities for unloading at the candidate site plus the purchase or long term lease of additional property adjacent to the canal for construction of such facilities. Both terminal facilities would have to be large enough to accommodate manuevering of the barges. Knowing that it would be impossible to barge the wastes directly to the landfill working face, there would still be the necessity for transfer trailer units or transfer containers to transport the wastes from the unloading terminal to the disposal area. This would entail securing a right-of-way from the Canal to Road 412 and the construction of a haul road within this right-of-way. All of this not withstanding, there would still be Corps of Engineers permits to be obtained for both terminal facilities and any wetlands which would be disturbed by this activity.

4.5 ECONOMIC CONSIDERATIONS

4.5.1 Estimated Landfill Development Costs

Table 4.5-1 presents the estimated capital needed at the start of the project if this candidate site were selected for development as the NSWF*. The construction costs were developed from the Authority's experience with the Central Solid Waste Facility (CSWF) in Sandtown, Kent County. Actual bid prices were escalated by 9% per year to reflect the time differential between the bid date (July 1980) and the 1984 projected start date.

With regard to the capital costs shown in Part A of the Summary on Table 4.5-1, the engineering/surveying/legal costs are associated with facility permitting, detailed design of the first disposal area, preliminary design of remaining disposal areas, preparation of bid documents (Specifcations, Drawings, Contract) for construction of the first disposal area, evaluation of bids, and construction services.

Screening of site would be with a combination of 5 ft. or 10 ft. high earthen berms and fast growing trees or shrubs as depicted on Figure 4.2-12. It has been assumed that the berms will be constructed with about a 10 ft. wide crest and 2:1 sideslopes and will be built of materials excavated from within the buffer zone.

To prevent trespassing, approximately 17,500 L.F. of chain-link fencing will be needed. Since there are no natural barriers to impede unauthorized access it has been assumed that the entire site perimeter will be fenced.

A septic system, water supply, electricity, and communications would have to be provided. The maintenance building was assumed to be centrally located.

*Exclusive of highway improvement costs.

TABLE 4.5-1
Road 412 Site
AUTHORITY OWNED/CONTRACTOR OPERATED SANITARY LANDFILL
SUMMARY OF CAPITAL COST*

A. Estimated Projected Start-up Costs

1.	Land Purchase	$ 700,000
2.	Engineering/Surveying	340,000
3.	Legal/Administrative	50,000
4.	Clearing/Grubbing/Stripping and Stockpiling Topsoil**	96,500
5.	Subgrade Preparation (Excavation, Backfilling, Compacting)	259,000
6.	Installation of Liners and Leachate Collection Facilities	506,000
7.	Placement of Liner Protective Cover (Procurred on-site)	96,000
8.	Erosion Control Facilities (Sedimentation Basins, Swales, Berms)	123,000
9.	Access Roads	120,000
10.	Fencing	261,000
11.	Screening of Site (Berms, Landscaping)	594,000
12.	Structures (Office Trailer/Maintenance Building)	140,000
13.	Utilities (Electricity, Water, Sanitary, Communications)	33,500
14.	Groundwater Monitoring Wells	26,000
15.	Decomposition Gas Monitoring Wells	23,500
16.	Interest During Construction (4 months; 9.6% interest)	108,000
		$3,476,500

B. Estimated Annual Cost of Start-Up Capital

Amortization Period: 20 years
Interest Rate: 9.6%
Annual Cost of Capital: $397,503 say $397,500

C. Recurring Costs*

1. 10-Year Frequency

Erosion Control Facilities (sedimentation basins)	$108,000

2. 3-Year Frequency**

a.	Engineering/Surveying/Legal	185,000
b.	Clearing/Grubbing/Stripping and Stockpiling Topsoil	96,500
c.	Subgrade Preparation (Excavation, Backfilling, Compacting)	259,000
d.	Installation of Liners and Leachate Collection Facilities	506,000
e.	Importation and Placement of Liner Protective Cover***	96,000
f.	Erosion Control Facilities (Swales, Berms)	15,000
g.	Access Roads	120,000
h.	Decomposition Monitoring Wells	23,500
		$1,301,000

* Costs shown are projected 1984 dollars

** Costs are representative of the development of approximately 21 acres of property for use as a sanitary landfill. Overall site development will consist of 7 phases of 21 acres each. Each phase will last approximately 3 years.

*** There is insufficient material available to avoid importation of protective cover during last developmental phase of the landfill. This is reflected in the Cost Summary presented later in this report.

Pertaining to the capital costs shown in Part C, other than engineering, these should be self explanatory. The engineering, surveying, and legal fees are associated with the detailed design of subsequent landfill areas, the preparation of Specifications, Drawings, and Contracts to accomplish the work, and construction services.

To handle the expected traffic increase, it is anticipated that Road 413 will have to be improved for a distance of approximately 7000 feet between U.S. 13 and the site entrance as shown on Figure 4.4-1. The estimated cost of $530,000 for this work includes replacement of the existing bridge over Scott Run. To upgrade Bird's Landing Road for the return trip to Pigeon Point would cost approximately $430,000 including intersection improvements to the approach to the north-bound lane of U.S. 13. These costs, however, are not incorporated in Table 4.5-1, but are accounted for in Table 4.5-4, Summary Table of Projected Capital Needs and Yearly Costs.

4.5.2 Estimated Landfill Operating Costs

Table 4.5-2 presents the estimated first year operating cost for an Authority owned/Contractor operated land disposal facility. Of the landfill personnel needed to operate the site, it was assumed that one person would be in the direct employ of the Authority. It also was anticipated that the Authority would directly pay for all fuel for operation of the Contractor's equipment and for all utilities such as electricity, gas, heating oil, or telephone. Costs associated with the groundwater monitoring program and gas monitoring program would be borne by the Authority.

Contractor costs were estimated taking into consideration owning and operating costs for seven items of equipment (including a landfill compactor, scraper, bulldozer, and tracked loader), and wages (assuming union labor) for five employees (1 supervisor, 3 equipment operators, 1 laborer).

The bottom portion of Table 4.5-2 shows that the first year cost for owning, developing, and operating a landfill at the Road 412 site is estimated at about $1.588 million. If this cost is divided by the tonnage landfilled during the first year, it results in a cost equivalent to approximately $10.00/ton landfilled.

TABLE 4.5-2
ROAD 412 SITE
FIRST YEAR OPERATING EXPENSES/TOTAL FIRST YEAR COSTS
AUTHORITY OWNED/CONTRACTOR OPERATED LANDFILL*

FIRST YEAR OPERATING EXPENSES

A.	AUTHORITY DIRECT COSTS:		
	1. Labor (1 Person: includes fringe benefits)		$ 24,000
	2. Equipment Fuel		96,500
	3. Utilities (Electricity, telephone, etc.)		3,700
	4. Groundwater Monitoring Program		26,000
	5. Decomposition Gas Monitoring		2,000
	6. Access Road Maintenance		17,300
	7. Miscellaneous Expenses		6,500
		Subtotal	$ 176,000
B.	ESTIMATED CONTRACTOR'S FEE		$1,014,000
C.	TOTAL		1,190,000

TOTAL FIRST YEAR COSTS

A.	Annual Cost of Capital (From Table 4.5-1)		$ 397,500
B.	First Year Operating Cost		1,190,000
		Total	$1,587,500

C. Cost/Ton If Spread Over Tonnage Landfilled:

$1,587,500/159,000 Tons = $9.98 ~ $10.00

* Costs shown are projected 1984 dollars

Table D-1 of Appendix 4D projects owning and operating costs for the 20-year planning period and "equivalent disposal fees" for the tonnage landfilled. The projection is made assuming that initial project costs are financed with revenue bonds at 9.6% interest and with an escalation factor of 9%/year for both capital costs and operating expenses. The projected "equivalent disposal fees" are depicted graphically in Figure 4.5-1. The fees are "normalized" for three year periods which coincide with the anticipated triannual development program.

4.5.3 Estimated Haul Costs

Table 4.5-3 presents the initial year costs estimated for the hauling of residues and non-processables from the DRP at Pigeon Point to the Road 412 site. It has been assumed that the Authority will contract the hauling operation as opposed to operating the system itself. Therefore, to arrive at the cost associated with a Contract operation, costs were developed as if the Authority was intending to develop and operate the system and a 35% surcharge was incorporated to account for contingencies and contractor's overhead and profit. Since it will be common to all site alternatives, transfer station development and operating costs were not incorporated in the estimates.

The round-trip distance is estimated at 39 miles. The round trip is estimated to require approximately 70 minutes to complete including turnaround time at the disposal site. Therefore, the number of trips which can be made each day with a single hauling unit is estimated at 6. At an average payload of 15 tons, approximately 50 trips per day would be necessary based upon the estimated 10th year tonnage. At 6 trips per truck, about 9 tractors will be needed. To provide for contingencies, a 10th tractor should be added. Similarly, it is estimated that 12 trailers would be necessary to provide flexibility and sufficient back-up or reserve capacity.

TABLE 4.5-3
ROAD 412 SITE
FIRST YEAR HAULING COSTS*

A. EQUIPMENT

1. Tractors 10 @ $71,000 = 710,000
   Tractors 12 @ $45,000 = 540,000

2. Tractors - Annual Cost Amortized at 15% Over 5 Yrs.	=	$	212,000
Trailers - Annual Cost Amortized at 15% Over 7 Yrs.	=		130,000
Subtotal	=	$	342,000

B. OPERATING COSTS (EXCLUDING FUEL)

1. Labor (Assume Union Labor)

9 Drivers - 40 Hrs. Regular Time and 4 Hrs. Overtime Per Week: $8683.20/week x 52 = $451,526	$ 452,000
2. Oil, Filters, Tires, Insurance, Maintenance: $0.389/ Mile: $0.389/Mile x 517,140 Miles =	201,000
Subtotal	$ 653,000

C. FUEL COSTS

$1.70/gallon ÷ 6.5 miles/gallon (high torque-rise diesel) = $0.26/mile $0.26/Mile x 517,140 Miles = $135,000	$ 135,000
Total	$1,130,000
10% Contingency:	113,000
10% Overhead:	113,000
15% Profit:	170,000
Grand Total Estimated First Year Cost	$1,526,000

Cost/Ton Hauled: $1,526,000/159,000 Tons = $9.60

* 1984 Dollars

With regard to manpower, 9 drivers will be needed to staff the hauling operation. Wage rates are based upon the United States Department of Labor, Area Wage Survey, Wilmington, Del. - N.J. - Md., April 1981. Other data regarding maintenance, tires, insurance, etc., were obtained from a 1977 study performed for the Southeastern Public Service Authority of Virginia by Henningson, Durham, and Richardson and from "A Handbook for Transfer System Analysis", The Heil Co., 1974. Applicable cost data appearing in these studies were updated by escalating at a rate of 9% per year. It was assumed that compacting-type transfer trailers will be utilized.

Fuel costs, starting with a current value of $1.20/gallon, were escalated at 12% per year for the 3-year interval between 1981 and the project start year (1984) and at 9% per year for the 20-year project life. A utilization factor of 6.5 miles per gallon was used for estimating purposes. This means that the 1st year fuel cost would be $0.26/mile multiplied by the total number of miles travelled (517,140 miles per year). All other operating costs also were escalated at 9% per year.

The annual cost of capital for the purchase of the tractors and trailers was based on projected 1984 unit costs of $71,000 and $45,000, respectively. Tractors were amortized over a 5 year period and the trailers over a 7-year period. An interest rate of 15% was utilized. Table D-2 of Appendix 4D presents projected contractor hauling costs and equivalent tonnage fees for the 20-year planning period. Figure 4.5-2 presents this information graphically.

A summary of the anticipated capital needs and yearly costs for owning and operating a sanitary landfill at the Road 412 site is shown in Table 4.5-4. This table also summarizes the projected yearly costs for the transfer of waste materials from Pigeon Point.

TABLE 4.5-4

ROAD 412 SITE

SUMMARY TABLE OF PROJECTED CAPITAL NEEDS AND YEARLY COSTS *

	Landfill Development and Operation							Hauling Operation		
	Capital Needs Schedule			Debt Service						
Year	Initial	10-Yr	3-Yr	Initial	10-Yr	3-Yr	Annual Operating Cost	Total Annual Cost	Project Total Annual Cost	$/Ton of Materia Transporte and Landfilled
1984	$3,476,500	---	---	$ 396,000	---	---	$ 1,190,000	$ 1,526,000	$ 3,112,000	$19.65
1985	---	---	---	396,000	---	---	1,297,000	1,621,000	3,314,000	20.30
1986	---	---	---	396,000	---	---	1,414,000	1,725,000	3,535,000	21.10
1987	---	---	$ 1,685,000	396,000	---	$ 701,500	1,541,000	1,839,000	4,477,500	26.10
1988	---	---	---	396,000	---	701,500	1,680,000	1,963,000	4,740,500	26.95
1989	---	---	---	396,000	---	701,500	1,831,000	2,252,000	5,180,500	28.70
1990	---	---	2,182,000	396,000	---	908,500	1,996,000	2,399,000	5,699,500	30.85
1991	---	---	---	396,000	---	908,500	2,175,000	2,705,000	6,184,500	32.70
1992	---	---	---	396,000	---	908,500	2,371,000	2,880,000	6,555,500	33.85
1993	---	---	2,826,000	396,000	---	1,176,500	2,585,000	3,071,000	7,228,500	36.45
1994	---	$256,500	---	396,000	$ 45,300	1,176,500	2,817,000	3,516,000	7,950,800	39.20
1995	---	---	---	396,000	45,300	1,176,500	3,071,000	3,742,000	8,430,800	40.60
1996	---	---	3,659,000	396,000	45,300	1,523,500	3,347,000	3,989,000	9,300,800	43.80
1997	---	---	---	396,000	45,300	1,523,500	3,648,000	4,259,000	9,871,800	45.45
1998	---	---	---	396,000	45,300	1,523,500	3,977,000	4,817,000	10,758,800	48.50
1999	---	---	4,739,000	396,000	45,300	1,973,000	4,334,000	5,502,000	12,250,300	54.00
2000	---	---	---	396,000	45,300	1,973,000	4,725,000	5,851,000	12,990,300	56.05
2001	---	---	---	396,000	45,300	1,973,000	5,150,000	6,231,000	13,795,300	58.30
2002	---	---	6,137,000	396,000	45,300	2,555,000	5,613,000	6,645,000	15,254,300	63.10
2003	---	---	---	396,000	45,300	2,555,000	6,118,000	7,097,000	16,211,300	65.70
2004	---	---	---	---	---	2,555,000	6,669,000	8,150,000	17,374,000	69.00
TOTALS	$3,476,500	$256,000	$21,228,000	$7,920,000	$453,000	$26,514,000	$67,549,000	$81,780,000	$184,216,000	
1984 $**	$3,476,500	$108,000	$ 7,857,000	$3,955,000	$135,000	$ 9,000,000	$25,000,000	$30,550,000	$ 68,640,000	

*Exclusive of haul road improvement costs. If haul road improvement costs are incorporated, add $0.70/ton to the initial year costs for material landfilled. Initial Capital Needs would be increased by $960,000 to $4,436,500. Total project debt service would be increased by $2,200,000 to $10,120,000. Total Project Cost also would be increased by $2,200,000 to $186,416,000. To determine the increase for any year to the $/Ton column, divide $110,000 (which represents the annual cost of the $960,000 increase to the initial capital needs) by the appropriate tonnage for that year as obtained from Table 3.2-1. For instance, for the year 1994: $110,000/202,900 tons landfilled is equal to approximately $0.55/ton. Add this to $39.20 and the result is $39.75.

**Totals in 1984 Dollars as determined via a "present worth" analysis.

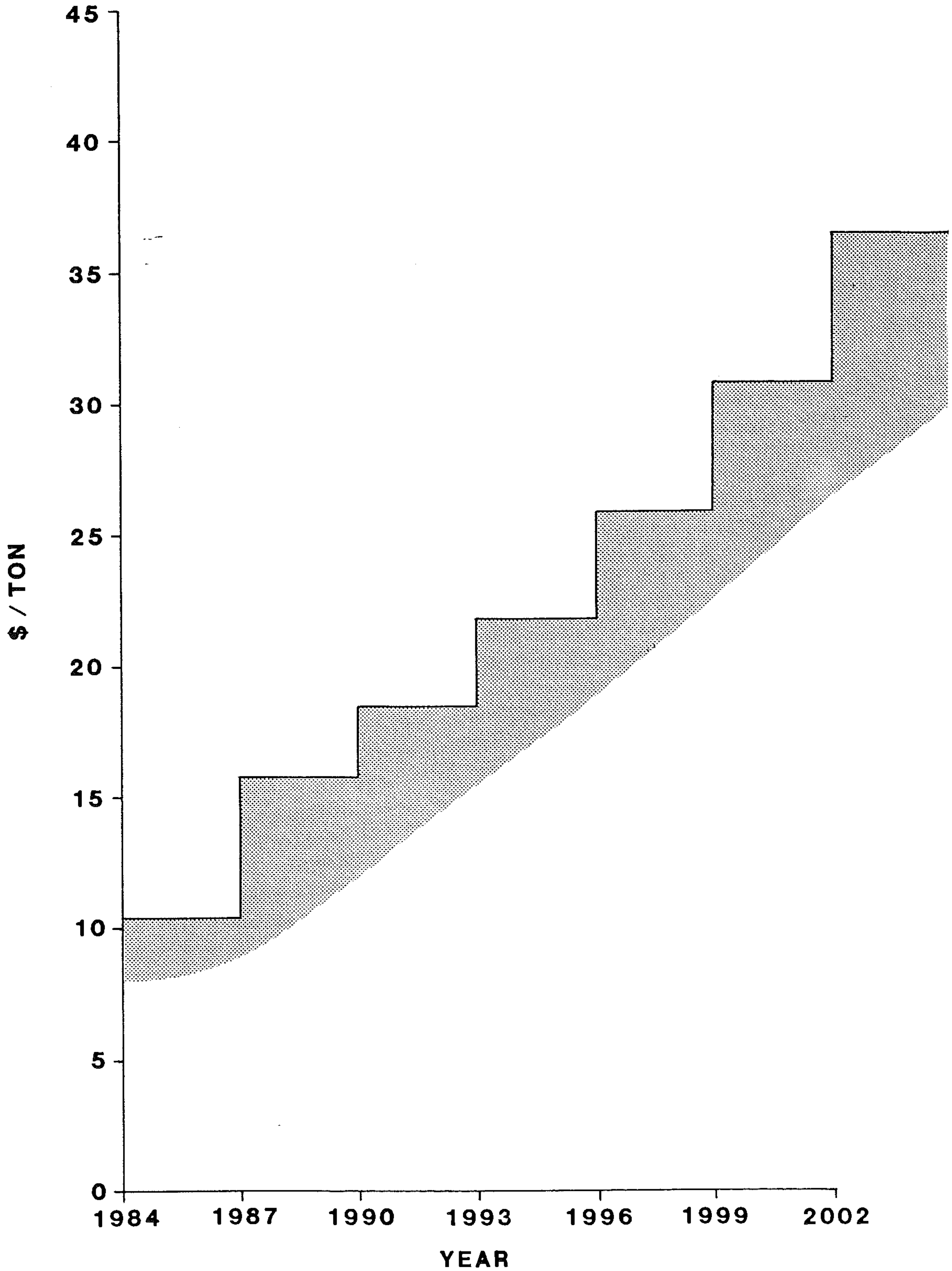


FIGURE 4.5-1
ROAD 412
ESTIMATED COST ($ / TON)
FOR LANDFILLING

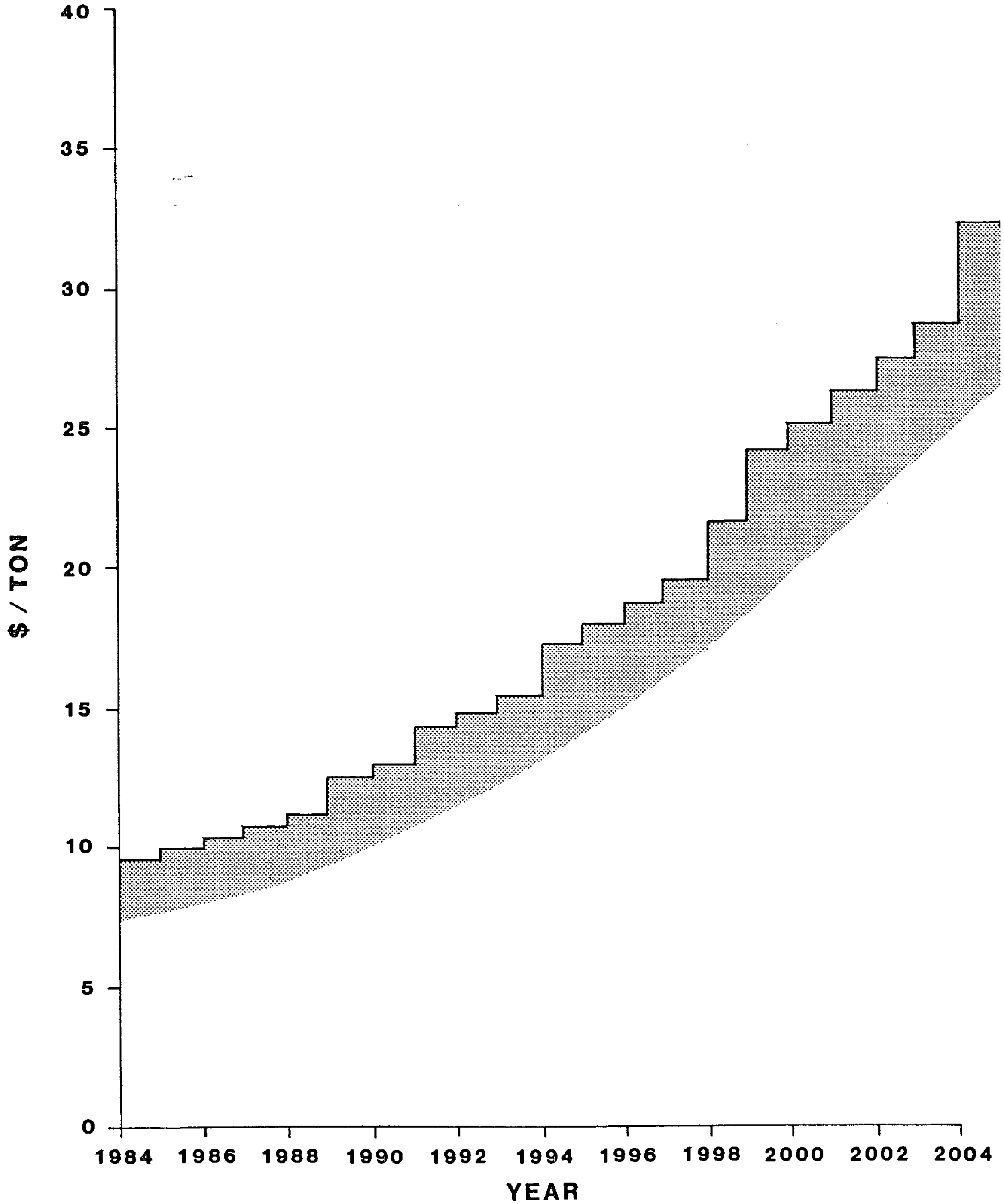


FIGURE 4.5-2
ROAD 412
ESTIMATED COST ($ / TON)
FOR HAULING

APPENDIX 4A

GEOLOGIC LOGS

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 1 OF 1

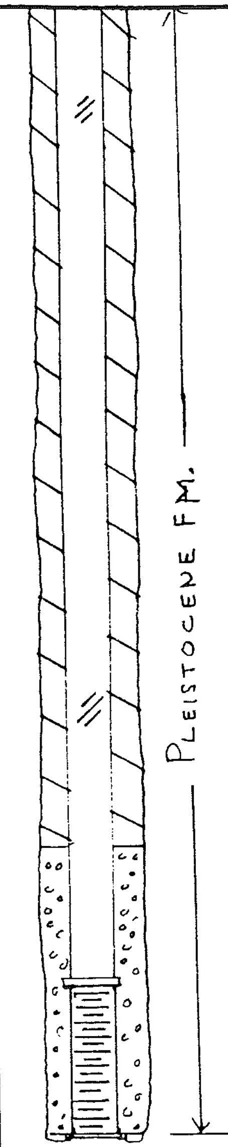
PROJECT: DSWA W.O. 06-7390-002 SITE AREA Road 412 DRILL HOLE NO. P-1

CONTRACTOR: Middletown Well Drilling COORDINATES ______ ELEVATION 73.0'

DRILLER: J. Unruh GWL 0 HRS 31.0

CLASSIFIED BY: BWB DATE: 7/17/81 24 HRS ______

Depth Ft.	Sample No.	SPT Blows/6 In. (6 / 12 / 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
0					0-5 Brown fine to medium sand some silt, some clay					
5					5-10 Rust brown fine to coarse sand some black gravel (magnetite)					
10					10-15 Rust brown silty fine to medium sand, trace to little black gravel					
15					15-20 Rust brown fine to medium sand, silty trace of quartz gravel					
20					20-25 As above					
25					25-30 As above					
30					30-35 As above - no gravel					
35					35-40 As above					
40					Total Depth 40'					



Drilling Notes:

1. Set 4" PVC screen 35 to 40'
2. Gravel packed from 30 to 40'
3. Developed 1 gpm clear
4. Bentonite seal 2-30'
5. Installed protection casing and cap

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 1 OF 1

PROJECT: DSWA W.O. 06-7390-002 SITE AREA Road 412

DRILL HOLE NO. P-2

CONTRACTOR: Middletown Well Drilling COORDINATES

ELEVATION 73.5

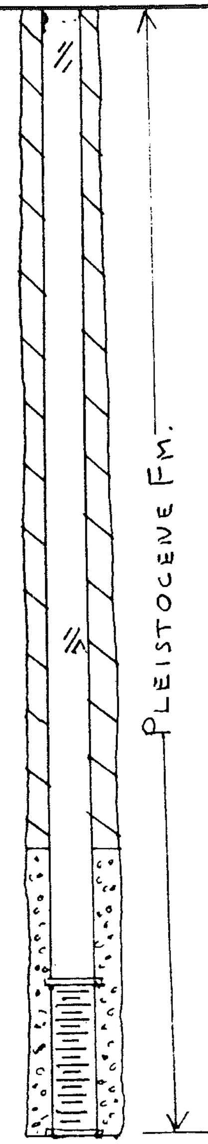
DRILLER: J. Unruh

GWL 0 HRS

CLASSIFIED BY: BWB DATE: 7/17/81

24 HRS

Depth Ft.	Sample No.	SPT Blows/6 In. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Soil Or Rock: Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
0					0-5 Brown silty sand and cream silty clay (soil sample 4.5-5.0' backhoe)					
5					5-10 Gray to brown fine to coarse sand coarse sands - magnetite					
10					10-15 As above					
15					15-20 Rust brown to gray gravelly sand gravel - magnetite some quartz - gravel					
20					20-25 As above.					
25					25-30 Light brown fine to medium sand, some silt, trace of quartz gravel					
30					30-35 As above.					
35					35-40 As above - some magnetite gravel					
40					Total Depth 40'					



Total Depth 40'

Drilling Notes

1. Set 4" PVC screen 35-40
2. Gravel packed from 30-40'
3. Developed 1 gpm fair
4. Bentonite seal 2-30'
5. Installed protector casing and cap

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 1 OF 1

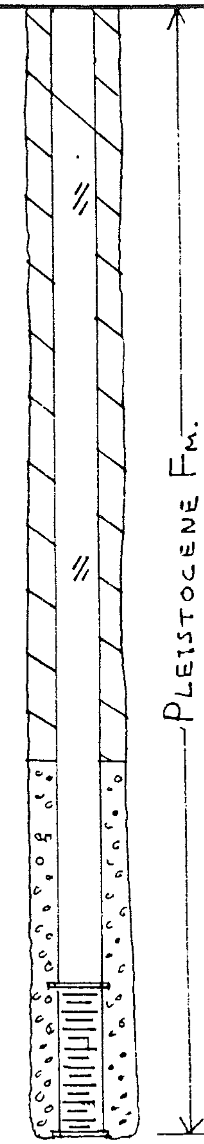
PROJECT: DSWA W.O. 06-7390-002 SITE AREA Road 412 DRILL HOLE NO. P-3

CONTRACTOR: Delmarva Drilling Co. COORDINATES ______ ELEVATION 74.5'

DRILLER: C. Wallace GWL 0 HRS ______

CLASSIFIED BY: BWB DATE: 7/17/81 24 HRS 33.0'

Depth Ft.	Sample No.	SPT Blows/6 In. (6 / 12 / 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
0					0-5 Light brown silty fine sand some clay soil sample at 5.0'					
5					5-10 Dark rust brown fine to coarse sand silty, some cream clay some coarse magnetite sand trace of quartz gravel					
10					10-15 As above					
15					15-20 As above - increase in cream clay, some brown clay					
20					20-25 Rust brown silty fine to medium sand some magnetite gravel trace to little clay					
25					25-30 As above					
30					30-35 As above - color grades to light rust brown					
35					35-40 As above					
40										



Total Depth 40'

Drilling Notes:

1. Set 4" PVC screen 35-40'
2. Gravel packed from 27-40'
3. Developed 1 gpm fair
4. Bentonite seal 2-27'
5. Installed protector casing and cap

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 1 OF 1

PROJECT: DSWA W.O. 06-7390-002 SITE AREA Road 412

DRILL HOLE NO. P-4

CONTRACTOR: Middletown Well Drilling COORDINATES

ELEVATION 61.5

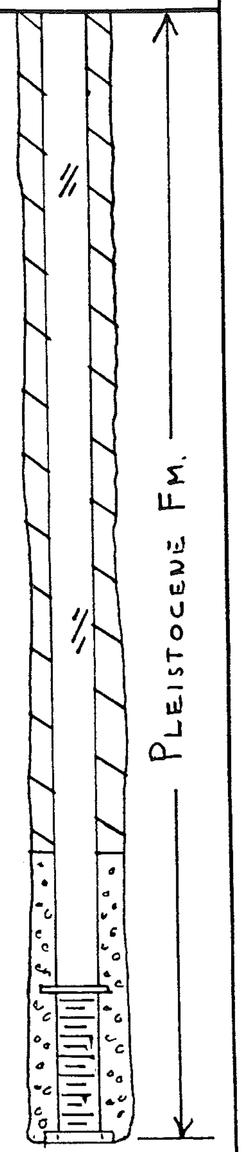
GWL 0 HRS

DRILLER: T. Unruh

CLASSIFIED BY: BWB DATE: 7/17/81

24 HRS

Depth Ft.	Sample No.	SPT Blows/6 In. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
0					0-5 Brown silty clay little to some sand					
5					5-10 Brown fine to coarse sand some glauconite, some silt some quartz gravel					
10					10-15 As above, color grades to rust brown					
15					15-20 Rust brown fine to medium sand, silty					
20					20-25 As above - some quartz gravel					
25					25-30 Light brown silty fine to medium sand slightly micaceous					
30					30-35 As above					
35					35-40 As above					
40					Total Depth 40'					



Drilling Notes:

1. Set 4" PVC screen 35'-40'
2. Gravel packed from 30-40'
3. Developed 1 gpm fair
4. Bentonite seal 2-30'
5. Installed protector casing and cap

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 1 OF 1

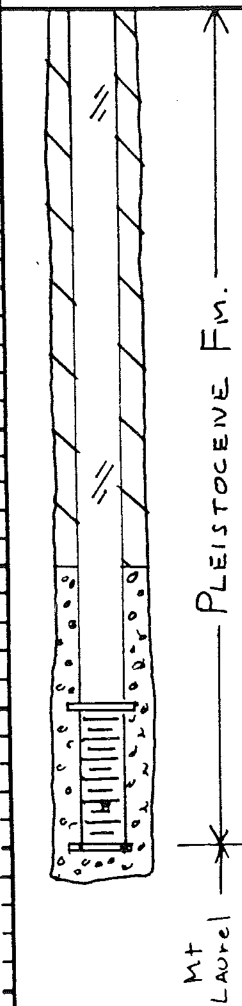
PROJECT: DSWA   W.O. 06-7390-002   SITE AREA Road 412   DRILL HOLE NO. P-5

CONTRACTOR: Delmarva Drilling Co.   COORDINATES ______   ELEVATION 51.0

DRILLER: C. Wallace   GWL 0 HRS 21.0

CLASSIFIED BY BWB   DATE: 7/14/81   24 HRS 20.9

Depth Ft.	Sample No.	SPT Blows/6 In. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
0					0-5 Brown to rust brown fine to medium sand some silt, trace of clay soil sample at 5.0'					
5					5-10 Dark rust brown fine to medium sand trace of silt, little magnetite gravel, some quartz gravel					
10					10-15 Brown clayey gravel to gravelly clay, multi-colored gravel, little magnetite gravel					
15					15-20 Brown silty fine to medium sand, little to some clay, little to some glauconite sand					
20					20-25 As above, fine sand					
25					25-30 As above					
30					31' Dark gray clayey silt, silty clay					



Total Depth 31'

Drilling Notes:

1. Set 4" PVC screen 25 to 30'
2. Gravel packed from 20 to 30'
3. Developed 1 gpm clear
4. Bentonite seal 2-20'
5. Installed protector casing and cap

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 1 OF 1

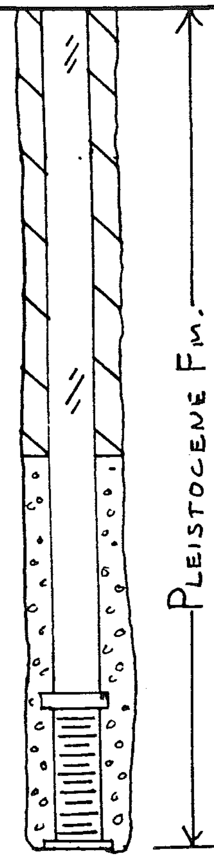
PROJECT: DSWA W.O. 06-7390-002 SITE AREA Road 412 DRILL HOLE NO. P-6

CONTRACTOR: Delmarva Drilling Co. COORDINATES ______ ELEVATION 42.5

DRILLER: C. Wallace GWL 0 HRS ______

CLASSIFIED BY: BWB DATE: 7/16/81 24 HRS 14.0'

Depth Ft.	Sample No.	SPT Blows/6 In. (6 / 12 / 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
0					0-2 Brown sandy clay					
					2-5 Light brown silty fine to medium sand trace of clay, trace of quartz gravel					
5					5-10 Brown fine to coarse sand some quartz gravel little silt					
10					10-15 Brown silty fine to medium sand trace of gravel					
15					15-20 Rust brown fine silty sand trace of clay					
20					20-25 Light brown silty fine sand trace of quartz gravel very silty					
25					25-30 As above					
30					Total Depth - 30'					



Drilling Notes:

1. Set 4" PVC screen 25-30'
2. Gravel packed from 16-30'
3. Developed 5 gpm clear
4. Bentonite seal 2-16'
5. Installed protector casing and cap

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 1 OF 1

PROJECT: DSWA W.O. 06-7390-002 SITE AREA Road 412

DRILL HOLE NO. P-7

CONTRACTOR: Delmarva Drilling Co. COORDINATES

ELEVATION 39.5

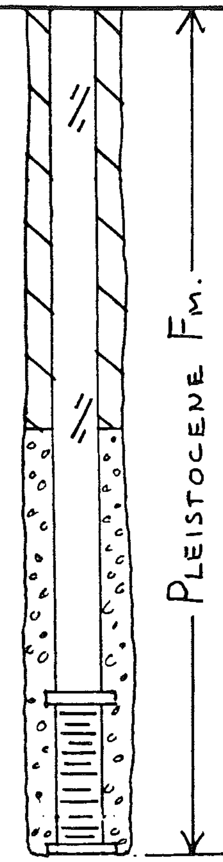
DRILLER: C. Wallace

GWL 0 HRS

CLASSIFIED BY: BWB DATE: 7/16/81

24 HRS 18.6

Depth Ft.	Sample No.	SPT Blows/6 In. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
0					0-4 Light brown silty clay some fine sand					
5					4-10 Light brown fine to coarse sand some silt, some quartz gravel some brown clay					
10					10-15 As above					
15					15-20 As above					
20					20-25 Rust brown fine to coarse sand some quartz gravel trace to no clay					
25					25-30 As above					
30					Total Depth 30'					



Total Depth 30'

Drilling Notes:

1. Set 4" PVC screen 25-30'
2. Gravel packed from 15-30'
3. Developed 2.5 gpm clear
4. Bentonite sealed 2-15'
5. Installed protector casing and cap

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 1 OF 1

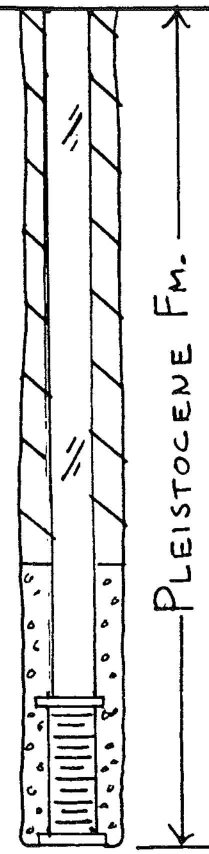
PROJECT: DSWA   W.O. 06-7390-002   SITE AREA Road 412   DRILL HOLE NO. P-8

CONTRACTOR: Middletown Well Drilling   COORDINATES ____   ELEVATION 47.0

DRILLER: T. Unruh   GWL 0 HRS 13.0

CLASSIFIED BY: BWB   DATE: 7/21/81   24 HRS ____

Depth Ft.	Sample No.	SPT Blows/6 In. (6, 12, 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock Range Size / Core Run	Soil Or Rock Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
0					0-4 Brown fine to medium clayey sand some gravel					
5					4-10 Rust brown silty fine to medium sand trace to little gravel					
10					10-15 As above with some magnetite					
					15-20 As above color grades to light brown					
15					20-25 As above					
20					25-30 As above					
25										
30										



Total Depth - 30'
Drilling Notes:

1. Set 4" PVC screen 25-30'
2. Gravel packed from 20-30'
3. Developed 10 gpm clear
4. Bentonite seal 2-20'
5. Installed protector casing and cap

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 1 OF 3

PROJECT: DSWA W.O. 06-7390-002 SITE AREA Road 412

DRILL HOLE NO. E-1

CONTRACTOR: Middletown Well Drilling COORDINATES

ELEVATION 68.5

DRILLER: J. Unruh

GWL 0 HRS 50.0

CLASSIFIED BY: BWB DATE: 7/22/81

24 HRS

Depth Ft.	Sample No.	SPT Blows/6 In. 6 12 18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
0					0-5 Rust brown silty fine to medium sand some clay trace of shell fragments					Pleistocene Fm.
5					5-10 Brown fine to coarse sand some silt					
10					10-15 As above - color grades to rust brown					
15					15-20 As above - some magnetite					
20					20-25 Light brown silty fine to medium sand					
25					25-30 As above					
					30-35 As above					
30					35-40 As above					
35					40-45 As above - color grades to rust brown					
40					45-50 As above					
45										
50										

GAI - 227 9/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 2 OF 3

PROJECT: DSWA W.O. 06-7390-002 SITE AREA

CONTRACTOR: Middletown Well Drilling COORDINATES

DRILLER: J. Unruh

CLASSIFIED BY: BWB DATE: 7/22/81

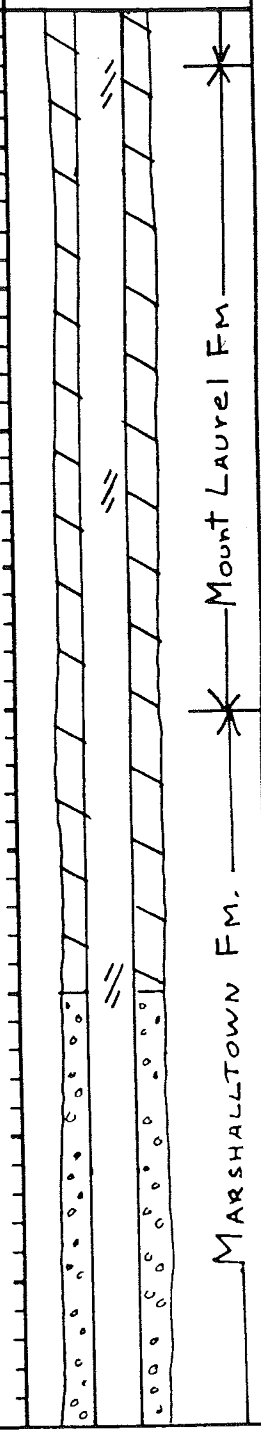
DRILL HOLE NO. E-1

ELEVATION 68.5

GWL 0 HRS 50.0

24 HRS

Depth Ft.	Sample No.	SPT Blows/ 6 In. (6, 12, 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Soil Or Rock: Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
50					50-52 Brown clay layer					
					52-55 Green gray silty fine sand trace of cream clay glauconite					
55					55-60 Green gray clayey silty sand to sandy silty clay sand: fine					
60					60-65 As above					
65					65-70 As above trace of shell fragments					
70					70-75 Green gray silty fine sand some green gray clay some shell fragments					
75					75-81 Green gray sandy silt with some clay					
80					81-85 Dark green gray silty clay little to some sand trace of shell fragments					
85					85-90 As above					
90					90-95 As above -increase in shell fragments, more fine sand					
95					95-99 As above					
100										



GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

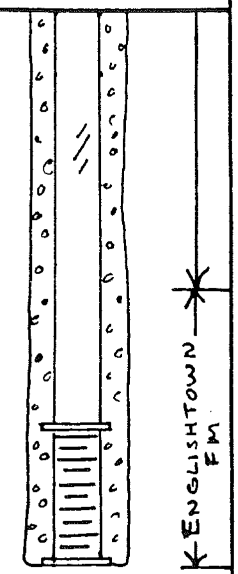
SHEET 3 OF 3

PROJECT: DSWA W.O. 06-7390-002 SITE AREA Road 412 DRILL HOLE NO. E-1

CONTRACTOR: Middletown Well Drilling COORDINATES ______ ELEVATION 68.5

DRILLER: J. Unruh GWL 0 HRS 50.0

CLASSIFIED BY: BWB DATE: 7/22/81 24 HRS ______

Depth Ft.	Sample No.	SPT Blows/6 In. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
100					99-105 Dark green gray sandy silty clay some shell fragments					
105					105-110 As above					
110					110-115 Green gray clayey silty fine sand slightly micaceous some shell fragments					
115					115-120 Green gray silty fine sand to fine sandy silt					
120					Total Depth 120'					

Drilling Notes:

1. At 120' driller noted hard drilling and sample indicated dark green gray clay
2. Set 4" PVC screen 115-120'
3. Gravel packed from 85-120
4. Developed 5 gpm clear
5. Bentonite seal 2-85'
6. Installed protector casing and cap

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 1 OF 3

PROJECT: DSWA W.O. 06-7390-002 SITE AREA Road 412

DRILL HOLE NO. E-2

CONTRACTOR: Delmarva Drilling Co. COORDINATES

ELEVATION 61.5

DRILLER: C. Wallace

GWL 0 HRS

24 HRS 49.9

CLASSIFIED BY: BWB DATE: 7/16/81

Depth Ft.	Sample No.	SPT Blows/6 In. (6 / 12 / 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
0-4					Brown silty clay trace of fine sand slightly micaceous					PLEISTOCENE Fm (0-40)
4-10					Rust brown fine to coarse sand, some quartz gravel some brown clay, trace of shell fragments, slightly micaceous					
10-15					As above					
15-20					Rust brown silty fine to medium sand, some coarse quartz gravel, trace of glauconite trace of clay slightly micaceous					
20-25					As above increased coarse sands; color grades to light brown					
25-29					As above					
29-30					Light brown clay layer					
30-35					Brown fine to coarse sand some quartz gravel little to some glauconite little clay					
35-40					As above					
40-45					Green brown silty fine to medium sand some glauconite trace of clay, micaceous					Mount Laurel Fm. (40-50)
45-51					As above					

GAI - 227 9/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 2 OF 3

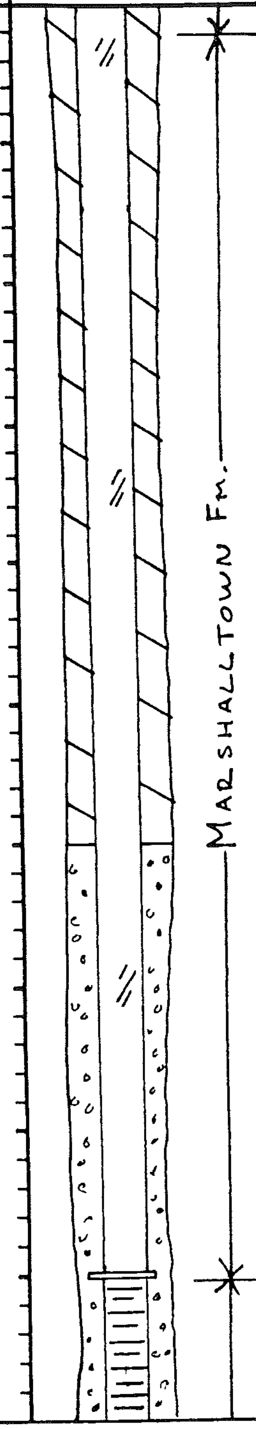
PROJECT: DSWA W.O. 06-7390-002 SITE AREA Road 412 DRILL HOLE NO. E-2

CONTRACTOR: Delmarva Drilling Co. COORDINATES ____ ELEVATION 61.5

DRILLER: C. Wallace GWL 0 HRS ____

CLASSIFIED BY: BWB DATE: 7/16/81 24 HRS 49.9

Depth Ft.	Sample No.	SPT Blows/6 In. (6 / 12 / 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Grain Shape; Core Run / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
50									
					51-55 Green gray silty sandy clay some rust brown clay trace of gravel, trace of shell fragments				
55					55-60 As above				
60									
65					65-70 As above				
70					70-75 As above				
75					75-80 As above				
80					80-85 Green gray silty fine sand trace to little clay				
85					85-90 Dark green gray silty clay some fine sand trace of shell fragments				
90					90-95 As above				
95					95-100 Green gray silty fine sand some shell fragments trace of clay slightly micaceous				
100									



GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 3 OF 3

PROJECT: DSWA W.O. 06-7390-002 SITE AREA Road 412

DRILL HOLE NO. E-2

CONTRACTOR: Delmarva Drilling Co. COORDINATES

ELEVATION 61.5

DRILLER: C. Wallace

GWL 0 HRS

CLASSIFIED BY: BWB DATE: 7/16/81

24 HRS 49.9

Depth Ft.	Sample No.	SPT Blows/6 In. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
100–105							100-105 As above increased glauconite					 ENGLISH-TOWN FM
							Total Depth 105'					
							Drilling Notes: 1. Set 4" PVC screen 95-105' 2. Gravel packed from 80-105' 3. Developed 2.5 gpm clear 4. Bentonite seal 2-80' 5. Installed protector casing and cap					

GAI - 227 9/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 1 OF 3

PROJECT: DSWA W.O. 06-7390-002 SITE AREA Road 412

DRILL HOLE NO. E-3

CONTRACTOR: Middletown Well Drilling COORDINATES

ELEVATION 47.0

DRILLER: J. Unruh

GWL 0 HRS 27.0

CLASSIFIED BY: BWB DATE: 7/21/81

24 HRS 26.6

Depth Ft.	Sample No.	SPT Blows/6 In. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
0					0-4 Brown clayey fine to medium sand					PLEISTOCENE FM.
5					4-10 Rust brown silty fine to medium sand, trace to little gravel					
10					10-15 As above - Some magnetite gravel					
15					15-20 As above - color grades to light tan					
20					20-25 As above					
25					25-30 As above					
					30-25 As above					
30					35-40 As above - color grades to brown					
					40-48 As above					
35										
40										
45										
50					48-55 green gray clayey fine to medium sand					

GAI - 227 9/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 2 OF 3

PROJECT: DSWA W.O. 06-7390-002 SITE AREA Road 412 DRILL HOLE NO. E-3

CONTRACTOR: Middletown Well Drilling COORDINATES ______ ELEVATION 47.0

DRILLER: J. Unruh GWL 0 HRS 27.0

CLASSIFIED BY: BWB DATE: 7/21/81 24 HRS 26.6

Depth Ft.	Sample No.	SPT Blows/6 In. (6 / 12 / 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
50					some silty, some glauconite trace of shell fragments trace to little red sands					MOUNT LAUREL FM
55					55-60 As above - trace of brown silty clay					
60					60-65 Light green gray silty fine to medium sand, some glauconite, trace to little cream clay, trace of shell fragments					
65					65-70 As above- increased cream clay					
70					70-75 Green gray silty sandy clay to clayey sandy silt some glauconite, some shell fragments sand: fine to medium					MARSHALLTOWN FM.
75					75-80 As above					
80					80-85 Dark gray silty clay to clayey silt some fine sand, some glauconite, some shell fragments					
85					85-90 As above.					
90					90-95 Increased shell fragments					
95					95-100 As above - micaceous					
100										

GAI - 227 9/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

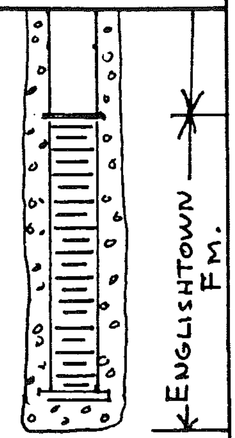
SHEET 3 OF 3

PROJECT: DSWA W.O. 06-7390-002 SITE AREA Road 412 DRILL HOLE NO. E-3

CONTRACTOR: Middletown Well Drilling COORDINATES ______ ELEVATION 47.0

DRILLER: J. Unruh GWL 0 HRS 27.0

CLASSIFIED BY: BWB DATE: 7/21/81 24 HRS 26.6

Depth Ft.	Sample No.	SPT Blows/6 In. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
100					100-104 As above					
105					104-110 Green gray silty sand some shell fragments little clay, micaceous					
110					110-115 As above more silt					
115					Total Depth 115 Drilling Notes: 1. Set 4" PVC screen 104-114' 2. Gravel packed 80-115' 3. Developed 7-10 gpm clear 4. Bentonite seal 2-80' 5. Installed protector casing and cap					

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 1 OF 5

PROJECT: DSWA W.O. 06-7390-002 SITE AREA Road 412

DRILL HOLE NO. M-1

CONTRACTOR: Delmarva Drilling Co. COORDINATES ______

ELEVATION 73.0

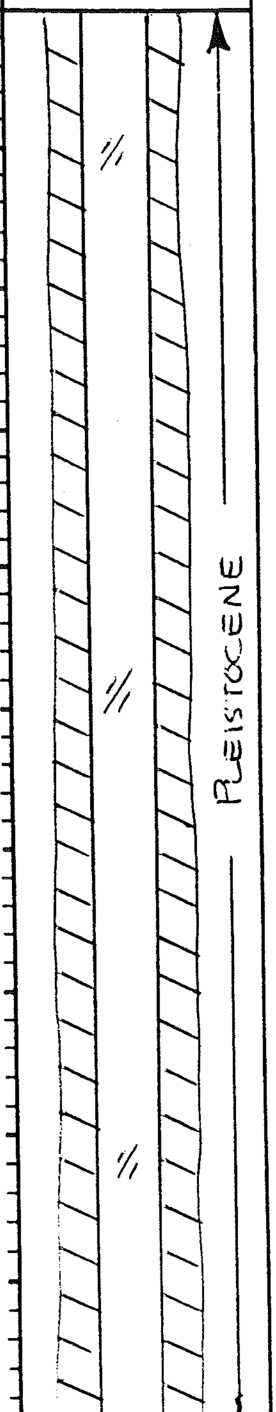
DRILLER: C. Wallace

GWL 0 HRS ______

24 HRS 83'

CLASSIFIED BY: BWB DATE: 7/21/81

Depth Ft.	Sample No.	SPT Blows/6 In. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
0					0-5 Rust brown fine to medium sand, trace silt					
5					5-10 Rust brown fine to coarse trace fine gravel, trace silt					
10					10-15 Rust brown coarse sand with clay interbeds, some gravel					
15					15-20 Brown fine to medium sand silty					
20					20-30 As above					
25										
30					30-45 As above, more silt					
35										
40					40-45 As above, trace fine gravel					
45					45-50 Rust brown fine to medium sand, some silt, some clay trace fine gravel					
50										



GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 2 OF 5

PROJECT: DSWA W.O. 06-7390-002 SITE AREA Road 412

DRILL HOLE NO. M-1

CONTRACTOR: Delmarva Drilling Co. COORDINATES

ELEVATION 73.0

DRILLER: C. Wallace

GWL 0 HRS

CLASSIFIED BY: BWB DATE: 7/21/81

24 HRS 83'

Depth Ft.	Sample No.	SPT Blows/6 In. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
50					50-55 As above, mixed with green gray sandy silty clay					PLEIST.
55					55-60 Green gray sandy clayey silt					MOUNT LAUREL
60					60-70 As above					
65										
70					70-75 As above, more clay					
75					75-80 Green gray clayey silt-silty clay, some sand					
80					80-85 Green gray silty fine to medium sand, some light gray clay beds					MARSHALLTOWN
85					85-90 As above					
90					90-95 Green gray clayey silty sand, little shell fragments					
95					95-100 Green gray fine to medium sandy clay, some silt, trace shell fragments					
100										

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 3 OF 5

PROJECT: DSWA W.O. 06-7390-002 SITE AREA Road 412

DRILL HOLE NO. M-1

CONTRACTOR: Delmarva Drilling Co. COORDINATES

ELEVATION 73.0

DRILLER: C. Wallace

GWL 0 HRS

CLASSIFIED BY: BWB DATE: 7/21/81

24 HRS 83

Depth Ft.	Sample No.	SPT Blows/6 In. (6 / 12 / 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
100					100-105 Dark gray clayey sandy silt, some shell fragments					MARSH.
105					105-110 Dark green gray fine to medium sand, micaceous, some silt, trace to little clay, trace shell fragments					ENGLISHTOWN
110					110-115 As above, more silt					
115					115-120 Dark green gray silty sand, micaceous, trace to little clay, trace shell fragments					
120										
125					125-130 As above					
130					130-135 As above, more clay					
135					135-140 Dark green gray silty clay, some sand, micaceous trace shell fragments					MERCHANTVILLE
140					140-145 As above					
145					145-150 As above					
150										

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: DSWA W.O. 06-7390-002 SITE AREA Road 412

DRILL HOLE NO. M-1

CONTRACTOR: Delmarva Drilling Co. COORDINATES

ELEVATION 73.0

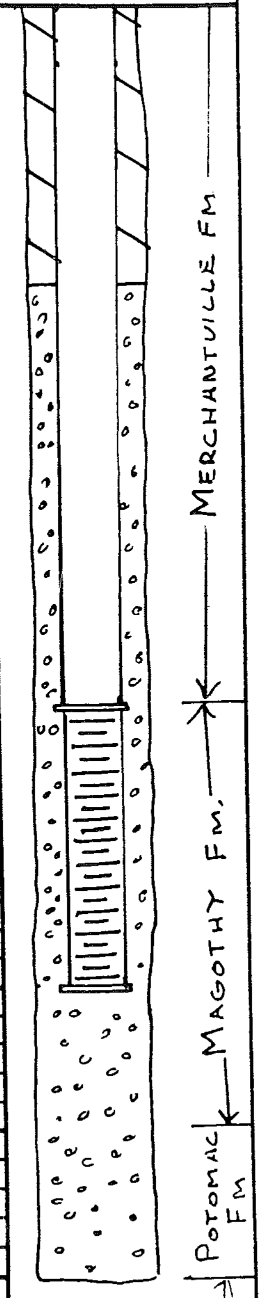
DRILLER: C. Wallace

GWL 0 HRS

24 HRS 83'

CLASSIFIED BY: BWB DATE: 7/21/81

Depth Ft.	Sample No.	SPT Blows/6 In. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
150					150-155 As above, trace to no sand, trace to no shell fragments					
155					155-160 As above					
160					160-165 As above					
165					165-170 As above					
170					170-175 As above, trace shell fragments, trace sand					
175					175-180 Green gray silty fine sand, micaceous, slightly sugary					
180					180-185 Dark green gray silty fine to medium sandy clay					
185					185-190 As above					
190					190-195 Gray, red cream sandy clay some quartz gravel					
195					Total Depth 195'					



GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 5 OF 5

PROJECT: DSWA W.O. 06-7390-002 SITE AREA Road 412

DRILL HOLE NO. M-1

CONTRACTOR: Delmarva Drilling Co. COORDINATES

ELEVATION 73.0

DRILLER: C. Wallace

GWL 0 HRS

CLASSIFIED BY: BWB DATE: 7/21/81

24 HRS 83'

Depth Ft.	Sample No.	SPT Blows/ 6 In. 6 12 18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
					Drilling Notes: 1. Set 4" PVC screen 175-185 2. Gravel packed from 160-195 3. Developed 1 gpm (poor). Development time was in excess of 1 hour. Low yield and presence of clay prevented clear development 4. Bentonite seal 2-160 feet 5. Installed protector casing and cap					

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 1 OF 5

PROJECT: DSWA   W.O. 06-7390-002   SITE AREA Road 412   DRILL HOLE NO. M-2

CONTRACTOR: Delmarva Drilling Co.   COORDINATES ______   ELEVATION 51.0

DRILLER: C. Wallace   GWL 0 HRS 65

CLASSIFIED BY: BWB   DATE: 7/14/81   24 HRS 56

Depth Ft.	Sample No.	SPT Blows/6 In. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
0–5					0-5 Brown to rust brown fine to medium sand, some silt, trace clay					PLEISTOCENE FM
5–10					5-10 Dark rust brown fine to medium sand, trace silt little magnetite gravel some quartz gravel					
10–15					10-15 Brown clayey gravel to gravelly clay, multi-colored gravel, little glauconitic gravel					
15–20					15-20 Brown silty fine to medium sand, little to some clay, little to some glauconitic sand					
20–25					20-25 As above, fine sand					
25–30					25-30 As above					
30–35					30-35 Green gray sandy clay - clayey sand some silt, glauconitic gravel, with seams of rust clay (stiff) trace gravel					MOUNT LAUREL FM
35–40					35-40 As above					
40–45					40-45 As above					
45–50					45-50 As above, with shell fragments					

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 2 OF 5

PROJECT: DSWA W.O. 06-7390-002 SITE AREA Road 412

DRILL HOLE NO. M-2

CONTRACTOR: Delmarva Drilling Co. COORDINATES ______

ELEVATION 51.0'

DRILLER: C. Wallace

GWL 0 HRS 65'

CLASSIFIED BY: BWB DATE: 7/14/81

24 HRS 56'

Depth Ft.	Sample No.	SPT Blows/6 In. (6 / 12 / 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
50					50-55 Green gray silty sandy clay - clayey sandy silt, glauconite					MARSHALLTOWN FM (50–76)
55					55-60 As above					
60					60-65 As above					
65					65-70 As above					
70					70-76 As above					
75					76-85 Green gray silty fine to medium sand, slightly micaceous, trace shell fragments, trace red fine sand					ENGLISHTOWN FM (76–90)
80										
85					85-90 As above					
90					90-95 Dark green gray silty clay clayey silt micaceous, some sand					
95					95-100 As above					
100										

GAI - 227 9/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 3 OF 5

PROJECT: DSWA W.O. 06-7390-002 SITE AREA Road 412 DRILL HOLE NO. M-2

CONTRACTOR: Delmarva Drilling Co. COORDINATES ELEVATION 51.0'

DRILLER: C. Wallace GWL 0 HRS 65'

CLASSIFIED BY: BWB DATE: 7/14/81 24 HRS 56'

Depth Ft.	Sample No.	SPT Blows/6 In. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
100					100-105 As above					
105					105-110 As above					
110					110-115 As above, less sand, very micaceous					
115					115-120 As above					
120					120-125 As above					MERCHANTVILLE FM
125					125-130 As above, less micaceous					
130					130-135 As above					
135					135-140 As above					
140					140-145 Green gray silty clay, little sand, micaceous glauconite					
145					145-150 As above, more fine sand					
150										

GAI - 227 9/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 4 OF 5

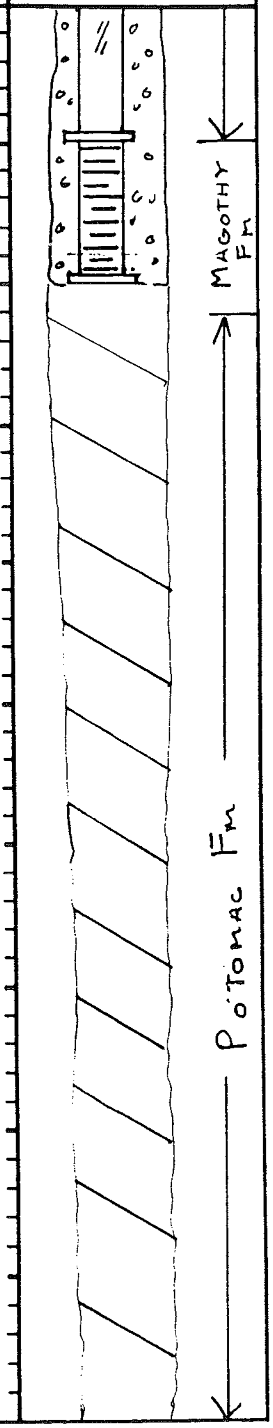
PROJECT: DSWA W.O. 06-7390-002 SITE AREA Road 412 DRILL HOLE NO. M-2

CONTRACTOR: Delmarva Drilling Co. COORDINATES ______ ELEVATION 61.0

DRILLER: C. Wallace GWL 0 HRS 65'

CLASSIFIED BY: BWB DATE: 7/14/81 24 HRS 56

Depth Ft.	Sample No.	SPT Blows/ 6 In. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
150					150-155 As above					
155					155-161 Green Gray clayey sandy silt - sandy silty clay, trace shell fragments					
160					161-165 Cream and green gray silty clay, some sand					
165					165-170 As above, more fine sand some red silty clay					
170					170-175 As above					
175					175-180 Gray cream red sandy clay, some silt					
180					180-185 Gray cream red silty clay some sand					
185					185-200 As above					
190					Note: Test hole collapsed redrilled to 160'					
195										
200					Total Depth 200'					



GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 5 OF 5

PROJECT: DSWA W.O. 06-7390-002 SITE AREA Road 412

DRILL HOLE NO. M-2

CONTRACTOR: Delmarva Drilling Co. COORDINATES

ELEVATION 51.0

DRILLER: C. Wallace

GWL 0 HRS 65'

CLASSIFIED BY: BWB DATE: 7/14/81

24 HRS 56

Depth Ft.	Sample No.	SPT Blows/ 6 In. (6 / 12 / 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core / Run	Grain Shape / Rec. / Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
					Drilling Notes: 1. Set 4" PVC, 16 slot, screen 155-160 2. Gravel packed, No. 2 Morie 145-160 3. Developed less than 1 gpm clear 4. Bentonite seal 2-145 5. Install protector casing and cap Notes: Gamma Log 1. Mr. John Talley - DE Geological Survey Logger 2. Formation Breaks from Log a. Pleistocene 0-30 b. Mount Laurel 30-52 c. Marshalltown 52-76 d. Englishtown 76-88 e. Merchantville 88-155 f. Magothy 155-161 g. Potomac 161-200					

GAI - 227 9/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 1 OF 4

PROJECT: DSWA W.O. 06-7390-002 SITE AREA Road 412

DRILL HOLE NO. M-3

CONTRACTOR: Delmarva Drilling Co. COORDINATES ______

ELEVATION 47.0

DRILLER: C. Wallace

GWL 0 HRS 57'

CLASSIFIED BY: BWB DATE: 7/20/81

24 HRS ______

Depth Ft.	Sample No.	SPT Blows/6 In. (6, 12, 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Soil Or Rock: Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
0					0-4 Brown clayey fine to medium sand					Pleistocene Fm (0–48)
5					4-10 Rust brown silty fine to medium sand, trace to little gravel					
10					10-15 As above, some magnetite gravel					
15					15-20 As above - color grades to light tan					
20					20-25 As above					
					25-30 As above					
25					30-35 As above					
30					35-40 As above - color grades to brown					
35					40-48 As above					
40										
45										
50					48-55 Green gray fine to medium clayey sand					

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 2 OF 4

PROJECT: DWSA W.O. 06-7390-002 SITE AREA Road 412

DRILL HOLE NO. M-3

CONTRACTOR: Delmarva Drilling Co. COORDINATES ______

ELEVATION 47.0

DRILLER: C. Wallace

GWL 0 HRS 57'

24 HRS ______

CLASSIFIED BY: BWB DATE: 7/20/81

Depth Ft.	Sample No.	SPT Blows/ 6 In. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
50					some silt, some glauconite, trace of shell fragments, trace to little red sands					MOUNT LAUREL FM
55					55-60 As above, trace of brown silty clay					
60					60-65 Light green gray silt fine to medium sand, some glauconite, trace to little cream clay, trace of shell fragments					
65					65-70 As above - increased cream clay					
70					70-75 Green gray sandy silty clay to sandy clayey silt some glauconite, some shell fragments, sand: fine to medium					MARSHALLTOWN FM
75					75-80 AS above					
80					80-85 Dark gray silty clay to clayey silt some fine sand, some glauconite some shell fragments					
85					85-90 As above					
90					90-95 Increased shell fragments					
95					95-100 As above					
100										

GAI - 227 9/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

PROJECT: DSWA W.O. 06-7390-002 SITE AREA Road 412 DRILL HOLE NO. M-3

CONTRACTOR: Delmarva Drilling Co. COORDINATES ______ ELEVATION 47.0

DRILLER: C. Wallace GWL 0 HRS 57'

CLASSIFIED BY: BWB DATE: 7/20/81 24 HRS ______

Depth Ft.	Sample No.	SPT Blows/6 In. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
100					100-103 As above					
					103-110 Dark green gray silty fine sand with glauconite micaceous, trace of shell fragments					ENGLISHTOWN FM
110					110-116 As above					
					116-120 Dark green gray silty clay with littel to some fine sand, few shell fragments					MERCHANTVILLE FM
120					120-125 As above increased shell fragments					
125					125-130 As above					
130					130-135 As above					
135					135-140 As above					
140					140-145 As above - trace to no fine sand					
145					145-150 As above					
150										

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 4 OF 4

PROJECT: DSWA W.O. 06-7390-002 SITE AREA Road 412

DRILL HOLE NO. M-3

CONTRACTOR: Delmarva Drilling Co. COORDINATES

ELEVATION 47.0

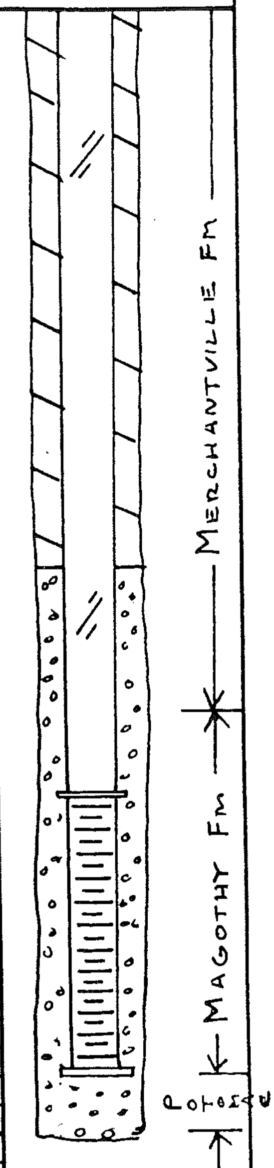
DRILLER: C. Wallace

GWL 0 HRS 57'

CLASSIFIED BY: BWB DATE: 7/20/81

24 HRS

Depth Ft.	Sample No.	SPT Blows/6 In. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
150					150-155 As above					
155					155-160 As above increased fine sand					
160					160-165 As above					
165					165-170 As above					
					170-175 As above					
170										
175					175-178 Green gray fine sandy clay to clayey fine sand sand: sugary when cleaned Clay: cream clay seams					
180					178-188 Light green gray silty fine sand, trace of cream clay sand: sugary when cleaned					
185										
					188-190 Red and white clay					
190										



Total Depth - 190'

Drilling Notes:

1. Set 4" PVC screen 178 to 188'
2. Gravel packed from 170 to 190'
3. Developed 5 gpm clear
4. Bentonite seal 2-170 feet
5. Install protector casing and cap

GAI - 227 9/72

APPENDIX 4B

GEOPHYSICAL LOG

GAMMA RAY LOG

Delaware Geological Survey

Well No. Eb35-19 | Run No. 2 | Date Logged 7/15/81

Local No. M-2 | DNREC No.

Logging Information

Logger: Logmaster

Tool: Neltronic

Logging speed: 24 ft/min up down

Footage logged: 196

Module calibration: 0 - 50 cps

Scale: 10 cps/inch

Time constant: 1 sec.

Sensitivity:

Remarks:

Logged by: John Talley

Well Information

Owner: Delaware Solid Waste Authority

Project Name: Retz Property

Local Well No.: M-2

Elevation of land surface: Approximately 55 ± 5'

T.D. driller: 200

T.D. logger: 196

TOC: 0 l.s. Log M.P.: grd. sfc

Casing size: NA inches to ____ (ls), Type ____

____ inches to ____ (ls), Type ____

Screen size: NA inches, from ____ to ____, Type ____

Gravel pack: NA

Open Hole size: 6.75"

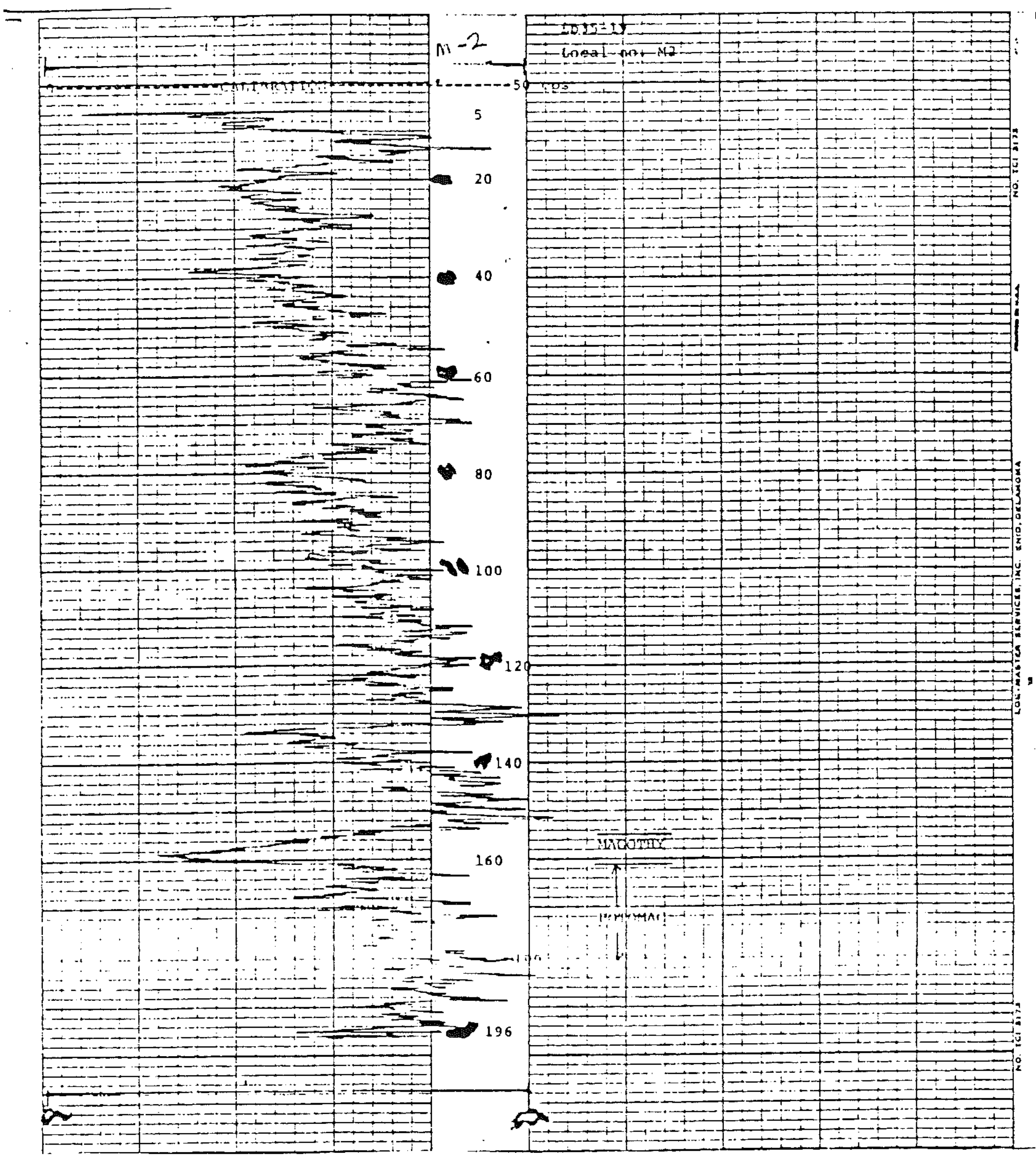
Fluid type: Formation water & mud

Driller: Delmarva Drilling Co.

Aquifer or formation screened: Magothy

Date started: 7/14/81 completed: 7/15/81

Remarks: Witnessed by David Stanislawcyzk of Gilbert Associates. Well drilled as part of a site investigation for the Delaware Solid Waste Authority.



APPENDIX 4C

GRAIN SIZE ANALYSES

Gilbert/Commonwealth engineers and consultants

LABORATORY SERVICES

GILBERT ASSOCIATES, INC., P. O. Box 1498, Reading, PA 19603/Tel. 215 775-2600

CERTIFICATE OF ANALYSIS

LABORATORY NO: 11478 RECEIVED: 7/24/81 REPORTED: 8/10/81

CLIENT: Delaware Solid Waste Auth - WO 06-7390-002

SAMPLE DESCRIPTION: Soil Analysis
Road 412, Site P-2 (5')
Sampled 7/24/81

- - - - - - - - - -

PARTICLE SIZE DETERMINATION
SIEVE ANALYSIS

Sieve Size	% Retained
4 Mesh	3.6
10 "	1.5
18 "	1.6
30 "	2.9
50 "	12.8
100 "	9.7
200 "	4.3
Pass200 "	63.6

HYDROMETER ANALYSIS

Diameter (mm)	% Passing
0.074	63.6
0.038	54.3
0.018	35.8
0.006	15.9
0.002	13.9

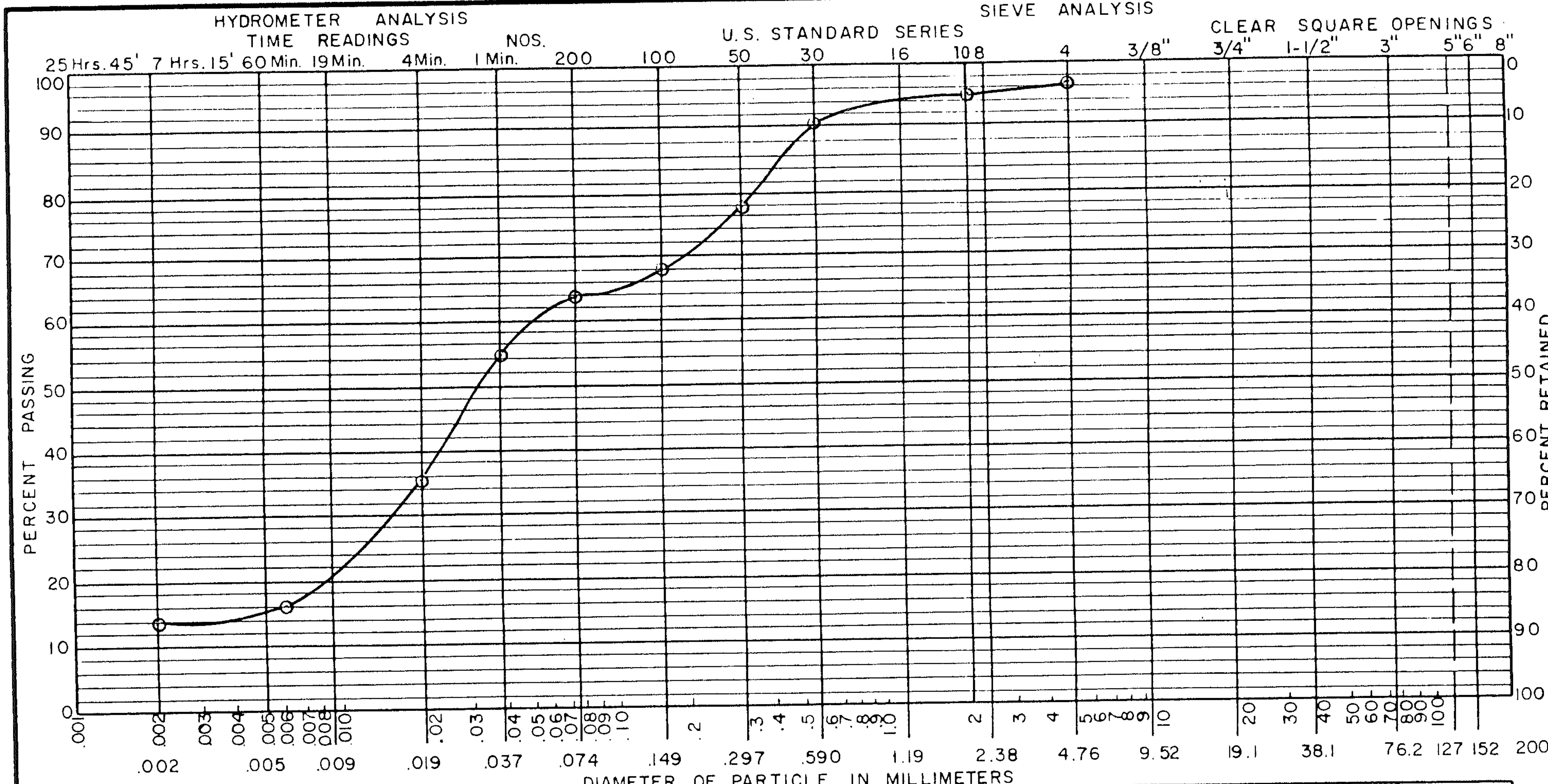
Respectfully submitted,

C. J. Wummer, Supervisor
Laboratory Services

MAH

cc: D. Stanislaw (2)

ROAD 412 SITE
WELL NO. P-2
GRADATION CURVE



CLAY (PLASTIC) TO SILT (NON PLASTIC)	SAND			GRAVEL		COBBLES
	FINE	MEDIUM	COARSE	FINE	COARSE	

Sample No.	Elev. or Depth	Classification	Nat WC	LL	PL	PI	
	5 ft.	Sandy clayey silt					

GILBERT ASSOCIATES, INC.
GRADATION TEST

Gilbert/Commonwealth engineers and consultants

LABORATORY SERVICES
?0 NOBLE STREET, READING, PA 19611

GILBERT ASSOCIATES, INC., P. O. Box 1498, Reading, PA 19603/Tel. 215 775-2600

CERTIFICATE OF ANALYSIS

LABORATORY NO: 11479   RECEIVED: 7/24/81   REPORTED: 8/10/81

CLIENT: Delaware Solid Waste Auth - WO 06-7390-002

SAMPLE DESCRIPTION: Soil Analysis
Road 412 Site P-3 (5')
Sampled 7/24/81

\- - - - - - - -

PARTICLE SIZE DETERMINATION
SIEVE ANALYSIS

Sieve Size	% Retained
4 Mesh	0.0
10 "	0.9
18 "	0.0
30 "	1.9
50 "	7.4
100 "	7.2
200 "	5.1
Pass 200 "	77.5

HYDROMETER ANALYSIS

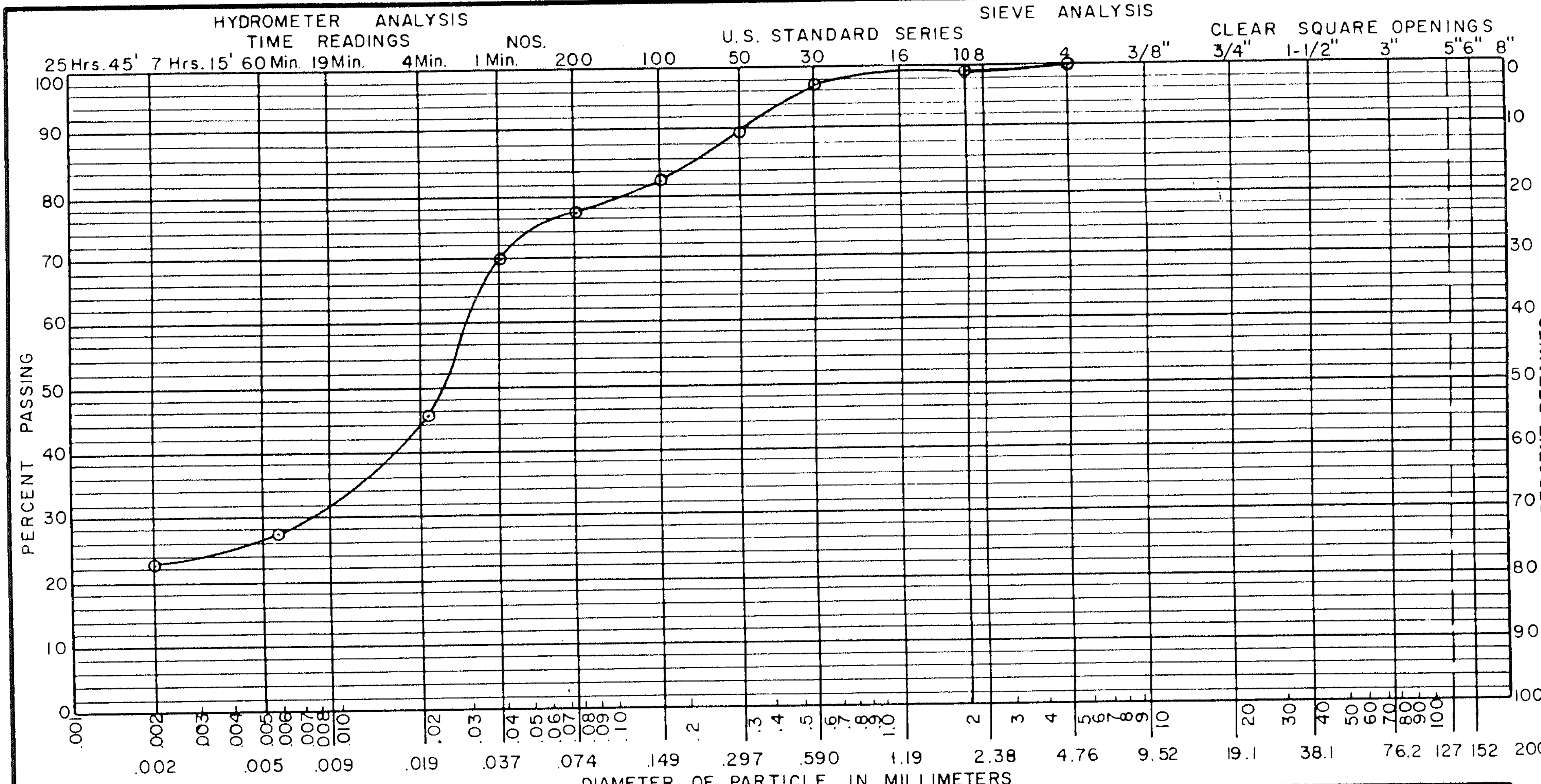
Diameter (mm)	% Passing
0.074	77.5
0.038	70.0
0.018	45.7
0.006	27.5
0.002	22.5

Respectfully submitted,

C. J. Wummer, Supervisor
Laboratory Services

MAH
cc: D. Stanislaw (2)

ROAD 412 SITE
WELL No. P-3
GRADATION CURVE



CLAY (PLASTIC) TO SILT (NON PLASTIC)	SAND			GRAVEL		COBBLES
	FINE	MEDIUM	COARSE	FINE	COARSE	

Sample No.	Elev. or Depth	Classification	Nat WC	LL	PL	PI
	5.0 ft.	Sandy clayey silt				

GILBERT ASSOCIATES, INC.
GRADATION TEST

Gilbert/Commonwealth engineers and consultants

LABORATORY SERVICES

[illegible] STREET READING, PA 1961[illegible]

GILBERT ASSOCIATES, INC., P. O. Box 1498, Reading, PA 19603/Tel. 215 775-2600

CERTIFICATE OF ANALYSIS

LABORATORY NO: 11480 RECEIVED: 7/24/81 REPORTED: 8/10/81

CLIENT: Delaware Solid Waste Auth - WO 06-7390-002

SAMPLE DESCRIPTION: Soil Samples
Road 412 Site P-5 (5')
Sampled 7/24/81

- - - - - - - - - -

PARTICLE SIZE DETERMINATION
SIEVE ANALYSIS

Sieve Size	% Retained
4 Mesh	0.0
10 "	1.1
18 "	7.5
30 "	27.1
50 "	44.7
100 "	12.8
200 "	1.6
Pass 200 "	5.2

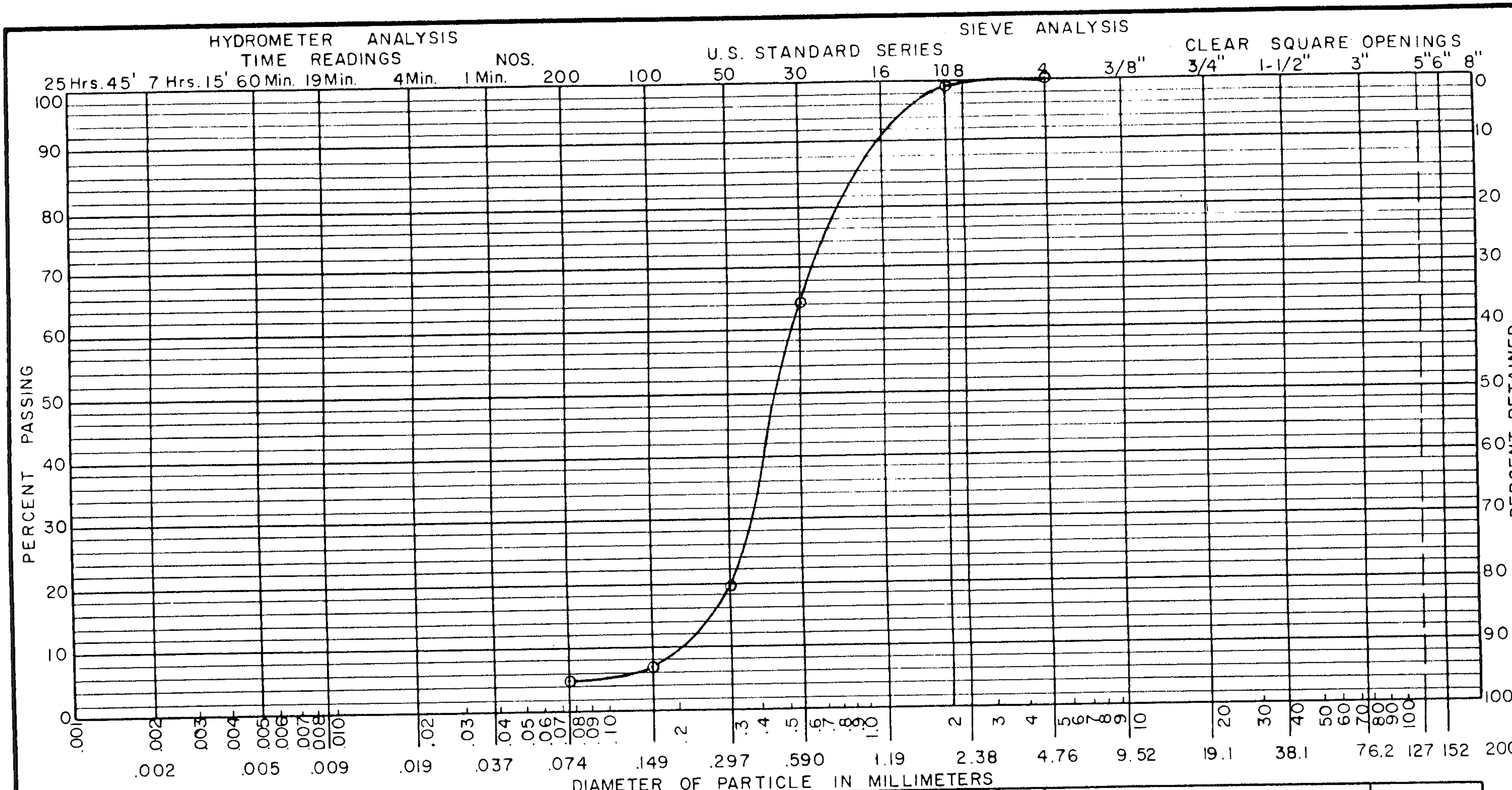
Respectfully submitted,

C. J. Wummer, Supervisor
Laboratory Services

MAH

cc: D. Stanislaw (2)

ROAD 412 SITE
WELL NO. P-5
GRADATION CURVE



Sample No.	Elev. or Depth	Classification	Nat WC	LL	PL	PI	
	5 ft.	Fine to medium sand					

GILBERT ASSOCIATES, INC.
GRADATION TEST

Gilbert/Commonwealth engineers and consultants

LABORATORY SERVICES

GILBERT ASSOCIATES, INC., P. O. Box 1498, Reading, PA 19603/Tel. 215 775-2600

CERTIFICATE OF ANALYSIS

LABORATORY NO: 11481 RECEIVED: 7/24/81 REPORTED: 8/10/81

CLIENT: Delaware Solid Waste Auth - WO 06-7390-002

SAMPLE DESCRIPTION: Soil Samples
Road 412 Site P-6 (5')
Sampled 7/24/81

\- - - - - - - - - -

PARTICLE SIZE DETERMINATION
SIEVE ANALYSIS

Sieve Size	% Retained
4 Mesh	0.0
10 "	0.8
18 "	3.7
30 "	13.4
50 "	56.0
100 "	17.8
200 "	2.0
Pass 200 "	6.3

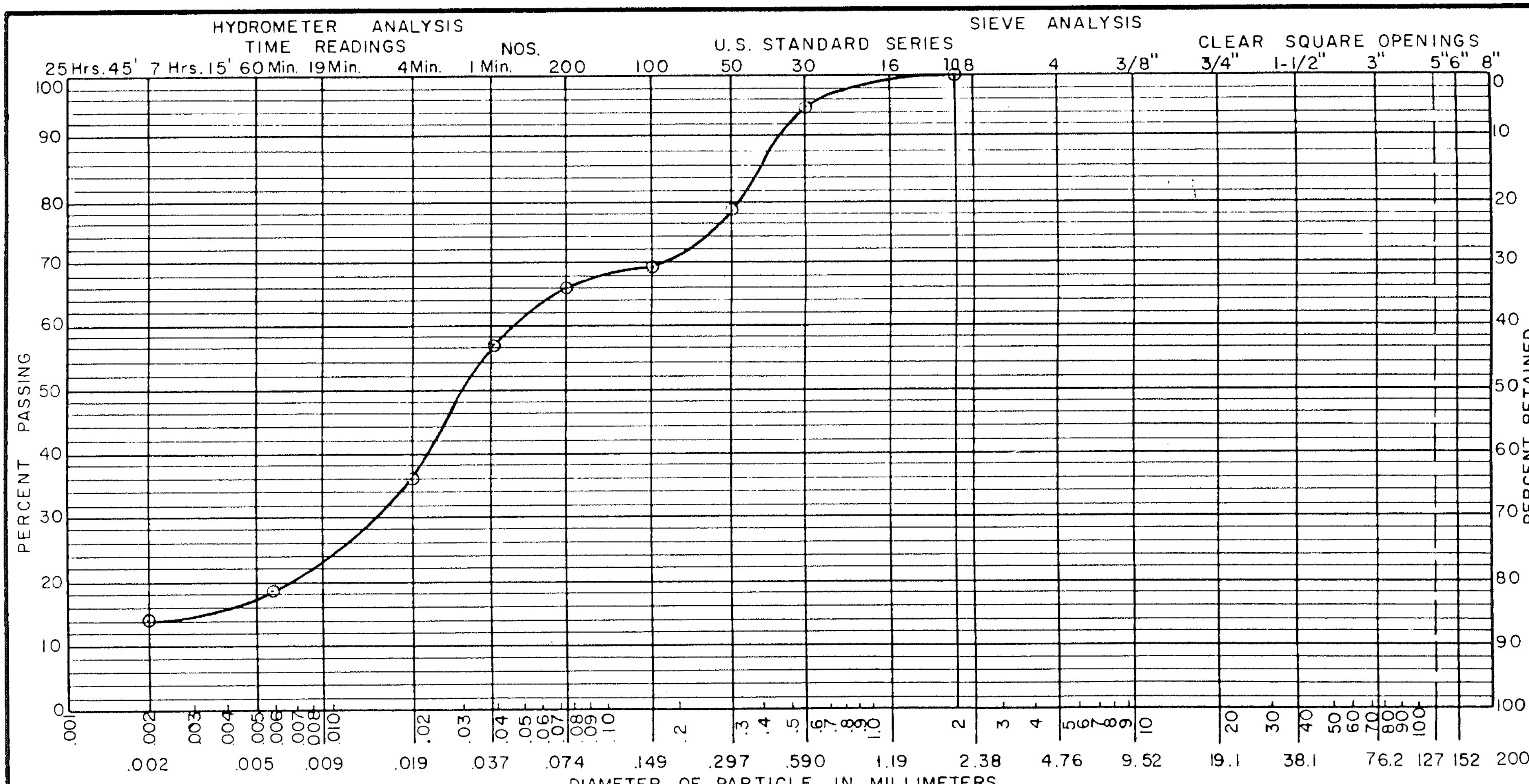
Respectfully submitted,

C. J. Wummer, Supervisor
Laboratory Services

MAH

cc: D. Stanislaw (2)

ROAD 412 SITE
WELL NO. P-7
GRADATION CURVE



CLAY (PLASTIC) TO SILT (NON PLASTIC)	SAND			GRAVEL		COBBLES
	FINE	MEDIUM	COARSE	FINE	COARSE	

Sample No.	Elev. or Depth	Classification	Nat WC	LL	PL	PI
	5 ft.	Sandy silt				

GILBERT ASSOCIATES, INC.
GRADATION TEST

Gilbert/Commonwealth engineers and consultants

LABORATORY SERVICES

GILBERT ASSOCIATES, INC., P. O. Box 1498, Reading, PA 19603/Tel. 215 775-2600

CERTIFICATE OF ANALYSIS

LABORATORY NO: 11483 RECEIVED: 7/24/81 REPORTED: 8/10/81

CLIENT: Delaware Solid Waste Auth - WO 06-7390-002

SAMPLE DESCRIPTION: Soil Samples
Road 412 Site P-7 (10')
Sampled 7/24/81

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PARTICLE SIZE DETERMINATION
SIEVE ANALYSIS

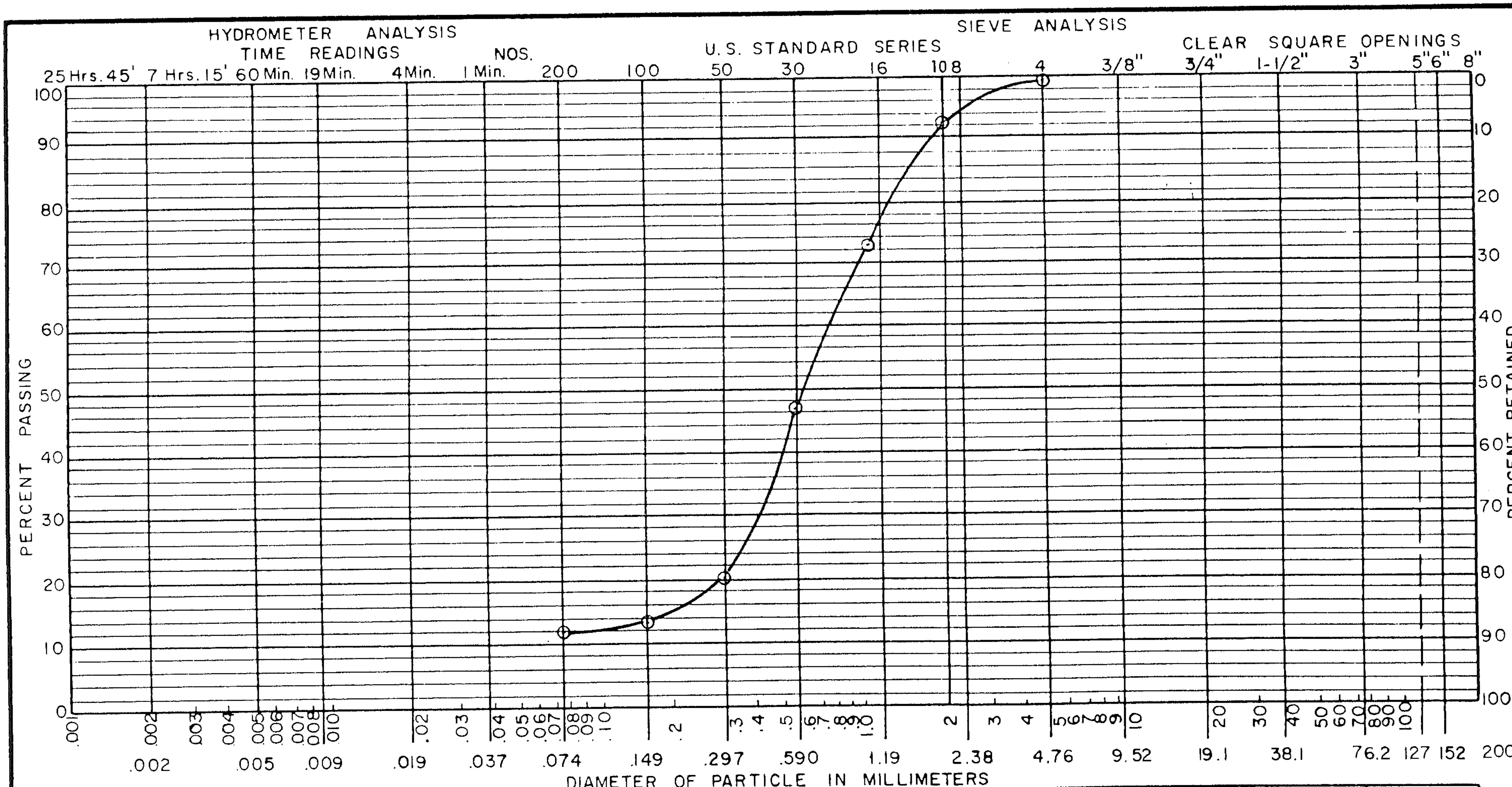
Sieve Size	% Retained
4 Mesh	0.7
10 "	7.2
18 "	19.7
30 "	26.0
50 "	26.1
100 "	6.6
200 "	2.0
Pass 200 "	11.7

Respectfully submitted,

C. J. Wummer, Supervisor
Laboratory Services

MAH
cc: D. Stanislaw (2)

ROAD 412
WELL NO. P-7
GRADATION CURVE



CLAY (PLASTIC) TO SILT (NON PLASTIC)	SAND			GRAVEL		COBBLES
	FINE	MEDIUM	COARSE	FINE	COARSE	

Sample No.	Elev. or Depth	Classification	Nat WC	LL	PL	PI
	10 ft.	Silty fine to coarse sand				

GILBERT ASSOCIATES, INC.
GRADATION TEST

Gilbert/Commonwealth engineers and consultants

LABORATORY SERVICES

GILBERT ASSOCIATES, INC., P. O. Box 1498, Reading, PA 19603/Tel. 215 775-2600

CERTIFICATE OF ANALYSIS

LABORATORY NO: 11484 RECEIVED: 7/24/81 REPORTED: 8/10/81

CLIENT: Delaware Solid Waste Auth - WO 06-7390-002

SAMPLE DESCRIPTION: Soil Analysis
Road 412 Site P-8 (5')
Sampled 7/24/81

- - - - - - - - - -

PARTICLE SIZE DETERMINATION
SIEVE ANALYSIS

	Sieve Size	% Retained
	4 Mesh	15.9
	10 "	2.9
	18 "	5.1
	30 "	6.9
	50 "	18.2
	100 "	12.5
	200 "	8.2
Pass	200 "	30.3

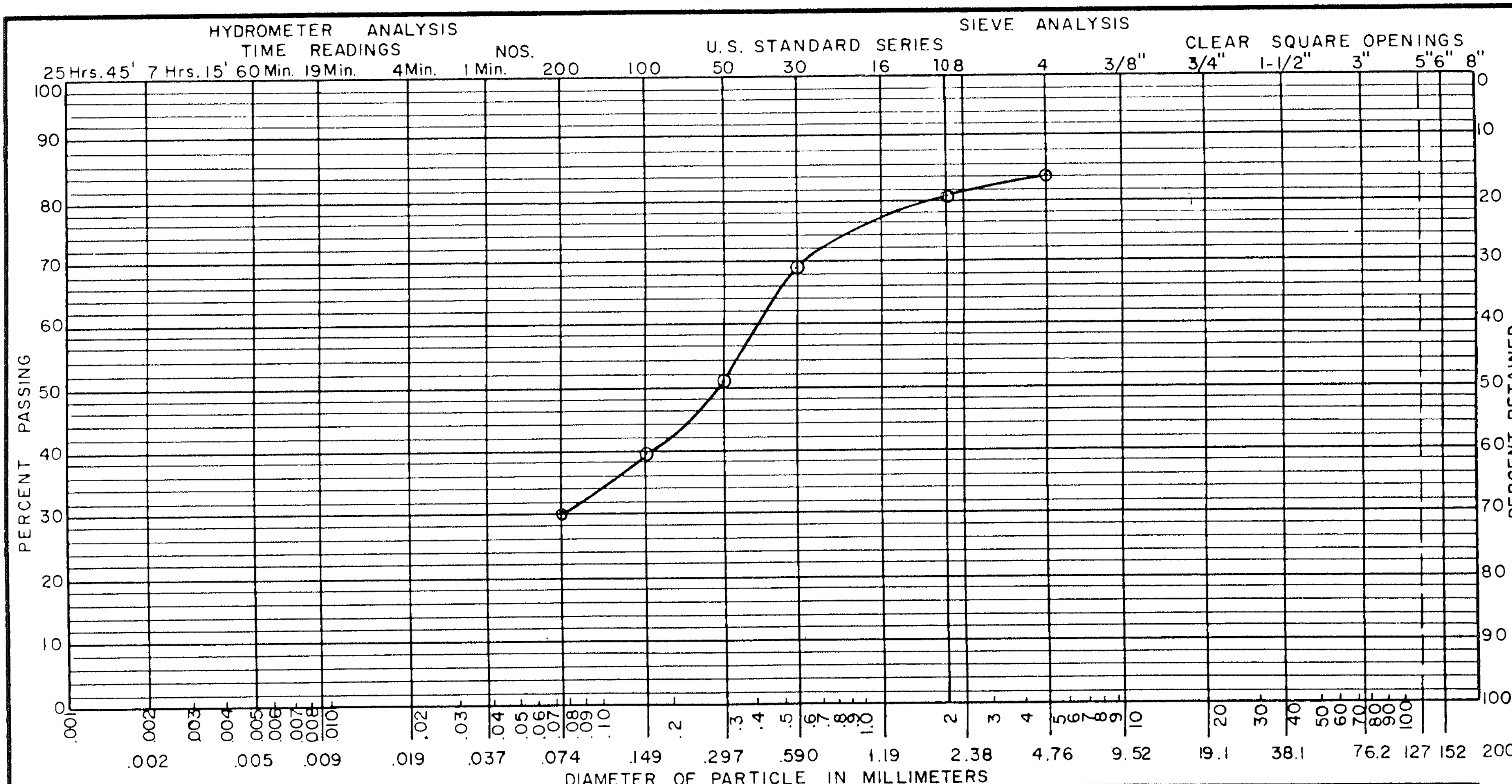
Respectfully submitted,

C. J. Wummer, Supervisor
Laboratory Services

MAH

cc: D. Stanislaw (2)

ROAD 412
WELL NO. P-8
GRADATION CURVE



Sample No.	Elev. or Depth	Classification	Nat WC	LL	PL	PI
	5 ft.	Silty sand, little gravel				

GILBERT ASSOCIATES, INC.
GRADATION TEST

Gilbert/Commonwealth engineers and consultants
LABORATORY SERVICES
GILBERT ASSOCIATES, INC., P. O. Box 1498, Reading, PA 19603/Tel. 215 775-2600

CERTIFICATE OF ANALYSIS

LABORATORY NO: 11477 RECEIVED: 7/24/81 REPORTED: 8/10/81

CLIENT: Delaware Solid Waste Auth - WO 06-7390-002

SAMPLE DESCRIPTION: Soil Analysis
Road 412 Site E-2 (5')
Sampled 7/24/81

\- - - - - - - -

PARTICLE SIZE DETERMINATION
SIEVE ANALYSIS

Sieve Size	% Retained
4 Mesh	6.6
10 "	0.0
19 "	1.9
30 "	9.1
50 "	23.0
100 "	9.2
200 "	4.2
Pass200 "	46.0

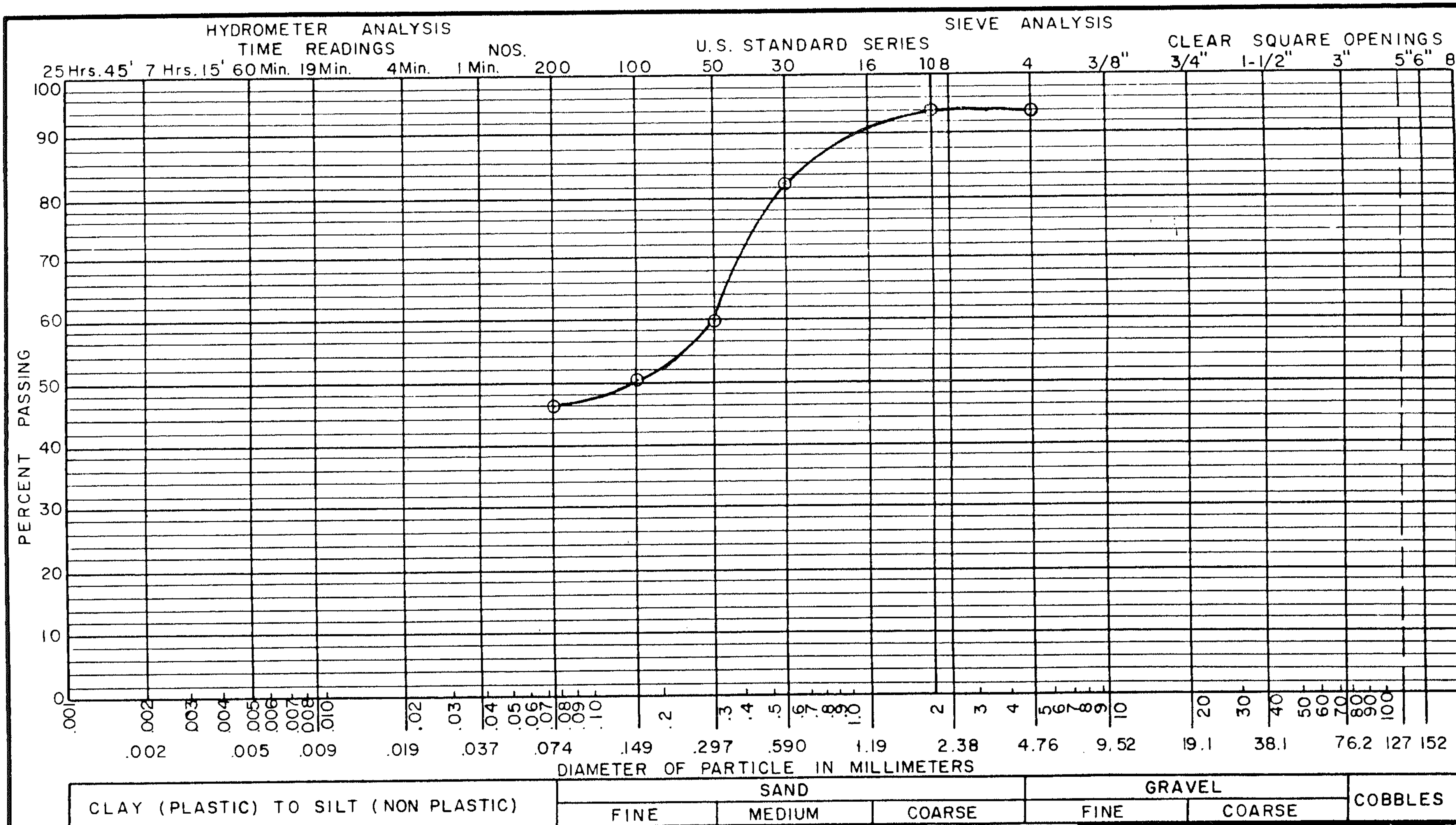
Respectfully submitted,

C. J. Wummer, Supervisor
Laboratory Services

MAH

cc: D. Stanislaw (2)

ROAD 412 SITE
WELL NO. E-2
GRADATION CURVE



Sample No.	Elev. or Depth	Classification	Nat WC	LL	PL	PI
	5.0 ft.	silt, and sand				

GILBERT ASSOCIATES, INC.
GRADATION TEST

APPENDIX 4D

COST PROJECTIONS

TABLE D-1

ROAD 412 SITE: PROJECTED OWNING AND OPERATING COSTS AND EQUIVALENT DISPOSAL FEES

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
OPERATING EXPENSES	1190000.	1297099.	1413836.	1541079.	1679775.	1830953.	1995737.	2175350.	2371130.	2584530.	2817135.
DISPOSAL AREA PREPARATION -											
CAPITAL COST	1301000.	0.	0.	1684827.	0.	0.	2181894.	0.	0.	2825608.	0.
ANNUAL FIXED COST	0.	0.	0.	701478.	701478.	701478.	908432.	908432.	908432.	1176442.	1176442.
EQUIPMENT -											
CAPITAL COST	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
ANNUAL FIXED COST	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
OTHER CAPITAL EXPENSES	2067500.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
20-YR AMORTIZATION	396155.	396155.	396155.	396155.	396155.	396155.	396155.	396155.	396155.	396155.	396155.
OTHER CAPITAL EXPENSES	108000.	0.	0.	0.	0.	0.	0.	0.	0.	0.	255673.
10-YR AMORTIZATION	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	45250.
REFUSE GENERATION (TONS)	159000.	163200.	167400.	171700.	176000.	180400.	184800.	189200.	193800.	198300.	202900.
REVENUE DIFF. FROM PREV. YEAR	0.	66652.	69864.	-2.	74381.	78014.	-5.	102743.	106903.	-9.	168664.
TOTAL ANNUAL EXPENSES	1586155.	1693254.	1809991.	2638712.	2777408.	2928586.	3300323.	3479936.	3675716.	4157127.	4434982.
NORMALIZED FEE ($/TON)	10.40	10.40	10.40	15.80	15.80	15.80	18.41	18.41	18.41	21.81	21.81
REVENUE GENERATED	1652807.	1696466.	1740125.	2713095.	2781041.	2850567.	3403071.	3484096.	3568804.	4325800.	4426146.
DIFFERENCE	66652.	69864.	-2.	74381.	78014.	-5.	102743.	106903.	-9.	168664.	159828.
ACTUAL TIPPING FEE ($/TON)	9.98	10.38	10.81	15.37	15.78	16.23	17.86	18.39	18.97	20.96	21.86
LEVELIZED TIPPING FEE ($/TON)*	9.98	10.17	10.37	11.50	12.25	12.81	13.39	13.88	14.31	14.79	15.24

NOTES : (1) 20-YEAR AMORTIZATION OF CAPITAL AT LONG TERM BOND RATE OF 9.56 PCT
(2) DISCOUNT RATE FOR LEVELIZING ASSUMED TO BE EQUAL TO BOND RATE
(3) OTHER CAPITAL AMORTIZED AT 12.00 PCT
(4) CAPITAL ESCALATED AT 9.00 PCT/YEAR
(5) EXPENSES ESCALATED AT 9.00 PCT/YEAR

*A levelized cost is the constant annual cost equivalent to an escalating actual cost stream.

TABLE D-1 (CONT.)

ROAD 412 SITE: PROJECTED OWNING AND OPERATING COSTS AND EQUIVALENT DISPOSAL FEES

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
OPERATING EXPENSES	3070673.	3347031.	3648259.	3976600.	4334487.	4724589.	5149798.	5613274.	6118460.	6669117.	7269330.
DISPOSAL PREPARATION -											
CAPITAL COST	0.	3659233.	0.	0.	4738796.	0.	0.	6136865.	0.	0.	7947393.
ANNUAL FIXED COST	1176442.	1523522.	1523522.	1523522.	1972998.	1972998.	1972998.	2555084.	2555084.	2555084.	3308898.
EQUIPMENT -											
CAPITAL COST	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
ANNUAL FIXED COST	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
OTHER CAPITAL EXPENSES	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
20-YR AMORTIZATION	396155.	396155.	396155.	396155.	396155.	396155.	396155.	396155.	396155.	0.	0.
OTHER CAPITAL EXPENSES	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
10-YR AMORTIZATION	45250.	45250.	45250.	45250.	45250.	45250.	45250.	45250.	45250.	0.	0.
REFUSE GENERATION (TONS)	207600.	212300.	217100.	221900.	226800.	231700.	236700.	241700.	246800.	251900.	257100.
REVENUE DIFF. FROM PREV. YEAR	159828.	-18.	185935.	194965.	-41.	249532.	260204.	-46.	187527.	55542.	-66.
TOTAL ANNUAL EXPENSES	4688520.	5311958.	5613186.	5941527.	6748890.	7138992.	7564201.	8609763.	9114949.	9224201.	10578228.
NORMALIZED FEE ($/TON)	21.81	25.90	25.90	25.90	30.86	30.86	30.86	36.40	36.40	36.40	41.14
REVENUE GENERATED	4528674.	5497911.	5622216.	5746521.	6998463.	7149664.	7303951.	8797336.	8982964.	9168593.	10578227.
DIFFERENCE	-18.	185935.	194965.	-41.	249532.	260204.	-46.	187527.	55542.	-66.	-67.
ACTUAL TIPPING FEE ($/TON)	22.58	25.02	25.86	26.78	29.76	30.81	31.96	35.62	36.93	36.62	41.14
LEVELIZED TIPPING FEE ($/TON)*	15.65	16.11	16.55	16.95	17.41	17.84	18.25	18.71	19.15	19.53	19.96

NOTES : (1) 20-YEAR AMORTIZATION OF CAPITAL AT LONG TERM BOND RATE OF 9.56 PCT
(2) DISCOUNT RATE FOR LEVELIZING ASSUMED TO BE EQUAL TO BOND RATE
(3) OTHER CAPITAL AMORTIZED AT 12.00 PCT
(4) CAPITAL ESCALATED AT 9.00 PCT/YEAR
(5) EXPENSES ESCALATED AT 9.00 PCT/YEAR

*A levelized cost is the constant annual cost equivalent to an escalating actual cost stream.

TABLE D-2

ROAD 412 SITE: PROJECTED CONTRACTOR HAULING COSTS AND EQUIVALENT TONNAGE FEES

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
OPERATING EXPENSES -											
O & M	653000.	711769.	775828.	845651.	921759.	1004716.	1095140.	1193700.	1301133.	1418233.	1545873.
FUEL COST	135000.	147150.	160393.	174828.	190563.	207713.	226407.	246783.	268994.	293203.	319591.
EQUIPMENT - TRACTORS	710000.	0.	0.	0.	0.	1092417.	0.	0.	0.	0.	1680812.
5-YR AMORTIZATION	211805.	211805.	211805.	211805.	211805.	325886.	325886.	325886.	325886.	325886.	501414.
EQUIPMENT - TRAILERS	540000.	0.	0.	0.	0.	0.	0.	987134.	0.	0.	0.
7-YR AMORTIZATION	129795.	129795.	129795.	129795.	129795.	129795.	129795.	237268.	237268.	237268.	237268.
CONTRACTOR FEE (35%)	395360.	420181.	447237.	476727.	508872.	583838.	622029.	701273.	746648.	796106.	911451.
TOTAL ANNUAL EXPENSES	1524958.	1620697.	1725055.	1838805.	1962792.	2251945.	2399255.	2704908.	2879926.	3070693.	3515595.
TONNAGE HAULED	159000.	163200.	167400.	171700.	176000.	180400.	184800.	189200.	193800.	198300.	202900.
ANNUAL RATE ($/TON)	9.59	9.93	10.30	10.71	11.15	12.48	12.98	14.30	14.86	15.49	17.33
LEVELIZED RATE ($/TON)	9.59	9.75	9.91	10.07	10.23	10.49	10.71	10.97	11.20	11.41	11.65

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
OPERATING EXPENSES -											
O & M	1684999.	1836648.	2001944.	2182118.	2378504.	2592568.	2825897.	3080225.	3357440.	3659608.	3988968.
FUEL COST	348354.	379705.	413878.	451127.	491728.	535983.	584221.	636800.	694111.	756581.	824672.
EQUIPMENT - TRACTORS	0.	0.	0.	0.	2586122.	0.	0.	0.	0.	3979053.	0.
5-YR AMORTIZATION	501414.	501414.	501414.	501414.	771483.	771483.	771483.	771483.	771483.	1187016.	1187016.
EQUIPMENT - TRAILERS	0.	0.	0.	1804507.	0.	0.	0.	0.	0.	0.	3298687.
7-YR AMORTIZATION	237268.	237268.	237268.	433733.	433733.	433733.	433733.	433733.	433733.	433733.	792875.
CONTRACTOR FEE	970212.	1034262.	1104076.	1248936.	1426405.	1516817.	1615365.	1722783.	1839867.	2112927.	2377735.
TOTAL ANNUAL EXPENSES	3742244.	3989295.	4258579.	4817325.	5501850.	5850581.	6230696.	6645022.	7096632.	8149863.	9171265.
TONNAGE HAULED	207600.	212300.	217100.	221900.	226800.	231700.	236700.	241700.	246800.	251700.	256800.
ANNUAL RATE ($/TON)	18.03	18.79	19.62	21.71	24.26	25.25	26.32	27.49	28.75	32.38	35.71
LEVELIZED RATE ($/TON)	11.87	12.07	12.25	12.44	12.65	12.84	13.01	13.17	13.31	13.47	13.62

NOTES -
(1) INTEREST RATE = 15.00
(2) DISCOUNT RATE = 18.00
(3) O&M INFL. RATE = 9.00
(4) FUEL INFL. RATE = 9.00
(5) CAPITAL INFL RATE = 9.00
(6) CONTRACTOR FEE = 35.00

*A levelized cost is the constant annual cost equivalent to an escalating actual cost stream.

5.0 ROBERTS FARM

5.1 SITE DESCRIPTION

5.1.1 Location

The proposed Roberts Farm site is situated in the southern part of New Castle County approximately 2.5 miles southeast of Odessa Delaware. Figure 5.2-1 shows the relationship of the site with its more immediate surroundings. The Delaware River is approximately 3 miles to the east/northeast of the site.

5.1.2 Size and Features

The property which comprises the Roberts Farm totals 720+ acres. It is a mixture of open farmland, small clusters of trees along some stream banks, marshland, and open water. The open water is a pond along Hangman's Run which is created by a dam across the stream on the eastern part of the site. The site is split into two parts by this pond and Hangman's Run. A power transmission line parallels Route 9 immediately west of the property and then turns to the east and forms the northern boundary of the property.

5.1.3 Boundaries/Description of Adjacent Lands

The site is bounded on the west by Stump Corner Road (state Route 9) and farmland just beyond; on the south by Stave Landing Road (State Road 450) with farmlands or wetlands beyond that; on the east by wetlands associated with Hangman's Run; and on the north by farmland and some residential development (along Route 9).

5.1.4 Utilities

No public water supply is available at this site; sewerage facilities are located nearby.

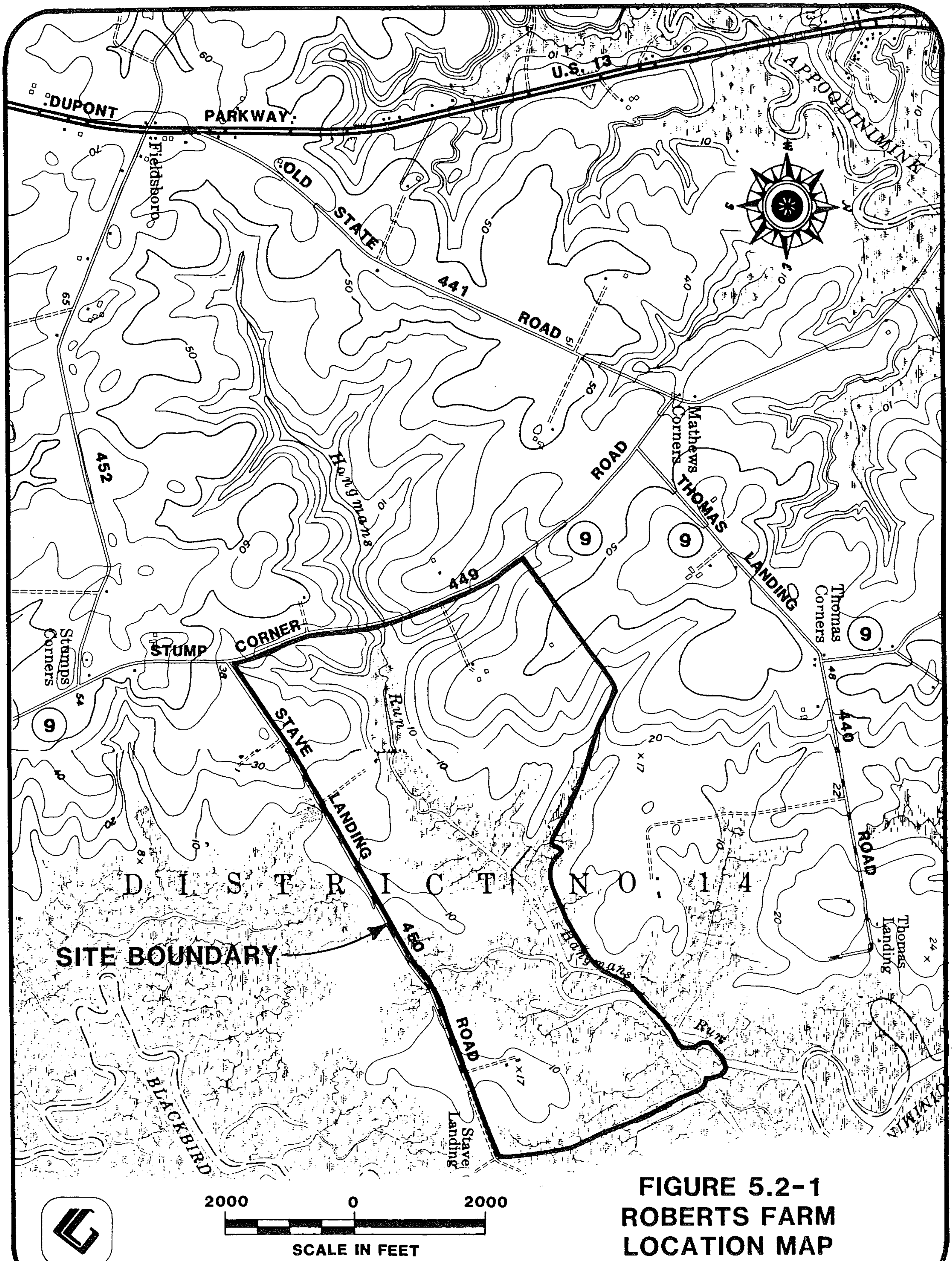


FIGURE 5.2-1
ROBERTS FARM
LOCATION MAP

West of the dam, the water in Hangman's Run is fresh. East of the dam or in the lower lying areas of the site, which is subject to tidal flooding, the water is brackish.

The Coastal Plain Province is comprised of a wedge of unconsolidated materials which consists of gravels, sands, silts, and clays. This wedge of materials which overlies the crystalline basement is thinnest at the Piedmont/Coastal Plain boundary and gradually thickens in a general southeastern direction towards the Continental Shelf. As reported by Sundstrom and Pickett, 1971, the thickness of the Coastal Plain sediments in New Castle County varies from 0 feet near Newark and Wilmington to approximately 2300 feet near the Smyrna River which serves as the County boundary. At the Roberts Farm tract, the Coastal Plain sediments are approximately 1700 feet thick. As reported by Pickett and Spoljaric, 1971, these materials range in age from Lower Cretaceous (135 million years) to Pleistocene (1 million years) and comprise numerous geologic formations. As mapped by Pickett and Spoljaric, 1971, the deepest and oldest Coastal Plain deposit underlying the site is the Potomac formation. This formation lies at a depth of approximately 500 feet and consists of variegated red, gray, purple, yellow and white lignitic silt and clay which contains interbedded white, gray and rust brown quartz sand and some gravel. The Potomac formation is of lower Cretaceous age and is unconformably overlain by the Magothy formation. The Magothy formation is Upper Cretaceous in age and consists of white to buff well sorted quartz sand with beds of gray and black clayey silt. This formation occurs at a depth of approximately 375 feet. Overlying the Magothy formation at a depth of approximately 225 feet, the Marshalltown formation has been mapped. This formation subcrops Pleistocene sediments several miles south of Armstrong, Delaware and consists of dark greenish-gray, massive, highly glauconitic very silty fine sand. The Marshalltown formation like the overlying Mount Laurel formation is Upper Cretaceous in age. The Mount Laurel formation is typically a gray, green and red-brown glauconitic fine to medium quartz sand.

The Paleocene-Eocene age Rancocas Group which is comprised of the lower Hornerstown formation and the upper Vincentown formation is comprised of primarily green gray and red-brown fine to coarse silty sand with glauconite. The sands of the Vincentown formation are coarser than those of the Hornerstown formation.

Overlying the Rancocas Group and subcroping Pleistocene sediments in the site area, the Calvert formation has been mapped. This formation is of Miocene age and consists of gray to bluish gray silt with some fine sand and shell beds.

Finally, Pleistocene sediments surficially blanket the site region and primarily consists of sands and gravels with some interbedded silts and clays.

5.2.1.3 Subsurface Exploration Program

The subsurface exploration and monitoring well installation program for the Roberts Farm tract was undertaken during the period extending from July 9, 1981 through July 22, 1981. Delmarva Drilling Company, Inc. of Bridgeville, Delaware was contracted to perform the well drilling work. In total, ten Pleistocene wells, two Rancocas wells and one Mount Laurel well were constructed. Additional data pertinent to these wells is detailed in the following sections of this report. Drilling equipment utilized consisted of a Failing Model 1250 rotary rig and a hollow stem auger rig which was equipped with 12-inch diameter augers having a 6-inch diameter hollow stem.

Field Procedures

As previously described, a total of ten Pleistocene wells were constructed during the monitoring well installation program. The locations of these borings, which are designated P-1 through P-9 and R-3, are shown on Figure 5.2-2. The monitoring wells were

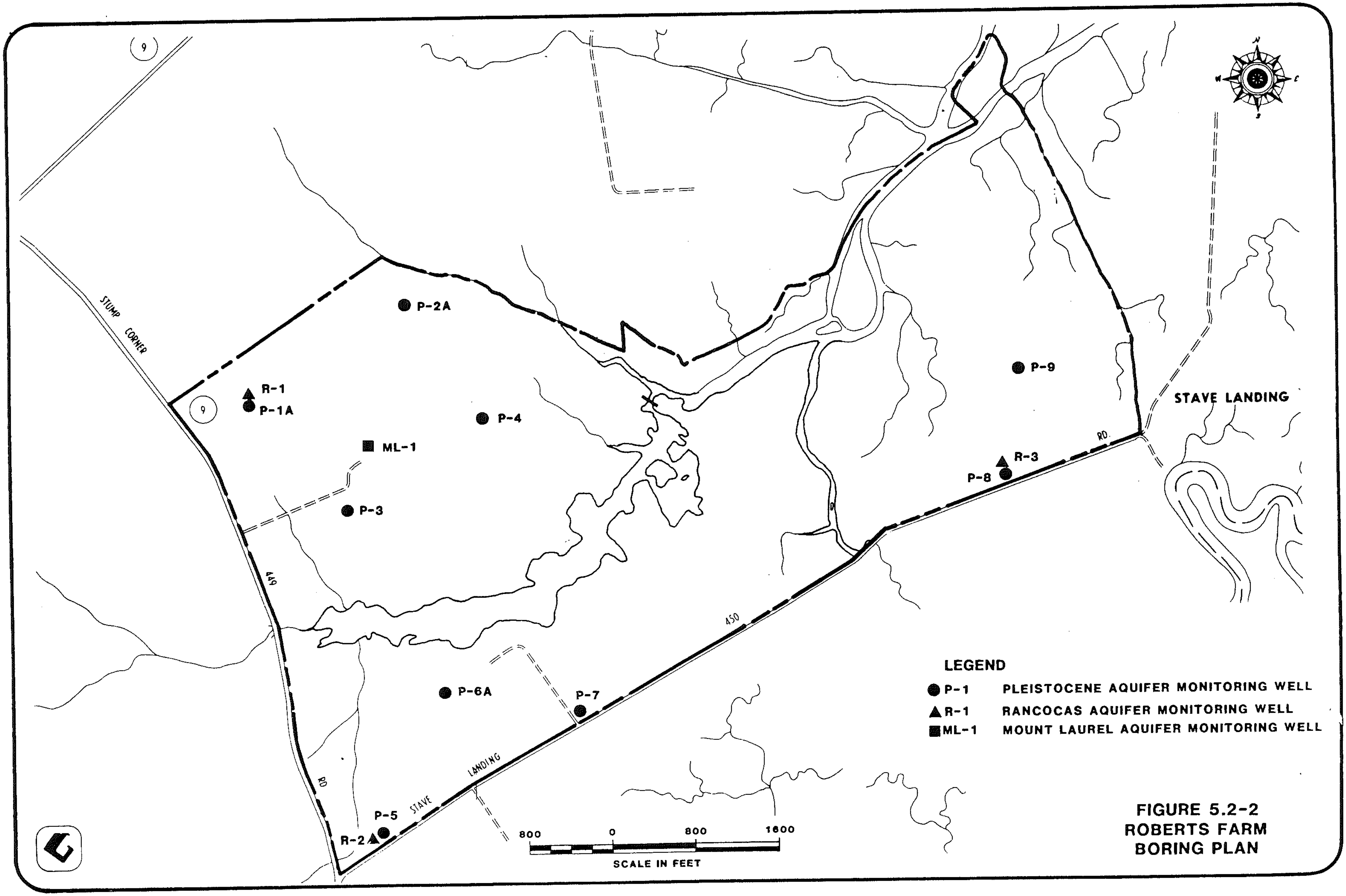


FIGURE 5.2-2
ROBERTS FARM
BORING PLAN

contructed for the purpose of identifying the types and thicknesses of the various sediments comprising the Pleistocene Formation, which surficially blankets the site, and for the purpose of determining groundwater elevations, flow directions and water quality data.

In determining the types and thicknesses of the sediments, samples from the well bore were collected at five foot intervals for identification and geologic logging. Due to the inability of the hollow stem auger rig to collect representative samples during drilling, three Pleistocene wells (P-1, P-2, P-6) were re-drilled using rotary drilling equipment. The new wells are identified on Figure 5.2-2 with the suffix "A", the original wells were completely grouted with bentonite after the casings were removed.

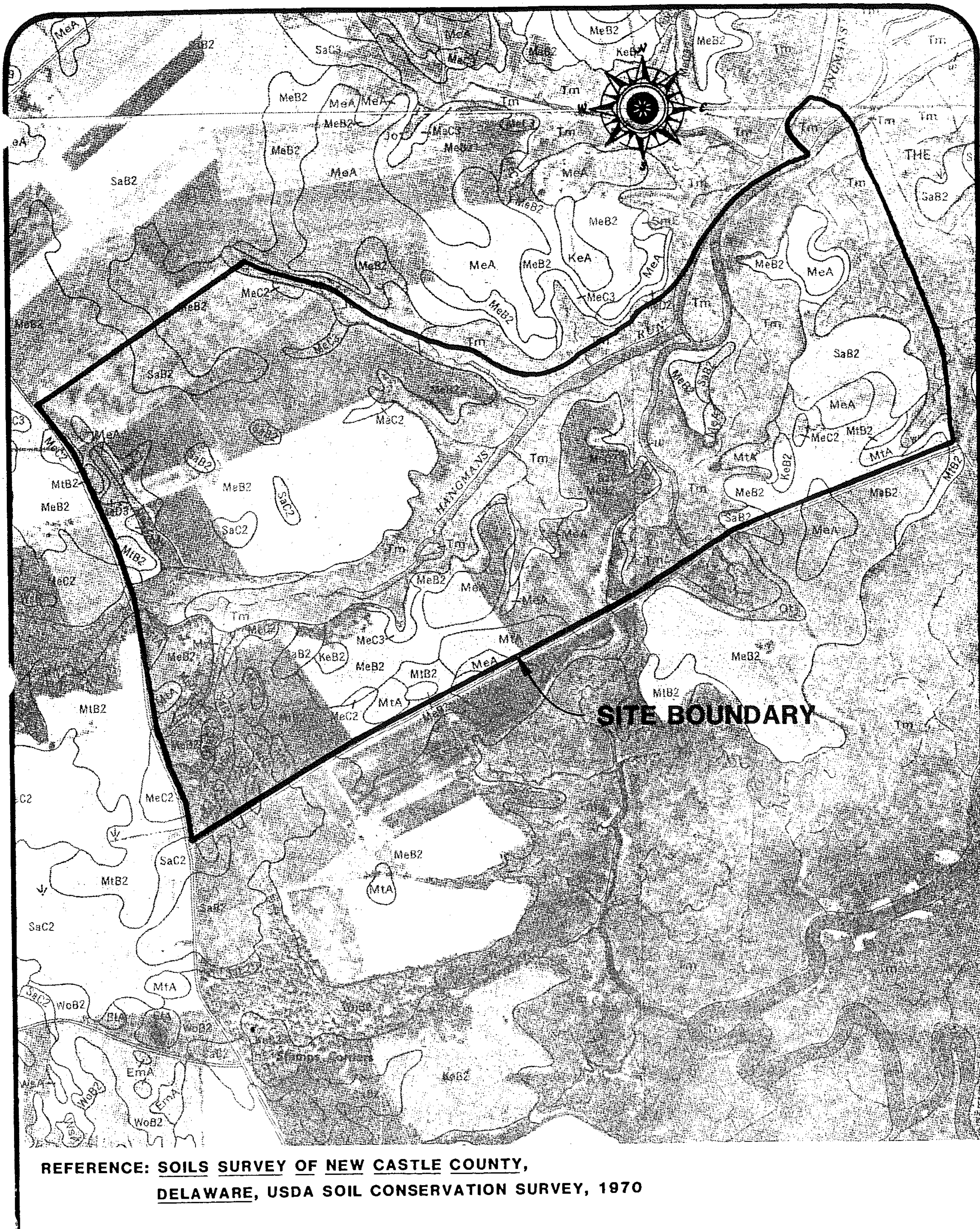
In order to determine groundwater elevations and flow directions, 4-inch diameter polyvinyl chloride (PVC) pipes with 5 foot long PVC screen sections were installed in each well. The PVC screens had a number 16 slot size and were gravel packed with No. 2 Morie gravel. Above the gravel pack to within 2 feet of the surface, the annular space between the well bore and PVC casing was sealed with bentonite grout. A 6-inch diameter steel protector casing with a locking cap was installed and the steel casing was set in concrete grout for approximately 2 feet. The Pleistocene monitoring wells were monitored during the course of the subsurface exploration program and a complete set of water level elevations was obtained on July 28, 1981. The geologic logs of the ten Pleistocene wells are included as Appendix A of this section. Note that monitoring well R-3 was originally intended to be a Rancocas well, however, drilling at the R-3 location revealed that the Calvert and Vincentown formations are absent and a thick sequence of Pleistocene sediments occurs. Accordingly, the well was constructed in Pleistocene materials.

In order to determine the characteristics of the underlying Rancocas aquifer and potentiometric surface data, two wells were constructed in the Vincentown formation. As previously stated, a third well was intended to be constructed in the Rancocas but the Vincentown sediments were absent in that area of the site. The Rancocas wells are shown on Figure 5.2-2 and are designated R-1 and R-2. The geologic logs of the wells are included in Appendix A. The Rancocas wells were constructed identical to the previously described Pleistocene well construction. However, a ten foot long, rather than five foot long, screen section was utilized.

One deep monitoring well was installed at the Roberts Farm tract. This well, labeled ML-1 on Figure 5.2-2, was drilled into the Mount Laurel formation. The well was the first drilled at the site and served as the data base for the remaining well construction. Upon drilling completion and drill tool removal, the Delaware Geological Survey performed differential single point electric logging of the open hole. Gamma ray logging of the well was also attempted, however, electronic problems with the probe precluded this activity. After completion of logging the various formations comprising the site were identified. Construction of the deep well then proceeded with the installation of a ten-foot screen section, gravel packing, development, bentonite sealing and installation of a steel protector casing set in cement grout. Because the Mount Laurel formation was found to consist of very silty and clayey sediments the screen was installed in the immediately overlying Hornerstown formation where fine to medium grained sands were encountered. The geologic and geophysical logs of this well are included in Appendix A and B, respectively.

USDA Soil Descriptions

According to the United States Department of Agriculture - Soil Conservation Service publication entitled, "Soil Survey - New Castle County, Delaware", numerous soil series surficially blanket



REFERENCE: SOILS SURVEY OF NEW CASTLE COUNTY, DELAWARE, USDA SOIL CONSERVATION SURVEY, 1970

FIGURE 5.2-3
ROBERTS FARM
SOILS MAP

the site. As shown on Figure 5.2-3 tidal marsh soils (TM) blanket the low lying portions of the tract and Matapeake soils (MeA) (MeB2) (MeC2) (MeC3) predominantly blanket the remaining portions of the site. As stated in the above referenced publication, a description of the Matapeake series follows:

MeA - Matapeake silt loam, 0-2 percent slopes: The soil forming this unit is deep, well-drained soil that occurs on uplands of the Coastal Plain. The surface layer consists of brown silt loam which is underlain by a thin layer of yellow brown silt loam and brown silty clay loam. The soil has a high available moisture capacity and is suited to practically all uses. Engineering properties of this unit indicate that the soil typically has a pH of 4.5 to 5.5, has a permeability ranging from 0.2 to 6.3 inches per-hour and has a low to moderate shrink swell potential.

MeB2 - Matapeake silt loam, 2 to 5 percent slopes, moderately eroded: This soil is like the unit described above but has lost a significant amount of its original surface layer to erosion.

MeC2 - Matapeake silt loam, 5 to 10 percent slopes, moderately eroded: This soil unit is like the MeA but is slightly more eroded than the MeB2 unit.

MeC3 - Matapeake silt loam, 5 to 10 percent slopes, severly eroded: This soil is like the MeA unit described above but most of the original surface layer has been washed away and the subsoil layer is now exposed at the surface.

Sediment Description

Based on the results of the subsurface exploration and monitoring well installation program, Figures 5.2-4A, and 5.2-4B which are geologic cross-sections of the Roberts Farm tract, have been developed. In reference to these figures, the Coastal Plain sediments, which underlie the above defined soil units, are quite variable and comprise numerous geologic formations some of which serve as groundwater aquifers in New Castle County.

The Pleistocene sediments present consist of tan to rust fine to medium sand, tan silty sand, cream to brown sandy clay and silty clay. The thickness of the Pleistocene sediments varies from 7 feet at the location of monitoring wells R-2 and P-5 to greater than 60 feet at the location of monitoring well R-3.

The underlying Calvert formation was encountered in several of the deeper monitoring wells. As shown on the cross sections, the Calvert formation consists of a dark gray to black clayey silt to silty clay which is slightly micaceous and contains some fine sand. The Calvert formation is not consistent across the site and appears to be eroded away along Hangman's Run and in the eastern portion of the site. This erosion probably occurred during the Pliocene period (10 million years ago) or during part of the Pleistocene period (1 million years ago).

As shown on Figure 5.2-4A, both the Vincentown and Hornerstown formations directly underlie Calvert or Pleistocene sediments. These formations comprise the Rancocas aquifer in Delaware and will be discussed in later sections of this report. The Vincentown formation and Hornerstown formation consist of greenish gray sands with variable amounts of silt and shell beds. The mineral glauconite is abundant throughout the formations. As measured in monitoring well ML-1, the total thickness of the formations was 112 feet.

At an elevation of approximately - 100 feet below sea level, the Mount Laurel formation was penetrated by monitoring well ML-1. As sampled, the Mount Laurel formation consisted of a dark gray to black silty sand which graded into a sandy clay with abundant shell fragments. Samples of the formation were taken by the Delaware Geological Survey since the sediments did not conform to the typical Mount Laurel section. These samples were reviewed by members of the Survey, who confirmed that the minerals penetrated were that of the Mount Laurel formation.

5.2.1.4 Suitability of Insitu Materials for Cover

In order to determine the suitability of the insitu materials occurring above the water table for use as cover materials, representative soil samples were collected and submitted for laboratory testing of grain size distribution. This testing included hydrometer testing of the sediments passing the No. 200 sieve. The testing results and gradation curves are included in Appendix C of this section.

Ideally, cover materials should be of such character that they can be compacted to minimize percolation of water through the cover, will not crack excessively when dry and are free of large objects and putrescible materials. Cover materials may consist of stockpiled soils obtained from excavations at the site and/or materials imported to the site. In general, the bulk of materials excavated on site will consist of soils comprising the surficial 5 to 20 feet.

The results of the grain size analyses are summarized on Table 5.2-1. Review of the table indicates that the soils comprising the surficial 5 to 10 feet of the site vary from silty sand and gravel (R-1, 5 feet) to sandy silty clay (P-4, 5 feet).

In general, the on-site soils are suitable for use as daily and final cover. Most of the soils contain sufficient fines (materials passing No. 200 sieve) to facilitate compaction and reduce percolation of precipitation. However, in several cases (P-4, 5 feet & R-1, 10 feet) the percentages of fines represent approximately half or more of the size fraction and these soils may have a tendency to crack when dry. However, measures can be

TABLE 5.2-1

ROBERTS FARM TRACT

GRAIN SIZE ANALYSES

Well No.	Depth (ft)	Cumulative Percent Retained, Sieve Sizes: 4	10	18	30	50	100	200	Classification	USCS*
P-3	5	1.0	3.9	11.3	24.0	53.8	68.7	74.3	Silty fine to medium sand	SM
P-4	5	0	0	1.0	4.8	21.1	32.0	39.0	Sandy clayey silt	ML
P-6	5	6.7	12.2	20.2	32.8	53.9	64.1	71.4	Silty fine to coarse sand	SM
P-9	5	0	0	0.6	3.9	54.1	91.8	94.2	Fine to medium sand	SP
R-1	5	38.7	41.2	43.3	46.8	58.7	69.0	74.2	Silty sand and gravel	SM
R-1	10	0.0	2.3	5.1	13.9	27.9	40.9	52.5	Silty clay and sand	SM-SC
R-2	5	0.0	2.1	15.3	36.6	75.2	94.9	96.5	Fine to medium sand	SP

*Unified Soil Classification System

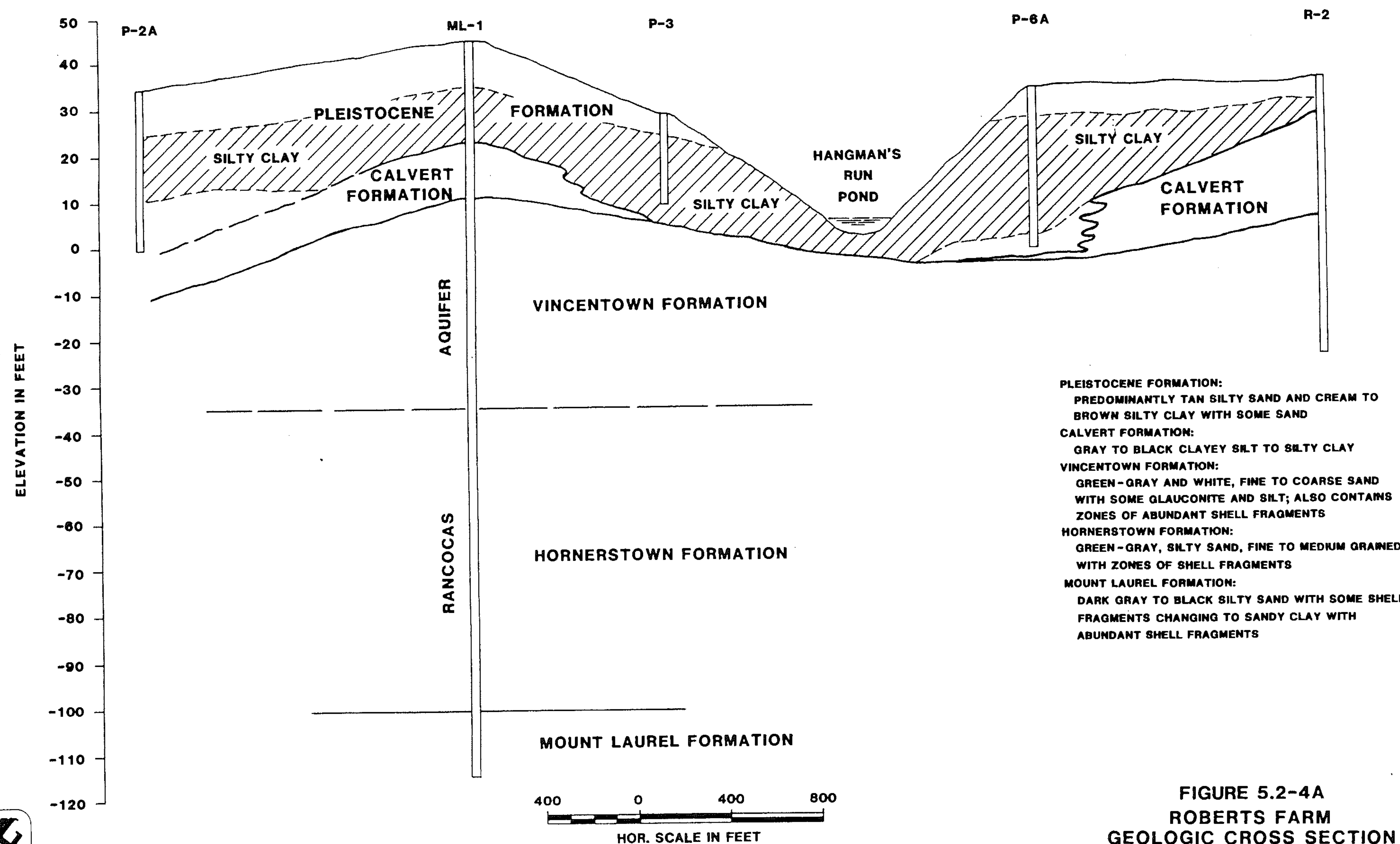
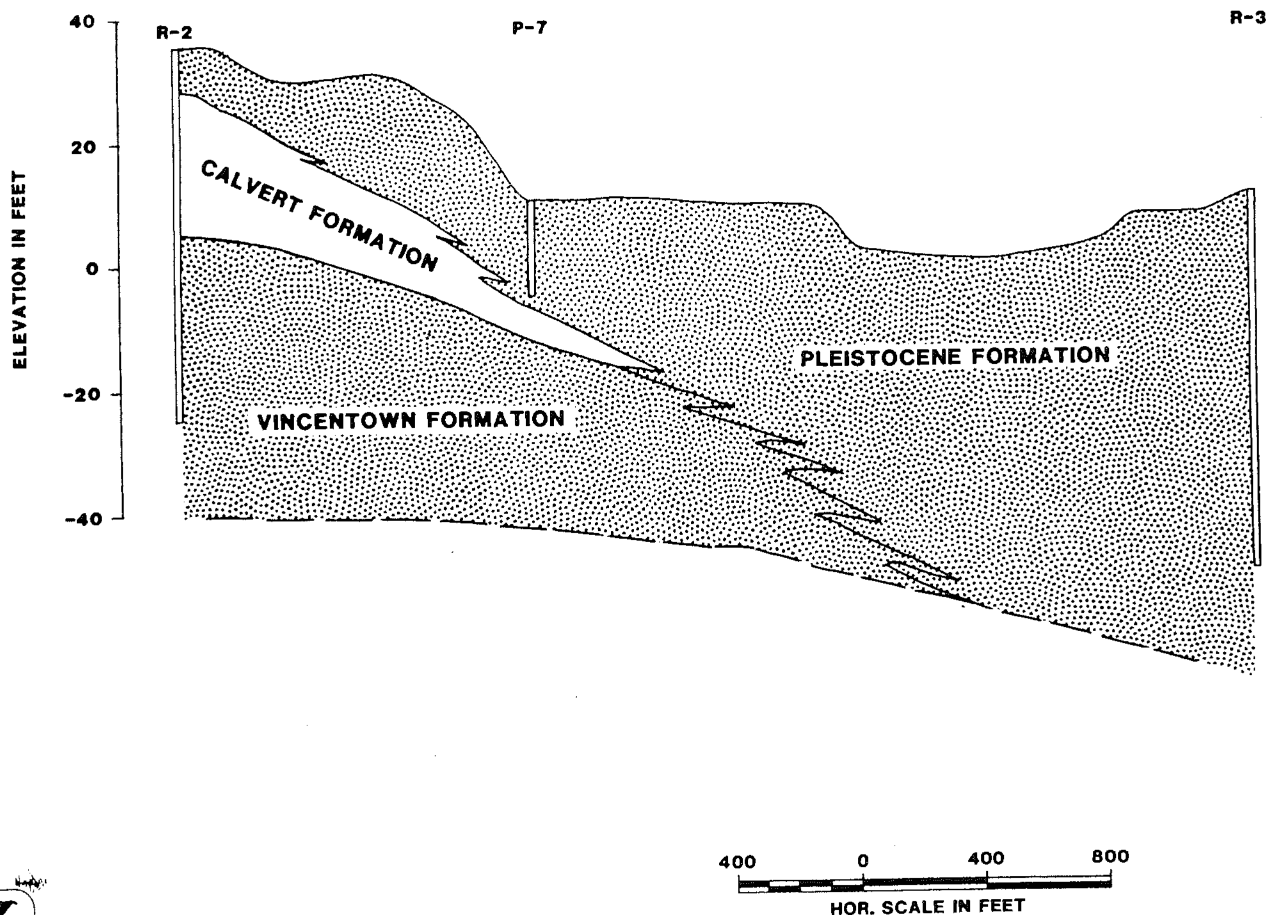


FIGURE 5.2-4A
ROBERTS FARM
GEOLOGIC CROSS SECTION



PLEISTOCENE FORMATION:
PREDOMINANTLY TAN SILTY SAND AND CREAM TO BROWN SILTY CLAY WITH SOME SAND

CALVERT FORMATION:
GRAY TO BLACK CLAYEY SILT TO SILTY CLAY

VINCENTOWN FORMATION:
GREEN-GRAY AND WHITE, FINE TO COARSE SAND WITH SOME GLAUCONITE AND SILT; ALSO CONTAINS ZONES OF ABUNDANT SHELL FRAGMENTS

FIGURE 5.2-4B
ROBERT'S FARM
GEOLOGIC CROSS SECTION

taken to blend these soils with other on-site soils to preclude this from occurring if it becomes a problem.

Finally based on the grain size analyses the on-site soils are free of aggregate, rocks or solid materials greater than 2-inches in diameter and can be utilized for protective cover material for the liner.

5.2.1.5 Hydrogeology

As defined in the following sections of this report, data pertinent to the hydrogeologic regime of the Roberts Farm tract is presented.

<u>Aquifer Discussion</u>

As evidenced through the construction of a series of monitoring wells on the Roberts Farm tract, three groundwater aquifers comprise the surficial 100-200 feet of Coastal Plain sediments. These aquifers, namely the Pleistocene water table aquifer, the Rancocas confined aquifer and the Mount Laurel confined aquifer vary in their hydraulic properties, water yielding capabilities and their local use. A hydrogeologic description of these aquifers follows:

> Pleistocene Water Table Aquifer - This aquifer blankets all of New Castle County south of the "fall line" and typically consists of medium to coarse sands and gravel. In New Castle County, the aquifer has a transmissivity in the range of 16,000 to 100,000 gallons per day per foot, has a storage coefficient of 0.12 to 0.15 and an average specific capacity of 14.8 gallons per minute per foot of drawdown. (Sundstrom and Pickett, 1971).

These values are representative of the aquifer where large saturated thicknesses and high sediment permeabilities are present. In the general area of the Roberts Farm tract, the samples obtained from the construction of the monitoring wells and subsequent water level measurements indicate that the Pleistocene sediments have limited saturated thicknesses and that the permeabilities of the sediments are relatively low due to the amounts of fines present in the samples. (See Appendix C). Accordingly the Pleistocene aquifer is not widely used in the immediate area of the site since only limited amounts of water can be derived from the formation. At the eastern portion of the Roberts Farm, a residential well has been constructed in the Pleistocene aquifer. In this area, erosion of the underlying Calvert and Vincentown formations has occurred and a thick sequence of Pleistocene sediments has been deposited in their place. This thick sequence of materials has afforded a large saturated thickness and the construction of a Pleistocene well. This well is, however, considered to be atypical of the area.

Rancocas Aquifer - This aquifer is an important source of water in southern New Castle County and reportedly supplies more than 25 percent of the groundwater used in the area of the County south of the Canal (Sundstrom & Pickett, 1971). Based on personal communication with members of the Delaware Geological Survey, the Rancocas aquifer is one of the primary sources of groundwater for most wells within a several mile radius of the Roberts Farm tract. The aquifer has a transmissivity of 14,000 to 19,000 gallons per day per foot and a storage coefficient of 0.00019 to 0.00028 (Sundstrom & Pickett, 1971). These values together with an average specific capacity value of 2.3 gallons per minute per foot of drawdown are considered to be representative of the Rancocas Aquifer in the Roberts Farm area. Using an average transmissivity of 17,000 gpd/ft or 2275 ft^2/day and an aquifer thickness of 110 ft (see monitoring well ML-1), the hydraulic conductivity of the aquifer is estimated to be in the range of 7 x 10^{-3} cm/sec.

The Rancocas aquifer is reportedly confined by the Calvert formation in the region of the Roberts Farm. However, monitoring wells constructed on site indicate that the Calvert formation has been lost to erosion in the immediate area of Hangman's Run. Water level measurements of both Rancocas and adjoining Pleistocene wells, however, do indicate confinement or partial confinement. This confinement is probably provided by silty clay layers within the Pleistocene formation.

Mount Laurel Aquifer - The Mount Laurel aquifer directly underlies the Rancocas Aquifer. Electric logging of monitoring well ML-1 indicates that the aquifer occurs at elevation -100 feet or approximately 145 feet below the surface. In New Castle County, the Mount Laurel is described as a minor aquifer which has fair to poor water-yielding properties. The transmissivity of the aquifer is reported to be low (1,800 gpd/ft) and the storage coefficient is reported to be 0.00025 (Sundstrom & Pickett, 1971). Specific capacities of sixteen wells ranged between 1 to 2 gpm/foot of drawdown. Samples collected from monitoring well ML-1 indicates that the top fifteen feet of the aquifer consisted of silty sand which graded into a sandy clay. As typical of the aquifer, these materials suggest poor water yielding capabilities. Most domestic wells in the Roberts Farm area which are constructed in the Mount Laurel aquifer are open hole, suggesting relatively poor water yielding capabilities.

Aquifer Monitoring

In constructing the Pleistocene monitoring wells, four-inch diameter PVC casings containing 5-foot long screen sections were installed in each well. These standpipes were utilized to obtain data pertinent to the phreatic surface of the water table aquifer and to determine groundwater flow directions. Further, the wells were used to obtain a representative groundwater sample.

Similarly, four-inch diameter PVC casings containing 10-foot long PVC screen sections were installed in the Rancocas and Mount Laurel monitoring wells. These standpipes were utilized to obtain data pertinent to the potentiometric surface of the confined aquifers and to obtain representative groundwater samples.

During the course of the investigation program, water level readings were taken of the wells as completed and a complete set of water level readings were obtained on July 28, 1981, after drilling completion. The water level data obtained on July 28, 1981 are summarized on the following table.

Potentiometric Surfaces and Groundwater Flow

Based on the water level data presented on Table 5.2-2, potentiometric surface maps of the Pleistocene water table aquifer and the Rancocas aquifer have been prepared. These maps appear as Figure 5.2-5 and Figure 5.2-6 of this report.

Figure 5.2-5 represents a water table map of the Pleistocene aquifer. In reference to the figure, the groundwater table at the Roberts Farm tract is quite variable. In the area of the site north of Hangman's Run, the water table varies from approximately elevation 20, in the north central portion of the area, to approximately elevation 5 near Hangman's Run. In this area, groundwater flows westward toward an unnamed tributary of Hangman's Run, eastward toward another unnamed tributary of Hangman's Run and southward towards Hangman's Run.

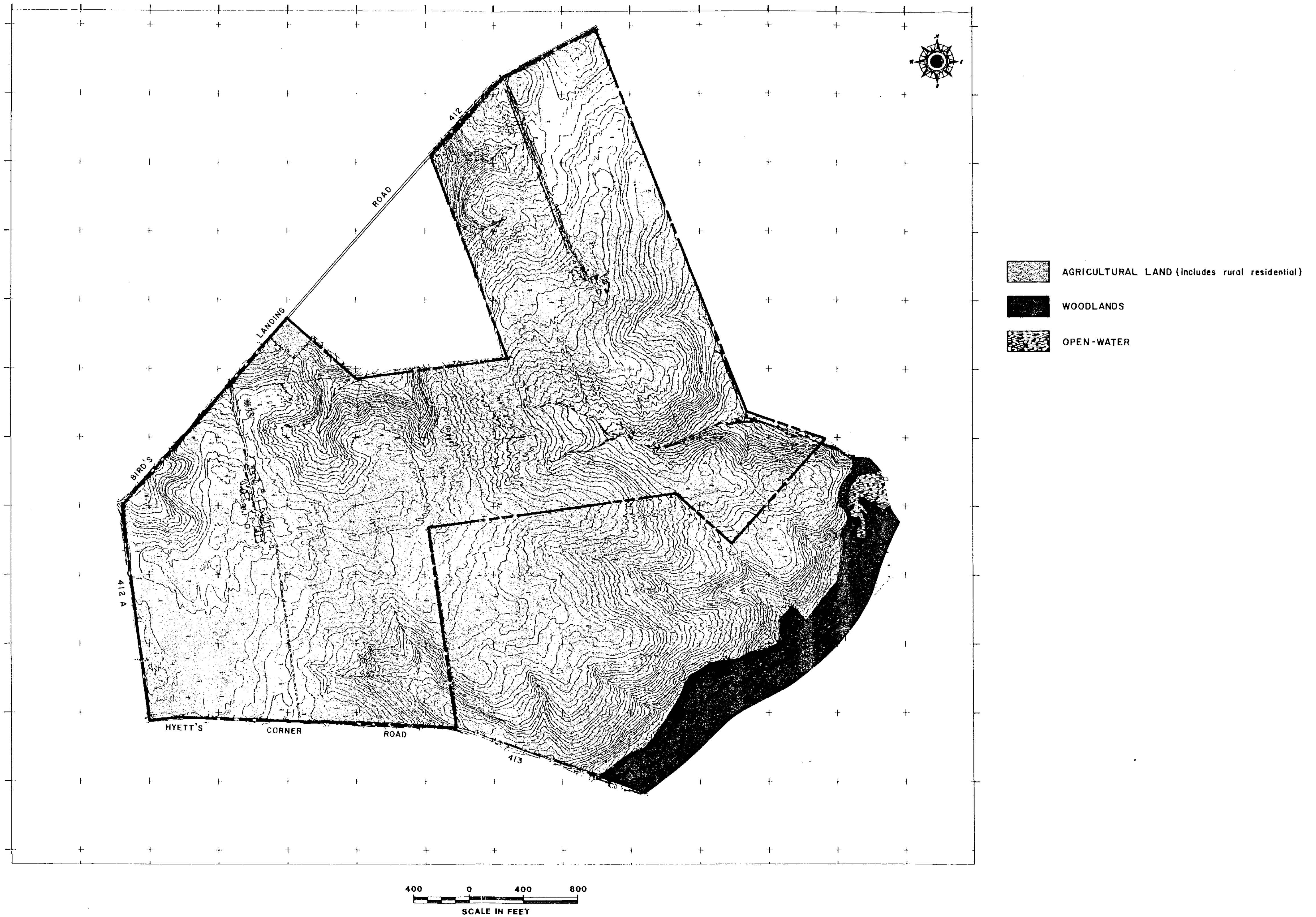
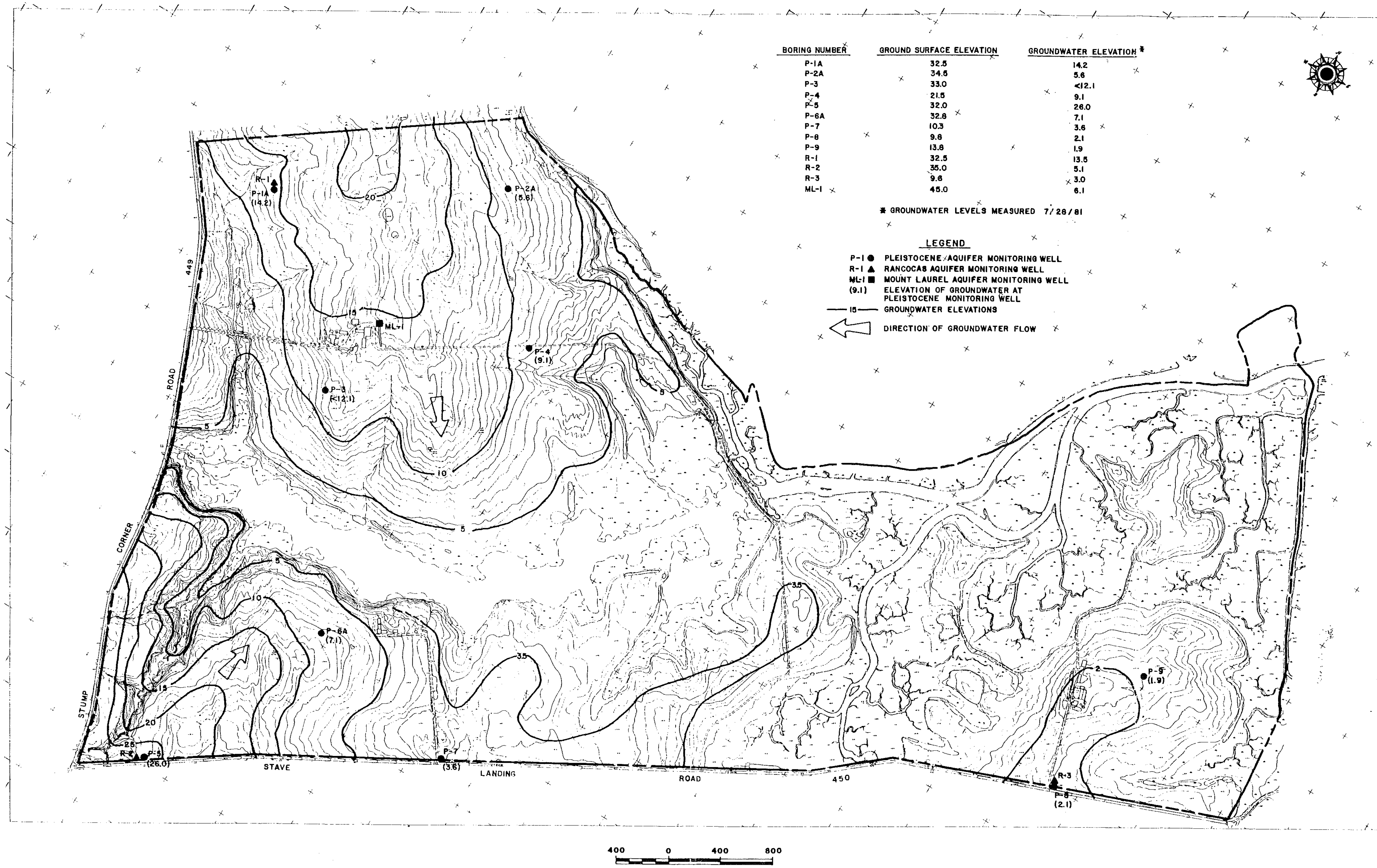


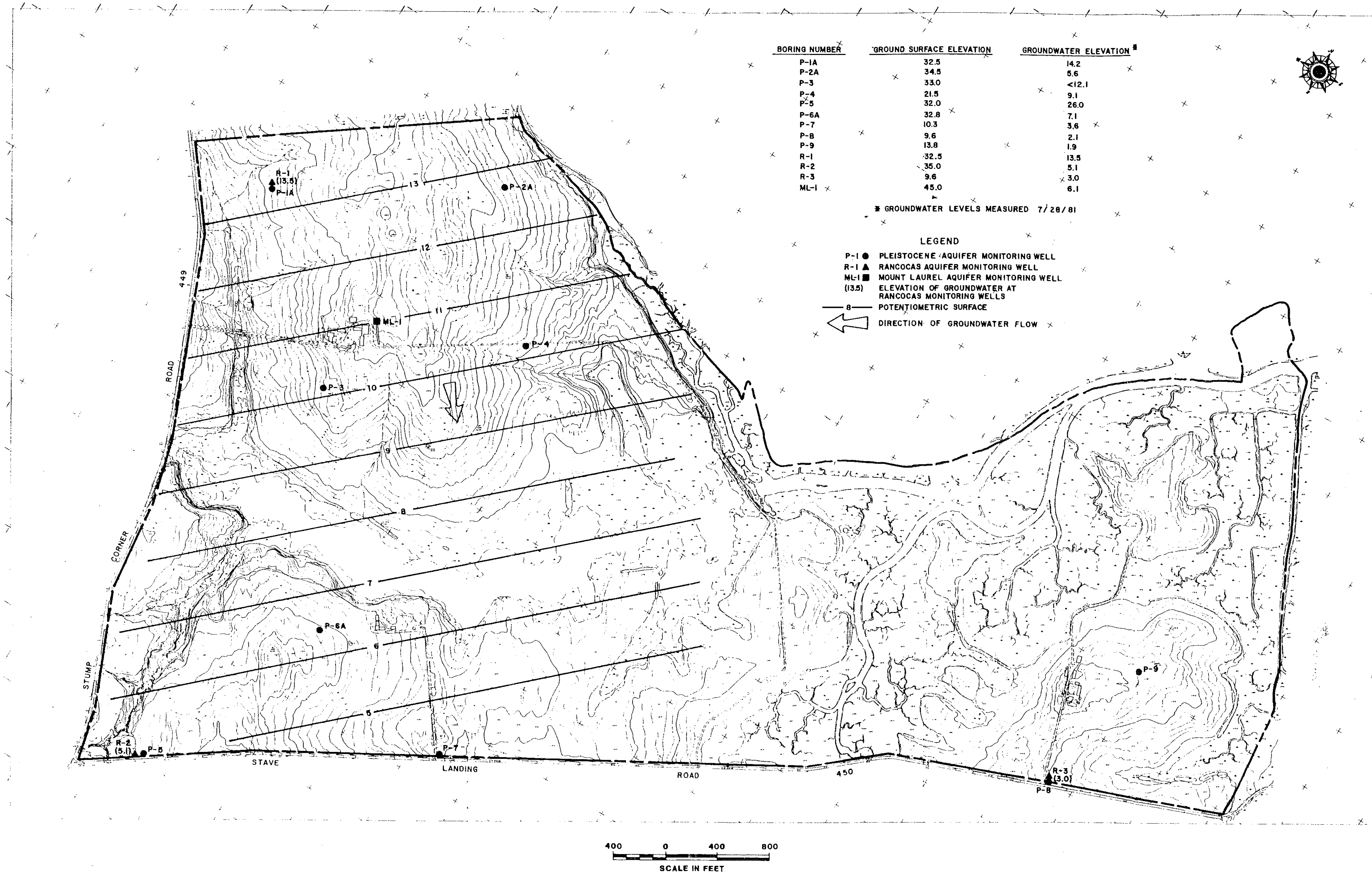
FIGURE 4.3-1
ROAD 412
MAJOR VEGETATION TYPES



BORING NUMBER	GROUND SURFACE ELEVATION	GROUNDWATER ELEVATION *
P-1A	32.5	14.2
P-2A	34.5	5.6
P-3	33.0	<12.1
P-4	21.5	9.1
P-5	32.0	26.0
P-6A	32.8	7.1
P-7	10.3	3.6
P-8	9.8	2.1
P-9	13.8	1.9
R-1	32.5	13.5
R-2	35.0	5.1
R-3	9.6	3.0
ML-1	45.0	6.1

* GROUNDWATER LEVELS MEASURED 7/28/81

FIGURE 5.2-5
ROBERTS FARM
WATER TABLE MAP
PLEISTOCENE AQUIFER



BORING NUMBER	GROUND SURFACE ELEVATION	GROUNDWATER ELEVATION *
P-1A	32.5	14.2
P-2A	34.5	5.6
P-3	33.0	<12.1
P-4	21.5	9.1
P-5	32.0	26.0
P-6A	32.8	7.1
P-7	10.3	3.6
P-8	9.6	2.1
P-9	13.8	1.9
R-1	32.5	13.5
R-2	35.0	5.1
R-3	9.6	3.0
ML-1	45.0	6.1

* GROUNDWATER LEVELS MEASURED 7/28/81

FIGURE 5.2-6
ROBERTS FARM
POTENTIOMETRIC SURFACE MAP
RANCOCAS AQUIFER

In the southwestern portion of the site, south of Hangman's Run, the groundwater table varies from elevation 25 to elevation 3.5 feet with the dominant groundwater flow direction being northeastward towards Hangman's Run.

In the eastern most portion of the Roberts Farm site, the groundwater table was approximately at elevation 2 feet during the July reading. As shown on the figure, this portion of the site is virtually surrounded by tidal marsh and accordingly groundwater flows in numerous directions.

TABLE 5.2-2
ROBERTS FARM TRACT
WATER LEVEL DATA

Well No.	Ground Surface Elev.	Top of PVC Casing Elev.	Depth to Water (ft)	Elev. of G.W.**
P-1	32.5	34.2	20.0	14.2
P-2	34.5	36.8	31.2	5.6
P-3	33.0	34.4	22.3*	<12.1
P-4	21.5	24.1	15.0	9.1
P-5	32.0	33.7	7.7	26.0
P-6	32.8	34.3	27.2	7.1
P-7	10.3	12.1	8.5	3.6
P-8	9.6	11.2	9.1	2.1
P-9	13.8	15.5	13.6	1.9
R-1	32.5	34.3	20.8	13.5
R-2	35.0	37.0	31.9	5.1
R-3	9.6	11.3	8.3	3.0
ML-1	45.0	46.4	40.3	6.1

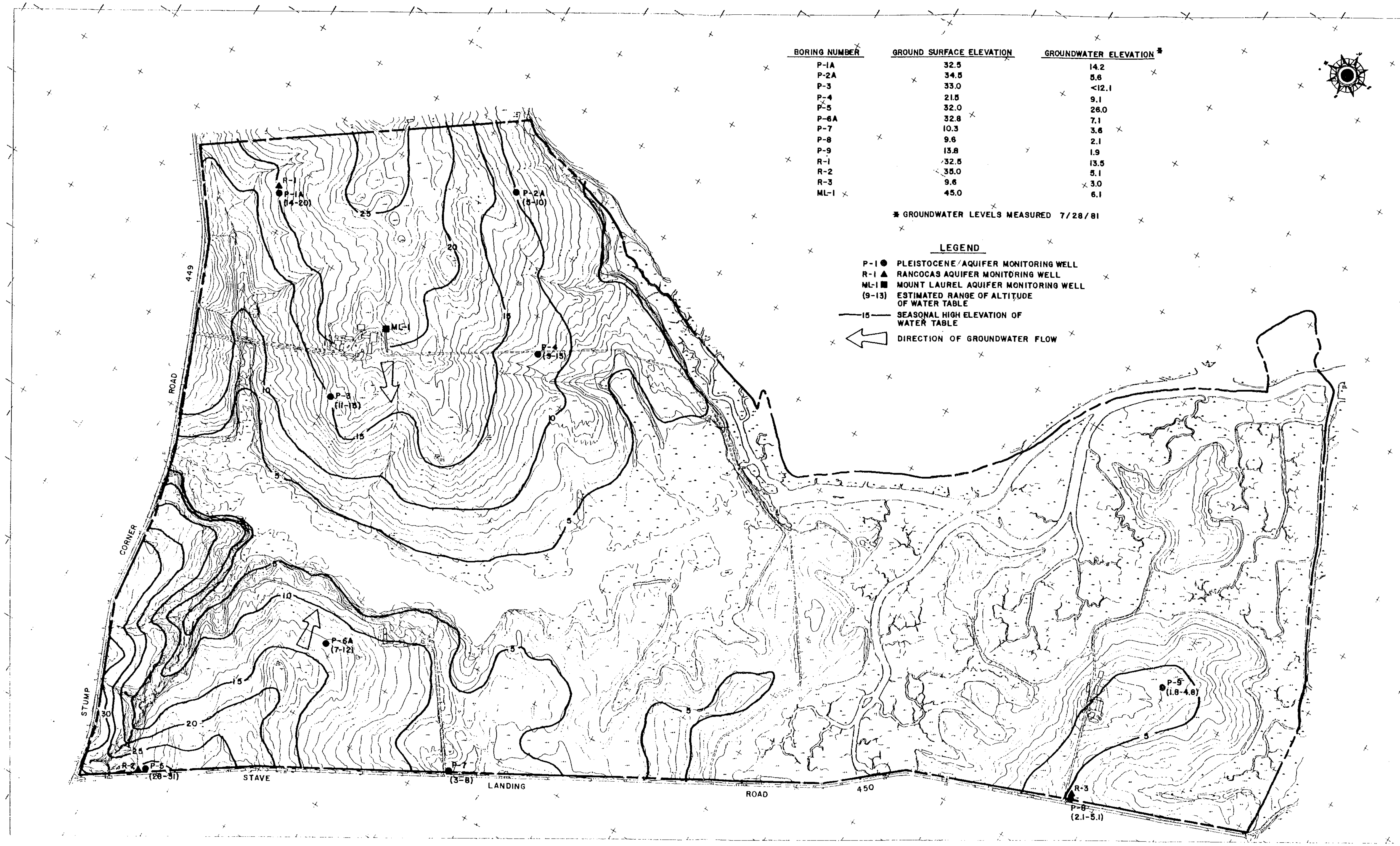
*Bottom of boring; hole dry
**Elevation of G.W. = Elevation of top of PVC casing - Depth to Water (as measured from top of PVC casing)

Figure 5.2-6 represents the potentiometric surface of the Rancocas Aquifer. This surface varies from elevation 13.5, at the monitoring well R-1 location to elevation 5 feet at the monitoring well R-2 location. Groundwater flow, within the aquifer, is probably toward the south-southwest. Note that the precise direction of groundwater flow within the Rancocas aquifer is unknown since only two wells penetrate the formation. The third well R-3 which was intended to penetrate the Rancocas aquifer, was constructed in Pleistocene materials. In this area, the upper portion of the Rancocas aquifer and overlying Calvert formation have been eroded away.

Comparison of the two potentiometric surface figures indicates in general, the potentiometic surface of the Rancocas aquifer is lower than the potentiometric surface of the water table aquifer in areas of the site that appear to be useable. Accordingly, in these areas, downward movement of contaminants would be possible.

Water Table Fluctuations

Because the Delaware Solid Waste Disposal Regulation requires that at least 3 feet of separation between refuse deposits and the yearly high groundwater table be maintained, an estimate of the seasonal high water table at the Roberts Farm site has been prepared using data published by the United States Geological Survey (see Adams and Boggess, 1964). In this publication, which has been prepared for the Taylor's Bridge Area of Delaware, a hydrograph showing the average depth to groundwater for an eleven year period (1950-1961) for 13 water table wells in Delaware, is presented and indicates that seasonal fluctuations of the groundwater table have varied from 1.5 to 4.5 feet and that the seasonal water levels are predominantly at their lowest in July and August. Further, the report indicates that the fluctuations of the groundwater table varied from 3 feet in the Stave Landing area to as much as 7 to 8 feet in other portions of the surrounding area.



BORING NUMBER	GROUND SURFACE ELEVATION	GROUNDWATER ELEVATION *
P-1A	32.5	14.2
P-2A	34.5	5.6
P-3	33.0	<12.1
P-4	21.5	9.1
P-5	32.0	26.0
P-6A	32.8	7.1
P-7	10.3	3.6
P-8	9.6	2.1
P-9	13.8	1.9
R-1	32.5	13.5
R-2	35.0	5.1
R-3	9.6	3.0
ML-1	45.0	6.1

* GROUNDWATER LEVELS MEASURED 7/28/81

400 0 400 800
SCALE IN FEET

FIGURE 5.2-7
ROBERTS FARM
SEASONAL HIGH WATER TABLE MAP

Using this data, Figure 5.2-7, which shows the estimated seasonal high water levels of Roberts Farm, has been prepared. Figure 5.2-7 can be utilized along with topographic maps of the site to estimate permissible depths of excavation.

Groundwater Quality

After construction of the monitoring wells, one representative groundwater sample was obtained from each aquifer underlying the site. These samples were obtained on July 28, 1981 with a 2-inch diameter stainless steel bailer and submitted for laboratory testing the same day. All samples were filtered through a .45 micron filter prior to testing. The results of the chemical analyses performed on the samples are summarized on Table 5.2-3 of this report. The laboratory results of sample ML-1 are indicative of groundwater quality of the basal portion of the Rancocas aquifer and surficial portion of the Mount Laurel aquifer.

Review of Table 5.2-3 indicates that the groundwater occurring in all three aquifers is of good quality with minor exceptions. The groundwater samples from Well P-1 and ML-1 slightly exceed the Delaware Drinking Water Standard for manganese and the P-1 water sample also slightly exceeds the standard for nitrates.

All three water samples showed relatively high TOC (Total Organic Carbon) levels which is attributed to the solvent used in cementing the PVC casing lengths together. The pH value for the P-1 sample is problematical. It is unexplainably low and requires additional sampling for verification.

Local Water Use

As previously stated, the residential wells surrounding the Roberts Farm tract primarily obtain their supplies from the Rancocas and Mount Laurel aquifers. In reference to Figure 5.2-8,

TABLE 5.2-3
ROBERTS FARM TRACT
WATER QUALITY ANALYSES

Chemical Constituent	Pleistocene Well P-1	Rancocas Well R-1	Mount Laurel Well ML-1	Delaware Limit
Alkalinity mg/l	136	82	155	-
Arsenic mg/l	< 0.002	< 0.002	< 0.002	0.05
Chloride mg/l	11	5	7	250
Chromium mg/l	0.013	0.027	0.013	0.05
Conductivity μmhos	960	349	339	-
Copper mg/l	< 0.009	0.010	0.014	1.0
Hardness mg/l	72	160	168	-
Iron mg/l	0.084	0.092	0.038	0.3
Lead mg/l	< 0.04	< 0.04	< 0.04	0.05
Manganese mg/l	0.063	0.039	0.058	0.05
Mercury μg/l	< 0.5	< 0.5	< 0.5	2.0
Nickel mg/l	< 0.01	< 0.01	< 0.01	
Nitrates N mg/l	11.3	< 1.0	< 1.0	10
Nitrites mg/l	0.008	0.014	< 0.005	-
N. Ammonia mg/l	0.11	0.06	0.11	-
N/Kjeldhahl mg/l	2.24	0.336	0.39	-
pH	2.9	6.7	7.8	-
Diss. Solids mg/l	184	216	200	500
Selenium mg/l	< 0.002	< 0.002	< 0.002	0.10
Sulfate mg/l	152	82.9	15.2	250
TOC mg/l	70.3	23.5	61.0	-

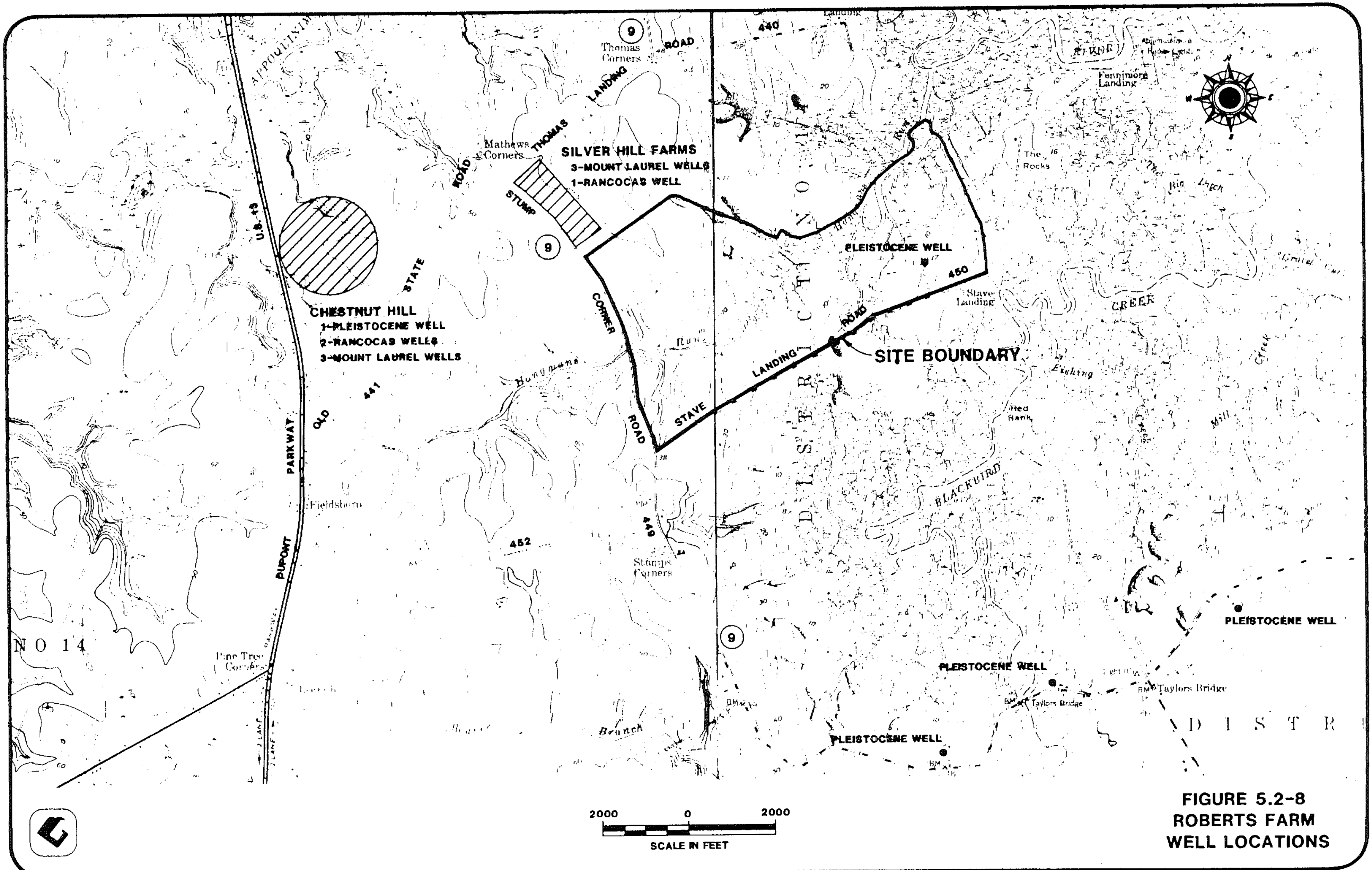


FIGURE 5.2-8
ROBERTS FARM
WELL LOCATIONS

data supplied by the Delaware Geological Survey indicates that at the Silver Hill Farms development, which is located just north of the site along Route 9, there are at least three Cretaceous (Mount Laurel) wells and one Rancocas well. The Cretaceous wells are open hole wells and range in depth from 202 to 265 feet. The Rancocas well is screened from 72 to 77 feet.

West of the site at the Chestnut Hill development along Route 13 there is one Pleistocene well, two Rancocas wells and three Cretaceous wells. The Rancocas wells are screened from 80 to 90 feet and the Mount Laurel wells are open hole wells which vary from 215 to 247 feet in depth.

The Pleistocene wells shown on Figure 5.2-8 were located from the United States Geological Survey, Adams and Boggess, 1964. The depth of these wells is unknown.

Potential Impacts

In the construction of any solid waste disposal facility, potential impacts upon both the geologic and hydrogeologic regimes exist. These impacts include: 1) potential contamination of the water table aquifer and subsequently downgradient shallow wells and/or surface waters; and, 2) potential contamination of deeper, confined aquifers and subsequently downgradient municipal or residential wells. Based on the physical and interpretative data developed through the subsurface exploration and monitoring well construction program, these impacts are discussed below. It should be noted that based on the geologic properties of the Roberts Farm tract, a solid waste disposal facility incorporating lined disposal areas and a leachate collection system will be required in order to comply with State regulations. Further, it should be noted that a lined landfill with a leachate collection system greatly reduces, if not precludes, contamination of groundwater from leachate.

At the Roberts Farm site, if leachate were to escape the liner or collection system and no corrective actions were taken, the leachate would percolate downward and may reach the water table aquifer. As demonstrated in previous sections of this report, groundwater flow in this aquifer is towards Hangman's Run which bisects the site. Due to the limited saturated thickness of the water table aquifer in the Roberts Farm area, the aquifer is not extensively used and any surrounding wells are all upgradient and would not suffer an impact from contamination of the aquifer on the Roberts Farm tract.

The Rancocas aquifer is a primary source of potable groundwater in the area. Based on the potentiometric surface maps, should there be a significant breach of the liner, downward movement of leachate is possible. This vertical movement however, is restricted by the Calvert formation which confines the Rancocas aquifer under the useable portions of the site. Using Darcy Law ($Q = KIA$) the maximum amount of vertical seepage that could occur in both the northern portion and southern portion of the site has been calculated. These calculations, however, are based on certain simplifying assumptions that must be understood: First, the entire area is completed (filled with refuse); second, the liner material(s) are presumed to have failed instantaneously and uniformly throughout the disposal area. Thus, the calculations represent a scenario that would be equivalent to not having a liner in place. In estimating the amount of seepage that could occur in this situation, a hydraulic conductivity of 9.9×10^{-8} cm/sec was utilized for the Calvert formation and 135 acres and 50 acres were utilized for the area of vertical inflow in the northern portion of the site and southern portion of the site, respectively.

The results of the calculations indicate that approximately 270 gpd ($\backsim$ 2 gpd/acre) of vertical seepage can occur in the northern portion of the site, where the potentiometric surfaces of the Rancocas and Pleistocene aquifers are similar, and 4520 gpd ($\backsim$ 90 gpd/acre) can occur in the southwestern portion of the site where a head difference of approximately 20 feet exists between the potentiometric surfaces of the aquifers.

As leachate seeps vertically downward, natural renovation will occur through cation exchange. Further, as the seepage enters the Rancocas aquifer it will be diluted with groundwater flowing within the aquifer. The dilution ratio that will occur has also been calculated using a hydraulic conductivity of the Rancocas aquifer of 6.98×10^{-3} cm/sec, an aquifer thickness of 110 feet and a cross sectional area of 5.06×10^{5} ft^{2}. The results of the calculations indicate that a dilution ratio of 510 to 1 exists in the northern portion of the site and a ratio of 31 to 1 exists in the southern portion of the site. Diluted leachate that enters the Rancocas aquifer would move southward or away from the residential wells of the new development situated along Route 9 just north of the site.

5.2.1.6 Geotechnical Summary

The Roberts Farm site is situated in the Coastal Plain Physiographic Province of Delaware and is underlain by a thick sequence of unconsolidated sediments which contain three aquifers within the surficial two hundred feet. Monitoring wells have been constructed in these aquifers and representative soil and water samples have been collected and submitted for laboratory analyses. Based on these laboratory analyses and in conjunction with other data developed during the construction of the Pleistocene, Rancocas, and Mount Laurel aquifer monitoring wells, the following geotechnical conclusions are presented.

1. Useable thicknesses of soil for cover materials are variable across the site and range from 12 to 20 feet in the northern portion of the site to an average of 10 feet and 5 feet in

the southwestern and southeastern portions of the site, respectively. These soils are suitable for use as daily or final cover materials.

2. The Pleistocene water table aquifer is variable across the site and due to a limited saturated thickness is not extensively utilized for well supplies in the area. Flow within the aquifer is towards Hangman's Run. Accordingly, if the aquifer should become contaminated and no corrective actions are taken, it could subsequently cause surface water contamination of Hangman's Run. However, this would not jeopardize surrounding wells since they are all situated upgradient.

3. The Rancocas aquifer is a principal water supply aquifer in the area. This aquifer is confined by the Calvert formation and or semi-confined by clayey Pleistocene materials where the Calvert formation has been eroded away. Potentiometric surfaces of the Rancocas and water table aquifer indicate that vertical seepage of leachate is possible should the liner and leachate collection system fail and no corrective actions are taken. Flow within the aquifer is southward or away from the Route 9 residential development.

5.2.2 Hydrology

5.2.2.1 Topography

From a practical standpoint the Roberts Farm can be divided into three drainage areas which shall be referred to as the northern, southern, and eastern portions of the site. The northern portion (north of Hangman's Run) varies in elevation* from less than 4 ft. at the waterline of the pond to more than 54 ft. along the power line right-of-way forming the northern boundary of the site. The southern portion (south of Hangman's Run) varies in elevation from

* Datum: Mean Sea Level

less than 4 ft. at the waterline of the pond to just less than 40' in the field between the pond and Road 450. The eastern portion of the site varies in elevation from less than 3 ft. in the surrounding salt water marsh (which is the most characteristic feature of this area) to 18 ft. near the existing farm house.

5.2.2.2 Runoff Control

Drainage of surface runoff from precipitation falling upon the northern portion of the site is to the south towards Hangman's Run or to the east towards a tributary of Hangman's Run which forms the eastern boundary of the property. Drainage of surface runoff from the southern portion of the site is to the north toward Hangman's Run or to the west towards a tributary to Hangman's Run which lies within the limits of the property. Surface runoff from the eastern portion is towards the marshlands which virtually surround this area. Therefore, there should be no difficulties at this candidate site relating to control of surface runoff onto adjacent properties and erosion problems which may be attendant thereto.

For the northern portion of the site, upgradient drainage from neighboring properties to the north is not intercepted by any existing condition such as a road. Therefore, provisions would have to be made to divert runoff from these properties around the proposed disposal area. On the east, upgradient runoff is intercepted by a tributary of Hangman's Run. On the west it is intercepted by State Route 9. Runoff from upgradient buffer zones can be handled by the construction of diversion berms, ditches, or swales. Enough relief exists that sedimentation basins may be necessary to help control surface runoff and prevent erosion.

For the southern portion of the site surface runoff from upgradient properties is diverted by Route 9 on the west and by Stave Landing Road on the south. Runoff water from the upgradient buffer zones can be handled by berms, diversion ditches, and/or swales. Enough relief exists that sedimentation basins may be necessary to help control surface runoff and erosion.

Existing streams along the western edge of both the southern and northern portions of the site and along the eastern edge of the northern portion of the site will have to be taken into account in the design of the site. This is discussed in following paragraphs.

5.2.3 Flood Plain Limits

The 100-year flood plain associated with Hangman's Run and its tributaries have an impact upon the useable area of the property. In consonance with the Delaware Solid Waste Authority's siting criteria the disposal area must be outside the limits of the 100-year flood plain. The area excluded by adhering to this criterion is illustrated in Figure 5.2.9.

5.2.4 Wetlands

State of Delaware Wetlands along Hangman's Run and two smaller tributaries to Hangman's Run encroach upon all parts of the site. Most of the eastern part of the site is unavailable for use as the result of this criteria. The southern and northern portions of the site are less affected. In keeping with the Authority's siting criteria the disposal area must be a minimum 100 yards (300 ft.) from the State of Delaware Wetlands. The area excluded by adhering to this criterion is illustrated in Figure 5.2.10.

Since areas defined as State of Delaware Wetlands are limited to salt water wetlands, the Authority felt that it was encumbent upon them to insure that wastes also are not deposited within wetland areas as defined by the Corps of Engineers. A visit to this candidate site was arranged and a representative of the Corps of

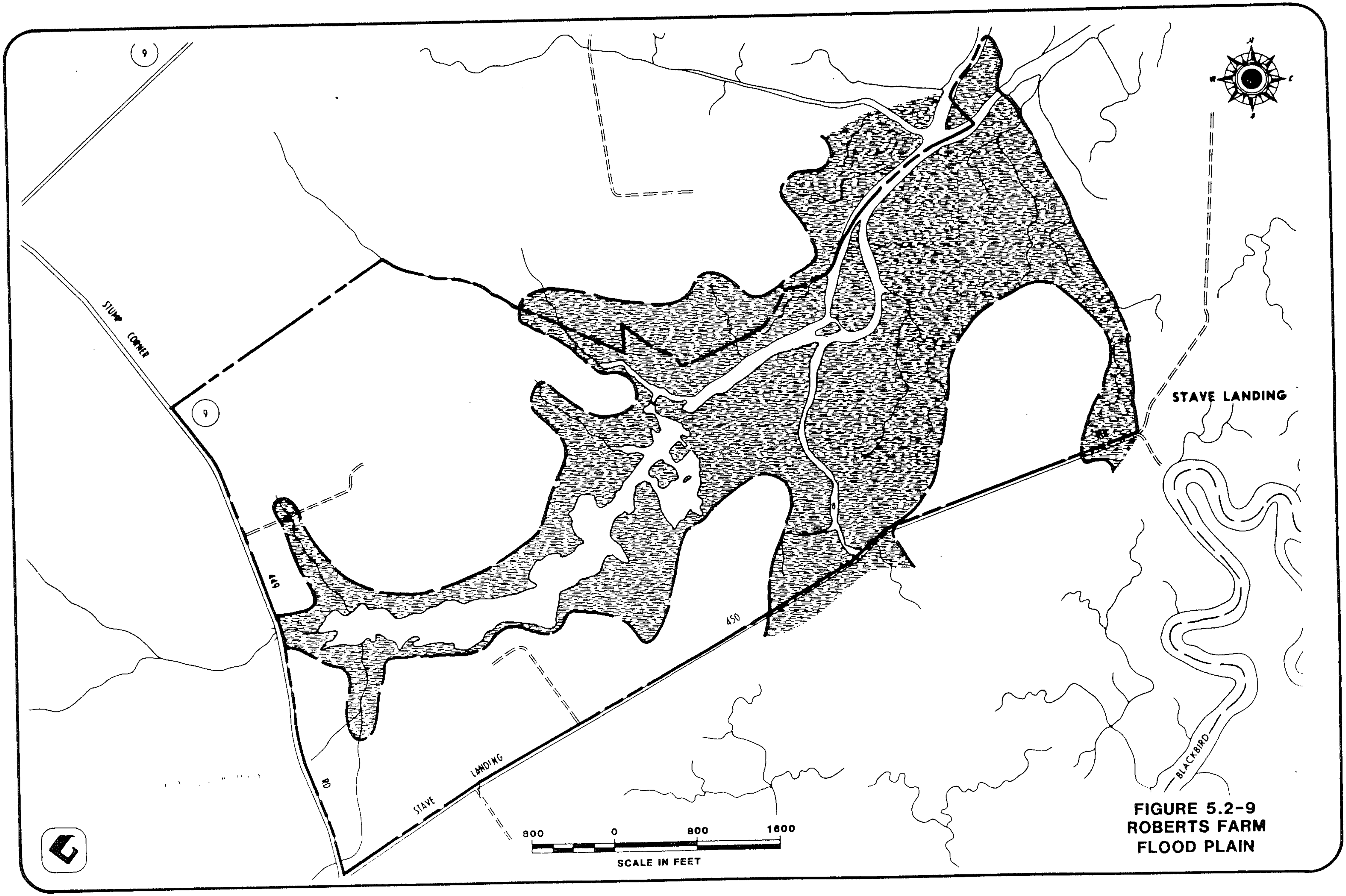


FIGURE 5.2-9
ROBERTS FARM
FLOOD PLAIN

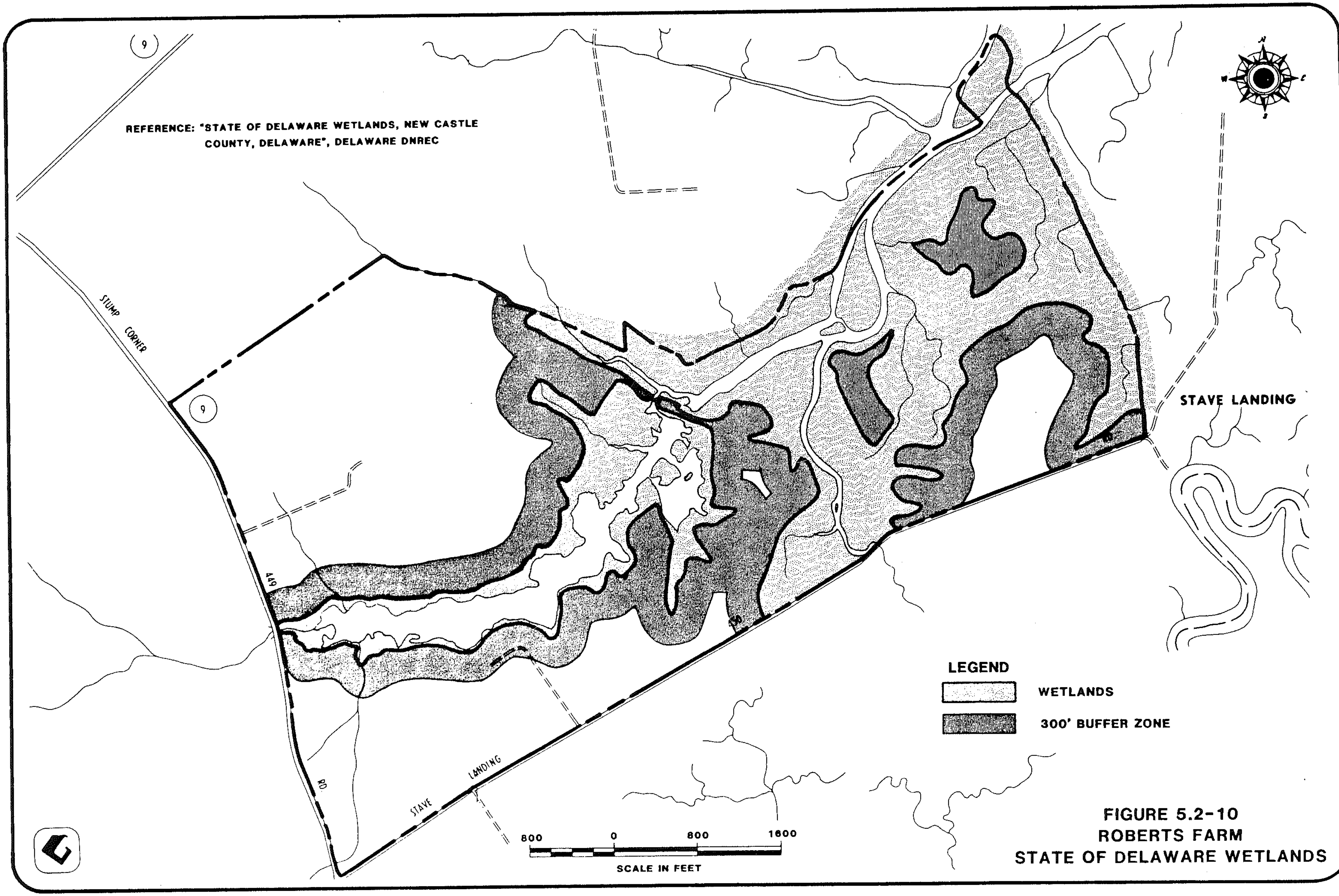


FIGURE 5.2-10
ROBERTS FARM
STATE OF DELAWARE WETLANDS

Engineers Philadelphia Office and a representative of DNREC's Wetlands Section surveyed the site on May 29, 1981. Although the Authority would have to petition the Corps of Engineers for a determination of jurisdiction as it regards Hangman's Run, the Corps representative felt that adhering to the DNR&EC requirement of maintaining a minimum 100' buffer between the disposal area and the edge of any pond, stream, or marsh, as well as the other buffer criteria, would preclude infringing upon the wetlands associated with this site.

5.2.5 Streams

Other than Hangman's Run there are several small streams (tributaries to Hangman's Run) which have an impact upon the site. One stream is along the western edge of the southern part of the property and somewhat parallel to Route 9. Another is along a small portion of the western edge of the northern part of the site. Another one is along the eastern edge of the northern part of the site. In accordance with the State of Delaware's Solid Waste Regulation, a minimum of 100' must be maintained between the edge of the disposal area and the edge of the body of water in question. The area excluded by adhering to this criterion is illustrated in Figure 5.2.11.

5.2.6 Property Line Setbacks

The property line setback established by the Delaware Solid Waste Authority for the purposes of this study is 200 ft. Therefore, there will be a minimum 200 ft. buffer zone around the perimeter of the site in which no wastes will be landfilled. This does not, however, necessarily preclude the use of this buffer for other purposes such as service or access roads, support facilities and borrow areas. The area excluded for landfilling by adhering to this criterion is illustrated in Figure 5.2.12.

5.2.7 Site Capacity

5.2.7.1 Useable Area

It is estimated that of the total 720+ acres of the Roberts Farm Site, only 28% or approximately 202 acres are useable for landfilling. Also, approximately 201 acres are classified as State of Delaware Wetlands. Buffer zones account for the remaining 317 acres. The useable acres are illustrated in Figure 5.2.13 which is a composite of Figures 5.2.9 thru 5.2.12. The breakdown with respect to each area is as follows: 135 acres in the northern portion of the site; 50 acres in the southern portion; and 17 acres in the eastern portion.

5.2.7.2 Estimated Depth of Refuse Deposits Below Existing Grade

Using the "Seasonal High Water Table Map", Figure 5.2.7, as a guide, and keeping in mind the DNREC requirements of a minimum 3 ft. of vertical buffer between the seasonal high groundwater table and the refuse deposit, it is estimated that soil depths* for the northern portion of the site range from approximately 4 ft. near Hangman's Run to a maximum of 27 ft. near the center of this area. Taking into account the 3 ft. of vertical buffer required between the seasonal high water table and the base of the refuse deposit (which has been assumed to be the soil/liner interface), excavation depths range between 1 ft. near Hangman's Run to 24 ft. near the center of the area. Since there will be 2 ft. of protective cover soil placed over the liner prior to the placement of any wastes, the depth of wastes placed below the existing grades will range between zero near Hangman's Run to 22 ft. near the center of this portion of the site.

*Soil depth is defined as the depth of soils to a limiting condition which, in this case, is the seasonal high groundwater table.

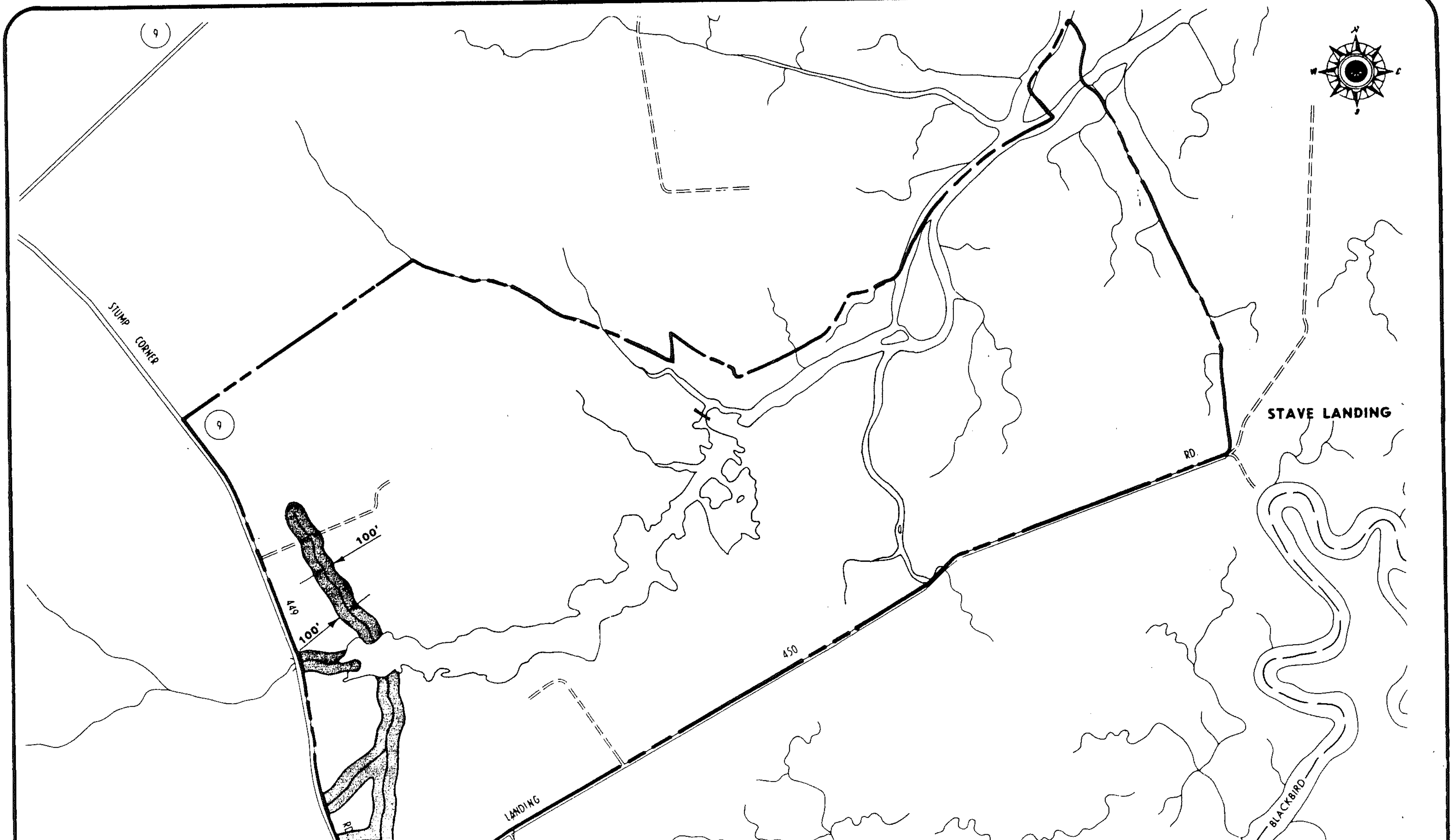


FIGURE 5.2-11
ROBERTS FARM
100' STREAM BUFFER ZONE

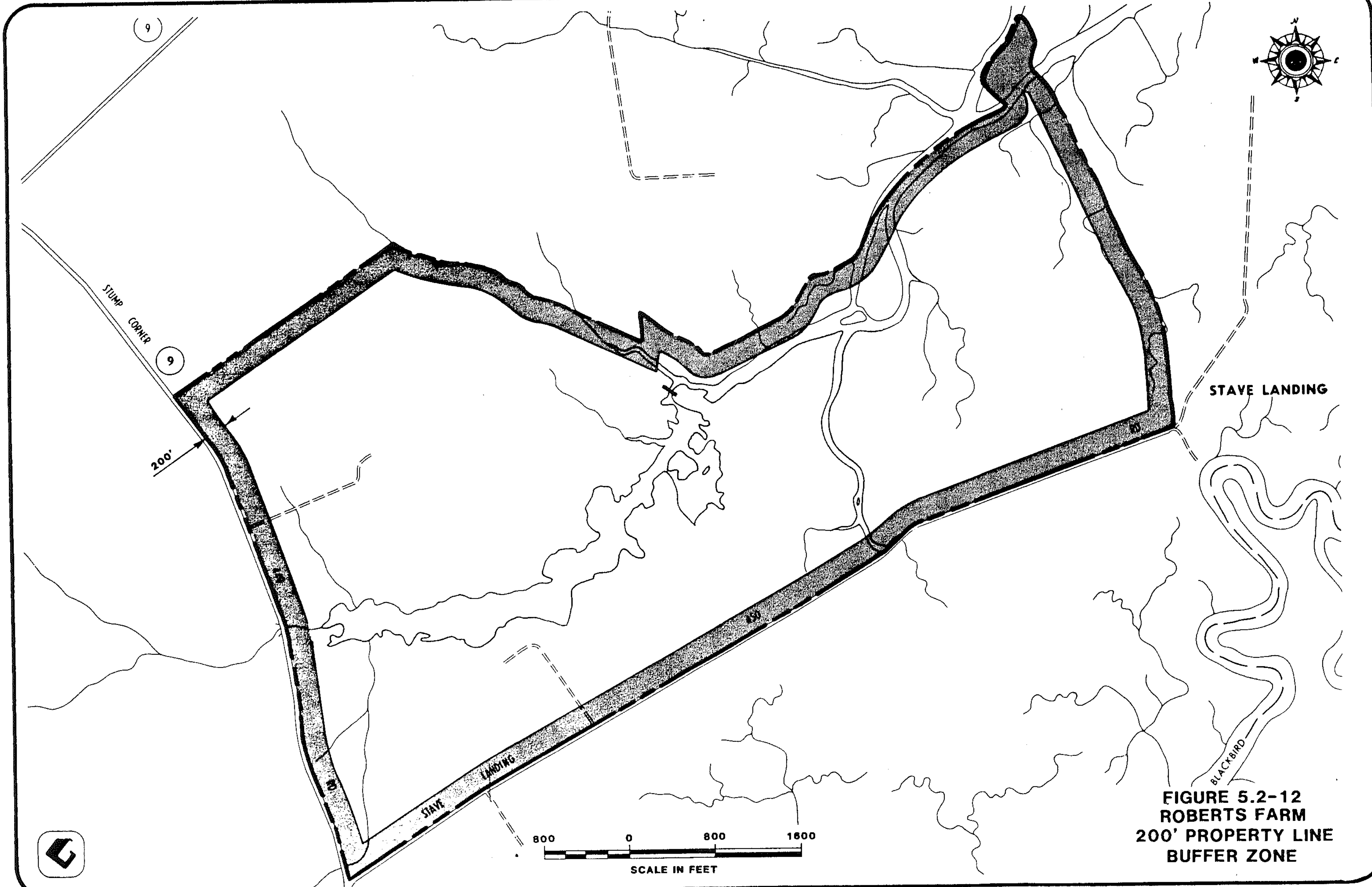


FIGURE 5.2-12
ROBERTS FARM
200' PROPERTY LINE
BUFFER ZONE

Soil depths for the southern portion of the site are estimated to range from 5 ft. to a maximum of 20 ft. Excavation depths, therefore, would range between 2 ft. to 17 ft. and the refuse depth below existing grade would range between zero to 15 feet.

For the useable area of the eastern portion of the site the soil depths are estimated to range from a minimum of 4 ft. on the east to a maximum of 12 ft. at the existing farmstead. Excavation depths would range between 1 ft. and 9 ft., and the refuse depth below existing grade from zero to 7 ft.

5.2.7.3 Height of Refuse Deposit Above Existing Grade

The nominal height of the refuse deposit above the existing grade will be approximately 40 feet for all three identified disposal areas. It will be assummed that the top surface of the fill will be graded such as to conform to the existing site contours.

5.2.7.4 Estimated Site Volumes/Longevity

Of the 202 acres classified as useable, approximately 15% should be reserved for leachate storage and/or treatment facilities. The following table summarizes for each portion of the Roberts Farm Site the area, estimated volumes, estimated capacities, estimated site lives, cover material availability, and cover material requirements.

If the total capacity in tons (5,455,800) is compared to the cumulative tonnage column of Table 3.2.1, it can be seen that the estimated life of this candidate landfill site is in excess of 25 years. This is somewhat lower than the total obtained by summing the estimated life for each portion of the site as shown on Table 5.2-4, which uses the tonnage for 10th year of the 20 year planning period as an average.

TABLE 5.2-4
SUMMARY TABLE FOR ROBERTS FARM

Area	Acres For Landfilling	Acres[1] For Leachate Storage	Total Volume of Disposal Area (c.y.)	Volume Of Refuse (c.y.)	Volume Of Cover (c.y.)	Cover Material Available (c.y.)	Capacity[2] in Tons (@0.625 tons/c.y.)	Estimated Life at 10th yr. Tonnage Rate (198300)	Excavation Depth (ft.)
Eastern Section	14.45	2.55	710,900[3]	533,200	177,700	93,300	333,300	1.7 years	4
Southern Section	42.50	7.50	2,523,200	1,892,400	630,800	548,400	1,182,800	6.0 years	8
Northern Section	114.75	20.25	8,404,900	6,303,700	2,101,200	2,036,400	3,939,800	19.9 years	11
Total	171.70	30.30	11,639,000	8,729,300	2,909,700	2,678,100	5,455,900		

1. Area reserved for leachate storage and/or treatment facilities incorporates space needed for berms, access roads, and service roads for such facilities.

2. In-place density estimated at 1250 lbs/c.y. which is equivalent to 0.625 tons/c.y.

3. Volume and tonnage figures were rounded off to nearest hundred.

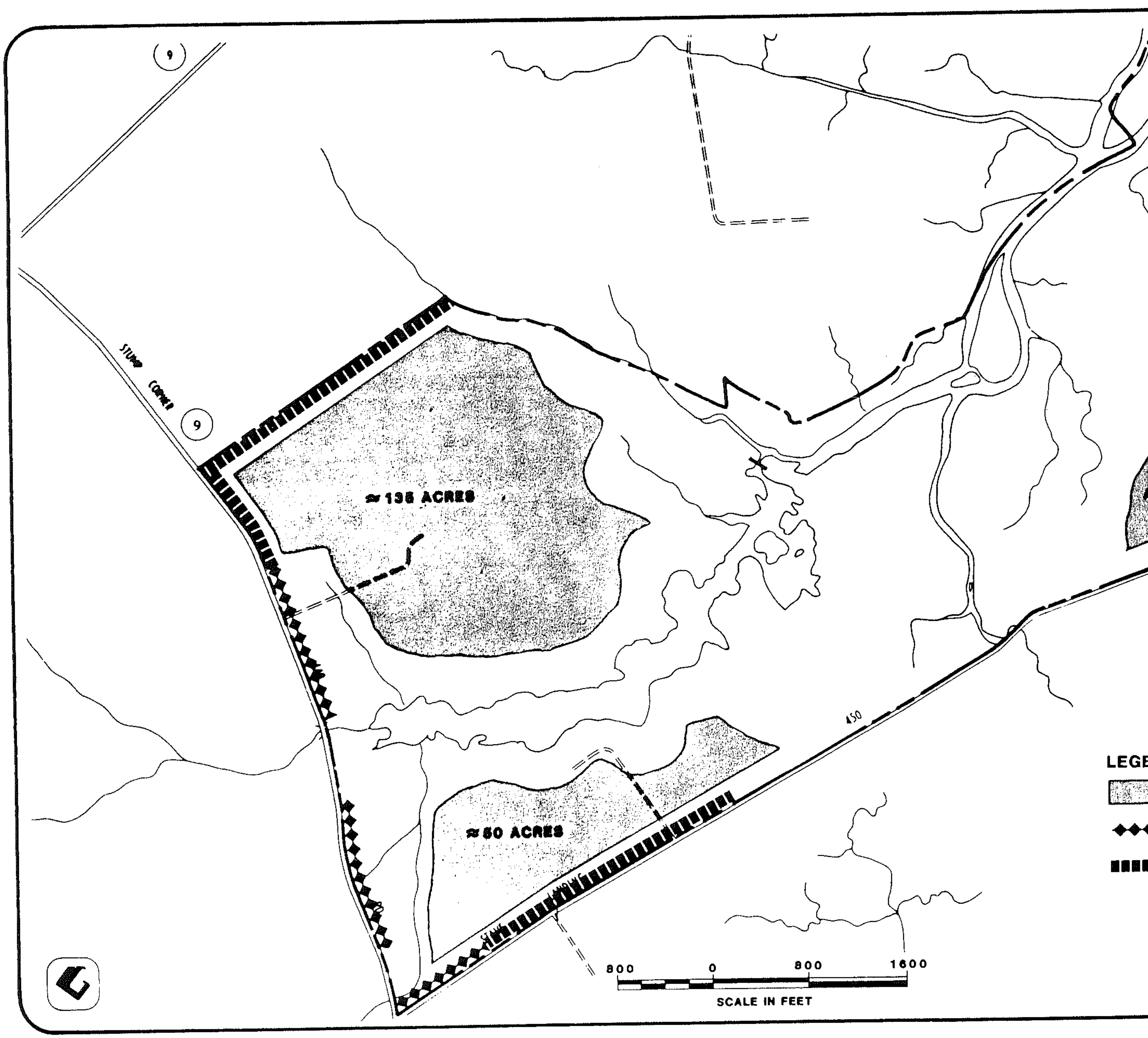


FIGURE 5.2-13
ROBERTS FARM
USEABLE AREAS FOR LANDFILLING OF RESIDUES AND WASTES

5.2.7.5 Estimated Cover Material Requirements and Availability

As can be seen from Table 5.2-4, it appears that there will be a total deficit of approximately 232,000 c.y. of cover material over the life of the project if all three areas are developed for landfilling. That deficit becomes most noticeable toward the end of development of each portion of the site when cover materials would have to be imported or obtained from other portions targeted for future development. If it is obtained from other areas to be developed, the need for importation of cover materials would be delayed until the waning years of the project. If liner protective cover requirements are added to this, the total cover materials deficit will be on the order of 789,000 c.y. For this site it will be assumed that all of the liner protective cover will be imported to the site. This will be accounted for in the construction cost estimates to be developed in a following section of this report.

Generally the on-site soils are suitable for daily and final cover. However, at times, a soil material may be encountered which would require some crude blending with other on-site soils to create a more acceptable cover material. This would have to be accomplished as part of the routine operation of the landfill.

5.2.7.6 Potential On-Site Borrow Areas

To preclude the importation of cover material, it would be advantageous, should this site be selected for development, to forgo the development of the eastern portion as a disposal area, reserving it instead as a borrow area. An average excavation depth of approximately 6 ft. should be possible. Under this scenario 2,732,000 c.y. of cover material would be needed for the northern and southern portions of the site: approximately 2,584,000 c.y. would be available from excavating within these areas; and an additional 140,000 c.y. would be available from the eastern portion. Total available would be 2,724,800 c.y. which leaves a negligible deficit of 7,200 c.y. The difference could be obtained by extending borrow operations into the 200' property buffer on the eastern portion. Since the eastern area would not be used for landfilling, such a wide buffer would no longer be a requisite.

It may be possible to utilize other buffer zones for obtaining borrow materials. For instance, those portions of the 300' wetlands buffer which are currently farm fields would be likely areas to reserve for borrow areas. The same holds for portions of the 200' property buffers on the north and on the south. None of the buffer areas east of and parallel to Route 9 should be disturbed (from an aesthetic viewpoint).

5.2.8 Screening of Sites

Screening of the site should be accomplished by landscaping with a combination of earthern berms and plantings. Although for about half of the year the existing trees parallel to Route 9 south of, and for a short distance north of, Hangman's Run would screen landfill activities from passersby, a five foot high berm should be constructed parallel to Route 9 where the existing road cut is not sufficient to block the view of the area. The berm would be approximately 10 ft. wide at the top, would be constructed with sideslopes of 2:1 from soils excavated within the buffer area, and would be seeded with appropriate native grasses. The location of this berm is shown on Figure 5.2-13. A higher berm seeded with native grasses and planted with appropriate fast growing trees or shrubs should be constructed within the north buffer zone and portions of the south buffer zone also as illustrated on the above referenced Figure. Material for the construction of these berms also would come from within the buffer zone.

5.3 ENVIRONMENTAL CONSIDERATIONS

5.3.1 Ecology

5.3.1.1 Terrestrial Communities

Vegetation: The Roberts Farm Site consists primarily of open farmland and wetlands. Most of the western portion of the site (upstream of the dam along Hangman's Run) is cultivated as is the southeastern corner of the site. Corn was the only crop observed onsite during site investigations conducted in June, 1981. The wetland areas occupy most of the eastern half of the site, and areas along Hangman's Run in the western part. Significant wooded areas occur only in the western portion of the site. Figure 5.3.1 is a map of the site showing the major vegatation types. Of these major types, cultivated land (including rural residential areas) occupies 58 percent of the site, wetlands occupy 28 percent, and woodland and shrub communities occupy 6 percent. Approximately 8 percent of the area is open water.

The wetlands onsite, and those adjacent to the site, would be classified as estuarine emergent wetlands according to the Fish and Wildlife Service classification (Cowardin et al., 1979). The dam along Hangman's Run near the center of the site effectively divides the wetlands into two types. Below the dam the wetlands are under tidal influence and are dominated by saltmarsh cordgrass and reed grass, with saltmeadow cordgrass and marsh mallow as subordinate species. Above the dam, the impoundment is nontidal and the wetlands are dominated by reed grass with pickerelweed and cattail as subordinates.

The wooded area along Hangman's Run and a small tributary stream in the southwestern portion of the site is the only significant wooded area onsite. Smaller woodlots and fencerows are scattered over the site, primarily along the road across the dam at the center of the site and at the edges of cultivated fields. The drier slopes along the stream support a mixed oak woods containing white, pin, red, and swamp white oaks. Other associated species are beech, black cherry, white ash, and red maple. The moister sites along the tributary stream support a more mesophytic community containing white ash, black cherry, maples, hickory, black locust, sweet gum, willow, and sumac. The understory contains such species as dogwood, maple-leaved viburnum, witch hazel, and mountain laurel.

Across its length the site traverses the transition from the coastal marshes on the east to the agricultural uplands to the west. The eastern marshes are part of the extensive Appoquinimink River - Blackbird Creek system, and as such are part of the largest undisturbed marshland in Delaware (Fleming, 1978). The onsite wetlands represent a small portion of the total system, but are part of a rapidly disappearing habitat type of regional, or even national, significance. The cultivated land on the western part of the site is also part of a larger area of agricultural land and as such is not unique in the region.

Wildlife: Because of its proximity to the coastal marshes, the site's wildlife resources are primarily waterfowl. Waterfowl counts for 1978-1981 conducted by the Delaware Department of Natural Resources and Environmental Control are summarized in Table 5.3.1. These counts include the area from the Chesapeake and Delaware Canal to just south of Blackbird Creek, and extend west to Middletown. It includes both the Augustine and Appoquinimink Wildlife areas.

Because Canada geese feed on both aquatic plants and plants of field and cropland, proximity of cultivated fields and wetlands provides good habitat.

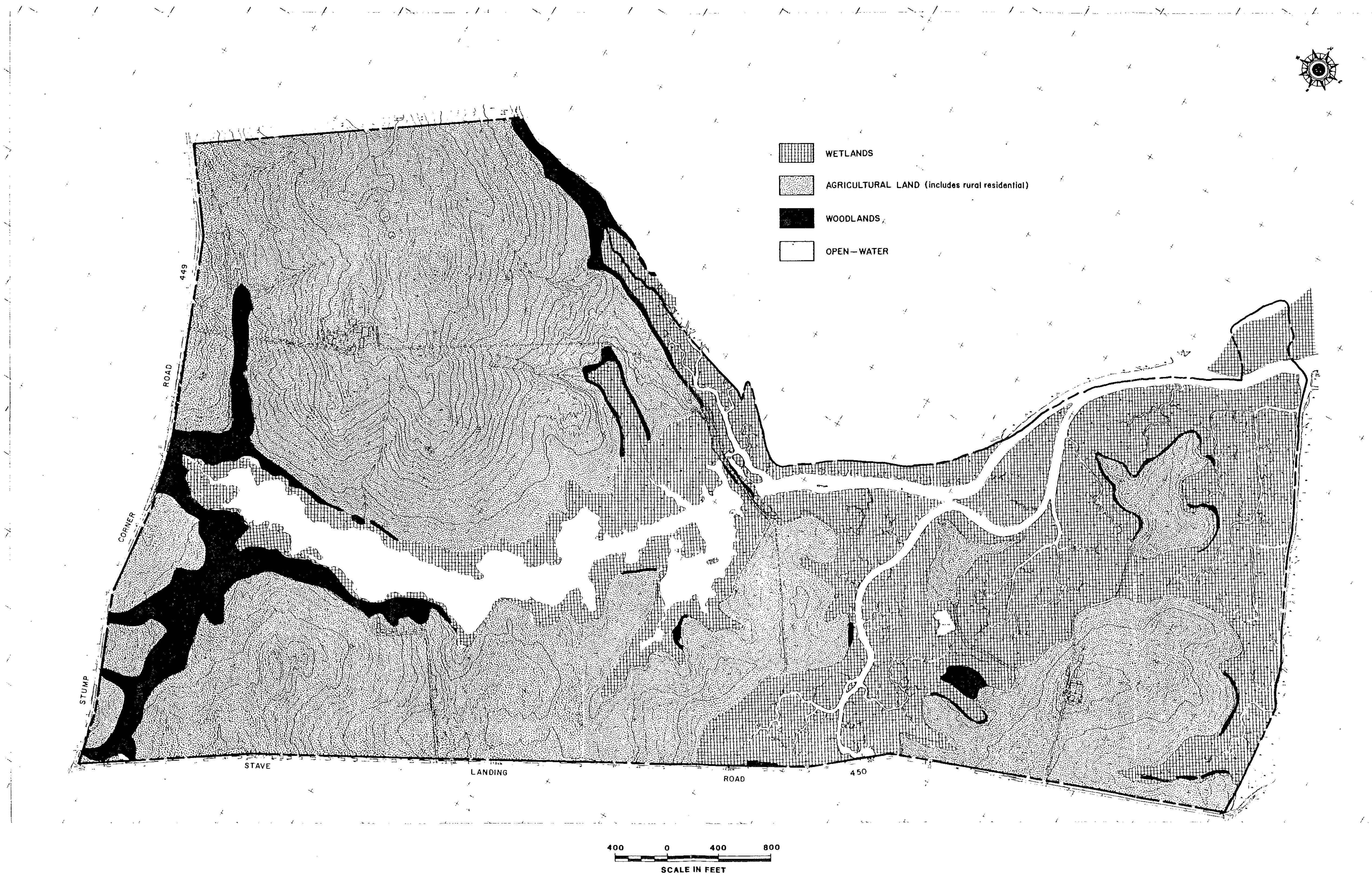


FIGURE 5.3-1
ROBERTS FARM
MAJOR VEGETATION TYPES

TABLE 5.3-1

WATERFOWL COUNTS FOR ROBERTS FARM AREA

SPECIES	DATE											
	10/18/78	11/20/78	12/12/78-12/13/78	1/4/79-1/5/79	10/17/79-10/18/79	11/20/79-11/21/79	12/12/79-12/13/79	1/4/80	10/20/80	11/20/80-11/21/80	12/17/80-12/18/80	1/7/81
Black duck	564	194	1,977	317	55	682	698	256	21	204	693	151
Mallard	1,259	1,997	4,945	129	162	1,262	900	284	90	278	1,645	58
Pintail	1,710	-	-	5	10	300	-	-	10	-	50	-
Green-winged teal	3,400	1,948	584	-	145	149	5	-	747	530	-	1
Wood duck	-	-	-	-	75	-	-	-	-	10	-	-
Gadwall	273	-	-	20	35	-	-	-	5	-	-	-
Shoveler	2	-	-	2	-	-	-	-	-	-	20	-
Baldpate	480	-	-	-	435	-	-	-	-	-	-	-
Bufflehead	1	-	-	-	-	-	-	-	-	-	-	-
Goldeneye	-	-	4	-	-	-	-	-	-	2	-	-
Merganser	-	-	-	-	-	-	-	-	-	-	-	27
Scaup	-	-	-	5	-	-	-	-	-	-	-	-
Oldsquaw	-	-	-	-	-	-	2	-	-	-	-	-
Snow goose	-	-	-	-	-	-	-	50	-	-	-	-
Canada goose	48,129	19,075	10,602	2,026	34,240	19,498	15,502	9,310	24,890	14,595	11,740	8,324
Swan	-	-	482	-	-	36	2,557	1,526	-	-	-	6
TOTALS	55,818	23,214	18,594	2,504	35,157	21,891	19,664	11,426	25,763	15,619	14,148	8,567

Reference: Mr. H. Lloyd Alexander; letter dated June 25 , 1981.

During onsite investigations, deer tracks and woodchuck holes were observed in the wooded areas in the western portion of the site. Birds observed onsite are listed in Table 5.3.2.

The Appoquinimink, Augustine, and Woodland Beach Wildlife areas, all located within a radius of ten miles of the Roberts Farm site, are important wildlife areas. These are described in section 5.3.1.3.

TABLE 5.3-2
ROBERTS FARM TRACT
BIRDS OBSERVED ON ROBERTS FARM AND VICINITY

Common Name	Scientific Name
Bob-white	*Colinus virginianus*
Crow	*Corvus brachyrhynchos*
Ducks	Anatidae gen et. spp.
Eastern kingbird	*Tyrannus tyrannus*
Great blue heron	*Ardea herodias*
Pigeon hawk	*Falco columbarius columbarius*
Red-eyed vireo	*Vireo olivaceus*
Red-winged blackbird	*Agelaius phoeniceus*
Snowy egret	*Leucophoyx thula thula*
Tree swallow	*Iridoprocne bicolor*

5.3.1.2 Aquatic Communities

Physical Description

The Roberts Farm site drains into Hangman's Run, a tributary to the Appoquinimink River which is located about one-quarter mile north of the site. Hangman's Run is tidal downstream of the dam, and freshwater upstream of it. The dam forms a freshwater pond, surrounded by marsh, which is located within the site boundaries. A small tidal branch of Hangman's Run is located on the east end of the site, and Blackbird Creek, also tidal, is located less than one-tenth of a mile southeast of the site.

The tidal amplitude in the lower part of tidal creeks in the vicinity is 5.8 feet (Smith, 1971). The channel depth at high tide in the Appoquinimink River is 15 feet (Martin, 1974). The stream bottom, which appears to be similar for all three streams, varies from sandy mud to mud. The stream channel walls consist of compressed mud and plant debris (Smith, 1971). The Appoquinimink is similar to other tidal streams in the region. The tidal currents in the lower portions of the Appoquinimink River and Blackbird Creek prevent the growth of rooted aquatic plants. The freshwater pond formed by the Hangman's Run dam, however, supports thick growths of aquatic and emergent plants.

Water Quality

Salinity of the Delaware River estuary and tidal creeks varies with rainfall, and tidal stage. Generally the salinity is low in spring and early summer, and increases up to 15 ppt in late summer and fall (Smith, 1971).

Water quality of the Appoquinimink-Blackbird system is generally good, with some parameters occasionally exceeding state standards (Delaware DEC, 1975). The two streams are considered to be the same water quality segment by the state because they are very similar. Both stream basins contain extensive marshes. Agriculture is the major land use. Both are tidal along the lower half, and have small, sluggish headwater streams which tend to dry up during extended dry periods. Designated water uses for the streams are: industrial water supply, secondary contact recreation in tidal reaches, primary contact recreation in lakes and ponds, maintenance and propagation of fish, preservation of aquatic life and wildlife, agricultural water supply, drainage, anadromous fish, and navigation in tidal reaches. Water quality is listed as "good" for fish and aquatic life throughout the stream.

Water quality data for the Appoquinimink River at River Mile 1.38 are given in Table 5.3-3. (Water quality data for Hangman's Run have not been taken by the State for the Water Quality Inventory). Phosphate and bacteria concentrations are the two parameters which have periodically exceeded water quality standards as indicated in Table 5.3-3. It was suggested that the source of bacteria is wildlife, including water fowl, and the source of phosphate is fertilizer used in the agricultural areas (Delaware DNREC, 1975, and personal communication with Technical Services Section, DNREC, 1981).

Fishes. The Appoquinimink River drainage supports a diverse fish community. A total of 56 species of fish were captured by trawl and seine in the Appoquinimink River from 1969 through 1974 (Schuler et al., 1976). These included marine, brackish water and freshwater species. They are listed on Table 5.3-4. The most abundant species were bay anchovy, followed by white perch and Atlantic menhaden. Other abundant species are so indicated on Table 5.3-4. Most specimens taken were young (age 0+) indicating that the Appoquinimink (as well as other tidal streams sampled during the study) is used for a spawning/ and or nursery area by fish. The abundance of freshwater fish in the Appoquinimink is probably due to fish being washed over the several dams within the drainage (Schuler et al., 1976).

The dam on Hangman's Run would prevent access to the pond on Roberts Farm by marine and brackish water fish. The pond probably supports the same freshwater species as are found within the upper Appoquinimink. These include carps and minnows, pikes, suckers, freshwater catfish, killifish, sticklebacks, and sunfish. The species composition in the Appoquinimink is similar to that of two other tidal streams in the region (Hope Creek and Alloway Creek).

TABLE 5.3-3
Water Quality of the Appoquinimink River for October 1978 - September 1979 (at River Mile 1.38)

Parameter	Concentration (mg/1 unless otherwise indicated)*	State Criteria for non-tidal segments	State Criteria for tidal segments	U.S. EPA Quality Criteria for Water**
Dissolved Oxygen	6.4	not <4	not <5	5.0
BOD (5-day)	2.8	-	-	-
Color (units)	92	-	-	75
Turbidity (FTU)	30	-	-	-
pH (units)	7.4	6.5-8.5	-	6.5-9.0
Alkalinity	51	not <20	-	≥20 (for fresh water)
Acidity	7.0	shall not exceed alkalinity by 20	-	-
Hardness	360	-	-	-
Chloride	950	-	-	-
Total nitrogen	1.4	-	-	-
Organic nitrogen	1.0	-	-	-
Ammonia nitrogen	0.04	-	-	-
Nitrite	0.02	-	-	-
Nitrate	0.9	-	-	-
Total phosphate	0.20	-	-	0.10
Total coliforms (#/100 ml)	6400	-	70 (for shellfish waters)	-
Fecal coliforms (#/100 ml)	100	200	200	200 (for bathing waters)
Fecal streptococcus (#/100 ml)	400	-	-	-

* Data based on two sampling points (personal communication with Technical Services Section, DNREC, 1981) Delaware DNREC (1980)

** Source: U.S. EPA (1976).

TABLE 5.3-4
Fishes Collected in Appoquinimink River
(January 1969 through December 1974)

Common Name	Scientific Name	Habitat**	Most Abundant Species
Lampreys	Petromyzontidae		
Sea lamprey	Petromyzon marinus	M, B, F	
Eels	Anguillidae		
American eel	Anguilla rostrata	M, B, F	
Herrings	Clupeidae		
Blueback herring	Alosa aestivalis	M, B, F	
Hickory shad	Alosa mediocris	M, B, F	
Alewife	Alosa pseudoharengus	M, B, F	
American shad	Alosa sapidissima	M, B, F	
Atlantic menhaden	Brevoortia tyrannus	M, B, F	x
Gizzard shad	Dorosoma cepedianum	B, F	
Anchovies	Engraulidae		
Bay anchovy	Anchoa mitchilli	M, B, F	x
Pikes	Esocidae		
Redfin pickerel	Esox americanus	B, F	
Chain pickerel	Esox niger	B, F	
Minnows & Carps	Cyprinidae		
Goldfish	Carassius auratus	B, F	
Carp	Cyprinus carpio	B, F	
Silvery minnow	Hybognathus nuchalis	B, F	
Golden shiner	Notemigonus crysoleucas	B, F	
Satinfin shiner	Notropis analostanous	F	
Spottail shiner	Notropis hudsonius	B, F	
Creek chub	Semotilus atromaculatus	F	
Suckers	Catostomidae		
White sucker	Catostomus Commersoni*	F	
Creek chubsucker	Erimyzon oblongus*	F	

* Found in upper reaches
** M - Marine; B - Brackish (salinity 1.0-10.0 ppt); F - Fresh

Table 5.3-4 (Cont'd)

Common Name	Scientific Name	Habitat	Most Abundant Species
Freshwater Catfishes	Ictaluridae		
White catfish	*Ictalurus catus*	B, F	
Brown bullhead	*Ictalurus nebulosus*	B, F	
Yellow bullhead	*Ictalurus natalus*	F	
Channel catfish	*Ictalurus punctatus*	F	
Needlefishes	Belonidae		
Atlantic needlefish	*Strongylura marina*	M, B, F	
Killifishes	Cyprinodontidae		
Banded killifish	*Fundulus diaphanus*	M, B, F	x
Mummichog	*Fundulus heteroclitus*	M, B, F	x
Rainwater killifish	*Lucania parva*	M, B	
Livebearers	Poecillidae		
Mosquitofish	*Gambusia affinis*	M, B, F	
Silversides	Atherinidae		
Tidewater silverside	*Menidia beryllina*	M, B, F	x
Atlantic silverside	*Menidia menidia*	M, B, F	x
Sticklebacks	Gasterosteidae		
Fourspine stickleback	*Apeltes quadracus*	M, B, F	
Threespine stickleback	*Gasterosteus aculeatus*	M, B, F	
Pipefishes & Seahorses	Syngnathidae		
Northern pipefish	*Syngnathus fuscus*	M, B, F	
Temperate Basses	Percichthyidae		
White perch	*Morone americana*	M, B, F	x
Striped bass	*Morone saxatilis*		
Sunfishes	Centrarchidae		
Bluespotted sunfish	*Enneacanthus gloriosus*	F	
Pumpkinseed	*Lepomis gibbosus*	B, F	x
Bluegill	*Lepomis macrochirus*	B, F	x
Smallmouth bass	*Micropterus dolomieui*	B, F	
Largemouth bass	*Micropterus salmoides*	B, F	

Table 5.3-4 (Cont'd)

Common Name	Scientific Name	Habitat	Most Abundant Species
White crappie	*Pomoxis annularis*	B, F	
Black crappie	*Pomoxis nigromaculatus*	B, F	x
Perches	Percidae		
Tessellated darter	*Etheostoma olmstedi*	B, F	
Yellow perch	*Perca flavescens*	B, F	
Bluefishes	Pomatomidae		
Bluefish	*Pomatomus saltatrix*	M, B, F	
Jacks & Pompanos	Carangidae		
Crevalle Jack	*Caranx hippos*	M, B, F	
Snappers	Lutjanidae		
Gray snapper	*Lutjanus griscus*	M, B, F	
Drums	Sciaenidae		
Silver perch	*Bairdiella chrysura*	M, B, F	
Weakfish	*Cynoscion regalis*	M, B, F	
Spot	*Leiostomus xanthurus*	M, B, F	x
Atlantic croaker	*Micropogon undulatus*	M, B, F	
Black drum	*Pogonias cromis*	M, B, F	
Gobies	Gobiidae		
Naked goby	*Gobiosoma bosci*	M, B, F	
Righteye Flounder	Pleuronectidae		
Winter flounder	*Pseudo pleuronectes americanus*	M, B, F	
Soles	Soleidae		
Hogchoker	*Trinectes maculatus*	M, B, F	

Source: Schuler et al. (1976)

Several migratory species were found in the Appoquinimink. Both blueback herring and alewife adults ascend the Appoquinimink in spring to spawn in fresh water. American shad and hickory shad have been found there also, but in very small numbers (Schuler et al., 1976). Atlantic menhaden juveniles apparently migrate upstream within the basin. The dam on Hangman's Run would prevent these species from entering the freshwater portion of Hangman's Run, much of which is on Roberts Farm.

5.3.1.3 Special Ecological Considerations

Endangered and Threatened Species

The Roberts Farm vicinity is not presently used for nesting by bald eagles. However, "historically, bald eagles have been known to nest (in), feed (in) and migrate through the vicinity of the Roberts Farm. The current feeling of the Delmarva Bay Region Bald Eagle Recovery Team is that the region's population is at least stable and possibly increasing. The team has documented that when the eagle population begins to expand, it is highly likely that they will utilize former nest site areas rather than go into habitat that never had historic eagle nests. It is important, therefore, to protect the vicinity of historic eagles nests and feeding areas if the population is to recover to a secure status." (personal communication, Mr. H. Lloyd Alexander, Jr.).

Abbott (1978) indicates that four former eagle nesting sites were located north of Blackbird Creek, in the vicinity of Roberts Farm. Two formerly-used nesting areas are located south of Roberts Farm. One of these is within Cedar Swamp, which is located about 2.5 miles southeast of the proposed disposal site. The other area which was last used in the early 1970's, is near Blackbird Landing on Blackbird Creek, about 2.75 miles south-southwest of the site (personal communication, Mr. H. Lloyd Alexander, Jr.).

Of the five presently active nest sites within Delaware, the closest to Roberts Farm is at Bombay Hook, which is over ten miles southeast of the site (personal communication, Mr. H. Lloyd Alexander, Jr.).

Data from the 1980 Midwinter Bald Eagle survey indicated that no bald eagles were sighted in New Castle County during that survey (Pramstaller, 1981). The survey report indicated that, because some eagles may have been overlooked because of their mobility and other conditions, the survey should take place annually for several years for a more accurate assessment of numbers. Bald eagles have been sighted by state and Federal biologists in the vicinity of Roberts Farm within the past few years (personal communication, Mr. H. Lloyd Alexander, Jr.).

Shortnose sturgeon occur in the Delaware River, which is about 2.5 miles east of Roberts Farm. Five shortnose sturgeon have been recently taken in the Delaware River across from the confluence of the Appoquinimink River and Blackbird Creek (Brundage, 1981). Although no specimens have been captured in either of these two streams (possibly because of the sampling methods used) the sturgeon are known to enter tidal creeks, and most likely forage in the lower reaches of the Appoquinimink and Blackbird Creeks in spring and summer. How far upstream they might occur, and availability of food organisms in these streams, are not known. Although the appropriate spawning substrate is available in both streams, the sturgeon are not likely to spawn there because of their preference for spawning in large rivers with fast current.

Economically and Recreationally Valuable Species

The Delaware coastline is a major flyway for game, as well as non-game shore birds. The coastline from Augustine Wildlife area (south of the Chesapeake and Delaware Canal) to below Bombay Hook, is a major waterfowl area, and supports substantial hunting.

Hunting surveys conducted at Woodland Beach (8 miles south of Roberts Farm) reported 8,000 licensed hunters in 1977 and 6,000 in 1978. Only ten to twenty percent of hunting within the state occurs on public lands (personal communication, Mr. H. Lloyd Alexander, Jr.). Landowners usually charge fees to take hunters to, and allow use of, hunting blinds on private lands.

Roberts Farm is located within the coastal flyway. The nearest state-owned hunting area is the Appoquinimink Wildlife Area, located on the south shore of the Appoquinimink River at its confluence with the Delaware River. Access to the area is by boat only. The State maintains two hunting blinds within the area, and allows hunting for waterfowl only. Canada goose is the major species hunted here; other game birds include mallards, black ducks, green wing teal, blue wing teal, and wood duck. These species could be expected to use the waterways on and adjacent to Roberts Farm.

Other major hunting areas are Augustine Wildlife Area about two miles north of Roberts Farm, and Woodland Beach, mentioned above. Both provide hunting for waterfowl and upland birds and mammals such as deer, rabbit, quail, pheasant, dove, and woodcock (State information sheets on Wildlife Areas). Roberts Farm provides some habitat for upland species as evidenced by the deer signs and woodchuck burrows observed during the site visit.

The Appoquinimink River and Blackbird Creek support a sport fishery. White perch fishing is exceptional near the mouth of the Appoquinimink (Martin, 1974). Other species fished include catfish, eels, carp, yellow perch, and blue crabs. Blueback herring and alewife contribute to the fishery in spring. "White catfish, channel catfish and sea trout use Blackbird Creek as a major nursery and feeding area" (Martin, 1974).

The freshwater species in Hangman's Run could contribute to a fishery, but access to the stream and pond are limited because Roberts Farm is privately-owned. In comparison, fishing at 24 state-owned freshwater ponds is popular; in 1976 an estimated 159,000 man-days of fishing effort was expended at these ponds (Miller, 1978a).

Saltwater sport fishing in the State, is a multi-million dollar business (Miller, 1978b). The closest public boat launch areas to Roberts Farm are located at Woodland Beach and Augustine Wildlife Areas. Access to Blackbird Creek and Appoquinimink River is available from the road bridges (Rts. 9 and 13 and Delaware Road 445). Small boats can be launched by hand at some of these bridges (Martin, 1974).

5.3.1.4 Potential Project Impacts

Construction of dikes for screening purposes, and preparation of a haul road at the site would initially disturb some habitat and could temporarily increase levels of turbidity and sedimentation in the streams receiving site runoff. The latter can be controlled by implementation of a suitable erosion and sedimentation control plan.

Actual use of the landfill will involve stripping off the topsoil, and stockpiling it, preparing the subgrade to guide leachate to central collection points, and lining the areas to be filled with an impermeable liner. No more than approximately twenty acres will be in preparation to receive fill at any one time; and no more than about thirty acres will be in some stage of preparation or use at any one time.

The useable areas for landfilling on Roberts Farm are presently cultivated. Landfilling will not occur on the wetlands portion of the site. Effects of a landfill operation on existing wildlife habitat are expected to be minor. They will consist primarily of increased levels of activity and noise near the portions of the site actively being utilized.

As each section of the useable site is filled, it will be covered with a layer of soil, over which the original top layer of soil (topsoil) will be replaced. The site ultimately will be returned to open space uses. Its value for wildlife is not expected to be diminished from what presently occurs.

5.3.2 Land Use

5.3.2.1 Future Land Use

The site is located in the Middletown-Odessa-Townsend Planning District and the plan for this district was prepared by the new Castle County Department of Plannng on May 15, 1973.

This Planning District is the largest of the nine districts in the County, bounded on the north by the C&D Canal; on the west by the Maryland-Delaware State Line; on the south by the County Line, and on the east by the Delaware River.

The proposed Roberts Farm site has been designated stream valley, flood plain, and marshland protection along the tributary to the Appoquinimink River which bisects the site. Small, selective portions have also been designated for agricultural use and the remainder has been placed in the Post-1985 Coastal Zone Industrial Development category. Generally, all land from Route 9 to the Delaware River, has been classified as a Coastal Zone protection area.

The County's recommendations for this site in the proposed Comprehensive Plan update remain the same as in 1973.

5.3.2.2 Farm Land Classification

The proposed Roberts Farm site contains 720+ acres, 432 acres or 60% of which is prime farmland (Class I and Class II soils).

The Class I and Class II soils found on the site include the following:

Symbol	Soil Name	Capability
KeB	Keyport silt loam (2-5% slope)	IIe-13
MeA	Matapeake silt loam (0-2% slope)	I-4
MeB	Matapeake silt loam (2-5% slope)	IIe-4
MtA	Mettapex silt loam (0-2% slope)	IIw-1
MtB	Mettapex silt loam (2-5% slope)	IIe-16
SaB	Sassafras sandy loam (2-5% slope)	IIe-5
WsA	Woodstown loam (0-2% slope)	IIw-1

New Castle County contains an estimated 279,680 acres, of which 111,532 acres (39.9 percent) are prime agricultural land. The Roberts Farm Site, therefore, contains less than 2/5 of 1% (0.4%) of all of the prime agricultural land found in New Castle County.

The estimated average yield per acre of principal crops, based on good conservation practices of prime soils found on the site, is as follows:

	Bushels				
Soil	Corn	Oats	Wheat	Irish Potatoes	Soybeans
KeB	90	55	35	-	35
MeA	115	60	40	650	40
MeB	115	60	40	650	40
MtA	100	60	40	-	40
MtB	105	60	40	-	40
SaB	100	55	40	600	45
WsA	90	50	40	-	45

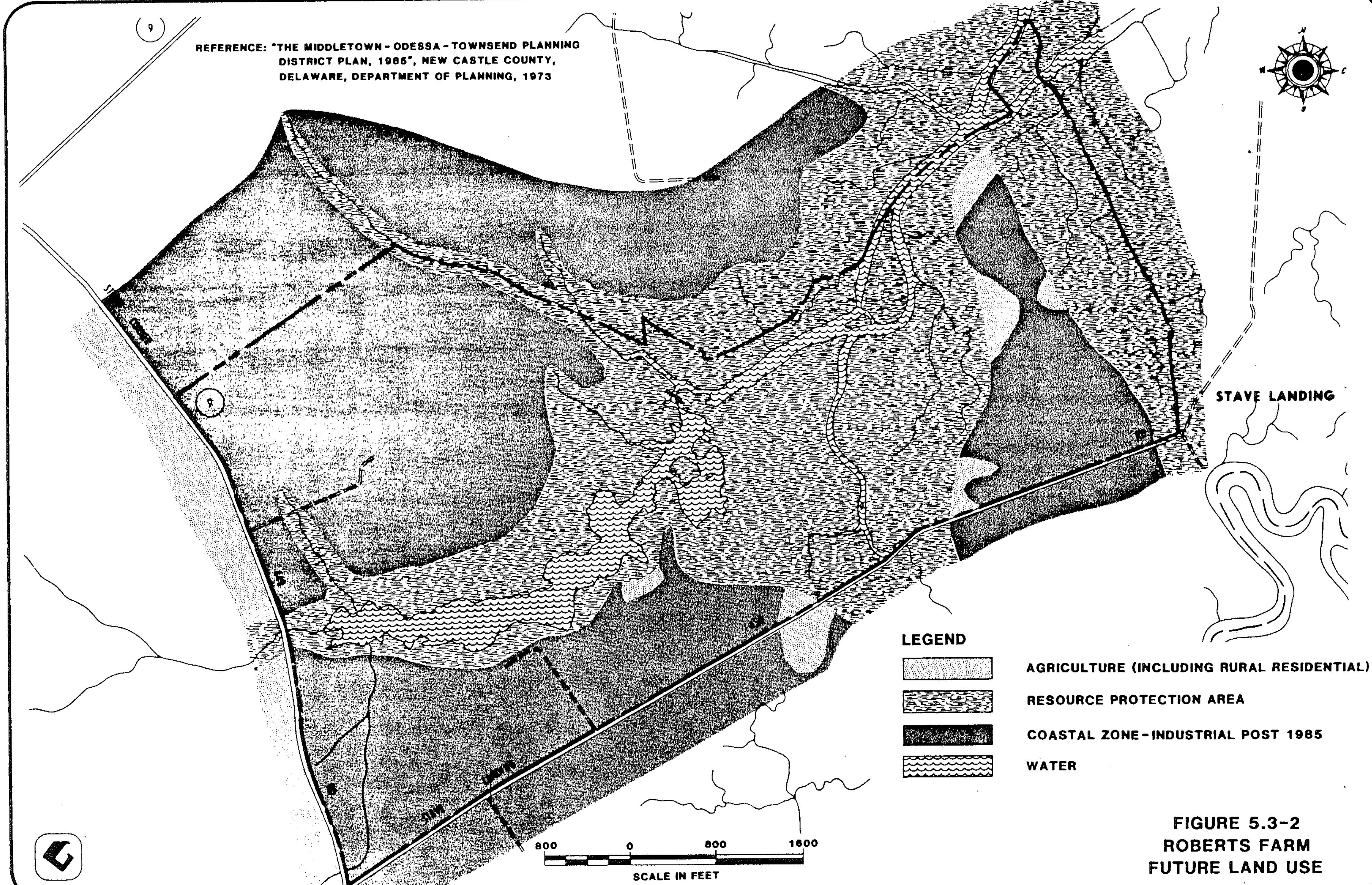


FIGURE 5.3-2
ROBERTS FARM
FUTURE LAND USE

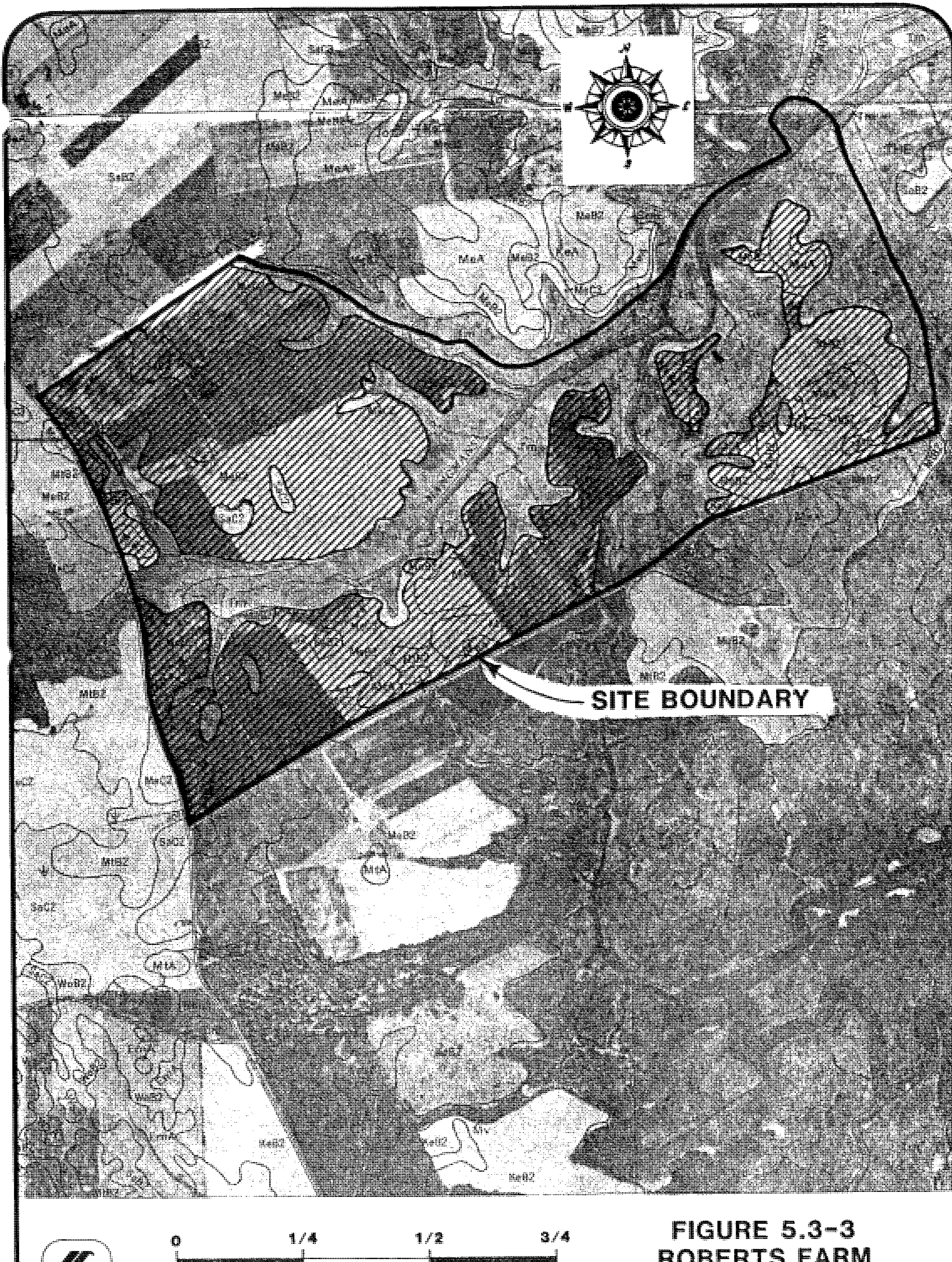


FIGURE 5.3-3
ROBERTS FARM
PRIME AGRICULTURAL LAND

5.3.3 Zoning

The site has been designated as an R-2 (Agricultural and General Purpose) District by the New Castle County Zoning Code. The R-2 District permits single-family residences, mobile homes, churches, schools, police, and fire stations, libraries, museums and art galleries, country clubs, agricultural uses, professional offices, and parks and playgrounds.

In addition, commercial greenhouses, hospitals, aviation facilities, cemeteries, amusement parks, camps, riding clubs, social and fraternal organizations, verterinary hospitals and kennels, tourist homes, armories, and other utility or public service structures are permitted by special exception.

The minimum lot area for any dwelling or permitted non-residential use is one-half acre (21,780 sq. ft.) with a minimum lot width of 75 feet.

5.3.4 Demography

There are five dwellings within 300 yards of the site boundary. Based on the 1980 Preliminary Census of Population and Housing, the Middletown-Odessa Division had a population of 13,181 and 4,440 housing units. The area outside of the towns of Middletown, Odessa, Townsend and Smyrna had a 1980 population of 9,506 and had 3,051 housing units. Assuming that all housing units were permanently occupied, the population per unit was 3.12. Utilizing this population per housing unit, it is estimated that 16 people reside within 300 yards of the site boundary.

5.3.5 Cultural, Recreational and Natural Areas

There are no cultural or recreational areas within 300 yards of the Roberts Farm boundary. However, the State's Appoquinimink Wildlife Area, consisting of 34 acres used exclusively for hunting, is located at the confluence of the Appoquinimink River and the Delaware River, approximately three miles northeast of the proposed site.

Roberts Farm is designated as part of the Marshes of the Appoquinimink River - Blackbird Creek System Natural Area. The area is described as the only large marsh system in the State which has remained essentially undisturbed. The importance of fish and wildlife is described as national in scope because of the area's size and its quality of habitat. The area is said to be a nursery for several species of fish including the white catfish, weakfish, channel catfish, spot and eels. Breeding birds most common to the area include ducks, egrets, herons and birds of prey.

The Blackbird Creek and Appoquinimink River have both been reviewed under the National Wild and Scenic Rivers Act by the U.S. Department of Interior, Heritage Conservation and Recreation Service, and found to have significant recreation, cultural, and urban values, but have not yet been included in the National Wild and Scenic Rivers System.

Roberts Farm is also part of a section designated as an area for Natural Vistas found along Route 9 (from Delaware City to the New Castle-Kent County line). Several points identified contain a view of the proposed site and its adjacent areas. In additon, Route 9 has been designated as a state Scenic Highway by the State of Delaware.

5.3.6 Historic Sites

There are no historic sites, as listed in the National Register of Historic Places, in the vicinity of the Roberts Farm site. The site contains three structures which have been inventoried by Division of Historical and Cultural Affairs as having unique

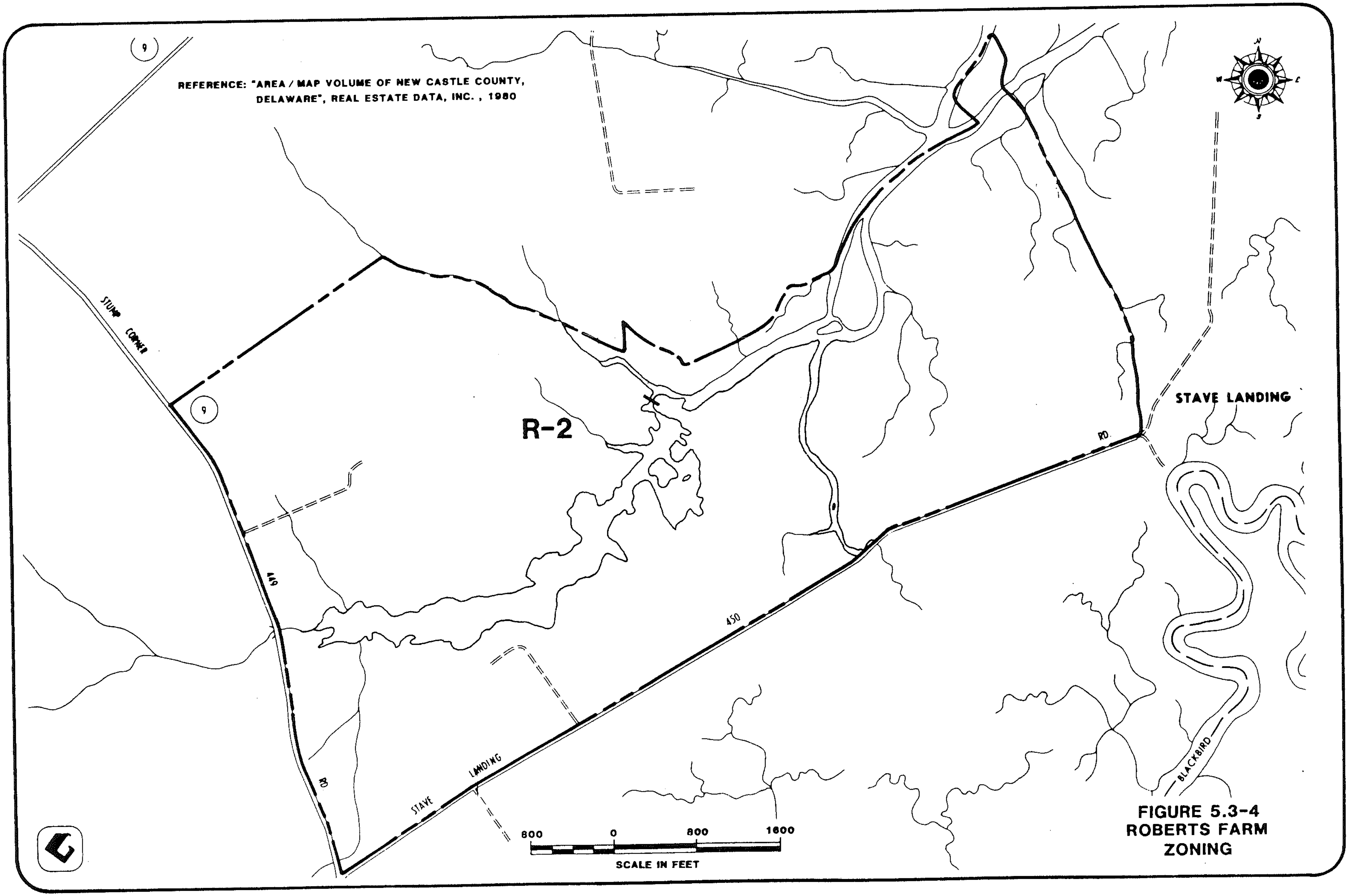


FIGURE 5.3-4
ROBERTS FARM
ZONING

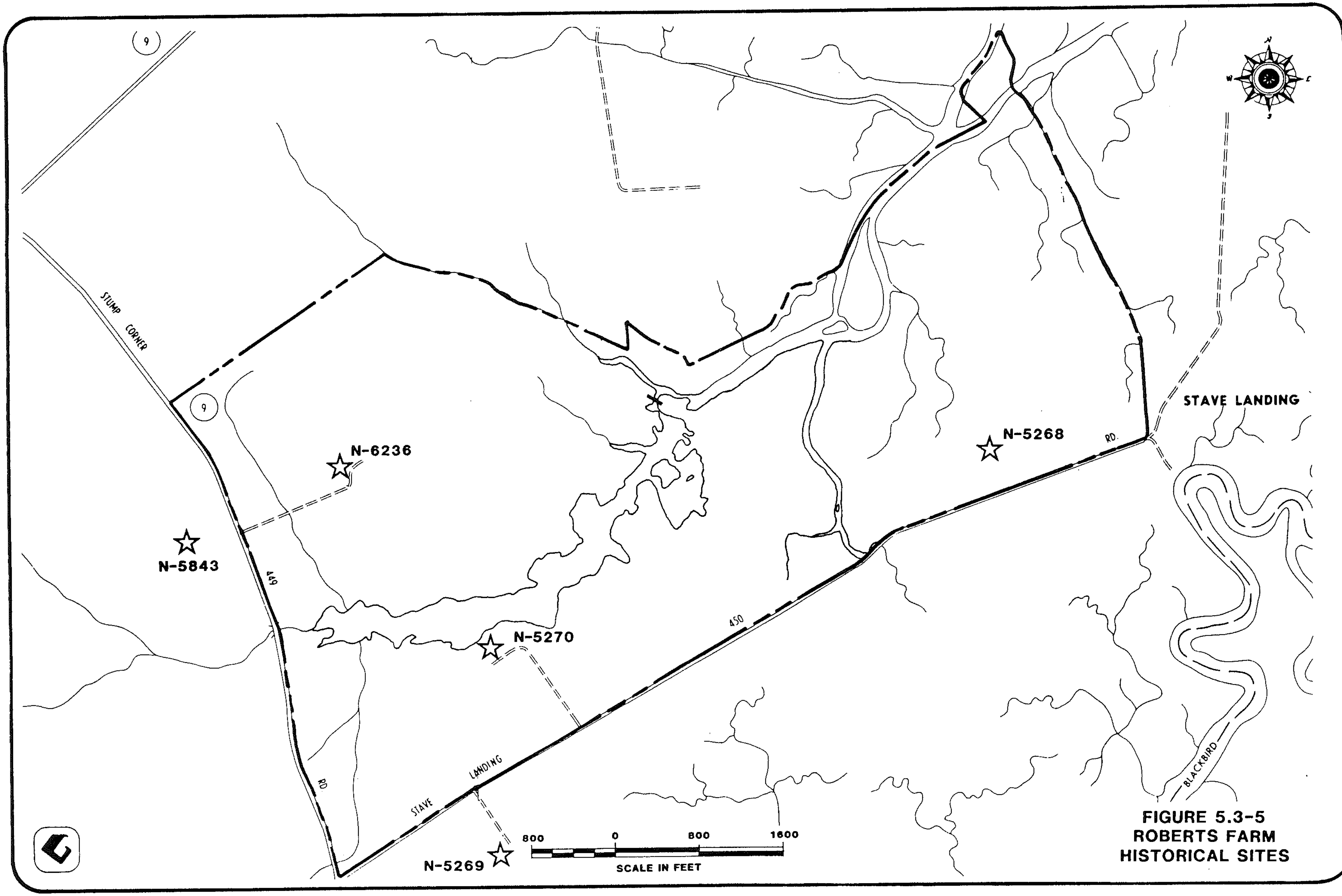


FIGURE 5.3-5
ROBERTS FARM
HISTORICAL SITES

architectural significance. The J. H. Appleton House (N-6236); the D. Corbit Residence (N-5270), and the D. Corbit House (N-6268).

N-6236: J. M. Appleton House, "Poplar Hill." This residence, exhibiting two building campaigns from the early to mid 19th century and associated farm outbuildings, maintains traditional 19th century architectural detailing. This property is eligible for the National Register of Historic Places.

N-5270: D. Corbit Residence. Only the outbuildings from this farm complex remain. The house was moved from the site. This site is not eligible for the National Register.

N-5268: D. Corbit House. This 1840-1850's double frame tenant farm house with barns, sheds, and associated outbuildings, maintains a high degree of architectural integrity. This property is eligible for the National Register.

In addition to the three buildings noted above, the E and A. Moore House and the Milligan House are located within 300 yards of the proposed site boundaries.

N-5843: E and A Moore House: This mid 19th century aluminium sided clapboard structure has recieved various modifications unsympathetic to the original construction detailing. It is not eligible for listing on the National Register.

N-5269: R. Milligan House: An 18th century brick with 19th century frame addition residence and late 19th to early 20th century outbuilding complex, maintains a high degree of architectural integrity. It is eligible for inclusion in the National Register.

In addition, Hangman's Creek, which meanders through the site, is an important micro-environmental factor making the area adjacent to the stream ideal for prehistoric occupation.

5.3.7 Aesthetics

Delaware's Outstanding Natural Areas and Their Preservation, published by Delaware Nature Education Society described the Roberts Farm vicinity as an area containing unique or unusually attractive views of Delaware's natural scenery, and as such it was designated as a "Natural Vista". Route 9 has also been designated as a state Scenic Highway by the State of Delaware and was evaluated in a study prepared by the Delaware Department of Highways and Transportation Unified Systems Planning in cooperation with the Federal Highway Administration, U.S. Department of Transportation, entitled "National Scenic Highway Study for the State of Delaware."

The use of the Roberts Farm site, therefore, will have a significant aesthetic impact by disrupting the visual character of the area. Route 9 is also a moderately used highway and the site would be visible to motorists, although selective screening of operations is possible.

5.4 TRANSPORTATION CONSIDERATIONS

5.4.1 Highway Access

Suggested highway access to the site would be as shown on Figures 1.0-1 and 5.4-1 and as delineated in Table 5.4-1. There appears to be no reasonable alternate access to the Roberts Farm Site which would avoid either Odessa or Middletown, both of which are situated astride a major north-south highway. An alternate route suggested by an official of the Delaware Department of Transportation, Division of Highways was for southbound vehicles

TABLE 5.4-1
ROBERTS FARM
PROPOSED HAUL ROUTE DATA

NAME/ROAD #	MILES	ALONG ROUTE	CLASSIFICATION	LIMITATIONS	TOTAL AADT*	TRUCK AADT	% ** INCREASE AADT	% ** INCREASE TRUCK AADT
Pigeon Point Road (State (Road 377)	1.1	2	Heavy Duty	None	2300	161	4.3	62
State Road 359	0.4	0	Heavy Duty	None	3650	1095	2.7	9.1
Interstate 495	1.1	0	Heavy Duty	None	33307	4996	0.3	2.0
U.S. Route 13	22.5	170	Heavy Duty	None	North of U.S. 40 46654	6224	0.2	1.6
					South of U.S. 40 22416	3837	0.4	2.6
State Road 452	1.8	13	Light Duty	None	260	39	38	256
State Route 9	0.7	5	Medium Duty	For northern part of site: two-lane bridge over Hangman's Run; no posted limit.	460	46	21.7	217
		190						

Total one-way mileage: 27.60

* AADT - Annual Average Daily Traffic as reported by DELDOT.
** Based upon: 10th year tonnage estimate; 260 working days/year, 15 tons payload per truck approximately 50 truck loads of waste per day would be hauled to the disposal site; therefore, traffic counts should be increased by 100 to reflect impact of the hauling operation.

to proceed south on U.S. 13 to Vance Neck Road (Road 37), proceed east on Vance Neck Road to State Route 9 and then south on Route 9 to the site. Although this route would skirt Odessa, the increased truck traffic due to the hauling of wastes from Pigeon Point would be much more noticeable along this alternate route which incorporates more than 5 miles of travel along Route 9, a state scenic highway. For instance, the most recent average daily traffic count for Route 9 is approximately 460 with approximately 10% of this being truck traffic. The current truck traffic appears to consist mainly of light trucks such as delivery trucks and farm trucks. Compare this with the traffic counts for Route 13. In addition, there are several more tight turns along this route as well as two bridges over the Appoquinimink which would have to be traversed day-in and day-out.

State Route 299 was not considered as a viable route because of the historic district along this route between U.S. 13 and the Appoquinimink River.

The anticipated truck traffic volume associated with hauling the wastes from Pigeon Point to any of the sites (assuming an average net load of 15 tons per truck, the 10th year waste generation rate and hauling 260 days/year) is an average of about 50 truck loads per day. This means an increase of 100 in the truck count along any portion of the haul route. Table 5.4-1 shows the effect of this on the different segments of the suggested haul route for which traffic counts are available.

The conditions of the roads along the suggested route are good to excellent with the exception of State Road 452 which would probably be considered to be in fair condition. For purposes of the economic investigation discussed in Section 5.4.6, it will be assumed that this road would have to be upgraded from the intersection with Route 13 to its intersection with Route 9. Also, to be conservative, it will be assumed that intersection

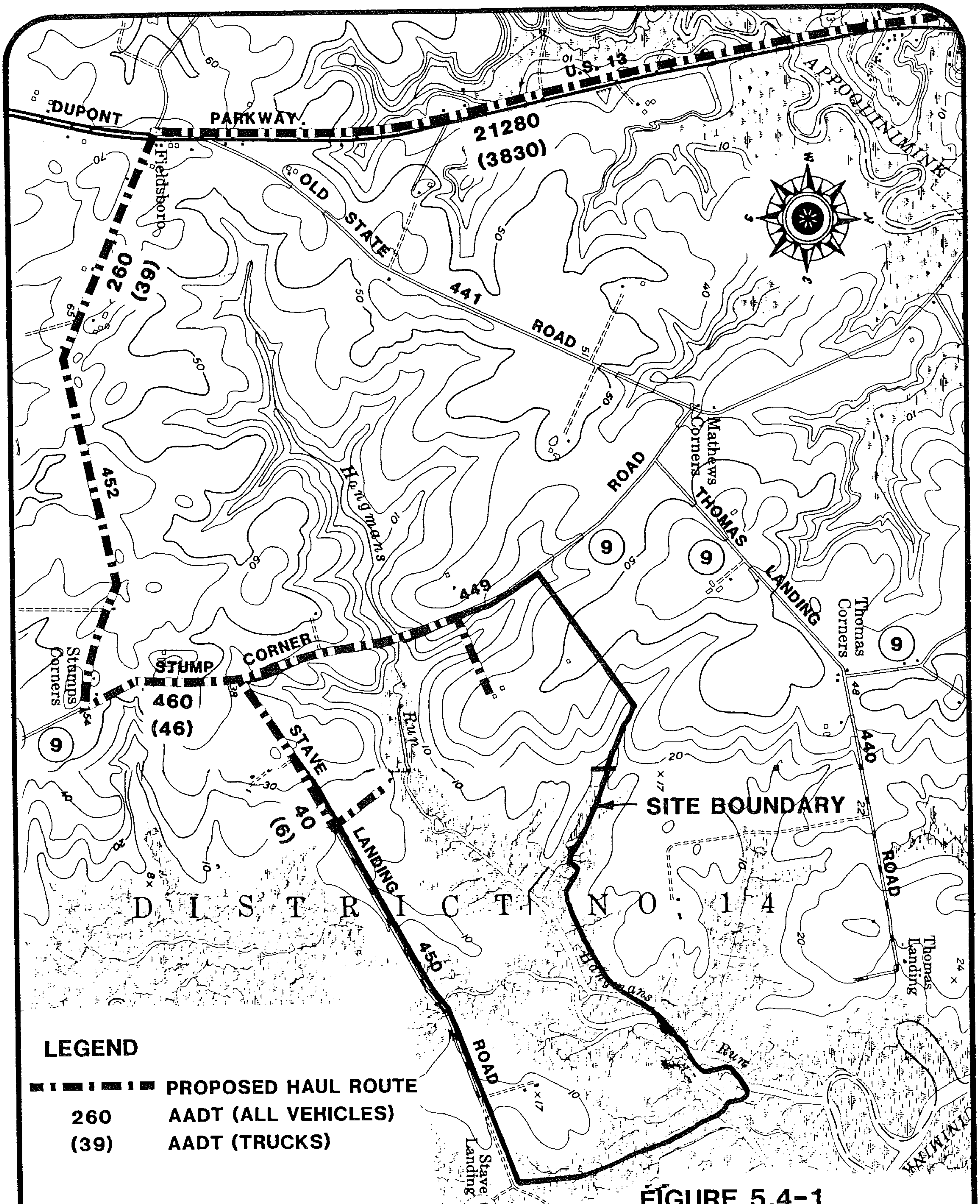


FIGURE 5.4-1
ROBERTS FARM
PROPOSED ACCESS / EXISTING AADT

improvements at Route 13 will be necessary to safely handle the anticipated volume of truck traffic. As it regards restrictions or limitations along the route, the only structure which may be of significance would be the two lane bridge over Hangman's Run which would have to be traversed to get to the northern portion of the site. DelDOT currently has no posted limit for this bridge.

5.4.2 Rail Access

The nearest rail line to this site is four miles to the west near Middletown. Consequently hauling wastes to the site by rail would require at a minimum the construction of a 4 mile spur, switching facilities, and three grade crossings and related traffic control/facilities: one across busy Route 896, one across U.S. Route 13 (a four lane divided highway), and one across Route 9. An overpass or underpass may be the only currently acceptable means to cross U.S. 13. The number of stream crossings is estimated at 3.

Special loading facilities would be required at Pigeon Point along with a small yard to accommodate empty (spare) rail cars. Since it is anticipated that it would take the better part of the day, if not the whole day, to make a round trip, at least one set of spare cars would be needed. To unload the mix of wastes anticipated, anything from residue to mattresses (and other awkward items) special cars and unique unloading facilities may be required.

As a practical consideration, the rail cars could not be maneuvered to the working face, therefore a certain number of transfer trailer units would be required to move the wastes from the unloading facility to the working face of the landfill. Some of the handling facilities could be avoided if transfer trailers were hauled "piggy-back" to the site. However, to handle one day's worth of waste at the average tonnage rate, more than

50 trailers would be needed for each set of rail cars. Assuming two trailers to a flat car, at least 25 rail road flat cars would be needed along with trackage and space to store and shift the units as necessary. As an alternative to "piggy-backing", the use of specially modified freight containers can be used for transfer of refuse. This would be similar to a system currently in operation in London, England and recently considered by Philadelphia, Pa. Although this may reduce, somewhat, the number of flat cars needed to haul a day's worth of waste, it would have little effect on other facilities necessary for a functioning rail-haul system.

Logistical problems with regard to manning the equipment (train) may be cumbersome from the standpoint of current union requirements.

The rail haul alternative, in terms of susceptibility to weather, probably would be the most reliable. Since there is only one trackage route to the site, however, flexibility is poor should there be a breakdown such as a derailment along the route. The derailment would have to be cleared and track repaired before the system could function again. On the other hand, if a portion of a highway haul route is blocked, a temporary alternative routing can be readily initiated.

5.4.3 Waterway Access (Barging)

The closest navigable water to the site is the Delaware River which is distant enough to make barging of wastes appear to be impractical. Proceeding with such a venture would require construction of marine terminal facilities for loading at Pigeon Point and marine terminal facilities for unloading at the candidate site. Both terminal facilities would have to be large enough to accommodate manuevering of the barges. It would require construction of a channel, maintenance and dredging of a channel, and dredge spoil disposal areas or impoundment facilities. Knowing that it would be impossible to barge the wastes directly to the landfill working face, there would remain a necessity for transfer trailer units to transport the wastes from the terminal to the disposal area. All of this not withstanding, there would still be Corps of Engineers permits to be obtained for both terminal facilities, the channel construction, dredge spoil disposal area, and the wetlands which would be disturbed by this activity.

5.5 ECONOMIC CONSIDERATIONS

5.5.1 Estimated Landfill Development Costs

Table 5.5-1 presents the estimated capital needed at start of the project if this candidate site were selected for development as the NSWF. The construction costs were developed from the Authority's experience with the Central Solid Waste Facility (CSWF) in Sandtown, Kent County. Actual bid prices were escalated by 9% per year to reflect the time differential between the bid date (July 1980) and the 1984 projected start date.

With regard to the capital costs shown in Part A of the Summary on Table 5.5-1, the engineering/surveying/legal costs are associated with facility permitting, detailed design of the first disposal area, preliminary design of remaining disposal areas, preparation of bid documents (Specifications, Drawings, Contract) for construction of first disposal area, evaluation of bids, and construction services. Screening of site will be with a combination of 5 ft. or 10 ft. high earthen berms and rapid growing trees or shrubs as depicted on Figure 5.2-12. It is anticipated that the berms will be constructed with about a 10 ft. wide crest and 2:1 sideslopes and will be built of materials excavated from within the buffer zone. Fencing of the site for discouraging unauthorized persons from entering the premises will

TABLE 5.5-1
ROBERTS FARM SITE
AUTHORITY OWNED/CONTRACTOR OPERATED SANITARY LANDFILL
SUMMARY OF CAPITAL COSTS*

A.	Estimated Project Start-Up Costs	
	1. Land Purchase	$1,600,000
	2. Engineering/Surveying	340,000
	3. Legal/Administrative	50,000
	4. Clearing/Grubbing/Stripping and Stockpiling Topsoil**	109,000
	5. Subgrade Preparation (Excavation, Backfilling, Compacting)	292,000
	6. Installation of Liners and Leachate Collection Facilities	570,500
	7. Importation and Placement of Liner Protective Cover	513,000
	8. Erosion Control Facilities (Sedimentation Basins, Swales, Berms)	70,000
	9. Access Roads	90,000
	10. Fencing	224,000
	11. Screening of Site (Berms, Landscaping)	459,000
	12. Structures (Office Trailer/Maintenance Building)	140,000
	13. Utilities (Electricity, Water, Sanitary, Communications)	31,000
	14. Groundwater Monitoring Wells	26,000
	15. Decomposition Gas Monitoring Wells	16,000
	16. Interest During Construction (4 months; 9.6% interest)	163,000
		$4,693,500
B.	Estimated Annual Cost of Start-Up Capital	
	Amortization Period: 20 years	
	Interest Rate: 9.6%	
	Annual Cost of Capital: $534,835, say $535,000	
C.	Recurring Costs*	
	1. 10-Year Frequency	
	Erosion Control Facilities (sedimentation basins) and relocation of trailer/office	$ 79,000
	2. 3-Year Frequency**	
	a. Engineering/Surveying/Legal/Administrative	185,000
	b. Clearing/Grubbing/Stripping and Stockpiling Topsoil	109,000
	c. Subgrade Preparation (Excavation, Backfilling, Compacting)	292,000
	d. Installation of Liners and Leachate Collection Facilities	570,500
	e. Importation and Placement of Liner Protective Cover	513,000
	f. Erosion Control Facilities (Swales, Berms)	16,000
	g. Access Roads	90,000
	h. Decomposition Monitoring Wells	16,000
		$1,791,500

* Costs shown are projected 1984 dollars

**Costs are representative of the development of approximately 24 acres of property for use as a sanitary landfill. Overall site development will consist of 7 phases of 24 acres each. Each phase will last approximately 3 years.

require an estimated 15,000 L.F. of chain-link fencing. This is almost evenly split between the northern and southern portions. Because the candidate site is split into two parts by Hangman's Run, some duplication of utilities are necessary to satisfactorily serve the office trailer which would be relocated to the northern portion after completion of the southern portion, or vice-versa. A septic system, water supply, electricity, and communications would have to be provided at each location. The maintenance building was assumed to be constructed on the northern portion of the site with equipment using the existing dam crest road to gain access to the southern portion of the site.

Pertaining to the capital costs shown in Part C, other than engineering these should be self explanatory. The engineering, surveying, and legal fees are associated with the detailed design of subsequent landfill areas, the preparation of Specifications, Drawings, and Contracts to accomplish the work, and construction services.

It is anticipated that both Road 450 and Road 452 will have to be improved to handle the expected traffic increase. Road 452 would be upgraded for its entire length between U.S. 13 and Route 9, a distance of approximately 1.8 miles. Road 450 would be upgraded for approximately 1.5 miles east of its junction with Route 9. The estimated cost of 1,050,000 for this work includes some monies for intersection and bridge improvements (bridge on Route 9 over Hangman's Run).

5.5.2 Estimated Landfill Operating Costs

Table 5.5-2 presents the estimated first year operating cost for an Authority owned/Contractor operated land disposal facility. Of the landfill personnel needed to operate the site, it was assumed that one person would be in the direct employ of the Authority. It also was anticipated that the Authority would directly pay for all fuel for operation of the Contractor's equipment and for all utilities such as electricity, gas, heating oil, or telephone. Costs associated with the groundwater monitoring program and gas monitoring program would be borne by the Authority.

Contractor costs were estimated taking into consideration owning and operating costs for seven items of equipment (including a landfill compactor, scraper, bulldozer, and tracked loader) and wages (assuming union labor) for five employees (1 supervisor, 3 equipment operators, 1 laborer).

The bottom portion of Table 5.5-2 shows that the first year cost for owning, developing, and operating a landfill at the Roberts Farm site is estimated at about $1.72 million. If this cost is divided by the tonnage landfilled during the first year, it results in a cost equivalent to $10.80/ton landfilled.

Table D-1 of Appendix 5D projects owning and operating costs and "equivalent disposal fees" for the tonnage landfilled. The projection is made assuming that initial project costs are financed with revenue bonds at 9.6% interest and an escalation factor of 9%/year for both capital costs and operating expenses. The projected "equivalent disposal fees" are depicted graphically in Figure 5.5-1. The fees are "normalized" for three year periods which coincide with the anticipated triannual development program.

5.5.3 Estimated Haul Costs

Table 5.5-3 presents the initial year costs estimated for the hauling of residues and non-processables from the DRP at Pigeon Point to the Roberts Farm site. It has been assumed that the Authority will contract the hauling operation as opposed to operating the system itself. Therefore, to arrive at the cost associated with a Contract operation, costs were developed as if

TABLE 5.5-2
ROBERTS FARM SITE
FIRST YEAR OPERATING EXPENSES/TOTAL FIRST YEAR COSTS
AUTHORITY OWNED/CONTRACTOR OPERATED LANDFILL*

FIRST YEAR OPERATING EXPENSES

A.	AUTHORITY DIRECT COSTS:		
	1. Labor (1 Person: includes fringe benefits)		$ 24,000
	2. Equipment Fuel		96,500
	3. Utilities (Electricity, telephone, etc.)		3,700
	4. Groundwater Monitoring Program		26,000
	5. Decomposition Gas Monitoring		1,300
	6. Access Road Maintenance		13,000
	7. Miscellaneous Expenses		6,500
		Subtotal	$ 171,000
B.	ESTIMATED CONTRACTOR'S FEE		$1,014,000
		Total	$1,185,000

TOTAL FIRST YEAR COSTS

A.	Annual Cost of Capital (From Table 5.5-1)		$ 535,000
B.	First Year Operating Cost		1,185,000
		Total	$1,720,500

C. Cost/Ton If Spread Over Tonnage Landfilled:

$1,720,500/159,000 Tons = $10.80

*Costs shown are projected 1984 dollars

the Authority was intending to develop and operate the system and a 35% surcharge was incorporated to account for contingencies and contractor's overhead and profit. Since it will be common to all site alternatives, transfer station development and operating costs were not incorporated in the estimates.

The round-trip distance is estimated at just over 55 miles. The round trip is estimated to require approximately 90 minutes to complete including turnaround time at the disposal site. Therefore, the number of trips which can be made each day with a single hauling unit is estimated at 5. At an average payload of

15 tons, approximately 50 trips per day would be necessary based upon the estimated 10th year tonnage. At 5 trips per truck, about 11 tractors will be needed. To provide for contingencies, a 12th tractor should be added. Similarly, it is estimated that 15 trailers would be necessary to provide flexibility and sufficient back-up or reserve capacity.

With regard to manpower, 11 drivers will be needed to staff the hauling operation. Wage rates are based upon the United States Department of Labor, Area Wage Survey, Wilmington, Del. - N.J. - Md., April 1981. Other data regarding maintenance, tires, insurance, etc., were obtained from a 1977 study performed for the Southeastern Public Service Authority of Virginia by Henningson, Durham, and Richardson and from "A Handbook for Transfer System Analysis", The Heil Co., 1974. Applicable cost data appearing in these studies were updated by escalating at a rate of 9% per year. It was assumed that compacting-type transfer trailers will be utilized.

Fuel costs, starting with a current value of $1.20/gallon, were escalated at 12% per year for the 3-year interval between 1981 and the project start year (1984) and at 9% per year for the 20-year project life. A utilization factor of 6.5 miles per gallon was used for estimating purposes. This means that the 1st year fuel cost would be $0.26/mile multiplied by the total number of miles travelled (746,200 miles per year). All other operating costs also were escalated at 9% per year.

The annual cost of capital for the purchase of the tractors and trailers was based on projected 1984 unit costs of $71,000 and $45,000, respectively. With each tractor travelling approximately 72,000 miles per year it was felt that the tractors should be amortized over a 5 year period and the trailers over a 7-year period. An interest rate of 15% was utilized. Table D-2 of Appendix 5D presents projected contractor hauling costs and equivalent tonnage fees for the 20-year planning period. Figure 5.5-2 presents this information graphically.

TABLE 5.5-3
ROBERTS FARM SITE
FIRST YEAR HAULING COSTS*

A.	EQUIPMENT		
	1. Tractors 12 @ $71,000 = $852,000		
	Tractors 15 @ $45,000 = $675,500		
	2. Tractors - Annual Cost Amortized at 15% Over 5 Yrs.	=	$ 254,000
	Trailers - Annual Cost Amortized at 15% Over 7 Yrs.	=	162,000
	Subtotal		$ 416,000
B.	OPERATING COSTS (EXCLUDING FUEL)		
	1. Labor (Assume Union Labor)		
	11 Drivers - 40 Hrs. Regular Time and 4 Hrs. Overtime Per Week: $10,600/Week x 52 = $551,000		$ 551,000
	2. Oil, Filters, Tires, Insurance, Maintenance: $0.389/ Mile: $0.389/Mile x 746,200 Miles = $290,000		290,000
	Subtotal		$ 841,000
C.	FUEL COSTS		
	$1.70/gallon ÷ 6.5 miles/gallon (high torque-rise diesel) = $0.26/mile $0.26/Mile x 746,200 Miles = $194,000		$ 194,000
	Total		$1,451,000
	10% Contingency:		145,000
	10% Overhead:		145,000
	15% Profit:		218,000
	Grand Total Estimated First Year Cost		$1,959,000

Cost/Ton Hauled: $1,959,000/159,000 Tons = $12.32/Ton ≈ $12.30/Ton
*1984 Dollars

A summary of the anticipated capital needs and yearly costs for owning and operating a sanitary landfill at the Roberts Farm site is shown in Table 5.5-4. This table also summarizes the projected yearly costs for the tranfer of waste materials from Pigeon Point.

TABLE 5.5-4

ROBERTS FARM SITE

SUMMARY TABLE OF PROJECTED CAPITAL NEEDS AND YEARLY COSTS*

	Landfill Development and Operation							Hauling Operation		
	Capital Needs Schedule			Debt Service						
	Initial	10-Yr	3-Yr	Initial	10-Yr	3-Yr	Annual Operating Cost	Total Annual Cost	Project Total Annual Cost	$/Ton of Material Transported and Landfilled
1984	$4,693,500	---	---	$ 540,000	---	---	$ 1,185,000	$ 1,959,000	$ 3,684,000	$23.15
1985	---	---	---	540,000	---	---	1,292,000	2,085,000	3,917,000	24.00
1986	---	---	---	540,000	---	---	1,408,000	2,222,000	4,170,000	24.90
1987	---	---	$ 2,320,000	540,000	---	$ 966,000	1,535,000	2,372,000	5,413,000	31.50
1988	---	---	---	540,000	---	966,000	1,673,000	2,534,000	5,713,000	32.45
1989	---	---	---	540,000	---	966,000	1,823,000	2,897,000	6,226,000	34.50
1990	---	---	3,005,000	540,000	---	1,250,000	1,987,000	3,090,000	6,867,000	37.15
1991	---	---	---	540,000	---	1,250,000	2,166,000	3,483,000	7,439,000	39.30
1992	---	---	---	540,000	---	1,250,000	2,361,000	3,712,000	7,863,000	40.60
1993	---	---	3,891,000	540,000	---	1,620,000	2,574,000	3,963,000	8,697,000	43.85
1994	---	$187,000	---	540,000	$ 33,000	1,620,000	2,805,000	4,520,000	9,518,000	46.90
1995	---	---	---	540,000	33,000	1,620,000	3,058,000	4,818,000	10,069,000	48.50
1996	---	---	5,039,000	540,000	33,000	2,098,000	3,333,000	5,143,000	11,147,000	52.50
1997	---	---	---	540,000	33,000	2,098,000	3,633,000	5,496,000	11,800,000	54.35
1998	---	---	---	540,000	33,000	2,098,000	3,960,000	6,213,000	12,844,000	57.90
1999	---	---	6,525,000	540,000	33,000	2,717,000	4,316,000	7,071,000	14,677,000	64.70
2000	---	---	---	540,000	33,000	2,717,000	4,705,000	7,529,000	15,524,000	67.00
2001	---	---	---	540,000	33,000	2,717,000	5,128,000	8,028,000	16,446,000	69.50
2002	---	---	8,450,000	540,000	33,000	3,518,000	5,590,000	8,573,000	18,254,000	75.50
2003	---	---	---	540,000	33,000	3,518,000	6,093,000	9,166,000	19,350,000	78.40
2004	---	---	---	---	---	3,518,000	6,641,000	10,485,000	20,644,000	82.00
TOTALS	$4,693,500	$187,000	$29,230,000	$10,800,000	$330,000	$36,507,000	$67,266,000	$105,359,000	$220,262,000	
1984 $**	$4,693,500	$ 79,000	$10,817,000	$ 5,400,000	$100,000	$12,400,000	$24,900,000	$ 39,400,000	$ 82,200,000	

*Exclusive of haul road improvement costs. If haul road improvement costs are incorporated, add $0.75/ton to the initial year costs for material landfilled. Initial capital needs would increase by $1,050,000 to $5,743,500. Total project debt service would be increased by $2,400,000 to $13,200,000. Total project cost also would increase by $2,400,000 to $222,662,000. To determine the increase for any year to the $/ton column, divide $120,000 (which represents the annual cost of the $1,050,000 increase in initial capital) by the appropriate tonnage for that year. For example, for the year 1994: $120,000/202,900 tons landfilled is equivalent to approximately $0.60/ton. Add this to $39.20 and the result is $39.80.

**Totals in 1984 Dollars as determined via a "present worth" analysis.

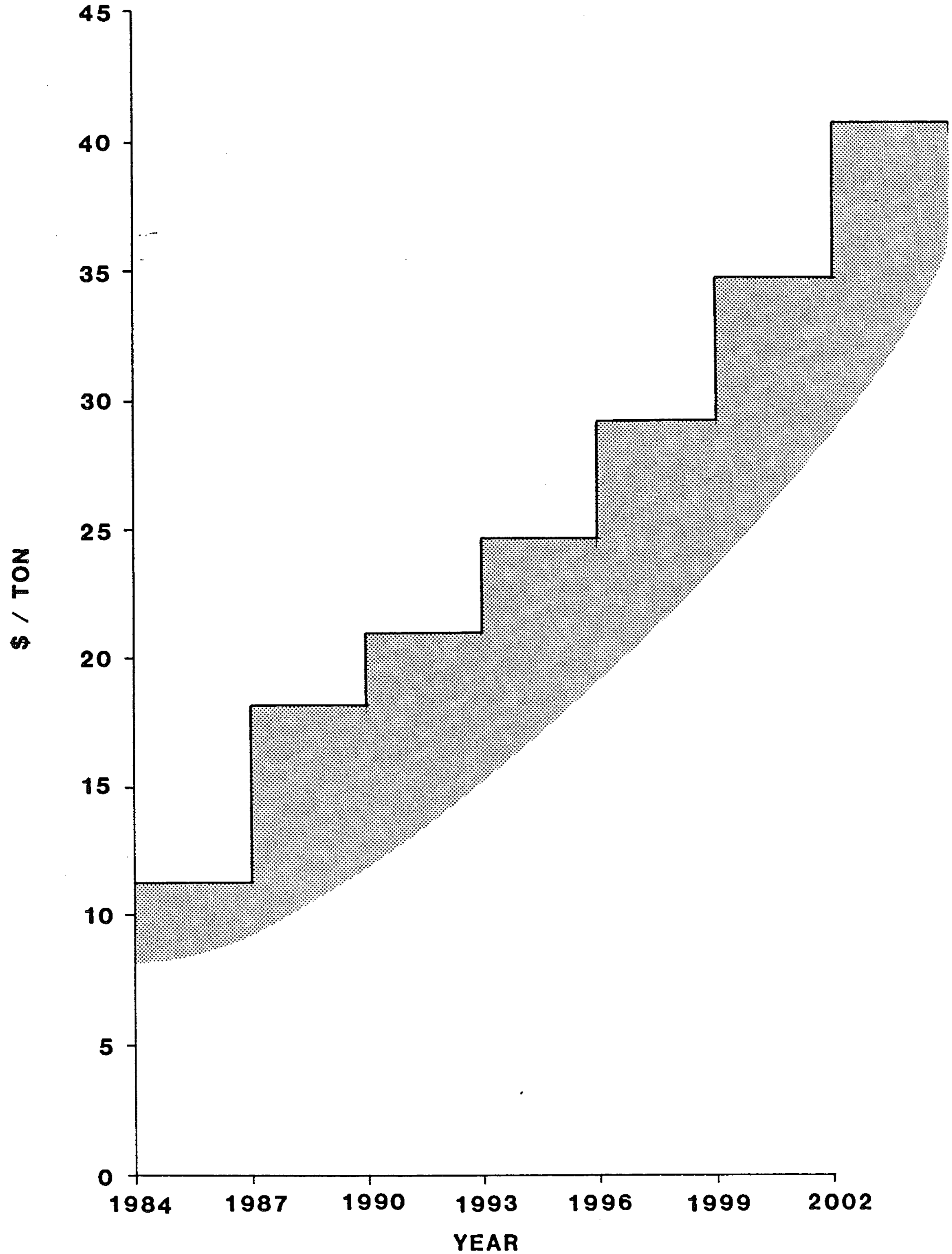


FIGURE 5.5-1
ROBERTS FARM
ESTIMATED COST ($ / TON)
FOR LANDFILLING

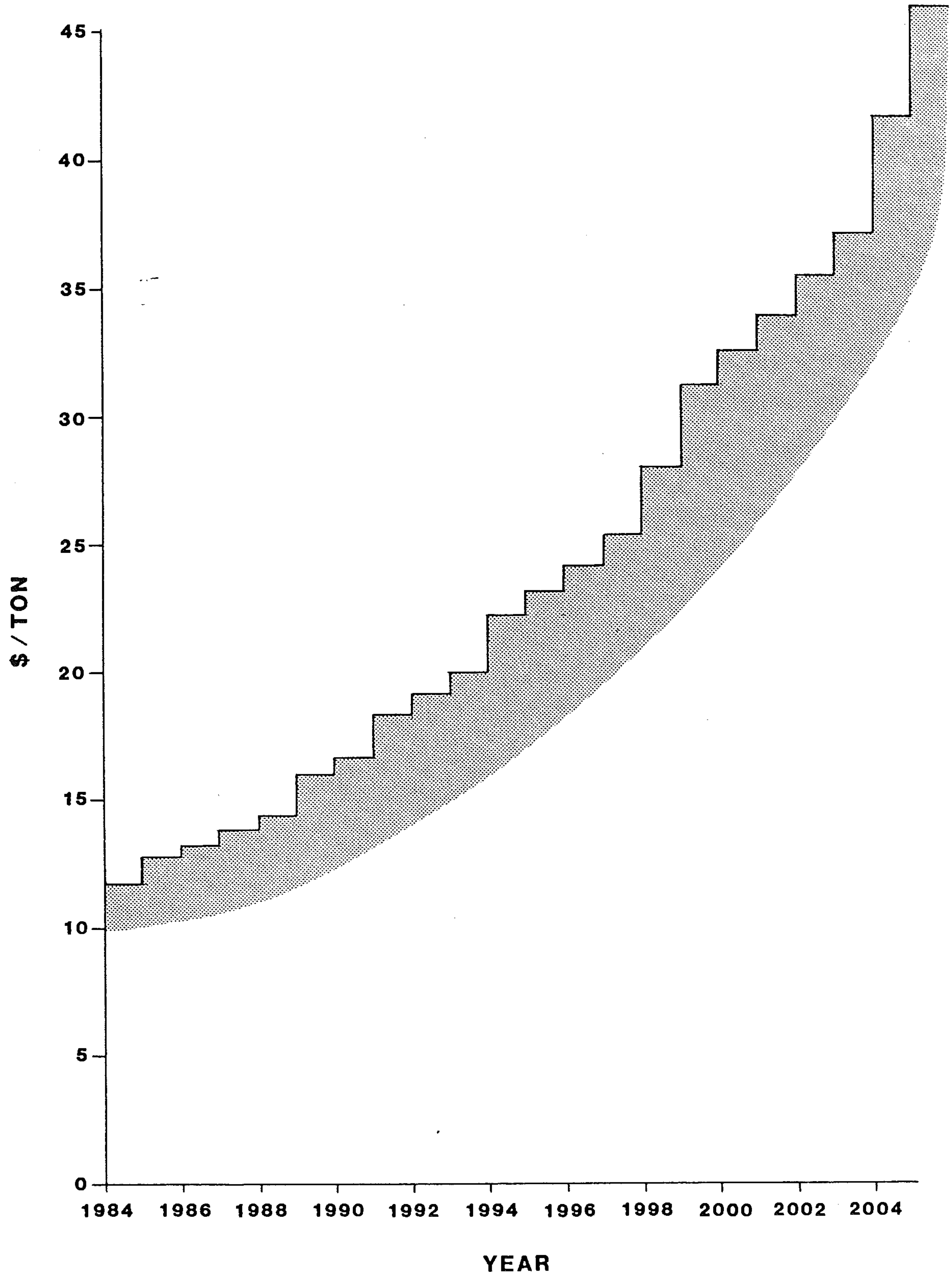


FIGURE 5.5-2
ROBERTS FARM
ESTIMATED COST ($ / TON)
FOR HAULING

APPENDIX 5A

GEOLOGIC LOGS

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

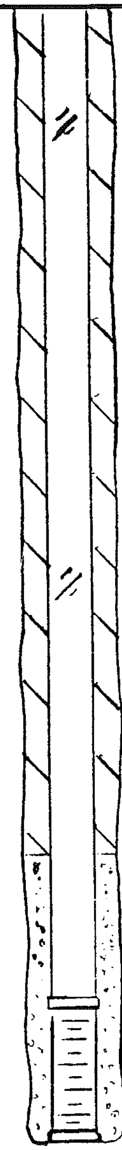
SHEET 1 OF 1

PROJECT: DSWA W.O. 06-7390-002 SITE AREA Robert's Farm DRILL HOLE NO. P-1A

CONTRACTOR: C. Wallace COORDINATES ______ ELEVATION 32.5

DRILLER: Delmarva Drilling Co. GWL 0 HRS ______

CLASSIFIED BY: BWB DATE: 7/22/81 24 HRS ______

Depth Ft.	Sample No.	SPT Blows/6 In. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
0					0-2 Cream to Brown silty clay					
					2-4 Brown silty sand - fine to coarse, some gravel.					
					4-10 Cream silty clay with trace of quartz gravel.					
5					10-15 Cream to Light Brown gravelly silty clay with some sand, fine to coarse quartz gravel, trace of glaucomite.					
10										
15					15-20 Rust to Light Brown silty sand, fine to coarse grained, trace of quartz gravel.					
20					20-25 As above.					
					25-30 Dark Rust Brown - fine to coarse sand, some quartz gravel, trace of shells					
25										
30					30-35 Rust Brown silty sand - fine to coarse grained, trace gravel.					
35					35-40 As above.					
40					Total Depth 40'.					
					Notes:					
					1. Set 4' PVC screen 35'-40'					
					2. Gravel pack 30'-40'					
					3. Develope 5 gpm clear					
					4. Bentonite seal 3'-30'					

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 1 OF 1

PROJECT: DSWA W.O. 06-7390-002 SITE AREA Roberts Farm DRILL HOLE NO. P-2A

CONTRACTOR: Delmarva Drilling Co. COORDINATES ______ ELEVATION 345

DRILLER: Al Whitelock GWL 0 HRS 28

CLASSIFIED BY: B.W.B DATE: 7-22-81 24 HRS ______

Depth Ft.	Sample No.	SPT Blows/6 In. (6 / 12 / 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
0					0-5' Interbedded Brown Sand and Lt. Brown clay. Some fine to coarse gravel Sand: fine to medium Clay: medium to highly plastic.					
5					5-10 Cream to Rust Brown silty clay. Trace of sand. Some coarse gravel.					
10					10-15 Cream silty clay. Trace of sand. Some rust silty clay. low to medium plastic.					
15					15-20 Cream to Brown silty clay Little to some sand. Trace of rust silty sand. Low to medium plastic. Trace of gravel.					
20					20-25 As above: more sand.					
25					25-30 Lt. Brown silty sand. Fine to coarse grained with some cream clay. Some fine quartz gravel.					
30					30-35 Rust Brown to Lt. Brown Gravelly sand. Sand: fine to coarse. Gravel: fine, subrounded.					
35					Total Depth 35' Notes: 1. 4" PVC screen (No.16 Slot)30-35 ' 2. Gravel Packed (No.2 Morie)25-35 ' 3. Developed 4. Sealed w/Bentonite 2'-25'					

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

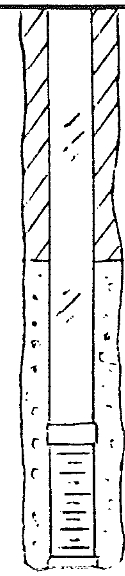
SHEET 1 OF 1

PROJECT: DSWA W.O. 06-7390-002 SITE AREA Roberts Farm DRILL HOLE NO. P-3

CONTRACTOR: Delmarva Drilling Co. COORDINATES ______ ELEVATION 28.5

DRILLER: C. Wallace GWL 0 HRS ______

CLASSIFIED BY: B.W.B. DATE: 7/13/81 24 HRS ______

Depth Ft.	Sample No.	SPT Blows/ 6 In. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
0					0-5 Rust brown clayey sand with some silt, fine to medium grained sand.					
5					5-10 Cream silty clay w/subangular to round gravel and cobbles, some sand.					
10					10-15 Do above, no gravel, trace sand.					
15					15-20 Do above - silty clay cream to brown.					
20					T.D. 20 D'					

Notes:

1. Set 4" PVC screen 15' to 20'
2. Set 4" PVC casing 0-15
3. Gravel pack 9' to 20'
4. Developed - clay prohibited clear development
5. Sealed 2-9'
6. Set protector casing and cap

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 1 OF 1

PROJECT: DSWA W.O. 06-7390-002 SITE AREA ~~Roberts Farm~~

DRILL HOLE NO. P-4

CONTRACTOR: Delmarva Drilling Co. COORDINATES ______

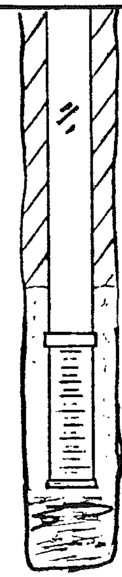
ELEVATION 21.5

DRILLER: Allen Whitelock

GWL 0 HRS 13.0'

CLASSIFIED BY: B.W.B DATE: 7/8/81

24 HRS 10.5'

Depth Ft.	Sample No.	SPT Blows/6 In. (6, 12, 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
0					0-5 Rust - silty sand damp, clayey					
5					5-10 As above moist					
					10-15 As above					
10					13' saturated					
15										
					17'-20' tan clay					
20					T.D. 20'					

Notes:

1. Set screen 12'-17' (4" PVC)
2. 4" Casing 0-12' w/2' stickup
3. Natural gravel pack 10'-17'
4. Sealed 2.5' to 10'
5. Developed 1 gpm

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

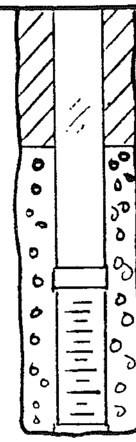
SHEET 1 OF 1

PROJECT: DSWA W.O. 06-7390-007 SITE AREA Roberts Farm DRILL HOLE NO. P-5

CONTRACTOR: Delmarva Drilling Co. COORDINATES ______ ELEVATION 32.0

DRILLER: C. Wallace GWL 0 HRS ______

CLASSIFIED BY: DJS DATE: 7/9/81 24 HRS ______

Depth Ft.	Sample No.	SPT Blows/6 In. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
0					0-5 Rust tan fine med sand w/trace silt					
5					5-10 Cream to yellow tan medium sand with cream clay interbeds					
10					10-15 Grey to black clayey silt to silty clay - Calvert Fm.					
15					T.D. 15.0'					

Notes:

1. Set 5' screen 4" I.D.; No. 16 slot 10'-15'
2. Casing 0-10' (4" PVC)
3. Gravel pack 5-15'
4. Develop - 1 gpm - hole dry
5. Seal 2-5' w/Bentonite
6. Set protector casing and cap

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 1 OF 1

PROJECT: DSWA W.O. 06-7390-002 SITE AREA Roberts Farm

DRILL HOLE NO. P-6A

CONTRACTOR: Delmarva Drilling Co. COORDINATES ______

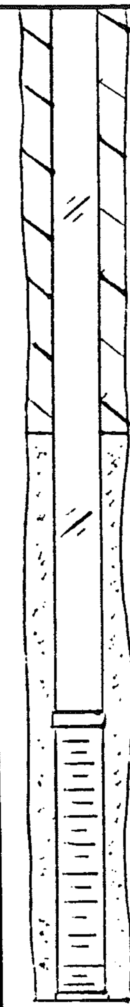
ELEVATION 32.8

DRILLER: C. Wallace

GWL 0 HRS ______

CLASSIFIED BY: BWB DATE: 7-22-81

24 HRS ______

Depth Ft.	Sample No.	SPT Blows/ 6 In. (6, 12, 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
0					0-6 Brown to rust brown - sandy clay to clayey sand, fine to med. sand, trace of cream silty clay.					
5					6-10 Cream silty clay with gravel up to 1.5", trace of sand.					
10					10-15 As above - no gravel.					
15					15-20 As above.					
					20-23 Brown to cream clay, some sand.					
20					23-25 Light brown silty sand, some clay.					
25					25-33 As above.					
30					33-35 Rust brown sand - fine to medium grained, some silt, trace of clay.					
35										

Total Depth 35'

Notes:

1. Set 4" PVC screen 25-35'
2. Gravel packed 15'-35'
3. Developed < 1 gpm
4. Sealed with bentonite 3-15
5. Set protector casing and cup

GAI - 227 9/72

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

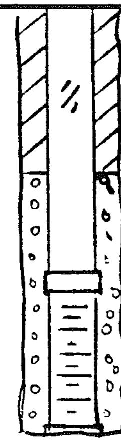
SHEET 1 OF 1

PROJECT: DSWA W.O. 06-7390-002 SITE AREA Roberts Farm DRILL HOLE NO. P-7

CONTRACTOR: Delmarva Drilling Co. COORDINATES ______ ELEVATION 10.3

DRILLER: C. Wallace GWL 0 HRS 7.6'

CLASSIFIED BY: BWB DATE: 7/13/81 24 HRS ______

Depth Ft.	Sample No.	SPT Blows/6 In. (6, 12, 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
0					0-5 Brown silty sand - fine to medium grained with some clay and gravel					
5					5-10 As above					
10					10-15 Rust brown sand fine to coarse grained, trace of quartz gravel.					
15					T.D. 15.0'					

Notes:

1. Set 4" PVC screen (No. 16 slot) from 10-15 feet.
2. Gravel packed 6'-15'.
3. Developed 4 gpm - clear
4. Sealed 2'-6' with bentonite
5. Set protector casing and cap.

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

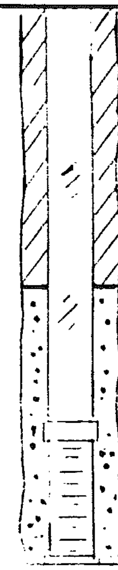
SHEET 1 OF 1

PROJECT: DSWA W.O. 06-7390-002 SITE AREA Roberts Farm DRILL HOLE NO. P-8

CONTRACTOR: Delmarva Drilling Co. COORDINATES ______ ELEVATION 9.6

DRILLER: DJS GWL 0 HRS ______

CLASSIFIED BY: ______ DATE: 7/10/81 24 HRS ______

Depth Ft.	Sample No.	SPT Blows/6 In. (6, 12, 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Soil Or Rock: Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
0					0-5 Light tan to cream inter-layered sand and silty clay					
5					5-10 Cream silty clay w/sandy zones					
10					10-15 As above. Slightly more sand					
15					15-20 Rust tan medium to coarse sand.					
20					T.D. 20'					

Notes:

1. Set 4" I.D. Screen (No. 16 slot) from 15 to 20'
2. Set 4" I.D. PVC casing 0-15'
3. Gravel pack 10-20'
4. Develop 2-3 gpm - clear
5. Seal 2-10' w/bentonite
6. Set protector casing and cap.

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

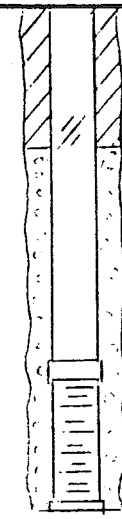
SHEET 1 OF 1

PROJECT: DSWA   W.O. 06-7390-002   SITE AREA Roberts Farm   DRILL HOLE NO. P-9

CONTRACTOR: Delmarva Drilling Co.   COORDINATES ____   ELEVATION 13.8

DRILLER: C. Wallace   GWL 0 HRS ____

CLASSIFIED BY: DJS   DATE: 7/13/81   24 HRS ____

Depth Ft.	Sample No.	SPT Blows/ 6 In. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
0					0-5' Rust brown sand: fine to medium grained, silty, trace of clay.					
5					5-10 Rust brown sand: fine to coarse grained, silty w/ beds of cream clay.					
10					10-18 Rust brown sand: fine to coarse grained with some silty, clayey, trace to some quartz gravel.					
15										
20					T.D. 18.0'					

Notes:

1. Set 4" PVC screen (No. 16 slot) from 13'-18'
2. Gravel packed 5'-18'
3. Developed
4. Sealed w/Bentonite 2'-5'
5. Set protector casing and cap.

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 1 OF 2

PROJECT: DSWA W.O. 06-7390-002 SITE AREA Roberts Farm DRILL HOLE NO. R-1

CONTRACTOR: Delmarva Drilling Co. COORDINATES ____ ELEVATION 32.5

DRILLER: A. Whitelock GWL 0 HRS ____

CLASSIFIED BY: BWB DATE: 7/9/81 24 HRS 20.9 7/10

Depth Ft.	Sample No.	SPT Blows/6 In. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
0					0-2 Cream to brown silty clay					
					2-4 Brown silty sand					
5					5-10 Cream silty clay with trace of quartz gravel					
10					10-15 As above w/gravel and some sand					
15					15-20 Rust to light brown silty sand, fine to coarse, trace of gravel					
20					20-25 As above					
25					25-30 As above - darker color, trace of shells					
					30-35 Rust brown silty sand - fine to coarse grained					
30					35-40 As above					
					40-45 No samples - materials soupy - no return of materials from augers, possibly calvert					
35										
					45-50 As above					
40										
45				Calvert ?						
50										

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

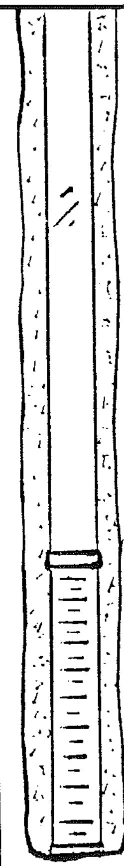
SHEET 2 OF 2

PROJECT: DSWA   W.O. 06-7390-002   SITE AREA Roberts Farm   DRILL HOLE NO. R-1

CONTRACTOR: Delmarva Drilling Co.   COORDINATES ______   ELEVATION 32.5

DRILLER: A. Whitelock   GWL 0 HRS ______

CLASSIFIED BY: BWB   DATE: 7/9/81   24 HRS ______

Depth Ft.	Sample No.	SPT Blows/6 In. (6 / 12 / 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
50					50-55 Gray fine to med. sand with glauconite, trace of silt					
55					55-60 As above					
60					60-65 As above - increase in glauconite					
65					65-70 As above					
70					70-75 As above					
75					75-80 As above					
80										

T.D. - 80.0'

Notes:

1. Set 4' PVC screen from 70'-80'
2. Natural gravel pack 45-80
3. Develop 10-15 gpm, clear
4. Sealed 2-45' w/bentonite

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 1 OF 2

PROJECT: DSWA W.O. 06-7390-002 SITE AREA Roberts Farm

DRILL HOLE NO. R-2

CONTRACTOR: Delmarva Drilling Co. COORDINATES

ELEVATION 35.0

DRILLER: C. Wallace

GWL 0 HRS

CLASSIFIED BY: DJS DATE: 7/9/81

24 HRS

Depth Ft.	Sample No.	SPT Blows/ 6 In. (6 / 12 / 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
0					0-5 Rust tan - fine to med. sand					
5					5-7 Cream to tan silty sandy clay					
					7-10 Gray clayey silt to silty clay					
10					10-15 As above					
15					15-20 As above					
20					20-25 As above					
25					25-30 As above w/trace fine sand					
30					30-35 Gray fine sand w/some silt					
35					35-40 As above - less silt					
40					40-45 Greenish gray silty fine sand					
45					45-50 As above w/glauconite and trace of shells					
50										

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

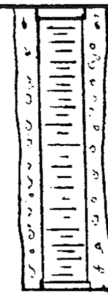
SHEET 2 OF 2

PROJECT: DSWA W.O. 06-7390-002 SITE AREA Roberts Farm DRILL HOLE NO. R-2

CONTRACTOR: Delmarva Drilling COORDINATES ______ ELEVATION 35.0

DRILLER: C. Wallace GWL 0 HRS ______

CLASSIFIED BY: DJS DATE: 7/9/81 24 HRS ______

Depth Ft.	Sample No.	SPT Blows/6 In. (6 / 12 / 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Soil Or Rock: Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
50					50-55 Greenish gray fine to med. sand w/trace to some silt					
55					55-60 As above					
60										
					T.D. - 60'					
					Notes:					
					1. Set 4' screen No. 16 slot from 50 to 60					
					2. Gravel pack 45-60 No. 2 gravel					
					3. Develop 5-10 gpm about clear					
					4. Sealed 3-45'					
					5. Set protector casing and cap					

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 1 OF 2

PROJECT: DSWA W.O. 06-7390-002 SITE AREA Roberts Farm

DRILL HOLE NO. R-3

CONTRACTOR: Delmarva Drilling Co. COORDINATES ____________

ELEVATION 9.6

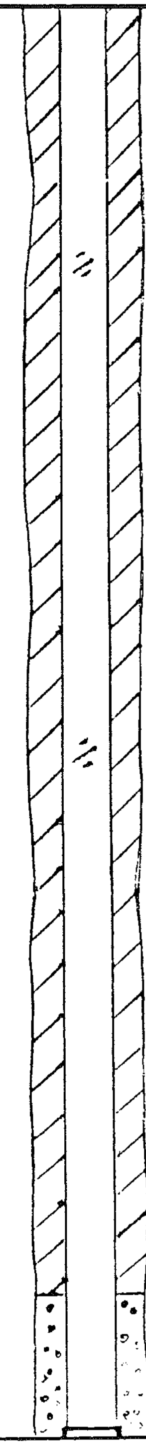
DRILLER: C. Wallace

GWL 0 HRS ____________

CLASSIFIED BY: DJS DATE: 7/10/81

24 HRS ____________

Depth Ft.	Sample No.	SPT Blows/6 In. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Soil Or Rock: Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
0					0-5 Light tan to cream, inter-layered sand and silty clay					
5					5-10 Cream silty clay w/sandy zones					
10					10-15 As above					
15					15-20 Rust tan-medium to coarse sand with fine gravel					
20					20-25 As above with trace silt					
25					25-30 Light brown med. to coarse sand					
30					30-35 Rust tan fine to coarse sand with trace of fine gravel					
35					35-40 As above					
40					40-45 As above					
45					45-50 As above					
50										



GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 2 OF 2

PROJECT: DSWA W.O. 06-7390-002 SITE AREA ~~Roberts Farm~~

DRILL HOLE NO. R-3

CONTRACTOR: Delmarva Drilling Co. COORDINATES

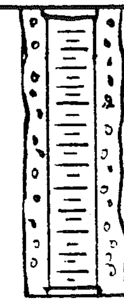
ELEVATION 9.6

DRILLER: C. Wallace

GWL 0 HRS

CLASSIFIED BY: DJS DATE: 7/10/81

24 HRS

Depth Ft.	Sample No.	SPT Blows/6 In. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
50					50-55 Rust tan fine to coarse sand with trace of fine gravel					
55					55-60 Tan; fine to medium sand					
60					T.D. - 60'					

Notes:

1. Calvert & Rancocas Absent
2. Set 4" PVC Screen (No. 16 flot) from 50' - 60'
3. Casing 0-50' - 4" PVC
4. Gravel pack 45'-60'
5. Develop 20 gpm of clear water
6. Seal 2-45' w/bentonite
7. Protector casing & cap

Bolton Farm Well (20 Deep)

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 1 OF 3

PROJECT: DSWA W.O. 06-7390-002 SITE AREA Roberts Farm DRILL HOLE NO. ML-1

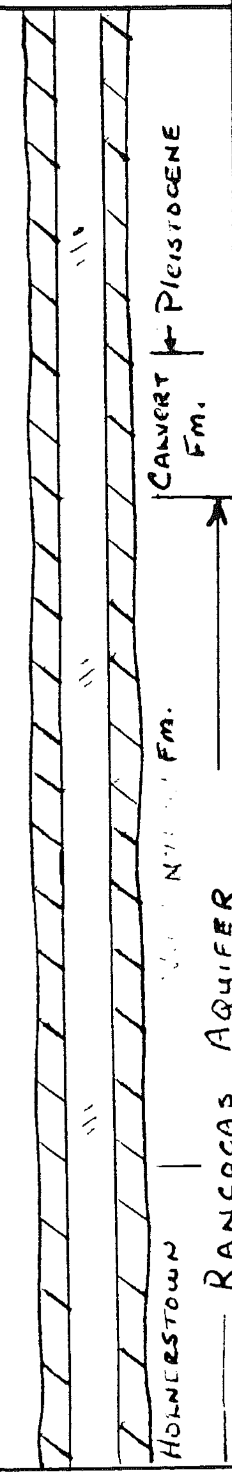
CONTRACTOR: Delmarva Drilling Co. COORDINATES ______ ELEVATION 45.0

DRILLER: C. Wallace GWL 0 HRS ______

CLASSIFIED BY: DJS/BWB DATE: 7/9/81 24 HRS ______

Depth Ft.	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories
0-5	Brown silty clay with fine to medium sand
5-10	Rust tan fine to medium sand, trace of silt
10-22	Cream to brown silty clay to clayey silt with some fine sand
22-34	Gray to black clayey silt to silty clay, slightly micaceous, low to medium plastic
35-40	Green, gray and white fine to coarse sand, some glauconite, some silt
45-50	As above
50-55	As above-increased glauconite
55-60	As above with abundant shell fragments, some gravel
60-65	Increased shell fragments
65-70	As above
70-80	As above, more silt at 80'
80-90	Green, gray silty sand, few shell fragments, no gravel
90-95	Abundant shell fragments
95-100	As above

REMARKS (Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.):



SOIL AND ROCK CLASSIFICATION SHEET

SHEET 2 OF 3

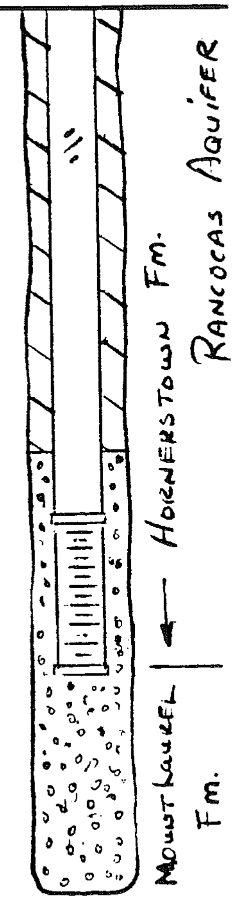
PROJECT: DSWA W.O. 06-7390-002 SITE AREA Roberts Farm DRILL HOLE NO. ML-1

CONTRACTOR: Delmarva Drilling Co. COORDINATES ____ ELEVATION 45.0

DRILLER: C. Wallace GWL 0 HRS ____

CLASSIFIED BY: DJS/BWB DATE: 7/9/81 24 HRS ____

Depth Ft.	Sample No.	SPT Blows/6 In. (6, 12, 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
100					100-110 As above					
110					110-120 As above					
					120-130 As above, few shell fragments					
120										
					130-140 As above - well sorted fine to medium sand					
130										
140					140-145 As above					
					145-150 Dark gray to black, glauconitic, silty sand, some shell fragments					
150					150-155 As above					
					155-160 Black sandy clay, abundant shell fragments					
160										



Total Depth 160'

Drilling Notes:

1. Set 4" PVC screen 135 to 145 feet
2. Gravel packed from 130 to 160 feet
3. Developed 20 gpm clear
4. Bentonite seal 2-130'
5. Install protector casing and cap

GIBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 3 OF 3

PROJECT: DSWA W.O. 06-7390-002 SITE AREA Roberts Farm DRILL HOLE NO. ML-1

CONTRACTOR: Delmarva Drilling Co. COORDINATES ______ ELEVATION ______

DRILLER: C. Wallace GWL 0 HRS ______

CLASSIFIED BY: DJS DATE: 7/9/81 24 HRS ______

Depth Ft.	Sample No.	SPT Blows/ 6 In. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
							Notes: Single Point Electric Log					
							1. Mr. Ken Woodruff - Dela. Geol. Survey Logger					
							2. Formation Breaks from Log					
							a. Pleistocene 0-22					
							b. Calvert 22-34					
							c. Rancocas Vincetown 34-80 Hornerstown 80-145					
							d. Mount Laurel 145-160+					

APPENDIX 5B

GEOPHYSICAL LOG

WELL ML-1
OWNER DEL. SOLID WASTE AUTH.
LOCATION ROBERTS FARM

DELAWARE GEOLOGICAL SURVEY

ELECTRIC LOG

WELL Fe53-1
OWNER Delaware Solid Waste Authority
AREA Odessa
COUNTY New Castle STATE
EQUIP. USED: Logmaster

COORDINATES:
N
ELEVATION:
D.F.
K.B.
G.L. 40'
LOG MEASURED FROM G.L., FT. ABOVE G.L.

	RUN NO. 1	RUN NO. 2	RUN NO. 3
DATE	7/8/81		
FIRST READING	161		
LAST READING	10'		
FOOTAGE LOGGED	151'		
BOTTOM (DRILLER)	160		
CASING (FROM LOG)	none at time		
CASING (DRILLER)			
CASING SIZE			
BIT SIZE:			
BIT SIZE:			

SURFACE TEMP.: AT R_m:

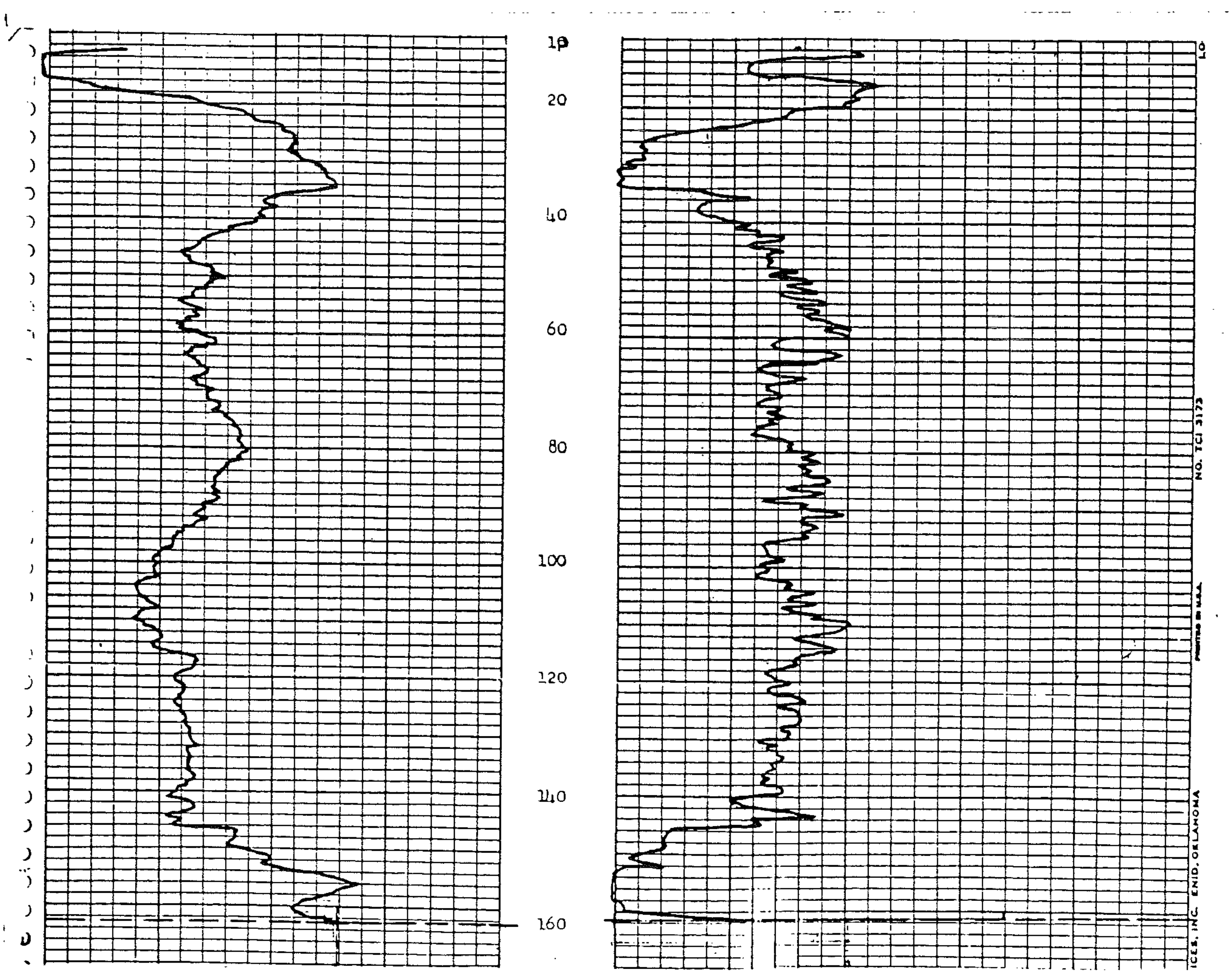
LOGGED BY Woodruff WITNESSED BY Stanislawczyk

REMARKS

POTENTIAL + 25 mv/inch

TEMPERATURE LOG °F/inch

RESISTIVITY
Single point ohms/inch
16" normal ohm-m/inch
64" normal ohm-m/inch
6' lateral ohm-m/inch
Differential S.P. 10 ohms/inch



APPENDIX 5C

GRAIN SIZE ANALYSES

Gilbert/Commonwealth engineers and consultants

LABORATORY SERVICES

GILBERT ASSOCIATES, INC., P. O. Box 1498, Reading, PA 19603/Tel. 215 775-2600

CERTIFICATE OF ANALYSIS

LABORATORY NO: 11474 RECEIVED: 7/24/81 REPORTED: 8/10/81

CLIENT: Delaware Solid Waste Auth - WO 06-7390-002

SAMPLE DESCRIPTION: Soil Samples
Robert's Farm Site R-1 (5')
Sampled 7/24/81

\- - - - - - - - -

PARTICLE SIZE DETERMINATION
SIEVE ANALYSIS

Sieve Size	% Retained
4 Mesh	38.7
10 "	2.5
18 "	2.1
30 "	3.5
50 "	11.9
100 "	10.3
200 "	5.2
Pass 200 "	25.8

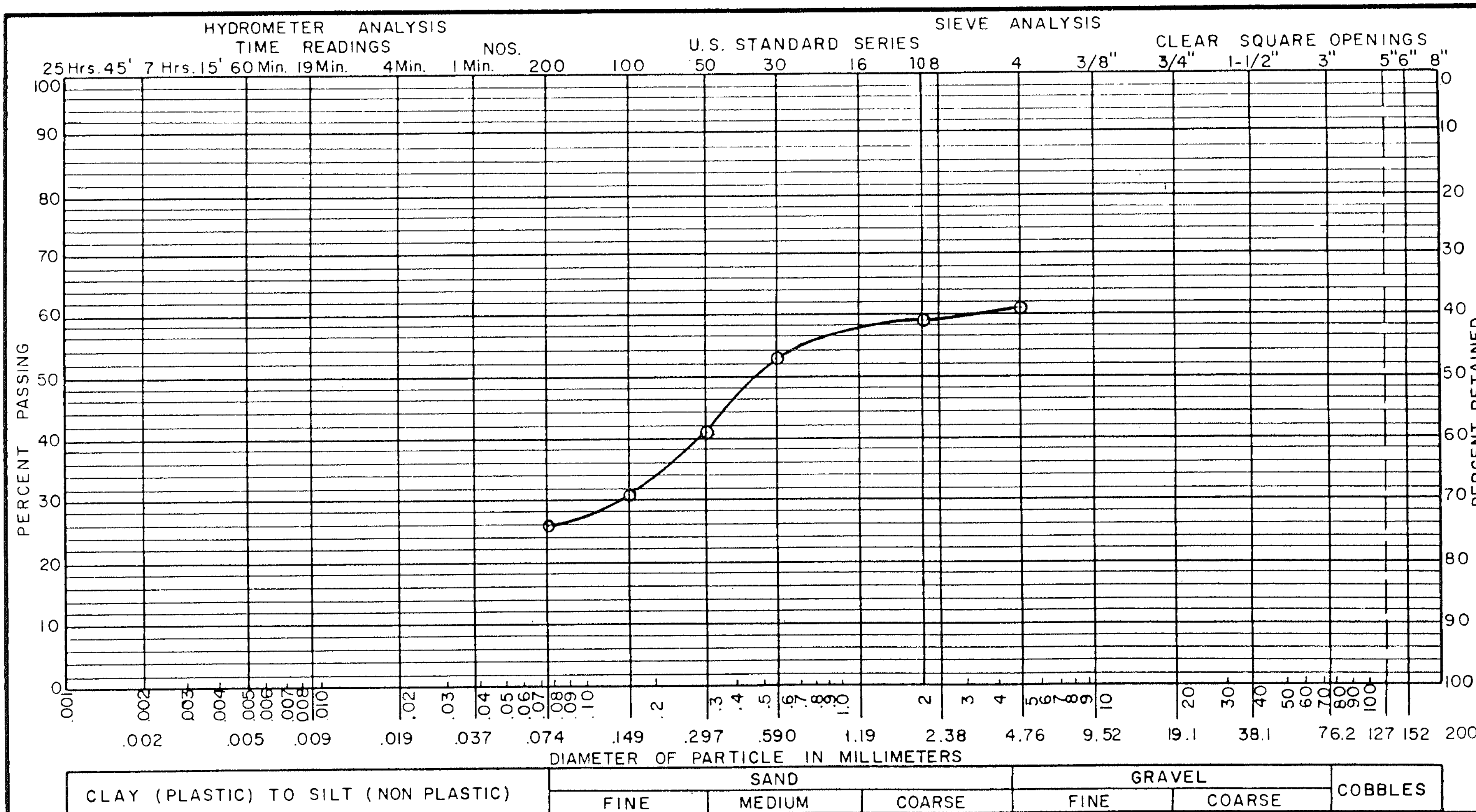
Respectfully submitted,

C. J. Wummer, Supervisor
Laboratory Services

MAH

cc: D. Stanislaw (2)

ROBERTS FARM SITE
WELL NO. R-1
GRADATION CURVES



Sample No.	Elev. or Depth	Classification	Nat WC	LL	PL	PI	
	5 ft.	Silty sand and gravel					

GILBERT ASSOCIATES, INC.
GRADATION TEST

Gilbert/Commonwealth engineers and consultants
LABORATORY SERVICES
GILBERT ASSOCIATES, INC., P. O. Box 1498, Reading, PA 19603/Tel. 215 775-2600

CERTIFICATE OF ANALYSIS

LABORATORY NO: 11475 RECEIVED: 7/24/81 REPORTED: 8/10/81

CLIENT: Delaware Solid Waste Auth - WO 06-7390-002

SAMPLE DESCRIPTION: Soil Samples
Robert's Farm Site R-1 (10')

\- - - - - - - -

PARTICLE SIZE DETERMINATION
SIEVE ANALYSIS

Sieve Size	% Retained
4 Mesh	0.0
10 "	2.3
18 "	2.8
30 "	8.8
50 "	14.0
100 "	13.0
200 "	11.6
Passing 200 Mesh	47.5

HYDROMETER ANALYSIS

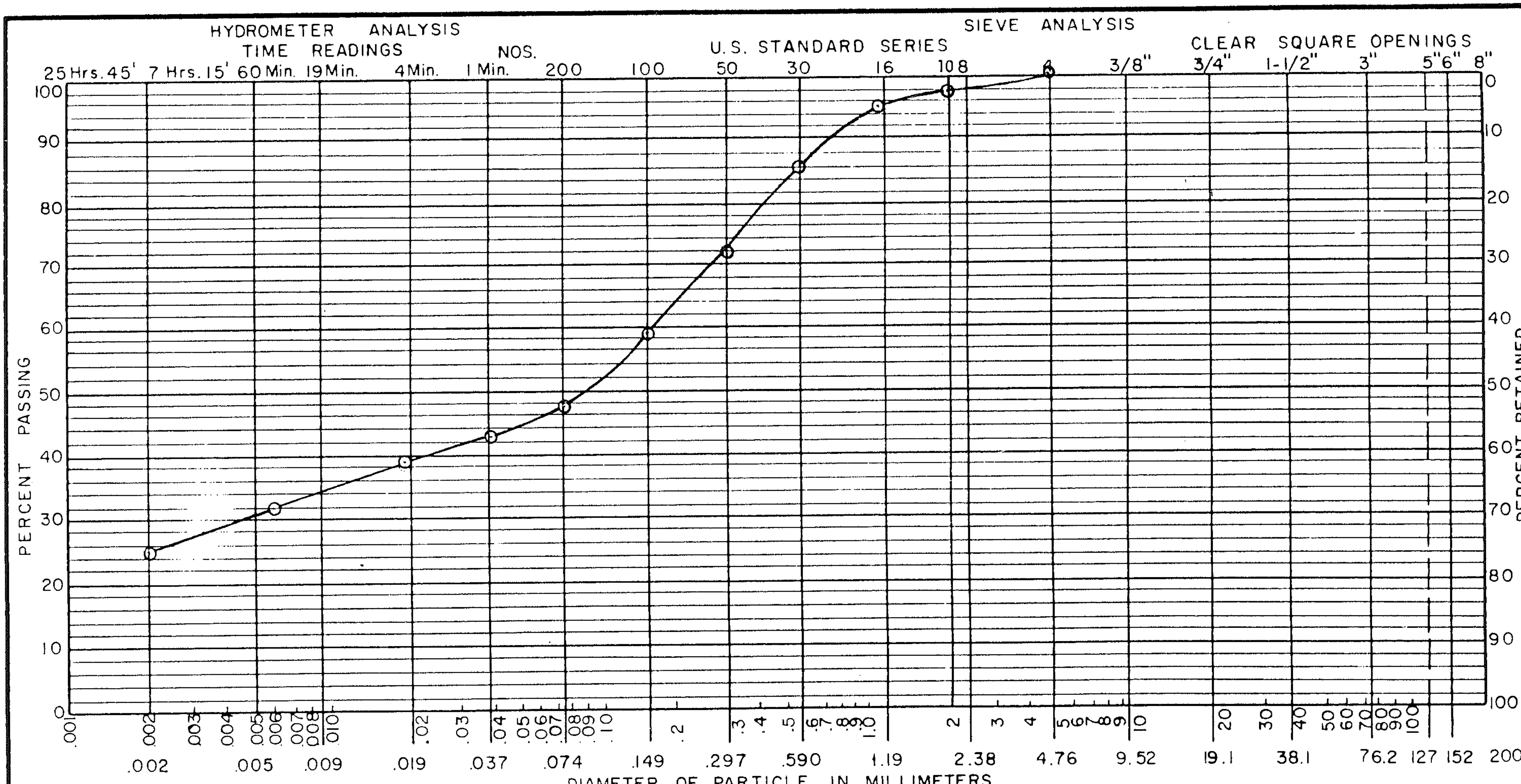
Diameter (mm)	% Passing
0.074	47.5
0.038	43.2
0.018	39.1
0.006	32.0
0.002	25.1

Respectfully submitted,

C. J. Wummer, Supervisor
Laboratory Services

MAH
cc: D. Stanislaw (2)

ROBERTS FARM SITE
WELL NO. R-1
GRADATION CURVE



CLAY (PLASTIC) TO SILT (NON PLASTIC)	SAND			GRAVEL		COBBLES
	FINE	MEDIUM	COARSE	FINE	COARSE	

Sample No.	Elev. or Depth	Classification	Nat WC	LL	PL	PI
	10 ft.	Silty clay and sand				

GILBERT ASSOCIATES, INC.
GRADATION TEST

Gilbert/Commonwealth engineers and consultants

LABORATORY SERVICES

GILBERT ASSOCIATES, INC., P. O. Box 1498, Reading, PA 19603/Tel. 215 775-2600

CERTIFICATE OF ANALYSIS

LABORATORY NO: 11476   RECEIVED: 7/24/81   REPORTED: 8/10/81

CLIENT: Delaware Solid Waste Auth - WO 06 7390-002

SAMPLE DESCRIPTION: Soil Samples
Robert's Farm Site R-2 (5')
Sampled 7/24/81

\- - - - - -

PARTICLE SIZE DETERMINATION
SIEVE ANALYSIS

Sieve Size	% Retained
4 Mesh	0.0
10 "	2.1
18 "	13.2
30 "	21.3
50 "	38.6
100 "	19.7
200 "	1.6
Pass No. 200 Mesh	3.5

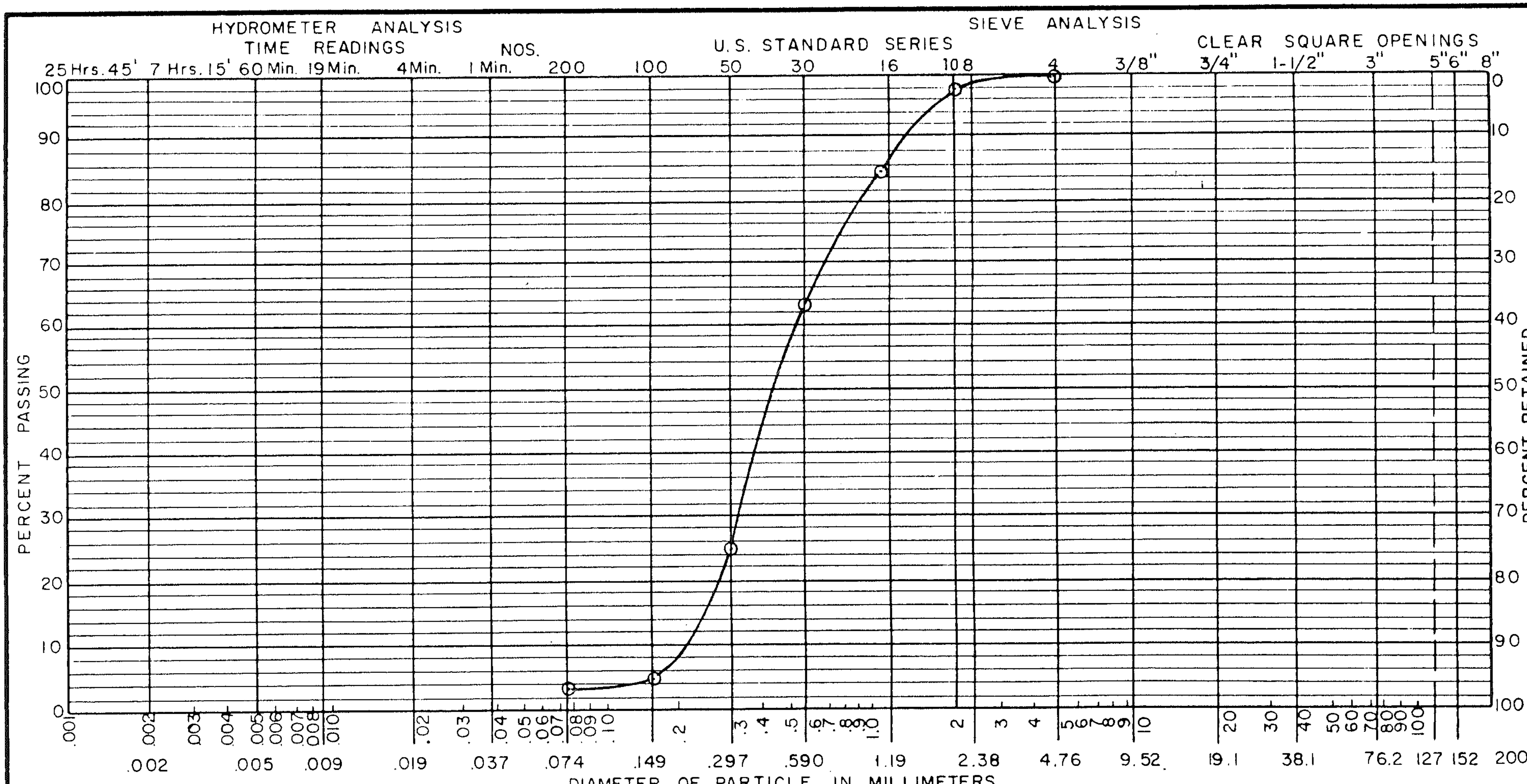
Respectfully submitted,

C. J. Wummer, Supervisor
Laboratory Services

MAH

cc: D. Stanislaw (2)

ROBERTS FARM
WELL NO. R-2
GRADATION CURVE



CLAY (PLASTIC) TO SILT (NON PLASTIC)	SAND			GRAVEL		COBBLES
	FINE	MEDIUM	COARSE	FINE	COARSE	

Sample No.	Elev. or Depth	Classification	Nat WC	LL	PL	PI	
	5 ft.	Fine to medium sand					

GILBERT ASSOCIATES, INC.
GRADATION TEST

Gilbert/Commonwealth engineers and consultants
GILBERT ASSOCIATES, INC., P. O. Box 1498, Reading, PA 19603/Tel. 215 775-2600

LABORATORY SERVICES

CERTIFICATE OF ANALYSIS

LABORATORY NO: 11470 RECEIVED: 7/24/81 REPORTED: 8/6/81

CLIENT: Delaware Solid Waste Auth - WO 06-7390-002

SAMPLE DESCRIPTION: Soil Samples
Robert's Farm Site P-3 (5')

- - - - - - - - - - -

PARTICLE SIZE DETERMINATION
SIEVE ANALYSIS

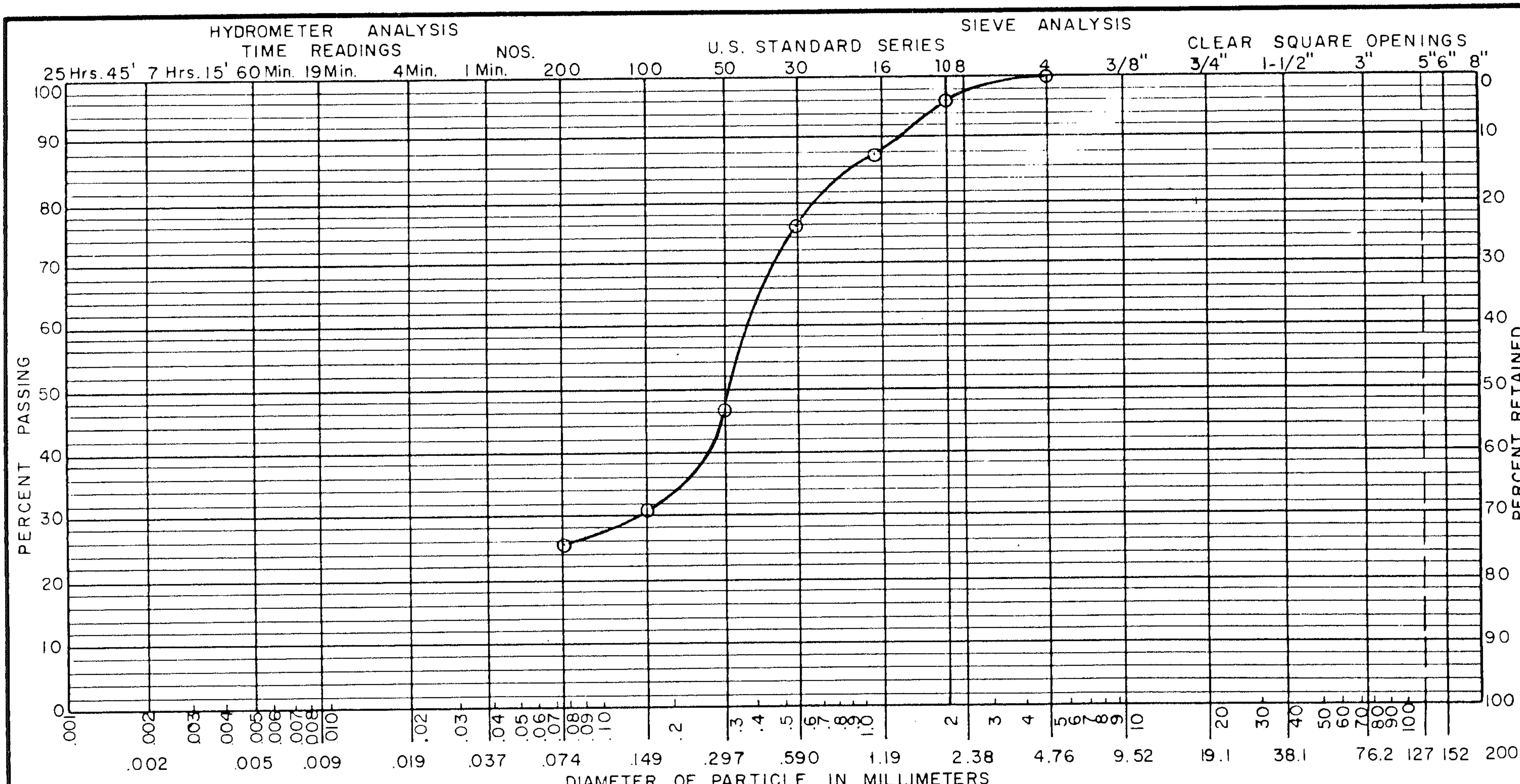
Sieve Size	% Retained
4 Mesh	1.0
10 "	2.9
18 "	7.4
30 "	12.7
50 "	29.8
100 "	14.9
200 "	5.6
Pass 200 Mesh	25.7

Respectfully submitted,

C. J. Wummer, Supervisor
Laboratory Services

MAH
cc: D. Stanislaw (2)

ROBERTS FARM
WELL NO. P-3
GRADATION CURVE



CLAY (PLASTIC) TO SILT (NON PLASTIC)	SAND			GRAVEL		COBBLES
	FINE	MEDIUM	COARSE	FINE	COARSE	

Sample No.	Elev. or Depth	Classification	Nat WC	LL	PL	PI
	5 ft.	Silty fine to medium sand				

GILBERT ASSOCIATES, INC.
GRADATION TEST

Gilbert/Commonwealth engineers and consultants

LABORATORY SERVICES

GILBERT ASSOCIATES, INC., P. O. Box 1498, Reading, PA 19603/Tel. 215 775-2600

CERTIFICATE OF ANALYSIS

LABORATORY NO: 11471 RECEIVED: 7/24/81 REPORTED: 8/6/81

CLIENT: Delaware Solid Waste Auth - WO 06-7390-002

SAMPLE DESCRIPTION: Soil Samples
Robert's Farm Site P-4 (5')

\- - - - - -

PARTICLE SIZE DETERMINATION
SIEVE ANALYSIS

Sieve Size	% Retained
4 Mesh	0.0
10 "	0.0
18 "	1.0
30 "	3.8
50 "	16.3
100 "	10.9
200 "	7.0
Pass 200 "	61.0

HYDROMETER ANALYSIS

Diameter (mm)	% Passing
0.074	61.0
0.038	58.0
0.018	40.4
0.006	25.0
0.002	19.2

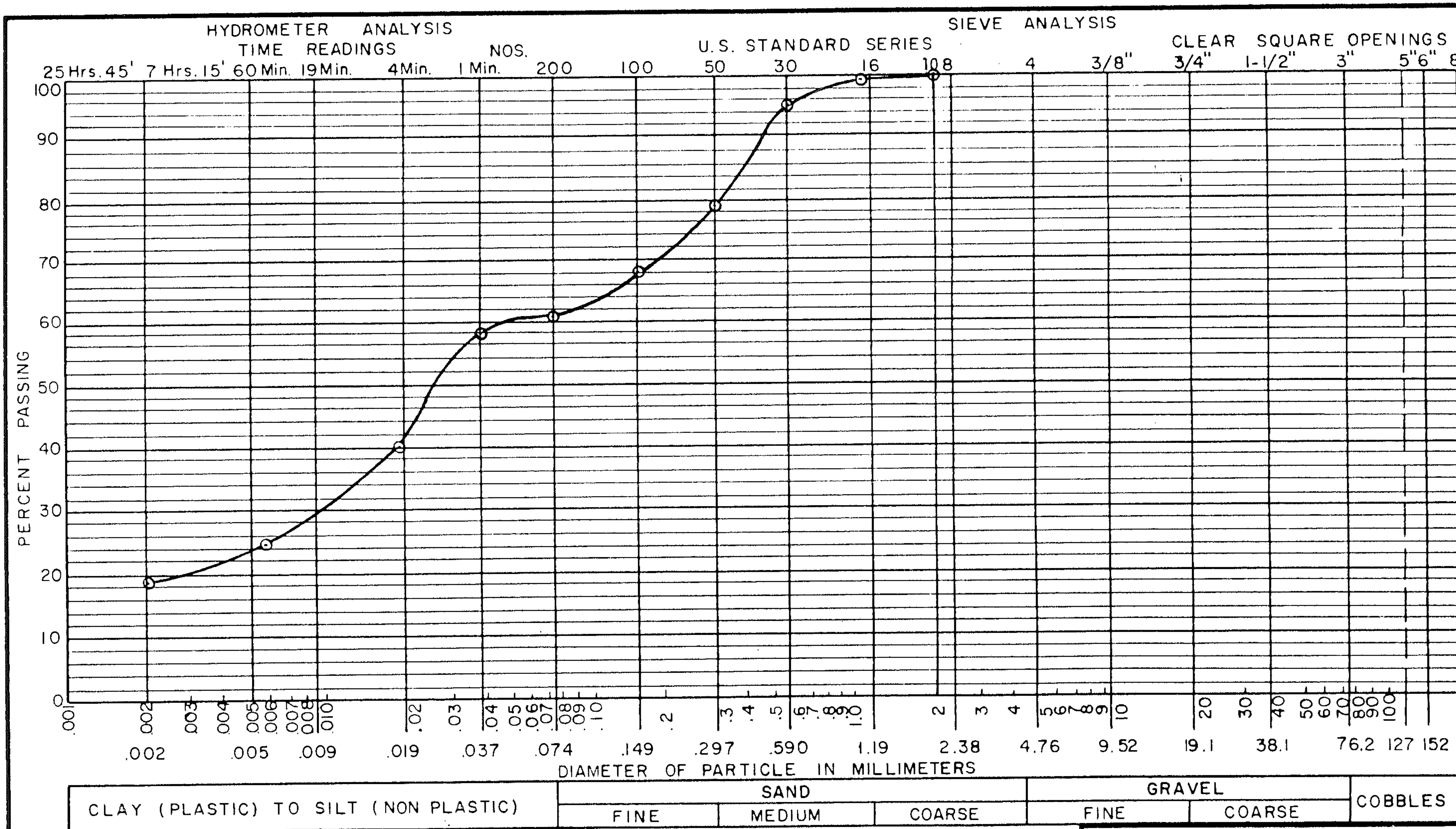
Respectfully submitted,

C. J. Wummer

C. J. Wummer, Supervisor
Laboratory Services

MAH
cc: D. Stanislaw (2)

ROBERTS FARM
WELL NO. P-4
GRADATION CURVE



Sample No.	Elev. or Depth	Classification	Nat WC	LL	PL	PI
	5 ft.	Sandy clayey silt				

GILBERT ASSOCIATES, INC.
GRADATION TEST

Gilbert/Commonwealth engineers and consultants
LABORATORY SERVICES
GILBERT ASSOCIATES, INC., P. O. Box 1498, Reading, PA 19603/Tel. 215 775-2600

CERTIFICATE OF ANALYSIS

LABORATORY NO: 11472 RECEIVED: 7/24/81 REPORTED: 8/6/81

CLIENT: Delaware Solid Waste Auth - WO 06 7390 002

SAMPLE DESCRIPTION: Soil Analysis
Roberts Farm Site P-6 (5')

- - - - - - - -

PARTICLE SIZE DETERMINATION
SIEVE ANALYSIS

Sieve Size	% Retained
4 Mesh	6.7
10 "	5.5
18 "	8.0
30 "	12.6
50 "	21.1
100 "	10.2
200 "	7.3
Pass200 "	28.6

Respectfully submitted,

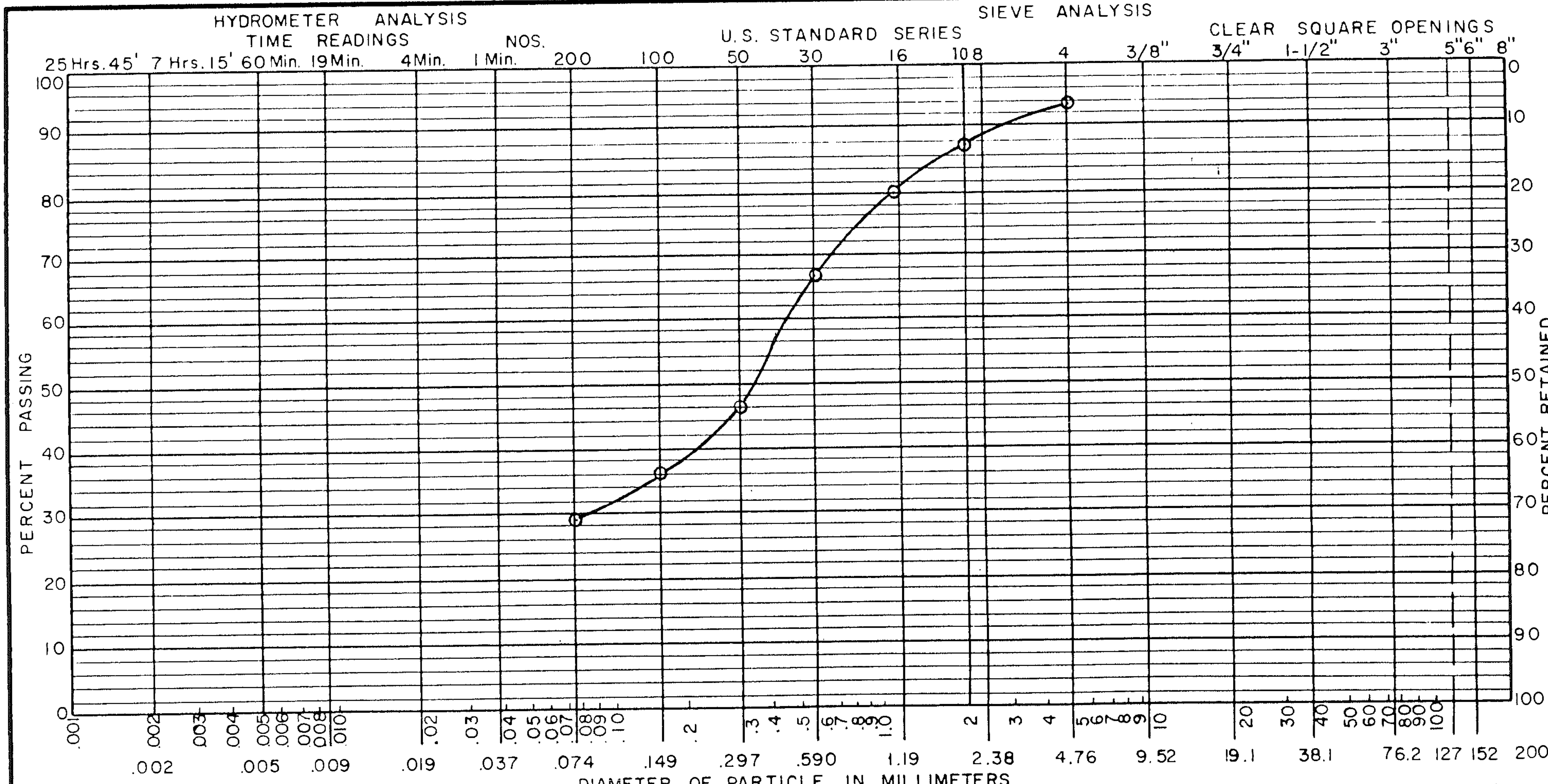
C. J. Wummer

C. J. Wummer, Supervisor
Laboratory Services

MAH

cc: D. Stanislaw (2)

ROBERTS FARM
WELL NO. P-6
GRADATION CURVE



CLAY (PLASTIC) TO SILT (NON PLASTIC)	SAND			GRAVEL		COBBLES
	FINE	MEDIUM	COARSE	FINE	COARSE	

Sample No.	Elev. or Depth	Classification	Nat WC	LL	PL	PI	
	5 ft.	Silty fine to coarse sand					

GILBERT ASSOCIATES, INC.
GRADATION TEST

Gilbert/Commonwealth engineers and consultants
LABORATORY SERVICES
GILBERT ASSOCIATES, INC., P. O. Box 1498, Reading, PA 19603/Tel. 215 775-2600

CERTIFICATE OF ANALYSIS

LABORATORY NO: 11473 RECEIVED: 7/24/81 REPORTED: 8/7/81

CLIENT: Delaware Solid Waste Auth - WO 06 7390-002

SAMPLE DESCRIPTION: Soil Analysis , P-9 (5')
Sampled 7/24/81

- - - - - - - -

PARTICLE SIZE DETERMINATION
SIEVE ANALYSIS

Sieve Size	% Retained
4 Mesh	0.0
10 "	0.0
18 "	0.6
30 "	3.3
50 "	50.2
100 "	37.7
200 "	2.4
Pass 200 "	5.8

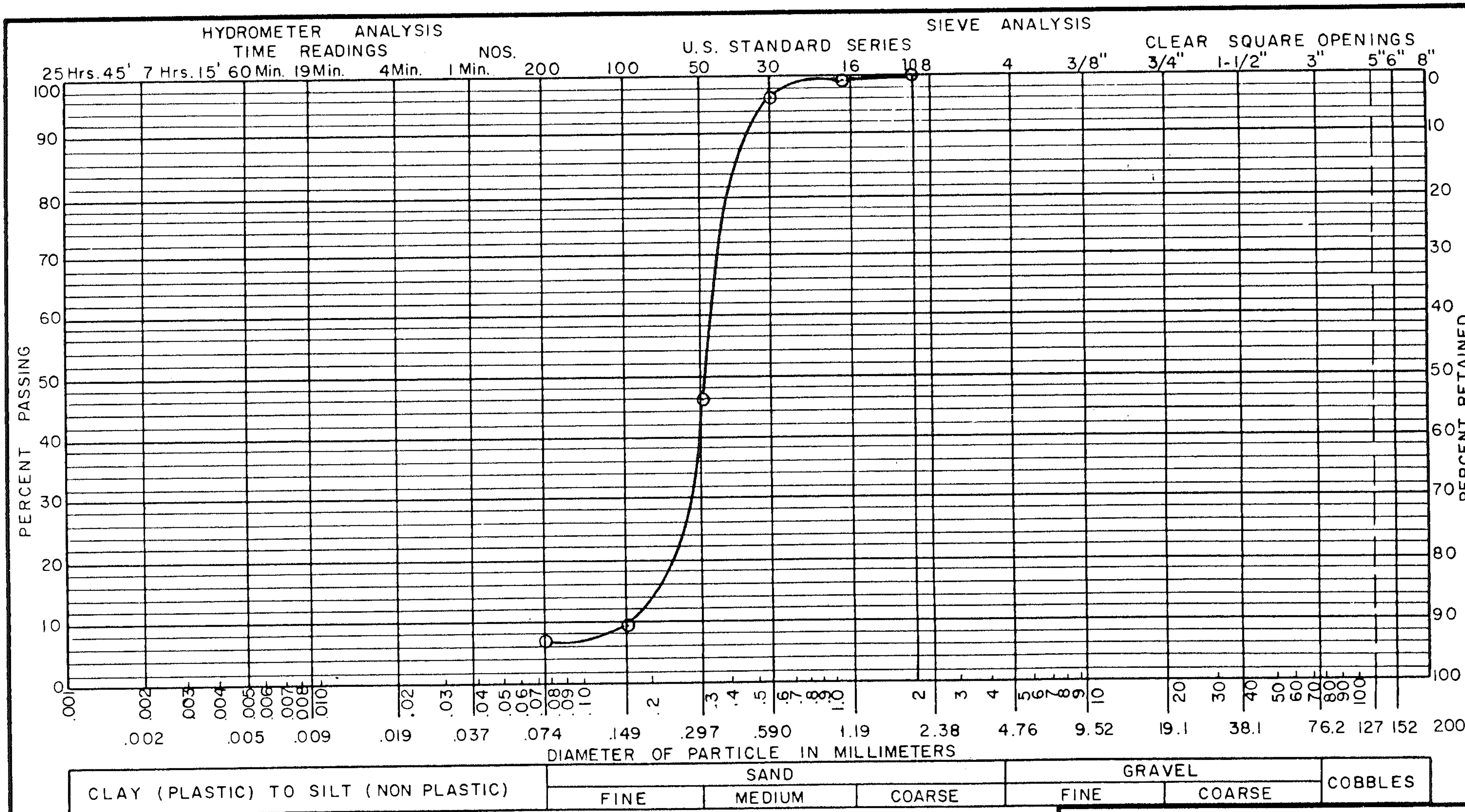
Respectfully submitted,

C. J. Wummer, Supervisor
Laboratory Services

MAH

cc: D. Stanislaw (2)

ROBERTS FARM
WELL NO. P-9
GRADATION CURVE



Sample No.	Elev. or Depth	Classification	Nat WC	LL	PL	PI	
	5 ft.	Fine to medium sand					

GILBERT ASSOCIATES, INC.
GRADATION TEST

APPENDIX 5D
COST PROJECTIONS

TABLE D-1

ROBERTS FARM SITE: PROJECTED OWNING AND OPERATING COSTS AND EQUIVALENT DISPOSAL FEES

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
OPERATING EXPENSES	1185000.	1291649.	1407896.	1534604.	1672717.	1823260.	1987352.	2166210.	2361168.	2573670.	2805299.
DISPOSAL AREA PREPARATION –											
CAPITAL COST	1791500.	0.	0.	2320037.	0.	0.	3004507.	0.	0.	3890912.	0.
ANNUAL FIXED COST	0.	0.	0.	965948.	965948.	965948.	1250927.	1250927.	1250927.	1619981.	1619981.
EQUIPMENT –											
CAPITAL COST	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
ANNUAL FIXED COST	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
OTHER CAPITAL EXPENSES	2823000.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
20-YR AMORTIZATION	534835.	534835.	534835.	534835.	534835.	534835.	534835.	534835.	534835.	534835.	534835.
OTHER CAPITAL EXPENSES	79000.	0.	0.	0.	0.	0.	0.	0.	0.	0.	187020.
10-YR AMORTIZATION	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	33100.
REFUSE GENERATION (TONS)	159000.	163200.	167400.	171700.	176000.	180400.	184800.	189200.	193800.	198300.	202900.
REVENUE DIFF. FROM PREV. YEAR	0.	62760.	65959.	-2.	64030.	67570.	-7.	90824.	94796.	-9.	146720.
TOTAL ANNUAL EXPENSES	1719835.	1826484.	1942731.	3035386.	3173499.	3324042.	3773114.	3951972.	4146930.	4728486.	4993214.
NORMALIZED FEE ($/TON)	11.21	11.21	11.21	18.05	18.05	18.05	20.91	20.91	20.91	24.59	24.59
REVENUE GENERATED	1782595.	1829683.	1876770.	3099418.	3177039.	3256465.	3863945.	3955944.	4052125.	4875215.	4988307.
DIFFERENCE	62760.	65959.	-2.	64030.	67570.	-7.	90824.	94796.	-9.	146720.	141813.
ACTUAL TIPPING FEE ($/TON)	10.82	11.19	11.61	17.68	18.03	18.43	20.42	20.89	21.40	23.85	24.61
LEVELIZED TIPPING FEE ($/TON) *	10.82	11.00	11.19	12.65	13.59	14.27	14.98	15.56	16.05	16.62	17.12

NOTES : (1) 20-YEAR AMORTIZATION OF CAPITAL AT LONG TERM BOND RATE OF 9.56 PCT
(2) DISCOUNT RATE FOR LEVELIZING ASSUMED TO BE EQUAL TO BOND RATE
(3) OTHER CAPITAL AMORTIZED AT 12.00 PCT
(4) CAPITAL ESCALATED AT 9.00 PCT/YEAR
(5) EXPENSES ESCALATED AT 9.00 PCT/YEAR

*A levelized cost is the constant annual cost equivalent to an escalating actual cost stream.

TABLE D-1 (CONT.)

ROBERTS FARM SITE: PROJECTED OWNING AND OPERATING COSTS AND EQUIVALENT DISPOSAL FEES

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
OPERATING EXPENSES	3057771.	3332968.	3632930.	3959892.	4316275.	4704738.	5128160.	5589689.	6092752.	6641096.	7238786.
DISPOSAL AREA PREPARATION –											
CAPITAL COST	0.	5038829.	0.	0.	6525407.	0.	0.	8450572.	0.	0.	10943701.
ANNUAL FIXED COST	1619981.	2097917.	2097917.	2097917.	2716854.	2716854.	2716854.	3518397.	3518397.	3518397.	4556411.
EQUIPMENT –											
CAPITAL COST	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
ANNUAL FIXED COST	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
OTHER CAPITAL EXPENSES	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
20-YR AMORTIZATION	534835.	534835.	534835.	534835.	534835.	534835.	534835.	534835.	534835.	0.	0.
OTHER CAPITAL EXPENSES	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
10-YR AMORTIZATION	33100.	33100.	33100.	33100.	33100.	33100.	33100.	33100.	33100.	0.	0.
REFUSE GENERATION (TONS)	207600.	212300.	217100.	221900.	226800.	231700.	236700.	241700.	246800.	251900.	257100.
REVENUE DIFF. FROM PREV. YEAR	141813.	-17.	169477.	178471.	-34.	229742.	240240.	-47.	122043.	-52184.	-76.
TOTAL ANNUAL EXPENSES	5245686.	5998819.	6298781.	6625743.	7601063.	7989526.	8412948.	9676020.	10179083.	10159493.	11795197.
NORMALIZED FEE ($/TON)	24.59	29.05	29.05	29.05	34.53	34.53	34.53	40.54	40.54	40.54	45.88
REVENUE GENERATED	5103856.	6168313.	6307775.	6447238.	7830839.	8000024.	8172661.	9798110.	10004856.	10211601.	11795196.
DIFFERENCE	-17.	169477.	178471.	-34.	229742.	240240.	-47.	122043.	-52184.	-76.	-77.
ACTUAL TIPPING FEE ($/TON)	25.27	28.26	29.01	29.86	33.51	34.48	35.54	40.03	41.24	40.33	45.88
LEVELIZED TIPPING FEE ($/TON)*	17.58	18.11	18.59	19.04	19.55	20.04	20.49	21.00	21.49	21.90	22.38

NOTES : (1) 20-YEAR AMORTIZATION OF CAPITAL AT LONG TERM BOND RATE OF 9.56 PCT
(2) DISCOUNT RATE FOR LEVELIZING ASSUMED TO BE EQUAL TO BOND RATE
(3) OTHER CAPITAL AMORTIZED AT 12.00 PCT
(4) CAPITAL ESCALATED AT 9.00 PCT/YEAR
(5) EXPENSES ESCALATED AT 9.00 PCT/YEAR

*A levelized cost is the constant annual cost equivalent to an escalating actual cost stream.

TABLE D-2

ROBERTS FARM SITE: PROJECTED CONTRACTOR HAULING COSTS AND EQUIVALENT TONNAGE FEES

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
OPERATING EXPENSES -											
O & M	841000.	916689.	999190.	1089115.	1187135.	1293976.	1410433.	1537369.	1675732.	1826546.	1990933.
FUEL COST	194000.	211460.	230491.	251235.	273846.	298492.	325356.	354637.	386554.	421344.	459264.
EQUIPMENT - TRACTORS	852000.	0.	0.	0.	0.	1310900.	0.	0.	0.	0.	2016974.
5-YR AMORTIZATION	254166.	254166.	254166.	254166.	254166.	391063.	391063.	391063.	391063.	391063.	601696.
EQUIPMENT - TRAILERS	675000.	0.	0.	0.	0.	0.	0.	1233917.	0.	0.	0.
7-YR AMORTIZATION	162244.	162244.	162244.	162244.	162244.	162244.	162244.	296585.	296585.	296585.	296585.
CONTRACTOR FEE (35 PCT)	507993.	540595.	576131.	614865.	657086.	751020.	801183.	902879.	962477.	1027438.	1171967.
TOTAL ANNUAL EXPENSES	1959400.	2085151.	2222220.	2371621.	2534473.	2896792.	3090275.	3482531.	3712409.	3962973.	4520445.
TONNAGE HAULED	159000.	163200.	167400.	171700.	176000.	180400.	184800.	189200.	193800.	198300.	202900.
ANNUAL RATE ($/TON)	12.32	12.78	13.27	13.81	14.40	16.06	16.72	18.41	19.16	19.98	22.28
LEVELIZED RATE ($/TON)*	12.32	12.53	12.75	12.96	13.17	13.50	13.79	14.13	14.42	14.70	15.00

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
OPERATING EXPENSES -											
O & M	2170114.	2365423.	2578307.	2810354.	3063280.	3338974.	3639479.	3967028.	4324054.	4713216.	5137400.
FUEL COST	500597.	545651.	594758.	648286.	706631.	770227.	839547.	915105.	997463.	1087234.	1185084.
EQUIPMENT - TRACTORS	0.	0.	0.	0.	3103347.	0.	0.	0.	0.	4774864.	0.
5-YR AMORTIZATION	601696.	601696.	601696.	601696.	925779.	925779.	925779.	925779.	925779.	1424420.	1424420.
EQUIPMENT - TRAILERS	0.	0.	0.	2255634.	0.	0.	0.	0.	0.	0.	4123359.
7-YR AMORTIZATION	296585.	296585.	296585.	542166.	542166.	542166.	542166.	542166.	542166.	542166.	991094.
CONTRACTOR FEE (35 PCT)	1249147.	1333273.	1424971.	1610875.	1833249.	1952001.	2081439.	2222527.	2376311.	2718462.	3058299.
TOTAL ANNUAL EXPENSES	4818139.	5142627.	5496317.	6213377.	7071104.	7529147.	8028409.	8572605.	9165773.	10485498.	11796297.
TONNAGE HAULED	207600.	212300.	217100.	221900.	226800.	231700.	236700.	241700.	246300.	251700.	256800.
ANNUAL RATE ($/TON)	23.21	24.22	25.32	28.00	31.18	32.50	33.92	35.47	37.14	41.66	45.94
LEVELIZED RATE ($/TON)*	15.28	15.54	15.78	16.03	16.29	16.53	16.76	16.96	17.15	17.34	17.54

NOTES -
(1) INTEREST RATE = 15.00
(2) DISCOUNT RATE = 18.00
(3) O&M INFL. RATE = 9.00
(4) FUEL INFL. RATE = 9.00
(5) CAPITAL INFL RATE = 9.00

*A levelized cost is the constant annual cost equivalent to an escalating actual cost stream.

6.0 CHERRY ISLAND

6.1 SITE DESCRIPTION

6.1.1 Location

The proposed Cherry Island site is located in the Northern part of New Castle County on the north shore of the Christina River at its confluence with the Delaware River. As can be seen from Figure 6.2-1, the Wilmington Marine Terminal is located on the opposite shore (southern shore) of the Christina River. Pigeon Point is located approximately 8,000 feet south of the site.

6.1.2 Size and Features

This candidate site comprises a number of parcels of land which together total approximately 500 acres. See Figure 6.2-2. Most of the area under consideration is land reclaimed with dredging spoils. The site continues to be used by the U.S. Army Corps of Engineers for disposal of materials dredged from the river channels serving the Port of Wilmington.

Earthen dikes encircle the site. Another dike bisects the site into two distinct dredge disposal areas referred to as the "Wilmington" Area and the "Edgemoor" Area. The "Wilmington" Area is about 8 to 10 feet lower than the "Edgemoor" Area. The "Edgemoor Area" more precisely defines the areas of interest with regard to this study.

6.1.3 Boundaries/Description of Adjacent Lands

The site is bounded on the east by the Delaware River. On the north it is bounded by the Wilmington Sewage Treatment Plant. The Christina River borders the site on the south; and, on the west, the site is bounded by Interstate 495, the Penn Central (Conrail)

Railroad, and power transmission lines. Reportedly, an area north of the site is occupied by an industrial waste treatment facility and associated landfill areas.

6.1.4 Utilities

Both water and sewer service are available near this candidate site.

6.2 ENGINEERING CONSIDERATIONS

6.2.1 Geology/Hydrogeology

6.2.1.1 General

The following sections of this report detail the geologic and hydrogeologic characteristics of the Cherry Island site. The methodology utilized in preparing this analysis has been described in Chapter 3.0 of this report. Included within is a description of the surficial soils and underlying sediments which comprise the site and a hydrogeologic assessment of an unconfined (water table) aquifer and a confined aquifer which underlie the site.

6.2.1.2 Physiography and Area Geology

The Cherry Island site is situated in the Coastal Plain Physiographic Province. Topographically this province is defined as a low lying and partially submerged area which is bordered to the east by the continental shelf and to the west by the Piedmont Province. The continential shelf or eastern boundary of the Coastal Plain Province lies approximately 100 miles offshore at a depth of approximately 100 fathoms. The Piedmont Province consists of crystalline rocks and the contact between the Piedmont and Coastal Plain Province is referred to as the "Fall Zone". At this contact, water flowing in streams has eroded away the softer

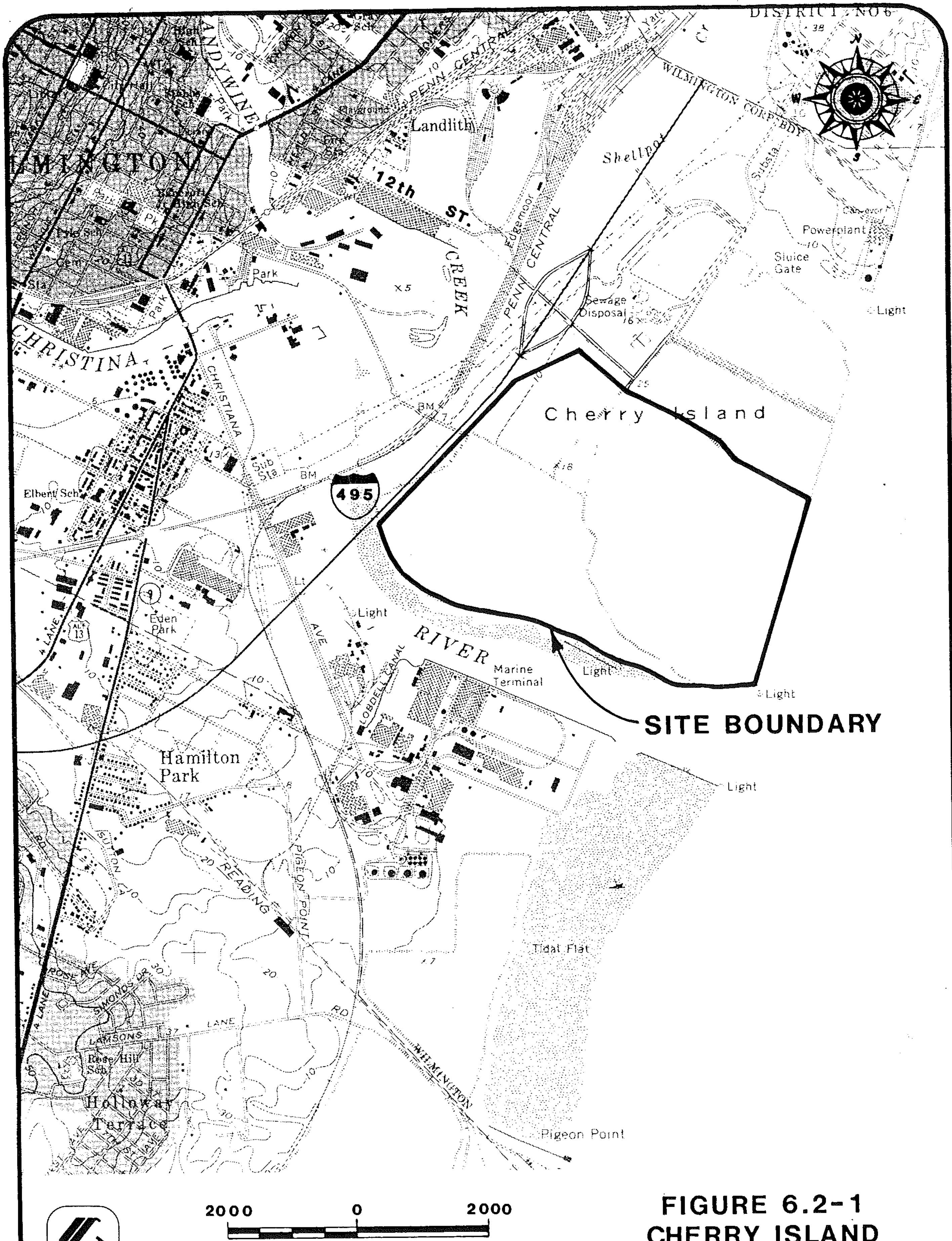


FIGURE 6.2-1
CHERRY ISLAND LOCATION MAP

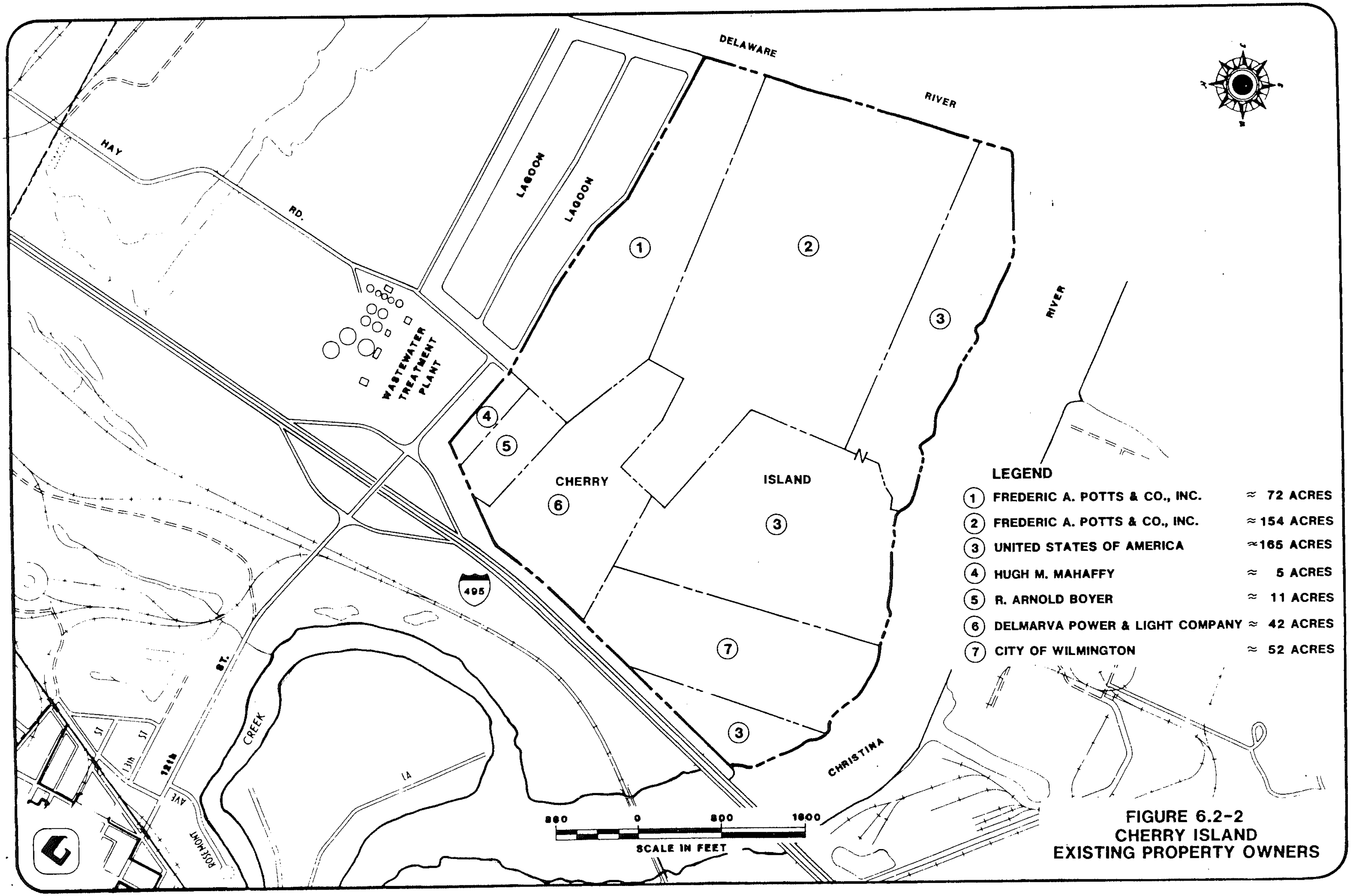


FIGURE 6.2-2
CHERRY ISLAND
EXISTING PROPERTY OWNERS

overlying coastal plain sediments and this erosion has created numerous small water falls.

The Coastal Plain Province is comprised of a wedge of unconsolidated materials which consists of gravels, sands, silts and clays. This wedge of materials, which overlies the crystalline basement is thinnest at the Piedmont/Coastal Plain boundary and gradually thickens in a general southeastern direction towards the Continental Shelf. As reported by Sundstrom and Pickett, 1971, the thickness of the Coastal Plain sediments in New Castle County varies from 0 feet near Newark and Wilmington to approximately 2,300 feet near the Smyrna River which serves as the southern boundary of the County. At the Cherry Island site, the Coastal Plain sediments are approximately 200 feet thick. These sediments range in age from lower Cretaceous (135 million years) to Recent and comprise several geologic formations. The oldest and deepest formation underlying the region of the Cherry Island site is the Potomac formation. This formation lies at a depth of approximately 100 feet and extends to the crystalline basement. The Potomac formation typically consists of variegated red, gray, purple, yellow and white lignitic silt and clay which contains interbedded white, gray and rust brown quartz sand and some gravel. The Potomac formation is of lower Cretaceous age and is unconformably overlain by the Columbia (Pleistocene) formation. The Columbia formation consists typically of orange, tan, and yellow medium to coarse sands and gravel.

At the Cherry Island site, the Columbia formation or Pleistocene deposits are blanketed by Recent estuarine soils. These soils consists of silty clay to clayey silt with organic materials. Further these soils have been covered with 20 to 40 feet of dredge spoil which surficially blankets the site. The dredge spoils consists of sandy silty clays to clayey silts. As indicated on Figure 6.2-1, the surficial dredge spoil materials form a flat featureless plain which is surrounded by and bisected by man-made dikes. Natural drainage of the area is provided by the Delaware River to the east, and the Christina River to the south. Man-made drainage has also been provided by the United States Army Corps of Engineers which presently dispose dredge spoil materials on site. Although Figure 6.2-1 depicts the topographic expression of the Cherry Island site, this figure has been prepared from a 1967 United States Geological Survey 7.5 minute quadangle map. Dredge disposal operations since 1967 have increased the general elevation* of the site to approximately elevation 28 feet in the western dredge spoil impoundment and to approximately elevation 35 feet in the eastern dredge spoil impoundment.

6.2.1.3 Subsurface Exploration Program

The subsurface exploration and monitoring well installation program for the Cherry Island site was undertaken during the period extending from September 9, 1981 through September 14, 1981. Delmarva Drilling Company, Inc. of Bridgeville, Delaware was contracted to perform the monitoring well installations. Two Potomac formation monitoring wells were installed with the one well being extended into the crystalline basement. Drilling equipment utilized in constructing the wells consisted of one Failing Model 1250 rotary rig. A third monitoring well into the Potomac formation was originally planned. However, this well was deleted when right of entry could not be secured from the U.S. Army Corps of Engineers.

Field Procedures

The locations of the two Potomac formation monitoring wells, which are designated P-1 and P-2, are shown on Figure 6.2-3. The monitoring wells were constructed for the purpose of identifying the types and thicknesses of the various sediments comprising the Cherry Island site. In addition, the wells were constructed for

*Datum: Mean Seal Level

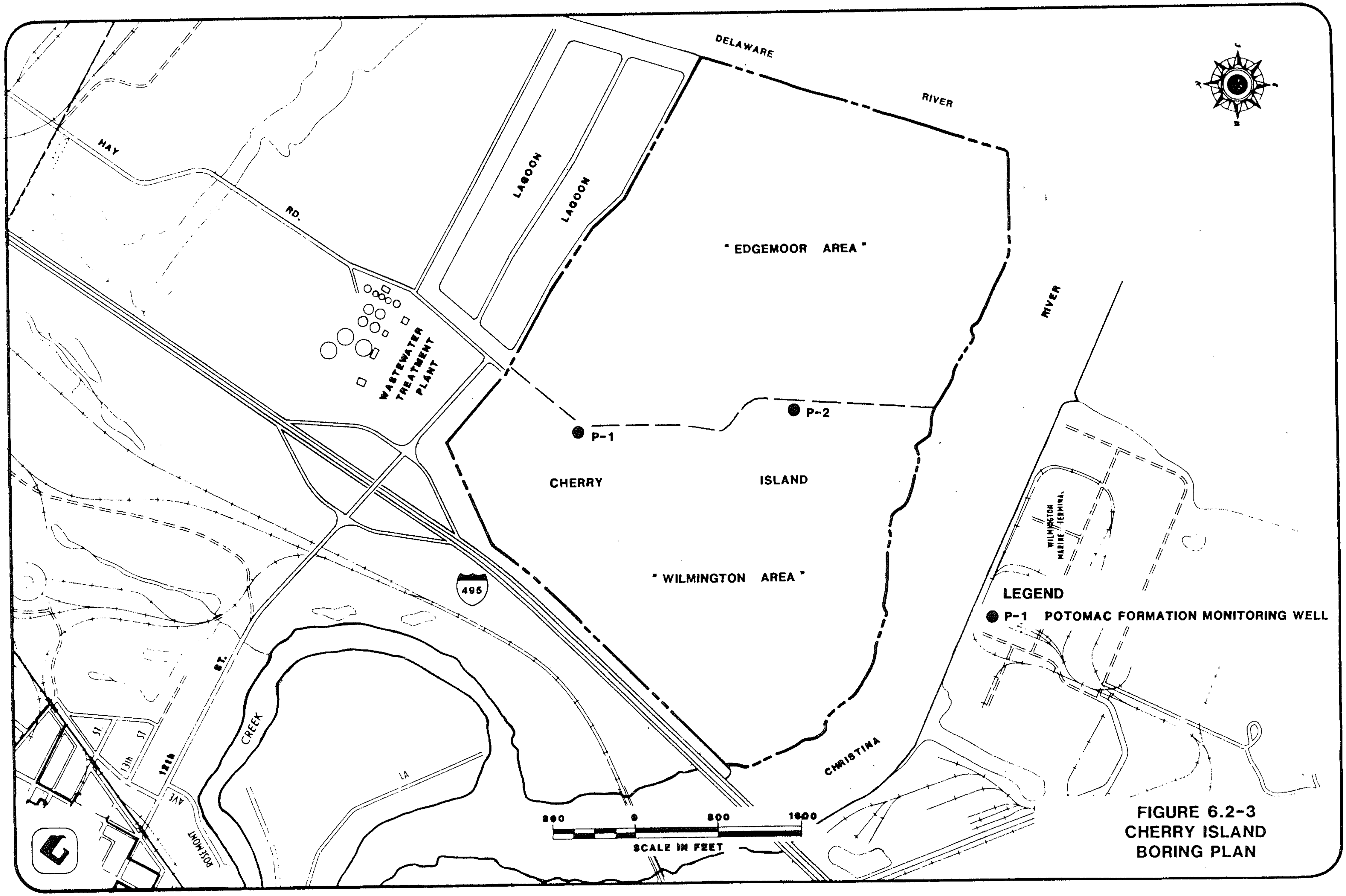


FIGURE 6.2-3
CHERRY ISLAND
BORING PLAN

the purpose of determining the depth of the crystalline basement, the flow direction of groundwater occuring in the Potomac formation, the potentiometric surface of the groundwater occuring in the Potomac formation and the quality of the groundwater.

In determining the types and thicknesses of the sediments, samples from each well bore were collected and logged at five foot intervals. In order to determine groundwater elevations and flow directions, 4-inch diameter polyvinyl chloride (PVC) pipe with 10 foot long PVC screen sections was installed in each well. The PVC screen had a number 16 slot opening size. This screen was gravel packed with No. 2 Morie gravel after installation. After development of the water in each monitoring well, the annular space between the well bore and the PVC casing was sealed with bentonite grout from the top of the gravel pack to within 2 feet of the surface. A 6-inch diameter steel protector casing with a locking cap was installed and the steel casing was set in concrete grout at a depth of approximately 2 feet.

The Potomac formation monitoring wells were monitored during the course of the subsurface exploration program and an additional set of water level readings was obtained on October 20, 1981. The geologic logs of the wells are included in Appendix A of this section. The geophysical log of well P-1 is included in Appendix B. This logging was performed by the Delaware Geological Survey and was utilized to facilitate identification of the various formations comprising the site.

USDA Soil Descriptions

According to the United States Department of Agriculture - Soil Conservation Service publication entitled, "Soil Survey - New Castle County, Delaware", several soil series previously blanketed the Cherry Island site prior to dredge disposal operations. As shown on Figure 6.2-4, soils of the Othello-Fallsington-Urban land complex (Ou) blanketed the western portion of the site and tidal marsh soils (Tm) blanketed the eastern portion of the site. As stated in the above referenced publication, a description of the soils follows:

Oe - Othello - Fallsington Urban Land Complex:

These soils consist of flat-lying, poorly drained soils of the Othello silt loam and the Fallsington loam which have been used for residential, commercial, and industrial development. About 25 percent of this complex has been relatively undisturbed. Most of the remaining 75 percent has been covered with as much as 18 inches of fill material. (Note: as previously discussed, the depth of fill on Cherry Island is now many times greater than the 18-inches indicated in this reference.)

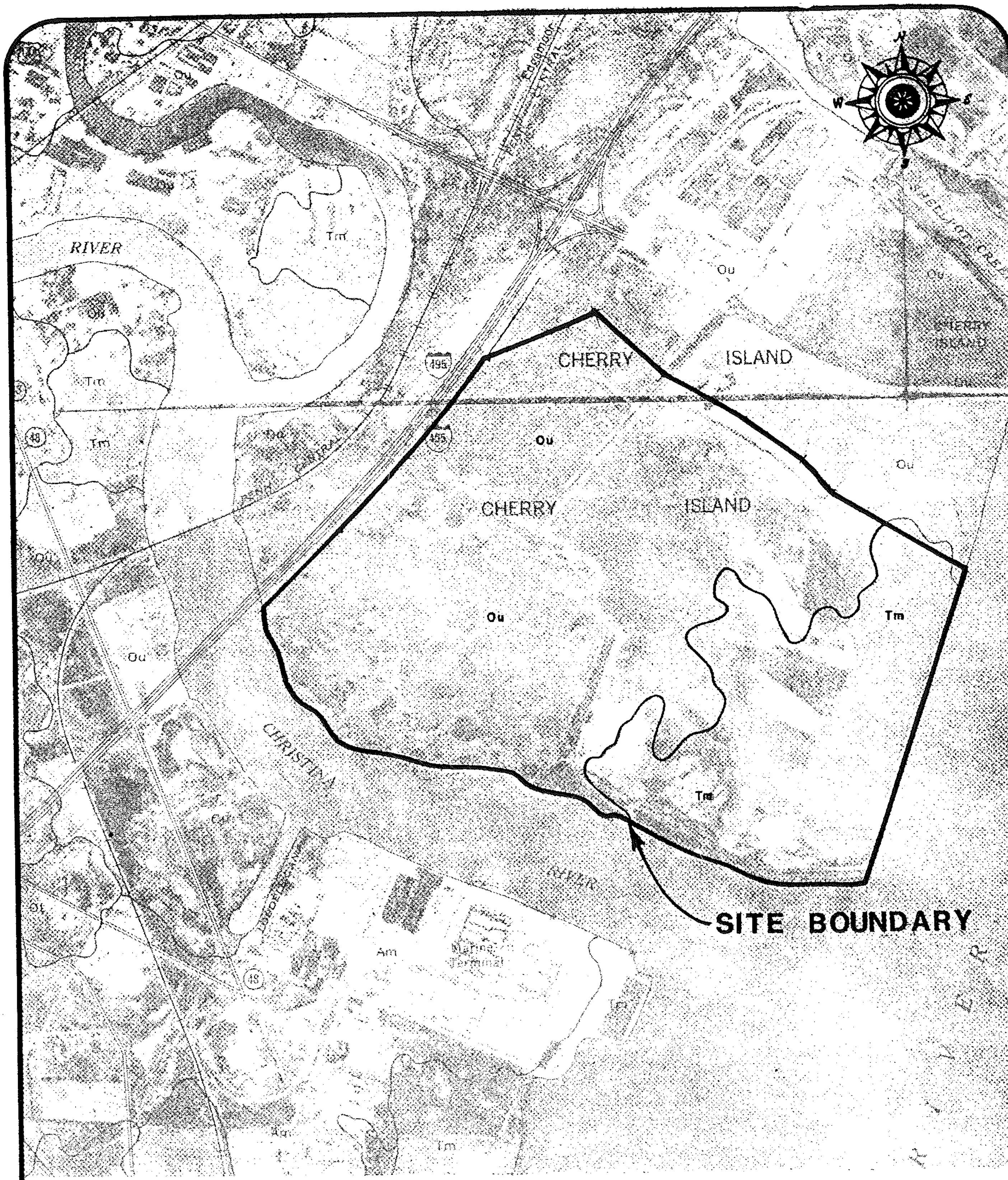
Tm - Tidal Marsh Soils:

Tidal marsh consists of areas that are regularly flooded by tidal waters. The soil material has not been examined in detail, but it ranges from sand to clay and in some places is mucky or peaty. Some areas (Chery Island) have been hydraulically covered with fill material to create made land.

Since both the above defined soil units are inaccessible, being covered by 15 to 30 feet of dredge spoil at the Cherry Island site, their usefulness for cover materials was not evaluated.

Sediment Description

Based on the results of the subsurface exploration and monitoring well installation program, Figures 6.2-5A and 6.25B, which are geologic cross sections of the Cherry Island site, have been developed. In reference to these figures, the dredge spoil materials and Coastal Plain sediments at the site are variable and



REFERENCE: SOILS SURVEY OF NEW CASTLE COUNTY, DELAWARE, USDA SOIL CONSERVATION SURVEY, 1970

0 1/4 1/2 3/4

SCALE IN MILES

FIGURE 6.2-4
CHERRY ISLAND
SOILS MAP

comprise several geologic formations, some of which serve as groundwater aquifers in New Castle County.

The dredge spoil materials present consist of predominantly organic sandy silty clays to clayey silts. In general, these materials are extremely soft and settlement sensitive. Previous work performed on the site by Michael Baker, Jr., Inc., indicates that the moisture content of the dredge spoil materials ranges from 58 to 108 percent and the plasticity index varies from 18 to 22. Further, laboratory permeability data indicates that the permeability of the dredge spoil materials varied from 1×10^{-6} to 4.3×10^{-7} cm/sec. Although these permeabilities are 4 to 10 times greater than the State requirement of 1×10^{-7} cm/sec for unlined areas, consolidation of the dredge spoil materials will further reduce the permeability of the spoil.

Immediately underlying the dredge spoil materials, estuarine deposits were encountered in monitoring wells P-1 and P-2. These deposits consisted of silty clay materials which contained organic (peat) layers. Both the dredge spoil and the estuarine deposits are very similar in appearance and character and the contact between the units is only estimated. The reported moisture contents of the estuarine deposits was 52-100 percent for organic clay materials and 24-57 percent for low plasticity inorganic clays. Permeability testing indicated that the permeability of the estuarine deposits varied from 3.3×10^{-6} to 3.6×10^{-7} cm/sec. As shown on Figure 6.2-5A, the thickness of the dredge spoil and the estuarine deposits varied from 50 to 60 feet at monitoring well P-1 and P-2, respectively.

Directly underlying the above materials at approximately elevation -20 feet, Pleistocene sediments were encountered in both wells. These sediments consisted of multicolored fine to coarse sands and gravels with traces of silt and clay and occassional clayey lenses. As shown on Figure 6.2-5A, the thickness of the

Pleistocene (Columbia formation) materials varied from 40 feet at monitoring well P-1 to 60 feet at monitoring well P-2.

The Potomac formation underlies the Pleistocene sediments at elevations varying from -60 to -80 feet. This formation rests directly on the crystalline basement and consists of approximately 80 feet of red and gray sandy silty clay with some silty sand lenses.

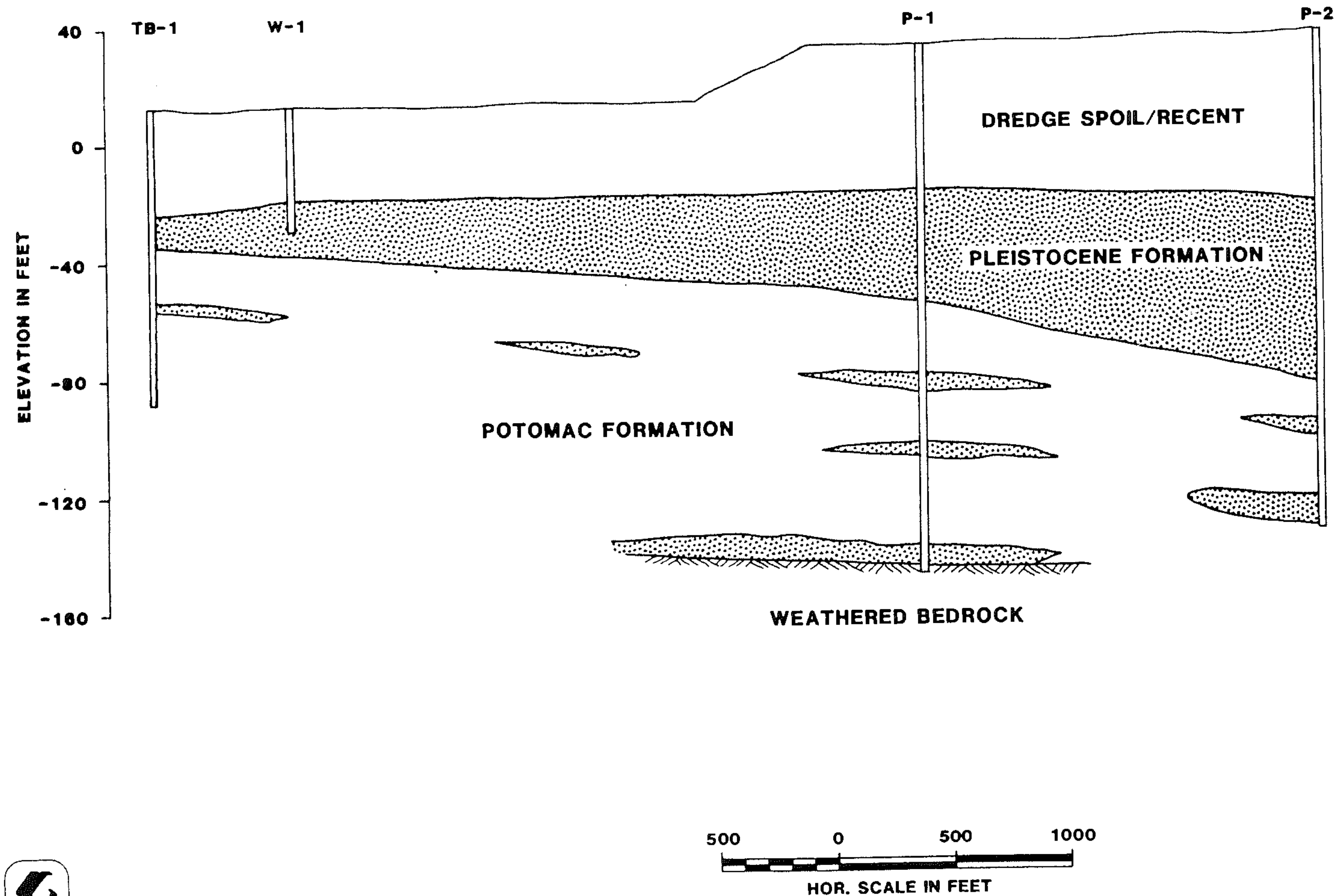
Weathered bedrock was encountered, in monitoring well P-1, at a depth of 170 feet. The weathered materials consisted of dark green silty clay to silty sand. These materials extended downward to a depth of 194 feet (elevation-160) where competent rock was encountered.

6.2.1.4 Suitability of Insitu Materials for Cover

In order to determine the suitability of the dredge spoil materials, occurring above the water table, for use as cover materials, representative soil samples were collected and submitted for laboratory testing of grain size distribution. This testing included hydrometer testing of the sediments passing the No. 200 sieve size. The testing results and gradation curves are included within Appendix C of this section.

Ideally, cover materials should be of such character that they can be compacted to minimize percolation of water through the cover, will not crack excessively when dry and are free of large objects and putrescible materials. Cover materials may consist of stockpiled soils obtained from excavations at the site and/or materials imported to the site.

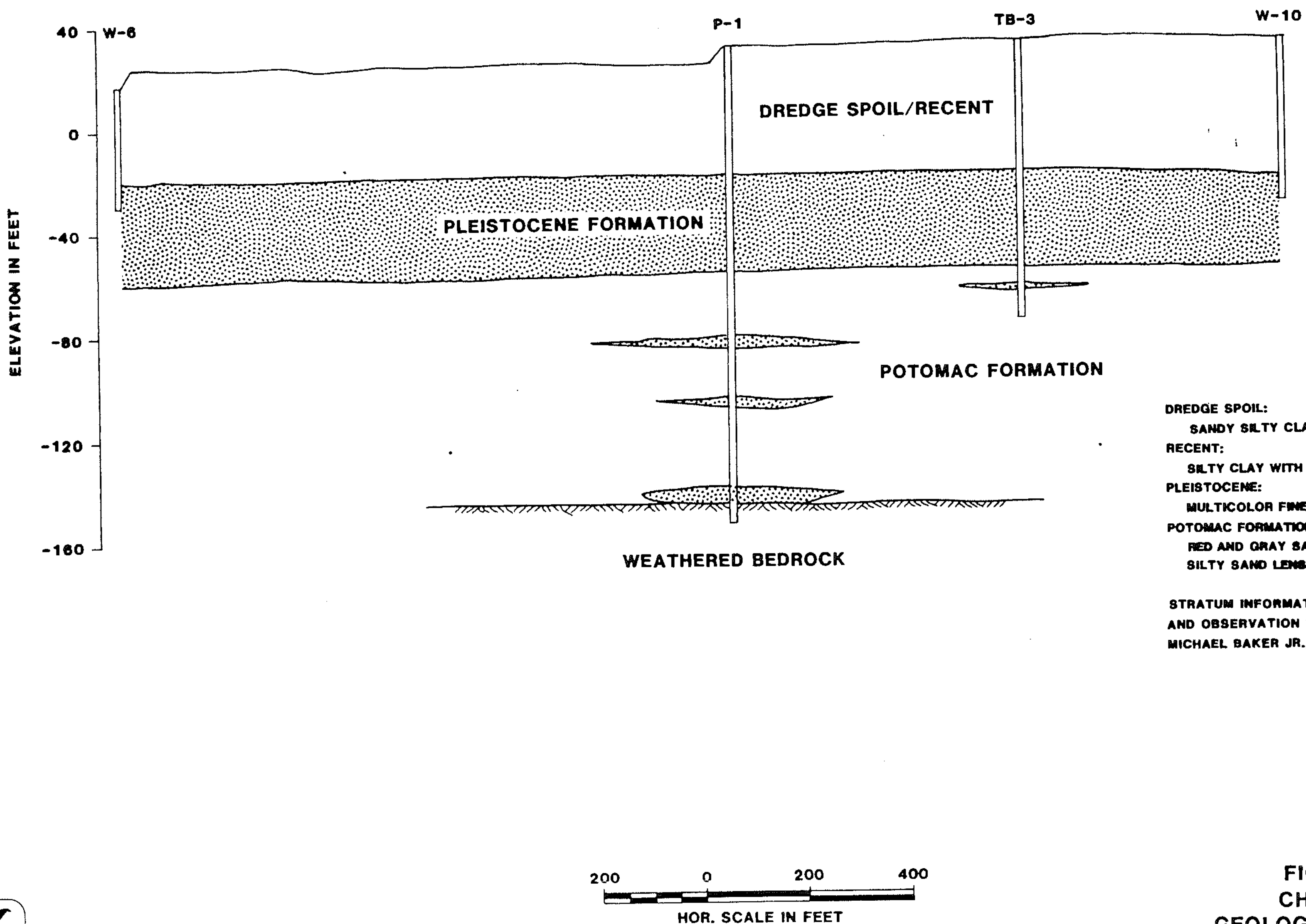
The results of the grain size analyses are summarized in Table 6.2-1. Review of the table indicates that the dredge spoil consists of sandy silty clay with the percentage of soil particles



DREDGE SPOIL:
SANDY SILTY CLAY TO SANDY CLAYEY SILT
RECENT:
SILTY CLAY WITH ORGANIC MATERIALS
PLEISTOCENE:
MULTICOLOR FINE TO COARSE SAND AND GRAVEL
POTOMAC FORMATION:
RED AND GRAY SANDY SILTY CLAY WITH SOME SILTY SANDY LENSES

STRATUM INFORMATION FOR TEST BORING (TB-1) AND OBSERVATION WELL (W-1) BY MICHAEL BAKER JR., INC. 1981

FIGURE 6.2-5A
CHERRY ISLAND
GEOLOGIC CROSS SECTION



DREDGE SPOIL:
SANDY SILTY CLAY TO SANDY CLAYEY SILT
RECENT:
SILTY CLAY WITH ORGANIC MATERIALS
PLEISTOCENE:
MULTICOLOR FINE TO COARSE SAND AND GRAVEL
POTOMAC FORMATION:
RED AND GRAY SANDY SILTY CLAY WITH SOME SILTY SAND LENSES

STRATUM INFORMATION FOR TEST BORING (TB-3) AND OBSERVATION WELLS (W-6, W-10) BY MICHAEL BAKER JR., INC. 1981

FIGURE 6.2-5B
CHERRY ISLAND
GEOLOGIC CROSS SECTION

TABLE 6.2-1

CHERRY ISLAND SITE

GRAIN SIZE ANALYSES

Sieve Size or Particle Dia. (mm)	Cumulative Percent Passing P-1 @ 5.0'	Cumulative Percent Passing P-2 @ 5.0'
.002 mm	22.2	23.5
.008 mm	33.3	38.4
.017 mm	46.2	53.4
.036 mm	55.4	61.9
.074 mm/200 mesh	57.8	66.5
100 mesh	68.2	76.1
50 mesh	82.0	89.5
30 mesh	96.3	98.7
10 mesh	100	100

CLASSIFICATION

P-1	Sandy Clayey Silt	OL*
P-2	Sandy Clayey Silt	OL*

*Unified Soils Classification System

passing the No. 200 sieve varying from 57.8 to 66.5 percent. Data developed by Michael Baker, Jr., Inc. also indicates that the dredge spoil materials are organic (10% organic content), have moisture contents between 58 and 108 percent, have a plasticity index ranging from 18-22 and have an average relative density (N-value) of 0.

Review of the above parameters indicates that the dredge spoil is suitable for cover materials from a grain size distribution standpoint. However, excessive moisture contents will create a serious workability problem which includes excavation, stockpiling and compaction of the cover materials. The materials also are very erodable.

6.2.1.5 Hydrogeology

As defined in the following sections of this report, data pertinent to the hydrogeologic regime of the Cherry Island site is presented.

Aquifer Discussion

As evidenced through the construction of several monitoring wells on the Cherry Island site, two geologic formations, both of which are utilized as groundwater aquifers in New Castle County, comprise portions of the unconsolidated materials occurring in the area. These formations, namely the Columbia formation (Pleistocene sediments) and the Potomac formation, vary in their hydraulic properties, water yielding capabilities and their local use. From the standpoint of local use, there are no residential, industrial or municipal water supply wells within the immediate vicinity of the Cherry Island site. The closest wells are believed to be industrial wells operated by the Brandywine Chemical Company. These wells are approximately 5,000 feet southwest of the disposal site.

Hyrdrogeologic descriptions of the Columbia and Potomac formations follow:

Columbia formation - The Columbia formation or Pleistocene water table aquifer blankets all of New Castle County south of the "fall line" and typically consists of medium to coarse sands and gravel. In New Castle County, the aquifer has a transmissivity in the range of 16,000 to 100,000 gallons per day per foot, has a storage coefficient of 0.12 to 0.15 and an average specific capacity of 14.8 gallons per minute per foot of drawdown. (Sundstrom and Pickett, 1971). Data prepared by Michael Baker, Jr., Inc., indicates that the average hydraulic conductivity of the Columbia formation at the Cherry Island site is 5×10^{-3} cm/sec or 110 gpd/sq.ft. Due to the pressure of the overlying estuarine deposits and the dredge spoil materials, the Columbia formation is confined or semi-confined in the area of Cherry Island. Water level data, which will be discussed in following sections, indicates that the dredge spoil materials and the Pleistocene sediments have separate potentiometric surfaces and that the dredge spoil materials contain a perched water table that lies near the surface and the Pleistocene materials have a potentiometric surface which lies at approximately elevation +2.0 feet .

Potomac formation - This formation, which consists primarily of variegated silts and clay with many beds of sand that are usually laterally restrictive, is utilized for groundwater supplies in New Castle County. Groundwater is primarily obtained from two sandy zones which occur within the silt and clay materials. These sandy zones form an upper and lower hydraulic zone within the formation. As reported by Sundstrom et al:1967, the thickness of the sands within the Potomac formation can be as great as 400 feet, however, monitoring wells installed on Cherry Island show that sandy zones within the Potomac were only a few feet in thickness and it is not thought that either of the two hydrologic zones are present on

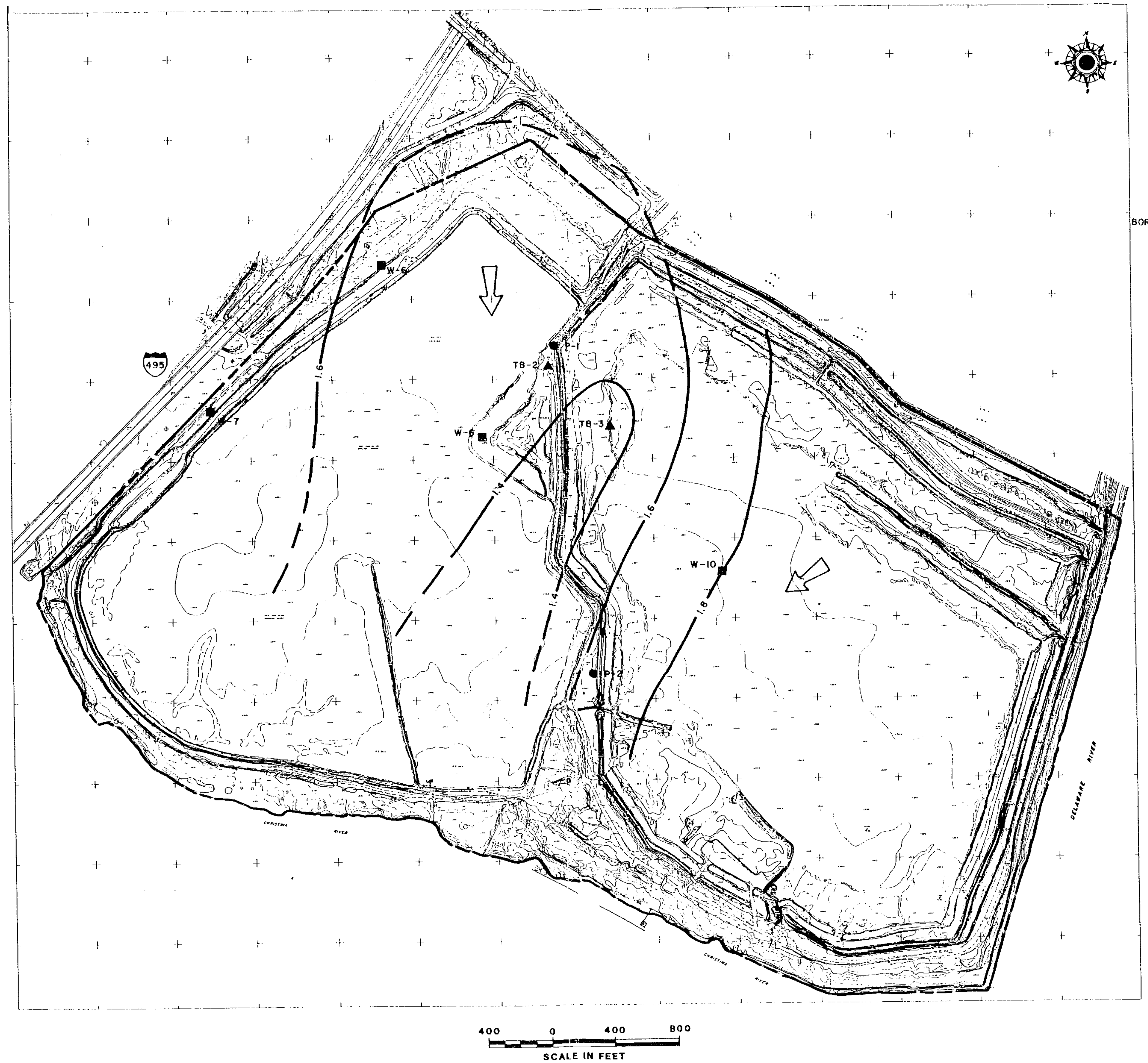
Cherry Island. Where present, the reported transmissivity of the upper zone ranges from 3,960 to 8,600 gpd/ft. and the transmissivity of the lower zone ranges from 4,570 to 6,420 gpd/ft. (Sundstrom el al, 1967). Sundstrom also reports a vertical permeability of the Potomac clays of .002 to .007 gpd/sq.ft. (9.2 x 10^{-8} cm/sec to 3.3 x 10^{-9} cm/sec). Although large supplies of groundwater are obtained from the Potomac formation in areas of New Castle County, the construction of two Potomac formation monitoring wells on Cherry Island indicate that only small supplies (< 5 gpm) are available in the Cherry Island area.

Aquifer Monitoring

In constructing the Potomac formation monitoring wells, four-inch diameter PVC casings containing 10 foot long screen sections were installed in each well. The standpipes were utilized to obtain data pertinent to the potentiometric surface of sandy zones occurring within the Potomac formation and to determine groundwater flow directions. The wells were also utilized to obtain a representative groundwater sample.

Water level data pertaining to the Pleistocene materials (Columbia formation) were obtained from information reported by Michael Baker, Jr., Inc. This data was obtained from Columbia formation monitoring wells installed on Cherry Island in 1980.

Water level readings obtained from monitoring wells P-1 and P-2 on October 20, 1981 are reported in the following table.



BORING NUMBER	GROUND SURFACE ELEVATION	GROUNDWATER ELEVATION*
P-1	31.9	+1.0
P-2	35.1	-3.7

*GROUNDWATER LEVELS MEASURED 10/20/81

LEGEND

- ● P-1 POTOMAC FORMATION MONITORING WELL
- ■ W-6 OBSERVATION WELL DATA AS REPORTED BY MICHAEL BAKER JR. INC. 1981
- ▲ TB-3 TEST BORINGS DATA AS REPORTED BY MICHAEL BAKER JR. INC. 1981
- —1.4— POTENTIOMETRIC SURFACE OF THE COLUMBIA FORMATION AFTER DATA REPORTED BY MICHAEL BAKER JR. INC. 1981
- ⇦ DIRECTION OF GROUNDWATER FLOW

FIGURE 6.2-6
CHERRY ISLAND
POTENTIOMETRIC SURFACE MAP
COLUMBIA FORMATION

TABLE 6.2-2
CHERRY ISLAND SITE
POTOMAC FORMATION
WATER LEVEL DATA

Well No.	Ground Surface Elev. (Ft.)	Top of PVC Casing Elev.	Depth to Water (Ft.)*	Elev. of G.W. (Ft.)*
P-1	31.90	33.90	32.9	+1.0
P-2	35.10	37.40	41.1	-3.7

*As Measured from Top of PVC Casing
**Elev. of G.W. = Elev. Top of PVC Casing - Depth to Water Level

Potentiometric Surfaces and Groundwater Flow

Based on the water level data presented in Table 6.2-2 and information reported by Michael Baker Jr., Inc., one potentiometric surface map of the Columbia formation (Pleistocene sediments) and one potentiometric surface map of a sandy zone within the Potomac formation has been prepared. These maps appear as Figures 6.2-6 and 6.2-7 of this report.

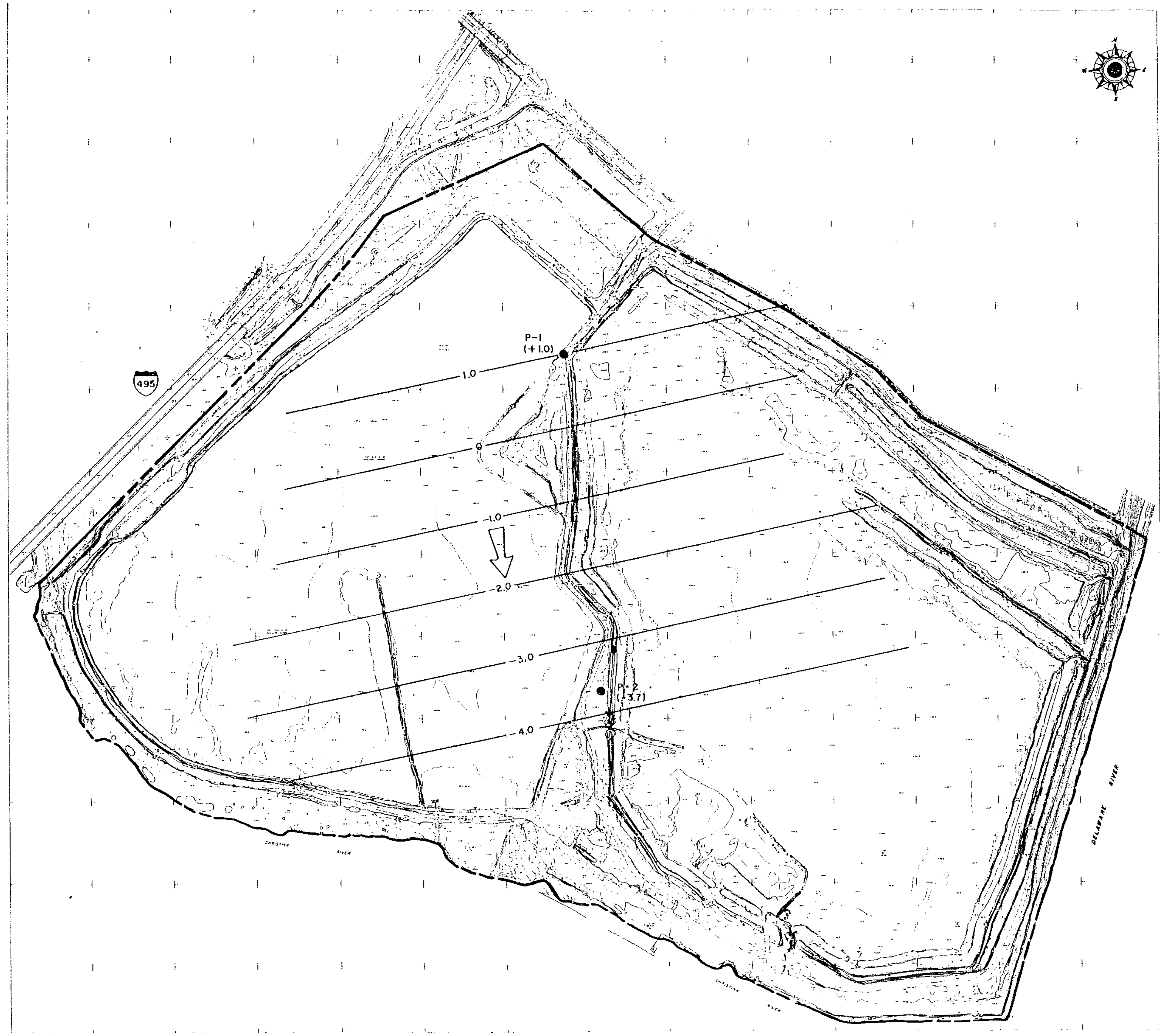
Figure 6.2-6 represents the potentiometric surface of the Columbia formation in July, 1980. As previously defined this formation is confined or semi-confined by the overlying dredge spoil and estuarine deposits. Review of the Figure indicates that the potentiometric surface varies approximately from elevation 1.0 to 2.0 feet across the Cherry Island site and that the surface is approximately 20 feet above the estuarine deposits/Columbia formation contact. Further, the figure indicates the potentiometric surface forms a northeast trending trough through Cherry Island. This is reported to correspond with buried channel fill of the Columbia materials and suggest groundwater flow in the aquifer is towards the Christina River.

Figure 6.2-7 represents the potentiometric surface of a sandy zone within the predominantly clay Potomac formation. In preparing this figure, it was assumed that the screened zones in each Potomac monitoring well are hydraulically connected. Review of the figure indicates that groundwater occurring in the sandy zones of the Potomac formation is confined and that the potentiometric surface varies from approximately elevation +1.0 feet to elevation -4.0 feet across the site. Further, the figure shows that flow within the aquifer is probably towards the south or down dip as would typically be expected. The exact orientation of flow, however, is unknown since only two data points were available. Comparison of Figures 6.2-6 and 6.2-7 indicates that in some portions of the Cherry Island site, the potentiometric surface of the sandy zones within the Potomac formation is lower than the potentiometric surface of the Columbia formation. Accordingly, downward leakage of Columbia groundwater is possible. Note that piezometric head differences are slight and that the vertical permeability of the Potomac clays is reported to range from 8.8×10^{-8} to 3.3×10^{-8} cm/sec.

Although not shown on any figure or drawing, a third water surface occurs on the Cherry Island site. This surface has been created by a perched water table which occurs in the dredge spoil materials. This perched water table lies at or very close to the surface and is dictated by dredging operations and the poorly drained nature of the spoil materials. Having a positive head above the potentiometric surface of the Columbia formation (Pleistocene sediments), leakage from the perched water table downward into the Columbia formation occurs, but at an extremely slow rate due to the impermeable nature of the materials.

Water Table Fluctuations

The Delaware Solid Waste Disposal Regulation requires that at least 3 feet of separation between refuse deposits and the yearly



BORING NUMBER	GROUND SURFACE ELEVATION	GROUNDWATER ELEVATION *
P-1	31.9	+1.0
P-2	35.1	-3.7

* GROUNDWATER LEVELS MEASURED 10/20/81

LEGEND

● P-1 POTOMAC FORMATION MONITORING WELL

(+1.0) ELEVATION OF GROUNDWATER IN POTOMAC FORMATION MONITORING WELL

—1.0— POTENTIOMETRIC SURFACE OF SANDY ZONE WITHIN THE POTOMAC FORMATION

⇦ DIRECTION OF GROUNDWATER FLOW

400 0 400 800
SCALE IN FEET

FIGURE 6.2-7
CHERRY ISLAND
POTENTIOMETRIC SURFACE MAP
OF SANDY ZONE WITHIN THE
POTOMAC FORMATION

TABLE 6.2-3

CHERRY ISLAND SITE

WATER QUALITY ANALYSES

Chemical Constituent	Columbia Formation	Potomac Formation	Delaware Limit
Alkalinity mg/l	-	80	-
Arsenic mg/l	0.02	<0.002	0.05
Chloride mg/l	116-190	45	250
Chromium, total mg/l	<.02	<0.01	0.05
Conductivity umho	1130-1650	348	-
Copper mg/l	0.01-.03	0.018	1.0
Hardness, total mg/l	-	62	-
Iron, total mg/l	0.05-10	.028	0.3
Lead mg/l	0.03-.06	<0.04	0.05
Maganese mg/l	1.2-9.7	0.026	0.05
Mercury ug/l	<.5	<0.5	2
Nickel mg/l	-	<0.01	-
Nitrates N mg/l	-	<0.005	10
N. Ammonia mg/l	3.8-12	1.12	-
N. Kjeldahl mg/l	-	2.71	-
pH	5.9-6.2	7.4	-
Total Solids mg/l	-	894	-
Dissolved Solids mg/l	704-1552	212	500
Suspended Solids mg/l	-	664	-
Selenium mg/l	<.005	<0.002	0.10
Sodium mg/l	110-200	56.5	-
Sulfate mg/l	20-800	19.5	250
TOC mg/l	-	24.4	-

high groundwater table be maintained. Further, the regulation defines groundwater as any water found under the surface of the earth. Since a perched water table exists on site and since this perched water table lies at or close to the surface, it has been assumed that refuse may not be placed in excavated pits or trenches. When dredge spoil disposal operations cease, the perched water table will gradually drain. Based on the previously discussed permeabilities of the dredge spoil materials, this drainage will be very slow.

Groundwater Quality

After construction of the Potomac formation monitoring well, one representative groundwater sample was obtained on September 15, 1981. The sample was collected through the utilization of a 2-inch diameter stainless steel bailer and the sample was submitted for laboratory testing the same day. The pH and residue series were run on unfiltered water. All other parameters were analyzed on a filtered (.45 micron) and preserved portion of the sample.

The results of the chemical analysis is summarized on Table 6.2-3 of this report. Also listed on the table are reported analyses form the Columbia formation (see Michael Baker, Jr., Inc.) and allowable constituents for drinking water for the State of Delaware.

Review of Table 6.2-3 indicates that groundwater occurring in the sandy zones within the Potomac formation is of excellent quality and meets all Delaware Drinking Water Limits. The high TOC value for the Potomac sample has probably been caused by the solvent used in cementing the PVC casing lengths together.

The reported quality of the Columbia formation is poor from the standpoint of iron, maganese, sulfate, chloride, and total

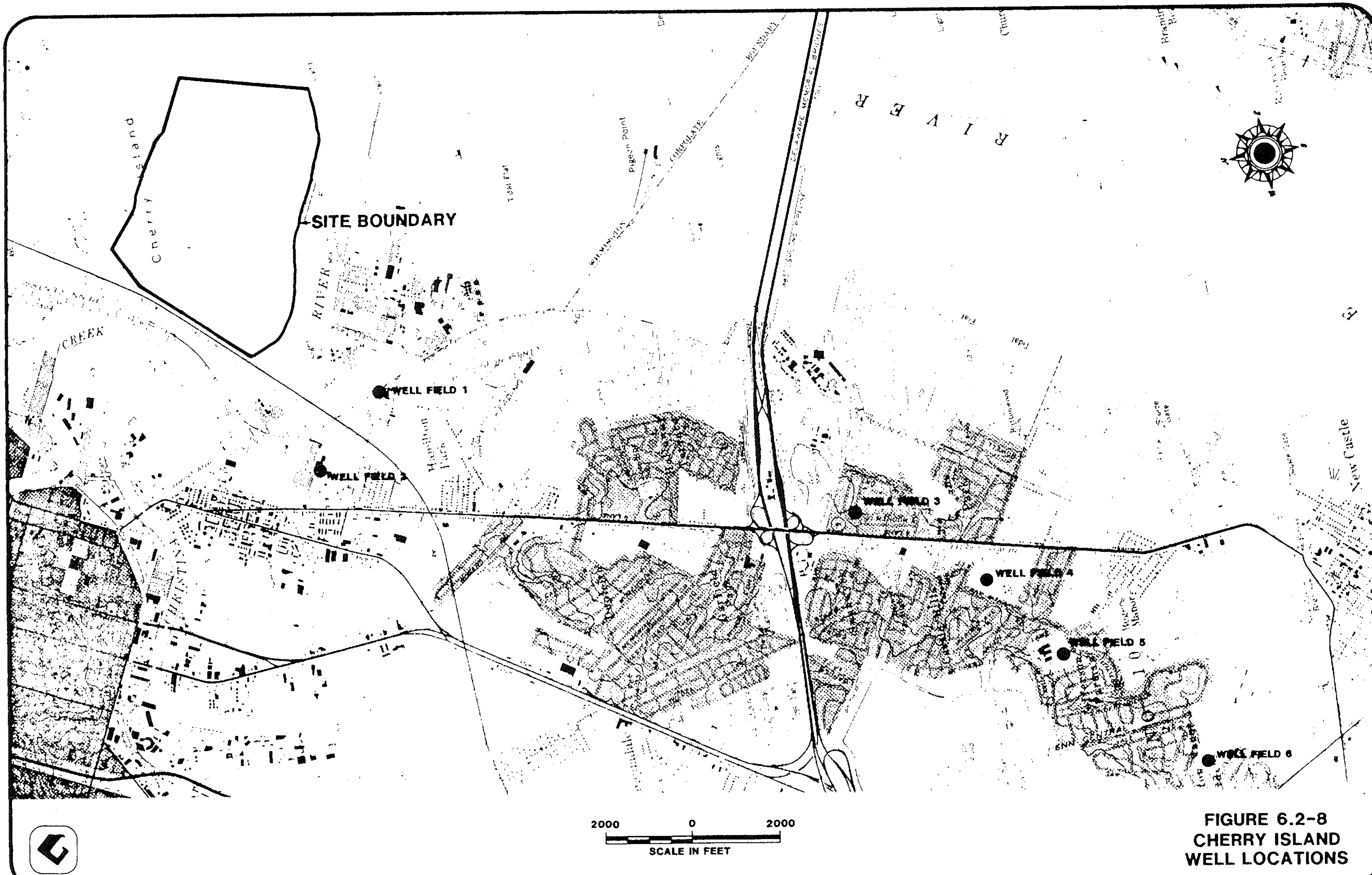


FIGURE 6.2-8
CHERRY ISLAND
WELL LOCATIONS

dissolved solids. The relatively high sulfate, chloride and total dissolved solids levels are reported to be caused by pumpage of brackish water onto the site during dredging operations and infiltration of this water into the underlying Columbia formation. The cause of high iron and manganese levels are reported to be caused by seepage from iron and manganese rich organic clays in the estuarine deposits and the dredge spoil. Trace metal concentrations of the Columbia formation groundwater are low and generally meet the Delware standards.

Local Water Use

As previously reported, there are no residential, industrial or municipal wells within a quarter mile radius of the site and the closest such well is thought to be situated approximately 2,500 feet west-southwest of Cherry Island. As shown on Figure 6.2-8 and 5,000 feet west-southwest of the proposed disposal area.

Brandwine Chemical Company apparently utilizes the closest wells south west of Cherry Island. In addition, Forbes Steel Corporation and the Artesian Water Company own wells in a general south west direction from the Cherry Island site. In reference to Figure 6.2-8, the wells shown as belonging to the Brandywine Chemicals Co., Forbes Steel Corp., and Artesian Water Company are summarized in the following Table.

TABLE 6.2-4

CHERRY ISLAND SITE
WELLFIELD DATA

Well Field No.	Well Field Name	No. of Wells	Distance From Proposed Disposal Area on Cherry Island	Reported Yield (gpm)
1	Brandwine Chem.	3	5,000 ft.	15-30
2	Forbes Steel Corp.	1	6,100 ft.	90
3	*Collins Park	1	15,000 ft.	300
4	*Castle Hills	3	18,400 ft.	750
5	*Jefferson Farms	2	20,700 ft.	600
6	*Wilmington Manor Gardens	3	24,900 ft.	500

*Owned by Artesian Water Company

6.2.1.6 Settlement Analysis

As previously identified in the sediment description of the materials comprising the Cherry Island site, the dredge spoil and estuarine deposits are very soft and settlement sensitive. Accordingly, any loading such as the disposal of refuse materials will cause consolidation of the compressible sediments and subsequent settlement of the land will occur.

In estimating the consolidation of dredge spoil and estuarine materials, it was assumed that refuse would be placed to a height of 40 feet; that the refuse would weigh approximately 1,250 lbs/cubic yard; and, that 25 percent of the total placed volume of refuse would consist of soil having an average unit weight of 100 lbs/cubic foot. Further, averaged reported initial void ratios and compression index values for the dredge spoil and estuarine deposits (Michael Baker, Jr., Inc.) were utilized in the settlement equation.

The results of the analysis indicates that the 40 ft. high refuse deposit would result in a subgrade settlement of approximately 3.5 to 5 feet. The rate of consolidation was also estimated using both single and double drainage assumptions. The results of this preliminary analysis indicates that a realistic estimate of the time required for the primary consolidation of the spoil materials is 4-to 5 years under full load.

6.2.1.7 Potential Impacts

In the construction of any solid waste disposal facility potential impacts upon both the geologic and hydrogeologic regimes exist. These impacts include the potential contamination of underlying groundwater in one or several aquifers and the potential contamination of surface water supplies. Based on the physical and interpretative data developed through a literature search and subsurface exploration program conducted on-site, these impacts are discussed below. Based on the geotechnical properties of the Cherry Island site, where relatively large settlements caused by foundation loading is predicted, the incorporation of a conventional lined disposal area and leachate collection system does not appear practical. Accordingly, the solid waste disposal facility would have to be unlined or, unless preloaded, would have to incorporate a unique lining and leachate collection system. The existing dredge spoil materials are reported to have low permeabilities and during part or after total consolidation of the spoil, these materials will probably meet if not exceed current State requirements for natural soil liners ($<1 \times 10^{-7}$ cm/sec). Further, unless sophisticated and time consuming settlement acceleration or foundation stabilization techniques are utilized, total leachate collection* would not be possible even utilizing a combination of peripheral and central collection points.

*Total leachate collection meaning the ability to grade and compact the base of the disposal area such that the leachate flows, unimpeded by depressions or other irregularities in the subgrade, to a central collection point.

At the Cherry Island site, assumming an unlined facility, leachate generated by precipitation filtering through the refuse would drain downward to the perched water table. This water table presently lies at or near the surface of Cherry Island and may change as dredging operations continue. For purposes of seepage calculations it is assumed that the piezometric surface of the perched water table lies approximately at elevation 35 feet which corresponds with observations made during a site visit on October 20, 1981. Based on the piezometric surface of the perched water table and the potentiometric surface of the Columbia formation (see Figure 6.2-6), downward movement of leachate into the Columbia formation is possible. This vertical movement, however, is restricted by the dredge spoil and estuarine sediments which have a permeability on the order of 1 x 10^{-7} cm/sec. Using Darey's Law (Q = KIA) the amount of vertical seepage that could occur has been calculated. This calculation has been based on an assumed useable area of approximately 200 acres and a potentiometric surface of 1.5 feet for the Columbia formation. The results of the calculation indicate that approximately 11,109 gpd (55 gpd/acre) of seepage can occur at the Cherry Island site. As leachate seeps vertically downward, natural renovation will occur through cation exchange. Further, as the seepage enters the Columbia formation, it will be diluted with groundwater flowing within the aquifer. This dilution ratio has been calculated to be 2:1.

Similarly, the amount of seepage that could enter the sandy zone occurring within the Potomac aquifer has also been calculated using 200 acres as the potential vertical inflow area. The results of this calculation indicates that 4305 gpd or 21 gpd/acre of seepage could occur and that a dilution ratio of slightly greater than one to one exists.

6.2.1.8 Geotechnical Sumamry

The Cherry Island site is situated in the Coastal Plain Physiographic Province of Delaware and is underlain by a thick sequence of unconsolidated materials which includes dredge spoil, Recent estuarine deposits, the Columbia formation and the Potomac formation. The latter two formations are utilized for groundwater supplies in New Castle County but are unimportant for such use in the Cherry Island area. Monitoring wells have been installed in the Potomac formation and representative dredge spoil samples and Potomac groundwater samples have been collected and submitted for laboratory analyses. Based on these explorations, testing results, calculations and other data developed on Cherry Island by Michael Baker, Jr., Inc., the following geotechnical conclusions are presented.

1. Based strictly on tested and reported grain size analyses of the dredge spoil materials, these materials appear suitable for use as cover materials. However, excessive moisture contents create a severe workability problem in that adequate compaction of the dredge spoil materials can not be accomplished without first reducing the moisture content through excavating, aerating and stockpiling of the spoil. The presence of a perched water table may also limit the volume of dredge spoil for cover, since materials obtained at depth will require additional drying time. The materials are very erodable.

2. The dredge spoil materials and underlying estuarine deposits are very soft and settlement sensitive. Estimates of settlements indicates that consolidation of 3 to 5 feet will occur under a 40 foot high refuse deposit. These settlements appear to preclude the utilization of a membrane type liner and total leachate collection system. Consolidation of the dredge spoil will result in permeabilities of the dredge

materials which should meet State requirements for natural soil liners. Partial leachate collection could be accomplished through a combination of peripheral and central collection points.

3. A perched water table exists on site at or very near the surface. The general level of this water table is expected to decline upon cessation of dredging operations. This decline will be very slow based on the permeabilities of the dredge spoil materials. The presence of the perched water table precludes placement of refuse in excavated pits or trenches. Leachate generated from the landfill may seep into the perched water table. This seepage will continue to move downward toward the Columbia formation and will move laterally toward both the Delaware and Christina River.

4. The Pleistocene Aquifer or Columbia formation underlies the site and is confined due to the presence of overlying estuarine and dredge spoil materials. Seepage into the Columbia formation has been calculated to be 55 gpd/acre. Movement of groundwater in the formation is southward or towards the Christina River. There are no Pleistocene wells within the general area of Cherry Island.

5. The Potomac formation is the deepest and oldest unconsolidated deposit underlying the site. The formation serves as a principal source of groundwater in New Castle County. Monitoring wells constructed in the Potomac formation on Cherry Island indicate that the water yielding properties of the formation at Cherry Island are poor. Potentiometric surface data indicates that vertical seepage of leachate is possible assuming failure of the leachate collection system and that no corrective actions are taken. Flow in the sandy zones occurring within the formation is southward. There are no Potomac wells within the general area of Cherry Island.

6.2.2 Hydrology

6.2.2.1 Topography

Elevations* on the Cherry Island site within the diked areas do not vary by more than 4 or 5 ft. A review of the topographic mapping prepared form recent aerial photography (April 1981) shows that the dike defining the "Edgemoor" dredge disposal area varies in elevation from 42 ft. to 50 ft. The area encompassed by this dike varies in elevation from 30 ft. to 35 ft. Drainage within the area is to the south and east. The dike which defines the "Wilmington" dredge disposal area varies in elevation from 32 ft. to 35 ft. The area encompassed by this dike varies in elevation from 24 ft. to 28 ft. and drainage of the area is to the south.

The dike on the east of the "Edgemoor" area, which fronts the Delaware River, appears to rise almost directly from the edge of the water to the crest. Therefore, the river bank is almost indistinguishable. On the south of the Edgemoor area, particularly as one approaches the Delaware River, there is a sharp rise from the Christina River to an elevation of approximately 12 ft. There is then a gradual rise over a 200' wide area to the toe of the dike which is at an elevation of approximately 30 ft.

At the toe of the dike on the south side of the "Wilmington" area there is a low lying area varying in elevation from 4 ft. to 8 ft. and varying in width from 100 ft. to 200 ft. This low lying area continues around to the western side of the Wilmington area, where it at first widens considerably and then, as one proceeds north, is confined by earth fill ramps associated with the I-495 interchange located just beyond the northwest corner of the site.

*Datum: Mean Sea Level

6.2.2.2 Runoff Control

Upgradient runoff from properties to the north and west are currently intercepted either by existing dikes (as on the north) or by existing highway drainage facilities and lower lying areas (as on the west). These existing barriers would not be altered and should still provide satisfactory control of upgradient runoff should this site be selected for the NSWF. Provisions for incorporation of sedimentation basin(s) and/or other suitable methods to preclude surface runoff from being discharged directly to the Christina or Delaware Rivers will be necessary.

6.2.3 Flood Plain Limits

The dikes constructed by the Corps of Engineers over the years for the containment of dredge spoils serve to protect this site from inundation by the 100-year flood. The elevation of the 100-year flood at Cherry Island is estimated at approximately 10 ft. As indicated earlier, the tops of the dikes are well above this. Consequently, the 100-year flood plain criterion has little impact upon this site since most of the area of 10 ft. elevation or less lies within the 200 ft. property line buffer zone.

6.2.4 Wetlands

Cherry Island and its environs are not considered to be, or lie within, any State of Delaware Wetlands. Therefore, adherance to the wetlands criterion will not have an impact upon this site.

6.2.5 Streams

A minimum of 100 ft. must be maintained between the edge of the disposal area and the edge of a body of water. Therefore, the edge of the disposal area must be at least 100 ft. from the Delaware River (on the east) and the Christina River (on the south). Since the shores of the rivers are assumed to be coincident with the property lines at this site, the 200 ft. property line buffer zone also would incorporate this "stream" buffer requirement. Therefore, adherence to this criterion has no significant impact upon the site.

6.2.6 Property Line Setbacks

The property line setback established by the Delaware Solid Waste Authority is 200 feet. Therefore, there will be a minimum 200 ft. buffer zone around the perimeter of the site in which no wastes will be landfilled. The area excluded to landfilling by adhering to this criterion is illustrated in Figure 6.2-9. Excluding this 200 feet from landfilling does not necessarily preclude its use for other purposes such as service or access roads and support facilities.

6.2.7 Site Capacity

6.2.7.1 Useable Area

For the purposes of this report, it has been assumed that only that portion of the site known as the "Edgemoor" area will be utilized. Taking advantage of the existing dikes and the area which they define, approximately 215 acres will be considered available. This area is illustrated in Figure 6.2-10. It should be recognized, however, that the "Wilmington Area" represents a significant expansion potential for development as a future disposal area.

6.2.7.2 Estimated Depth of Refuse Deposit Below Existing Grade

Because of the high moisture content soils and associated poor stability and high compressibility, it will be presumed that all landfilling will be by the area fill method and will not involve any significant excavation into the dredge spoils which surficially blanket the site.

6.2.7.3 Height of Refuse Deposit Above Existing Grade

The nominal height of the landfill above the existing grade will be limited to approximately 40 feet.

6.2.7.4 Estimated Site Volume/Longevity

Of the 215 acres considered useable in the "Edgemoor Area", approximately 15% should be reserved for leachate collection and/or treatment facilities. Table 6.2-5 summarizes for the Cherry Island site the estimated volume (cubic yards), capacity (tons), life (years), cover material requirements (cubic yards), and cover material available.

Comparing the total estimated capacity (5,120,600 tons) shown in Table 6.2-5 with the cumulative tonnage column of Table 3.2-1, it can be seen that the estimated life of this candidate landfill site is somewhat greater than 24 years. This is slightly lower than the estimated life arrived at by using the 10th year tonnage as a mean value for the 20-year planning period.

6.2.7.5 Estimated Cover Material Requirements and Availability

Since it is anticipated that the site will be operated on a strict "area fill" basis, no excavation within the proposed disposal area will occur and there will be no cover materials available from this potential source. As can be seen on Table 6.2-5, approximately 2,731,000 cubic yards of cover material will be needed over the life of the project. All of this material will have to be imported to the site.

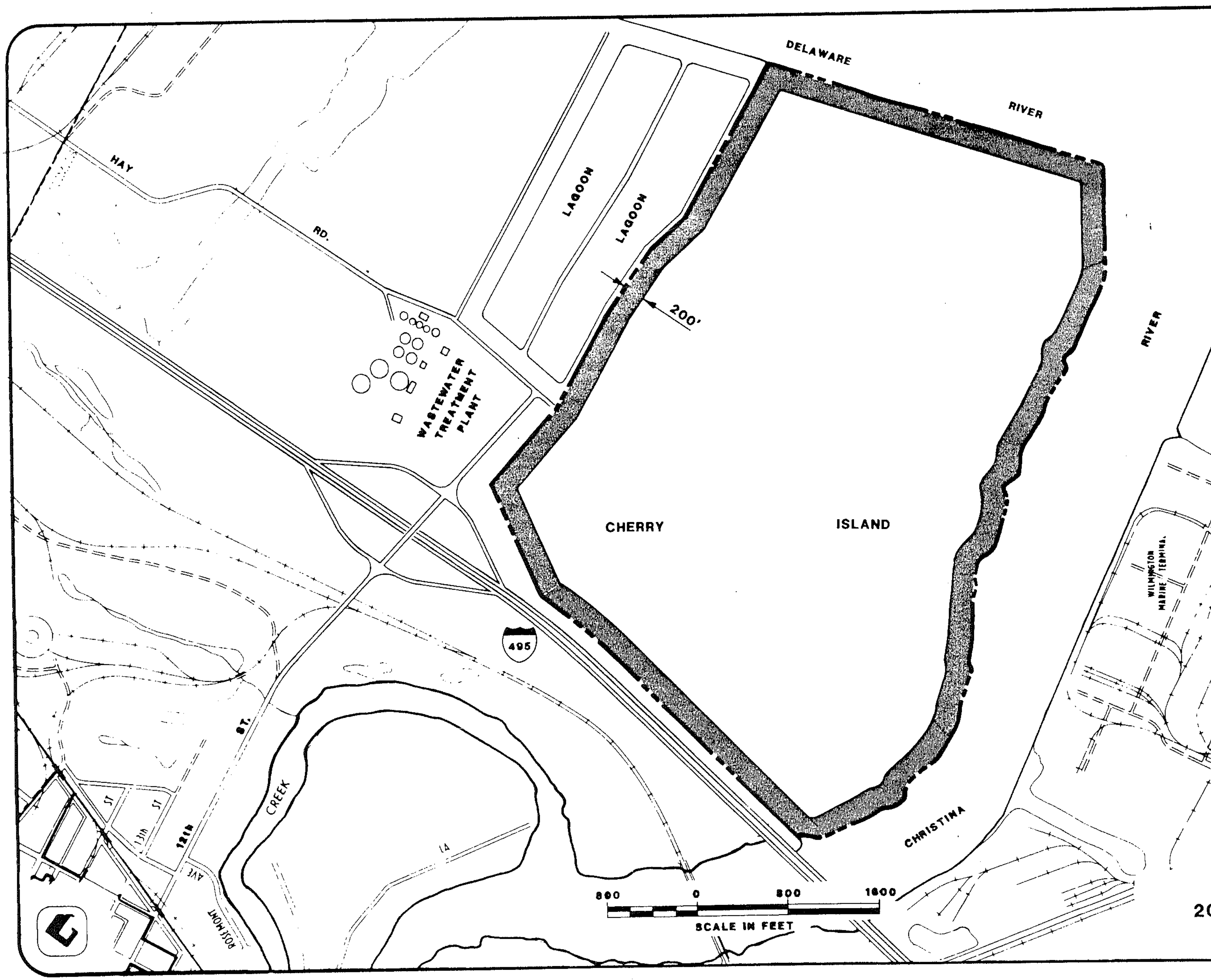


FIGURE 6.2-9
CHERRY ISLAND
200' PROPERTY LINE
BUFFER ZONE

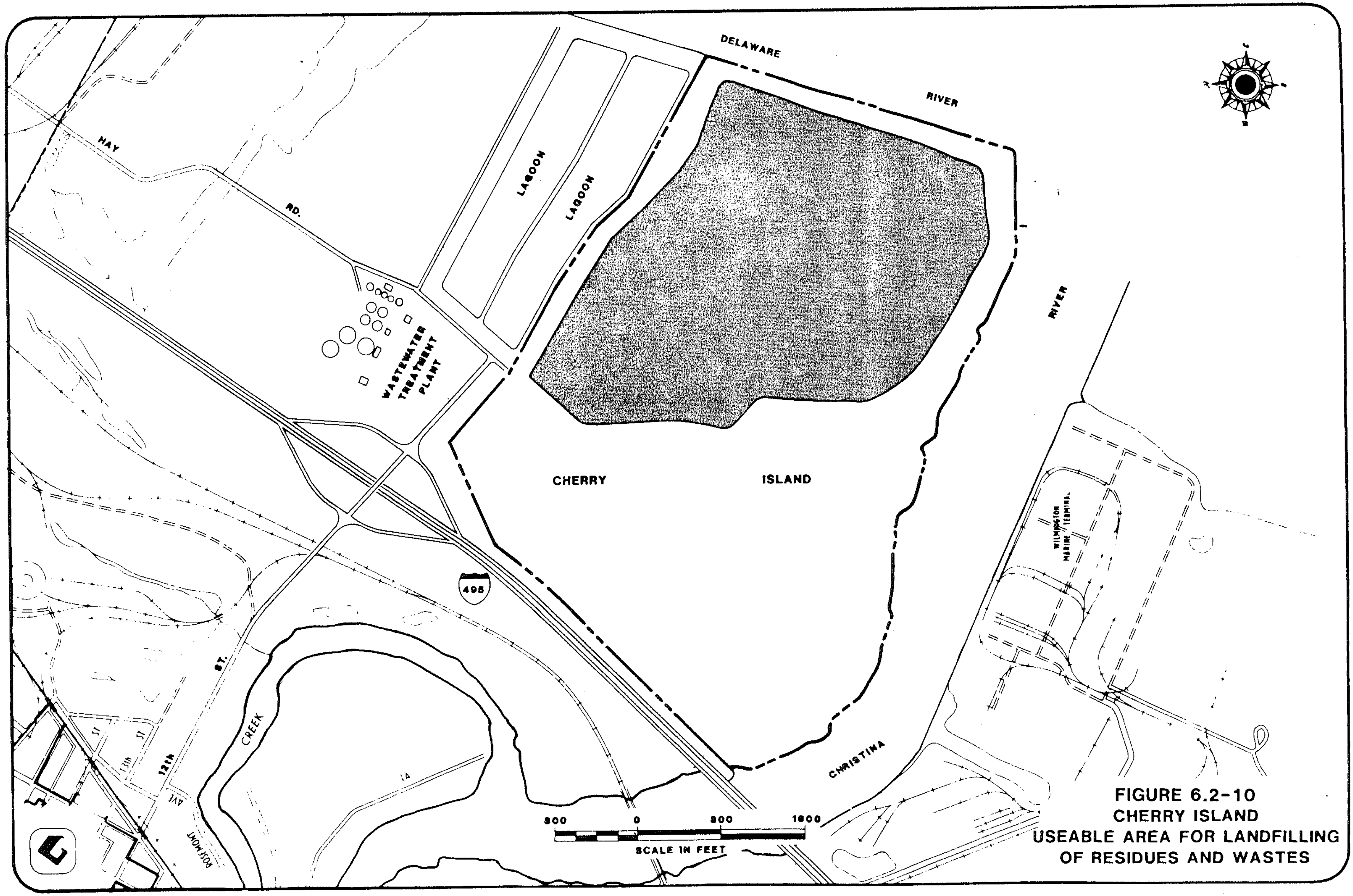


FIGURE 6.2-10
CHERRY ISLAND
USEABLE AREA FOR LANDFILLING
OF RESIDUES AND WASTES

TABLE 6.2-5
SUMMARY TABLE FOR CHERRY ISLAND

Acres for Landfilling	Acres for Leachate Storage[1]	Total Volume of Disposal Area (c.y.)	Volume of Refuse (c.y.)	Volume of Cover Material[2] (c.y.)	Cover Material Available (c.y.)	Capacity (tons) @ 0.625 tons per c.y.[3]	Estimated Life at 10th yr. Tonnage Rate (198,300 tons)	Average Excavation Depth (ft.)
183	32	10,924,000[4]	8,193,000	2,731,000	-0-	5,121,000	25.8 years	-0-

1. Area reserved for leachate storage and/or treatment facilities incorporates space needed for berms, access roads, and service roads.

2. "Cover" refers to the materials needed for daily and final covering of the refuse.

3. In-place density estimated at 1,250 lbs/c.y. which is equivalent to 0.625 tons/c.y.

4. Volume and tonnage figures are rounded off to the nearest thousand.

6.2.7.6 Potential On-Site Borrow Areas

There are no potential on-site borrow areas. However, dredge spoils within the adjacent "Wilmington Area" represent a potential source of cover materials. Their use, though, presents significant operational problems with regard to workability, compaction, and erodability. If utilized, methods would have to be developed to satisfactorily excavate and then dry the materials to facilitate placement. Should this candidate site be selected for the NSWF it would warrant further investigation into the possibilities of utilizing the dredge spoils for cover material. For the purposes of this report, however, it will be assumed that all cover materials will have to be imported from remote areas.

6.2.8 Screening of Sites

Screening of this site is considered impractical. There are no residential areas within 300 yards of the site. Immediately north of the site is the Wilmington Area Wastewater Treatment Plant which has two large lagoons parallel to the northern boundary of the "Edgemoor Area". Farther north is a Delmarva Power and Light generating station.

6.3 ENVIRONMENTAL CONSIDERATIONS

6.3.1 Ecology

6.3.1.1 Terrestrial Communities

Vegetation: As previously mentioned, the site is completely surrounded by dikes, and is divided into two disposal areas by another dike. The western area contains spoil from recent dredging operations and supports virtually no vegetation. The eastern portion is being colonized by plants characteristic of waste deposits, but these could not be directly observed because

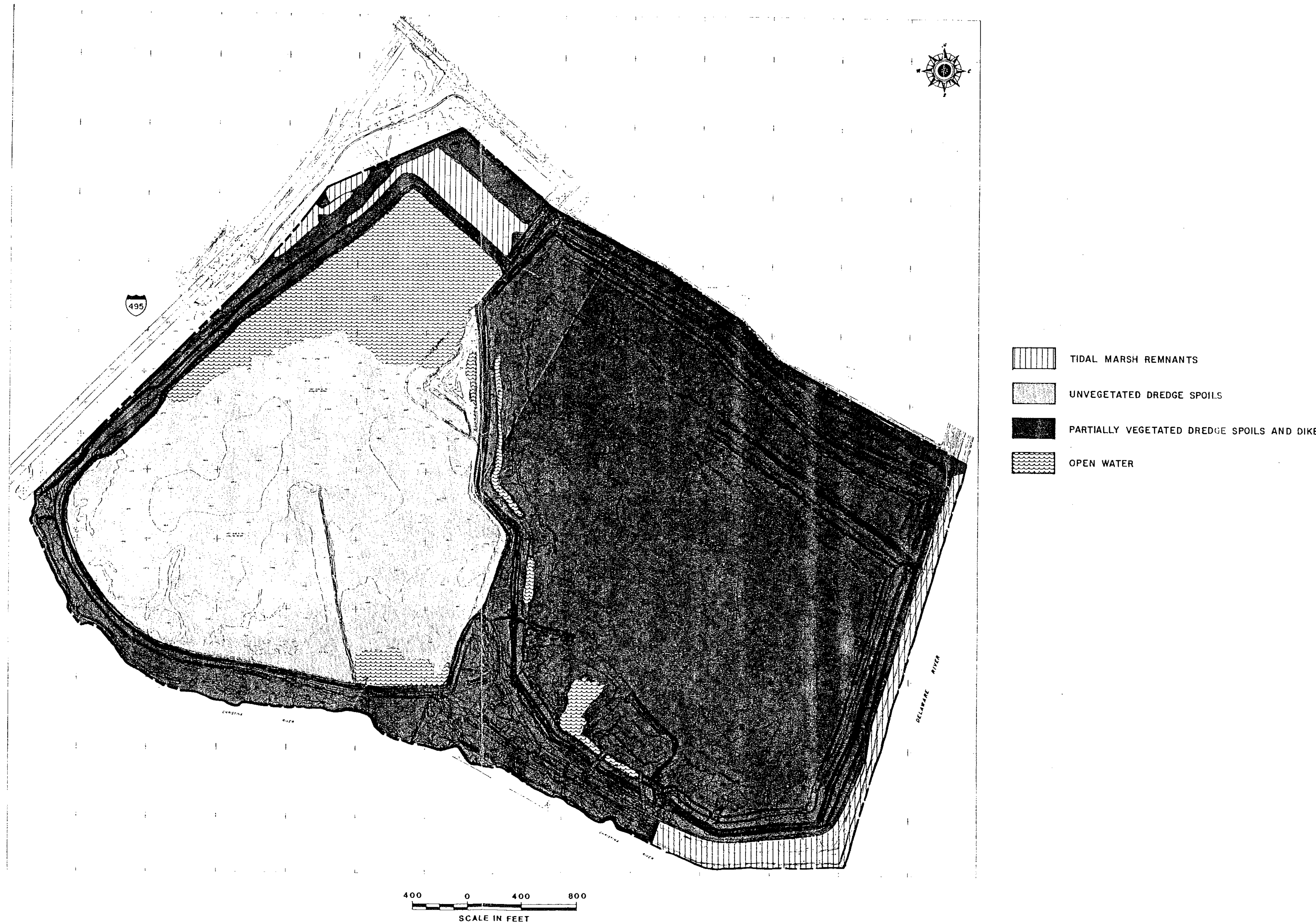


FIGURE 6.3-1
CHERRY ISLAND
MAJOR VEGETATION TYPES

of access restrictions. The only significant vegetated areas occur outside the perimeter dikes, and these areas are dominated by stands of reed grass.

The spoils in the eastern area have been placed over tidal wetland areas the remnants of which are located between the dike and the Delaware and Christina rivers on the eastern and southern boundaries of the site. Although these areas could not be surveyed because of access restrictions, on the basis of aerial photography and observations from the Interstate 495 bridge over the Christina River, it appears that they could be classified as an emergent wetland according to the U.S. Fish and Wildlife Service classification (Cowardin et al., 1979). Since these areas are very narrow, maintaining the 200 ft. buffer zone will protect these areas from impact resulting from landfill operations.

Wildlife: Because of the extensively disturbed character of the site resulting from its use for the disposal of dredging spoils there is very little habitat suitable for wildlife. It is expected that populations of small mammals, including mice, shrews, and voles, and some larger forms, such as raccoons or rabbits, would inhabit the vegetated areas outside the diked portion of the site, but that very few animals would be found within the spoil-covered areas. Similarly, waterfowl would probably not use the site to any great extent. The water-covered spoil observed in the western portion of the site might be attractive as a resting area, but the birds would not remain for extended periods of time because of the lack of feeding areas on the site.

6.3.1.2 Aquatic Communities

Physical Description

The Cherry Island site is located within Wilmington at the confluence of the Christina River with the Delaware River. To the west is the Brandywine Creek (which flows into the Christina River). To the north is Shellpot Creek. The shoreline of these tidal streams are industrialized, with some small areas of tidal marsh remaining. The mean tidal range of the Delaware River at Wilmington is 5.6 feet, with a maximum range of levels from -6 feet to +10 feet (Lindstedt-Siva, 1979). The tidal period is about 12 hours 25 minutes (Delmarva Power and Light Co., 1973).

Water Quality

The salinity of the tidal streams varies with streamflow and tidal stage.

Water quality data for the Christina River and Brandywine and Shellpot Creeks are given on Table 1. Water quality of the lower Christina River is listed as fair (Delaware DNREC, 1980). In 1979, fecal coliform levels did not meet state requirements. However, levels of DO and metals were noted to have improved since 1977. Sources of contamination may be the Delaware River during flood tide (bacterial) and urban and industrial runoff (metals). Water uses designated for the lower river are: industrial water supply, secondary contact recreation, maintenance and propagation of fish and aquatic life, wildlife preservation, navigation, drainage, and passage of anadromous fish. The Delaware DNREC recently stated "The current water quality will provide for all of these uses, however, some lower areas of this segment cannot support a well balanced aquatic population."

The water quality of the Brandywine Creek is listed as good (Delaware DNREC, 1980). The stream serves as Wilmington's water supply upstream of the city and dissolved oxygen levels are high throughout. The stream's water quality is periodically affected by non-point sources of pollutants and storm water runoff. Fecal coliform concentrations are generally above state and federal standards. Designated water uses include public and industrial

TABLE 6.3-1 Water Quality of the Christina River (at River Mile 2.00), the Brandywine Creek (at RM 3.03), and Shellpot Creek (at RM 0.47)

Parameter*	Christina River	Brandywine Creek	Shellpot Creek **
Dissolved Oxygen	8.5	10.0	9.5-11.0
BOD (5-day)	3.3	<2.4	2.7-6.7
Color (units)	26	15	34-40
Turbidity (FTU)	18	6.0	8-40
pH (units)	7.2	7.5	7.5-7.6
Alkalinity	43	47	29-76
Acidity	4	3	4-5
Hardness	85	78	61-95
Chloride	23	15	9-45
Total Nitrogen	1.0	0.7	1.2-1.5
Organic Nitrogen	0.7	0.5	0.4-1.3
Ammonia Nitrogen	0.25	0.10	0.15-0.80
Nitrite	0.04	0.04	0.03-0.04
Nitrate	1.78	2.1	0.72-1.21
Total Phosphate	0.40	0.25	0.10-0.45
Phenol (ppb)	<5	<5	<5-7
Total Residue	210	172	158-238
Iron (ug/l)	1350	1420	320-5000
Copper (ug/l)	<100	<100	<100
Manganese (ug/l)	160	100	<100-320
Chromium (ug/l)	<100	<100	<100
Silver (ug/l)	<100	<100	<100
Calcium (ug/l)	14,500	20,000	10,000-26,250
Zinc (ug/l)	<100	<100	<100
Lead (ug/l)	<100	<100	<100
Nickel (ug/l)	<100	<100	<100
Cadmium (ug/l)	<100	<100	<100
Total Coliforms (#/100 ml)	9,400	6,500	5,900-24,000
Fecal Coliforms (#/100 ml)	480	190	340-490
Fecal streptococcus (#/100 ml)	690	220	200-210

* Median values given; mg/l unless otherwise indicated
** Low and High values given - no median values given in reference

Source: Delaware DNREC (1980).

water supply, primary and secondary contact recreation, and agricultural water supply. The stream "does support a balanced aquatic population" (Delaware DNREC, 1980).

Although Shellpot Creek's dissolved oxygen levels are high, its water quality is not considered good because of high levels of fecal coliforms. This may be a result of the heavy urbanization within the stream's drainage, and the influence of Delaware River water. "Presently, this segment does not completely support balanced populations of aquatic life throughout its length" (Delaware DNREC, 1980).

Water quality data for the Delaware River at Cherry Island are given on Table 6.3-2. This river segment is affected by the highly urbanized and industrialized sections upstream (Tyrawski, 1979). DO levels are periodically below standards, and fecal coliform levels are high. DO levels are frequently 4 to 5 mg/l (Tyrawski, 1979). In 1976-77, the maximum DO level was 11.9, and minimum was 1.9 at Delaware Memorial Bridge (U.S.G.S., 1977). In addition, levels of some metals occasionally are higher than the limits recommended by the EPA and the Delaware River Basin Commission (DRBC). As a result, water quality is "marginal" (Tyrawski, 1979). The heavily impacted middle Estuary . . . is not likely to provide for fish propagation or primary contact recreation in the foreseeable future (Delaware DNREC, 1980). In spite of this, water quality of the lower Delaware River has improved since the 1940's (Kiry, 1974).

Fishes. The numbers of species of fish found in the Delaware River at Cherry Island are relatively limited. A survey along the west shore in the vicinity of the Edgemoor Power Station resulted in the capture of 11 species in October through December. Seven species were taken in January through May, 1974, and 17 in June through November (Tyrawski, 1979). Mummichog and silvery minnow

TABLE 6.3-2

Water Quality of the Delaware River at Cherry Island

Parameter	Minimum	Mean	Maximum
Dissolved oxygen (mg/1)	2.0	5.5	9.9
pH	7.0	7.3	7.8
Nitrogen (mg/1)	1.7	2.7	3.6
Phosphate (mg/1)	0.1	0.3	0.7
Fecal Coliforms (mfm-fcbr/10 M)	10	80	450
Cr (mg/1)*	-	0.022	0.080
Cu (mg/1)*	-	<0.100	-
Cd (mg/1)*	-	0.007	0.020
Ni (mg/1)*	-	<0.100	-
Zn (mg/1)*	-	<0.100	0.150
Pb (mg/1)	-	0.053	0.220
Hg (mg/1)	-	<0.005	-

* for 1972

Source: Delaware DNREC, 1980
Tyrawski, 1979

were most abundant. Bay anchory was also abundant in June through November. Table 6.3-3 lists species that were found on the intake screens and walkways at Edgemoor Station in 1972.

Fish larvae found in 1973 consisted of bay anchory, Atlantic croaker, naked goby, and hogchoker. Of ichthyoplankton taken in January to May of 1974, striped bass dominated the eggs, and river herring and minnows dominated the larvae (Tyrawski, 1979). In June through November, ichthyoplankton in the Delaware and Christina Rivers was dominated by minnows, bay anchovy, river herrings (primarily in the Christina River), naked goby, and hogchoker.

6.3.1.3 Special Considerations

Endangered and Threatened Species

Bald eagles do not nest in the site vicinity, but may pass through the area during migration (personal communication with H. Lloyd Alexander).

Shortnose sturgeon have not been captured near Cherry Island, but specimens have been captured in the Delaware River both upstream and downstream of the site. "Considering this distribution and knowledge of seasonal movements in other estuaries, shortnose sturgeon almost certainly utilize the Delaware River near Cherry Island as a migratory route during spring and fall" (Brundage, 1981). As the sturgeon do not tolerate low dissolved oxygen levels, they are most likely not present near the site during summer. "If water quality were improved, the Philadelphia-Wilmington reach would probably be utilized as a summer foraging grounds." (Brundage, 1981). One species of isopod and one amphipod, both of which are important foods to juvenile sturgeon, are dominant invertebrates in the site vicinity. In addition, the river's salinities at the site are favorable for summer foraging.

Table 6.3-3
Fishes Collected at the Edgemoor Station in 1972*

Common Name	Scientific Name
Eels	Anquillidae
American eel	_Anguilla rostrata_
Herrings	Clupeidae
Blueback herring	_Alosa aestivalis_
Alewife	_Alosa pseudoharengus_
Gizzard shad	_Dorosoma cepedianam_
Anchovies	Engraulidae
Bay anchovy	_Anchoa mitchilli_
Minnows & Carps	Cyprinidae
Goldfish	_Carrasius auratus_
Carp	_Cyprinus carpio_
Silvery minnow	_Hybognathus nuchalis_
Satinfin shiner	_Notropis analostanus_
Freshwater Catfishes	Ictaluridae
Brown bullhead	_Ictalurus nebulosus_
Killifishes	Cyprinodontidae
Mummichog	_Fundulus heteroclitus_
Temperate basses	Percichthyidae
White perch	_Morone americana_
Striped bass	_Morone saxatilis_
Silversides	Atherinidae
Atlantic silverside	_Menidia menidia_
Sunfishes	Centraridae
Pumpkinseed	_Lepomis gibbosus_
Bluegill	_Lepomis macrochirus_
Perches	Percidae
Yellow perch	_Perca flavescena_
Drums	Sciaenidae
Weakfish	_Cynoscion regalis_
Spot	_Leiostomas xanthurus_
Soles	Soleidae
Hogchoker	_Trinectes maculatus_

* Taken from the intake screens and adjacent walkways.
Source: Delmarva Power and Light Co., 1973

Economically and Recreationally Valuable Species

Cherry Island is located within the City of Wilmington. There are no state owned hunting areas adjacent to or near the site. As the general area is highly industrialized, little habitat exists that is favorable for game species.

Miller (1980) indicated that 2.1 percent of the state's boat fishing in marine waters occurred on the Delaware River in 1978, but did not give data for the river as far upstream as Wilmington.

6.3.1.4 Project Impacts

Because of the nature of the site regarding its present use for the disposal of dredge material, dikes are already in place on the island. Thus, erosion associated with site preparation is expected to be minimal and localized.

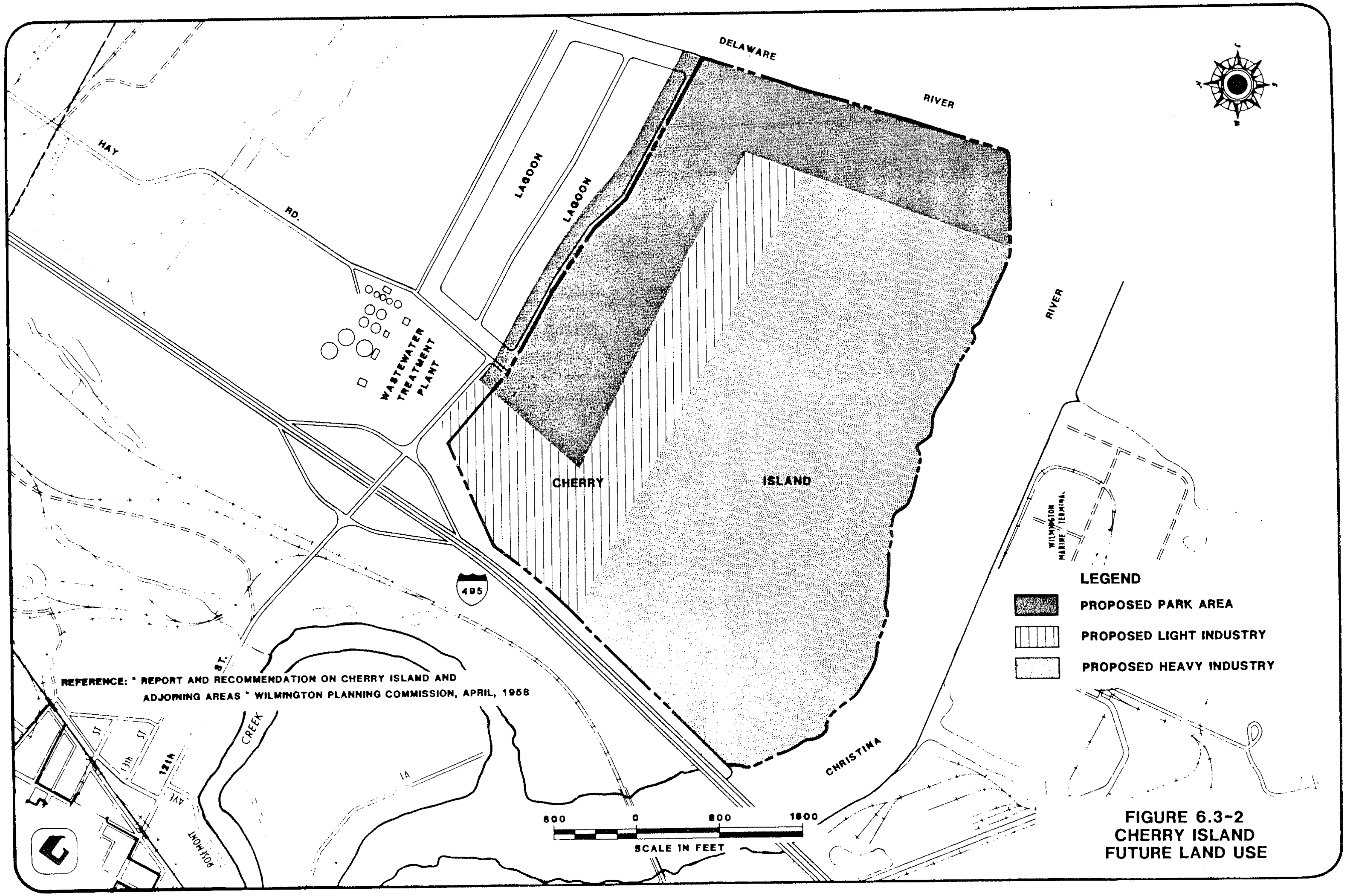
Use of the site will not disturb wildlife habitat, because the site is presently being used to deposit dredge spoils. The surrounding area is industralized, and the levels of noise and activity associated with the landfill should not be much different from what occurs presently.

Because of the proximity to the Wilmington Area Sewage Treatment Plant, it may be more expedient to pump leachate, if necessary, directly to this wastewater treatment plant for treatment (as opposed to constructing on-site treatment facilities with separate discharge directly to the Delaware or Christina River).

6.3.2 Land Use

6.3.2.1 Future Land Use

The Wilmington Planning Commission, on April 2, 1958, adopted a study entitled "Report and Recommendation on Cherry Island and



REFERENCE: " REPORT AND RECOMMENDATION ON CHERRY ISLAND AND ADJOINING AREAS " WILMINGTON PLANNING COMMISSION, APRIL, 1958

FIGURE 6.3-2
CHERRY ISLAND
FUTURE LAND USE

Adjoining Areas" as part of the City's Comprehensive Development Plan.

The Plan proposed a 324 acre, multi-use park on Cherry Island consisting of a marina, baseball diamonds, auditorium, aquarium, dance and skating pavilion, restaurant, swimming pools, bathhouse, tennis, archery, games and parking areas. The park was to extend from Shellpot Creek south to a midpoint between 4th and 8th Streets; and from Hay Road to the Delaware River. In addition, the park extended south to the Christina River and included 8000 feet of the Delaware River shoreline. This waterfront area was recommended to be used for informal promenades, lagoons and reflecting pools.

The remaining portion of Cherry Island was recommended to be used for either light or heavy industry. The area south of 4th Street was recommended for heavy industrial use while the portion of the site north of 4th (between 4th and 8th), with the exception of the park area, was recommended for light industry use.

Portions of the area originally proposed for the park appear to have been encroached upon by the Wilmington Wastewater Treatment Plant. The New Castle County Department of Planning is, in its Comprehensive Plan update which is presently under preparation, considering recommending that the Cherry Island site be developed as proposed by the City of Wilmington in its 1958 study.

6.3.2.2 Farm Land Classification

The proposed Cherry Island site contains more than 500 acres, none of which have prime agricultural soils. The proposed site is mapped as containing Othello-Fallsingston-Urban land complex and Tidal Marsh soil groupings.

The Othello-Fallsingston-Urban land complex lies mainly along the lower part of the Christina River and the Delaware River between

Wilmington and the State of Pennsylvania. This soil group is described as poorly drained, nearly level soils, with 75 percent being covered with fill material. Seasonal wetness and a high water table limit this soil type for residential or community uses or for building sites.

Tidal Marsh consists of areas that are flooded regularly by tidal waters. Besides being salty, some areas contain large amounts of sulfur compounds. Tidal marshes are of little or no value for farming and are unsuitable for crops, pasture, or timber production. If drained, the sulfur compounds oxidize to other compounds that are normally highly toxic to crops and most other plants.

The Cherry Island site, therefore, has no agricutural value and the use of this site for a landfill would have no effect on agricultural productivity or potential productivity.

6.3.3 Zoning

The Cherry Island site is zoned M-1 (Light Manufacturing) and M-2 (General Manufacturing) by the City of Wilmington.

The M-1 District permits book publishing, laboratories, light manufacturing, wholesale sales and warehousing, retail stores or service establishments, restaurants, and public utility and service uses.

The M-2 Zoning District permits all uses not otherwise prohibited. Only a few specific industrial uses are specifically prohibited - fertilizer manufacturing, explosive manufacturing, reduction of garbage, offal or dead animals on a commerical basis, and refining or processing of crude petroleum.

No minimum lot area restrictions apply to either the M-1 or M-2 Zoning District.

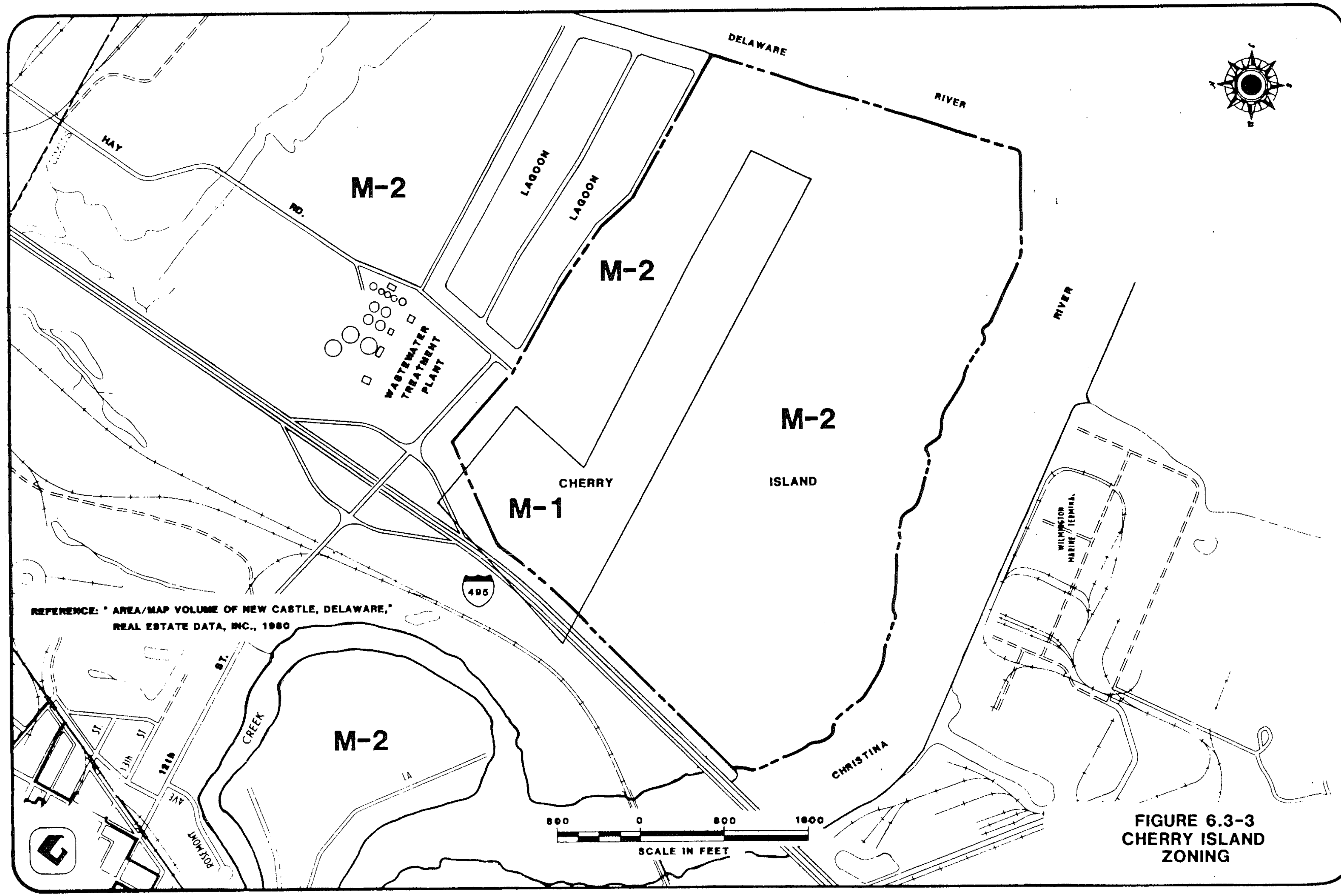


FIGURE 6.3-3
CHERRY ISLAND
ZONING

6.3.4 Demography

There are no dwellings within 300 yards of the proposed site.

6.3.5 Cultural, Recreational and Natural Areas

There are no cultural, recreational or natural areas within 300 yards of the proposed site.

6.3.6 Historic Sites

There are no known historic sites, national or state, within 300 yards of the proposed site.

6.3.7 Aesthetics

The Cherry Island site is adjacent to I 495 which is elevated because of the Christina River bridge crossing. North bound traffic, therefore, has a clear unobstructed view of the site with no opportunity for screening the site to reduce the aesthetic impact that the landfill operations will produce. The site will therefore have a high degree of visibility albeit the viewing public primarily will be motorists who will view the site operations from a relatively fast moving vehicle, for a short period of time.

Because of the industrial character of the surrounding area, the development of a landfill at Cherry Island will not significantly affect the quality of the area nor the landscape of the viewing area.

6.4 TRANSPORTATION CONSIDERATIONS

6.4.1 Highway Access

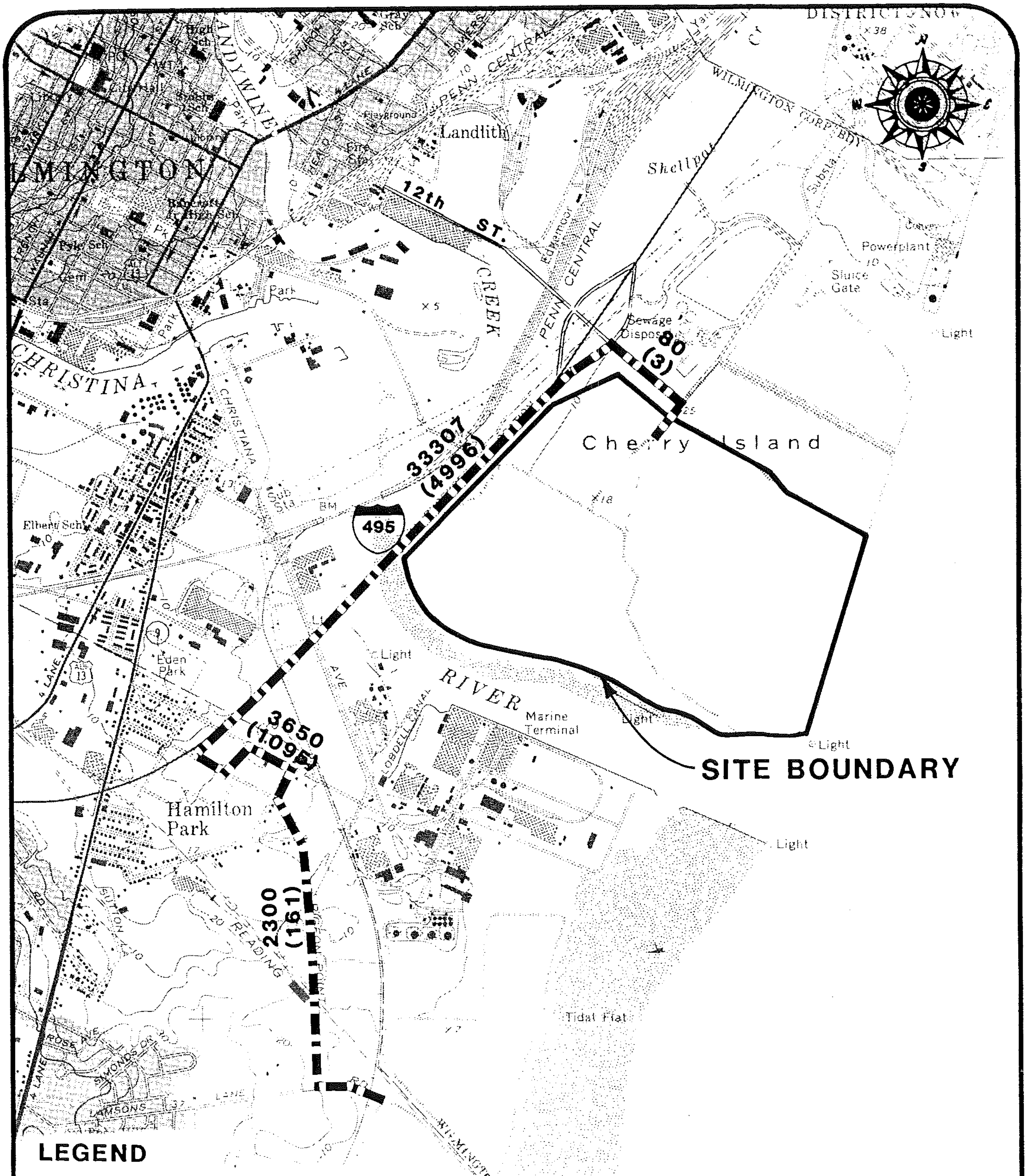
The suggested highway access to this candidate site would be as shown on Figures 1.0-1 and 6.4-1 and as delineated in Table 6.4-1. Virtually no homes (residences) are found along this route.

The anticipated truck traffic volume associated with hauling the wastes from Pigeon Point to any of the sites (assuming an average net load of 15 tons/per truck, the 10th year waste generation rate and hauling 260 days/year) is approximately 50 truck loads per day. This results in an increase of 100 in the truck count along the proposed haul route. Table 6.4-1 also shows the effect of this in terms of % increase on the different segments of the suggested haul route.

The conditions of the roads along the suggested route are good to excellent. For purposes of the economic investigation which is discussed in Section 6.6.6, it will be assumed that no roads will require upgrading. There appears to be no restrictions or limitations along the route which would impede travel to the site.

6.4.2 Rail Access

The nearest rail line is approximately 800 ft. west of the site. Because of this proximity to a rail line, rail access, at first glance appears to be an attractive alternative. It would require at a minimum the construction of a 0.15 mile spur, some rights-of-way acquisition (a good portion of which probably would be associated with I 495), and switching facilities. Assuming clearances beneath I-495 are sufficient, no special provisions for highway crossings or stream crossings would be needed although a low lying, marshy area would have to traversed to get to the base of the dike of the "Wilmington Area".



LEGEND

PROPOSED HAUL ROUTE

80 AADT (ALL VEHICLES)

(3) AADT (TRUCKS)

2000 0 2000

SCALE IN FEET

FIGURE 6.4-1
CHERRY ISLAND
PROPOSED ACCESS/
EXISTING AADT

TABLE 6.4-1

CHERRY ISLAND
PROPOSED HAUL ROUTE DATA

NAME/ROAD #	MILES	HOUSES ALONG ROUTE	CLASSIFICATION	LIMITATIVE	TOTAL AADT	TRUCK AADT*	% INCREASE AADT**	% INCREASE TRUCK AADT**
Pigeon Point Road (State Road 377)	1.1	2	Heavy Duty (Collector)	None	2300	161	4.3	62
State Road 359	0.4	0	Heavy Duty (Collector)	None	3650	1095	2.7	9.1
Interstate 495	1.5	0	Heavy Duty (Interstate)	None	33307	496	0.3	2.0
12th Street (State Road 9)	0.4	0	Heavy Duty (Collector)	None	80	3	225	3433
		2						
Total one-way mileage:	3.4							

* AADT - Annual Average Daily Traffic as reported by DELDOT

** Based upon: 10th year tonnage estimate; 260 working days/year; and 15 tons payload per truck, approximately 50 truck loads of waste per day would be hauled to the disposal site; therefore, traffice counts should be increased by 100 to reflect impact of the hauling operation.

Special loading/unloading facilities would be required at Pigeon Point and at the Cherry Island site along with a small railyard to accomodate the rail cars. A certain number of transfer units would be required to move the wastes from the unloading facility to the working face of the landfill, a distance of approximately 3,400 feet (0.65 miles). Considering that the total one-way road mileage to Pigeon Point is only about 3.4 miles, it is doubtful that such a capital intensive alternative would be cost effective. In addition it may not be any more efficient from a labor standpoint if one considers that separate crews may be needed for loading, transit, and unloading operations.

6.5.3 Waterway Access (Barging)

Both the Delaware and Christina Rivers which bound the site on the east and south, respectively, are navigable within these reaches. The Wilmington Marine Terminal is on the opposite shore of the Christina River from the Cherry Island site. Similar to the rail haul alternative, barging of wastes also may appear to be an attractive alternative at first glance. However, this transport alternative also would be a capital intensive project. From a labor standpoint, special crews may be needed for loading, transit, and unloading operations resulting in little, if any, savings over highway hauling. Transfer units would still be needed to haul the wastes from a new marine terminal at Cherry Island to the landfill working face, an average distance of 1,600 feet (0.3 miles), assuming the terminal facilities are parallel to either shoreline of the "Edgemoor Area".

Proceeding with such a venture would require marine terminal facilities for loading at Pigeon Point and marine terminal facilities at the candidate site. Both terminal facilities would have to be large enough to accomodate maneuvering of the barges. Corps of Engineers permits would be required for both terminal facilities.

6.5 ECONOMIC CONSIDERATIONS

6.5.1 Estimated Landfill Development Costs

The estimated capital needed at the start of the project if this candidate site is selected for development as the NSWF is presented in Table 6.5-1 and 6.5-2. As appropriate construction costs were developed from the Authority's experience with the Central Solid Waste Facility (CSWF) and/or from Means Building Contruction Cost Data. Table 6.5-1 presents costs associated with developing a lined landfill at this site. Table 6.5-2 presents costs associated with developing an unlined landfill.

With regard to the capital cost shown in Part A of the tables, the engineering/surveying/legal costs are associated with facility permitting, detailed design of the first disposal area, preliminary design of remaining disposal areas, preparation of bid documents (specifications, drawings, contract) for construction of the first disposal area, evaluation of bids, and construction services. Land purchase is for approximately 350 acres. This represents that amount which would have to be purchased if it is assumed that landfilling will be restricted to the "Edgemoor Disposal Area".

The Cherry Island site is unique in many ways and the construction costs shown in Tables 6.5-1 and 6.5-2 reflect this. Assuming that the site will have to be lined to receive a permit from the DNREC, Table 6.5-1 shows the development costs associated with this alternative. Site preparation requirements would be extensive. They would consist of preloading the site to accelerate the anticipated settlement of dredge spoils. The consolidation process can be accelerated further through the utilization of sand drains or "Geodrains". The area preloaded should be of a size compatible with placement of several years of refuse. While refuse is being placed in the first preconsolidated area, other portions of the site can be preconsolidated.

TABLE 6.5-1

CHERRY ISLAND SITE
AUTHORITY OWNED/CONTRACTOR OPERATED SANITARY LANDFILL
SUMMARY OF CAPITAL COST FOR LINED LANDFILL FACILITY*

A.	Estimated Project Start-Up Costs	
1.	Land Purchase	$ 2,165,000
2.	Engineering/Surveying	340,000
3.	Legal	50,000
4.	Clearing/Grubbing/Stripping and Stockpiling Topsoil	-
5.	Subgrade Preparation (includes dike improvements/construction)	271,000
6.	Installation of Liners and Leachate Collection System/Storage	634,000
7.	Liner Protective Cover	571,000
8.	Erosion Control Facilities	35,000
9.	Relocation of Preload	2,900,000
10.	Access Roads	88,000
11.	Fencing	130,000
12.	Landscaping	25,000
13.	Structures	181,000
14.	Utilities	25,000
15.	Groundwater Monitoring Wells	21,000
16.	Decomposition Gas Monitoring Wells	6,000
17.	Geodrains and Preloading	9,014,000
18.	Interest during Construction on Items 1-17	1,103,000
	Total	$17,559,000
B.	Cost Summary - Recurring Costs (3-Yr. Amortization)	
1.	Engineering/Surveying	$ 160,000
2.	Legal	25,000
3.	Clearing/Grubbing, etc.	-
4.	Subgrade Preparation	271,000
5.	Installation of Liners/Leachate Facilities	634,000
6.	Liner Protective Cover	571,000
7.	Erosion Control Facilities	10,000
8.	Relocation of Preload	2,900,000
9.	Access Roads	88,000
10.	Decomposition Gas Monitoring Wells	6,000
	Total	$ 4,665,000

*Costs shown are projected 1984 dollars

**Costs are representative of the development of approximately 27 acres in a phased development program consisting of 7 phases each lasting approximately 3 years.

A more detailed description of the work required for preconsolidation of the dredge spoil at Cherry Island is defined as follows:

1. Install 2 foot thick sand working pad to be utilized for equipment accessibility. This pad would blanket the entire area to be preconsolidated.

2. Install drains (Geodrains or equal) on five-foot triangular grid over entire area. Drains should be installed to a depth of approximately 50 feet at an estimated cost of \$0.80/lin. foot installed.

3. Construct preload and leave for 1 year. Height of the preload is determined as follows:

$$\frac{\text{2400 psf (wt. of 40' of refuse \& cover)}}{\text{110 pcf (Density of preload)}} \times 1.2 = \text{26 ft. Height of Preload}$$

   During and after construction of the preload a monitoring system will be required to monitor the consolidation of the materials.

4. Remove preload and relocate to next area of site to be developed.

5. Install liner and leachate collection system.

As can be seen, the costs associated with this are very expensive. It is estimated that the geodrains would cost approximately \$2,380,000 to install and the preload material \$6,634,000 to import and place. In addition, it is estimated that another \$2,900,000 would be needed to remove the preload and relocate it to the next area of the site. For the purposes of this analysis it was assumed that the area needed to provide approximately

3 years of life would be pre-loaded; this is approximately 27 acres. The recurring costs in this analysis do not incorporate costs for geodrains. Reasons for this are that with the subsequent areas to be developed, the preload would be on each area for three years (approximately) and the geodrains may not be needed, or the number significantly reduced.

One problem associated with this alternative that may not be readily apparent is the time involved for construction and then the subsequent removal of the preload. It may take up to 15 months to construct and another 6 months to remove, all sandwiched about the 12 months the preload is left in place.

Another consideration is that the geodrains are not removed, and as such, should there be a significant break in the liner, offer expedient avenues of flow directly to the underlying aquifer.

Since the existing dredge spoils in an unconsolidated state have a permeability that comes very close to meeting the permeability requirement of 1×10^{-7} established by DNREC, Table 6.5-2 presents costs associated with the development of unlined disposal areas on Cherry Island. It has been estimated in the settlement analysis that this permeability requirement will be met or bettered after consolidation of the dredge spoils under the waste load. Taking these things into consideration along with the depth of the dredge spoils (30 to 35 ft.), it appears that a "man-made" liner may not be necessary or practical.

Because of the settlement problem, conventional means of collecting leachate with perforated PVC headers and laterals would not be feasible. A combination of peripheral drains and a centrally located sump is suggested. A three ft. layer of porous material (coarse sand) would have to be placed over the subgrade to provide a working cushion and permeability contrast, thus creating a flow zone on top of the dredge spoils. The sand layer

TABLE 6.5-2

CHERRY ISLAND SITE
AUTHORITY OWNED/CONTRACTOR OPERATED SANITARY LANDFILL
SUMMARY OF CAPITAL COST FOR UNLINED FACILITY*

A. Estimated Project Start-Up Costs

1.	Land Purchase	$2,165,000
2.	Engineering/Surveying	340,000
3.	Legal/Administrative	50,000
4.	Subgrade Preparation (Including dike construction and renovation)**	271,000
5.	Leachate Collection and Storage Facilities	1,273,000
6.	Erosion Control Facilities	35,000
7.	Access Roads	88,000
8.	Fencing	130,000
9.	Site Landscaping	25,000
10.	Structures (Office Trailer/Maintenance Bldg.)	181,000
11.	Utilities (Electricity, Water, Sewer, Communications)	25,000
12.	Groundwater Monitoring Wells	21,000
13.	Decomposition Gas Monitoring Wells	6,000
14.	Interest During Construction (9.6%; 4 months)	148,000
	Total	$4,758,000

B. Estimated Annual Cost of Start-Up Capital

Amortization Period: 20 years
Interest Rate: 9.6%
Annual Cost of Capital: $542,000

C. Recurring Costs*
3-Year Frequency**

1.	Engineering/Surveying/Legal	$ 185,000
2.	Subgrade Preparation	271,000
3.	Leachate Collection and Storage Facilities	1,273,000
4.	Erosion Control	10,000
5.	Access Roads	88,000
6.	Decomposition Gas Monitoring Wells	6,000
	Total	$1,833,000

*Costs shown are projected 1984 dollars
**Costs are representative of the development of approximately 27 acres in a phased development program consisting of 7 phases each lasting approximately 3 years.

will conform to whatever shifts in the subgrade occur. Depending upon the seriousness of the differential settlement and its relation to the sump and peripheral drain all of the leachate may not be able to be collected. The result may be a constant foot or two of head over certain areas.

Screening of the site is not considered practical.

To prevent trespassing, approximately 8700 L.F. of chain link fencing will be needed. The fencing will be along the north and west sides of the site. The Christina and Delaware Rivers are considered natural impediments to access.

It has been assumed that water will be provided by tapping the public supply serving the Wilmington Area Wastewater Treatment Facility. Likewise it has been assumed that sanitary wastes will be discharged directly to the sewerage system of the Wilmington Area Wastewater Treatment Plant. (The discharge of leachate directly or after some minimal pre-treatment to this system will be investigated in detail as part of the design work).

Electricity and communications will have to be provided. The maintenance building and other structures will be assumed to be centrally located. Thirty percent will be added to the construction of such structures to account for foundation problems associated with building on dredge spoils.

Pertaining to the capital costs shown in Part C, other than engineering, these should be self-explanatory. The engineering, surveying, and legal fees are associated with the detailed design of subsequent landfill areas, the preparation of Specifications, Drawings, and Contracts to accomplish the work; and construction services.

6.5.2 Estimated Landfill Operating Costs

Table 6.5-3 presents the estimated first year operating cost for an Authority owned/Contractor operated land disposal facility. Of the landfill personnel needed to operate the site, it was assumed that one person would be in the direct employ of the Authority. It also was anticipated that the Authority would directly pay for all fuel for operation of the Contractor's equipment and for all utilities such as electricity, gas, heating oil, or telephone. Costs associated with the groundwater monitoring program and gas monitoring program would be borne by the Authority.

Contractor costs were estimated taking into consideration owning and operating costs for six items of equipment (including a landfill compactor, bulldozer and tracked loader), and wages (assuming union labor) for five employees (1 supervisor, 3 equipment operators, 1 laborer).

The bottom portion of Table 6.5-3 shows for the two alternatives the first year cost for owning, developing, and operating a landfill at the Cherry Island site.

Tables D-1 and D-1A of Appendix 6D projects owning and operating costs and "equivalent disposal fees" for the tonnage landfilled for the lined and unlined alternatives, respectively. The projections are made assuming that initial project costs are financed with revenue bonds at 9.6% interest and an escalation factor of 9%/year for both capital costs and operating expenses. The projected "equivalent disposal fees" are depicted graphically in Figures 6.5-1 and 6.5-2. The fees are "normalized" for three year periods which coincide with the anticipated triannual development program.

TABLE 6.5-3

CHERRY ISLAND SITE
FIRST YEAR OPERATING EXPENSES/TOTAL FIRST YEAR COSTS
AUTHORITY OWNED/CONTRACTOR OPERATED SANITARY LANDFILL

FIRST YEAR OPERATING EXPENSES*

A.	Authority Direct Costs	
	1. Labor (1 Person, including Fringe Benefits)	$ 24,000
	2. Equipment Fuel	68,000
	3. Utilities (Electricity, telephone, etc.)	3,700
	4. Groundwater Monitoring Program	20,800
	5. Decomposition Gas Monitoring Program	1,000
	6. Access Road Maintenance	17,000
	7. Miscellaneous Expenses	6,500
	Subtotal	$ 141,000
B.	Estimated Contractor's Fee (Excluding cover material importation costs)	$ 861,000
C.	Estimated Cost for Importation (Acquisition and hauling) Cover Material	$ 954,00
	Total	$1,956,000

TOTAL FIRST YEAR COSTS

		Lined	Unlined
A.	Annual Cost of Capital (From Table 6.5-1)	$2,001,000	$ 542,000
B.	First Year Operating Cost	1,956,000	1,956,000
	Total	$3,957,000	$2,498,000

C. Cost/Ton if Allotted to Tonnage Landfilled:
$3,957,000/159,000 Tons = $24.90 (Lined)
$2,498,000/159,000 Tons = $15.70 (Unlined)

* Costs shown are projected 1984 dollars.

6.5.3 Estimated Haul Costs

Table 6.5-4 presents the initial year costs estimated for the hauling of residues and non-processables from the DRP at Pigeon Point to the Cherry Island site. It has been assumed that the Authority will contract the hauling operation as opposed to operating the system itself. Therefore, to arrive at the cost associated with a Contract operation, costs were developed as if the Authority was intending to develop and operate the system and a 35% surcharge was incorporated to account for contingencies and contractor's overhead and profit. Since it will be common to all site alternatives, transfer station development and operating costs were not incorporated in the estimates.

The round-trip distance is estimated at 6.8 miles. The round trip is estimated to require approximately 30 minutes to complete including turnaround time at the disposal site. Therefore, the number of trips which can be made each day with a single hauling unit is estimated at 15. At an average payload of 15 tons, approximately 50 trips per day would be necessary based upon the estimated 10th year tonnage. At 15 trips per truck, about 4 tractors will be needed. To provide for contingencies, a 5th 7 tractor should be added. Similarly, it is estimated that 7 trailers would be necessary to provide flexibility and sufficient back-up or reserve capacity.

With regard to manpower, 5 drivers will be needed to run the hauling operation. Wage rates are based upon the United States Department of Labor, Area Wage Survey, Wilmington, Del. - N.J. - Md., April 1981. Other data regarding maintenance, tires, insurance, etc., were obtained from a 1977 study performed for the Southeastern Public Service Authority of Virginia by Hennington, Durham, and Richardson and from "A Handbook for Transfer System Analysis", The Heil Co., 1974. Applicable cost data appearing in these studies were updated by escalating at a rate of 9% per year.

TABLE 6.5-4

CHERRY ISLAND SITE
FIRST YEAR HAULING COSTS*

A. EQUIPMENT

1.	Tractors - 5 @ $71,000 = $355,000	
	Annual Cost Amortized at 15% over 5 yrs.	$ 106,000
2.	Trailers - 7 @ $45,000 = $315,000	
	Annual Cost Amortized at 15% over 7 yrs.	76,000
	Subtotal	$ 182,000

B. OPERATING COSTS (Excluding Fuel)

1.	Labor (Assuming Union Labor) 5 Drivers - 40 hrs. Regular Time and 4 hrs. at double overtime per week: $4824.00/week x 52 weeks =	$ 251,000
2.	Oil, Filters, Tires, Maintenance, Insurance: 0.389/mile x 90,168 miles =	35,000
	Subtotal	$ 286,000

C. FUEL COSTS

$1.70/gallon ÷ 6.5 miles per gallon (using equipment with high torque rise diesel) is $0.26 mile

$0.26/mile x 90,168 miles =	23,500
Total	$ 491,500
Add 10% for Contingency:	49,100
Add 10% for Overhead:	49,100
Add 15% for Profit:	73,800

D. Grand Total Estimated First Year Hauling Cost $ 663,500

Cost/ton if allotted to tonnage landfilled: $663,500/159,000 tons = $4.15/ton

* Costs shown are projected 1984 dollars

It was assumed that compacting-type financing trailers will be utilized.

Fuel costs, starting with a current value of $1.20 gallon, were escalated at 12% per year for the 3-year interval between 1981 and the project start year (1987) and at 9% per year for the 20-year project life. A utilization factor of 6.5 miles per gallon was used for estimating purposes. This means that the 1st year fuel cost would be $0.26/mile multiplied by the total number of miles travelled (90,168 miles per year). All other operating costs also were escalated at 9% per year.

The annual cost of capital for the purchase of the tractors and trailers was based on projected 1984 unit costs of $71,000 and $45,000, respectively. Tractors were amortized over a 5 year period and the trailers over a 7-year period. An interest rate of 15% was utilized. Table D-2 of Appendix 6D presents projected contractor hauling costs and equivalent tonnage fees for the 20-year planning period. Figure 6.5-2 presents this information graphically.

A summary of the anticipated capital needs and yearly costs for owning and operating a sanitary landfill at the Cherry Island Site for the lined and unlined alternatives are shown in Tables 6.5-5 and 6.5-6, respectively. These tables also summarize the projected yearly costs for the transfer of waste materials from Pigeon Point.

TABLE 6.5-5

CHERRY ISLAND SITE

SUMMARY TABLE OF PROJECTED CAPITAL NEEDS AND YEARLY COSTS

Alternative 1 - Lined Facility

	Landfill Development and Operation							Hauling Operation		
	Capital Needs Schedule			Debt Service			Annual Operating Cost	Total Annual Cost	Project Total Annual Cost	$/Ton of Material Transported and Landfilled
Year	Initial	10-Yr	3-Yr	Initial	10-Yr	3-Yr				
1984	$17,559,000	---	---	$ 2,001,000	---	---	$ 1,956,000	$ 663,000	$ 4,620,000	$29.05
1985	---	---	---	2,001,000	---	---	2,132,000	701,000	4,834,000	29.60
1986	---	---	---	2,001,000	---	---	2,324,000	742,000	5,067,000	30.25
1987	---	---	$ 6,041,000	2,001,000	---	$ 2,515,000	2,533,000	786,000	7,835,000	45.65
1988	---	---	---	2,001,000	---	2,515,000	2,761,000	835,000	8,112,000	46.10
1989	---	---	---	2,001,000	---	2,515,000	3,010,000	965,000	8,491,000	47.05
1990	---	---	7,824,000	2,001,000	---	3,257,000	3,280,000	1,023,000	9,561,000	51.75
1991	---	---	---	2,001,000	---	3,257,000	3,576,000	1,171,000	10,005,000	52.90
1992	---	---	---	2,001,000	---	3,257,000	3,897,000	1,239,000	10,394,000	53.65
1993	---	---	10,132,000	2,001,000	---	4,218,000	4,248,000	1,314,000	11,781,000	59.40
1994	---	---	---	2,001,000	---	4,218,000	4,631,000	1,514,000	12,364,000	60.95
1995	---	---	---	2,001,000	---	4,218,000	5,047,000	1,603,000	12,869,000	62.00
1996	---	---	13,121,000	2,001,000	---	5,463,000	5,502,000	1,700,000	14,666,000	69.10
1997	---	---	---	2,001,000	---	5,463,000	5,997,000	1,806,000	15,267,000	70.30
1998	---	---	---	2,001,000	---	5,463,000	6,536,000	2,076,000	16,076,000	72.45
1999	---	---	16,992,000	2,001,000	---	7,075,000	7,125,000	2,384,000	18,585,000	81.95
2000	---	---	---	2,001,000	---	7,075,000	7,766,000	2,521,000	19,363,000	83.55
2001	---	---	---	2,001,000	---	7,075,000	8,465,000	2,670,000	20,211,000	85.40
2002	---	---	22,005,000	2,001,000	---	9,162,000	9,227,000	2,833,000	23,223,000	96.10
2003	---	---	---	2,001,000	---	9,162,000	10,057,000	3,011,000	24,231,000	98.20
2004	---	---	---	---	---	9,162,000	10,962,000	3,484,000	23,608,000	93.70
TOTALS	$17,559,000	---	$76,115,000	$40,020,000	---	$95,070,000	$111,032,000	$35,041,000	$281,163,000	
1984 $*	$17,559,000	---	$28,168,000	$19,980,000	---	$32,400,000	$ 41,300,000	$13,100,000	$106,780,000	

*Totals in 1984 Dollars as determined via a "present worth" analysis.

TABLE 6.5-6

CHERRY ISLAND SITE

SUMMARY TABLE OF PROJECTED CAPITAL NEEDS AND YEARLY COSTS

Alternative 2 - Unlined Facility

	Landfill Development and Operation							Hauling Operation		
	Capital Needs Schedule			Debt Service						
Year	Initial	10-Yr	3-Yr	Initial	10-Yr	3-Yr	Annual Operating Cost	Total Annual Cost	Project Total Annual Cost	$/Ton of Material Transported and Landfilled
1984	$4,758,000	---	---	$ 542,000	---	---	$ 1,956,000	$ 663,000	$ 3,161,000	$19.90
1985	---	---	---	542,000	---	---	2,132,000	701,000	3,375,000	20.70
1986	---	---	---	542,000	---	---	2,324,000	742,000	3,608,000	21.55
1987	---	---	$ 2,374,000	542,000	---	$ 988,000	2,533,000	786,000	4,849,000	28.25
1988	---	---	---	542,000	---	988,000	2,761,000	835,000	5,126,000	29.10
1989	---	---	---	542,000	---	988,000	3,010,000	965,000	5,505,000	30.50
1990	---	---	3,074,000	542,000	---	1,280,000	3,280,000	1,023,000	6,125,000	33.15
1991	---	---	---	542,000	---	1,280,000	3,576,000	1,171,000	6,569,000	34.70
1992	---	---	---	542,000	---	1,280,000	3,897,000	1,239,000	6,958,000	35.90
1993	---	---	3,981,000	542,000	---	1,658,000	4,248,000	1,314,000	7,762,000	39.15
1994	---	---	---	542,000	---	1,658,000	4,631,000	1,514,000	8,345,000	41.15
1995	---	---	---	542,000	---	1,658,000	5,047,000	1,603,000	8,850,000	42.65
1996	---	---	5,156,000	542,000	---	2,147,000	5,502,000	1,700,000	9,891,000	46.60
1997	---	---	---	542,000	---	2,147,000	5,997,000	1,806,000	10,492,000	48.35
1998	---	---	---	542,000	---	2,147,000	6,536,000	2,076,000	11,301,000	50.95
1999	---	---	6,677,000	542,000	---	2,780,000	7,125,000	2,384,000	12,831,000	56.55
2000	---	---	---	542,000	---	2,780,000	7,766,000	2,521,000	13,609,000	58.75
2001	---	---	---	542,000	---	2,780,000	8,465,000	2,670,000	14,457,000	61.10
2002	---	---	8,646,000	542,000	---	3,600,000	9,227,000	2,833,000	16,202,000	67.05
2003	---	---	---	542,000	---	3,600,000	10,057,000	3,011,000	17,210,000	69.75
2004	---	---	---	---	---	3,600,000	10,962,000	3,484,000	18,046,000	71.70
TOTALS	$4,758,000	---	$29,908,000	$10,840,000	---	$37,359,000	$111,032,000	$35,041,000	$194,272,000	
1984 $*	$4,758,000	---	$11,000,000	$ 5,400,000	---	$12,700,000	$ 41,300,000	$13,100,000	$ 72,500,000	

*Totals in 1984 Dollars as determined via a "present worth" analysis.

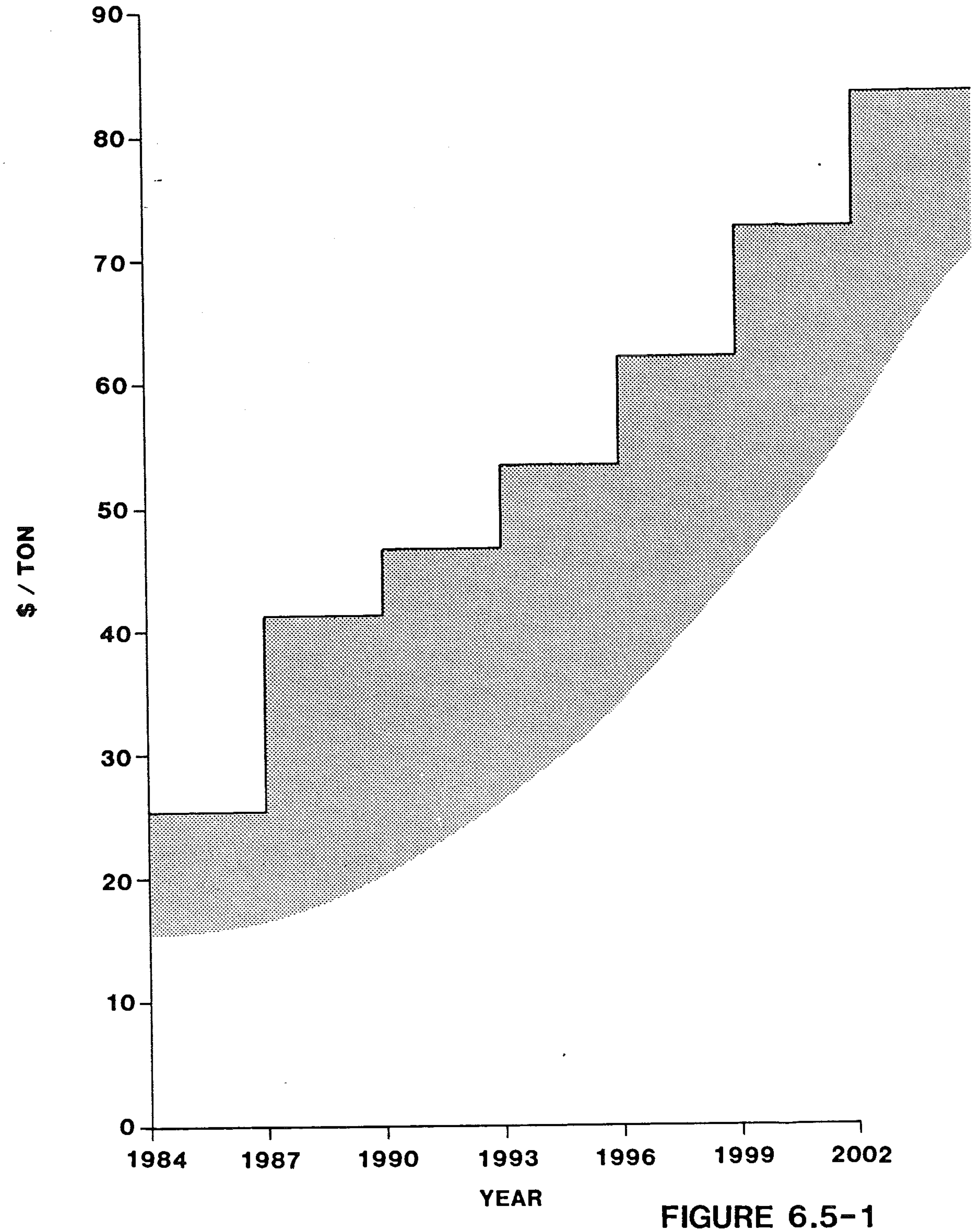


FIGURE 6.5-1
CHERRY ISLAND
ESTIMATED COST ($ / TON)
FOR LANDFILLING
ALTERNATIVE 1 (LINED)

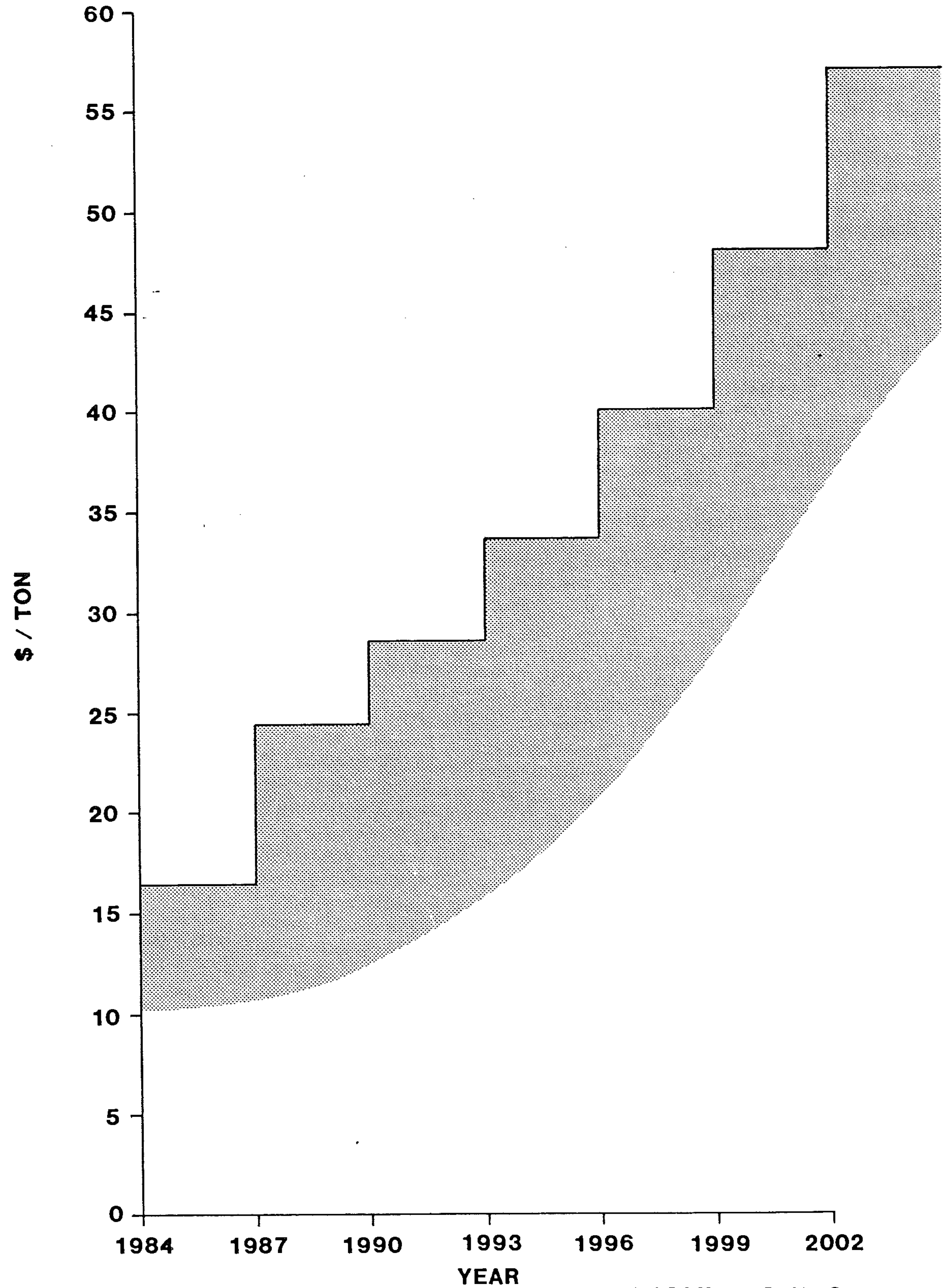


FIGURE 6.5-2
CHERRY ISLAND
ESTIMATED COST ($ / TON)
FOR LANDFILLING
ALTERNATIVE 2 (UNLINED)

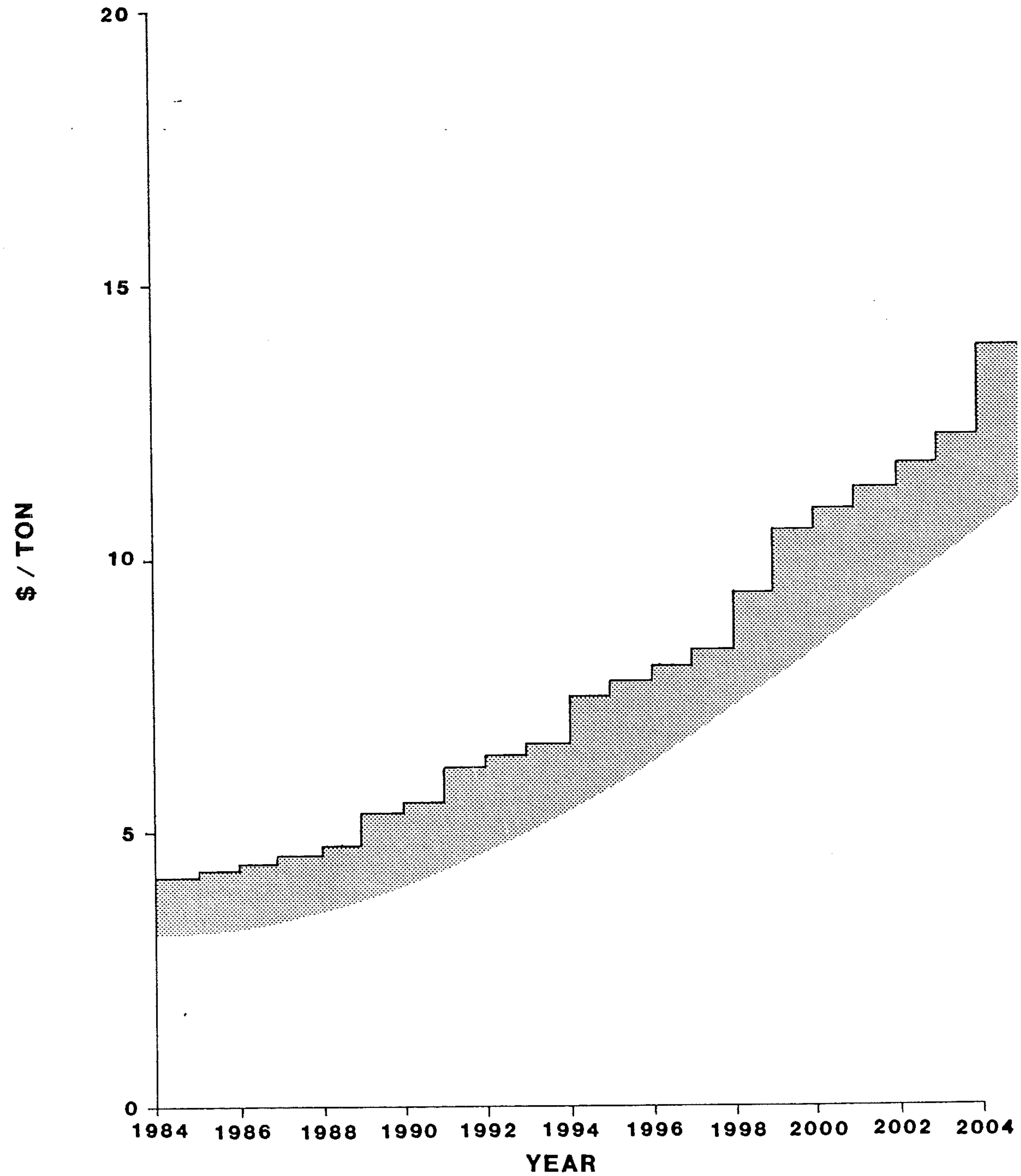


FIGURE 6.5-3
CHERRY ISLAND
ESTIMATED COST ($ / TON)
FOR HAULING

APPENDIX 6A

GEOLOGIC LOGS

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 1 OF 5

PROJECT: DSWA W.O. 06-7390-002 SITE AREA Cherry Island DRILL HOLE NO. P-1

CONTRACTOR: Delmarva Drilling Co. COORDINATES ________ ELEVATION 31.9

DRILLER: C. Wallace GWL 0 HRS 31.0

CLASSIFIED BY: B. W. Benyish DATE: 9/9/81 24 HRS ________

Depth Ft.	Sample No.	SPT Blows/ 6 In. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock Range Size / Core Run	Soil Or Rock Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
0					0 - 5 Brown clayey silt, some reddish brown silty clay, trace of sand					DREDGE SPOIL
5					5 - 8 As above					
					8 - 15 Dark gray silty clay micaceous, sticky streaks of black organics, trace to little vegetation fibers					
10										
15					15 - 20 As above					
20					20 - 25 As above					
25					25 - 30 As above					
30					30 - 35 As above					
35					35 - 40 As above					
40					40 - 45 Green gray silty clay micaceous, some black organic streaks, some brown vegetation fibers					RECENT
45					45 - 51 Increase in vegetation fibers					
50										

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 2 OF 5

PROJECT: DSWA W.O. 06-7390-002 SITE AREA Cherry Island DRILL HOLE NO. P-1

CONTRACTOR: Delmarva Drilling Co. COORDINATES ______ ELEVATION ______

DRILLER: C. Wallace GWL 0 HRS ______

CLASSIFIED BY: B. W. Benyish DATE: 9/9/81 24 HRS ______

Depth Ft.	Sample No.	SPT Blows/6 In. (6 / 12 / 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Soil Or Rock: Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
50										
51 - 55					Multi-color fine to coarse sand, some gravel, some green gray silty clay					PLEISTOCENE
55 - 65					Multi-color sandy gravel Sand: Fine to coarse Gravel: Fine to medium subangular quartz, trace of silt micaceous					
65 - 70					As above; gravel to .75 inch in dia., trace of light red clay					
70 - 75					As above					
75 - 80					As above; with sand lenses					
80 - 87					As above					
87 - 92					Gray to yellow silty clay					
92 - 97					Green gray fine to medium sand					
100										

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 3 OF 5

PROJECT: DSWA W.O. 06-7390-002 SITE AREA Cherry Island DRILL HOLE NO. P-1

CONTRACTOR: Delmarva Drilling Co. COORDINATES ______ ELEVATION ______

DRILLER: C. Wallace GWL 0 HRS ______

CLASSIFIED BY: B. W. Benyish DATE: 9/9/81 24 HRS ______

Depth Ft.	Sample No.	SPT Blows/6 In. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
100					97 - 105 Silty clay; colors: red, white, gray, and brown with quartz gravel					POTOMAC
105					105 - 112 As above; less gravel at 110 - 112					
110					112 - 119 Green gray clayey fine sand - fine sandy clay					
115					119 - 125 Red and gray sandy silty clay, trace of gravel					
120										
125					125 - 130 As above					
130					130 - 135 Red and gray silty clay with little green gray fine sand					
135					135 - 142 As above					
140					142 - 145 Silty sand with some red gray clay					
145					145 - 150 Silty clay - clayey silt; color: red, gray, white, with some sand					
150										

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 4 OF 5

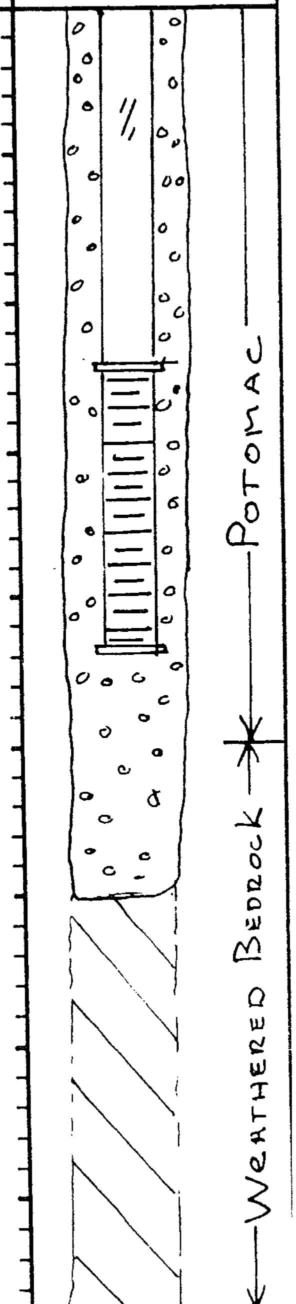
PROJECT: DSWA W.O. 06-7390-002 SITE AREA Cherry Island DRILL HOLE NO. P-1

CONTRACTOR: Delmarva Drilling Co. COORDINATES ______ ELEVATION ______

DRILLER: C. Wallace GWL 0 HRS ______

CLASSIFIED BY: B. W. Benyish DATE: 9/10/81 24 HRS ______

Depth Ft.	Sample No.	SPT Blows/6 In. (6 / 12 / 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
150					150 - 155 As above: increase in fine sand					
155					155 - 162 As above					
160					162 - 165 Silty fine sand to fine sandy silt; color: red, gray, brown					
165					165 - 169 Silty fine to medium sand; color: red, gray, white					
					169 - 175 As above; with some dark gray clayey silt layers					
170										
175					175 - 180 Dark green gray silty clay to clayey silt					
180					180 - 185 Green gray silt, fine to coarse sand, some clay					
185					185 - 190 As above; sand less coarse, less clay					
190										
					194 - Bedrock, hard, quartz					
195					Total Depth 194'					
200										



GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 5 OF 5

PROJECT: DSWA W.O. 06-7390-002 SITE AREA Cherry Island DRILL HOLE NO. P-1

CONTRACTOR: Delmarva Drilling Co. COORDINATES ____ ELEVATION ____

DRILLER: C. Wallace GWL 0 HRS ____

CLASSIFIED BY: B. W. Benyish DATE: 9/10/81 24 HRS ____

Depth Ft.	Sample No.	SPT Blows/ 6 In. 6	12	18	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
							Drilling Notes: 1 - Set 4" PVC screen 162 - 172' 2 - Gravel pack 150 - 180' 3 - Developed - 5 gpm clear 4 - Bentonite seal - 3 - 150' 5 - Installed protector casing and cap Notes: Single Point Electric Log 1 - Mr. John Tulley - Delaware Geol. Survey Logger 2 - Formation breaks from log: a - Dredge spoil/recent - 0 - 50' b - Pleistocene 50 - 92' c - Potomac 92 - 172' d - Weathered bedrock 172 - 194'					

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 1 OF 4

PROJECT: DSWA W.O. 06-7390-002 SITE AREA Cherry Island DRILL HOLE NO. P-2

CONTRACTOR: Delmarva Drilling Co. COORDINATES ____ ELEVATION 35.13

DRILLER: C. Wallace GWL 0 HRS ____

CLASSIFIED BY: B. W. Benyish DATE: 9/11/81 24 HRS 31.0'

Depth Ft.	Sample No.	SPT Blows/6 In. (6 / 12 / 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
0					0 - 7 Brown clayey silt, micaceous					DREDGE SPOIL (0–50)
5					7 - 10 Gray green silty clay, slightly micaceous, vegetation fibers					
10					10 - 15 As above					
15					15 - 20 Gray silty clay, micaceous, vegetation fibers					
20					20 - 25 As above; with brown silt lenses					
25					25 - 30 As above					
30					30 - 35 As above; increased vegetation fibers, black organic streaks					
35					35 - 40 As above					
40					40 - 45 As above					
45					45 - 50 As above					
50										

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

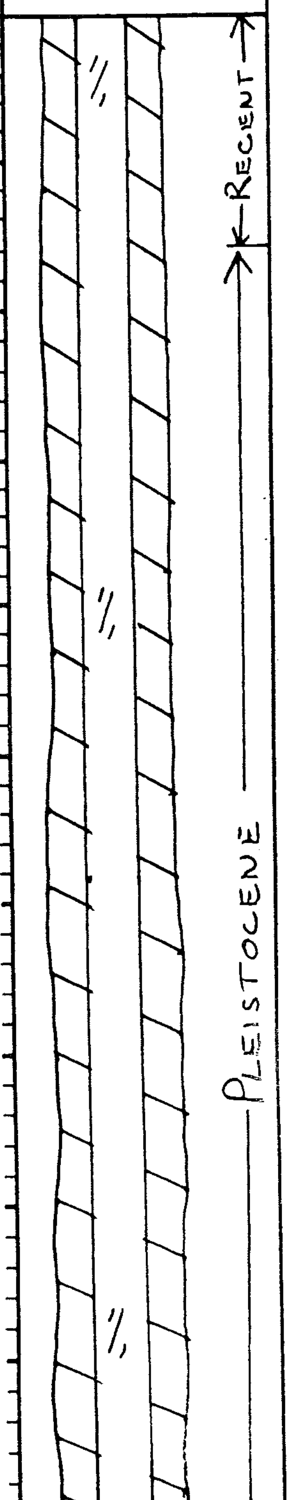
PROJECT: DSWA W.O. 06-7390-002 SITE AREA Cherry Island DRILL HOLE NO. P-2

CONTRACTOR: Delmarva Drilling Co. COORDINATES ____ ELEVATION ____

DRILLER: C. Wallace GWL 0 HRS ____

CLASSIFIED BY: B. W. Benyish DATE: 9/11/81 24 HRS ____

Depth Ft.	Sample No.	SPT Blows/6 In. (6 / 12 / 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock Range Size / Core Run	Soil Or Rock Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
50					50 - 58 Gray clayey silt with brown vegetation lenses, some sand, micaceous					
55										
60					58 - 60 Green gray clayey silty fine to medium sand, dome gray clay, micaceous					
					60 - 65 Green gray fine to coarse sand, micaceous; sand: quartz, trace to little silt, trace of quartz gravel					
65					65 - 70 As above					
70					70 - 75 Green gray gravelly fine to coarse sand; gravel: fine subangular quartz micaceous					
75					75 - 80 As above					
80					80 - 85 Green gray fine to medium sand trace to little					
85					85 - 90 As above					
90					90 - 95 As above					
95					95 - 100 As above					
100										



GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

SHEET 3 OF 4

PROJECT: DSWA   W.O. 06-7390-002   SITE AREA Cherry Island   DRILL HOLE NO. P-2

CONTRACTOR: Delmarva Drilling Co.   COORDINATES ______   ELEVATION ______

DRILLER: C. Wallace   GWL 0 HRS ______

CLASSIFIED BY: B. W. Benyish   DATE: 9/12/81   24 HRS ______

Depth Ft.	Sample No.	SPT Blows/6 In. (6 12 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
100					100 - 105 Green gray gravelly fine to coarse sand; gravel: fine subangular quartz, trace of silt					PLEISTOCENE
105					105 - 110 Red tan clayey sand, some quartz gravel, some silt ,micaceous					
110					110 - 115 Red silty fine to medium sand, some clay					
115					115 - 120 As above					
120					120 - 125 Silty clay; color: red, cream, white, dark gray, some fine sand					POTOMAC
125					125 - 130 As above					
130					130 - 135 Sandy silt; color: red, brown, cream, with some clay					
135					135 - 140 Silty clay - clayey silt color: red, white, dark gray, some fine sand lenses					
140					140 - 145 As above					
145					145 - 150 As above					
150										

GILBERT ASSOCIATES, INC.

SOIL AND ROCK CLASSIFICATION SHEET

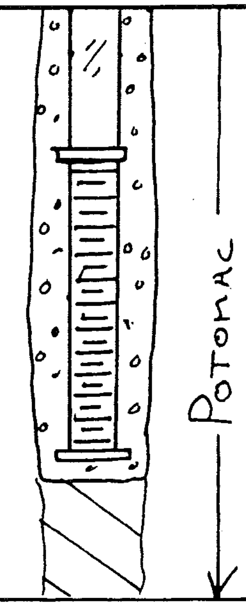
PROJECT: DSWA W.O. 06-7390-002 SITE AREA Cherry Island DRILL HOLE NO. P-2

CONTRACTOR: Delmarva Drilling Co. COORDINATES ______ ELEVATION ______

DRILLER: C. Wallace GWL 0 HRS ______

CLASSIFIED BY: B. W. Benyish DATE: 9/14/81 24 HRS ______

Depth Ft.	Sample No.	SPT Blows/6 In. (6, 12, 18)	Ft. Rec.	Profile	DESCRIPTION Density (or Consistency), Color Rock Or Soil Type - Accessories	U.S.C.S.	R.Q.D.	Soil Or Rock: Range Size / Core Run	Grain Shape / Rec. Core	REMARKS Chemical Comp, Geologic Data, Ground Water, Construction Problems, etc.
150					150 - 157 As above					
155										
					157 - 160 Red brown silty fine sand, slightly micaceous					
160					160 - 167 Red brown silty clayey fine to medium sand Note: Drilled hard, possible boulder, talus, etc.					
165										
					167 - 170 Note: Drilled hard, possible boulder, talus, etc.					
170										



Total Depth 170'

Drilling Notes:

1 - Set 4" PVC screen 155 - 165'

2 - Gravel pack 145 - 165'

3 - Developed 2 gpm clear

4 - Bentonite seal 2 - 145'

5 - Installed protector casing and cap

APPENDIX 6B

GEOPHYSICAL LOG

WELL P-1
OWNER D.S.W.A.
LOCATION CHERRY ISLAND

DELAWARE GEOLOGICAL SURVEY

ELECTRIC LOG

WELL Cd24-11

OWNER Delaware Solid Waste Authority

AREA Cherry Island

COUNTY New Castle STATE Delaware

EQUIP. USED: Logmaster

COORDINATES: ______

N ______

ELEVATION: ______

D.F. ______

K.B. ______

G.L. 31.9

LOG MEASURED FROM ______, ______ FT. ABOVE G.L.

	RUN NO. 1	RUN NO. 2	RUN NO. 3
DATE	9/10/81		
FIRST READING	5'		
LAST READING	194'		
FOOTAGE LOGGED	189'		
BOTTOM (DRILLER)	194'		
CASING (FROM LOG)			
CASING (DRILLER)			
CASING SIZE			
BIT SIZE:			
BIT SIZE:			

SURFACE TEMP.: ______ AT ______ R_m: ______

LOGGED BY J. Talley

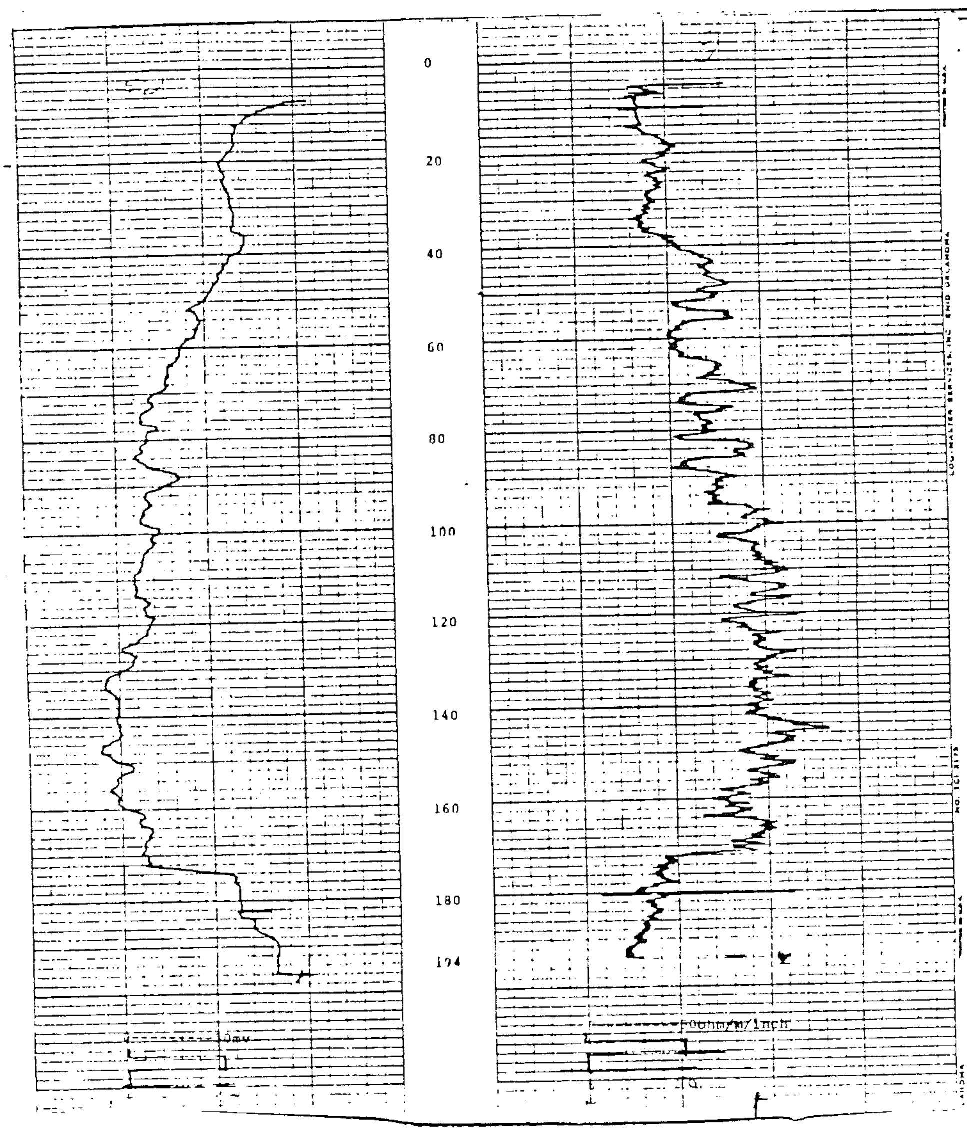
WITNESSED BY Bruce Benish

REMARKS ______

POTENTIAL +
50 mv/inch

TEMPERATURE LOG
______ °F/inch

RESISTIVITY
Single point ______ ohms/inch
16" normal ______ ohm-m/inch
64" normal ______ ohm-m/inch
6' lateral ______ ohm-m/inch
Differential S.P. 5 ohms/inch



APPENDIX 6C

GRAIN SIZE ANALYSES

Gilbert/Commonwealth engineers and consultants

LABORATORY SERVICES

GILBERT ASSOCIATES, INC., P. O. Box 1498, Reading, PA 19603/Tel. 215 775-2600

CERTIFICATE OF ANALYSIS

LABORATORY NO: 11761 RECEIVED: 9/16/81 REPORTED: 9/28/81

CLIENT: Cherry Island - WO 06-7390-002

SAMPLE DESCRIPTION: Soil Sample
P-1 5.0'
Sampled 9/16/81

\- - - - - - - - -

PARTICLE SIZE DETERMINATION
SIEVE ANALYSIS

SIEVE SIZE	% RETAINED
No. 10 Mesh	0.0
No. 30 Mesh	3.7
No. 50 Mesh	14.3
No. 100 Mesh	13.8
No. 200 Mesh	10.4
Pass No. 200 Mesh	57.8

HYDROMETER ANALYSIS

DIAM (Millimeter)	PASSING
.074	57.8
.036	55.4
.017	46.2
.008	33.3
.002	22.2

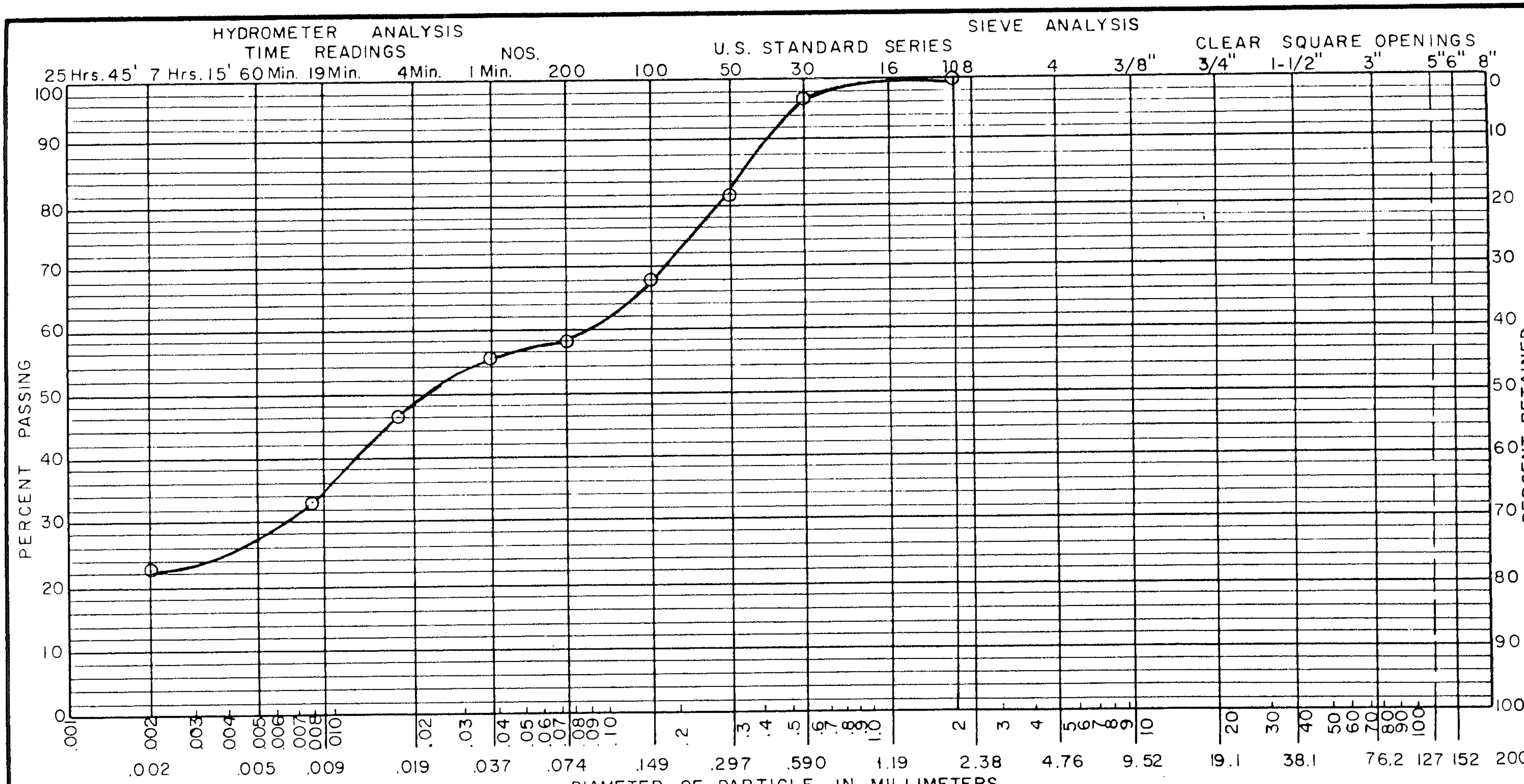
Respectfully submitted,

C. J. Wummer

C. J. Wummer, Supervisor
Laboratory Services

MAH
cc: D. Stanislaw (2)

CHERRY ISLAND SITE
WELL NO. P-1
GRADATION CURVE



CLAY (PLASTIC) TO SILT (NON PLASTIC)	SAND			GRAVEL		COBBLES
	FINE	MEDIUM	COARSE	FINE	COARSE	

Sample No.	Elev. or Depth	Classification	Nat WC	LL	PL	PI
	5 ft.	Sandy clayey silt				

GILBERT ASSOCIATES, INC.
GRADATION TEST

Gilbert/Commonwealth engineers and consultants

LABORATORY SERVICES

GILBERT ASSOCIATES, INC., P. O. Box 1498, Reading, PA 19603/Tel. 215 775-2600

CERTIFICATE OF ANALYSIS

LABORATORY NO: 11762 RECEIVED: 9/16/81 REPORTED: 9/28/81

CLIENT: Cherry Island - WO 06-7390-002

SAMPLE DESCRIPTION: Soil Sample
P-2 5.0'
Sampled 9/16/81

\- - - - - -

PARTICLE SIZE DETERMINATION
SIEVE ANALYSIS

SIEVE SIZE	% RETAINED
No. 10 Mesh	0.0
No. 30 Mesh	1.3
No. 50 Mesh	9.2
No. 100 Mesh	13.4
No. 200 Mesh	9.6
Pass No. 200 Mesh	66.5

HYDROMETER ANALYSIS

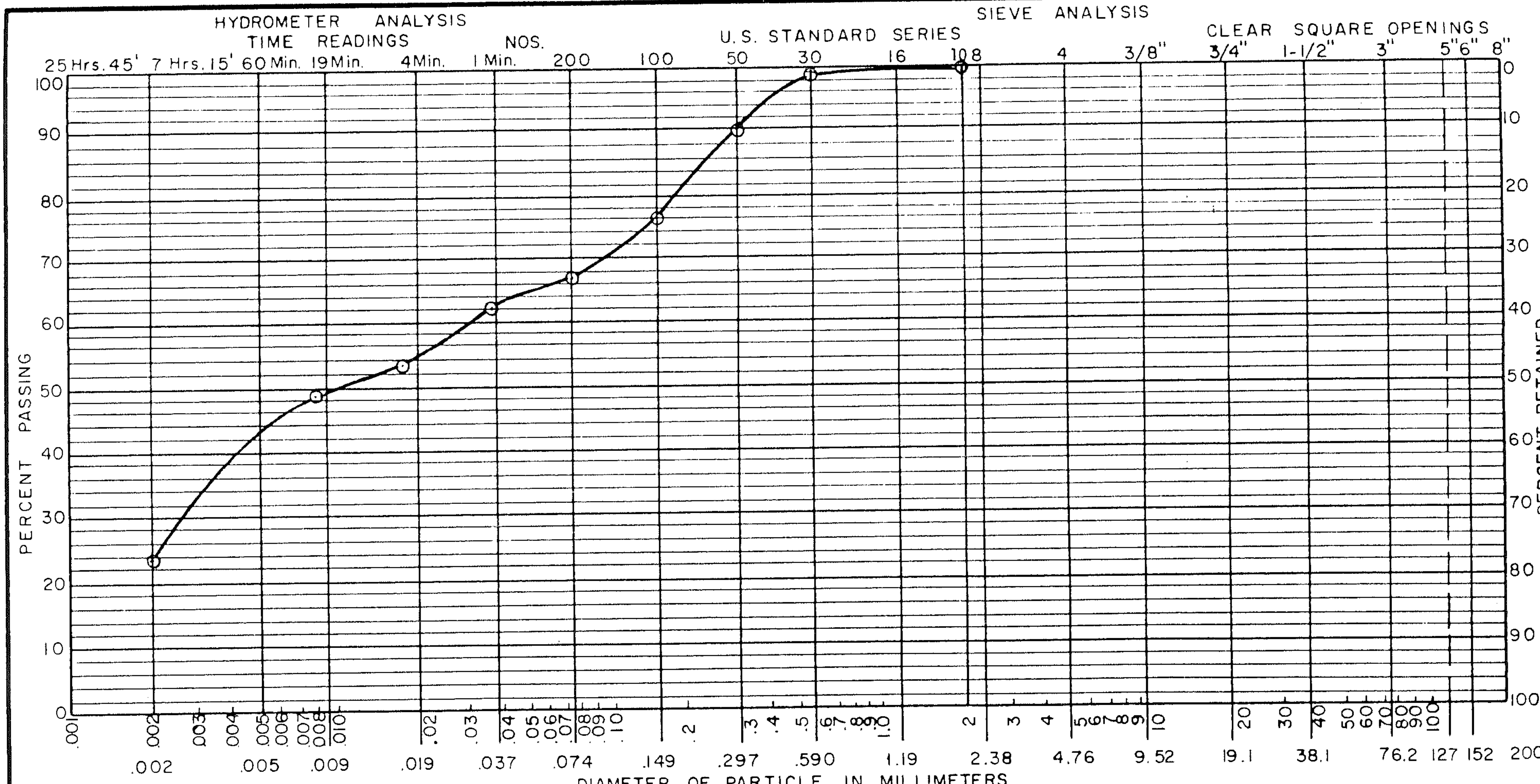
DIAM. (Millimeters)	% PASSING
.074	66.5
.036	61.9
.017	53.4
.008	38.4
.002	23.5

Respectfully submitted,

C. J. Wummer, Supervisor
Laboratory Services

MAH
cc: D. Stanislaw (2)

CHERRY ISLAND SITE
WELL NO. P-2
GRADATION CURVE



CLAY (PLASTIC) TO SILT (NON PLASTIC)	SAND			GRAVEL		COBBLES
	FINE	MEDIUM	COARSE	FINE	COARSE	

Sample No.	Elev. or Depth	Classification	Nat WC	LL	PL	PI
	5 ft/	Sandy clayey silt				

GILBERT ASSOCIATES, INC.
GRADATION TEST

APPENDIX 6D

COST PROJECTIONS

TABLE D-1 (ALTERNATIVE 1 - LINED DISPOSAL AREA)

CHERRY ISLAND SITE

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
OPERATING EXPENSES	1956000.	2132038.	2323919.	2533068.	2761043.	3009533.	3280389.	3575618.	3897422.	4248185.	4630519.
DISPOSAL AREA PREPARATION -											
CAPITAL COST	4665000.	0.	0.	6041291.	0.	0.	7823627.	0.	0.	10131792.	0.
ANNUAL FIXED COST	0.	0.	0.	2515292.	2515292.	2515292.	3257368.	3257368.	3257368.	4218373.	4218373.
EQUIPMENT -											
CAPITAL COST	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
ANNUAL FIXED COST	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
OTHER CAPITAL EXPENSES	12894000.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
20-YR AMORTIZATION	2000887.	2000887.	2000887.	2000887.	2000887.	2000887.	2000887.	2000887.	2000887.	2000887.	2000887.
OTHER CAPITAL EXPENSES	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
10-YR AMORTIZATION	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
REFUSE GENERATION (TONS)	159000.	163200.	167400.	171700.	176000.	180400.	184800.	189200.	193800.	198300.	202300.
REVENUE DIFF. FROM PREV. YEAR	0.	74819.	80098.	-6.	55494.	50948.	-21.	95371.	101106.	-46.	145767.
TOTAL ANNUAL EXPENSES	3956887.	4132925.	4324806.	7049247.	7277222.	7525712.	8538644.	8833873.	9155677.	10467445.	10849779.
NORMALIZED FEE ($/TON)	25.36	25.36	25.36	41.38	41.38	41.38	46.72	46.72	46.72	53.52	53.52
REVENUE GENERATED	4031706.	4138204.	4244702.	7104747.	7282676.	7464743.	8634036.	8839608.	9054525.	10613258.	10859456.
DIFFERENCE	74819.	80098.	-6.	55494.	60948.	-21.	95371.	101106.	-46.	145767.	155444.
ACTUAL TIPPING FEE ($/TON)	24.89	25.32	25.84	41.06	41.35	41.72	46.20	46.69	47.24	52.79	53.47
LEVELIZED TIPPING FEE ($/TON)*	24.89	25.10	25.33	28.88	31.06	32.55	34.14	35.36	36.36	37.55	39.56

NOTES : (1) 20-YEAR AMORTIZATION OF CAPITAL AT LONG TERM BOND RATE OF 9.55 PCT
(2) DISCOUNT RATE FOR LEVELIZING ASSUMED TO BE EQUAL TO BOND RATE
(3) OTHER CAPITAL AMORTIZED AT 12.00 PCT
(4) CAPITAL ESCALATED AT 9.00 PCT/YEAR
(5) EXPENSES ESCALATED AT 9.00 PCT/YEAR

*A levelized cost is the constant annual cost equivalent to an escalating actual cost stream.

TABLE D-1 (ALTERNATIVE 1 - LINED DISPOSAL AREA) - (CONT.)

CHERRY ISLAND SITE

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
OPERATING EXPENSES	5047257.	5501507.	5996635.	6536328.	7124586.	7765796.	8464710.	9226524.	10056898.	10962011.	11948579.
DISPOSAL AREA PREPARATION -											
CAPITAL COST	0.	13120926.	0.	0.	16991904.	0.	0.	22034976.	0.	0.	28495992.
ANNUAL FIXED COST	4218373.	5462899.	5462899.	5462899.	7074582.	7074582.	7074582.	9161775.	9161775.	9161775.	11864727.
EQUIPMENT -											
CAPITAL COST	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
ANNUAL FIXED COST	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
OTHER CAPITAL EXPENSES	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
20-YR AMORTIZATION	2000887.	2000887.	2000887.	2000887.	2000887.	2000887.	2000887.	2000887.	2000887.	0.	0.
OTHER CAPITAL EXPENSES	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
10-YR AMORTIZATION	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
REFUSE GENERATION (TONS)	207600.	212300.	217100.	221900.	226800.	231700.	236700.	241700.	246800.	251900.	257100.
REVENUE DIFF. FROM PREV. YEAR	155444.	-67.	211979.	226830.	-79.	301420.	318220.	-100.	-236996.	-879060.	-132.
TOTAL ANNUAL EXPENSES	11266517.	12965293.	13460421.	14000114.	16200055.	16841254.	17540176.	20389168.	21219552.	20123776.	23813296.
NORMALIZED FEE ($/TON)	53.52	62.07	62.07	62.07	72.76	72.76	72.76	83.38	83.38	83.38	92.62
REVENUE GENERATED	11111006.	13177339.	13475272.	13773205.	16501554.	15858054.	17221355.	20152272.	20577488.	21002704.	23813280.
DIFFERENCE	-67.	211979.	226830.	-79.	301420.	318220.	-100.	-236996.	-879060.	-132.	-148.
ACTUAL TIPPING FEE ($/TON)	54.27	61.07	62.00	63.09	71.43	72.69	74.10	84.36	85.98	79.89	92.62
LEVELIZED TIPPING FEE ($/TON)*	39.44	40.51	41.46	42.32	43.36	44.31	45.17	46.21	47.17	47.88	48.78

NOTES : (1) 20-YEAR AMORTIZATION OF CAPITAL AT LONG TERM BOND RATE OF 9.56 PCT
(2) DISCOUNT RATE FOR LEVELIZING ASSUMED TO BE EQUAL TO BOND RATE
(3) OTHER CAPITAL AMORTIZED AT 12.00 PCT
(4) CAPITAL ESCALATED AT 9.00 PCT/YEAR
(5) EXPENSES ESCALATED AT 9.00 PCT/YEAR

*A levelized cost is the constant annual cost equivalent to an escalating actual cost stream.

TABLE D-1 (ALTERNATIVE 2 - UNLINED DISPOSAL AREA)

CHERRY ISLAND SITE

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
OPERATING EXPENSES	1956000.	2132038.	2323919.	2533068.	2761043.	3009533.	3280389.	3575618.	3897422.	4248185.	4630519.
DISPOSAL AREA PREPARATION -											
CAPITAL COST	1833000.	0.	0.	2373780.	0.	0.	3074107.	0.	0.	3981045.	0.
ANNUAL FIXED COST	0.	0.	0.	988324.	988324.	988324.	1279905.	1279905.	1279905.	1657508.	1657508.
EQUIPMENT -											
CAPITAL COST	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
ANNUAL FIXED COST	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
OTHER CAPITAL EXPENSES	2925000.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
20-YR AMORTIZATION	542185.	542185.	542185.	542185.	542185.	542185.	542185.	542185.	542185.	542185.	542185.
OTHER CAPITAL EXPENSES	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
10-YR AMORTIZATION	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
REFUSE GENERATION (TONS)	159000.	163200.	167400.	171700.	175000.	180400.	184800.	189200.	193800.	198300.	202300.
REVENUE DIFF. FROM PREV. YEAR	0.	112360.	117640.	-4.	128996.	135019.	-9.	176483.	183436.	-12.	237576.
TOTAL ANNUAL EXPENSES	2498184.	2674222.	2866103.	4063575.	4291550.	4540040.	5102478.	5397707.	5719511.	6447877.	6830211.
NORMALIZED FEE ($/TON)	16.42	16.42	16.42	24.42	24.42	24.42	28.57	28.57	28.57	33.71	33.71
REVENUE GENERATED	2610544.	2679502.	2748459.	4192575.	4297573.	4405012.	5279370.	5404660.	5536063.	6685465.	6840549.
DIFFERENCE	112360.	117640.	-4.	128996.	135019.	-9.	176483.	183436.	-12.	237576.	247914.
ACTUAL TIPPING FEE ($/TON)	15.71	16.39	17.12	23.67	24.38	25.17	27.61	28.53	29.51	32.52	33.66
LEVELIZED TIPPING FEE ($/TON)*	15.71	16.04	16.38	18.02	19.13	19.98	20.86	21.61	22.28	23.02	23.69

NOTES : (1) 20-YEAR AMORTIZATION OF CAPITAL AT LONG TERM BOND RATE OF 9.56 PCT
(2) DISCOUNT RATE FOR LEVELIZING ASSUMED TO BE EQUAL TO BOND RATE
(3) OTHER CAPITAL AMORTIZED AT 12.00 PCT
(4) CAPITAL ESCALATED AT 9.00 PCT/YEAR
(5) EXPENSES ESCALATED AT 9.00 PCT/YEAR

*A levelized cost is the constant annual cost equivalent to an escalating actual cost stream.

TABLE D-1 (ALTERNATIVE 2 - UNLINED DISPOSAL AREA) - (CONT'D)

CHERRY ISLAND SITE

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
OPERATING EXPENSES	5047257.	5501507.	5996635.	6536328.	7124586.	7765796.	8464710.	9226524.	10056898.	10962011.	11948579.
DISPOSAL AREA PREPARATION -											
CAPITAL COST	0.	5155553.	0.	0.	6676567.	0.	0.	8646329.	0.	0.	11197211.
ANNUAL FIXED COST	1657508.	2146515.	2146515.	2146515.	2779789.	2779789.	2779789.	3599900.	3599900.	3599900.	4661960.
EQUIPMENT -											
CAPITAL COST	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
ANNUAL FIXED COST	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
OTHER CAPITAL EXPENSES	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
20-YR AMORTIZATION	542185.	542185.	542185.	542185.	542185.	542185.	542185.	542185.	542185.	0.	0.
OTHER CAPITAL EXPENSES	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
10-YR AMORTIZATION	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
REFUSE GENERATION (TONS)	207600.	212300.	217100.	221900.	226800.	231700.	235700.	241700.	246800.	251900.	257100.
REVENUE DIFF. FROM PREV. YEAR	247914.	-30.	317591.	332442.	-42.	423938.	441565.	-71.	384285.	228462.	-95.
TOTAL ANNUAL EXPENSES	7246949.	8190206.	8685334.	9225027.	10446559.	11087769.	11786683.	13368608.	14198982.	14561911.	16610539.
NORMALIZED FEE ($/TON)	33.71	40.07	40.07	40.07	47.93	47.93	47.93	56.90	56.90	56.90	64.51
REVENUE GENERATED	6999005.	8607827.	8700185.	8892543.	10870539.	11105396.	11345047.	13752964.	14043159.	14333354.	16610536.
DIFFERENCE	-30.	317591.	332442.	-42.	423938.	441565.	-71.	384285.	228462.	-95.	-98.
ACTUAL TIPPING FEE ($/TON)	34.91	38.58	40.01	41.57	46.06	47.85	49.80	55.31	57.53	57.81	64.51
LEVELIZED TIPPING FEE ($/TON)*	24.32	25.03	25.69	26.32	27.03	27.70	28.34	29.05	29.74	30.36	31.04

NOTES : (1) 20-YEAR AMORTIZATION OF CAPITAL AT LONG TERM BOND RATE OF 9.55 PCT
(2) DISCOUNT RATE FOR LEVELIZING ASSUMED TO BE EQUAL TO BOND RATE
(3) OTHER CAPITAL AMORTIZED AT 12.00 PCT
(4) CAPITAL ESCALATED AT 9.00 PCT/YEAR
(5) EXPENSES ESCALATED AT 9.00 PCT/YEAR

*A levelized cost is the constant annual cost equivalent to an escalating actual cost stream.

TABLE D-2

CHERRY ISLAND : PROJECTED CONTRACTOR HAULING COSTS AND EQUIVALENT TONNAGE FEES

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
OPERATING EXPENSES – O & M	286000.	311740.	339796.	370377.	403711.	440044.	479648.	522815.	569868.	621156.	677060.
FUEL COST	23500.	25615.	27920.	30433.	33172.	36157.	39412.	42959.	46825.	51039.	55633.
EQUIPMENT – TRACTORS	355000.	0.	0.	0.	0.	546209.	0.	0.	0.	0.	840406.
5-YR AMORTIZATION	105902.	105902.	105902.	105902.	105902.	162943.	162943.	162943.	162943.	162943.	250707.
EQUIPMENT – TRAILERS	315000.	0.	0.	0.	0.	0.	0.	575828.	0.	0.	0.
7-YR AMORTIZATION	75714.	75714.	75714.	75714.	75714.	75714.	75714.	138407.	138407.	138407.	138407.
CONTRACTOR FEE	171891.	181640.	192266.	203849.	216475.	250200.	265201.	303493.	321315.	340741.	392632.
TOTAL ANNUAL EXPENSES	663007.	700610.	741599.	786275.	834973.	965059.	1022917.	1170616.	1239357.	1314285.	1514436.
TONNAGE HAULED	159000.	163200.	167400.	171700.	176000.	180400.	184800.	189200.	193800.	198300.	202900.
ANNUAL RATE ($/TON)	4.17	4.29	4.43	4.58	4.74	5.35	5.54	6.19	6.40	6.63	7.46
LEVELIZED RATE ($/TON)*	4.17	4.23	4.29	4.34	4.40	4.51	4.60	4.72	4.82	4.91	5.01

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
OPERATING EXPENSES – O & M	737994.	804413.	876809.	955721.	1041734.	1135489.	1237682.	1349072.	1470487.	1602829.	1747082.
FUEL COST	60639.	66097.	72045.	78530.	85597.	93301.	101698.	110850.	120827.	131701.	143554.
EQUIPMENT – TRACTORS	0.	0.	0.	0.	1293061.	0.	0.	0.	0.	1989526.	0.
5-YR AMORTIZATION	250707.	250707.	250707.	250707.	385741.	385741.	385741.	385741.	385741.	593508.	593508.
EQUIPMENT – TRAILERS	0.	0.	0.	1052629.	0.	0.	0.	0.	0.	0.	1924234.
7-YR AMORTIZATION	138407.	138407.	138407.	253011.	253011.	253011.	253011.	253011.	253011.	253011.	462511.
CONTRACTOR FEE	415711.	440868.	468288.	538288.	618128.	653639.	692346.	734536.	780522.	903367.	1031329.
TOTAL ANNUAL EXPENSES	1603455.	1700489.	1806254.	2076255.	2384209.	2521179.	2670475.	2833208.	3010586.	3484414.	3977981.
TONNAGE HAULED	207600.	212300.	217100.	221900.	226800.	231700.	236700.	241700.	246800.	251700.	256800.
ANNUAL RATE ($/TON)	7.72	8.01	8.32	9.36	10.51	10.88	11.28	11.72	12.20	13.84	15.49
LEVELIZED RATE ($/TON)*	5.10	5.19	5.26	5.35	5.44	5.52	5.59	5.66	5.72	5.78	5.85

NOTES –

(1) INTEREST RATE = 15.00
(2) DISCOUNT RATE = 18.00
(3) O&M INFL. RATE = 9.00
(4) FUEL INFL. RATE = 9.00
(5) CAPITAL INFL RATE = 9.00
(6) CONTRACTOR FEE = 35.00

*A levelized cost is the constant annual cost equivalent to an escalating actual cost stream.

7.0 LIST OF ABBREVIATIONS

AADT	Annual Average Daily Traffic
AOPA	Aircraft Owners and Pilots Association
C & D Canal	Chesapeake and Delaware Canal
CFR	Code of Federal Regulations
CM/SEC	Centimeters Per Second
CSWF	Central Solid Waste Facility
C.Y.	Cubic Yards
DELDOT	Delaware Department of Transportation
DNREC	Delaware Department of Natural Resources and Environmental Control
DP&L	Delmarva Power and Light
DRP	Delaware Reclaimation Project
EPA	U.S. Environmental Protection Agency
FAA	Federal Aviation Administration
ft.	Feet
ft^2	Square Feet
ft^3	Cubic Feet
gpd	Gallons Per Day
gpm	Gallons Per Minute
I-00	Interstate Highways
JTU	Jackson Turbidity Units
lbs	Pounds
L.F.	Linear Feet
mg/l	Milligrams Per Liter
NPDES	National Pollutant Discharge Elimination System
NSWF	Northern Solid Waste Facility
ppt	Parts Per Thousand
PVC	Polyvinyl Chloride
sq. ft.	Square Feet
TOC	Total Organic Carbon
TPD	Tons Per Day
USDI	United States Department of Interior
USEPA	U.S. Environmental Protection Agency

USGS	United States Geological Survey
%	Percent
μg/l	Micrograms Per Liter

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David J. Stanislawczyk, Project Geologist
Bruce W. Benyish, Geologist
Anthony Savino, Environmental Engineer
Patricia A. Pingel, Environmental Scientist
James R. Shaw, Environmental Scientist
Leonard Schickler, Environmental Planner
Keith Li, Financial Consultant
Donald L. Wagner, Supervisor
George E. LeVan, Draftsman/Graphics
Greg A. Meyers, Cover Illustrator

9.0 DSWA LANDFILL SITE SELECTION CRITERIA

The criteria includes four (4) major categories as considerations. They are Environmental, Planning, State and Federal Regulatory Requirements, and Transportation.

The criteria are so varied that it would be impossible to find any one site which would meet all of the criteria. Therefore, evaluation of the sites should include potential for applying site preparation techniques which would minimize adverse impacts.

The following is a more detailed description of the criteria:

a. Environmental

1. The selection of the site should take into account the probable impact on wetlands. The landfill activity should not result in destruction of wetlands, flora, and fauna. A minimum distance of at least 100 yards should be maintained as a buffer between the toe of the landfill and the wetlands.

2. The selection of the site should take into account the probability of surface water pollution as a result of run off from the landfilling activity and the potential for minimizing such effects through application of best available technology.

3. The selection of the site should include the review of the probability of any impact on endangered species as such term is defined in the Endangered Species Act (16 USC S1501, et.seq.).

4. In selecting the site, attention should be paid to the probability of polluting aquifer systems and the site

selected should have a low potential for polluting groundwater. If there are wells surrounding the site tapping the water table aquifer (shallow pleistocene formations) special attention should be given to techniques of construction and operation which would prevent contamination of the water table aquifer and any other aquifer underlying.

5. The site under consideration for a landfill should be reviewed from the viewpoint of potential flooding from an incident which has the probability of occuring once in 100 years.

6. If the site is near a wildlife preserve, public park, or recreation area, designated natural area, natural reserve or recreation conservation corridor, adequate buffer should be maintained and special landscaping should be provided to prevent negative impact.

b. Planning

1. The site selected should be considered as an ultimate disposal site for each County's solid wastes and sludge with our without resource recovery. Such a site should have the capability of serving the County's needs for at least 20-30 years, assuming a 2% per year solid wastes growth rate.

2. The site selected should be able to meet the planning requirements of 7 Delaware Code, Chapters 60, 61, 64, and 70, and the Resource Conservation & Recovery Act (42 USC 6901), the Federal Water Pollution Control Act (33 USC 1251), Federal Clean Air Act (42 USC 7401 et. seq.), Federal Endangered Species Act (16 USC S1501 et.seq.), and other State, Interstate and Federal laws and regulations.

3. The site under considertion should affect the least number of people within a boundary of 300 yards from the perimeter of the site. If there are two or more sites which are comparable in all other criteria, then the site which affects the least number of people should be given the preference.

4. The site selected should have either sufficient cover material (dirt) available on site or be close to a major source of cover material in order to minimize trucking.

5. The site under consideration should be sufficiently far away from any existing or proposed airports.

6. The site under consideration should not be directly on the outcrop of a deep aquifer. The site selected should be consistent, to the extent practicable, with the County's long range land use plan. The site should be able to serve as an open space buffer in context with the County's land use plan and should be considered as a future outdoor recreation area or industrial development area.

7. The site under construction should, to the extent practicable, be able to serve multiple purposes including industrial and energy development by making provisions for storge of coal or other bulk materials on finished landfill areas. The potential for connecting to existing natural gas pipeline systems should be considered in site planning.

c. <u>Statutory and Regulatory Requirements</u>

1. The site under consideration should meet the requirements of "Sanitary Landfill" under the Resource

Conservation & Recovery Act and associated EPA Regulations.

2. The site under consideration should be able to satisfy the requirements of regulations adopted by the Department of Natural Resources and Environmental Control under 7 Delaware Code, Chapter 60.

3. The site under consideration should comply with State Interstate, and Federal laws and regulations such as 7 Delaware Code, Chapters 60, 61, 64, and 70, and the Resource Conservation and Recovery Act (42 USC 6901), the Federal Water Pollution Control Act (33 USC 1251), Federal Clean Air Act (42 USC 7401 et.seq.), Federal Endangered Species Act (16 USC S1501 et.seq.).

d. Transportation

1. The site under consideration should be accessible from and in reasonable proximity to the centers of solid waste generation in each County.

2. The site under consideration should have access from major highways and be served by secondary roads.

3. To the extent practicable, railroad and/or waterway transportation of solid wastes should be considered. The site under consideration should be reviewed from the viewpoint of minimizing the total annual cost.

ADOPTED BY THE BOARD OF DIRECTORS
DELAWARE SOLID WASTE AUTHORITY
OCTOBER 16, 1980

10.0 REVIEWING AGENCY RESPONSES

On November 17, 1981, a meeting with officials of local and state agencies was held at the Brandywine Hilton to solicit comments relative to their review of the draft reports for the candidate sites which were issued 10/2/81 (Roberts Farm), 11/5/81 (Road 412), and 11/10/81 (Cherry Island). Certain of the comments received at this meeting were taken into consideration by the Authority and have been incorporated within this report. All attendees were requested to develop their comments in writing and submit them, in letter form, to the Authority by December 14, 1981. Copies of these letters are incorporated within the following pages of this Section. Comprehensive responses to each of the comments and/or questions contained within these letters will be issued in a supplemental report.

STATE OF DELAWARE
DEPARTMENT OF TRANSPORTATION
DIVISION OF HIGHWAYS
P. O. BOX 778
DOVER, DELAWARE 19901

OFFICE OF THE
DIRECTOR

TELEPHONE:
736-4346

November 24, 1981

Mr. James H. Tung
Executive Director
WILMAPCO - Suite 201
Stockton Building
University Office Plaza
Newark, Delaware 19702

Attention: Mr. P. L. Johnston

RE: "Detailed Site Investigation of Candidate Sites for Northern Solid Waste Facility - 2(New Castle County)"
-"Transportation Considerations"
Candidate Sites: 1) Cherry Island
2) Robert's Farm
3) New Castle Road 412

Dear Mr. Tung:

We thank WILMAPCO for providing us with the opportunity to comment on the referenced.

In this document candidate sites are addressed solely from a transportation point of view. We leave the discussion of other aspects to those disciplines having expertise and authority to do so.

Because the introduction of an additional 100 one-way truck trips per day (15 tons payload = 10-wheeler, 3 axles?) on to the highway plant is undesirable from a traffic aspect. We have tried to isolate the least undesirable solid waste site access route.

The impacts on Pigeon Point Road (New Castle Road 377) and on New Castle Road 359 are common to all three sites so we eliminate same from further comparison (1.1 miles and 0.4 miles respectively = 1.5 miles).

This leaves:

	Cherry Island (miles)	Robert's Farm (miles)	New Castle Rd. 412 (miles)
I-495	1.5	1.1	1.1
12th Street	0.4		
U.S. Rte. 13		22.5	15.6
N.C. Rd. 452		1.8*	
Del. Rte. 9		0.7*	
N.C. Rd. 413			1.3*

* Very strong probability of a need for reconstruction.

Under the documentation for candidate site "New Castle Road 412", we suggest that the proposal under which New Castle Road 412 would provide truck access to U.S. Rte. 13 northbound lanes at the foot of the bridge introduces an acute traffic hazard and conflict.

Trucks would enter the northbound U.S. Rte. 13 bridge ramp with zero acceleration and thus would, in all probability, block the right northbound lane of U.S. Rte. 13 at this point.

We feel the suggestion of egress by New Castle Rd. 413 across two southbound lanes of U.S. Rte. 13 to reach the northerly lanes to be little safer.

Thus, we eliminate the potential of the "New Castle Road 412" site without addressing the generation of truck miles of travel per day and the need for reconstruction.

The "Robert's Farm" site is eliminated because of the long haul road and because of the probable need for 2.5 miles of road reconstruction.

Without further expansion on same we consequently feel the "Cherry Island" site to be the most desirable when evaluated by this compressed transportation analysis.

Yours very truly,

DIVISION OF HIGHWAYS

Wm. A. Elgie, Jr., MCIP
Chief Systems Planning Engineer

WAE:shm
cc: G. B. Homewood
J. L. Sipple

STATE OF DELAWARE
DEPARTMENT OF NATURAL RESOURCES
& ENVIRONMENTAL CONTROL
DIVISION OF ENVIRONMENTAL CONTROL
WATER RESOURCES SECTION
EDWARD TATNALL BUILDING
P.O. BOX 1401
DOVER, DELAWARE 19901

TELEPHONE: (302) 736-4761

December 14, 1981

Mr. N. C. Vasuki
General Manager
Delaware Solid Waste Authority
P. O. Box 455
Dover, DE 19901

Dear Mr. Vasuki:

The purpose of this letter is two-fold. Firstly, it is in response to your request of November 19, 1981, to waive the synthetic liner requirement for the proposed NSWF-2 site at Cherry Island. Secondly, in follow up to the November 17 and December 7 meetings, the Department has reviewed the three site suitability reports for the NSWF-2 and have addressed our main concerns herewith.

In regard to the request for a waiver of the synthetic liner requirement at the Cherry Island site, we draw your attention to the fact that the Department has only had an opportunity to review the preliminary reports for all three sites. We were informed that these reports were drawn up with only a view to considering the general suitability of each site as a future sanitary landfill. The Cherry Island site suitability report does not address specific details such as design consideration, the potential environmental impact on aquifers in the area if no synthetic liner were used, and the potential for heavy metal migration due to the acidic nature of the dredge spoils. These specifics are to be submitted with a complete permit application when a particular site selection is made. The Department will be able to make a decision on the need for a synthetic liner at the Cherry Island site only after reviewing these details. The Authority may choose to conduct all necessary studies at the Cherry Island site in advance, prior to making a site selection and permit application, so that the Department can determine the need for a synthetic liner at an earlier date.

In addition, the Authority would have to request a variance from the provisions of the Delaware Solid Waste Disposal Regulations Section 6.03(g)(1) in order to obtain a waiver for the liner requirement. Pursuant to 7 Del C. Chapter 60 §6011 (b)(3) "The variance may be granted if the Secretary finds that the person applying is unable to comply with the provisions of this chapter because the necessary technology or other alternative methods of control are not available .....".

At this time, however, there are two alternative sites available, and at the time a variance is requested, the Authority should provide sufficient justification for the same.

In addition, our comments on the "site suitability" reports are given in Attachments I through IV included herewith. Attachment I addresses general comments pertaining to all the reports, and Attachments II through IV address specifically the Roberts Farm, Road 412 and Cherry Island sites respectively.

If you should have any questions regarding these matters, please call the Solid Waste Management Branch at 736-4781.

Very truly yours,

Thomas P. Eichler
Director

ATTACHMENT I

General Comments:

1. It is evident that the county's and city's plans do not address the need nor the location of landfill sites as part of the land use planning process. However, pursuant to the Delaware Solid Waste Disposal Regulation, Section 6.01, "A land use for the completed disposal site shall be specified and operations adjusted accordingly." Therefore, you should include plans for future land use at each site, with the associated cost considerations.

2. The classification standard used to describe the grain size of underlying sediments is not given.

3. Sieve analysis would be better represented on the standard graphs for technical interpretation.

4. The hydrogeological characteristics should be given in consistent units.

5. We recommend that you predict the leachate generation (by water balance method) to consider the impact of the solid waste site on the aquifers and surface water.

6. Additional hydrogeological cross-sections should be provided to give a better understanding of the potential migration of leachate.

7. A method of calculation should be included to clearly show the dilution ratio of leachate obtained for each aquifer.

8. The interpretation based on descriptive logs and geophysical logs are misleading. The descriptive log indicates lesser permeable materials underlying the site than given by the geophysical log depending on the relative graph size interpretation.

9. The potential impact of leachate migration, if any, into the unsaturated zone is not given.

10. The leachate attenuation characteristics of the underlying material (top soil or base material of liner) are not given.

11. An inventory of the number, location, depth, screen interval and aquifer of all the water supply wells within a mile of each of the possible sites should be provided.

12. The potential for leachate migration, if any, outside of the boundary should be considered.

13. Ground water flow directions indicated on the potentiometric surface map of the deeper aquifers may not be the actual flow directions due to insufficient data.

ATTACHMENT II

ROBERTS FARM

(1) The effect of quality and quantity of water above the dam structure on the landfill ground water and surface water flow is not addressed.

(2) P.36 The rotary rig drilling technique may cause drill-cutting samples to have characteristics at some variance with the actual in place characteristics of the sediments. In particular, use of water as the drilling fluid may result in loss of the larger sand fraction, making the samples appear less permeable than the sediments penetrated actually are.

(3) P-43 You shall estimate the K, S, and porosity of the Pleistocene aquifer at the eastern portion of Roberts Farm? "At the eastern portion of the Roberts Farm, a residential well has been constructed in the Pleistocene aquifer. In this area, erosion of the underlying Calvert and Vincetown Formations has occurred and a thick sequence of Pleistocene sediments has been deposited in their place. This thick sequence of materials has afforded a large saturated thickness and the construction of a Pleistocene well. This well is, however, considered to be atypical of the area." This indicates that the Rancocas aquifer subcrops in this area and is directly connected to the Pleistocene aquifer.

(4) P-43 "Rancocas Aquifer - this aquifer is an important source of water in southern New Castle County and reportedly supplies more than 25 percent of the groundwater used in the area of the County south of the canal (Sundstrom (Pickett, 1971). Based on personal communication with members of the Delaware Geological Survey, the Rancocas aquifer is one of the primary sources of ground water for most wells within a mile radius of the Roberts Farm tract. The

aquifer has a transmissivity of 14,000 to 19,000 gallons per day per foot and a storage coefficient of 0.00019 to 0.00028 (Sundstrom & Pickett, 1971). These values together with an average specific capacity value of 2.3 gallons per minute per foot of drawdown are considered to be representative of the Rancocas Aquifer in the Roberts Farm area. Using an average transmissivity of 17,000 gpd/ft or 2275 ft^2/day and an aquifer thickness of 110 ft. (see monitoring well ML-1), the hydraulic conductivity of the aquifer is estimated to be in the range of 7×10^{-3} cm/sec." These hydrological parameters (given in the second paragraph, Page 43) parameter values are for the Rancocas Aquifer (south of New Castle County) where it is not subcropping. For subcropping Rancocas Aquifer the values of the storage coefficient are likely to be similar to the Pleistocene water table aquifer (See Report #3, Page 76).

"The Rancocas Aquifer is reportedly confined by the Calvert Foundation in the region of the Roberts Farm. However, monitoring wells constructed on site indicate that the Calvert Foundation has been lost to erosion in the immediate area of Hangman's Run."

This also indicates that the Rancocas is subcropping near Hangman's Run.

(5) P.48 How were the water quality samples preserved? Are pH and conductivities measured in the field?

(6) Table 5.2-3 Well P-1
Dissolved solids and conductivity are generally correlated but the values indicate some anomalies. Sulphate seems to be high.

(7) P.48 What explanation(s) can be made for the elevated manganese and nitrate levels in a few of the groundwater samples?

(8) P.50 Mention is made of residential wells constructed in all three aquifer in the vicinity of the proposed site. With the conclusion of the landfill, consideration should be given to alternative water supplies available to these users, if found to be necessary.

(9) P.52 Renovation would take place by cation exchange only. Anions are not exchanged. There may be limited cation exchange as it does not have a high value of CE.

(10) P.62 The Roberts Farm is located in one of the State's better areas for supporting a variety of wildlife species, and the surrounding properties are also high quality wildlife habitat. The siting of a landfill in this area would be a negative factor in maintaining the high quality of wildlife of the region.

(11) P.65 Any disturbance of the wetlands areas or increases in turbidity in the water courses or any failure of the liner/leachate collection system would have serious consequences due to the importance of this area as a

nursery area for estuarine biota. The Appoquinimink-Blackbird drainage area is a prime nursery area for weakfish, croaker, bluefish, white perch, striped bass and many other of Delaware's commercially and recreationally valuable species of fish. In addition, this area is located on the upper fringe of the American oyster reproducing areas which is very important for commercial and recreational crabbing.

(12) P.70 There is a distinct possibility that the landfill operation would have an unfavorable impact on the potential for the bald eagle to return as a nesting bird in the area.

(13) P.73 The useable areas for landfilling on Roberts Farm are prime farmland and are presently cultivated. Apart from the obvious food producing capabilities of this land, the crops serve as food for the geese and other waterfowl and the upland game that are all abundant in the Appoquinimink drainage area.

(14) The most viable highway access to this site would involve going through either Odessa or Middletown. This would result in considerable traffic increase through these towns and, therefore, all roads must be able to accommodate this. A knowledge of the weight limit for the two lane bridge of Hangman's Run should be obtained.

(15) Appendix 5B The geophysical logs are not provided with speed, time, constant temperature, resistivity and viscosity of mud (drilling fluid).

ATTACHMENT III

ROAD 412

1. 4.3.1.1. The report states that very few waterfowl or waterbirds utilize the area (U.S. Atomic Energy Commission, 1974). This statement is inaccurate in terms of Scotts Run where the Division of Fish and Wildlife has established several duck blind sites that provide quality hunting.

2. 4.3.1.4. The statement "Effects of landfill operation on adjacent wildlife habitats are expected to be minor" is an oversimplification of wildlife needs. Doves, quail, songbirds, rabbits, deer and a variety of other wildlife use agricultural crops as part of their habitat, especially as feeding areas.

3. 4.3.1.2. If landfill activities did not slope toward the tiny existing tributaries on the boundaries of the property, impact to the aquatic biota of Scott Run and the C & D Canal should be minimal. Leachate and/or turbidity should not reach the C & D Canal, since it is a significant spawning and nursery area for striped bass, a species currently much in the news because of concern over its population decline. The importance of the canal for spawning and transport of other important fish species is equally well documented.

All the other comments have been previously covered under Attachments I and II, (2, 5 & 8).

ATTACHMENT IV

CHERRY ISLAND

1. 6.2.1.2 You are to provide a recent topographic map to include the location of dikes and other relevant features.

2. 6.2.1.3 The subsurface exploration conducted on the nearby DP&L property and duPont Edgemoor sites should be considered in the study.

3. Permeability data for dredge spoil.
   Was the permeability data obtained from laboratory permeability tests or empirical data derived from other geotechnical parameters? If determined by laboratory methods which particular method was used? Are these data for horizontal or vertical permeability?

4. Is the dredge spoil material homogeneous throughout the site? What are the leachate attentuation and chemical characteristics of the dredge spoil?

5. 6.2.15 The industrial wells at Brandywine Chemicals Company (formerly Halby Chemical Company) and Forbes Steel and Wire Corporation are nearer than the Collins Park well. There are other potential production wells in the vicinity. All these water wells should be considered in the study.

6. Potomac:
   If either of the two zones of the Potomac are not present at Cherry Island, then what is the name of the zone present at Cherry Island?

7. The low production of Potomac wells may be attributed to the well construction and development since they were installed only as monitoring wells and not as production wells.

8. Figure 6.2.6 The location of the water table wells should be provided.

9. Figure 6.2.7 If the flow shown in the figure is correct, the flow direction in the Potomac will be in a downdip direction where the Potomac aquifer is used as a water supply aquifer.

10. The water level readings for the Columbia and Potomac aquifer monitoring wells were taken at different times. Provide the interpretation if the readings were taken at the same time.

11. The presence of a perched water table indicates that the dredged material is not homogeneous and/or is not evenly distributed. This mode of deposition may create windows of permeable material which may be potentially interconnected with water supply aquifers.

12. Ground water quality.

    The water quality parameters of the Potomac Formation are poorly correlated with relevant parameters. For example, sodium is not ionically balanced with chloride and sulphate. (i.e. there is no ionic balance).

13. Provide the water quality of perched water and dredge spoil spillage.

14. Potential Impact:

    If the facility were unlined, you should consider at least the following additional characteristics of the insitu material (besides permeability).

    (i) chemical characteristics of the dredge spoil solids and dredge spoil water

    (ii) Cation exchange properties of dredge spoil and estuarine deposits.

15. Evaluate the effect of these properties on a "typical" leachate generated at any sanitary landfill.

16. 6.2.17 In utilizing the settlement equation it appears that the full weight of refuse to be deposited is considered, and the time required for the primary consolidation of the spoil materials under full load is 4 to 5 years. It is not explicitly stated at which stage of consolidation the spoil is expected to meet the state requirements for the impermeability of a natural soil liner. In other words, it could take years before the dredge spoils meet the impermeability requirements, in the mean time possessing permeabilities of up to 4 to 10 times higher then required.

17. 6.2.1.7 The vertical seepage of leachate into the Columbia Formation has been calculated assuming a certain permeability. However, due to the nature of the dredge spoils it is possible that permeabilities in parts of the landfill site may be much higher than that, giving rise to an accelerated leachate movement downwards.

18. 6.2.2.2. Would the existing highway drainage facilities be sufficient to intercept the runoff to the west of the landfill?

19. 6.3.1.2. The water quality in the Delaware River near the landfill site has improved considerably over the past ten years and it is possible that it may once again be significant for the spawning of anadromous fish such as striped bass and Atlantic and shortnose sturgeon. A modest sport fishery has developed in the Christiana River in recent years, and the potential impact on these waters must be examined particularly in the absence of a synthetic liner.

20. Table 6.5 - 1

Land purchase costs are to be amended as per your correspondence submitted December 7, 1981.

WATER RESOURCES AGENCY FOR NEW CASTLE COUNTY

December 11, 1981

Mr. N. C. Vasuki, P.E.
General Manager
Delaware Solid Waste Authority
P.O. Box 455
Dover, DE 19901

RE: Candidate Sites for Northern Solid Waste Facility No. 2

Dear Mr. Vasuki:

We thank you for the opportunity to submit our comments on the investigation conducted by Gilbert Associates, Inc. of three candidates sites for your proposed Northern Solid Waste Facility No. 2. Our initial comments will be directed toward the overall analytical procedure. Further comments will address specific issues dealing with the individual sites.

General Comments on Analytical Procedure

1. All three sites should be compared on an equal-life basis.

Both the Roberts Farm (202 usable acres) and Road 412 (171 usable acres) have projected lives of approximately 24 years. The Cherry Island site, however, has the potential for a much greater life. Assuming 400 of the 501 acres are usable, and extending the consultant's refuse quantity projections (Table 3.2-1) beyond the thirtieth year, one finds that this site has a longevity in excess of 40 years. In order to effect an equitable comparison among the candidate sites, the acreage considered for purchase at the Cherry Island site should be reduced to a size commensurate with a twenty-four year life (i.e., approximately 215 acres). This could be accomplished by considering only the two tracts owned by Frederic A. Potts, Inc. Alternately, special consideration could be given in the ranking of this site due to its increased longevity.

2701 CAPITOL TRAIL NEWARK, DELAWARE 19711 (302) 731-7670

2. The means for and projected costs of leachate treatment and disposal should be included in the site analyses.

Over the life of the project leachate treatment and disposal costs can become quite significant. Moreover, these costs will vary with each site's location. Distance to a wastewater treatment plant, availability of a discharge point, and degree of treatment or pretreatment required will bear heavily upon the costs associated with a given site. Since each site is subject to different constraints, the inclusion of these costs in the site analysis is essential to determining the true costs of site development. Opportunities to utilize capacity in existing sewers and treatment facilities must, in the interest of minimizing site development and waste disposal costs, be exploited wherever possible and recognized in comparing the several sites.

3. All costs which are associated with any road and/or bridge reconstruction or improvement which are specifically required to afford access to a particular site should be included in the fiscal analysis for that site.

Proper engineering cost analysis dictates that all costs associated with facility development be internalized for consideration in evaluating its relative cost effectiveness. To eliminate such costs from consideration would have the effect of skewing the analysis. Existing highway capacity, like interceptors and treatment facilities, must be recognized as an advantage to particular sites in minimizing development and disposal costs. An adequate site comparison can only be made when the cost/value of new or existing capacity is made a part of the analysis. Even if the costs of offsite improvements are borne by the Division of Highways rather than the Solid Waste Authority, and thereby are not included in its bonded indebtedness, they will still be borne by the taxpayers, ergo the same individuals who will be utilizing the facility.

4. The value for ultimate use; i.e., salvage value, of each site should be considered in the analysis.

It is customary in the engineering cost analysis of a project to consider its ultimate value, if any, in the overall cost evaluation. Each of the three sites, by virtue of its individual characteristics and location, has a unique value after the landfill is completed. Whether or not the Roberts Farm and Road 412 sites, which are currently under cultivation, will be suitable for such use after the fill is completed and the evaluation of the site increased by some forty feet is questionable. On the other hand, it can be effectively argued that the Cherry Island site may be increased in value by the stabilization of dredge spoils through their consolidation under the fill loading. Such future uses and their associated value must be properly integrated into the site analyses in order to gain a true picture of the costs associated with each site.

Comments Relating to a Specific Site

- Roberts Farm

pg. 50 Potential Impacts:

Although the subject of groundwater pollution is thoroughly addressed in the site analysis, the contamination of Hangman's Run and its subsequent effect upon the adjacent wetlands is not considered. Based upon the stratigraphy of the site and the water table elevations, it would appear that surface water contamination would be a much more likely occurrence than the pollution of the deeper aquifers. The effects of leachate migration into the sensitive ecosystem present in a wetlands environment could be quite devastating to the vegetation and wildlife there. The potential for surface water contamination and its ramifications needs to be considered in order to fully evaluate the impacts of a landfill facility located at this site.

- Road 412

Section 4.2.1.5 Hydrogeology - Local Water Use

The statement is made that information pertaining to groundwater use in the Road 412 area is limited. A rather extensive survey of groundwater use within a five mile radius of the Summit site was conducted by Delmarva Power as a part of their generating facility siting study. The Authority's consultant should review a copy of this study and supplement their report with any relevant information.

Section 4.2.8 Screening of Site

The consultants discussion of screening this site to limit its visual impact was confined to the impact along adjacent roads. No consideration was given to the visual impact of the site upon southbound traffic on the St. George's (Route 13) Bridge. From such an elevated vantage point the site and any activity thereon would be quite obvious. This subject should be treated in the site analysis.

- Cherry Island

Section 6.2.5 Property Line Setbacks

Since the site is bordered on two sides by major bodies of water, it would seem acceptable to maintain the 100 foot water setback rather than the 200 foot property line setback. This could be accomplished without significantly increasing the impact upon adjacent properties or uses.

Section 6.2.7.6 <u>Potential On-Site Borrow Areas</u>

Although it is realized that, due to their characteristics, the on-site dredge spoils cannot be utilized to meet the total cover material needs, the assumption of total importation of borrow material is overly conservative. These on-site materials can be utilized to supplement borrow materials and may be stabilized through drying or the addition of admixtures. While these costs might currently meet or exceed the costs of total importation, with rising transportation costs, they will very probably become competitive. These factors should be considered in your analysis of cover material sources.

Section 6.5.1 <u>Estimated Landfill Development Costs</u>

The costs associated with the construction of foundations for the maintenance building and associated structures at this site will most certainly be greater than those for the other sites due to the compressibility of the dredge spoils. It is our understanding that the buildings required at the facility (i.e.; maintenance building and office trailer) will not produce particularly heavy foundation loadings. In view of this, the arbitrary 30 percent increase which has been assigned to structure costs for this site seems to be excessive.

Table 6.5-1 <u>Summary of Capital Cost</u>

Item A.5. Leachate Collection and Storage Facilities

From the description given of the leachate collection system for this site (Section 6.5.1), we cannot understand why its projected cost ($1,273,000) is over twice the combined costs of leachate collection system and liner for the Road 412 site. Although leachate removal may require pumping at Cherry Island and not at Road 412, the differential still seems inordinately high especially considering that a liner is not included in the Cherry Island costs. As earlier indicated, pumping may also be required at Road 412 to convey the leachate for treatment.

We believe that your consultant has done an adequate job of addressing the groundwater issues at this level of analysis. It is realized, of course, that, subsequent to the ranking of sites, more definitive information regarding the hydrology and geology of the selected site will be obtained. We are interested in reviewing such information. Your data suggest that, from the aspect of water resources protection, the Cherry Island site is clearly superior to the other sites. The Road 412, while not as desirable as Cherry Island, does appear to afford adequate protection to water resources given appropriate engineering measures.

The Roberts Farm site, due to the potentiality of surface water as well as groundwater contamination, presents the least desirable alternative of the limited number of sites considered according to our interpretation of your consultant's analysis.

In summary, the comments we have presented seek to accomplish two things: (1) to identify all relevant costs and make them part of the analysis; and (2) to identify unconsidered environmental, aesthetic and land use impacts for full consideration. We recognize the effect of addressing the issues we raise may have a significant impact upon the decision to be reached. To do otherwise would result in an unbalanced analysis which would certainly influence the decision process, perhaps to increase the cost of the ultimate choice. Given the magnitude of potential impacts of solid waste disposal, both short and long range, it is imperative that this not be the case for the Northern Solid Waste Disposal Facility.

We trust that the foregoing comments will be of assistance to you in the completion of your reports. As always, our staff stands ready to provide assistance or technical information to aid the authority in its deliberation. Please do not hesitate to contact us if we can be of any further help.

Very truly yours,

Bernard L. Dworsky
Administrator

N. Guy Winebrenner, P.E.
Senior Engineer

rcf

cc: Policy Board
Edward J. Hollos, P.E.
Gilbert Associates, Inc.

Department of Planning

OFFICE OF THE DIRECTOR

2701 Capitol Trail
Newark, Delaware 19711

(302) 366-7780

December 11, 1981

Mr. N. C. Vasuki
General Manager
Delaware Solid Waste Authority
P.O. Box 455
Dover, Delaware 19901

Dear Mr. Vasuki:

Pursuant to the Authority's request that concerned agencies review its consultant's Detailed Site Investigations for NSWF-2, the New Castle County Department of Planning hereby offers this evaluation. The questions raised and issues addressed are those that the Department feels are germane to the selection of a landfill site for New Castle County. The following are topics that need greater emphasis or clarification in order to adequately evaluate the merits and deficiencies of each site.

1) Off-Site Issues - Greater information needs to be developed for methods of transporting collected leachate to the nearest point of disposal. Whether this is accomplished by vehicle or pipeline, some impact will be felt. This issue needs to be evaluated for the three sites. Its existence is common to all but the solutions required may be quite divergent.

   The issue of road and bridge improvements for the two southern sites will translate into a consumer cost regardless of the source of funding. It is currently understood that this cost is to be shown as a capital item in each report, to be borne by the Authority. In addition, attention should be given to the eventuality of the Reclamation Plant being inoperative and private and public haulers having to deliver directly to the landfill site.

2) Future Land Use - In order to determine ultimate uses for the closed-out landfill, it will be necessary to project the condition of the site. Will gas reclamation be required? Will the soil characteristics support loads such as buildings or be stable enough for underground utilities? For some uses, such as agriculture, it may be necessary to import cover material. Would there be any restrictions on the use of the crops? For how long will leachate have to be collected? What would be the source

of funding in order to accomplish this conversion of land use?

3) Cherry Island Land Acquisition - There needs to be some clarification of the acreage requirements and how it relates to ownership patterns at Cherry Island. The size of the site then needs to correspond to its longevity. The acquisition of 500± acres presents the possibility of an extended life span. Would it be cost effective to purchase this much acreage now? This issue of acquisition needs to be dealt with in terms of consumer costs, site longevity and ultimate land use.

4) Cherry Island Site Preparation - The need for either a natural or synthetic liner needs to be clarified along with the resulting costs. How does the use of a liner affect the leachate collection system in terms of transporting leachate to the wastewater treatment plant.

5) Cherry Island - There are several peripheral issues at Cherry Island that need to be understood and potentially integrated. There are four operations in the immediate vicinity of Cherry Island, each of which produces an end product that would seem to have potential use in a landfill. The most obvious is the Authority's Pigeon Point Reclamation Plant and its shredded, separated debris. The Delmarva Power and Light Company's Edgemoor Plant will have a need to dispose of fly ash and the Wilmington Wastewater Treatment Plant produces sludge as a by-product. The Corps of Engineers is presently involved in a site selection process of its own to locate a disposal location for dredge spoils from the Christina and Delaware Rivers. Each of these materials or combinations thereof should be evaluated for suitability as landfill cover material. Recognizing the size of the Cherry Island site, there may be an opportunity for multi-agency cooperation on one disposal site.

6) Environmental Concerns - The reports address mitigating measures for controlling local visual impact of each site. In addition, attention should be given to visual conditions from greater distances. For instance, it is possible to develop buffers around a site such as Road 412, but that same site is highly visible from the Route 13 bridge over the C & D Canal.

   Regarding the likelihood of leachate contamination due to a flaw or damage to the collection system, it would be helpful to have projected the relative environmental impacts on or around each site. In effect, this would take the form of a worst-case scenario and would call for the interpretation of the report's technical information. Such projections would identify the capability of each site to tolerate this damage in terms of ground and surface water contamination, containment of same or magnitude of potential distribution. A method of indemnification should be developed for this eventuality.

All of the issues raised contain economic implications for New Castle County residents. The capital costs, operating procedures and costs, and site location and longevity will eventually translate to user fees. The site selection decision needs to be made by incorporating these kinds of concerns.

The New Castle County Department of Planning welcomes this opportunity to continue to provide input and comment on the site selection process. It will continue that involvement by way of the February 4, 1982, public hearing and participation in the Land Use Planning Act (S.B. 358) review.

The Department of Planning's comments made in this review are offered in the interest of facilitating the site selection process; while it is understood that the General Assembly has mandated to the Delaware Solid Waste Authority the responsibility of disposing waste in the State of Delaware, and consequently, the responsibility of site selection is under the Authority's control.

Should there be need for further discussion of the contents of this letter, please don't hesitate to contact this office.

Sincerely,

Richard M. Bauer
Director of Planning

DPL/daj

cc: Richard T. Collins
Michael E. Harkins
County Council Members
John Rago
Mary McKenzie
Bernard Dworsky
Edward Hollis

WILMAPCO

Wilmington Metropolitan Area Planning Coordinating Council
Suite 201 Stockton Building
University Office Plaza
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302-737-6205

Robert A. Engle, Chairman James H. Tung, Executive Director

December 14, 1981

Mr. N. C. Vasuki
General Manager
Delaware Solid Waste Authority
P. O. Box 455
Dover, Delaware 19901

Dear Mr. Vasuki:

WILMAPCO has completed its review of the "Detailed Site Investigation of Candidate Sites for Northern Solid Waste Facility - 2 (New Castle County)." Our internal review included consultation with the Delaware Department of Transportation, Division of Highways. DOT's response to our request for comments is attached.

To these comments we would only add that it seems appropriate to consider transportation impacts as an integral part of the comparative evaluation of the three sites. Despite the fact that transportation system costs do not directly effect the Authority, it remains a significant consideration in the decision process. It also seems appropriate for the Authority to attempt to minimize all of the costs to be borne by the public. In the final analysis, it is the public that must bear both the expense of upgrading the cost of transport routes, and the cost of the site and its operation.

Sincerely yours,

Peter L. Johnston
Environmental Planner

PLJ/er

enc.

cc: Mr. William A. Elgie, Jr., MCIP

2. Gilbert Associates, "Site Suitability Study for the Northern Solid Waste Facility – Supplemental Report, Responses to Agency Comments," prepared for the Delaware Solid Waste Authority, February, 1982.

SITE SUITABILITY STUDY

FOR THE

NORTHERN SOLID WASTE FACILITY

SUPPLEMENTAL REPORT

RESPONSES TO AGENCY COMMENTS

FEBRUARY 16, 1982

SITE SUITABILITY STUDY
FOR THE
NORTHERN SOLID WASTE FACILITY
NEW CASTLE COUNTY, DELAWARE

SUPPLEMENTAL REPORT

TABLE OF CONTENTS

INTRODUCTION

The following pages present the Delaware Solid Waste Authority's responses to written comments on the "Draft Reports" for each of the three candidate landfill sites for the location of the Northern Solid Waste Facility. The Authority requested such written comments to be forwarded to the Authority office on or before December 14, 1981. Comments from five State and local agencies were received. The agency comments are printed in "regular" type; the Authority's response to each comment is printed in "italics".

I. RESPONSES TO DNREC COMMENTS ON "DRAFT REPORTS" FOR THE SITE SUITABILITY STUDY FOR THE NORTHERN SOLID WASTE FACILITY

A. Excerpt From DNREC Letter to DSWA Dated December 14, 1981:

In regard to the request for a waiver of the synthetic liner requirement at the Cherry Island site, we draw your attention to the fact that the Department has only had an opportunity to review the preliminary reports for all three sites. We were informed that these reports were drawn up with only a view to considering the general suitability of each site as a future sanitary landfill. The Cherry Island site suitability report does not address specific details such as design consideration, the potential environmental impact on aquifers in the area if no synthetic liner were used, and the potential for heavy metal migration due to the acidic nature of the dredge spoils. These specifics are to be submitted with a complete permit application when a particular site selection is made. The Department will be able to make a decision on the need for a synthetic liner at the Cherry Island site only after reviewing these details. The Authority may choose to conduct all necessary studies at the Cherry Island site in advance, prior to making a site selection and permit application, so that the Department can determine the need for a synthetic liner at an earlier date.

In addition, the Authority would have to request a variance from the provisions of the Delaware Solid Waste Disposal Regulations Section 6.03(g)(1) in order to obtain a waiver for the liner requirement. Pursuant to 7 Del C. Chapter 60 § 6011(b)(3) "The variance may be granted if the Secretary finds that the person applying is unable to comply with the provisions of this chapter because the necessary technology or other alternative methods of control are not available .....".

At this time, however, there are two alternative sites available, and at the time a variance is requested, the Authority should provide sufficient justification for the same.

DWSA Response

As a result of the above comments regarding the Cherry Island site, the "final report" presents two alternatives with regard to the development of Cherry Island as the NSWF: Alternative or Alternate 1 being development of the site with an impermeable synthetic membrane liner; and Alternative or Alternate 2 being its development without a liner as originally proposed. The cost differential is substantial.

B. General Comments

1. It is evident that the county's and city's plans do not address the need nor the location of landfill sites as part of the land use planning process. However, pursuant to the Delaware Solid Waste Disposal Regulation, Section 6.01, "A land use for the completed disposal site shall be specified and operations adjusted accordingly." Therefore, you should include plans for future land use at each site, with the associated cost considerations.

   DWSA Response:

   The only future land use proposed for any of the three candidate sites is "open space". Although there could be a potential for other uses such as for a park or limited agricultural activities, the long term maintenance of the completed site and associated responsibilities and liabilities would have a negative influence on the market value of the land, particularly since any prospective buyer probably would have to assume these responsibilities and liabilities from the Authority. Consequently the resale value of the properties at each candidate site were assumed to be negligible. To assume anything else would be very *subjective and extremely speculative. Long term maintenance activities and responsibilities of the completed landfill sites would include:*

- *maintenance of decomposition gas venting system*
- *maintenance of leachate control system*
- *sampling of decomposition gas monitoring wells*
- *sampling of groundwater monitoring wells*
- *as appropriate, sampling of surface water monitoring points*
- *maintenance of erosion control facilities*
- *maintenance of completed landfill grades and slopes*
- *maintenance of proper vegetative cover*

2. The classification standard used to describe the grain size of underlying sediments is not given.

   DSWA Response:

   The classification standard utilized was the Unified Soils Classification System (USCS). Notes have been added to the grain size tables indicating the classification utilized.

3. Sieve analysis would be better represented on the standard graphs for technical interpretation.

   DSWA Response:

   Grain size curves have been prepared for each tested soil sample. These curves appear in Appendix C of each site report.

4. The hydrogeological characteristics should be given in consistent units.

DSWA Response:

The text has been revised and appropriate hydrogeological characteristic values have been changed to centimeters per second (cm/sec).

5. We recommend that you predict the leachate generation (by water balance method) to consider the impact of the solid waste site on the aquifers and surface water.

DSWA Response:

As a normal design task, a leachate generation estimate using a recognized "water-balance" technique is made to provide data for the design of the various components of the leachate control system. To do so at this point was felt to be premature. However, giving due regard to the comment, attached is a "water balance" estimate which indicates that the expected leachate production, once field saturation of the landfilled wastes is achieved, is on the order of 366 gallons per acre per day. Assuming an average landfilled area of approximately 200 acres at completion, this represents about 73,200 gallons per day. The methodology utilized in arriving at this figure is described in EPA Report SW-168, "Use of the Water Balance Method for Predicting Leachate Generation from Solid Waste Disposal Sites"; Fenn, Hanley, and DeGeare. Additional information was obtained from the 1981 Michael Baker, Jr. Inc. report for DPL's Edgemoor Power Station entitled "Solid Waste Disposal Plan."

It must be recognized, however, that there only would be an impact on the aquifers and/or surface water if the sites are not lined or if the liners and leachate collection systems fail completely and

WATER BALANCE FOR DSWA NORTHERN SOLID WASTE FACILITY

Parameter	Month: Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
Potential Evapotranspiration (PET)	0.63*	1.14	3.07	3.31	4.02	5.08	5.00	4.41	2.95	1.85	1.18	0.63	33.27
Precipitation (P)	3.39	3.15	3.70	3.50	3.54	3.78	4.49	4.72	3.66	3.03	3.23	3.50	43.69
Runoff Coefficient (CR/O)	0.25	0.25	0.17	0.17	0.17	0.12	0.12	0.12	0.145	0.145	0.145	0.17	
Runoff (R/O)	0.85	0.79	0.63	0.60	0.60	0.45	0.54	0.57	0.53	0.44	0.47	0.60	7.07
Infiltration (I)	2.54	2.36	3.07	2.90	2.94	3.33	3.95	4.15	3.13	2.59	2.76	2.90	36.62
I - PET	1.91	1.22	0	-0.41	-1.08	-1.75	-1.05	-0.26	0.18	0.74	1.58	2.27	+3.35
Σ Negative (I-PET)	-	-	-	-0.41	-1.49	-3.24	-4.29	-4.55	-	-	-	-	-
Soil Moisture Storage (ST)	4.92	4.92	4.92	4.51	3.58	2.52	2.01	1.93	2.11	2.85	4.43	4.92	-
Change in Storage (ΔST)	0	0	0	-0.41	-0.93	-1.06	-0.51	-0.08	+0.18	+0.74	1.58	+0.49	-
Actual Evapotranspiration (AET)	0.63	1.14	3.07	3.31	3.87	4.39	4.46	4.23	2.95	1.85	1.18	0.63	31.71
Percolation (PERC)	1.91	1.22	0	0	0	0	0	0	0	0	0	1.78	4.91

*inches

Soil Cover	Field Capacity	Wilting Point	Available Water
Silty/Clayey Sands	7.87 inches	1.97 inches	5.90 inches

Depth of Final Cover: 2.5 ft. (30 inches or 0.762 m)

Storage Capacity = 5.90 inches/m x 0.762 m) = 4.50 inches (~115 mm, ∴ use Table 10 for soil moisture retention estimate: 125 mm or 4.92 inches)

Percolation Rate: 4.91 inches/year = 366 gallons/acre/day assuming field saturation of refuse and cover *instantaneously. It also assumes that no corrective actions would be taken. Please consider that the potential impact also is mitigated by the following:*

a. *The landfill will be developed in phases, which means that advancements in liner technology can be taken advantage of. In other words, the Authority is not locked into the use of only one liner system.*

b. *The bulk of materials which will be landfilled should be relatively inert. Except for those occasions when the DRP is shutdown, or operating at a reduced capacity, the organic constituent of the waste stream will be low.*

c. *Decomposition rates of the organic fraction and the types of decomposition are dependent upon moisture, available nutrients, temperature, oxygen and other factors. Since the quality of leachate is time dependent, being influenced by organic decomposition rates, the point in time at which a leachate collection system fails, if it fails, is critical. For instance, if failure occurs after 25 years, the bulk of the organic materials originally present will have been decomposed and converted to harmless by-products of the decomposition process.*

6. Additional hydrogeological cross-sections should be provided to give a better understanding of the potential migration of leachate.

DSWA Response:

Additional hydrogeological cross-sections for each site have been prepared and incorporated into the report. Note that the original cross-section for the Cherry Island site has also been revised to include additional boring data.

7. A method of calculation should be included to clearly show the dilution ratio of leachate obtained for each aquifer.

DSWA Response:

The method of analysis, used in determining the dilution ratio of leachate, was furnished by the DNREC. This sample calculation, prepared by the DNREC, is included as Exhibit 1. Review of the exhibit indicates that the dilution ratio is the ratio of the calculated horizontal discharge of an aquifer (Qh = water moving through aquifer) to the calculated vertical discharge (Qv = water seeping into aquifer). In calculating the horizontal discharge of the various aquifers underlying each site, the total site area times the average thickness of the aquifer was utilized as the cross-sectional area of the aquifer, the potentiometric surface maps were utilized to determine the hydraulic gradient and published or calculated hydraulic conductivity values were utilized for the aquifer being analyzed.

8. The interpretation based on descriptive logs and geophysical logs are misleading. The descriptive log indicates lesser permeable materials underlying the site than given by the geophysical log depending on the relative graph size interpretation.

DSWA Response:

The descriptive logs were based on visual identification of materials collected as cuttings from rotary drilling. This method of sample collection was approved by the DNREC prior to any drilling activities. The method of sample collection, whereby coarser materials may not be returned to the surface as cuttings, is probably responsible for any interpretative differences.

9. The potential impact of leachate migration, if any, into the unsaturated zone is not given.

DSWA Response:

The assessment of potential impacts of leachate migration into the unsaturated zone was not part of the site suitability study nor was it requested by the DNREC in their review of the proposed site suitability evaluation (see Exhibit 1). Such an assessment, could be performed, if required by the DNREC, during the additional data collection study of the selected site.

10. The leachate attenuation characteristics of the underlying material (top soil or base material of liner) are not given.

DSWA Response:

The appraisal of the leachate attenuation characteristics of the surficial soils comprising each site was not part of the site suitability study nor was it requested by the DNREC in their review of the proposed site suitability evaluation (see Exhibit 1). Such an appraisal, could be performed if required by the DNREC, during additional field studies and sample collections of the selected site.

11. An inventory of the number, location, depth, screen interval and aquifer of all the water supply wells within a mile of each of the possible sites should be provided.

DSWA Response:

Additional data pertinent to wells situated within a mile of each site has been provided in each site report.

12. The potential for leachate migration, if any, outside of the boundary should be considered.

DWSA Response:

The potential for leachate migration beyond the site boundaries should be minimized through the construction of a lined disposal site and the installation of a monitoring well network within the site boundaries. A discussion of groundwater flow directions within each aquifer is presented in each site report.

13. Groundwater flow directions indicated on the potentiometric surface map of the deeper aquifers may not be the actual flow directions due to insufficient data.

DSWA Response:

Where only two data points were available, the report indicates that the directions shown on the potentiometric surface maps are probable directions.

C. Roberts Farm

1. The effect of quality and quantity of water above the dam structure on the landfill groundwater and surface water flow is not addressed.

DSWA Response:

Because the edge of proposed disposal areas are identified as either the boundary of the 100 year flood plain or 300 ft. from the edge of the State of Delaware Wetlands (whichever is the more stringent), the water above the dam structure will have little, if any, effect on landfill surface water flow. The nine borings taken at the site incorporate the effect of this impoundment on *the groundwater both north and south of the impoundment. The wide buffer zones also diminish the effect of rising pond levels on the proposed disposal areas and the groundwater elevations beneath.*

2. P.36 The rotary rig drilling technique may cause drill-cutting samples to have characteristics at some variance with the actual in place characteristics of the sediments. In particular, use of water as the drilling fluid may result in loss of the larger sand fraction, making the samples appear less permeable than the sediments penetrated actually are.

DSWA Response:

The method of drilling and sediment sample collection was explained to the DNREC prior to the start of any drilling activities. There was no objections to the proposed sampling procedure at that time. Also, note that the seepage calculations were based on seepage through the Calvert Formation. This formation consists of silts and clays and contains little, if any, coarse sand materials.

3. P.43 You shall estimate the K, S, and porosity of the Pleistocene Aquifer at the eastern portion of Roberts Farm? "At the eastern portion of the Roberts Farm, a residential well has been constructed in the Pleistocene Aquifer. In this area, erosion of the underlying Calvert and Vincentown Formations has occurred and a thick sequence of Pleistocene sediments has been deposited in their place. This thick sequence of materials has afforded a large saturated thickness and the construction of a Pleistocene well. This well is, however, considered to be atypical of the area." This indicates that the Rancocas Aquifer subcrops in this area and is directly connected to the Pleistocene Aquifer.

DSWA Response:

The fact that the Calvert Formation has been eroded away in the eastern portion of the site is documented in at least three different sections of the *report. In addition, the report (Sediment Description-paragraph 4) states that both the Vincentown and Hornerstown Formations (Rancocas Aquifer) directly underlie Calvert or Pleistocene sediments. Accordingly, it was assumed that the reader would recognize that the Rancocas Aquifer subcrops the Pleistocene age sediments in several portions of the site. A new geologic cross-section (Figure 5.2-4B) which has been added to the report also shows that the Rancocas Aquifer subcrops Pleistocene sediments in the eastern portion of the site.*

In the western portion of the site, where the Calvert is absent, potentiometric surface data indicates that the Rancocas Aquifer is confined or partially confined. This confinement or partial confinement is probably provided by the silty clay layer contained within the Pleistocene age sediments. In the eastern portion of the site, potentiometric surface data suggest little if any confinement exists. However, there is no plan for landfilling in this area. Accordingly, predictions of leachate seepage from the water table to the Rancocas Aquifer is not required.

Using an assumed thickness of 100 feet and the published transmissivity values, the requested hydraulic properties of the Pleistocene sediments at the eastern portion of the Roberts Farm are as follows:

Hydraulic Conductivity = 4.7×10^{-2} *to* 7×10^{-3}
Storativity (coefficient of storage) = *0.12 to 0.15*
Porosity = *30%*

4. P.43 "Rancocas Aquifer - this aquifer is an important source of water in southern New Castle County and reportedly supplies more than 25 percent of the groundwater used in the area of the County south of the canal (Sundstrom & Pickett, 1971). Based on personal communication with members of the Delaware Geological Survey, the Rancocas Aquifer is one of the primary sources of groundwater for most wells within a mile radius of the Roberts Farm tract. The aquifer has a transmissivity of 14,000 to 19,000 gallons per day per foot and a storage coefficient of 0.00019 to 0.00028

(Sundstrom & Pickett, 1971). These values together with an average specific capacity value of 2.3 gallons per minute per foot of drawdown are considered to be representative of the Rancocas Aquifer in the Roberts Farm area. Using an average transmissivity of 17,000 gpd/ft or 2275 ft^2/day and an aquifer thickness of 110 ft. (see monitoring well ML-1), the hydraulic conductivity of the aquifer is estimated to be in the range of 7 x 10^{-3} cm/sec." These hydrological parameters (given in the second paragraph, Page 43) parameter values are for the Rancocas Aquifer (south of New Castle County) where it is not subcropping. For subcropping Rancocas Aquifer the values of the storage coefficient are likely to be similar to the Pleistocene water table aquifer (see Report #3, Page 76).

"The Rancocas Aquifer is reportedly confined by the Calvert Formation in the region of the Roberts Farm. However, monitoring wells constructed on site indicate that the Calvert Formation has been lost to erosion in the immediate area of Hangman's Run."

This also indicates that the Rancocas is subcropping near Hangman's Run.

DSWA Response:

See response to Comment No. 3 and Figure 5.2-4 of the report which shows the Rancocas subcropping Pleistocene age sediments in the area of Hangman's Run Pond.

5. P.48 How were the water quality samples preserved? Are pH and conductivities measured in the field?

DSWA Response:

Each water quality sample consisted of one half gallon bottle and two liter bottles. The liter bottles contained preservatives consisting of either nitric *acid (HNO_3) or sulfuric acid (H_2SO_4). Each sample was delivered to the testing laboratory several hours after they were obtained. Conductivity and pH were measured in the laboratory.*

6. Table 5.2-3 Well P-1

   Dissolved solids and conductivity are generally correlated but the values indicate some anomalies. Sulphate seems to be high.

   DSWA Response:

   There is a typo error for conductivity in sample P-1. The correct value is 184 mg/l. The sulfate value is correct.

7. P.48 What explanation(s) can be made for the elevated manganese and nitrate levels in a few of the groundwater samples?

   DSWA Response:

   The elevated nitrate level in sample P-1 may be the result of fertilization of the agricultural land. The reason for the slightly elevated manganese concentrations in samples P-1 and ML-1 is not known.

8. P.50 Mention is made of residential wells constructed in all three aquifer in the vicinity of the proposed site. With the conclusion of the landfill, consideration should be given to alternative water supplies available to these users, if found to be necessary.

   DSWA Response:

   Most residential wells, in the vicinity of the site, are upgradient of groundwater flow. The proposed landfill at the site is a lined landfill which should preclude such an occurrence.

9. P.52 Renovation would take place by cation exchange only. Anions are not exchanged. There may be limited cation exchange as it does not have a high value of CE.

DSWA Response:

Reference to Anion exchange has been removed from the text.

10. P.62 The Roberts Farm is located in one of the State's better areas for supporting a variety of wildlife species, and the surrounding properties are also high quality wildlife habitat. The siting of a landfill in this area would be a negative factor in maintaining the high quality of wildlife of the region.

DSWA Response:

First, it is doubtful that all of the surrounding properties could be classified as high quality wildlife habitat as one might infer from the above statement. We are referring here to the new residential area north of the site. Second, the proposed disposal areas have been located taking into account the siting criteria established through a series of well publicized and attended public hearings and associated comment periods. The criteria ultimately formulated was based upon in-put by the DNREC with just these things in mind, that is, to preserve wildlife habitat. Thus, at this site, there is a 300 ft. wide buffer zone between the limits of the disposal areas and the edge of the State of Delaware Wetlands. Third, from an operations viewpoint, considering the proposed phased development program, only a fraction of the proposed disposal areas will be in use at any one point in time. This fact was mentioned in the draft reports. Fourth, the proposed end use of the landfill as open space probably is more compatible with maintaining the character of this area over the long term then if it remained as farmland which would be much more attractive to residential development. Witness the stretch along Route 9 north of the site.

11. P.65 Any disturbance of the wetlands areas or increases in turbidity in the water courses or any failure of the liner/leachate collection system would have serious consequences due to the importance of this area as a nursery area for estuarine biota. The Appoquinimink-Blackbird drainage area is a prime nursery area for weakfish, croaker, bluefish, white perch, striped bass and many other of Delaware's commercially and recreationally valuable species of fish. In addition, this area is located on the upper fringe of the American oyster reproducing areas which is very important for commercial and recreational crabbing.

DSWA Response:

The importance of the Appoquinimink and Blackbird drainage areas for commercial and recreational crabbing and as prime nursery areas for commercially and recreationally valuable species of fish is recognized by the Authority. However, in our research efforts we found no mention of important oyster reproducing areas in the vicinity of any candidate site and this included consultations with DNREC personnel and review of references published and/or provided by the DNREC to aid in this evaluation. Again, wetland areas would not be disturbed by the landfilling activities because of the 300 ft. buffer zone which would be maintained between the edge of the disposal area and the edge of the wetlands. Increases in turbidity of the water courses over that which occurs through farming of the land will not be experienced. Erosion control plans developed as part of the design of the facility would be implemented and would preclude this. In fact, once such control measures are instituted the loss of soils may even be less than that which occurs at the site now.

12. P.70 There is a distinct possibility that the landfill operation would have an unfavorable impact on the potential for the bald eagle to return as a nesting bird in the area.

DSWA Response:

First, although several former bald eagle nesting sites were found to be located about 2.5 miles from the site, no former nesting sites were identified within the immediate vicinity of the Roberts Farm Site. It is difficult to follow the line of reasoning, therefore, that siting a landfill at this candidate site would have an unfavorable impact on the return of the eagles to those nesting areas. Second, the DNREC makes an assumption that landfills and bald eagles are not compatible. This is a position that is not supported in recent articles published by the National Wildlife Federation. Third, it wasn't landfills that pushed the eagles out of these areas originally, but the continued destruction of habitat by development and the degradation of the environment resulting from the introduction and uses of chemicals including insecticides and herbicides.

13. P.73 The useable areas for landfilling on Roberts Farm are prime farmland and are presently cultivated. Apart from the obvious food producing capabilities of this land, the crops serve as food for the geese and other waterfowl and the upland game that are all abundant in the Appoquinimink drainage area.

DSWA Response:

Of the 430+ acres of prime farmland identified as being within the Roberts Farm Property, roughly 200 acres have been proposed for use as solid waste disposal areas. Therefore, more than half of the prime farmland at this candidate site can still be cultivated under the auspices of the Authority. In addition, because of the proposed phased landfill development program, portions of the proposed disposal areas which have not yet been developed can continue to be cultivated. Finally, if necessary, crops can be grown within the 300 ft. wide buffer zone (separating the disposal area from the wetlands) specifically to provide forage for geese and other waterfowl and upland game. If the site is managed in this fashion, it would probably provide more food for wildlife than the current agricultural activities which are geared to provide crops for consumption either by humans or by domesticated animals.

14. The most viable highway access to this site would involve going through either Odessa or Middletown. This would result in considerable traffic increase through these towns and, therefore, all roads must be able to accommodate this. A knowledge of the weight limit for the two land bridge of Hangman's Run should be obtained.

DSWA Response:

First, as a result of an interview with DelDOT officials, it was found that the bridge over Hangman's Run did not have a posted limit. However, if the Roberts Farm site is selected for the location of the Northern Solid Waste Facility, it would become a priority task for DelDOT to determine a weight limitation and post it. Therefore, to be conservative, it was assumed in the economic analysis that improvements to the bridge would be necessary and the estimated $1,050,000 for haul route improvements includes monies for this. This is stated in the report. Second a review of Table 5.4-1 shows that the increase in total traffic through the town of Odessa via U.S. Route 13 is negligible (~ 0.4%) and the increase in total truck traffic would be insignificant (~ 2.6%). This is all based upon Annual Average Daily Traffic data as provided by DelDOT. The report indicates, however, that the increase of traffic along State Road 452 would be significant. The economic analysis incorporates upgrading of this road.

15. Appendix 5B The geophysical logs are not provided with speed, time, constant temperature, resistivity and viscosity of mud (drilling fluid).

DSWA Response:

The geophysical log appearing in Appendix 5B was provided by the Delaware Geological Survey. Details pertaining to these logs may be obtained from that agency.

D. Road 412

1. 4.3.1.1. The report states that very few waterfowl or waterbirds utilize the area (U.S. Atomic Energy Commission, 1974). This statement is inaccurate in terms of Scotts Run where the Division of Fish and Wildlife has established several duck blind sites that provide quality hunting.

DSWA Response:

Road 412(1) The report has been duly amended based upon this comment and a like comment received earlier from Mr. H. Lloyd Alexander.

2. 4.3.1.4. The statement "Effects of landfill operation on adjacent wildlife habitats are expected to be minor" is an oversimplification of wildlife needs. Doves, quail, songbirds, rabbits, deer and a variety of other wildlife use agricultural crops as part of their habitat, especially as feeding areas.

DSWA Response:

Road 412(2) Effects of the landfill operation on wildlife are expected to be minor because of the proposed phased landfill development program. Portions of the proposed disposal area which have not yet been developed can continue to be cultivated under the auspices of the Authority. If necessary, crops can be grown within the 200 ft. wide buffer zones around the perimeter of the site specifically to provide forage for wildlife. As stated earlier, if the site is managed in this fashion, it probably would provide more food for wildlife than the current agricultural activities.

3. 4.3.1.2. If landfill activities did not slope toward the tiny existing tributaries on the boundaries of the property, impact to the aquatic biota of Scott Run and the C & D Canal should be minimal. Leachate and/or turbidity should not reach the C & D Canal, since it is a significant spawning and nursery area for

striped bass, a species currently much in the news because of concern over its population decline. The importance of the canal for spawning and transport of other important fish species is equally well documented.

DSWA Response:

The Authority recognizes the importance of the canal for spawning and as a nursery area for important fish species. Consequently, although the majority of the landfill, upon completion, can be sloped away from these tributaries, it does not appear that it would be possible to preclude all drainage from eventually reaching these tributaries. Thus, other measures, which would be part of the disposal area design and/or the erosion control plan, would be necessary to insure that no contamination of the canal from leachate or turbidity occurs. Lining of the site and collection of leachate will preclude contamination from leachate. Sedimentation basins and/or other velocity reduction techniques should decrease turbidity to a point where it may be less than that experienced from the current agricultural activities associated with the site.

E. Cherry Island

1. 6.2.1.2 You are to provide a recent topographic map to include the location of dikes and other relevant features.

   DSWA Response:

   Recent topographic maps were incorporated within the "draft" report on Cherry Island. Refer to Figures 6.2-6 and 6.2-7. These same topographic maps have been incorporated within the final report also. They show the location of dikes and other pertinent features.

2. 6.2.1.3. The subsurface exploration conducted on the nearby DP&L property and duPont Edgemoor sites should be considered in the study.

DSWA Response:

Boring data from the DP&L property and duPont Edgemoor sites have been incorporated into the final report.

3. Permeability data for dredge spoil.

Was the permeability data obtained from laboratory permeability tests or empirical data derived from other geotechnical parameters? If determined by laboratory methods which particular method was used? Are these data for horizontal or vertical permeability?

DSWA Response:

Under the section "Sediment Description" the Gilbert report clearly indicates that the permeability data was from laboratory testing. The Michael Baker, Jr. "Solid Waste Disposal Plan" report, which has been filed with the DNREC and is part of the public record, was quoted as the source of the permeability values. The Michael Baker, Jr. report does not indicate what laboratory method was utilized in determining the permeability of the dredge spoil nor does the report indicate if the values are horizontal or vertical permeabilities. The Michael Baker, Jr. report does indicate that permeability testing of Columbia Formation materials was conducted in a 2.5 inch permeameter and tested under a constant head using gravity drainage. It may reasonably be assumed that testing of other materials (such as dredge spoil) was similarily conducted.

4. Is the dredge spoil material homogeneous throughout the site? What are the leachate attentuation and chemical characteristics of the dredge spoil?

DSWA Response:

Differences in consistency, grain size distribution, plasticity, moisture content and compressibility of the dredge spoil materials probably exists *from place to place throughout the Cherry Island site. However, when considered as a total geologic unit such as in the determination of seepage, it can reasonably be assumed that the dredge spoil acts as one homogeneous unit. Leachate attentuation and chemical characteristics of the dredge spoil were not part of the proposed suitability study which was approved by the DNREC. A cation exchange capacity of 13 me/100 grams for the dredge spoil material was reported in the Michael Baker, Jr. report. This report has been submitted to the DNREC and is part of the public record. Leachate attentuation will be addressed as part of the final design.*

5. 6.2.1.5 The industrial wells at Brandywine Chemicals Company (formerly Halby Chemical Company) and Forbes Steel and Wire Corporation are nearer than the Collins Park well. There are other potential production wells in the vicinity. All these water wells should be considered in the study.

   DSWA Response:

   Data from nearby industrial wells have been included in the final report.

6. Potomac:

   If either of the two zones of the Potomac are not present at Cherry Island, then what is the name of the zone present at Cherry Island?

   DSWA Response:

   The sandy zones present at Cherry Island (see Figure 6.2-5A) are thought to represent sand lenses contained within the formation. These lenses (see R.W. Sundstrom et al, 1967 p. 18) cannot be correlated and accordingly have no name.

7. The low production of Potomac wells may be attributed to the well construction and development since they were installed only as monitoring wells and not as production wells.

DSWA Response:

The monitoring wells were constructed in a very similar fashion as that of a production well. The silty and clayey nature of the thin sandy zones, which were developed, does not indicate large available water supplies. These zones are also thought to have limited areal extent.

8. <u>Figure 6.2.6</u> The location of the water table wells should be provided.

   DSWA Response:

   The locations of the water table wells have been provided on Figure 6.2.6.

9. <u>Figure 6.2.7</u> If the flow shown in the figure is correct, the flow direction in the Potomac will be in a downdip direction where the Potomac aquifer is used as a water supply aquifer.

   DSWA Response:

   This statement is true, but note that Michael Baker, Jr. Inc., report states that it will take several hundred years for the leachate to reach the Potomac Formation.

10. The water level readings for the Columbia and Potomac aquifer monitoring wells were taken at different times. Provide the interpretation if the readings were taken at the same time.

    DSWA Response:

    With the data available, it is not possible to accurately interpret the water level data of one aquifer with that of another aquifer for two different time periods. Accordingly, additional monitoring is required. This monitoring will be performed during the detailed exploration program, which will be conducted if the Cherry Island site is selected.

11. The presence of a perched water table indicates that the dredged material is not homogeneous and/or is not evenly distributed. This mode of deposition may create windows of permeable material which may be potentially interconnected with water supply aquifers.

DSWA Response:

Although the above statement is possible, the underlying estuarine deposits (layer of materials below dredge spoil) would tend to preclude any direct connection with the dredge spoil materials and underlying aquifers.

12. Ground water quality.

The water quality parameters of the Potomac Formation are poorly correlated with relevant parameters. For example, sodium is not ionically balanced with chloride and sulphate. (i.e. there is no ionic balance).

DSWA Response:

Although sodium is not ionically balanced with chloride and sulphate, ionic balance probably exists if other cations such as calcium, potassium and magnesium are considered in the material balance.

13. Provide the water quality of perched water and dredge spoil spillage.

DSWA Response:

Data pertaining to the water quality of the perched water and dredge spoil spillage is not available. This information will be supplied to the DNREC in the design of the site if it is chosen.

14. Potential Impact:

If the facility were unlined, you should consider at least the following additional characteristics of the insitu material (besides permeability).

(i) chemical characteristics of the dredge spoil solids and dredge spoil water

(ii) Cation exchange properties of dredge spoil and estuarine deposits.

DSWA Response:

The above characteristics will be identified and discussed in the design of the site, if it is chosen.

15. Evaluate the effect of these properties on a "typical" leachate generated at any sanitary landfill.

DSWA Response:

As stated in the above response, the chemical characteristics of the dredge spoil solids and dredge spoil water and the cation exchange properties of dredge spoil and estuarine deposits will be identified and discussed in the design of the site.

In addition the relevance of this comment to this phase of the project is not fully appreciated. This is an area of study which could be looked into in more detail later should this site be selected for the location of the Northern Solid Waste Facility. Even then, because of the many inherent differences in landfills handling mixed municipal refuse, it is not practical to develop a "typical" leachate, singling-out a particular value for specific parameters. It is possible, however, to provide a range of values for each parameter. Reference is made to Table 1 of EPA Publication SW-168, a

TABLE 1

CHARACTERISTICS OF LEACHATE AND DOMESTIC WASTE WATERS

Constituent	Range* (mg/l)	Range + (mg/l)	Range‡ (mg/l)	Leachate§ Fresh	Leachate§ old	Waste water§	Ratio§
Chloride (Cl)	34-2,800	100-2,400	600-800	742	197	50	15
Iron (Fe)	0.2-5,500	200-1,700	210-325	500	1.5	0.1	5,000
Manganese (Mn)	.06-1,400	--	75-125	49.	--	0.1	490
Zinc (Zn)	0-1,000	1-135	10-30	45	0.16	--	--
Magnesium (Mg)	16.5-15,600	--	160-250	277	81	30	9
Calcium (Ca)	5-4,080	--	900-1,700	2,136	254	50	43
Potassium (K)	2.8-3,770	--	295-310	--	--	--	--
Sodium (Na)	0-7,700	100-3,800	450-500	--	--	--	--
Phosphate (P)	0-154	5-130	--	7.35	4.96	10	0.7
Copper (Cu)	0-9.9	--	0.5	0.5	0.1	--	--
Lead (Pb)	0-5.0	--	1.6	--	--	--	--
Cadmium (Cd)	--	--	0.4	--	--	--	--
Sulfate (SO_4)	1-1,826	25-500	400-650	--	--	--	--
Total N	0-1,416	20-500	--	989	7.51	40	25
Conductivity (μmhos)	--	--	6,000-9,000	9,200	1,400	700	13
TDS	0-42,276	--	10,000-14,000	12,620	1,144	--	--
TSS	6-2,685	--	100-700	327	266	200	1.6
pH	3.7-8.5	4.0-8.5	5.2-6.4	5.2	7.3	8.0	--
Alk as $CaCO_3$	0-20,850	--	800-4,000	--	--	--	--
Hardness tot.	0-22,800	200-5,250	3,500-5,000	--	--	--	--
BOD_5	9-54,610	--	7,500-10,000	14,950	--	200	75
COD	0-89,520	100-51,000	16,000-22,000	22,650	81	500	45

*Office of Solid Waste Management Programs, Hazardous Waste Management Division. An environmental assessment of potential gas and leachate problems at land disposal sites. Environmental Protection Publication SW-110.of. [Cincinnati], U.S. Environmental Protection Agency, 1973. 33 p. [Open-file report, restricted distribution.]

+Steiner, R. C., A. A. Fungaroli, R. J. Schoenberger, and P. W. Purdom. Criteria for sanitary landfill development. Public Works, 102(3): 77-79, Mar. 1971.

‡Gas and leachate from land disposal of municipal solid waste; summary report. Cincinnati, U.S. Environmental Protection Agency, Municipal Environmental Research Laboratory, 1975. (In preparation.)

§Brunner, D. R., and R. A. Carnes. Characteristics of percolate of solid and hazardous waste deposits. Presented at AWWA [American Water Works Association] 94th Annual Conference, June 17, 1974. Boston, Mass. 23 p.

copy of which follows. Another consideration is that the waste composition of the Northern Solid Waste Facility cannot be classified as typical of most municipal landfills since, with the operation of the DRP, most of the metals and most of the organic fraction will be removed.

16. 6.2.17 In utilizing the settlement equation it appears that the full weight of refuse to be deposited is considered, and the time required for the primary consolidation of the spoil materials under full load is 4 to 5 years. It is not explicitly stated at which stage of consolidation the spoil is expected to meet the state requirements for the impermeability of a natural soil liner. In other words, it could take years before the dredge spoils meet the impermeability requirements, in the mean time possessing permeabilities of up to 4 to 10 times higher than required.

DSWA Response:

Based on existing laboratory testing data (see Michael Baker, Jr. Appendix C) the dredge spoil will decrease up to 75 percent in permeability under the full load of refuse and soil cover (1.2 tsf). Assuming the full load is in place, the tested dredge spoil material would meet the 1 x 10^{-7} cm/sec permeability limit in slightly less than one year.

17. 6.2.1.7 The vertical seepage of leachate into the Columbia Formation has been calculated assuming a certain permeability. However, due to the nature of the dredge spoils it is possible that permeabilities in parts of the landfill site may be much higher than that, giving rise to an accelerated leachate movement downwards.

DSWA Response:

The vertical seepage of leachate into the Columbia Formation has been calculated using a permeability of 1 x 10^{-7} cm/sec for the dredge spoil materials. Further, it has also been calculated that the transit time of the *leachate to reach the Columbia Formation is approximately 260 years. In performing this calculation an effective porosity of 0.3 and travel distance of 55 feet was utilized. Although, it is possible that portions of the dredge spoil may have higher permeabilities, these areas will undergo consolidation from the applied stresses of the landfill. This consolidation process will reduce the permeabilities of dredge spoil materials and impede accelerated leachate movement. Since complete primary consolidation of the dredge spoil materials will occur in approximately 4 to 5 years, reductions in the permeability will occur long before the first drop of leachate reaches the Columbia Formation (260 years).*

18. 6.2.2.2. Would the existing highway drainage facilities be sufficient to intercept the runoff to the west of the landfill?

DSWA Response:

Since these drainage facilities evidently are sufficient now to intercept runoff to the west of the dredge disposal areas, it was presumed that they would be sufficient, particularly in combination with the dikes of the Wilmington dredge disposal area, to intercept runoff to the west of the proposed NSWF disposal areas.

19. 6.3.1.2. The water quality in the Delaware River near the landfill site has improved considerably over the past ten years and it is possible that it may once again be significant for the spawning of anadromous fish such as striped bass and Atlantic and shortnose sturgeon. A modest sport fishery has developed in the Christiana River in recent years, and the potential impact on these waters must be examined particularly in the absence of a synthetic liner.

DSWA Response:

Although the "draft" report indicated that it would not be necessary to install a synthetic liner, it did indicate that the dredge spoils would *consolidate to a point which would make the sub-base of the site relatively impermeable (meeting or exceeding DNREC's permeability standard). Thus leachate would still be able to be collected and properly disposed of and the effect on the waters of the Christina and Delaware Rivers would be insignificant. This could be investigated in more detail in a subsequent study should this site be selected for the NSWF.*

20. Table 6.5 - 1

Land purchase costs are to be amended as per your correspondence submitted December 7, 1981.

DSWA Response:

Land purchase cost has been amended. The final report has been modified accordingly. It is estimated that only 350 acres out of the 500 acres available would actually have to be purchased.

II. RESPONSES TO DEPT. OF HEALTH AND SOCIAL SERVICES, DIVISION OF PUBLIC HEALTH COMMENTS ON "DRAFT REPORTS" FOR THE SITE SUITABILITY STUDY FOR THE NORTHERN SOLID WASTE FACILITY

1. Cherry Island

Comment

Section 6.1.3

Reference was made to an Industrial Waste Treatment site. Further investigation should be made to determine what/if any residual toxic chemicals remain and in what concentration for the Potomac formation only one representative sample for groundwater quality was taken. Additional samples should be taken to establish a definitive data base. Through the additional data collected possible claims of landfill contamination could be prevented.

DSWA Response:

Additional monitoring, to determine a background data base, will be accomplished as a matter of course if the Cherry Island site is selected.

2. Roberts Farm

Comment

Section Pg. 48

Why was only 1 sample (representative) for water quality taken? Additional information is needed.

Page 49

The qualitative result for pH (2.9) is questionable. Follow-up sampling is required.

Page 51

Long term leakage of leachates will not affect the wells upgradient from the landfill however, what is the potential for downgradient aquifer contamination? Considering 100% leakage of leachates will the dilution factor and cation/anion exchange hold for a prolonged time?

DSWA Response:

Page 48 A representative sample of each aquifer was obtained to define, on a cursory basis, the quality of groundwater flowing within each aquifer. Additional sampling will be performed if the site is selected.

Page 49 Follow up sampling in both the existing wells and new wells (installed for detailed design) will be performed if the site is selected.

Page 51 Stringent design measures will be taken to prevent the escape of any leachate. Hypothetically, however, there is the potential for movement of leachate into the underlying aquifers. For this reason, a monitoring well network will be established to detect any change in groundwater quality. The effects of dilution and cation exchange will be addressed through additional sampling, testing and analyses if the site is selected.

3. 412 Site

Comment

Section 4.2.1.5

Again, only one representative sample was taken. It is felt that additional sampling in needed.

4.2.1.5

What would be ultimate impact on the Pleistocene/ Mount Laurel Aquifer if leachate escaped to water table aquifer?

DSWA Response:

Section 4.2.1.5 As previously stated, additional sampling of groundwater will be accomplished if the Road 412 site is selected. This sampling will include testing of existing and new wells installed as part of the detailed design phase of the study.

The ultimate impact on the Pleistocene/Mount Laurel Aquifer can not be addressed at this time since data pertinent to leachate volumes, leachate quality, and attenuation or exchange potentials of underlying sediments will be collected during the detailed design phase of the study. Note, however, that stringent measures will be incorporated into the design of a lined landfill. These measures include leachate collection and groundwater monitoring.

III. RESPONSES TO NEW CASTLE COUNTY DEPT. OF PLANNING COMMENTS ON "DRAFT REPORTS" FOR THE SITE SUITABILITY STUDY FOR THE NORTHERN SOLID WASTE FACILITY

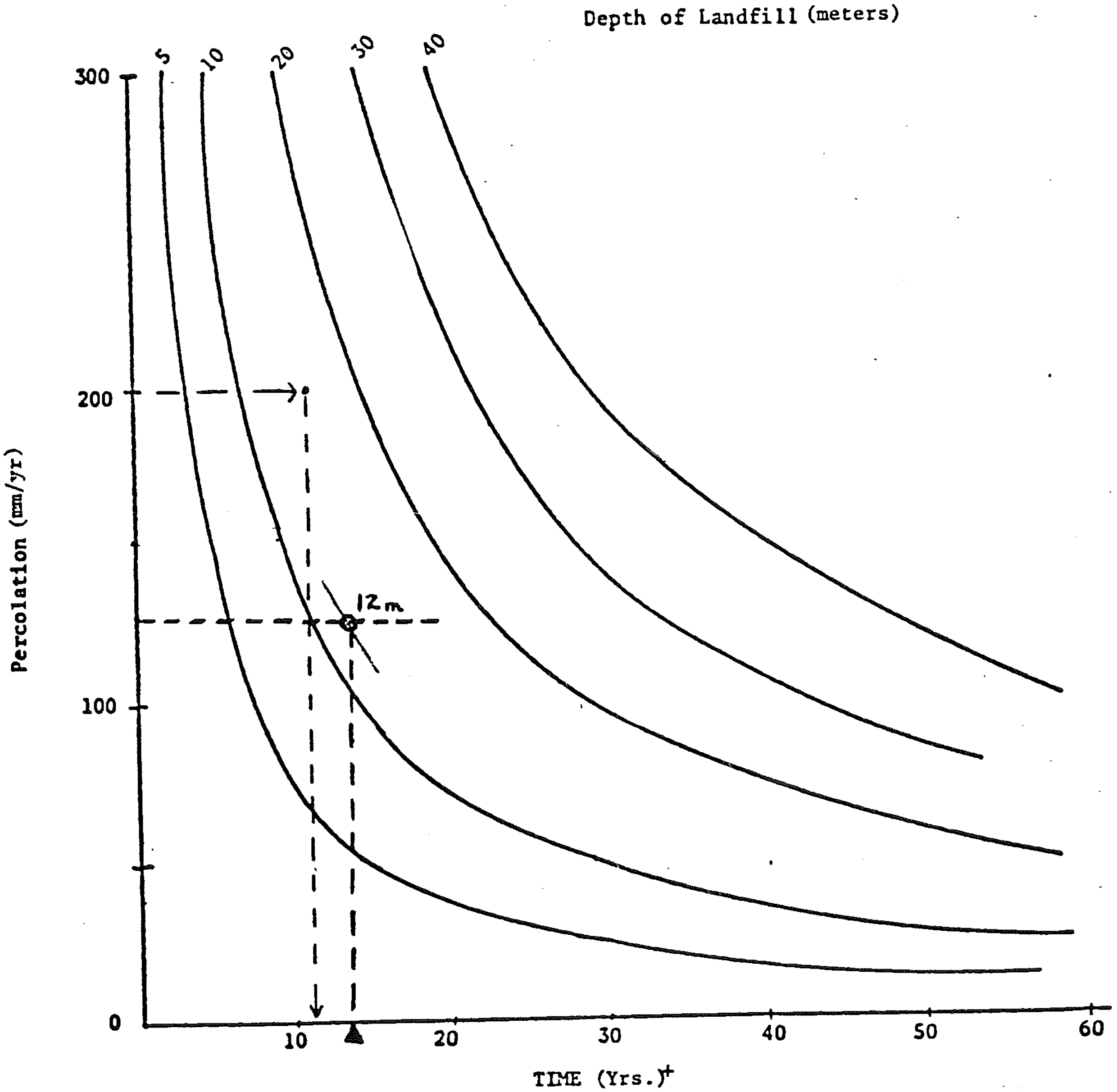
A. Off-Site Issues

1. Greater information needs to be developed for methods of transporting collected leachate to the nearest point of disposal. Whether this is accomplished by vehicle or pipeline, some impact will be felt. This issue needs to be evaluated for the three sites. Its existence is common to all but the solutions required may be quite divergent.

DSWA Response:

The leachate treatment question and related costs were discussed a number of times during the development of this report. As a matter of policy it was decided that for the purposes of this report leachate would be collected and treated on-site at all three sites and therefore the costs associated with such treatment would be common to all three sites. As a result it was not included in the analyses. Because all three sites are located in the same geographical area with little, if any, differences in meteorological characteristics, and because all three sites will be designed to preclude external factors such as groundwater, flooding, or surface runoff affecting leachate volumes, the quantity of leachate generated at each site should be about the same, differing only with respect to potential infiltration area. This varies from 171 acres at Road 412 to 215 acres at Cherry Island (a difference of 26%). The water balance prediction made in response to a DNREC comment was done on a per acre basis (366 gal/acre/day). Thus leachate quantities at the completion of the landfill would be expected to range between 63,000 gallons per day to 79,000 gallons per day respectively for the Road 412 site and the Cherry Island Site. According to the following graph

Figure 6. Time of First Appearance of Leachate *



* Based on a solid waste moisture absorption capacity of 150 mm/m.
+ Time zero is defined as that time when the field capacity of the soil cover is first exceeded, producing the first amounts of percolation.

which is extracted from EPA/S 30/SW-168, the time of first appearance of leachate would be approximately 13 years for a 40 ft. thick deposit of unprocessed mixed municipal refuse (MMR). From experience, we know that contaminated water that may require treatment will be produced earlier than this. The biggest unknown, of course, is the degree of contamination. Even for unprocessed MMR this is difficult to predict. (See response to DNREC Comment #15 for Cherry Island). Keep in mind that the Northern Solid Waste Facility will handle primarily inert residues and non-processable wastes from the DRP. The leachate from such a landfill may be so innocuous that little or no treatment would be necessary prior to discharge to a nearby water course. Therefore, relative cost advantages regarding on-site treatment requirements versus construction of sewer lines (gravity and/or force mains) and discharge to a local sewage treatment plant is still deemed to be more appropriately investigated at a later stage.

2. The issue of road and bridge improvements for the two southern sites will translate into a consumer cost regardless of the source of funding. It is currently understood that this cost is to be shown as a capital item in each report, to be borne by the Authority. In addition, attention should be given to the eventuality of the Reclamation Plant being inoperative and private and public haulers having to deliver directly to the landfill site.

   DSWA Response:

   The report has been modified to incorporate the cost of the road and bridge improvements for the two southern sites in the capital costs to be borne by the Authority. This resulted in an increase of approximately $0.70/ton for both sites. If the processing plant is inoperative, private haulers still would continue to haul wastes to Pigeon Point where a transfer station would remain operational for any such eventuality.

B. <u>Future Land Use</u>

In order to determine ultimate uses for the closed-out landfill, it will be necessary to project the condition of the site. Will gas reclamation be required? Will the soil characteristics support loads such as buildings or be stable enough for underground utilities? For some uses, such as agriculture, it may be necessary to import cover material. Would there be any restrictions on the use of the crops? For how long will leachate have to be collected? What would be the source of funding in order to accomplish this conversion of land use.

DSWA Response:

Although it may not be necessary, due to the characteristics of the wastes being landfilled, it was presumed that venting of gases would be required by DNREC. The Authority's projected end use for all of the sites is as open space. Therefore, it would be the responsibility of any would-be purchaser to determine the load bearing capabilities of the completed landfill with regard to constructing buildings and utilities on the sites. If managed appropriately, as suggested in the report, there should be no need to import cover material to the two southern sites to aid agricultural utilization. Experience to date indicates that row crops should be avoided from the standpoint of erosion control and the necessity to maintain a good vegetative cover. Leachate would have to be collected and monitoring programs continued well after the placement of the last load of solid wastes. At conventional landfills handling unprocessed MMR, this period may be up to 20 years after closure of the site. Thus, as explained in the response to DNREC's General Comments, any buyer or owner succeeding the Authority probably would have to take responsibility for the long term maintenance of the site. Obviously, the source of funding for the long term maintenance program also would be the responsibility of the new owner.

C. Cherry Island

1. Cherry Island Land Acquisition - There needs to be some clarification of the acreage requirements and how it relates to ownership patterns at Cherry Island. The size of the site then needs to correspond to its longevity. The acquisition of 500± acres presents the possibility of an extended life span. Would it be cost effective to purchase this much acreage now? This issue of acquisition needs to be dealt with in terms of consumer costs, site longevity and ultimate land use.

DSWA Response:

The costs now incorporated in the report reflect the purchase of 350 acres of land at Cherry Island instead of 500 acres. This represents the amount considered necessary to more closely correspond to the site's estimated longevity. The Authority is well aware of the expansion potential at this site as well as at the other 2 sites. The purchase of the additional 150 acres of land at inception of the project would add an estimated $0.70/ton to the estimated initial year tipping fee.

2. Cherry Island Site Preparation - The need for either a natural or synthetic liner needs to be clarified along with the resulting costs. How does the use of a liner affect the leachate collection system in terms of transporting leachate to the wastewater treatment plant.

DSWA Response:

The need for either a natural or synthetic liner cannot be clarified any further at this point since it will ultimately be the responsibility of DNREC to make this determination. However, the Authority has been pursuing DNREC with regard to a decision on this matter. At this point the Authority is considering obtaining *additional information on the Cherry Island dredge spoils incorporating a sampling program and laboratory testing of samples. This information, according to DNREC officials, would help them to decide whether or not a liner would be necessary at Cherry Island. Costs for both a lined and unlined facility at Cherry Island have been included in the final report. As stated previously, leachate will be handled on site.*

3. Cherry Island - There are several peripheral issues at Cherry Island that need to be understood and potentially integrated. There are four operations in the immediate vicinity of Cherry Island, each of which produces an end product that would seem to have potential use in a landfill. The most obvious is the Authority's Pigeon Point Reclamation Plant and its shredded, separated debris. The Delmarva Power and Light Company's Edgemoor Plant will have a need to dispose of fly ash and the Wilmington Wastewater Treatment Plant produces sludge as a by-product. The Corps of Engineers is presently involved in a site selection process of its own to locate a disposal location for dredge spoils from the Christina and Delaware Rivers. Each of these materials or combinations thereof should be evaluated for suitability as landfill cover material. Recognizing the size of the Cherry Island site, there may be an opportunity for multi-agency cooperation on one disposal site.

DSWA Response:

The Authority is aware of these peripheral issues and welcomes the opportunity to discuss a cooperative venture with other agencies and/or utilities to dispose of these materials in an environmentally safe and cost effective manor. This willingness to cooperate with other agencies has been expressed and demonstrated in the past. The sewage sludge processing module to be constructed as part of the DRP is proof of this. Should the Cherry Island site be selected as the location for the NSWF, the *potential uses of sewage sludge, fly ash, and dredge spoils in a manner beneficial to the operation of the NSWF certainly will be investigated. For the purposes of this report, however, the Authority has no recourse but to base its operational costs on the need to import cover material to the site.*

D. Environmental Concerns

1. The reports address mitigating measures for controlling local visual impact of each site. In addition, attention should be given to visual conditions from greater distances. For instance, it is possible to develop buffers around a site such as Road 412, but that same site is highly visible from the Route 13 bridge over the C & D Canal.

DSWA Response:

The visibility of the Road 412 site to occupants of vehicles crossing the C & D Canal by way of the St. Georges bridge is discussed in the report. The visibility to north bound traffic obviously would be less than to south bound traffic. The visibility to the driver of a vehicle probably would be minimal no matter what the direction. With the site close to a mile away from the bridge, and considering the small area in use at any particular time, the average vehicle speed combined with the bridge superstructure will represent impediments to good visul contact. Therefore, it is not considered that the site will be highly visible from the bridge.

2. Regarding the likelihood of leachate contamination due to a flaw or damage to the collection system, it would be helpful to have projected the relative environmental impacts on or around each site. In effect, this would take the form of a worst-case scenario and would call for the interpretation of the report's technical information. Such projections would identify the

capability of each site to tolerate this damage in terms of ground and surface water contamination, containment of same or magnitude of potential distribution. A method of indemnification should be developed for this eventuality.

DSWA Response:

The overall impact on the hydrogeological regime is discussed in the report and was discussed in the "Draft" reports. The discussion assumed a worse case scenario. It is emphasized that the design of the site, using best available technology, will preclude the contamination of both ground and surface waters. To verify this, monitoring programs will be established. If something does occur, the Authority has the capability to respond quickly and effectively to remedy the problem. Legal mechanisms do exist concerning proper indemnification of injured parties.

IV. RESPONSES TO WATER RESOURCES AGENCY FOR NEW CASTLE COUNTY COMMENTS ON "DRAFT REPORTS" FOR THE SITE SUITABILITY STUDY FOR THE NORTHERN SOLID WASTE FACILITY

A. General Comments on Analytical Procedure

1. All three sites should be compared on an equal-life basis.

Both the Roberts Farm (202 usable acres) and Road 412 (171 usable acres) have projected lives of approximately 24 years. The Cherry Island site, however, has the potential for a much greater life. Assuming 400 of the 501 acres are usable, and extending the consultant's refuse quantity projections (Table 3.2-1) beyond the thirtieth year, one finds that this site has a longevity in excess of 40 years. In order to effect an equitable comparison among the candidate sites, the acreage considered for purchase at the Cherry Island site should be reduced to a size commensurate with a twenty-four year life (i.e., approximately 215 acres). This could be accomplished by considering only the two tracts owned by Frederic A. Potts, Inc. Alternately, special consideration could be given in the ranking of this site due to its increased longevity.

DSWA Response:

The final report has been amended to incorporate this comment. The amount of land needed to be purchased was reduced to 350 acres and includes all of the Potts holdings, portions of the U.S. Government holdings south of the Potts property and a small portion west of the Potts property, all of the Mahaffey and Boyer properties, and all of the DPL property. Only about 25% of the DPL property actually would be necessary, but since this represents a significant portion of the utility's holdings, it was assumed that the property would have to be purchased in its entirety.

2. <u>The means for and projected costs of leachate treatment and disposal should be included in the site analyses</u>.

Over the life of the project leachate treatment and disposal costs can become quite significant. Moreover, these costs will vary with each site's location. Distance to a wastewater treatment plant, availability of a discharge point, and degree of treatment or pretreatment required will bear heavily upon the costs associated with a given site. Since each site is subject to different constraints, the inclusion of these costs in the site analysis is essential to determining the true costs of site development. Opportunities to utilize capacity in existing sewers and treatment facilities must, in the interest of minimizing site development and waste disposal costs, be exploited wherever possible and recognized in comparing the several sites.

DSWA Response:

In reference to this comment, please review the response to DNREC's Comment #15 on Cherry Island and the response to Comment #1 of the New Castle County Department of Planning.

It is not necessarily true that utilization of existing sewers and treatment facilities, if located within a reasonable distance, will be the most cost effective means of handling the leachate. The strength of the leachate and the volume of leachate are important factors in such an analysis. Although the leachate quantities can be predicted, to a degree, utilizing "water-balance" techniques, the strength (concentration of various contaminants) of the leachate would be very difficult to predict with any degree of accuracy.

The current agreement between DSWA and the County regarding the leachate collected from the well-points at Pigeon Point and discharged to the sewage system calls for payment on the basis of:

$1.10081 per thousand gallons of leachate discharged
$0.0808 per pound of BOD-5
$0.0786 per pound of suspended solids

Recent information indicates a flow rate of 50,000 gpd and BOD-5 and suspended solids concentrations of 86 mg/l and 49 mg/l, respectively. The annual cost of this service to the Authority based upon the above information is approximately $22,000. This does not include amortization of capital (engineering, construction, and equipment costs) nor does it include the annual operating cost associated with maintaining the system.

3. All costs which are associated with any road and/or bridge reconstruction or improvement which are specifically required to afford access to a particular site should be included in the fiscal analysis for that site.

Proper engineering cost analysis dictates that all costs associated with facility development be internalized for consideration in evaluating its relative cost effectiveness. To eliminate such costs from consideration would have the effect of skewing the analysis. Existing highway capacity, like interceptors and treatment facilities, must be recognized as an advantage to particular sites in minimizing development and disposal costs. An adequate site comparision can only be made when the cost/value of new or existing capacity is made a part of the analysis. Even if the costs of offsite improvements are borne by the Division of Highways rather than the Solid Waste Authority, and thereby are not included in its bonded indebtedness, they will still be borne by the taxpayers, ergo the same individuals who will be utilizing the facility.

DSWA Response:

The final report has been modified to incorporate the costs which are associated with highway and/or bridge improvements which are specifically required to afford access to both the Road 412 and the Roberts Farm sites.

4. The value for ultimate use; i.e., salvage value, of each site should be considered in the analysis.

It is customary in the engineering cost analysis of a project to consider its ultimate value, if any, in the overall cost evaluation. Each of the three sites, by virtue of its individual characteristics and location, has a unique value after the landfill is completed. Whether or not the Roberts Farm and Road 412 sites, which are currently under cultivation, will be suitable for such use after the fill is completed and the evaluation of the site increased by some forty feet is questionable. On the other hand, it can be effectively argued that the Cherry Island site may be increased in value by the stabilization of dredge spoils through their consolidation under the fill loading. Such future uses and their associated value must be properly integrated into the site analyses in order to gain a true picture of the costs associated with each site.

DSWA Response:

The value of the landfilled areas 20 years or more from now is a subject of much debate. The Authority's position, which is detailed in an earlier response to a similar comment from DNREC, is that the land will have little market value due to its past use as a landfill and the need for the owner to continue maintenance activities and responsibilities over a long period of time after closure.

B. Comments Relating to a Specific Site

1. Roberts Farm

pg. 50 Potential Impacts:

Although the subject of groundwater pollution is thoroughly addressed in the site analysis, the contamination of Hangman's Run and its subsequent effect upon the adjacent wetlands is not considered. Based upon the stratigraphy of the site and the water table elevations, it would appear that surface water contamination would be a much more likely occurrence than the pollution of the deeper aquifers. The effects of leachate migration into the sensitive ecosystem present in a wetlands environment could be quite devastating to the vegetation and wildlife there. The potential for surface water contamination and its ramifications needs to be considered in order to fully evaluate the impacts of a landfill facility located at this site.

DSWA Response:

The potential impact upon Hangman's Run has been taken into consideration in the sense that disposal areas are located with regard to siting criteria developed specifically to minimize potential impacts upon streams and/or wetlands. In addition, the disposal areas will be lined with provisions to collect leachate and dispose of it in an environmentally acceptable manner.

2. Road 412

a. Section 4.2.1.5 Hydrogeology - Local Water Use

The statement is made that information pertaining to groundwater use in the Road 412 area is limited. A rather extensive survey of groundwater use within a five mile radius of the Summit site was conducted by Delmarva Power as a part of their generating facility siting study. The Authority's consultant should review a copy of this study and supplement their report with any relevant information.

DSWA Response:

The Summit site environmental report has been obtained and pertinent information pertaining to groundwater use within a one mile radius of the Road 412 site has been incorporated into the report.

b. Section 4.2.8 Screening of Site

The consultants discussion of screening this site to limit its visual impact was confined to the impact along adjacent roads. No consideration was given to the visual impact of the site upon southbound traffic on the St. George's (Route 13) Bridge. From such an elevated vantage point the site and any activity thereon would be quite obvious. This subject should be treated in the site analysis.

DSWA Response:

With regard to southbound traffic on St. George's Bridge, the site or portions thereof can be seen from the bridge. However, because only a small portion of the site would be in use at any one time, whether the site and activity thereon would be quite obvious is subject to some debate. It would be difficult (and often unwise) for the driver of a southbound vehicle to catch more than fleeting glimpses of the area since he must also keep an eye on the roadway ahead and on other vehicles to his side and to his rear. Passengers obviously would have a better opportunity to view the site, but even their vision would be obstructed to some *degree by the structual elements of the bridge. Finally, from the aesthetic viewpoint of the naturalist, the site, with its final cover in place and revegetated as required by regulations, should be far less noticeable to the southbound traffic than the towers and other structures of the Getty Oil Refinery is to northbound traffic.*

3. Cherry Island

a. Section 6.2.5 Property Line Setbacks

Since the site is bordered on two sides by major bodies of water, it would seem acceptable to maintain the 100 foot water setback rather than the 200 foot property line setback. This could be accomplished without significantly increasing the impact upon adjacent properties or uses.

DSWA Response:

The 200' property line setback established by the Authority will continue to be utilized by the Authority for planning and evaluation purposes. From a practical standpoint, a 100 ft. setback along the frontage of the Delaware and Christina Rivers would not be of any advantage to the Authority. In other words, no additional disposal area would be realized by reducing the buffer zone to 100 ft. on these sides since the dredge disposal area dikes are further inland from the river than this. The useable area shown on Figure 6.2-9 represents the area encircled by the dikes common to the "Edgemoor" dredge disposal area. As such the distance from the property line equals or exceeds 200 ft.

b. Section 6.2.7.6 Potential On-Site Borrow Areas

Although it is realized that, due to their characteristics, the on-site dredge spoils cannot be utilized to meet the total cover material needs, the assumption of total importation of borrow material is overly conservative. These on-site materials can be utilized to supplement borrow materials and may be stabilized through drying or the addition of admixtures. While these costs might currently meet or exceed the costs of total importation, with rising transportation costs, they will very probably become competitive. These factors should be considered in your analysis of cover material sources.

DSWA Response:

It is acknowledged that assuming total importation of cover material is conservative if a method can be found to effectively utilize dredge spoils for partial fulfillment of the cover material requirements. Because of this the Authority, should this site be selected, would be looking into ways which the dredge spoils could be economically made more useable. As of this point, their use has not been approved by DNREC, significant handling problems and operational problems were evident from a trial use as cover material for Pigeon Point, and the materials are extremely erodable. The Authority is aware that rising transportation costs will effect both options. Since the rising transportation costs can probably be attributed basically to rising fuel costs, it also will effect the use of dredge spoils where equipment such as draglines, scrapers, and dozers are needed to excavate and mechanically aerate the dredge spoils to facilitate drying.

c. Section 6.5.1 Estimated Landfill Development Costs

The costs associated with the construction of foundations for the maintenance building and associated structures at this site will most certainly be greater than those for the other sites due to the compressibility of the dredge spoils. It is our understanding that the buildings required at the facility (i.e.; maintenance building and office trailer) will not produce particularly heavy foundation loadings. In view of this, the arbitrary 30 percent increase which has been assigned to structure costs for this site seems to be excessive.

DSWA Response:

Based upon the Authority's experience with construction at Pigeon Point, these costs are not considered excessive.

d. Table 6.5-1 Summary of Capital Cost

Item A.5. Leachate Collection and Storage Facilities

From the description given of the leachate collection system for this site (Section 6.5.1), we cannot understand why its projected cost ($1,273,000) is over twice the combined costs of leachate collection system and liner for the Road 412 site. Although leachate removal may require pumping at Cherry Island and not at Road 412, the differential still seems inordinately high especially considering that a liner is not included in the Cherry Island costs. As earlier indicated, pumping may also be required at Road 412 to convey the leachate for treatment.

DSWA Response:

Costs are based upon actual bid prices for similar work. There are significant differences in the acres developed per phase for each of the three sites. The footnotes at the bottom of each Table (4.5-1, 5.5-1, and 6.5-1) point this out. For instance, at the Road 412 site approximately 21 acres would have to be developed every three years as opposed to 24 acres (14% more) for Roberts Farm and approximately 27 acres (29% more) for Cherry Island. For a more valid comparison the County should be comparing Roberts Farm to Cherry Island since protective cover for the liner was presumed to be imported for Roberts Farm. It is deemed to be available on-site for Road 412. Adding Items 6 and 7 of Table 5.5-1, a total of $1,083,500 is obtained. Multiplying this by 1.125 to account for the area differential between Roberts Farm and Cherry Island, one gets a figure of $1,219,000. Compare this to the $1,273,000 estimated for Cherry Island. The difference of $54,000 (~4.25%) is attributable to the importation of a more select material (bank sand) for Cherry Island to insure the permeability contrast between the flow zone (created by the 3 ft. depth of sand) and the dredge spoils.

e. We believe that your consultant has done an adequate job of addressing the groundwater issues at this level of analysis. It is realized, of course, that, subsequent to the ranking of sites, more definitive information regarding the hydrology and geology of the selected site will be obtained. We are interested in reviewing such information. Your data suggest that, from the aspect of water resources protection, the Cherry Island site is clearly superior to the other sites. The Road 412, while not as desirable as Cherry Island, does appear to afford adequate protection to water resources given appropriate engineering measures. The Roberts Farm site, due to the potentiality of surface water as well as groundwater contamination, presents the least desirable alternative of the limited number of sites considered according to our interpretation of your consultant's analysis.

DSWA Response:

As more definitive information on a site or sites becomes available the Authority will make this information available to the Water Resources Agency. The Authority would like to point out to the Agency that these three sites were selected from a field of more than 10 candidate sites.

V. RESPONSES TO WILMAPCO COMMENTS ON "DRAFT REPORTS" FOR THE SITE SUITABILITY STUDY FOR THE NORTHERN SOLID WASTE FACILITY

WILMAPCO has completed its review of the "Detailed Site Investigation of Candidate Sites for Northern Solid Waste Facility - 2 (New Castle County)." Our internal review included consultation with the Delaware Department of Transportation, Division of Highways. DOT's response to our request for comments is attached....

... The impacts on Pigeon Point Road (New Castle Road 377) and on New Castle Road 359 are common to all three sites so we eliminate same from further comparison (1.1 miles and 0.4 miles respectively = 1.5 miles).

This leaves:

	Cherry Island (miles)	Robert's Farm (miles)	New Castle Rd. 412 (miles)
I-495	1.5	1.1	1.1
12th Street	0.4		
U.S. Rte. 13		22.5	15.6
N.C. Rd. 452		1.8*	
Del. Rte. 9		0.7*	
N.C. Rd. 413			1.3*

* Very strong probability of a need for reconstruction.

Under the documentation for candidate site "New Castle Road 412", we suggest that the proposal under which New Castle Road 412 would provide truck access to U.S. Rte. 13 northbound lanes at the foot of the bridge introduces an acute traffic hazard and conflict.

Trucks would enter the northbound U.S. Rte. 13 bridge ramp with zero acceleration and thus would, in all probability, block the right northbound land of U.S. Rte. 13 at this point.

We feel the suggestion of egress by New Castle Rd. 413 across two southbound lanes of U.S. Rte. 13 to reach the northerly lanes to be little safer.

Thus, we eliminate the potential of the "New Castle Road 412" site without addressing the generation of truck miles of travel per day and the need for reconstruction.

The "Robert's Farm" site is eliminated because of the long haul road and because of the probable need for 2.5 miles of road reconstruction.

Without further expansion on same we consequently feel the "Cherry Island" site to be the most desirable when evaluated by this compressed transportation analysis.

DSWA Response:

The costs to improve the roads marked with an asterisk by Mr. Elgie have been incorporated in the final report. Both the Authority and its consultant have discussed the situations presented by the Road 412 site and Roberts Farm site with other DOT officials. A letter to the consultant is attached. The problems are not insurmountable for either Road 412 or Roberts Farm as the above letter would seem to suggest.

EXHIBIT NO. 1

DATA TO BE INCLUDED IN THE SITE SUITABILITY REPORT FOR THE NSWF-2

I. Physical Data

A. shallow and deep borings

B. well logs

C. water levels and elevations

D. water quality

E. inventory domestic water use - 1/2 mile radius and 1 mile downgradient of site (from site boundaries)

- using quadrangle size scale map

F. permeabilities and transmissivities of the aquifers

- estimates using published data and field data

G. delineation of past and/or present waste disposal in the site area

II. Interpretive Data

A. cross sections describing the nature, thickness, and depth of underlying aquifers and confining units

B. water level data to determine seasonal high and near record water table

- using published data and field data to estimate range of fluctuation

C. potentiometric surface maps of the aquifers

D. description of ground water flow directions in the aquifers

E. evaluation of potential for vertical movement between the aquifers

III. Predictive Data

A. lined landfill - where would contamination go if liner leaked?

B. impact of contamination on ground water and surface water

C. dilution ratio - contamination from one aquifer, its impact on another aquifer

D. potential use of aquifers in the future in the area

- using New Castle County planning guidelines

ANALYSIS OF LEACHATE IMPACT ON FREDERICA AQUIFER

Kv = vertical hydraulic conductivity = 4×10^{-4} ft/day
Iv = vertical hydraulic gradient = $7.\times10^{-2}$ ft/ft
A = area vertical flow occurs through = 130 acres = 5.5×10^{6} ft^2
Qv = discharge in the vertical direction = flow through confining bed into aquifer

Darcy's Law

$$Qv = KIA$$
$$= (4\times10^{-4}\ \frac{ft.}{day})\ (7\times10^{-2})\ (5.5\times10^{6} ft^2)$$
$$= 154 \text{ gpd}$$

Kh = horizontal hydraulic conductivity = 5×10^{1} ft/day
Ih = 3.9×10^{-3} ft/ft
Qh = discharge in the horizontal direction
b = aquifer thickness = 22 ft.
L = length of aquifer under site = 4×10^{3} ft
A = cross sectional area of aquifer = bL

Darcy's Law

$$Qh = KbIL$$
$$= (5\times10^{1} ft/day)\ (22\ ft)\ (3.9\times10^{-3})(4\times10^{3}\ ft)$$
$$= 130{,}000 \text{ gpd}$$

$$\frac{Qh}{Qv} = \frac{130{,}000 \text{ gpd}}{150 \text{ gpd}} = \frac{900}{1} \text{ dilution ratio}$$

ANALYSIS OF LEACHATE IMPACT ON CHESWOLD AQUIFER

Kv = 4×10^{-4} ft/day
Iv = 2.5×10^{-2} ft/ft
A = 130 acres = 5.5×10^{6} ft^2

Darcy's Law

$$Qv = KIA$$
$$= (4\times10^{-4}\ ft/day)\ (2.5\times10^{-2})\ (5.5\times10^{6})$$
$$= 55 \text{ gpd}$$

Kh = 3×10^{1} ft/day
b = 7×10^{1} ft
I = 1×10^{-3} ft/ft
L = 4×10^{3} ft

Darcy's Law

$$Qh = KbIL.$$
$$= (3\times10^{1}\ ft/day)\ (7\times10^{1}\ ft)\ (1\times10^{-3})\ (4\times10^{3} ft)$$
$$= 63{,}000 \text{ gpd}$$

$$\frac{Qh}{Qv} = \frac{63{,}000 \text{ gpd}}{55 \text{ gpd}} = \frac{1100}{1} \text{ dilution ratio}$$

EXHIBIT NO. 2

STATE OF DELAWARE
DEPARTMENT OF TRANSPORTATION
DIVISION OF HIGHWAYS
P. O. BOX 778
DOVER, DELAWARE 19901

OFFICE OF THE DIRECTOR

736-4642
TELEPHONE: (302)XXX-XXXX

July 27, 1981

Mr. Edward J. Hollos
c/o Gilbert Associates, Inc.
P.O. Box 1498
Reading, PA 19603

RE: DSWA Access to Proposed Disposal Sites

Dear Mr. Hollos:

Per our conversation of July 9, 1981, attached are traffic counts for the roads which could provide access for the three sites which you are reviewing in detail. Regarding the classification of the roads themselves, based on Delaware's Functional Classification System, I-495 is classed as an Interstate roadway, U.S. Route 13 as a Principal Arterial roadway, Delaware Route 9 and Delaware Route 299 as Major Collector roadways and Terminal Avenue and Road 377 as Collector roadways. All other roadways may be considered as secondary roadways.

Regarding the condition of the roadways in question, I-495 and 12th Street, as a result of their recent construction, are in excellent condition. U.S. Route 13, as a result of numerous recent 3R projects, and Terminal Avenue are in good condition. In the last couple of years, Road 37 and Road 452 have been resurfaced. The remaining roadways are in varying degrees of disrepair. No work is contemplated in the very near future on these secondary roads.

Regarding access to the sites in question, a possible alternative to the proposed access to the Roberts Farm site would involve the use of Road 37 from U.S. Route 13 to Delaware Route 9 and the use of Route 9 to the site. This reduces the truck traffic thru Odessa. Road 413 into the Road 412 site would help the anticipated truck traffic particularly since Road 412 has only indirect access thru S. St. Georges to northbound U.S. Route 13. Access onto Road 412 from southbound U.S. Route 13 is also difficult since it comes directly off the St. Georges bridge.

It should be anticipated that the choice of a site, if it includes secondary roadway access, will include some cost for upgrading the secondary road. Depending upon detailed analyses of the existing secondary roadways and the potential increase in truck traffic, improvements could vary from minor intersection improvements to complete roadway reconstruction. From the standpoint of roadway condition and potential cost, the Cherry Island site is served by the best conditioned roadways and would probably be the least expensive in terms of roadway improvements.

We trust this information is sufficient for your needs.

Very truly yours,

DIVISION OF HIGHWAYS

Joseph T. Wutka, Jr.
Location Studies and
Environmental Engineer

JTW/aw
Attachments
cc: R. D. Bewick, Jr.
G. B. Homewood
J. L. Sipple
G. B. Pusey

RECEIVED
JUL 29 1981
GAI
ENV. DIV.
RDG.

3. Roy F. Weston, Inc., "Northern Solid Waste Management Center – Cherry Island Landfill, Phase V Disposal Area, Hydrogeologic, Geotechnical and Landfill Capping Report," prepared for the Delaware Solid Waste Authority, March 1995.

Delaware Solid Waste Authority
Dover, Delaware

Northern Solid Waste Management Center-
Cherry Island Landfill

Phase V Disposal Area

Hydrogeologic and Geotechnical Report

FINAL

March 1995

95P-1392

WESTON
MANAGERS DESIGNERS/CONSULTANTS

PRINTED ON RECYCLED PAPER

DELAWARE SOLID WASTE AUTHORITY
NORTHERN SOLID WASTE MANAGEMENT
CENTER - CHERRY ISLAND LANDFILL
PHASE V DISPOSAL AREA

HYDROGEOLOGIC AND GEOTECHNICAL REPORT

March 1995

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W.O. No. 02477-004-001

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APPENDICES

SECTION 1

1.0 INTRODUCTION

This report presents the results of the Hydrogeologic and Geotechnical Investigation conducted by Roy F. Weston, Inc. (WESTON) for the Delaware Solid Waste Authority's (DSWA) Cherry Island Landfill Disposal Area V (Phase V). The results of the Hydrogeologic and Geotechnical Investigation are presented in Sections 2 and 3, respectively.

The purpose of the Hydrogeologic and Geotechnical Investigation was to obtain additional information/data and perform the analyses/evaluations required for the Phase V design and permit. A significant existing database for the Cherry Island landfill exists from the investigation of previous phases (Phase I, IA, II, III, and IV). The scope of the Hydrogeologic and Geotechnical Field Investigation was outlined in the "Hydrogeologic and Groundwater Sampling Plans" (Work Plan) dated May 1993. This Work Plan was submitted to Delaware Department of Natural Resources and Environmental Control (DNREC). Verbal approval of the Work Plan was given by DNREC to DSWA in late May 1993 and field activities commenced in early June. Groundwater sampling occurred from 9 to 11 June 1993 and test boring drilling occurred from 10 to 30 June 1993.

The Hydrogeologic and Geotechnical Investigation for Phase V was performed in accordance with the Work Plan except for a few modifications. These modifications include:

- Monitor well C-109 and C-110 could not be located by the field team.
- Monitor well C-112 was deleted from the sampling effort becuase it was scheduled to be closed as part of the Phase IV construction activiites.
- Monitor well P-104 could not be sampled because of casing damage.

Recommendations on action to be taken on these wells is presented in Section 2.

The proposed Phase V disposal area of the Northern Solid Waste Management Center Cherry Island Landfill is located south of Phase IV as shown on Figure 1-1. Phase V is bounded on the north by the proposed Phase IV disposal area; by the perimeter dike along the Delaware River on the east; by the Wilmington dredge spoil area on the west; and by the perimeter dike along the Christina River on the south. The Phase V disposal area will include the use of the dredge spoils as a natural soil liner and a constructed leachate collection systemm similar to that being constructed for Phase IV.

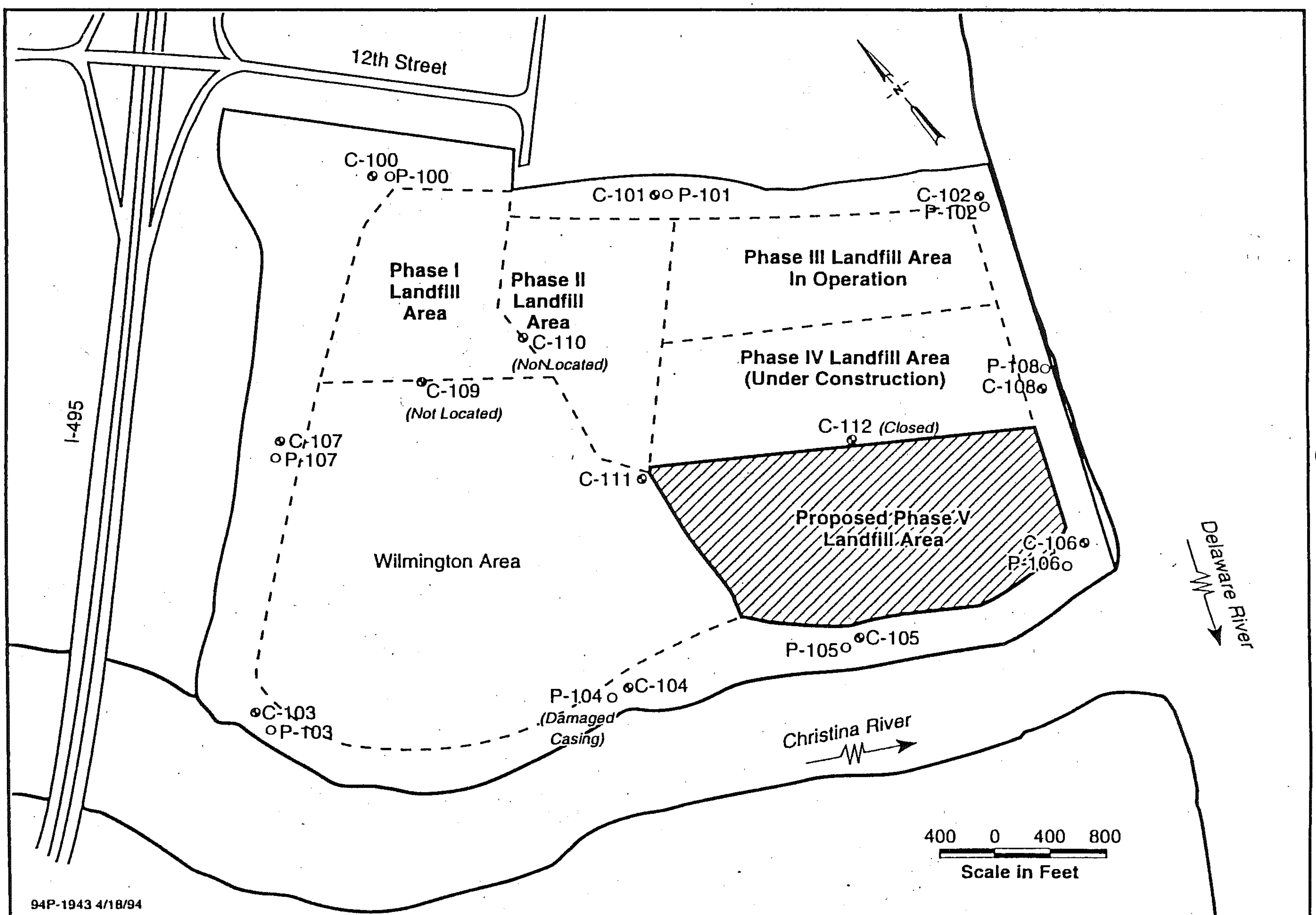


FIGURE 1-1 LOCATION OF PROPOSED PHASE V DISPOSAL AREA, CHERRY ISLAND LANDFILL

SECTION 2

HYDROGEOLOGIC INVESTIGATION/ANALYSIS

2.1 GENERAL SITE GEOLOGY AND REVIEW OF EXISTING DATA

2.1.1 General Site Geology

The Cherry Island Landfill site is situated at the confluence of the Christina River and the Delaware River Estuary. The site is bounded to the south by the Christina River and on the east by the Delaware River. The site was once predominantly marshland, but has been extensively filled with dredge spoils from adjacent waterways by the Corps of Engineers.

The site lies on the Coastal Plain physiographic province, several thousand feet southeast of the approximate boundary ("fall line") with the Piedmont physiographic province. The Coastal Plain physiographic province in the area is generally flat and its geology is characterized by layers of unconsolidated clays, silts, sands, and gravels of river, estuary, or marine depositional environments. The coastal plain sediments in the site vicinity are underlain by much older metamorphic and igneous rocks (Woodruff and Thompson, 1975).

The hydrogeology of the Cherry Island site is controlled by four major lithologic units. The lowermost and oldest of these units consists of metamorphic and igneous rocks of the Wilmington Complex (Woodruff and Thompson, 1975). Rocks in the upper part of this sequence are heavily weathered, resulting in a weakly consolidated mixture of clay, silt, sand, and rock fragments. Overlying rocks of the Wilmington Complex are weakly consolidated sediments of the Cretaceous age Potomac Formation. Sediments of the Potomac Formation were deposited in a fluvial environment which resulted in discontinuous channel deposits of clay, sand, and silt. Overlying the Potomac Formation are sediments of the Pleistocene age Columbia Formation. The unconsolidated sediments of the Columbia Formation are generally poorly sorted and coarser than those of the Potomac Formation, and consist of gravels, sands, and silts which are separated from the Potomac Formation by an erosional surface (Sundstrom, et al., 1975; Woodruff and Thompson, 1975; Woodruff, 1985).

Although the Columbia Formation is generally at or near the surface in much of eastern and southern New Castle County, at the site it is overlain by significant accumulations of clay and silt of Recent (Holocene) age. Some thin, discontinuous isolated coarse zones, deposited by the Delaware and Christina Rivers, exist within these recent accumulations of clays and silt. Overlying the Recent deposits are dredge spoils of similar lithology deposited following dredging of the Delaware and Christina Rivers by the U.S. Army Corps of Engineers. The predominant lithology of both the dredge spoils/recent deposits is that of low to high plasticity clayey silt with occasional thin, discontinuous lenses of coarse grained materials (Terraqua, 1984; Gannett-Fleming, 1986; Gannett-Fleming, 1990, WESTON 1992).

Soil borings have shown the existence of discontinuous sand lenses above the Columbia Formation in the Phase IV area of the landfill, particularly along the side adjacent to the Delaware River. More recent soil borings completed as part of the Phase V investigation along the perimeter dike adjacent to the Christina River, the interior portion of the perimeter dike along the Delaware River, and within the footprint of Phase V revealed no distinctive sand layers or lenses above the Columbia. These findings further indicate the isolated and distinct nature of these coarse material lenses.

2.1.2 Review of Existing Hydrogeologic Data

The hydrogeologic characteristics of the aforementioned lithologic units vary considerably. The igneous and metamorphic rocks of the Wilmington Complex do yield significant quantities of water in some parts of New Castle County, but are not considered a viable water supply aquifer in the site vicinity (Sundstrom and Pickett, 1971; Sundstrom et al., 1975; Woodruff, 1985). Sediments of the overlying Potomac Formation yield significant quantities of potable water within several miles of the site (Terraqua, 1984). However, in the site vicinity, the upper sand of the Potomac Formation, the most important water-bearing zone in the region, is absent (Woodruff, 1985) and probably eroded by the ancestarial Delaware River. Water in the Potomac Formation generally exists under confined conditions (Woodruff, 1985). Studies by Terraqua (1984) and Gannett-Fleming (1986; 1990) suggest that although the upper Potomac water-bearing zone may be absent in the study area, permeable zones in the Potomac Formation do yield water of marginally potable quality at the site. The quantity of water from such zones is unknown. Water-bearing zones in the Potomac Formation are generally separated from the overlying Columbia Formation by thick clays and silts normally considered to be effective confining layers (Sundstrom and Pickett, 1971; Sundstrom et al., 1975; Woodruff, 1975).

Although water in the Columbia Formation occurs under water table conditions in much of New Castle County, investigations by Terraqua (1984), Gannett-Fleming (1986), Gannett-Fleming (1990) and WESTON (1992) suggest that the thick (58-70 ft thick) accumulations of overlying Recent sediments and dredge spoils create confined conditions in the Columbia water-bearing zone at and near the Cherry Island Landfill. A lens of reworked Columbia sediment occurs within deposits of Recent age above the top of the Columbia Formation along the eastern edge of the site. This lens of higher permeable sediment is coarse-grained but contains considerable silt. This lens "interfingers" into the dredge spoils and recent sediments and pinches out beneath the Phase IV expansion area. Water level data indicate it is hydraulically distinct from the Columbia Formation. The wedge is described in the logs for monitor wells C-102, C-106, and C-108 provided in the Phase IV Hydrogeologic Report (WESTON 1992) and corresponds to the coarse "sand lens" lying above the Columbia described in Gannett-Fleming (1990). This lens was not encountered in borings along the perimeter berm adjacent to the Christina River, in the interior portion of the dike along the Delaware River between C-108 and C-106, or within the footprint of Phase V, indicating the lens is isolated and distinct in nature.

Water levels within the previously investigated water-bearing zones indicated that groundwater flowed predominantly from northwest to southeast in the confined water-bearing zones (Gannett-Fleming, 1986; 1990). The Columbia, and the thin, discontinuous, coarse zones above the Columbia, exhibited sinusoidal water level fluctuations described by Terraqua (1984) and Gannett-Fleming (1986; 1990). These were described as being related to tidal fluctuations in the Delaware and Christina Rivers, which exhibit regular tidal fluctuations. Terraqua (1984) suggested that the tidal response shown in the confined water-bearing zones demonstrated a direct hydraulic connection between these water-bearing zones. Gannett-Fleming (1986; 1990) used the amplitude of tidally related water level fluctuations to contradict Terraqua (1984) by suggesting that the Columbia and the coarse zone above it (defined by wells C-102, C-108, and C-106) were hydraulically distinct. WESTON (1992) recorded water levels in a Columbia well (C-104) and C-106. The readings were compared to tidal fluctuations and indicated the shallower coarse lens above the Columbia Formation, observed in C-106, responds to tidal water elevation changes in the Delaware River. Results from C-104 suggest less of a hydraulic connection to the Christina River than indicated in previous studies. The data further suggests no direct hydraulic connection between the coarser unit above the Columbia Formation and the Columbia itself.

The dredge spoils/Recent deposit materials possesses a very low permeability and therefore do not allow for the rapid dissipation of excess pore water pressures. When additional load is applied to the fine-grained dredge spoils/recent deposits during landfill operation, pore water pressures will increase. The resultant rise in the potentiometric surface within the dredge spoils/Recent deposits does not represent an elevated "water-table" when landfill surcharge loads are applied, but rather a temporary increase in excess pore water pressures during consolidation of these materials. Therefore, the depth at the top of a significant water-bearing zone should be considered the appropriate measure of depth to water.

The dredge spoils/Recent deposits comprise the natural liner system for the Cherry Island Landfill. These deposits are of a low permeability and are therefore not considered water-bearing zones but function as the barrier liner between the landfill and the underlying water-bearing zones.

The recharge and discharge characteristics of the hydrogeologic system in the site vicinity are dominated by the Delaware and Christina River embankments and the Piedmont physiographic province to the northwest. Woodruff (1985) indicated that both the Potomac and Columbia aquifers receive recharge waters from off-site outcrop and subcrop areas northwest of the Cherry Island facility. Gannett-Fleming (1986) reported that on-site recharge and discharge occur only to the recent sediments and dredge spoil materials. Groundwater discharge from the confined water-bearing zones underlying the Cherry Island site may occur, but the locations are not known. In general, the base of the Delaware and Christina Rivers would be appropriate discharge locations for the confined water-bearing zones. Vertical gradients measured at well pairs at the site suggest that over most of the site a downward vertical gradient exists between the Columbia and Potomac formations (Terraqua, 1984; Gannett-Fleming, 1986; 1990).

Sampling of groundwater from the Potomac Formation and the water-bearing zones of Recent geologic age has shown that groundwater quality varies widely. Evaluations of water quality analyses originally reported by Terraqua (1984) determined that although groundwater from the Potomac Formation was of marginally potable quality, groundwater from the Columbia and the shallower confined water-bearing zone was generally nonpotable. These groundwater quality results were inferred to represent background (pre-landfill) water quality conditions. Groundwater samples taken in 1992 (WESTON, 1992) from the

Columbia and from the isolated lens of coarse deposits above the Columbia (C-102, C-106, and C-108) exhibited relatively high levels of alkalinity and chloride (although within potable limits for both), specific conductance, hardness, iron, sodium, sulfate, and dissolved solids, among other analytes. Chloride, sulfate, and dissolved solids concentrations exceeded several generally accepted potable limits at most shallower wells. High levels of total organic carbon in groundwater samples collected from the Columbia Formation and the isolated lens of coarse deposits above the Columbia, as well as the high alkalinity and dissolved solids values, suggest that this groundwater is under reducing conditions, thus allowing metals to solubilize. High concentrations of soluble iron and manganese further confirm these observations. The results of the Phase V groundwater monitoring program confirmed earlier results (WESTON, 1992).

2.1.3 Hydrogeologic Data Objectives for Phase V

The review of existing hydrogeologic data for the Cherry Island site indicated the need to provide current data and confirm past results for the purpose of a hydrogeologic evaluation for the Phase V design and permitting. The Hydrogeologic data objectives for Phase V include:

- Determine current flow directions in the Columbia and Potomac water-bearing zones.
- Determine the extent of the isolated coarse materials lenses above the Columbia Formation within the Phase V area.
- Determine current quality of groundwater below the site.

The Phase V Work Plan (May 1993) defined the specific field activities and laboratory testing required to address these items for the hydrogeologic evaluation of Phase V. The following section presents a brief discussion on the groundwater monitoring and sampling activities. Section 2.3 presents the results of the Hydrogeologic Investigations that addressed the above items.

2.2 SUMMARY OF HYDROGEOLOGIC FIELD INVESTIGATION ACTIVITIES

2.2.1 Groundwater Sampling and Analysis

To evaluate groundwater quality in the significant coarse water-bearing zones below the site, groundwater samples were collected between June 9 and 11, 1993 and were analyzed for parameters required by the current DNREC permit for Phases III & IV for quarterly sampling. Filtered (for metals only) groundwater samples from 7 of the 9 designated Columbia wells were analyzed for the parameters required under the current DNREC permit for Phases III & IV for annual sampling. Of the sixteen existing wells proposed to be sampled for the quarterly sampling parameters, fourteen wells were sampled for groundwater quality as follows:

- Designated Columbia Formation Wells - C-101, C-102, C-104, C-105, C-106, C-108 and C-111. Monitor wells C-109 and C-110 could not be located by the field team, and C-112 was deleted from this sampling effort because it was scheduled to be closed as part of the Phase IV construction activities.

- Designated Potomac Formation Wells - P-100, P-101, P-102, P-105, P-106, P-107, and P-108. Monitor well P-104 could not be sampled because of casing damage. P-103 was not listed in the Work Plan to be sampled, and is suspected of being screened in the Columbia Formation.

DNREC was contacted by telephone on the modifications to the Work Plan regarding the reduction of the number of monitor wells to be sampled due to damage or scheduled closure. DNREC requested that the closure report on the well to be closed be submitted and that they be contacted when the other wells are located and repaired. Written comments on the work plan were received after this telephone conversation. The intent of the comments from the 8 June 1993 letter from DNREC was followed during the monitor well sampling program. Discrepancies from the proposed Work Plan and DNREC's comments with the actual field sampling program were discussed with DNREC on 28 July 1994. A telephone conversation memorandum was prepared for this discussion and filed in the project file.

Tables 2-1 and 2-2 provide a summary of the wells sampled and the parameters analyzed.

Groundwater samples were collected by qualified and experienced WESTON personnel following the standard protocols for decontamination and sample collection detailed in the Work Plan. Actual field procedures and equipment used that were not specified or detailed in the Work Plan are listed below:

- The bailers used to collect groundwater samples were of the disposable Teflon® variety. These bailers arrived in pre-sterilized, "sample-ready" condition in separate protective sheaths, thereby precluding the need for decontamination. One bailer was used to sample each well and was disposed-of afterwards.

- During purging, measurements were made in the field of the specific conductivity, temperature, pH, and salinity of the purged water. Although a minimum of three volumes were purged from each well, additional water was purged from some wells until these parameters showed minimal change with further pumping. Two low-yield wells were purged until dry then permitted to recover before sampling.

Table 2-1

Summary of Groundwater Quality Testing for all Existing Monitor Wells
Quarterly Permit Sampling Parameters

Well I.D.	Analysis Parameters												
	Sp. Conductance	TDS	TOC	Chloride	pH	COD	Fe(total)	Temperature (field)	Alkalinity	Manganese (total)	Nitrate-Nitrogen	Ammonia-Nitrogen	Sulfate
P-100	X	X	X	X	X	X	X	X	X	X	X	X	X
P-101	X	X	X	X	X	X	X	X	X	X	X	X	X
P-102	X	X	X	X	X	X	X	X	X	X	X	X	X
P-104(1)													
P-105	X	X	X	X	X	X	X	X	X	X	X	X	X
P-106	X	X	X	X	X	X	X	X	X	X	X	X	X
P-107	X	X	X	X	X	X	X	X	X	X	X	X	X
P-108	X	X	X	X	X	X	X	X	X	X	X	X	X
C-101	X	X	X	X	X	X	X	X	X	X	X	X	X
C-102	X	X	X	X	X	X	X	X	X	X	X	X	X
C-104	X	X	X	X	X	X	X	X	X	X	X	X	X
C-105	X	X	X	X	X	X	X	X	X	X	X	X	X
C-106	X	X	X	X	X	X	X	X	X	X	X	X	X
C-108	X	X	X	X	X	X	X	X	X	X	X	X	X
C-109(3)													
C-111	X	X	X	X	X	X	X	X	X	X	X	X	X
C-112(2)													

TDS: Total Dissolved Solids
TOC: Total Organic Carbon
COD: Chemical Oxygen Demand
Fe: Iron
(1): Well not sampled due to casing damage.
(2): Well not sampled because it was scheduled for closure as part of Phase IV construction (DNREC was notified of this modification from the Work Plan).
(3): Well not located in the field.

Table 2-2

Summary of Groundwater Quality Testing for Selected Monitor Wells
Annual Permit Sampling Parameters

Well I.D.	Water Bearing Unit	Supplemental Parameters		QA/QC Samples	
		Metals(1)	Organics(2)	Duplicate	Trip Blank(3)
C-101	Columbia	X	X		
C-102	(4)	X	X		
C-104	Columbia	X	X		
C-105	Columbia	X	X		
C-106	(4)	X	X	X	X
C-108	(4)	X	X		
C-109(5)	Columbia				
C-111	Columbia	X	X		
C-112(6)	(4)				

(1): The 6 metals include: Arsenic, Chromium (hexavalent), Copper, Lead, Mercury, Nickel. (Mercury is listed in permit but was not listed in Work Plan and was not analyzed for during this sampling program.)
(2): The organic compounds include: phenols, total petroleum hydrocarbons and halogenated and nonhalogenated volatile organics.
(3): Volatile organic analysis only.
(4): Screened in an isolated coarse grained lens above and distinct from the Columbia Formation.
(5): Well not located in the field.
(6): See note (2) on Table 2-1.

- Samples were collected and analyzed for total iron and total manganese at each location. In addition, soluble iron and soluble manganese samples were collected at all locations sampled for RCRA Subtitle D, Appendix I Metals. Soluble metals samples were first collected in clean, non-preserved bottles. This water was then field-filtered with a 45 micron disposable filter. This filtered water was then placed into the appropriately pre-marked and preserved sample bottles.

QA/QC samples were collected and analyzed to verify field decontamination procedures, and to document potential sample container and laboratory contamination. These QA/QC samples included:

- Trip blanks submitted for laboratory analysis for the batches that contained samples to be analyzed for VOCs. These blanks were only analyzed for VOCs, and originated at WESTON's Lionville Laboratory.

- A duplicate sample of groundwater was collected from well C-106. This sample was used for verification of analysis results. The duplicate sample was collected using the same procedures followed for collection of the initial well water sample and was stored, shipped, and analyzed in the same manner.

- Matrix spike and matrix spike duplicate samples were collected and analyzed at WESTON's Lionville Laboratory from the sample containers submitted by the field sampling team. The results of this analysis were used to evaluate the accuracy/efficiency of the laboratory instrumentation in terms of "percent recovery" of selected spiked, non-target parameters.

All field personnel followed the EPA chain-of-custody procedures as discussed in the Work Plan to ensure the integrity of all samples.

2.2.2 Water Level Monitoring

The groundwater sampling team recorded water level measurements for purposes of piezometric mapping. Water levels were collected with a hand-held water level indicator using the procedures detailed in the Work Plan. The location and elevation of the monitor wells were surveyed by VanDemark & Lynch, Inc. on 5 May 1992 Water level measurements and surveyed elevation are presented in Table 2-3.

The results of water level monitoring were used to develop piezometric maps of each water-bearing zone for which a piezometric surface could be determined. These maps are discussed in Subsection 2.3.

Table 2-3

Water Levels, Potentiometric Surface Elevations, and Total Measured Well Depths for Monitor Wells At the Cherry Island Facility

Well	Monitored Formation	Elevation Top of Casing (feet) 5 May 1992	Static Water Level June 9-11, 1993 (TIC)*	Piezometric Surface Elevations Above Mean Sea Level	Total Dept Measured During Sampling (TIC)*
C-100	Recent Deposits	18.44	14.01	4.43	38.07
C-101	Columbia	50.07	48.40	1.67	85.50
C-102	Isol. Sand Lens	28.95	28.53	0.42	55.87
C-103	Recent Deposits	13.13	Not Recorded	---	---
C-104	Columbia	18.00	15.21	2.79	67.30
C-105	Columbia	24.15	22.59	1.56	74.95
C-106	Isol. Sand Lens	30.06	27.62	2.44	47.09
C-107	Recent Deposits	13.17	Not Recorded	---	---
C-108	Isol. Sand Lens	29.68	24.49	5.19	40.33
C-109	Columbia	(1)	Well Not Located	---	---
C-110	Columbia	---	Well Not Located	---	---
C-111	Columbia	46.05	43.12	2.93	80.24
C-112	Columbia/Isolated Confined Unit	51.57	Well Closed	---	---
P-100	Columbia	18.27	15.65	2.62	59.12
P-101	Potomac	49.35	47.41	1.94	168.00
P-102	Potomac	27.98	27.45	0.53	177.93
P-103	Columbia	14.28	Not Recorded	---	---
P-104	Potomac	17.57	Well Damaged	---	---
P-105	Potomac	23.81	22.55	1.26	177.21
P-106	Potomac	29.54	30.67	-1.13	168.31
P-107	Columbia	12.60	10.22	2.38	53.27
P-108	Potomac	30.03	28.80	1.23	182.71

*All measurements recorded from top of innermost casing (TIC).
(1) Reported damaged at time of survey.

2.3 RESULTS OF HYDROGEOLOGIC INVESTIGATION

2.3.1 Water Level Interpretation

Analyses of borehole lithologies and water levels during Phase III and Phase IV investigations indicated that coarse-grained materials of the Columbia and Potomac Formations comprise separate hydrogeologic units. In addition, discontinuous sands above the Columbia appear to be hydrostratigraphically distinct from the Columbia (WESTON 1992). The dredge spoils/Recent deposits are not believed to be a significant water-bearing unit at the site since permeabilities between 10^{-6} to 10^{-8} cm/s have been measured from laboratory tests of this material for the Phase IV investigation. Monitor wells C-100, C-103 and C-107 are believed to be screened within this surficial unit. Water levels were not taken in C-103 and C-107 this round. Monitor wells C-102, C-106, and C-108 are screened in anisolated coarse grain unit above the Columbia Formation. Wells P-100 and P-107 are screened in the Columbia although they are designation Potomac wells. A summary of water levels collected on 9 to 11 June 1993, as well as total depth soundings for monitor wells is presented in Table 2-3.

2.3.1.1 Columbia Formation

The Columbia Formation is monitored by wells: C-101, C-104, C-105, C-109, and C-111. Monitor wells P-100 and P-107 are designated Potomac wells, but are suspected to be more closely associated with the Columbia Formation.

Across the site, the potentiometric surface in the Columbia is slightly above sea level. Net groundwater flow is towards the Delaware River (see Figure 2-1). However, the Columbia Formation is at least in part affected by tidal influence. Previous investigations have shown transient flow reversals in shallow water-bearing strata as a result of tidal influence (WESTON, 1992).

Because short-term tidally-related variation of groundwater levels reciprocates about an average water level slightly above sea level (WESTON, 1992), it is expected that perennial groundwater flow in the Columbia is towards the Delaware River.

The coarser lens encountered within the screen depth of wells C-102, C-106, C-108 corresponds to a hydrostratigraphically distinct unit overlying the Columbia formation. Water levels in these wells are above those in the Columbia Formation. Also, stratigraphic information from these wells and WESTON's TB-7 (Phase IV investigation) indicates that there is 10 to 15 feet of Recent deposits separating this shallow coarser lens from the underlying Columbia. For these reasons, water levels in those wells were not used to construct the piezometric surface for the Columbia Formation shown in Figure 2-1. Because these three wells lie approximately on a line, no piezometric surface map could be constructed for this shallower coarse lens. Water levels in C-102, C-106, and C-108 are above the top of the shallower coarse lens indicating that it is under confined conditions. Subsurface information obtained from borings completed within the Phase V area, along the perimeter dike adjacent to the Christina River, and on the interior of the dike along the

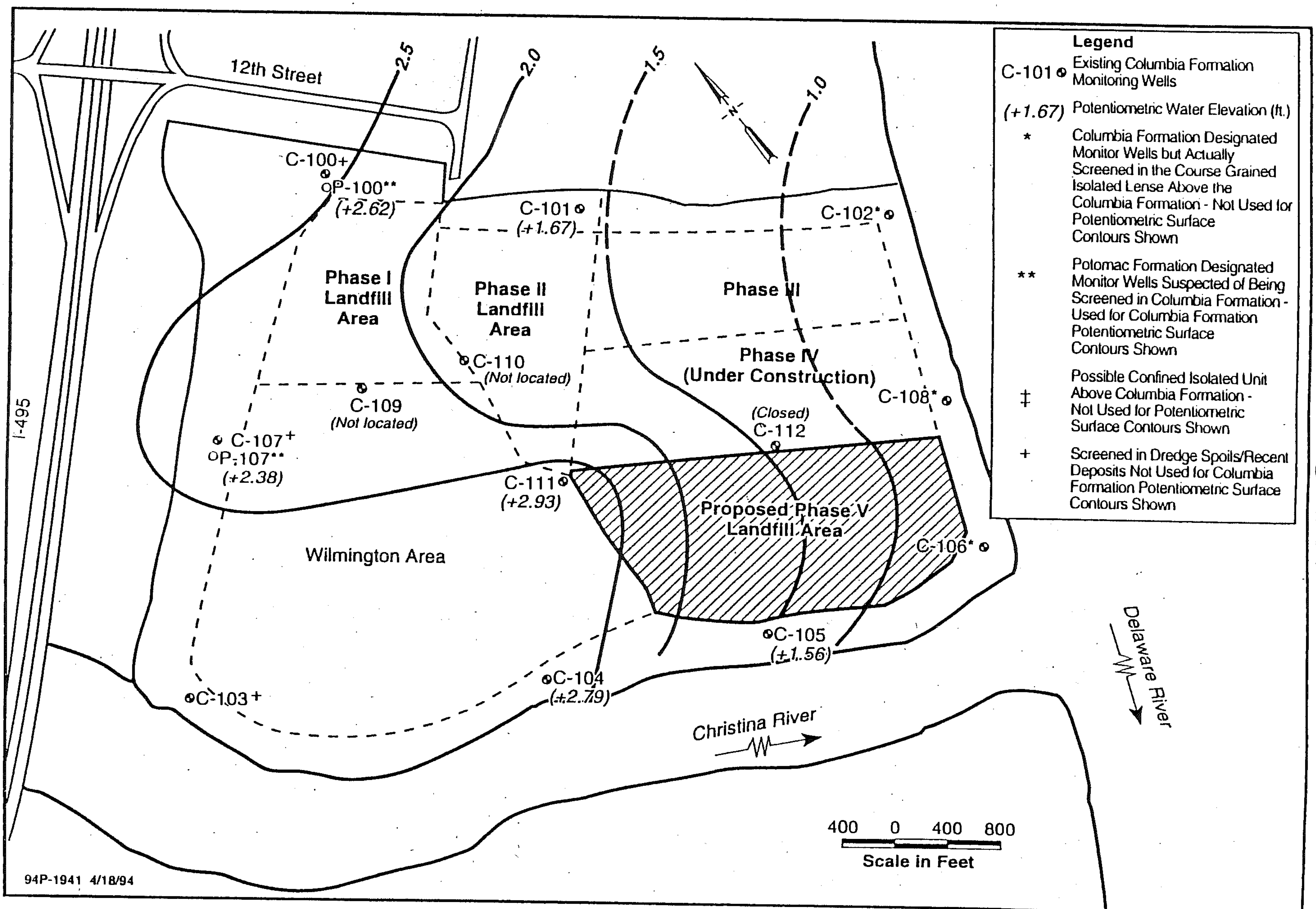


FIGURE 2-1 POTENTIOMETRIC SURFACE FOR THE COLUMBIA FORMATION, CHERRY ISLAND LANDFILL

Delaware River between C-108 and C-106, indicate that this lens is limited in extent since it was not encountered in these borings.

2.3.1.2 Potomac Formation

Groundwater in the Potomac Formation is monitored by wells: P-101, P-102, P-103, P-104, P-105, P-106, and P-108. Well P-104 was found to be damaged and could not be used to monitor the Potomac formation water levels.

Across the site, the potentiometric surface of the Potomac varies between several feet above mean sea level (MSL) and just over one foot below MSL (see Figure 2-2). A slight downward gradient exists between the Columbia and Potomac Formations in most areas across the site. On the average, less than one foot separates the potentiometric surface of these two formations. The gradient is slightly upward in the well pair C-101/P-101. Net groundwater flow in the Potomac is generally eastward, towards the Delaware River.

2.3.1.3 Tidal Influence Study

As reported in WESTON (1992), one well completed within the Columbia Formation (C-104) and one screened across the overlying coarse lens (C-106) were monitored to determine if a tidal influence exists in the Columbia Formation and the isolated coarse lens above the Columbia.

Water levels were compared to tide tables published by the National Oceanic and Atmospheric Administration (NOAA) for the period of investigation. Expected tides were generated from data for the reference station at Reedy Point, on the Delaware River.

The data analysis suggests that the shallower coarse lens above the Columbia Formation is more influenced by tides than the Columbia Formation as monitored in well C-104. The data further suggest no hydraulic connection between the coarser unit above the Columbia Formation and the Columbia itself. These conclusions are based on the following observations:

- The C-106 water-level data displayed regular sinusoidal fluctuations. These fluctuations corresponded with the expected tides for the area.

- Results from the WESTON (1992) tidal study for C-104 showed only a slight response to tides in the Christina River. The very different tidal responses in C-104 and C-106 indicate that these wells are screened in distinct, isolated units.

Changes in groundwater levels corresponding to changes in the tidal cycle do not necessarily imply direct hydraulic connection with the tidal water body. The degree of water movement into or out of a geologic unit in response to external pressure changes depends on the properties of the matrix and the time over which the pressure is applied. Most tidal loading problems, in fact, assume that the volume of water in the aquifer remains constant. The groundwater is not physically capable of migrating any significant distance in response to

WESTON

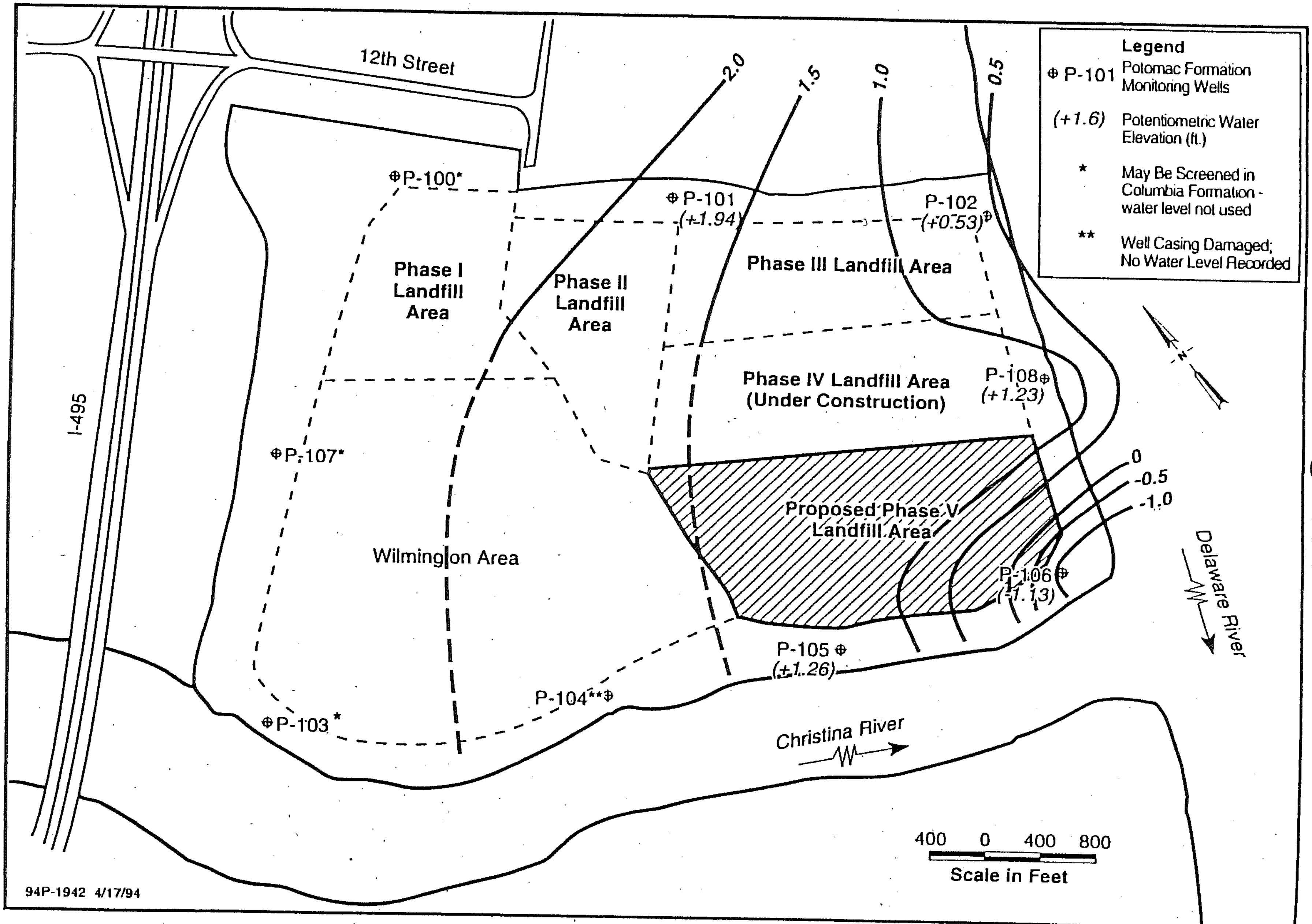


FIGURE 2-2 POTENTIOMETRIC SURFACE FOR THE POTOMAC FORMATION, CHERRY ISLAND LANDFILL

relatively short period, cyclic pressure changes. This would be particularly true in confined or isolated geologic units in which the changes in water levels are due primarily to compression and unloading of the aquifer framework. Confined units that are closer to the surface, as in the case of the coarse unit above the Columbia Formation monitored in C-106, will response earlier and to a greater degree to tidal cycles. The added load from high tides results in an increase in pore water pressure which is "felt" more (load dissipated with depth in lower confined units) in the upper unit than lower units.

2.3.1.4 In Situ Permeability Testing

During Phase IV investigations, slug tests were conducted on the wells C-108, C-111, and C-112 on 5 May, 1992 to obtain a better understanding of hydraulic properties of the coarser units. Rising head slug tests were used because this method provides the best representation of in-situ hydraulic properties. Data from the slug tests were used to derive hydraulic conductivity and seepage velocity values for these locations. These calculated hydraulic conductivities, hydraulic gradient, and seepage velocity are summarized in Table 2-4. The results indicate C-112 is screened in a fine-grained edge of the Columbia Formation that may be an isolated confined unit.

Hydraulic conductivities calculated for C-108 and C-111 are similar, 2.6 X 10^{-2} cm/sec and 2.77 x 10^{-2} cm/sec, respectively. These results are expected for clean to slightly silty sands (Freeze and Cherry, 1979). This is supported by the lithologies reported in boreholes logs for the well screen intervals of these wells. At both slug test locations, a return to pretest equilibrium conditions occurred within approximately one minute or less after slug removal. These results suggest that the Columbia is highly permeable.

Results of the C-112 slug test analysis indicated a marked decrease in hydraulic conductivity. A hydraulic conductivity of 6.1 X 10^{-4} cm/sec was calculated at this well. This value falls within the range for hydraulic conductivity values for silt (Freeze and Cherry, 1979). This value deviates from other calculated conductivity values by two orders of magnitude and is appropriate for the mixture of fine and coarse materials encountered in the screened interval.

The reduced permeability in C-112 suggests that it is approximately at the eastern edge of the Columbia formation. The unusually high water levels recorded in this well suggest that low permeabilities may not allow the well to accurately represent water levels in the Columbia formation or represent an isolated confined lens/unit of the Columbia formation. This monitor well was closed as part of the Phase IV construction.

Hydraulic conductivity values as determined by slug test results were used to determine seepage velocities for each of the slug test locations under static groundwater flow conditions. Seepage velocity is considered an approximation of the average advective

Table 2-4

Hydraulic Conductivity and Seepage Velocities for Selected Columbia Formation Wells

Monitor Well	Hydraulic Conductivity(k) (cm/sec)	Seepage Velocity(v)		
		Hydraulic Gradient[a]	Effective Porosity n^b	Velocity (cm/sec)
C-108	2.6×10^{-2}	1.4×10^{-3}	.15	2.4×10^{-4}
C-111	2.77×10^{-2}	3.3×10^{-4}	.15	6.09×10^{-5}
C-112	6.1×10^{-4}	9.2×10^{-4}	.15	3.74×10^{-6}

[a]Hydraulic gradient = change in head per distance; the gradients at C-108, C-111, and C-112 were estimated from Columbia formation piezometric mapping (WESTON, 1992).
[b]An n value of .15 approximates average expected effective porosities for Columbia Formation sand and gravels in Northern Delaware (K. Woodruff, personal communication, 1992).

groundwater transport rate for a conservative, non-retarded ionic species. Seepage velocities were calculated using the following equation:

$$\bar{V} = \frac{Ki}{n} \qquad (1)$$

$\bar{V}$	=	Seepage velocity (cm/sec).
K	=	Hydraulic conductivity (cm/sec).
i	=	Hydraulic gradient determined from the piezometric maps shown in (WESTON 1992).
n	=	Effective porosity of formation. An effective porosity value of .15 was used for all calculations (K. Woodruff, Delaware Geological Survey personal communication, May 1992).

Table 2-4 summarizes the results of seepage velocity calculations using this equation. The highest seepage velocity calculated was for C-108. The seepage velocity for C-111, 6.09 x 10^{-5} cm/sec is intermediate between C-108 (7.4 x 10^{-4} cm/sec) and C-112 (3.74 x 10^{-6} cm/sec). It should be noted that the seepage velocities calculated herein only provide an approximation of the rate of groundwater flow beneath the site because the effects upon groundwater gradient resulting from tidal influence cannot be determined precisely.

2.3.2 Groundwater Quality

All site monitor wells listed in Table 5-2 of the Phase V Hydrogeologic/Geotechnical Work Plan, with the exception of P-104, C-109, and C-112, were sampled between June 9 and 11, 1993. Monitor well P-104 was not sampled because a damaged casing which made the groundwater in that well inaccessible. Well C-109 could not be located, and C-112 was deleted from the sample round by agreement between WESTON and DNREC since this well was planned to be closed as part of the Phase IV construction. Groundwater quality parameters measured in the field are presented on Table 2-5.

Fourteen of the existing designated Columbia and Potomac Formation wells were sampled for the inorganic parameters required by the current DNREC permit for Phases III & IV for quarterly sampling. The results of the analysis for these parameters are presented in Table 2-6A. In addition, selected wells in the Columbia Formation and in the coarse unit above the Columbia Formation (C-101, C-102, C-104, C-105, C-106, C-107, C-108, and C-111) were also sampled and analyzed for parameters required under the current DNREC permit for Phases III & IV for annual sampling. These include the following metals: soluble, and total arsenic, chromium, copper, lead, mercury, nickel; and, phenols, total petroleum hydrocarbons and halogenated and nonhalogenated organic compounds. The organic compounds included in this analysis corresponds to the 47 volatile organics listed in Appendix I of the Subtitle D Regulations for which analytical procedures correspond to EPA SW-846 methods. The results of analysis of groundwater for these parameters are presented in Tables 2-6B and 2-6C.

Table 2-5

Groundwater Quality Parameters from Field Measurements
July 9-11, 1993

Well	Temperature °C	Specific Conductance (umhos)	Salinity (ppm)	pH	Comments
C-100	14.5	1,600	1,000	5.95	
C-101	16.0	1,250	800	6.2	Pumped dry, casing bent, must use 2" pump
C-102	15.5	2,700	2,900	7.0	Bentonite in well (on pump) in sample. Fe Bacteria and/or bentonite on surface; must use 2" pump to penetrate
C-104	15.0	2,300	1,500	5.7	Light sheen
C-105	15.0	1,350	1,000	6.4	
C-106	15.0	2,250	1,500	6.1	Odor
C-108	15.0	2,490	1,900	6.6	Strong odor, light sheen
C-109	NS	NS	NS	NS	Well reported damaged in 1992 not located during this sampling program
C-111	15.0	1,300	1,000	5.4	Light sheen
C-112	NS	NS	NS	NS	Well closed
P-100	14.0	1,100	500	5.8	
P-101	15.0	405	0.0	7.0	
P-102	17.0	820	200	7.5	
P-104	NS	NS	NS	NS	Well casing broken
P-105	16.0	900	600	6.4	Sulfur odor
P-106	18.0	910	300	6.7	Lt. sheen
P-107	14.5	1,300	1,500	6.4	
P-108	15.0	1,350	1,500	6.2	Pumped dry @ 15 gpm

NS = Not sampled
ppm = Parts per million
Values in table represent final volume observations.

Table 2-6A

Summary of Groundwater Quality Analyses Quarterly Permit Parameters Sampled June 9 to 11, 1993

Well I.D.	Water-Producing Unit	Analysis Parameters*											
		Sp. Conductance (umho/cm)	TDS (mg/L)	TOC (mg/L)	Chloride (mg/L)	pH	COD (mg/L)	Iron (total) (µg/L)	Alkalinity (mg/L)	Manganese (total) (µg/L)	Nitrate-Nitrogen (mg-N/L)	Ammonia-Nitrogen (mg/L)	Sulfate (mg/L)
C-101	Columbia	1,250	366	12.8	146	6.2	40.5	21,800	120	941	2.0	4.1	5.6
C-102	Isol. Sand Lens	2,700	1,930	303	866	7.0	424	105,000	790	628	--	80.4	--
C-104	Columbia	2,300	1,640	21.2	280	5.7	67.4	64,900	190	8,460	0.13	18.1	668
C-104(EB)		NA	5	--	--	NA	--	--	--	--	--	--	--
C-105	Columbia	1,350	816	19.0	261	6.4	54.0	28,500	290	160	0.32	25.9	2.5
C-105(EB)		--	9	--	--	--	--	--	--	--	0.10	--	--
C-106	Isol. Sand Lens	2,250	1,640	53.6	554	6.1	120	13,900	660	180	0.20	53.1	28.6
C-106(Dup)		2,250	1,640	50.8	553	6.1	120	43,800	650	1,650	0.16	53.1	30.0
C-108	Columbia	2,490	1,560	83.9	327	6.6	289	28,200	940	5,120	0.30	3.54	--
C-111	Columbia	1,300	964	11.6	276	5.4	48.1	73,600	240	1,560	0.72	4.6	2.6
P-100	Columbia	1,100	807	8.7	266	5.8	30.8	63,700	100	12,000	0.21	1.1	180
P-100(EB)		NA	--	--	--	NA	--	--	--	--	0.13	--	--
P-101	Potomac	405	416	0.62	113	7.0	--	1,610	50.0	31.9	0.29	0.94	32.6
P-102	Potomac	820	563	1.2	270	7.5	--	1,220	68.0	71.4	0.22	0.61	76.1
P-104	Potomac	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
P-105	Potomac	900	619	1.1	229	6.4	--	16,100	92.0	240	0.26	0.33	--
P-106	Potomac	910	574	1.3	223	6.7	--	13,900	115	180	0.26	0.30	--
P-107	Columbia	1,300	951	10.2	420	6.4	38.5	80,900	100	1,230	0.35	13.3	2.5
P-108	Potomac	1,350	959	1.2	488	6.2	9.7	34,900	30	330	0.20	0.53	68.5

*Temperature (°C) was measured in the field and is summarized on Table 2-5.
NA = Not analyzed.
-- = Not detected.
NS = Not sampled.
dup = Duplicate.
EB = Equipment Blank.

Table 2-6B

Summary of Groundwater Quality Analysis for Annual Permit Parameters-Metals
Sampled June 9 to 11, 1993

Metal Analyte ($\mu g/L$)	C-101	C-102	C-104	C-105	C-106		C-108	C-111	Field Blanks		
					Routine	Duplicate			P-100	C-104	C-105
Arsenic (total)	--	872	--	--	219	228	--	11	--	--	--
Arsenic (soluble)	--	46.0	--	--	91.5	1	--	--	--	--	--
Copper (total)	--	--	37.9	--	--	--	--	--	--	--	--
Copper (soluble)	--	--	--	--	--	--	--	--	--	--	--
Chromium VI	--	--	--	--	--	--	--	--	--	--	--
Iron (total)	21,800	10,500	64,900	28,500	44,700	43,800	28,200	73.600	--	--	--
Iron (soluble)	4,240	34,600	--	639	15,500	20,800	286	29,400	--	--	--
Lead (total)	--	4.0	11.8	5.8	9.1	4.7	7.5	4.5	--	--	9.6
Lead (soluble)	--	--	4.5	3.1	4.0	--	18.5	--	--	--	--
Manganese (total)	941	628	8,460	160	1,570	1,650	5,120	1,560	--	--	--
Manganese (soluble)	1,010	574	8,270	146	1,520	1,600	5,080	1,600	--	--	--
Nickel (total)	--	--	61.0	--	--	--	--	--	--	--	--
Nickel (soluble)	--	--	51.7	--	--	--	--	--	--	--	--

-- = Not detected.

Table 2-6C

Summary of Groundwater Quality Analysis Annual Permit Parameters-Organics Sampled June 9 to 11, 1993

Volatile Organic Compound (μg/L)			C-104				C-106				
Common Name	C-101	C-102	Routine	Equipment Blank	C-105	FB-C-105	Routine	Duplicate	C-108	C-111	Trip Blank
Acetone	3J	83	7J	6J	--	--	--	--	--	--	6J
Acrylonitrile	--	--	--	--	--	--	--	--	--	--	--
Benzene	--	--	--	--	--	--	--	--	--	--	--
Bromochloromethane	--	--	--	--	--	--	--	--	--	--	--
Bromodichloromethane	--	--	--	--	--	--	--	--	--	--	--
Bromoform; Tribromothane	--	--	--	--	--	--	--	--	--	--	--
Carbon Disulfide	--	--	--	--	--	--	--	--	--	--	--
Carbon tetrachloride	--	--	--	--	--	--	--	--	--	--	--
Chlorobenzene	--	--	--	--	--	--	--	--	--	--	--
Chloroethane; Ethyl chloride	--	--	--	--	--	--	--	--	--	--	--
Chloroform; Trichloromethane	--	--	--	5J	--	--	--	--	--	--	--
Dibromochloromethane; Chlorodibromomethane	--	--	--	--	--	--	--	--	--	--	--
1,2-Dibromo-3-chloropropane, DSCP	--	--	--	--	--	--	--	--	--	--	--
1,2-Dibromoethene; Ethylene dibromide; EDB	--	--	--	--	--	--	--	--	--	--	--
o-Dichlorobenzene; 1,2-Dichlorobenzene	--	--	--	--	--	--	--	--	--	--	--
p-Dichlorobenzene; 1,4-Dichlorobenzene	--	--	--	--	--	--	--	--	--	--	--
trans-1,4-Dichloro-2-butane	--	--	--	--	--	--	--	--	--	--	--
1,1-Dichloroethane; Ethylene chloride	--	--	--	--	--	--	--	--	--	--	--

-- = Parameter not detected in sample
J = Approximate concentration; analyte detected in sample below quantification limit.

Table 2-6C

Summary of Groundwater Quality Analysis Annual Permit Parameters-Organics
Sampled June 9 to 11, 1993
(Continued)

Volatile Organic Compound (μg/L)			C-104				C-106				
Common Name	C-101	C-102	Routine	Equipment Blank	C-105	FB-C-105	Routine	Duplicate	C-108	C-111	Trip Blank
1,2-Dichloroethane; Ethylene chloride	--	--	--	--	--	--	--	--	--	--	--
1,1-Dichlorotheylene; 1,1-Dichloroethene; Vinylidene chloride	--	--	--	--	--	--	--	--	--	--	--
cis-1,2-Dichloroethylene; cic-1,2-Dichloroethene	--	--	--	--	--	--	--	--	--	--	--
trans-1,2-Dichloroethylene; trans- 1,2-Dichloroethene	--	--	--	--	--	--	--	--	--	--	--
1,2-Dichloropropane; Propylene dichloride	--	--	--	--	--	--	--	--	--	--	--
cis-1,3-Dichloropropene	--	--	--	--	--	--	--	--	--	--	--
trans-1,3-Dichloropropene	--	--	--	--	--	--	--	--	--	--	--
Ethylbenzene	--	--	--	--	--	--	--	--	--	--	--
2-Hexanone; Methyl butyl ketone	--	--	--	--	--	--	--	--	--	--	--
Methyl bromide; Bromomethane	--	--	--	--	--	--	--	--	--	--	--
Methyl chloride; Chloromethane	--	--	--	--	--	--	--	--	--	--	--
Methylene bromide; Dibromomethane	--	--	--	--	--	--	--	--	--	--	--
Methylene chloride; Dichloromethane	1J	1J	--	4J	--	--	--	--	--	--	1J
Methyl ethyl ketone; MEK/2-Butanone	--	--	--	--	--	--	--	--	--	--	--
Methyl iodide; iodomethane	--	--	--	--	--	--	--	--	--	--	--
4-Methyl-2-pentanone; Methyl isobutyl ketone	--	--	--	--	--	--	--	--	--	--	--

-- = Parameter not detected in sample
J = Approximate concentration; analyte detected in sample below quantification limit.

Table 2-6C

Summary of Groundwater Quality Analysis Annual Permit Parameters-Organics
Sampled June 9 to 11, 1993
(Continued)

Volatile Organic Compound (µg/L)			C-104				C-106				
Common Name	C-101	C-102	Routine	Equipment Blank	C-105	FB-C-105	Routine	Duplicate	C-108	C-111	Trip Blank
Styrene	--	--	--	--	--	--	--	--	--	--	--
1,1,1,2-Tetrachloroethane	--	--	--	--	--	--	--	--	--	--	--
1,1,2,2-Tetrachloroethane	--	--	--	--	--	--	--	--	--	--	--
Tetrachloroethylene; Tetrachloroethene; perchloroethylene	--	--	--	--	--	--	--	--	--	--	--
Toluene	--	--	--	--	--	--	--	--	--	--	--
1,1,1-Trichloroethane; Methylchloroform	--	--	--	--	--	--	--	--	--	--	--
1,1,2-Trichloroethane	--	--	--	--	--	--	--	--	--	--	--
Trichloroethylene; Trichloroethene	--	--	--	--	--	--	--	--	--	--	--
Trichlorofluoromethane; CFC-11	--	--	--	--	--	--	--	--	--	--	--
1,2,3-Trichloropropane	--	--	--	--	--	--	--	--	--	--	--
Vinyl acetate	--	--	--	--	--	--	--	--	--	--	--
Vinyl chloride	--	--	--	--	--	--	--	--	--	--	--
Xylenes	--	--	--	--	--	--	--	--	--	--	--
Phenol	7.8	6.8	--	--	--	--	--	20.5	5.0	--	--

-- = Parameter not detected in sample
J = Approximate concentration; analyte detected in sample below quantification limit.

The most recent sampling of groundwater from the Potomac, Columbia, and the shallower water-producing zones has shown that groundwater quality varies widely. Water quality analyses originally reported by Terraqua (1984) and confirmed by WESTON (1992) showed that although groundwater from the Potomac Formation was generally of potable quality, groundwater from the Columbia and the shallower confined water-bearing zone were generally nonpotable. These groundwater quality results represented background (pre-landfill) water quality conditions. The 1984 report showed that groundwater samples from the Columbia and from the lens of coarse deposits above the Columbia (C-102, C-106, and C-108) exhibited relatively high levels of alkalinity, chloride, high specific conductance, hardness, iron, sodium, sulfate, and dissolved solids, among other analytes. Chloride, sulfate, and dissolved solids concentrations exceeded several generally accepted potable limits at most shallower wells. High levels of total organic carbon in groundwater samples collected from the Columbia Formation and the isolated coarse unit, as well as the high alkalinity and dissolved solids values, suggested that these groundwaters are under reducing conditions (with a resultant oxygen deficit) thus allowing metals to solubilize. The results of 1992 and current groundwater quality analyses for Phase V confirmed these earlier results.

2.3.2.1 Quarterly Permit Parameters Analysis

Fourteen of the existing accessible designated Columbia and Potomac Formation monitor wells at the site were sampled and then analyzed for the quarterly permit parameters presented on Table 2-6A.

These recent analysis results indicate that groundwater quality in both the Columbia and Potomac Formations is poor. Analysis also suggest that Potomac Formation water quality is only slightly better than in the overlying Columbia. Most of the inorganic parameters analyzed for in the June 1993 sampling round varied in concentration from earlier rounds, but were within the variations reported previously. Specific conductance, TDS, chloride, and total iron concentrations all showed some variations in concentration when compared with earlier rounds. However these variations would reasonably be expected between sampling rounds due to differences in groundwater recharge.

The only variation indicated in concentrations between the Columbia and Potomac wells was observed for TOC, COD, manganese, and ammonia-nitrogen which was all lower in the wells screen in the Potomac Formation.

2.3.2.2 Annual Permit Parameter Analysis

Columbia Formation wells C-101, C-104, C105, C-111, and wells screened in the isolated coarse unit above the Columbia Formation (C-102, C-106, and C-108) were sampled and analyzed for the 5 metals listed in the current DSWA Phase III and IV permits for annual sampling (6 metals including Mercury are listed in the permits, however mercury was not listed in the Work Plan and was not analyzed during this sampling program. Iron and manganese are quarterly sampling parameters). Both total (unfiltered) and soluble (field filtered) metal analyses were performed. The results of analysis are presented in Table 2-6B.

The recent metals analysis results are consistent with earlier findings. High levels of iron and manganese have previously been identified. Detected concentrations of lead, nickel, and copper were within previous ranges. The concentration of soluble arsenic in C-106 was above the MCL as listed in Table 1, Section 258.40 - Subtitle D. However, the concentration in the duplicate sample was well below this concentration. This well should be sampled for arsenic the next scheduled sampling round to confirm these results. The lower concentrations of metals in soluble (field-filtered) analysis results reflects their natural adsorption onto soil particles. The concentration of metals present in the dredge spoils as indicated by analysis of water entering leachate collection sumps may result in higher concentrations of metals in lower units. The metals concentrations in wells C-102, C-106 and C-108 most likely reflect water quality in the uppermost coarse grain unit that is influenced by metals and organic matter in the dredge spoils/recent deposits.

The apparent higher concentrations of soluble iron and manganese vs. total iron and manganese as listed in Table 2-6B probably results from samples dilution and indicates that nearly all of the iron and manganese is in the soluble form. Because of the high concentrations, these differences are not considered critical.

No significant organic compounds were detected in groundwater samples for site monitor wells. The acetone and methylene chloride detected in several wells are unrelated to landfilling activities and probably represent laboratory-related contamination. Phenol was detected in C-101, C-102, C-106 and C-108 at concentrations ranging from 5.0 to 20.5 $\mu g/L$. The results of analysis for organic substances are presented in Table 2-6C.

2.4 SUMMARY OF HYDROGEOLOGIC CHARACTERISTICS

The investigation of the Phase V Disposal Area confirmed earlier assessments of site hydrogeology and groundwater quality. The investigation of hydrogeologic characteristics during Phase IV and earlier investigations showed that the Potomac, Columbia, and shallower coarse units were confined by thick overlying silts/clays, and were hydraulically distinct. The Potomac and shallower coarse unit were found to be discontinuous.

Flow directions were found to be generally southeastward, confirming earlier investigations. Previous investigations (WESTON, 1992) showed that both the Columbia and the shallower coarser unit experienced water level fluctuations related to tidal effects which created transient reversals in flow direction. Recharge to coarser units is predominantly upgradient and off-site, while discharge areas probably include the Delaware River. Vertical hydraulic gradients are slightly downward at Columbia/Potomac well pairs. Previous investigations have shown hydraulic conductivities in the Columbia Formation were consistent with silty sands.

Sampling of groundwater from the Potomac Formation, the Columbia Formation, and the shallower coarser unit(s) has shown that groundwater quality varies widely. Recent evaluations confirmed WESTON (1992) and earlier evaluations of water quality. Groundwater from the Columbia and the shallower confined lens was confirmed to be nonpotable. Groundwater samples from the Columbia and from the shallower coarser unit above the Columbia exhibited relatively high (non-potable) levels of many analytes. High levels of total organic carbon in groundwater samples collected from the Columbia formation and the shallower confined water-bearing zone above the Columbia, as well as the high alkalinity and dissolved solids values, suggest that this groundwater is under reducing conditions (with a resultant oxygen deficit) thus allowing metals to solubilize. Higher concentrations of total (unfiltered) metals than soluble (filtered) metals confirmed earlier findings that metals are adsorbed by site soils.

2.5 RECOMMENDED MONITORING NETWORK MODIFICATIONS

2.5.1 Background

As part of Phase V evaluation, WESTON reviewed the sampling methodology for the Cherry Island facility, monitor well locations, groundwater sampling procedures and the sampling results. A comparison of the Terraqua sampling results before emplacement of the landfill, and the results obtained by WESTON (1992, 1993) indicated no significant changes in water quality. More importantly, however, the review indicated that it is difficult to distinguish the effects of the dredge spoils on groundwater quality from any effects which might be due to the overlying landfill for most of the quarterly permit general water quality parameters. Background water quality in the Columbia Formation and isolated coarse grain units above the Columbia is predominantly influenced by vertical leakage of poor quality water from the dredge spoils.

Chloride concentration between 400 and 500 mg/l suggest that groundwater in the underlying Potomac Formation may be affected by salt-water intrusion from the Delaware River at an earlier geologic period when these units were exposed and in contact with the river water. Lower concentrations of TOC, COD, and ammonia-nitrogen in the Potomac wells indicate lower organic matter present in these waters compared to the Columbia wells. The high organic content of the dredge spoils/Recent deposits are likely to result in the higher concentration of the parameters in the Columbia Formation and the coarse units above the Columbia. In addition, natural processes operating after emplacement of the landfill such as compaction of the dredge spoils, the removal of brackish water as a vertical recharge source, and alteration in the amount of local recharge will produce changes in the background water quality that cannot be separately quantified. These changes could mask changes in the concentration of most leachate parameters due to vertical infiltration of any leachate from the landfill. Selected, highly soluble organic compounds unique to MSW could serve as better monitoring parameters.

2.5.2 Recommendations

WESTON believes the current groundwater sampling could be more specifically focused to reduce the ambiguity in sampling results. For instance, analyses of heavy metals could be reduced. The fine-grained sediments composing the dredge spoils and the high organic content would attenuate the movement of many of the metals originating from the landfill. Also, current and past metals analysis results show that metals concentrations are highly variable, making them less useful for monitoring purposes. Also the dredge material itself has been affected by industrial and municipal effluent to the Delaware River for at least 100 years. Thus the potential of the dredge spoils as both a sink and source of heavy metals introduces a high degree of uncertainty into the interpretation of the heavy metal data. Chlorides, total dissolved solids, and specific conductivity are also partially duplicative and are non-unique indicators because of the pre-existing high salinity. These compounds could be selected from the Subtitle D Appendix I list and compared with actual leachate data. A certain amount of data on metals concentrations should however first be documented and variations compared. Where possible, statistical analysis should be performed to document variations. Once this information is compiled, a less frequent monitoring schedule for metals and inorganics can be proposed.

Furthermore, the Columbia Formation and underlying Potomac Formation do not everywhere function as an aquifer even though these units are regionally mappable. Drilling results at Cherry Island indicate that much of the Columbia Formation has been eroded and replaced by fine-grained Delaware River deposits. These recent age sediments and the Columbia Formation have little potential for water supply even though their combined thickness may exceed 100 feet. Likewise, the underlying Potomac Formation is mostly fined-grained with some interbedded sands. The sands are generally thin and are not reliably correlated from well to well. The area is served by public water and the nearest pumping well is in a low yielding part of the Potomac Formation, approximately 2500 feet to the southwest. The well site, however, has been impacted by both industrial processes and salt-water intrusion from the Delaware River Estuary. The nearest high yielding public supply well in Delaware is approximately two miles to the southwest. Water-level measurements have indicated that discharge from the groundwater system beneath Cherry Island is to the Delaware River. The Delaware River to the east and the Christina River to the south generally isolate the flow systems in the Recent and Pleistocene sediments, and possibly the shallow Potomac sands as well.

Based on these conclusions, WESTON recommends the following monitoring plan:

- Continue quality monitoring in Columbia Formation wells C-101, C-104, C-105, and C-111.

- Continue quality monitoring in the shallowest coarse unit, including the shallow coarse unit above the Columbia (C-102, C-106, and C-108) and the Potomac designated wells P-100, P-103 and P-107.

- Discontinue quality monitoring in wells completed in dredge spoils/Recent age silt/clay (C-100, C-103, and C-107) and consider closing these wells.

- Retain all other existing wells (except C-109, C-110, C-112 and P-104 which required special action) for possible future monitoring and for water level measurements.

- Discontinue quality monitoring in all Potomac monitoring wells but retain well for future monitoring if needed.

Table 2-7

Summary of Proposed Streamlined Groundwater Quality Monitoring System
Cherry Island/NSWF

Well	Monitored Formation	Proposed Action
C-100	Recent Silt/Dredge Spoils	Discontinue Quality Monitoring - Consider Closing.
C-101	Columbia	Continue Quality Monitoring.
C-102	Recent Sand	Continue Quality Monitoring.
C-103	Recent Silt/Dredge Spoils	Discontinue Quality Monitoring. - Consider Closing.
C-104	Columbia	Continue Quality Monitoring.
C-105	Columbia	Continue Quality Monitoring.
C-106	Recent Sand	Continue Quality Monitoring.
C-107	Recent Silt/Dredge Spoils	Discontinue Quality Monitoring - Consider Closing.
C-108	Recent Sand	Continue Quality Monitoring.
C-109	Columbia	Well Not Located. Locate and Repair or Properly Close.
C-110	Columbia	Well Not Located. Locate and Repair or Properly Close.
C-111	Columbia	Continue Quality Monitoring.
C-112	Recent Sands	Well Closed during Construction of Phase IV.
P-100	Columbia	Continue Quality Monitoring.
P-101	Potomac	Discontinue Quality Monitoring - Retain Well.
P-102	Potomac	Discontinue Quality Monitoring - Retain Well.
P-103	Columbia	Continue Quality Monitoring - Retain Well.
P-104	Potomac	Casing Damage, Discontinue Quality Monitoring - Repair and Retain Well.
P-105	Potomac	Discontinue Quality Monitoring - Retail Well.
P-106	Potomac	Discontinue Quality Monitoring - Retain Well.
P-107	Columbia	Continue Quality Monitoring.
P-108	Potomac	Discontinue Quality Monitoring - Retain Well.

Table 2-7 summarizes these proposed actions.

2.5.3 Review of Sampling Procedures

A review of the sampling procedures by the field sampling team identified possible areas of improvements. It is suggested that, with a quarterly sampling frequency, the installation of dedicated purge pumps result in a significant cost savings to the DSWA which would:

- Eliminate the labor-intensive tasks of assembling, disassembling, and decontamination of the non-dedicated purge pumps and any non-disposable tubing.
- Eliminate the potential for cross contamination from improperly decontaminated pumps.
- Eliminate the recurring cost of disposal purge tubing.
- Eliminate the contamination that may be found in potable water (such as chloroform) used to decontaminate pumps.
- Eliminate the need for any future QA sampling of the potable water source used for decontamination.

In addition, combined with the use of disposable bailers and dedicated/disposable sampling equipment may reduce or eliminate the need for collecting and analyzing equipment blanks.

SECTION 3

GEOTECHNICAL INVESTIGATION/ANALYSIS

3.0 INTRODUCTION/LIMITATIONS

The geotechnical investigation and analysis study reported herein was completed by WESTON for DSWA in conjunction with the design and construction of the Phase V Disposal Area at the Northern Solid Waste Management Center (NSWMC), Cherry Island Landfill located in Wilmington, Delaware. The location of the project site is shown on Figure 3-1.

Limitations

The analyses and recommendations provided herein were developed from the data obtained from the test borings and wellpoints completed by WESTON at this site. This data defines subsurface conditions at these specific locations and only at the particular time the work was performed. The nature and extent of variations between the test boring and wellpoint results and other site conditions may not become evident until construction. If variations become evident, they should be brought to the attention of WESTON immediately, as it may be necessary to re-evaluate the contents of this report to account for actual conditions encountered and/or new data which may arise. The analyses and design conclusions of this report are also based on the premise of competent field engineering and inspection during landfill construction.

The investigation and analyses discussed herein were performed in accordance with generally accepted geotechnical engineering principles, methodologies, and practices. No other warranty, expressed or implied, is made. In addition, WESTON is not responsible for the independent conclusions, opinions, or recommendations made by others based on the contents of this report.

3.1 PROJECT DESCRIPTION

The proposed Phase V Municipal Solid Waste (MSW) Disposal Area will be situated in the southeast corner of the Cherry Island Landfill site located in Wilmington, Delaware. The location of the Phase V Landfill is shown on Figure 3-2. Municipal solid waste is currently being landfilled at Cherry Island within the active Phase I, II and III Disposal areas. The Phase IV Landfill is currently under construction.

The Phase V area will encompass approximately 60 acres of landfill space, and similar to Phases I through IV, will be constructed upon impounded fine-grained dredge spoils. These low-permeability dredge spoils will serve as a natural soil liner for the Phase V Disposal Area. The proposed design floor and top elevations (at crown) of the Phase V landfill area are 48 and 165 feet, respectively. An approximate 5-acre sedimentation and stormwater management basin which is designed to accept stormwater runoff from Phases III, IV, and V will be built as part of the proposed Phase V construction activities. As shown on Figure

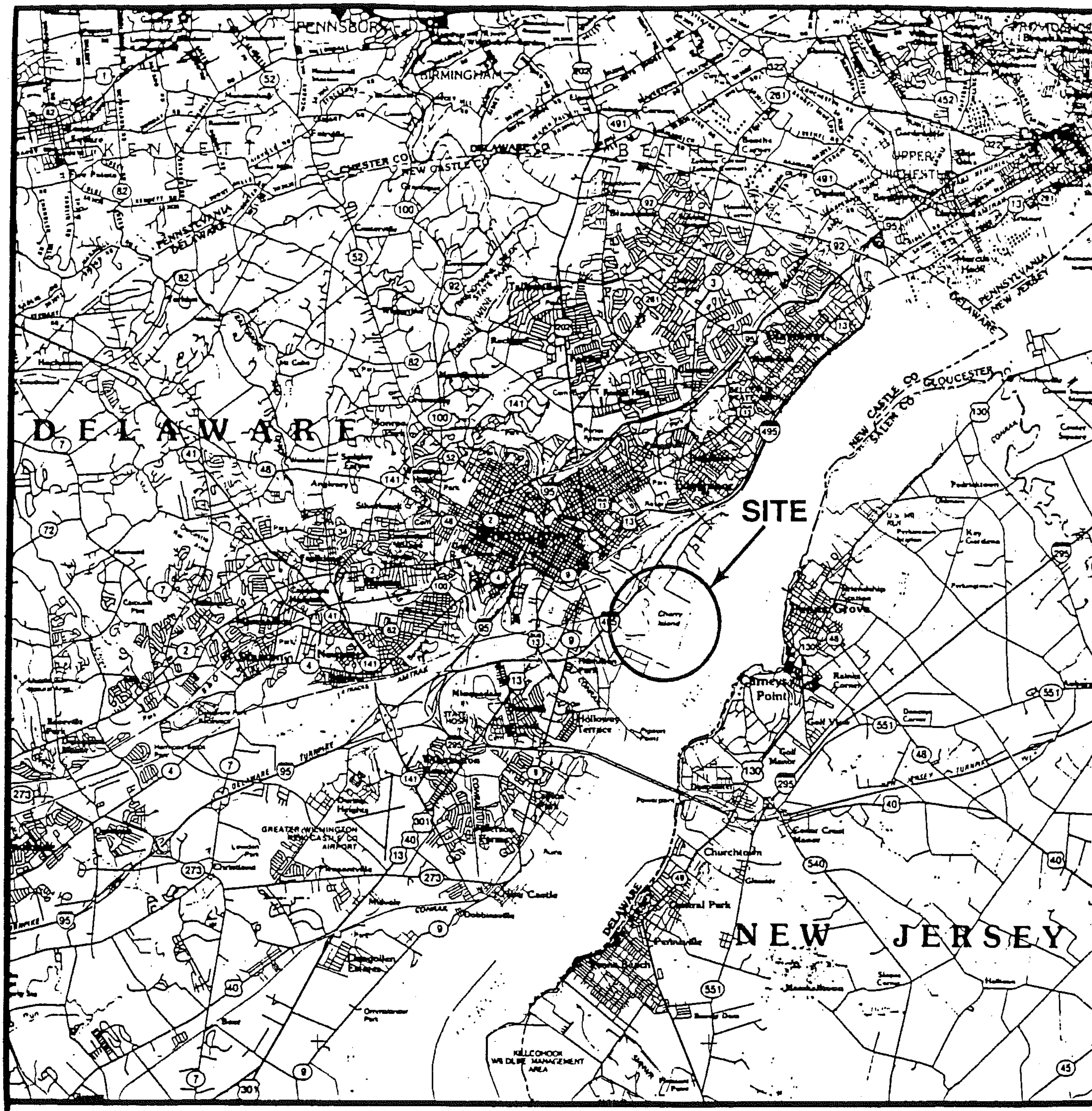
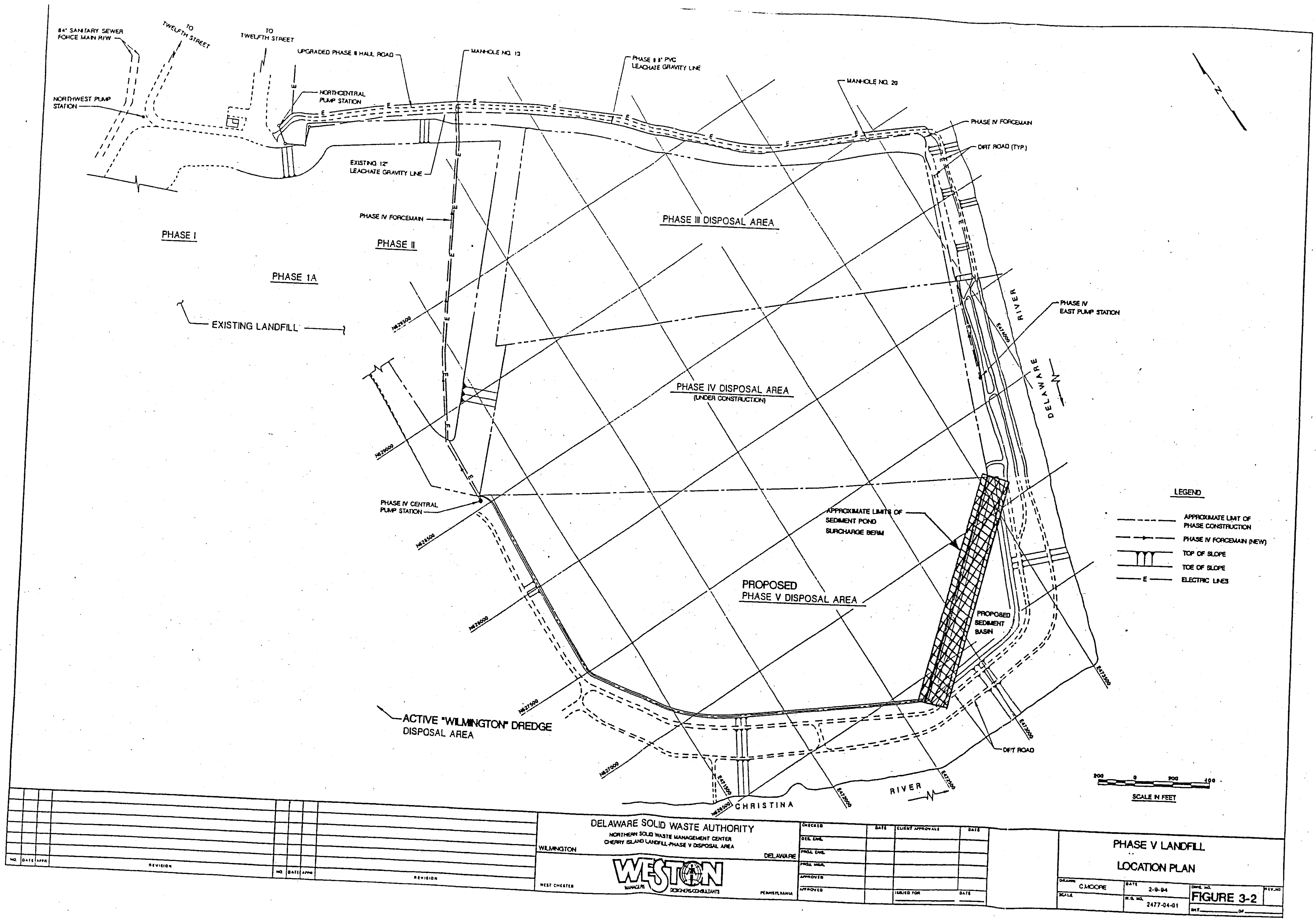


FIGURE 3-1
REGIONAL LOCATION PLAN

DSWA PHASE V DISPOSAL AREA CHERRY ISLAND LANDFILL WILMINGTON, DELAWARE	ROY F. WESTON, INC. WESTON MANAGERS DESIGNERS/CONSULTANTS			
	DRAWN A. DELTUFFO	DATE	DES. ENG. J. WARTMAN	DATE	W. O. NO.
	CHECKED		APPROVED		DWG. NO.



84" SANITARY SEWER FORCE MAIN R/W
TO TWELFTH STREET
TO TWELFTH STREET
UPGRADED PHASE II HAUL ROAD
MANHOLE NO. 13
PHASE II 8" PVC LEACHATE GRAVITY LINE
MANHOLE NO. 20
NORTHWEST PUMP STATION
NORTHCENTRAL PUMP STATION
PHASE IV FORCEMAIN
DIRT ROAD (TYP.)
EXISTING 12" LEACHATE GRAVITY LINE
PHASE III DISPOSAL AREA
PHASE IV FORCEMAIN
PHASE I
PHASE II
PHASE 1A
EXISTING LANDFILL
RIVER
PHASE IV EAST PUMP STATION
DELAWARE
PHASE IV DISPOSAL AREA
(UNDER CONSTRUCTION)
PHASE IV CENTRAL PUMP STATION
APPROXIMATE LIMITS OF SEDIMENT POND SURCHARGE BERM
PROPOSED PHASE V DISPOSAL AREA
PROPOSED SEDIMENT BASIN
ACTIVE "WILMINGTON" DREDGE DISPOSAL AREA
DIRT ROAD
CHRISTINA
RIVER
LEGEND
APPROXIMATE LIMIT OF PHASE CONSTRUCTION
PHASE IV FORCEMAIN (NEW)
TOP OF SLOPE
TOE OF SLOPE
ELECTRIC LINES
200 0 200 400
SCALE IN FEET
REVISION
REVISION
DELAWARE SOLID WASTE AUTHORITY
NORTHERN SOLID WASTE MANAGEMENT CENTER
CHERRY ISLAND LANDFILL-PHASE V DISPOSAL AREA
WILMINGTON
DELAWARE
WEST CHESTER
WESTON
MANAGERS DESIGNERS/CONSULTANTS
PENNSYLVANIA
PHASE V LANDFILL
LOCATION PLAN
C.MOORE
2-9-94
2477-04-01
FIGURE 3-2

3-2, it is proposed that a permanent surcharge berm be constructed with earthen fill soils within the limits of the sedimentation basin at a location adjacent to the toe of the Phase V Landfill Slope. The weight of this surcharge berm will be used to strength gain the underlying fine grained soils. The berm will measure approximately 1,000 ft in length, 10 ft in height, and 100 ft in width (measured at top) with approximate 3 horizontal :1 vertical outslopes.

A leachate collection system (LCS) will be included within the constructed Phase V Disposal Area and consist of a 1-foot thick granular drainage blanket over the floor of the landfill. The landfill floor will be sloped to perforated high-density polyethylene (HDPE) pipes that are entrenched within a high-permeability coarse granular stone. Leachate generated within the Phase V Disposal Area will be conveyed through the LCS to one of two wet wells. Leachate will be pumped from the wet wells and conveyed via force main to the nearby Wilmington Waste Water Treatment Plant for proper treatment prior to disposal.

3.2 SITE CONDITIONS

The Cherry Island Landfill Site is situated at the confluence of the Christina River and Delaware River. The Phase V Disposal Area will be bounded on the north by the Phase IV Landfill (currently under construction), an existing earthen perimeter berm along the Delaware River to the east, an existing earthen perimeter berm along the Christina River to the south, and an existing earthen berm to the west which separates the Edgemoor area from the Wilmington area of Cherry Island. The United States Army Corps of Engineers (USACE) is currently utilizing the Wilmington area as an active dredge spoil impoundment area.

The site of the proposed Phase V landfill consists of approximately 40 to 50 ft of impounded dredge spoils which were pumped to deposition within the Edgemoor area of Cherry Island during the periodic maintenance dredging of the Wilmington Harbor by the USACE. These dredge spoil materials typically classify as low plasticity silts and are soft, wet, and compressible, but generally exhibit a stronger surface crust due to surficial soil drying and the presence of shallow-depth rootmass. The dredge spoils over the floor of Phase V currently support growth of dense vegetation (reeds and brush). The ground surface elevation of the dredge spoils is approximately 48 feet within the Phase V area as determined from the topographic site base map prepared by Aerial Data Reduction Associates, Inc. of Pennsauken, NJ and dated 18 February 1993.

The dredge spoil soils are underlain by approximately 40 to 50 feet of soils classified as "recent deposits" on geologic maps of the area. These recent deposit soils are geotechnically similar to the overlying dredge spoils and typically classify as low-plasticity silts. Based on the results of field and laboratory tests, the recent deposits are known to be slightly denser with resulting greater shear strength than the overlying dredge spoils.

A continuous, man-made, earthen perimeter berm bounds the eastern, southern, and western limits of Phase V. The eastern and southern portions of this berm currently support the growth of dense vegetation (reeds). This perimeter berm is believed to have been constructed upon recent deposit soils by the USACE for use as a dredge spoil impoundment dike. The berm is comprised of low-plasticity silts with occasional granular inclusions. Based on the relatively low strengths of these soils (as measured during field and laboratory testing), it is believed that perimeter berm fill placement operations were not stringently controlled. The top elevation of the berm is approximately 53 feet as determined from the topographic site base map. The outslope of the perimeter berm includes man-made benches which are located between several short, steep outfall slopes. These benches are currently used as access roads to existing site monitoring wells. The average perimeter berm outslope is approximately 15% and 13% along the eastern and southern limits of Phase V, respectively.

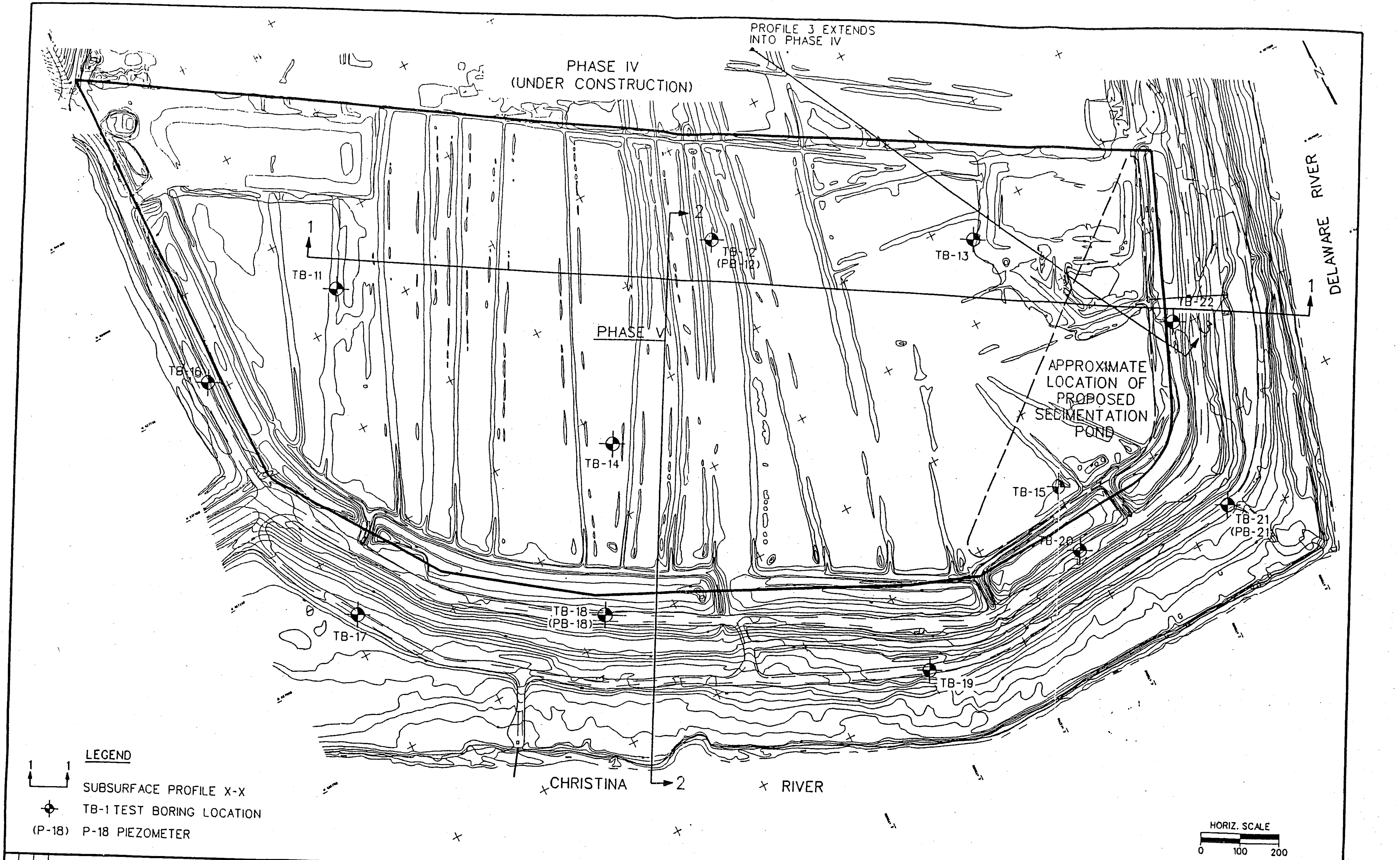
A description of Cherry Island's regional and site geology is found in Section 2 of this report.

3.3 SUBSURFACE INVESTIGATION

Subsurface conditions in the vicinity of Phase V were investigated by completing a total of eleven (11) test borings. They are designated as TB-11 through TB-22 (Borings TB-1 through TB-10 were completed by WESTON as part of the Phase IV geotechnical investigation). The boring locations are shown on Figure 3-3 and were selected to provide uniform coverage over the footprint of the Phase V disposal area and its adjacent earthen perimeter berms. Prior to drilling, the locations of the borings within the footprint of Phase V (TB-11 through TB-15) were surveyed and staked in the field by WESTON's surveying subcontractors, Vandemark and Lynch, Inc. (V&L) of Wilmington, Delaware. The borings located on the earthen perimeter berms (T-16 through TB-22) were located in the field by WESTON Engineers prior to commencement of drilling activities so as to permit drill rig access to these locations. At the completion of the drilling activities, the location of the completed borings were surveyed by V&L so that accurate horizontal coordinates and ground surface elevations could be determined. The horizontal survey coordinates, ground surface elevations, and wellpoint casing/cap elevations (if appropriate) of the completed test borings/wellpoints are presented on the test boring/wellpoint logs presented in Appendix A.

The test borings were completed between 10 June and 30 June 1993 by the Walton Corporation (WALTON) of Newark, Delaware. It is noted that WALTON is a certified drilling contractor in the State of Delaware (Corporate Registration No. 52). The test borings were completed under the full-time direct technical supervision of WESTON Field Engineers. Truck-mounted and track-mounted drilling rigs were used to complete the borings along the perimeter berm and floor of Phase V, respectively.

Each boring was initially advanced using hollow stem augers to a depth that was typically several feet below the saturated zone within the dredge spoils (i.e., generally 8 to 15 feet below the existing ground surface). This allowed the depth of free water within this saturated zone to be measured within the augers. At this point, the drilling technique was converted to mud rotary as a means to partially suppress methane emissions which were emerging from the boreholes from assumed biodegradation of subsurface organic deposits. All borings were advanced until the fine-grained dredge spoil and recent deposit soils were fully penetrated and the dense underlying granular deposits of the Columbia Formation were encountered.



DSWA PHASE V
CHERRY ISLAND LANDFILL
WILMINGTON DELAWARE

WESTON

FILE NO.: DSW5216.DGN

DCN: 02477-004-001-

DSWA PHASE V
SUBSURFACE PROFILE AND
BORING LOCATION PLAN

DATE 11-19-93

Figure 3-3

1" = 100'

02477-004-001

During the drilling work, representative samples of the encountered coarse and fine-grained soils were collected from the borings using the procedures of ASTM D-1586, "The Standard Penetration Test." This procedure requires that samples be obtained using a 2-inch outside diameter split-barrel sampler which is driven 18 inches into the soils by a 140 pound hammer which freely falls a distance of 30 inches. The number of hammer blows which were required to drive the sampler during the interval from 6 to 18 inches, or fraction thereof, is reported on the test boring logs as the "N" value. In many instances, Standard Penetration Testing within the very soft fine-grained soils resulted in a full 18 inches of split-spoon penetration into these materials from the weight of the rods (WOR) or the combined weight of the rods and 140 pound hammer (WOH). In these instances, the "N" value is recorded on the test borings logs as WOR or WOH.

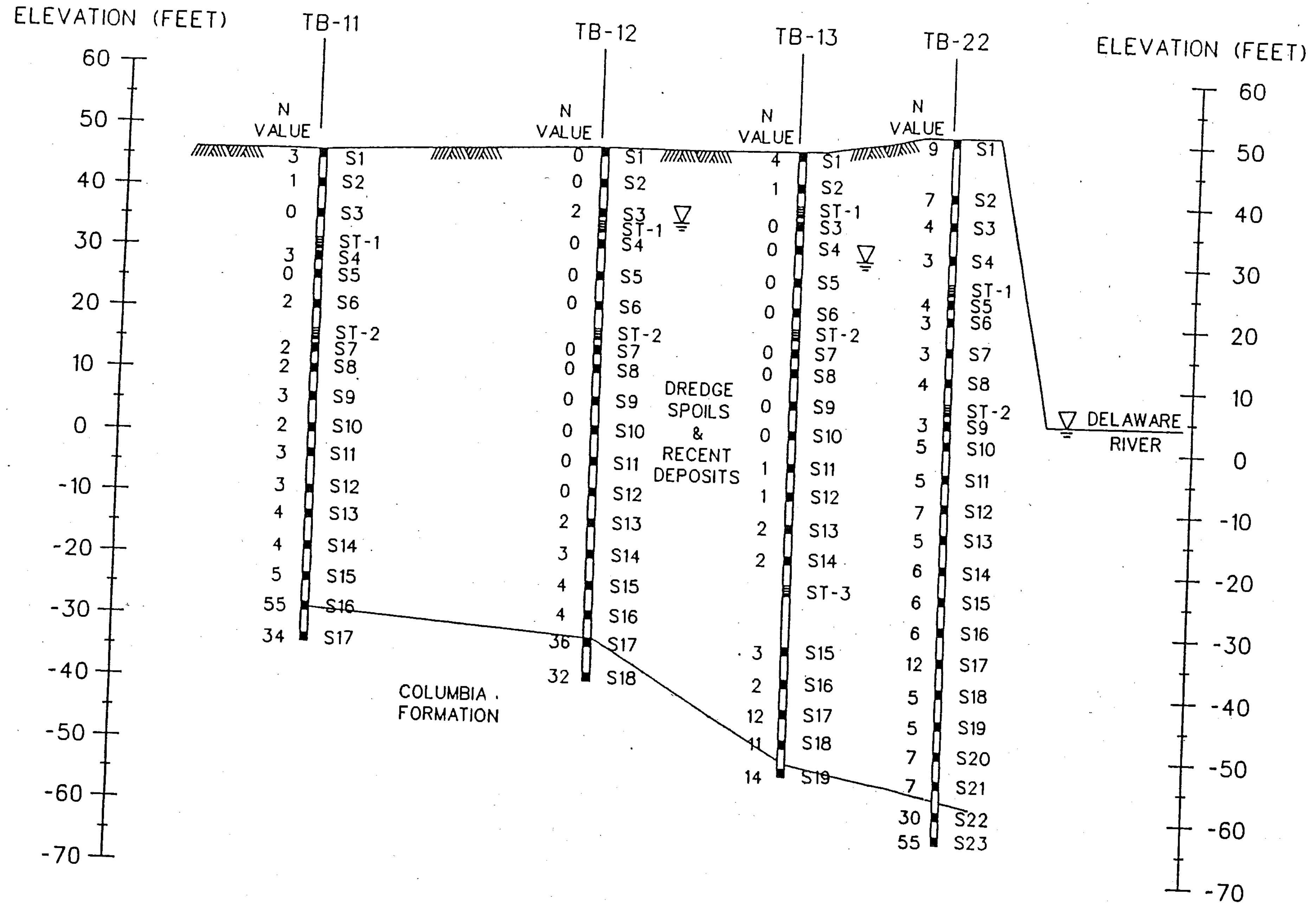
"Undisturbed" Shelby tubes samples of the encountered fine-grained soils were obtained using the procedures of ASTM D-1587, "Thin-Walled Tube Sampling of Soils." A total of 27 Shelby tubes were obtained during the drilling work. All tubes were trimmed, waxed, capped, sealed and transported in accordance with acceptable industry procedures so as to maintain the integrity of these samples.

At the completion of each boring, the borehole was fully grouted to the ground surface using an impervious cement/bentonite grout mix. This construction activity represents an environmental safeguard in that it will prevent future landfill leachate from migrating through the boreholes to the underlying granular soils.

Wellpoints were also installed at locations adjacent to three (3) of the completed boreholes for the purpose of obtaining long-term measurements of the depth to water within the saturated zone of the fine-grained soils. These wellpoints were installed adjacent to boreholes TB-12, TB-18, and TB-21, and extended to depths of approximately 10 to 15 feet below the encountered water level to allow for possible fluctuations of this level. The wellpoints are designated as P-12, P-18, and P-21 and their locations are shown on Figure 3-3. The wellpoints consist of 2-inch polyvinyl chloride (PVC) solid-wall pipe with a 5-foot length of slotted well screen. The bottom of each well screen was sealed with a plastic end cap. Following installation of the wellpoint, the borehole annulus was backfilled from the bottom of the borehole to approximately 1 foot above the well screen interval with a coarse grained sand which was gradationally compatible with the well screen. An approximate 2-foot (vertical dimension) bentonite plug was installed atop the well screen sand. The remainder of the borehole was subsequently backfilled to the ground surface with an impervious cement/bentonite grout mix. The wellpoint construction logs and DNREC Monitor/Observation Well Completion Reports are presented in Appendix A.

3.4 SUBSURFACE CONDITIONS

The subsurface conditions encountered at the site are noted on the individual test boring logs and depicted on Subsurface Profiles 1-1, 2-2, and 3-3 (Figures 3-4 through 3-6). The location of the profiles are shown on Figure 3-3. Stratigraphic descriptions, split-spoon sampler "blow counts," Standard Penetration Resistance (i.e., "N") values of the various soil strata encountered during the drilling work as well as the stratigraphic interface depths and top elevations of these strata, and the groundwater levels as measured during the drilling



LEGEND

N VALUE - STANDARD PENETRATION RESISTANCE (SPR) VALUE (ASTM D-1586)

WOR - WEIGHT OF ROD

WOH - WEIGHT OF HAMMER

S1 - SPLIT SPOON SAMPLE NO. 1

ST-3 - SHELBY TUBE SAMPLE NO. 3

∇ GROUNDWATER AS ENCOUNTERED DURING DRILLING

NOTE: SEE FIGURE 3-3 FOR LOCATION OF SUBSURFACE PROFILE 1-1

HORIZ. SCALE 0 200 400

DSWA PHASE V
CHERRY ISLAND LANDFILL
WILMINGTON DELAWARE

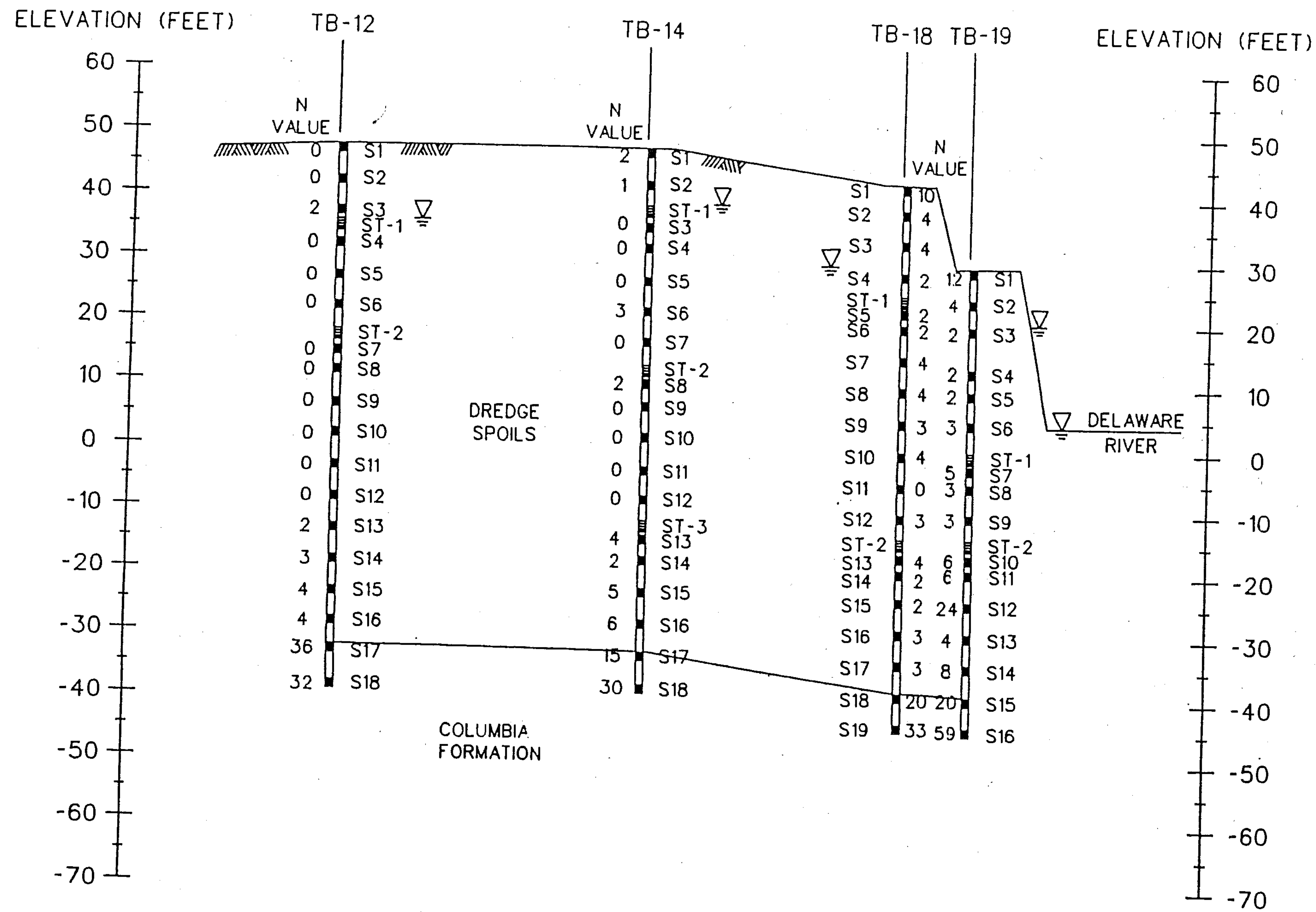
WESTON

FILE NO.: DSW5217.DGN

DCN: 02477-004-001-

DSWA PHASE V
CHERRY ISLAND LANDFILL
SUBSURFACE PROFILE 1-1

DATE	11-19-93
SCALE	V: 1"=10' H: 1"=200'
W.O. NO.	02477-004-001
DWG NO.	Figure 3-4



LEGEND

N VALUE - STANDARD PENETRATION RESISTANCE (SPR) VALUE (ASTM D-1586)

WOR - WEIGHT OF ROD

WOH - WEIGHT OF HAMMER

S1 - SPLIT SPOON SAMPLE NO. 1

ST-3 - SHELBY TUBE SAMPLE NO. 3

∇ GROUNDWATER AS ENCOUNTERED DURING DRILLING

NOTE: SEE FIGURE 3-3 FOR LOCATION OF SUBSURFACE PROFILE 2-2

HORIZ. SCALE
0 100 200

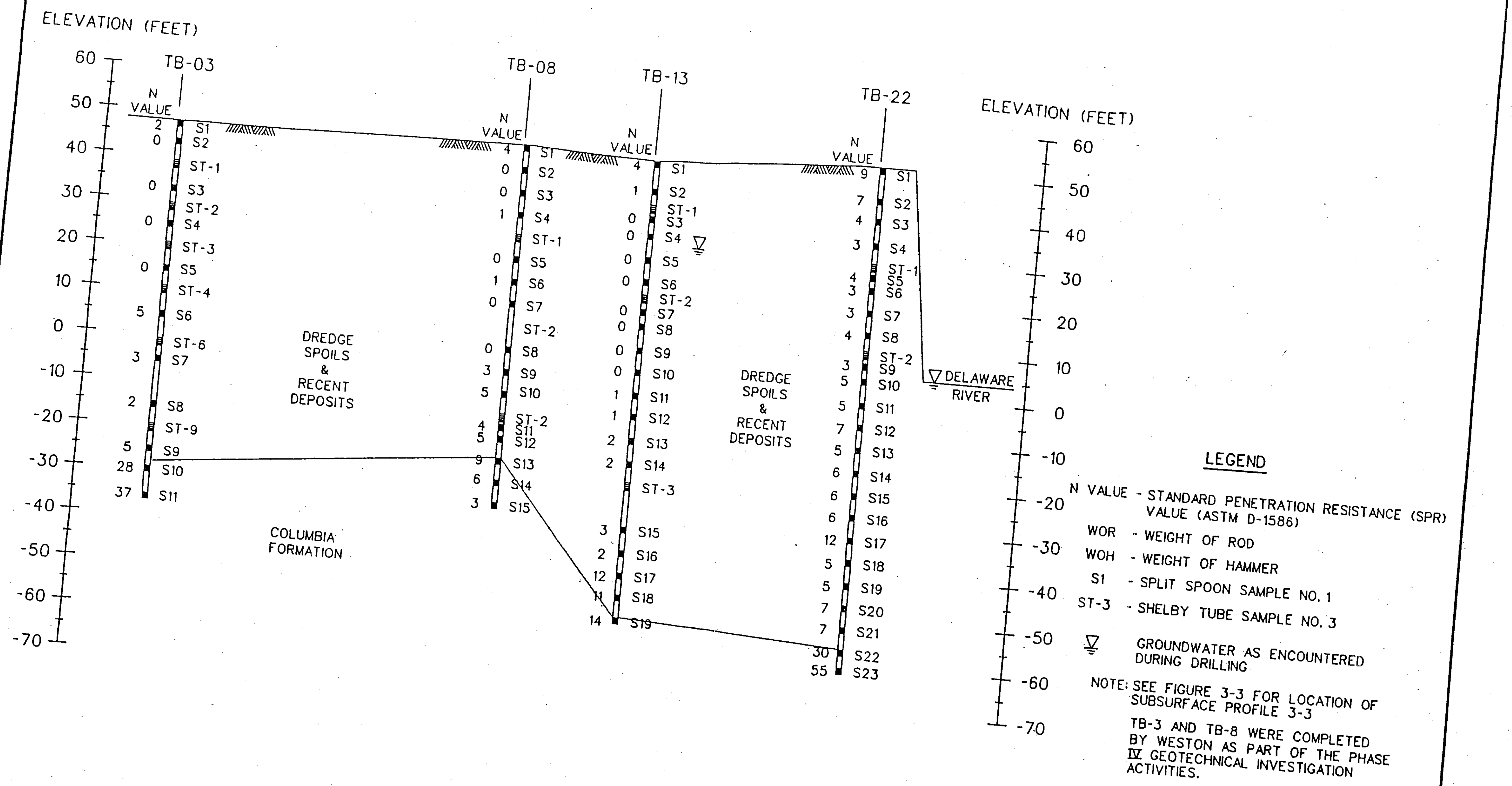
DSWA PHASE V
CHERRY ISLAND LANDFILL
WILMINGTON DELAWARE
WESTON

FILE NO.: DSW5218.DGN

DCN: 02477-004-001-

DSWA PHASE V
CHERRY ISLAND LANDFILL
SUBSURFACE PROFILE 2-2

11-19-93
V: 1"=10'
H: 1"=100'
02477-004-001
Figure 3-5



DSWA PHASE V
CHERRY ISLAND LANDFILL
WILMINGTON DELAWARE
WESTON
FILE NO.: DSW5219.DGN

DCN: 02477-004-001-
DSWA PHASE V
CHERRY ISLAND LANDFILL
SUBSURFACE PROFILE 3-3
V: 1"=10' H: 1"=100'
11-19-93
02477-004-001
Figure 3-6

program are presented on the boring logs and subsurface profiles. The classification of soils from within the various strata encountered during the drilling work as determined from the procedures of the Unified Soil Classification System (USCS) are documented in the results of the laboratory physical properties testing program presented in Appendix B.

The western and central portions of the Phase V landfill site are underlain by approximately 75 to 80 feet of fine-grained soils. In the eastern portion of the site, these fine-grained soils extend to depths of approximately 95 to 100 ft below ground surface. The upper approximately one-half of this stratum thickness is believed to consist of dredge spoils which were pumped to deposition within the diked Edgemoor Area. These materials are classified as ML (low plasticity clayey silt) or MH (high plasticity silt) soils based on their plasticity properties as determined by the USCS (see Figure 3-7). These materials were generally noted to be very soft, compressible and of very low in situ shear strength as noted by typical "N" values of WOR and WOH.

The lower approximately one-half of the fine-grained soil stratum thickness is believed to be of natural alluvial depositional history. These materials are designated as "recent deposits" on geologic maps of the area. Based on their plasticity properties, these materials are also classified as ML and MH soils according to the USCS as shown on Figure 3-8. These materials were also noted to be soft and compressible. However, the shear strength of these soils was noted to be considerably higher than the overlying dredge spoils because of the effects of densification and strength gain due to consolidation resulting from the weight of the overlying dredge spoils. "N" values within the recent deposit soils were WOR and WOH near the top of this substratum, and generally increased to approximately 4 to 12 blows per foot near the bottom of the substratum.

The soils of the underlying granular deposits generally consisted of coarse to fine sands and gravels with silt inclusions. These soils were noted to be of considerably higher shear strength than the overlying fine-grained soils as evidenced by "N" values which generally ranged from 15 to over 100 blows per foot. These materials extended to the depth of exploration within all of the test borings.

3.5 LABORATORY TESTING PROGRAM

A laboratory physical properties testing program was completed by WESTON's Geotechnical Laboratory in Lionville, PA on selected representative split-spoon samples of the encountered coarse and fine-grained soil strata. The program included completion of the following tests:

1. Natural Moisture Content (ASTM D-2216)
2. Liquid and Plastic Limits (ASTM D-4318)
3. Grain Size Distribution by Mechanical Sieve Analysis (ASTM D-422)
4. Grain Size Distribution by Mechanical Sieve and Hydrometer Analysis (ASTM D-422)

PLASTICITY CHART

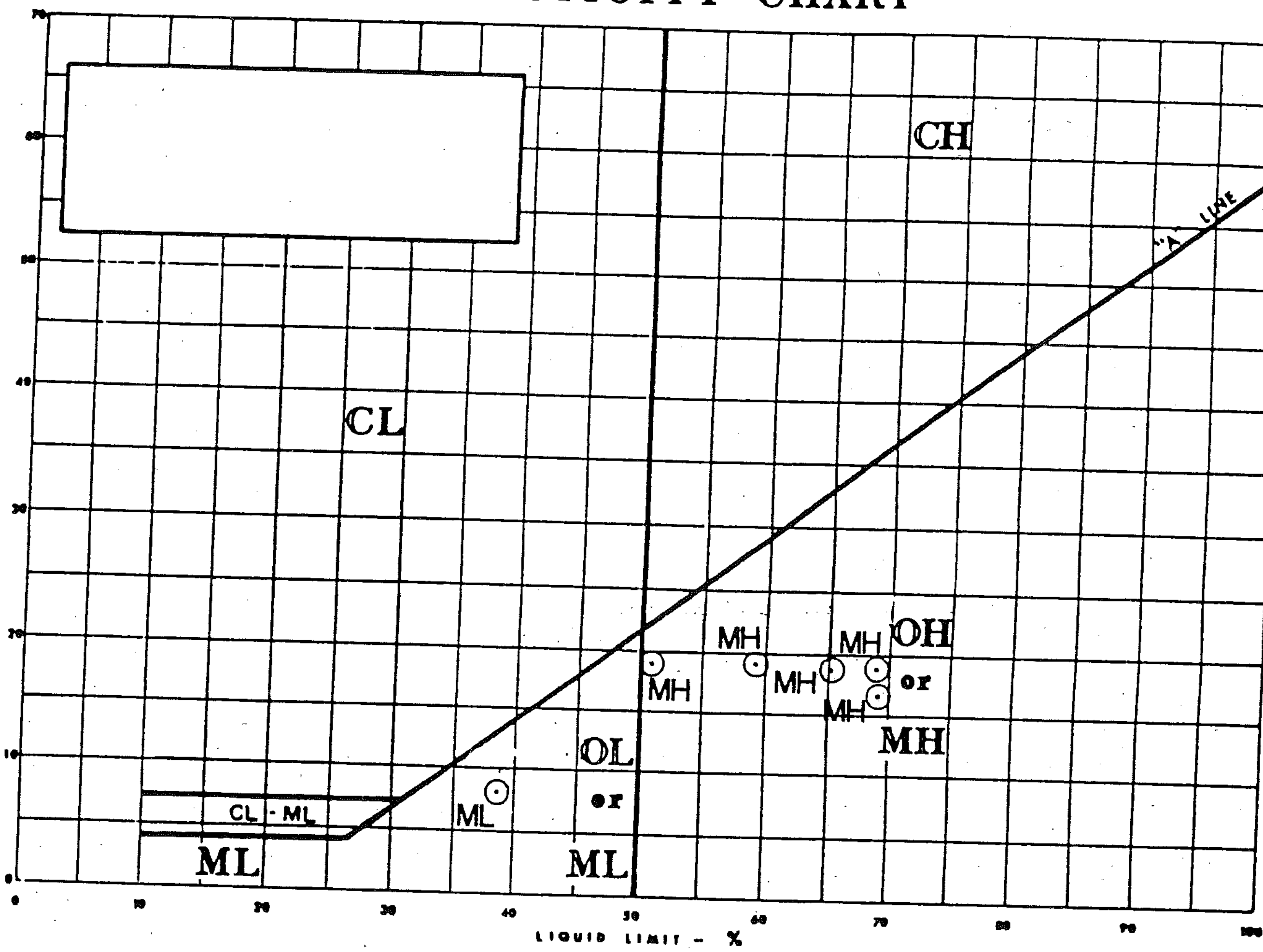


FIGURE 3-7
PLASTICITY OF DREDGE SPOILS

DSWA
PHASE V DISPOSAL AREA
CHERRY ISLAND LANDFILL
WILMINGTON, DELAWARE

ROY F. WESTON, INC.
WESTON
MANAGERS DESIGNERS/CONSULTANTS

DRAWN	DATE	DES. ENG.	DATE	W. O. NO.
A. DELTUFFO	11/19/93	J. WARTMAN		02477-004-001
CHECKED		APPROVED		DWG. NO.
S. STRAZZELLA				

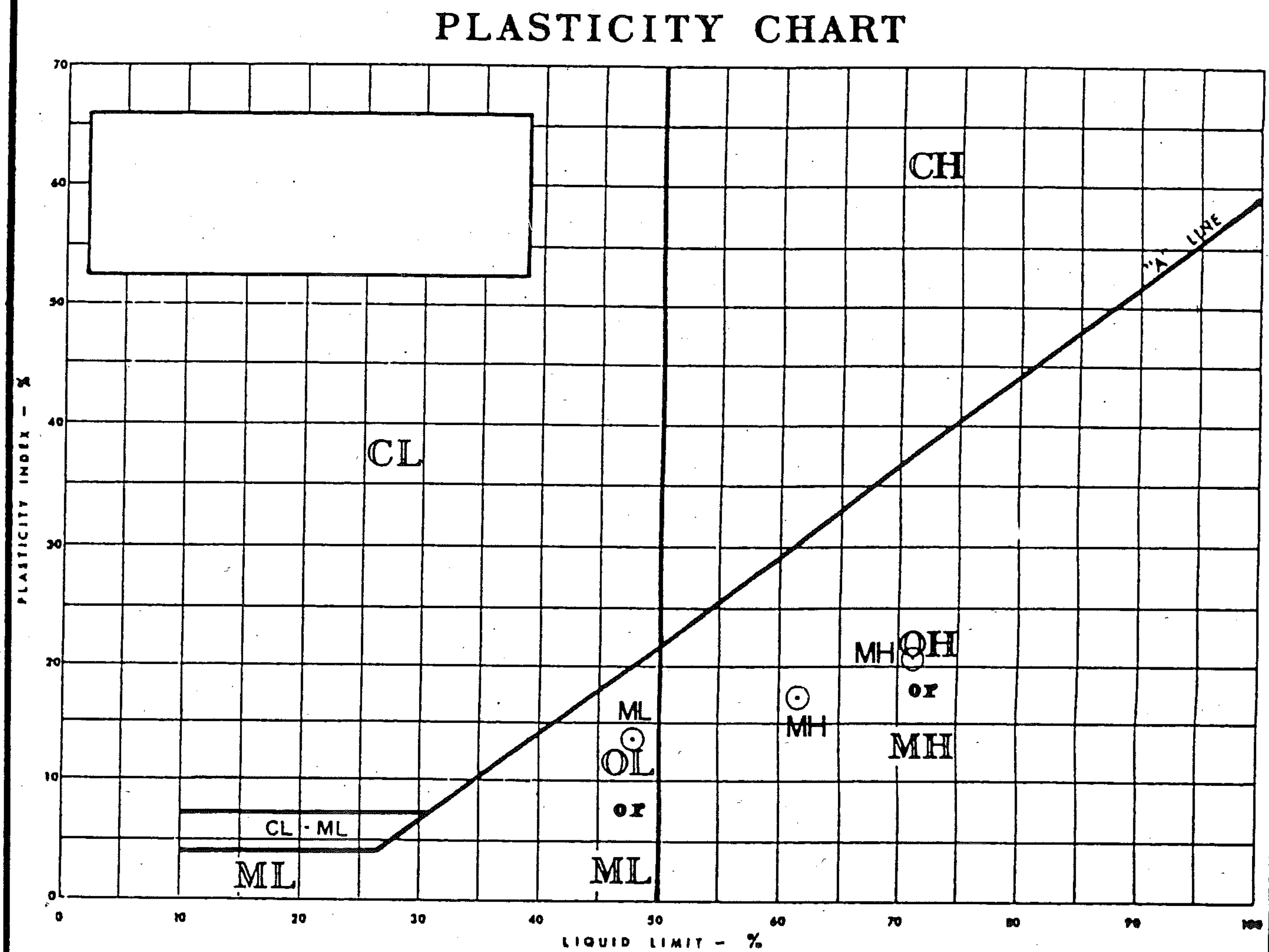


FIGURE 3-8
PLASTICITY OF RECENT DEPOSITS

DSWA
PHASE V DISPOSAL AREA
CHERRY ISLAND LANDFILL
WILMINGTON, DELAWARE

ROY F. WESTON, INC.
WESTON
MANAGERS DESIGNERS/CONSULTANTS

DRAWN A. DELTUFFO	DATE 11/19/93	DES. ENG. J. WARTMAN	DATE	W. O. NO. 02477-004-001
CHECKED S. STRAZZELLA		APPROVED		DWG. NO.

5. Specific Gravity (ASTM D-854)

6. Moisture, Ash, and Organic Content (ASTM D-2974)

7. Soil pH (ASTM D-4972)

These test results were used to classify soils according to the USCS (i.e., ASTM D-2487). They were also used to define stratigraphical continuity and serve as indices to soil behavior.

An engineering properties testing program was also completed by Bowser-Morner, Inc. of Dayton, Ohio and WESTON's Environmental Technology Laboratory (ETL) of Lionville, Pennsylvania on selected representative Shelby Tubes samples of the encountered fine-grained soil strata (i.e., dredge spoils, recent deposits, and perimeter berm fill). These tests consisted of the following:

1. Triaxial Permeability Testing using DSWA Cherry Island landfill leachate as the permeant (EPA Method 9100): These tests were completed on Shelby Tube samples of the dredge spoils and recent deposits which directly underlie the proposed landfill footprint, and which will be evaluated as a natural soil liner for this facility.

2. Consolidation Testing (ASTM D-2435): These tests were completed on Shelby Tube samples of the dredge spoils and recent deposits which directly underlie the proposed landfill footprint, and which will therefore undergo settlement under the proposed landfill loadings.

3. Triaxial Shear Strength Testing: These tests were completed on Shelby Tube samples of both the dredge spoils/recent deposits which underlie the landfill footprint as well as the fine-grained dike fill and recent deposit soils.

   Both the undrained and drained shear strength parameters of these soils were measured in Unconsolidated-Undrained (UU) and Consolidated-Undrained (with pore pressure measurements) (CIU) triaxial compression tests. (ASTM D-2850 and D-4767, respectively).

4. Compaction Testing: A Modified Proctor Compaction Test (ASTM D-1557) was completed on a bulk sample of the dredge spoils to determine the moisture/density relationship for these materials. These test results provide information regarding the potential use as excavated quantities of these materials as compacted fill to construct internal separation dikes within the landfill footprint.

5. Geochemical Analyses: These tests consisted of pH and Cation Exchange Capacity (CEC) and were completed on the dredge spoils to determine the contaminant attenuation capabilities of these materials if used as a natural soil liner. All chemical testing followed standard EPA procedures.

The results of the laboratory testing program are presented in Appendix B of this report.

3.6 ENGINEERING ANALYSES

Detailed engineering analyses were also completed as part of the Phase V landfill design. These included evaluation of bearing capacity, consolidation, natural soil liner permeability, geochemical analysis, and slope stability. The results of these analyses are presented as follows along with the technical assumptions utilized in the analyses. A complete set of engineering calculations and computer program input and output data which detail and document these analyses will be maintained in WESTON's project files.

3.6.1 Technical Assumptions

The following technical assumptions were used in completing the geotechnical analyses discussed below.

1. The entire Edgemoor disposal area which encompasses Phases III, IV and V will be landfilled as a single operating unit. That is, the combined area of Phases III, IV and V (approximately 165 acres) will be filled with a single lift of MSW before subsequent lifts are placed within this three phase area in a similar manner. In addition, the same direction of fill placement will be used for each MSW lift so as to maximize the time interval between placement of two successive lifts of waste at any given point within the landfill footprint.

2. As reported to WESTON by DSWA, the initial rate of municipal solid waste generation was assumed to be 532,000 tons/yr. This figure was increased 2% annually for anticipated future growth of the solid waste stream. For years 1 through 4, 178,000 tons was deducted from the waste stream for anticipated incineration of this material at a local Resource Recovery Facility.

3. Each lift of waste was assumed to be 10 feet in total thickness. This conservatively includes 9 feet of waste and one foot of daily soil cover (i.e., volumetric proportions of 90% waste/10% cover soil). It is noted that, in reality, daily cover typically varies from 6-inches to 1-foot in thickness.

4. The waste was assumed to be placed to a 3H:1V sloping configuration without benching around the perimeter of Phases III, IV, and V with the exception of the western end of Phases III and IV where an overfill against the existing sideslope of Phase II will be completed. A total peak landfill height of 117 feet, including the final cover system thickness, was evaluated. This includes 100 feet of landfill height (i.e., 10 waste lifts) to the top of the 3H:1V slope, and a 2% drainage pitch from this top of slope location to the crown of the landfill.

5. The initial placement density of the waste was assumed to be 43 pcf for calculation of the time intervals required to place the known volumes of the various waste lifts.

6. Based on assumptions 1 through 5 above, a total active landfill life of approximately 18 years was calculated.

7. The density of the waste was significantly increased above the initial placement density of 43 pcf for use in completing bearing capacity, settlement and slope stability analyses for the following reasons:

    a. The wetting of the waste by infiltrating rainwater which will dramatically increase its weight. This phenomena is especially important for paper and yard wastes which readily absorb water and which constitute approximately 51% of a typical MSW fill.

    b. Biodegradation of the organic constituents of the waste. This process creates a soft, weak, sludge-like mass which compresses under the weight of overlying materials, thereby densifying the mass in the process.

    c. Settlement of the non-biodegradable constituents of the waste mass under the weight of overlying lifts of this material (i.e., void ratio reduction) which results in a densification of this component of the mass.

    Based on a review of 16 references in which the in-place density of MSW was quoted, a representative value of 65 pcf was selected for this parameter. When weighted with the daily cover soil at an assumed field density of 120 pcf in 9 to 1 proportions, the density of the composite MSW/soil cover mass was determined to be 70 pcf for use in the various engineering analyses discussed subsequently.

3.6.2 <u>Bearing Capacity Analysis</u>

Undrained (i.e., total stress) and drained (i.e., effective stress) bearing capacity analyses were completed to determine if the low shear strength dredge spoils and recent deposits can safely support the proposed landfill loadings as well as the proposed sediment pond surcharge berm. The Terzaghi bearing capacity equation was used to quantify this evaluation. These analyses are discussed below:

3.6.2.1 Undrained Analysis

An undrained bearing capacity analysis was completed for both the landfill and the sediment pond surcharge berm and is discussed as follows.

3.6.2.1.1 Landfill

An undrained bearing capacity analysis was completed for each 10 foot MSW lift thickness of the Phase V Landfill. Strength gain between the time when a lift of waste was placed at a given location within the Phases III, IV and V footprint and that time when a subsequent

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waste lift was placed at this same location was incorporated into the analysis as discussed subsequently. The Factor of Safety (FS) against a potential bearing capacity failure under undrained soil shear strength conditions for a given MSW lift was defined as follows:

$$FS(\text{undrained}) = q_{ult}/q_{actual} \qquad (2)$$

In this equation, q_{ult} represents the ultimate bearing capacity of the dredge spoils/recent deposits assuming these soils have strength gained through consolidation from the placement of overlying lifts of waste. The value of q_{actual} is the total landfill loading including the weight of the given lift being evaluated.

Under undrained soil shear strength conditions, the values of undrained cohesion (c_u) and undrained angle of internal fraction (ϕ_u) are used in the analysis. For saturated or nearly saturated low permeability fine-grained soils, $\phi_u = 0°$. Actual undrained shear strength behavior for the dredge spoils/recent deposit soils was confirmed by the laboratory unconsolidated-undrained (UU) triaxial shear strength test results in which a horizontal Mohrs envelope was developed. For an applied loading at the ground surface (i.e., $D_f = 0$) of the supporting soils under a $\phi_u = 0°$ shear strength condition, the Terzaghi bearing capacity equation reduces to the following:

$$q_{ult} = c_u N_c s_c \qquad (3)$$

This equation was used to determine the undrained bearing capacity of the dredge spoils/recent deposits at the time of initial placement of each of the 10 MSW lift loadings.

The undrained cohesive strength utilized in this analysis for each MSW lift was determined as follows:

$$c_u = c_{uo} + (\Delta\bar{\sigma}_n)\,\text{Tan}\,\bar{\phi} \qquad (4)$$

in which:

c_u = the undrained cohesive shear strength of the fine-grained soil stratum under the new lift loading condition.

c_{uo} = the undrained cohesive shear strength of the fine-grained soil stratum under the previous lift loading condition.

$\Delta\bar{\sigma}_n$ = change in effective stress which occurs perpendicular (i.e., normal) to the critical shear failure surface which resulted from the previous lift loading condition.

$\bar{\phi}$ = effective angle of internal friction for the dredge spoils and underlying recent deposits which was assumed to be 30° based on a conservative evaluation of $\overline{\text{CIU}}$ laboratory test results and as verified using correlations of $\bar{\phi}$ with soil physical properties (i.e., plasticity index).

The effective normal stress increase ($\Delta\bar{\sigma}_n$) can be related to the major and minor principal effective stress increases (i.e., $\Delta\bar{\sigma}_1$ and $\Delta\bar{\sigma}_3$) using the following equation derived from the Mohrs circle of stress.

$$\Delta\overline{\sigma_n} = \frac{\left(\Delta\overline{\sigma_1} + \Delta\overline{\sigma_3}\right)}{2} + \frac{\left(\Delta\overline{\sigma_1} - \Delta\overline{\sigma_3}\right)}{2}\cos 2\theta_f \tag{5}$$

The angle of inclination of the shear failure plane (θ_f) is related to the drained internal friction angle of the soil by the following relationship:

$$\theta_f = 45° + \frac{\bar{\phi}}{2} \tag{6}$$

For $\bar{\phi} = 30°$, $\theta_f = 60°$. In addition, the major and minor principal effective stress increases ($\Delta\bar{\sigma}_1$ and $\Delta\bar{\sigma}_3$) correspond to the vertical and horizontal effective stress increases (i.e., $\Delta\bar{\sigma}_v$ and $\Delta\bar{\sigma}_h$), respectively, for the case of a loading of large areal extent on a horizontal subgrade surface. Therefore,

$$\Delta\overline{\sigma_1} = \Delta\overline{\sigma_v}$$

$$\Delta\overline{\sigma_3} = \Delta\overline{\sigma_h} \tag{7}$$

In addition, the vertical and horizontal effective stress increases are related by the at-rest lateral earth pressure coefficient (k_o) as follows:

$$\Delta\overline{\sigma_h} = k_o\,\Delta\overline{\sigma_v} \tag{8}$$

Also, k_o is related to $\bar{\phi}$ as follows:

$$k_o = 1 - \sin\bar{\phi} \tag{9}$$

For $\bar{\phi} = 30°$, $k_o = 0.5$. Using the values of $\theta_f = 60°$, $k_o = 0.5$ and the relationships of equations (7) and (8) as input to equation (5), the following relationship between $\Delta\bar{\sigma}_n$ and $\Delta\bar{\sigma}_v$ may be derived:

$$\Delta\overline{\sigma_n} = .625\,\Delta\overline{\sigma_v} \tag{10}$$

This relationship may then be input into equation (4) to derive the following:

$$c_u = c_{uo} + .625\ \Delta\overline{\sigma_v}\ \tan\overline{\phi} \tag{11}$$

The change in vertical effective stress ($\Delta\overline{\sigma}_v$) was calculated as the change in vertical total stress from the previous lift loading reduced by the average excess pore water pressure ($u_e(t)$) which exists within the fine-grained soil stratum thickness due to incomplete consolidation of these materials at the time the next lift loading is placed. This latter parameter ($u_e(t)$) was determined from the average degree of consolidation (U) of the stratum at this time as determined from the following expression:

$$u_e(t) = (1 - U)u_{ei} \tag{12}$$

The value of initial excess pore water pressure (u_{ei}) was assumed to be equal to the lift loading immediately following placement of the lift. This is an appropriate and reasonable assumption for a fully saturated, under or normally consolidated soil stratum subjected to a loading of large areal extent. Conventional time rate of settlement analysis procedures were used to calculate the average degree of consolidation of the stratum for the time interval between placement of a given MSW lift and a subsequent MSW lift at this same location at any point within the Phase V landfill footprint. The values of the coefficient of consolidation (c_v) of the dredge spoils/recent deposits used in this analysis were calculated for each waste lift placement condition from the functional relationship between c_v and permeability. In this regard, it is noted that the permeability of these materials decreases significantly with the placement of each successive waste lift due to the densification effects resulting from the significant settlements which these materials will undergo under load. This permeability decrease is estimated to be greater than one order of magnitude over the lifetime of the landfill. Values of c_v used in this analysis range from 0.007 to 0.014 in^2/minute. It is noted that the calculated degree of consolidation achieved within the fine-grained soil stratum during the referenced time intervals pertinent to the 10 MSW lifts varied from 16.0% to 31.2%. It is evident from these values that fully drained conditions within the dredge spoils/recent deposits never occurs during active filling of the landfill. Therefore, undrained bearing capacity governs the supporting capabilities of these fine-grained soils during the active life of the landfill.

Using the above analysis procedure, Figure 3-9 was prepared to illustrate the increase in the undrained cohesion of the dredge spoils and recent deposits as a function of the 10 MSW lifts. The initial values of undrained cohesion shown on this Figure (i.e., 290 psf for the dredge spoils and 865 psf for the recent deposits) represent the in-situ average values of this parameter as measured by field and laboratory shear strength testing. The selection of these values was based on the field and laboratory data of Figure 3-10. Note from this Figure that the numerical values noted above were determined from the $c_u/\overline{\sigma}_v$ relationship determined from $\overline{\text{CIU}}$ triaxial compression testing of undisturbed samples of the dredge spoil/recent deposit materials. However, direct measurement of c_u in UU triaxial compression tests and field vane shear tests, in general, support the $c_u/\overline{\sigma}_v$ relationship. Figure 3-11 was also prepared to illustrate the strength gain in both of these substrata as a function of time.

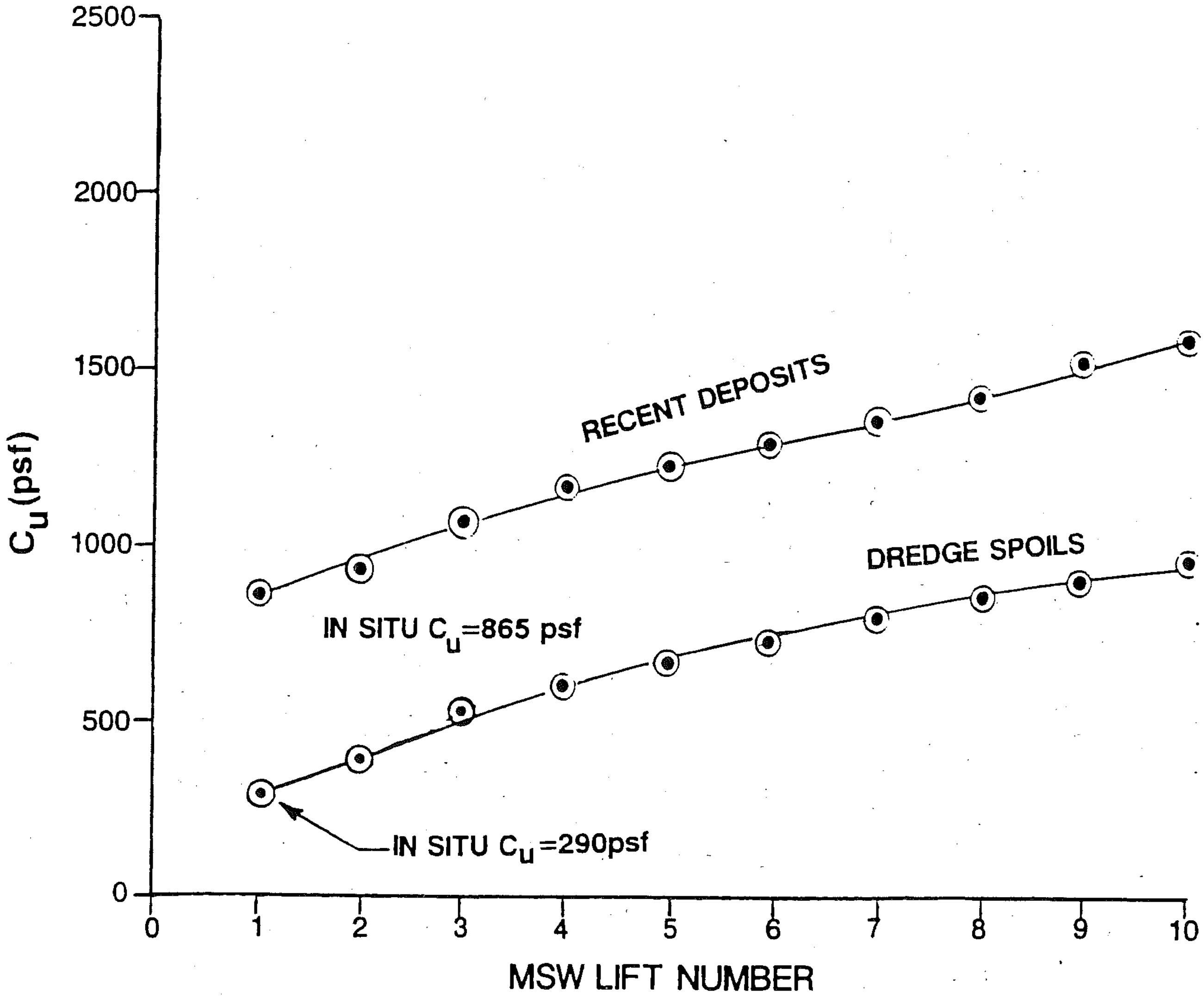

FIGURE 3-9
STRENGTH GAIN OF DREDGE SPOILS AND RECENT DEPOSITS AS A FUNCTION OF MSW LIFT NUMBER

DSWA PHASE V DISPOSAL AREA CHERRY ISLAND LANDFILL WILMINGTON, DELAWARE	ROY F. WESTON, INC. WESTON MANAGERS DESIGNERS/CONSULTANTS				
	DRAWN A. DELTUFFO	DATE 11/19/93	DES. ENG. J. WARTMAN	DATE	W. O. NO. 02477-004-001
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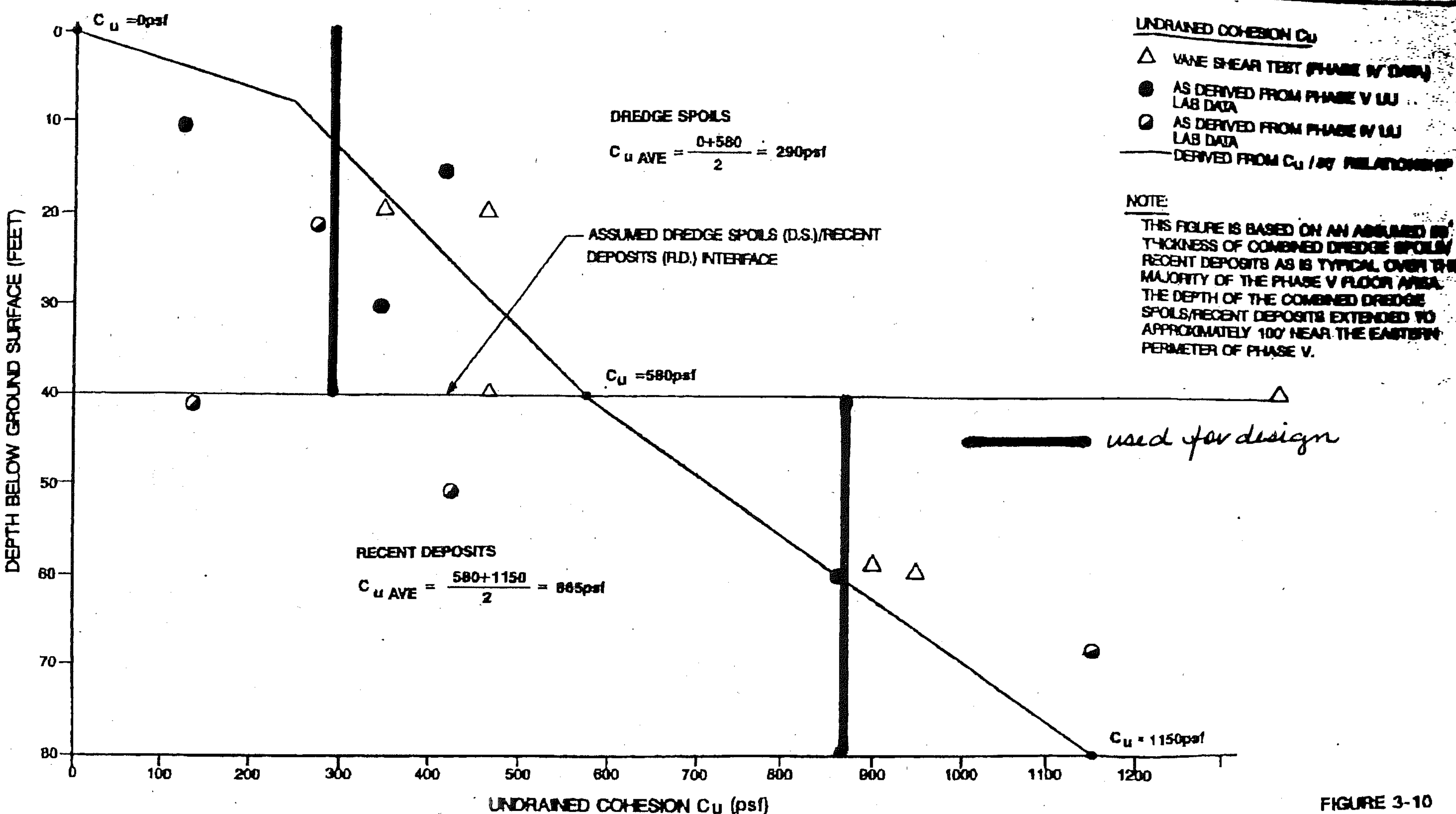

FIGURE 3-10

RESULTS OF FIELD AND LABORATORY MEASUREMENTS OF UNDRAINED COHESION FIGURE 3-10

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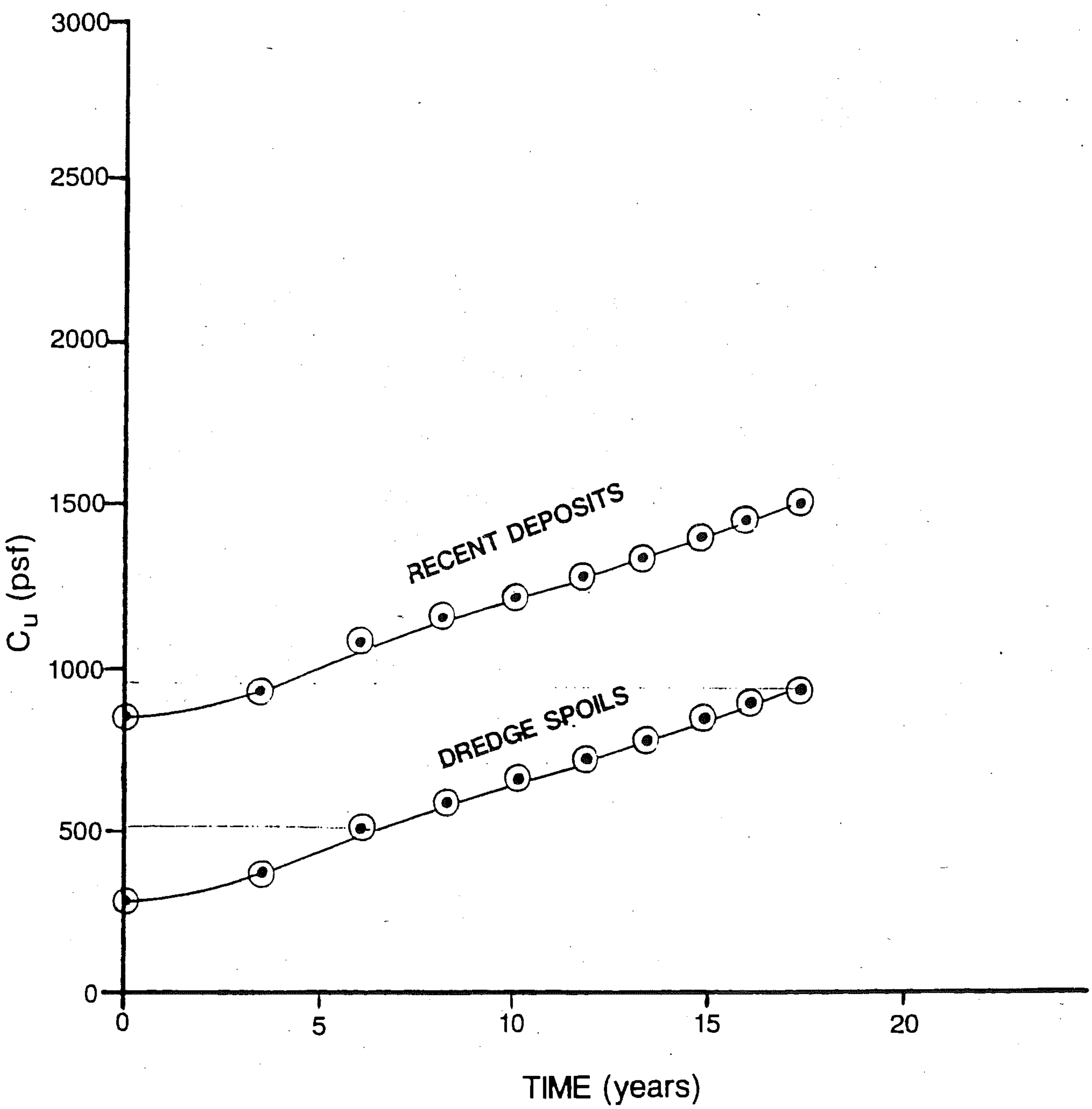

FIGURE 3-11
STRENGTH GAIN OF DREDGE SPOILS AND RECENT DEPOSITS AS A FUNCTION OF TIME

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The N_c factor for ϕ_u = 0° is 5.7 based on the Terzaghi theory. This value assumes that the same undrained cohesive shear strength exists within the entire thickness of the fine-grained soil stratum. However, as is evident from the above discussion, both the field and laboratory data suggest that the surficial dredge spoils are significantly lower in shear strength than the underlying recent deposits. Therefore, a quantitative procedure was used which allows this strength differential between substrata to be incorporated into the bearing capacity analysis through determination of an N_c' factor which is substituted for N_c in the undrained bearing capacity equation (Reddy et al, 1967). For the case of a higher cohesive shear strength soil underlying a surficial soil of lower cohesive shear strength, the N_c' factor is greater than N_c thereby increasing the value of q_{ult}. This analysis yielded N_c' factors which ranged from 9.8 for the first lift of waste to 8.2 for the tenth and final lift of waste.

The s_c factor in the Terzaghi bearing capacity equation is a shape factor which is determined from the geometry of the applied loading and was calculated as 1.26 for the undrained landfill bearing capacity analysis.

The results of the undrained bearing capacity analysis for the landfill are presented as a function of MSW lift in Figure 3-12. Note from this figure that the minimum calculated Factor of Safety value is 1.32 for the tenth and final lift of waste necessary to achieve the maximum height of the landfill at the top of the 3H:1V sideslope (i.e., 100 feet). This value is greater than the minimum acceptable Factor of Safety of 1.25 for dams, fills and embankment as recommended in the geotechnical literature (Bowles, 1988).

3.6.2.1.2 Sediment Pond Surcharge Berm

An undrained bearing capacity analysis was also completed for the sediment pond surcharge berm. The reduced form of the Terzaghi undrained soil bearing capacity equation, as discussed above, was also used in this analysis. Values of 8.8 and 1.0 were calculated for N_c' and s_c, respectively, based on the assumed surcharge berm geometry (i.e., 10 ft high, 1,000 ft long, 100 ft wide at the top, approximate 3H:1V outslopes). Since construction of the berm was assumed to be instantaneous, the in-situ undrained shear strength of the dredge spoils and recent deposits (i.e., 290 psf and 865 psf, respectively) were used in this analysis (i.e. no strength gain was assumed). This undrained bearing capacity analysis yielded an acceptable Factor of Safety value of 2.45.

3.6.2.2 Drained Analysis

A drained bearing capacity analysis was completed for both the landfill and the sediment pond surcharge berm and is discussed as follows.

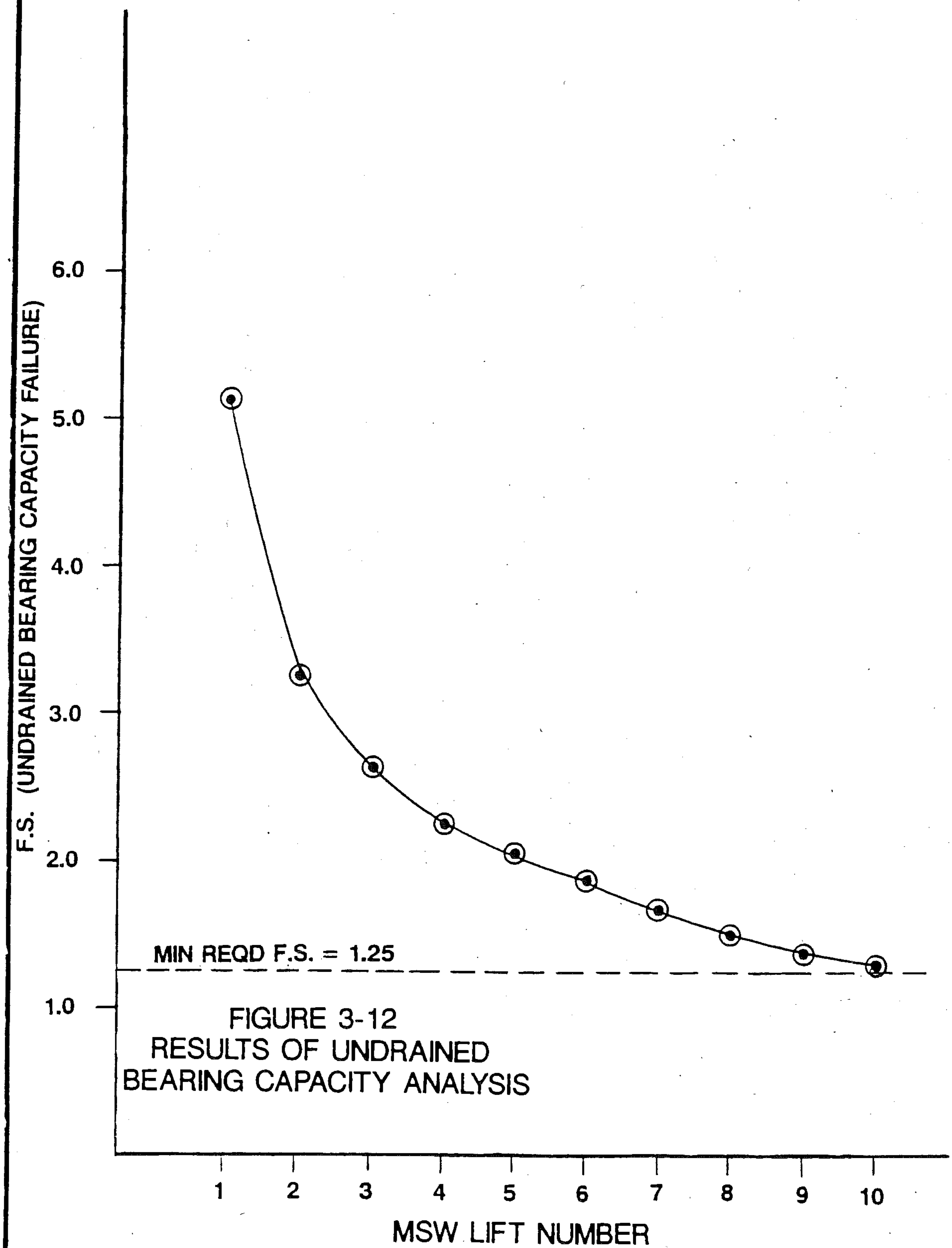

FIGURE 3-12
RESULTS OF UNDRAINED
BEARING CAPACITY ANALYSIS

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3.6.2.2.1 Landfill

As discussed above, the undrained bearing capacity of the dredge spoils/recent deposits governs the supporting capabilities of these soils as the landfill is being raised to its final design height. Approximately 89 years following placement of the final MSW lift, these soil strata will have fully dissipated excess pore water pressures induced by the landfill loadings. At and beyond this time, the shear strength and bearing capacity of these soils will be governed by the drained soil shear strength parameters of these materials. Therefore, a drained bearing capacity analysis was completed to evaluate the long-term capabilities of these soils to support the finished landfill loadings. The factor of safety (FS) against a potential bearing capacity failure under drained soil shear strength conditions was defined as follows:

$$FS = q_{ult}/q_{actual} \tag{13}$$

In this equation, q_{ult} is the ultimate bearing capacity of the soil as determined using drained soil shear strength parameters while q_{actual} is the landfill loading under the full finished landfill height condition.

Under drained soil shear strength conditions, the effective stress shear strength parameters ($\bar{c}$, $\bar{\phi}$) of the supporting soils are used in the analysis. A value of $\bar{\phi}$ = 30° was assumed for this analysis based on $\overline{CIU}$ triaxial shear strength testing of Shelby Tube samples of these soils. Cohesion was conservatively neglected in this analysis. The value of $\bar{\phi}$ was then reduced using the following expression:

$$\bar{\phi}_L = Tan^{-1}(2/3\ Tan\ \bar{\phi}) \tag{14}$$

This reduction accounts for the probability that local, rather than general, shear failure conditions (i.e., considerable vertical soil movement) would most likely develop in these soils before major shear movements occur in the event of a bearing capacity failure.

Under drained soil shear strength conditions with a cohesion value of zero, the Terzaghi bearing capacity equation appropriate to an applied loading at the ground surface of the supporting soils (i.e., D_f = 0) becomes:

$$q_{ult} = \tfrac{1}{2}\,\gamma B N_{\gamma L}\, s_\gamma\, r_\gamma \tag{15}$$

The bearing capacity factor $N_{\gamma L}$ is a function of $\bar{\phi}$ and was determined from tabulated values of these parameters pertinent to the local shear failure assumption. The loading shape factor, s_γ, can vary between 0.8 and 1.0 depending on the length to width ratio of the loading footprint. A conservative value of s_γ = 0.8 was used in the analysis. The least lateral dimension of the landfill footprint (B) was assumed to be 2,700 feet. This value was reduced by the r_γ factor appropriate for use in the case of large loading footprints. The value of this factor was calculated to be .337. Finally, a total soil unit weight (γ) of 95.5 pcf was selected consistent with the results of laboratory tests completed on "undisturbed" Shelby tube samples of the dredge spoil/recent deposit materials.

Based on this analysis, a Factor of Safety of 8.8 against long-term bearing capacity failure under drained soil shear strength conditions for the finished landfill loading was determined. This value is significantly greater than the recommended minimum value of 3.0 as determined by conventional geotechnical engineering practice.

3.6.2.2.2 Sediment Pond Surcharge Berm

A drained bearing capacity analysis was also completed for the sediment pond surcharge berm. The Terzaghi drained soil bearing capacity equation, as discussed above, was also used in this analysis. Values of 117 ft, 0.976, and 0.677 were calculated for B, s_γ, and r_γ, respectively, based on the assumed geometry of the surcharge berm. The drained bearing capacity analysis yielded an acceptable Factor of Safety value of 7.1.

3.6.3 Settlement Analysis

A settlement analysis was completed to estimate total and differential settlements which will occur within the fine-grained dredge spoils/recent deposits which underlie the landfill footprint as a result of the landfill loadings. A total of three (3) laboratory consolidation tests were completed to define the input parameters for the settlement analysis. The complete data sets from these consolidation tests are presented in Appendix B.

The stratigraphic profile used in the settlement analysis is shown in Figure 3-13. As shown on this Figure, the 80-foot fine grained soil stratum was divided into four 20-foot substrata for this analysis. A series of recent topographic mappings of the site indicate that the fine-grained soils over the floor of Phase V are settling approximately 1 to 2 feet per year under self weight. Based on this information, and as verified by the laboratory consolidation test data, the fine grained soils were determined to be underconsolidated. The total settlement (ΔH_{TOT}) within these underconsolidated soils was therefore calculated from the following general settlement equation.

$$\Delta H_{TOT\,(underconsolidated)} = \Delta H_{uc} + \Delta H_{pc} \qquad (16)$$

in which:

ΔH_{uc} = Settlement due to self weight resulting from the underconsolidated condition of the dredge spoils/recent deposits at the present time.

ΔH_{pc} = Settlement resulting from the landfill loadings (i.e., primary consolidation).

Appropriate procedures for underconsolidated soils as shown in Figure 3-14 were then used to construct the field e/log p curves from the laboratory e/log p curves. The field compression index (C_{cf}) was subsequently determined as the slope of the virgin compression limb of these curves. The largest C_{cf} value from the three (3) consolidation tests was then conservatively assigned to each of the four (4) substrata. The settlement due to combined underconsolidation and primary consolidation effects resulting from the assumed landfill surcharge loading was then determined from the following equation for each of the four

LEGEND

▼ - Depth to saturated dredge spoils. (This varied from 8 to 14 feet and was conservatively assumed to be 8 feet.) ~ 14 ft ?

γ_{sat} - Saturated unit weight values as determined from the consolidation test data.

e_o - Initial void ratio values as determined from the consolidation test data.

C_{cf} - Compression index values as determined from the field e/log p curve as graphically constructed from the laboratory e/log p curve using appropriate procedures for underconsolidated soils (i.e. soils in which $P_c < \bar{\sigma}_o$).

H - Thickness of compressible soil stratum. (This includes entire thickness of dredge spoils and recent deposits strata, and was assumed to be 80 feet).

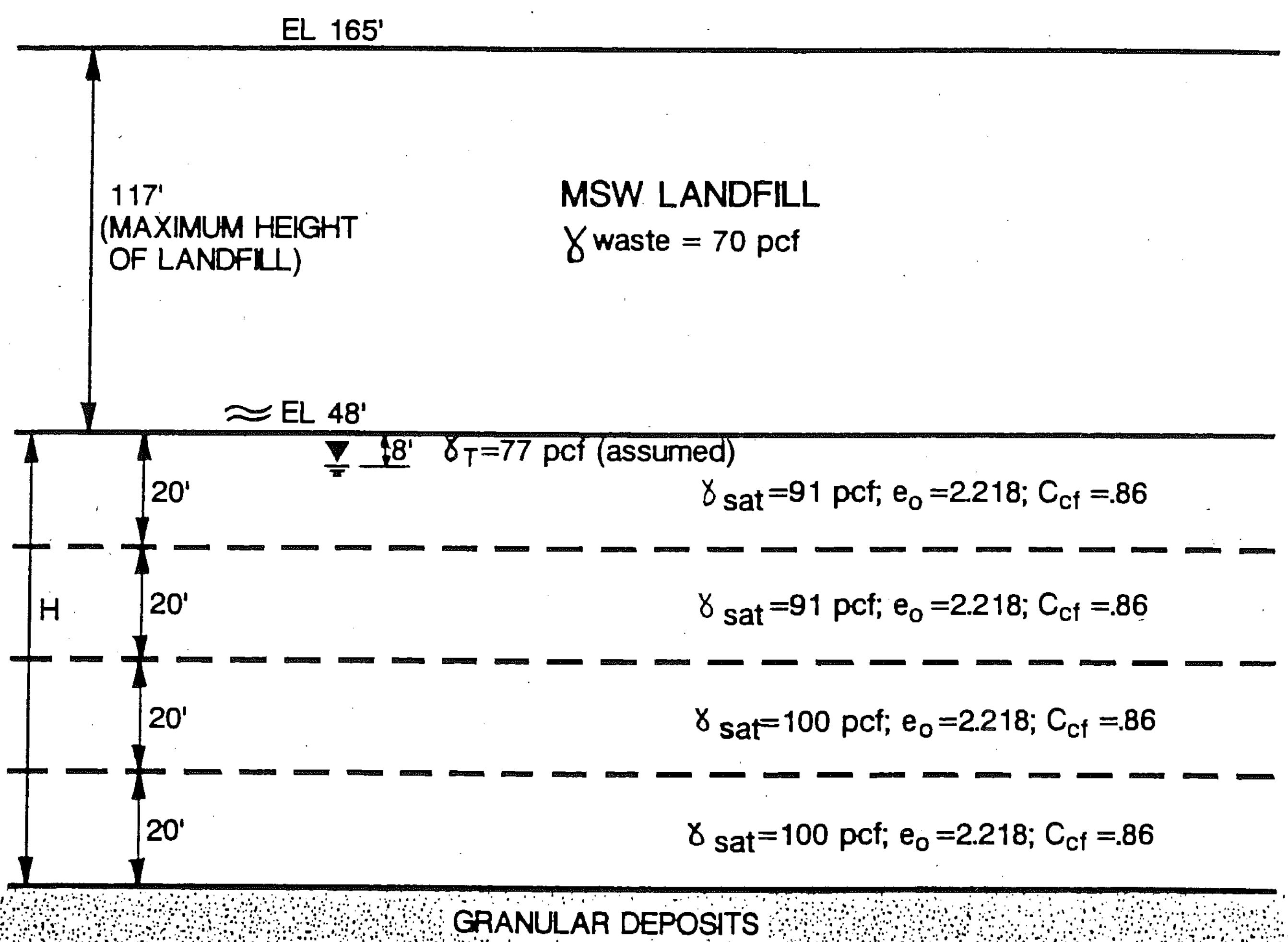

FIGURE 3-13
ASSUMED STRATIGRAPHIC PROFILE
FOR SETTLEMENT ANALYSIS

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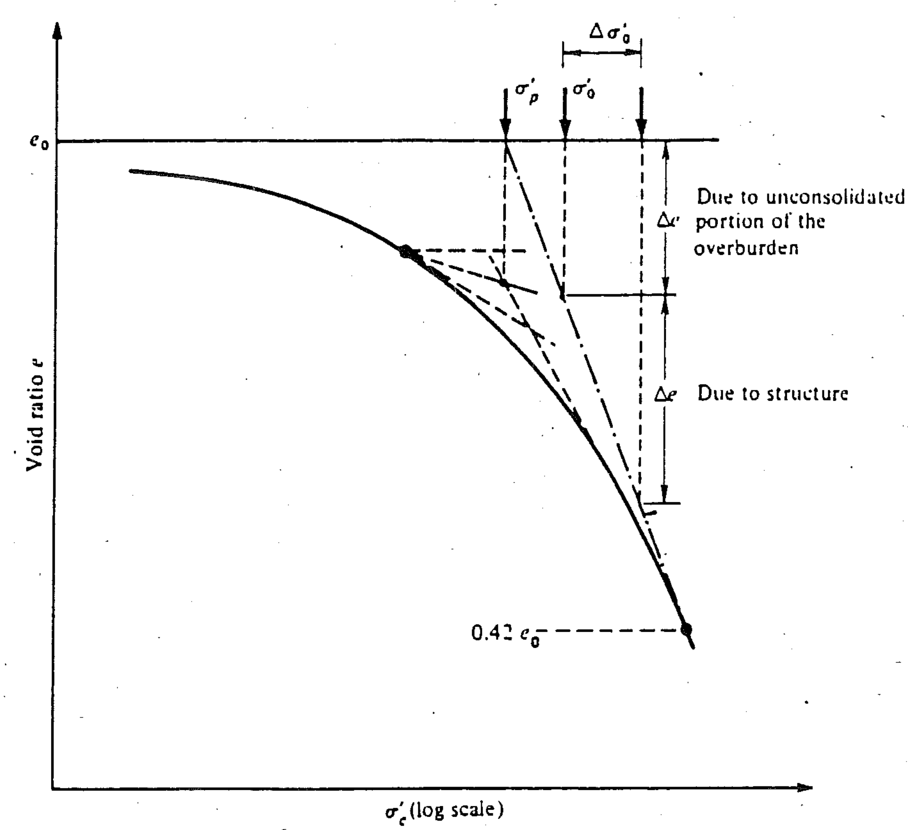

FIGURE 3-14
COMPRESSIBILITY OF
UNDERCONSOLIDATED COHESIVE SOIL

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substrata. These values were then summed to yield the total estimated settlement of the fine-grained dredge spoil and recent deposit materials.

$$\Delta H_{tot} = \frac{HC_{cf}}{1+e_o} \log \frac{(\bar{\sigma}_o + \Delta\sigma)}{P_c} \tag{17}$$

in which:

e_o = Initial void ratio
H = Thickness of the substratum
σ_o = Existing effective stress at mid-height of the sub-stratum
$\Delta\sigma$ = Surcharge loading from landfill weight
P_c = Preconsolidation pressure of soil as determined from the consolidation test data

This analysis yielded a total settlement due to underconsolidation and primary consolidation effects of approximately 19 feet.

Secondary compression in fine-grained soil strata is also a major design consideration. However, the laboratory test results indicate that secondary compression of the dredge spoils and recent deposits will not become significant until approximately 89 years after placement of the last lift of MSW (i.e., after primary consolidation of these materials is complete). Since this time period is well beyond the 30 year post-closure landfill monitoring period, settlements due to secondary compression were neglected.

To set landfill floor and leachate collection pipe grades, it is necessary to predict what percentage of this total settlement can be differential in nature. A procedure by Bjerrum was used for this purpose (Lambe and Whitman, 1969). Based on this procedure, it has been determined that the maximum potential differential settlement at the site is approximately 7.6 feet. Based on this value, the following design criteria have been established to compensate for the differential settlement potential of the site to the extent possible:

1. A "sawtooth" configuration consisting of multiple highpoints and lowpoints will be constructed across the width and length of the Phase V Landfill footprint. These depressions will be sloped at 2% grades (DNREC Controlling Slope Criterion) from highpoints near existing site grades (approximately elevation 48 feet) to lowpoints at which leachate collection pipes (laterals) will be located. These leachate collection laterals will be entrenched within a coarse gravel annulus. The leachate collection laterals will be spaced at a maximum distance of 150 feet.

2. Leachate will be conveyed from the leachate collection laterals to leachate collection headers. These leachate collection headers will transmit leachate to a series of wet wells which are located around the perimeter of the Phase V Landfill. The proposed design configuration of the laterals and headers of the

leachate collection system will reduce the required length of these sloping pipes. This in turn will allow this piping to be set at steeper inclinations as necessary to accommodate the potential differential settlement of the site, while, at the same time, will result in more readily constructable trench depths at the header endpoints.

3. As illustrated in Figure 3-15, the leachate collection laterals will be set at a minimum longitudinal inclination of 1% at locations behind the top of slope of the 3H:1V outslope of the landfill. At the top of the 3H:1V outslope, the piping inclination will be increased to a minimum of 3% to accommodate a greater differential settlement potential at these locations where the landfill height, and therefore the surcharge loading, varies significantly over relatively short distances.

4. To facilitate effective leachate flow from the floor of the landfill to the collection pipes, a 12-inch thick granular soil drainage blanket of at least 1 x 10^{-2} cm/sec permeability will be placed atop the entire Phase V footprint. (This granular soil layer is also extremely important to the design from the perspective of natural soil liner permeability as discussed in Subsection 3.6.4 of this report.) To reduce the probability of this granular soil layer becoming discontinuous with time due to differential settlement, a woven geotextile will initially be placed over the graded landfill bottom before placing the overlying granular soil. This geotextile will also help to reinforce the underlying weak dredge spoils, thereby reducing the probability of bearing capacity and/or slope failures occurring along the leading edge of the waste filling operations. The geotextile will also tend to somewhat equalize total settlements, thereby reducing the potential for the occurrence of significant differential settlements. It will also prevent the granular soil particles from being driven into, and mixed with, the underlying dredge spoils by construction equipment loads and/or future overlying waste overburden, thereby increasing the probability of maintaining the continuous nature and design thickness of this layer. Finally, its reinforcement capabilities will also facilitate more efficient fill placement across the landfill footprint during filling of the first lift of waste.

3.6.4 Natural Soil Liner

The approximate 80 to 100 foot thickness of the dredge spoils/recent deposits stratum is proposed for use as a natural soil liner for leachate containment at this site. The ability of these materials to effectively act as a liner is impacted by the permeability and geochemical properties of these materials as discussed below.

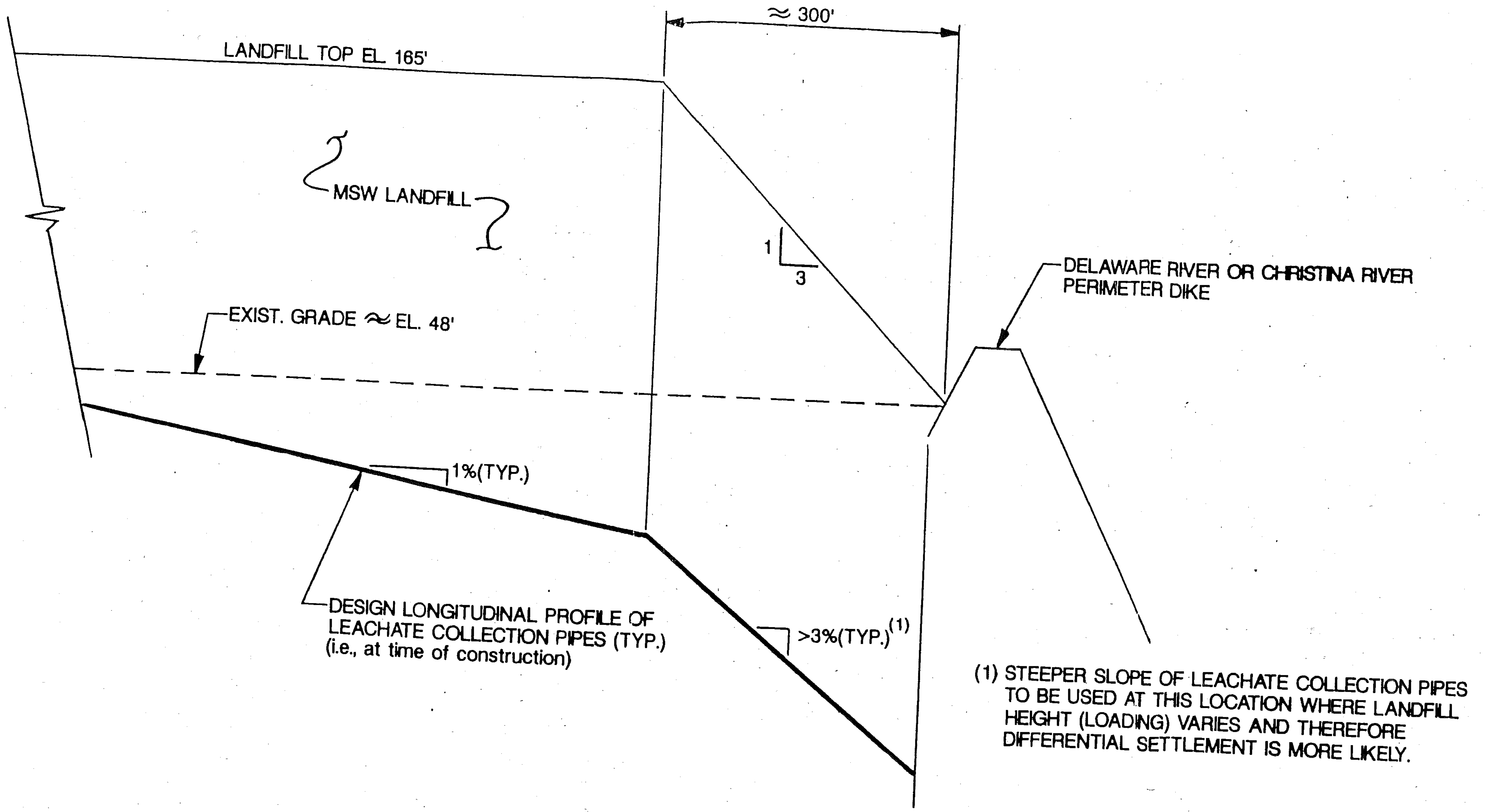

FIGURE 3-15
PHASE IV LEACHATE COLLECTION SYSTEM: LONGITUDINAL PROFILE OF LEACHATE COLLECTION PIPES

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3.6.4.1 Permeability

It is proposed to permit and operate the Phase V Disposal Area using the fine-grained dredge spoils and recent deposits as a natural soil liner. The DNREC MSW regulations allow use of a natural soil liner if there is at least 5 feet of thickness of these materials within which the vertical permeability is less than or equal to 1×10^{-7} cm/sec. To investigate this, WESTON completed a series of four (4) flexible wall permeability tests on four undisturbed Shelby Tube samples of these soils obtained from borings which underlie the proposed landfill footprint. These Shelby Tubes were selected at varying depths within the fine-grained stratum thickness, ranging from 17 feet to 71 feet below the existing ground surface. The permeability tests were completed using MSW landfill leachate from the active Phase of the Cherry Island landfill as the permeant. The procedures of EPA Test Method 9100, "Saturated Hydraulic Conductivity, Saturated Leachate Conductivity and Intrinsic Permeability" were used to complete these tests.

The results of the permeability testing program are presented in Table 3-1. The complete laboratory data package is presented in Appendix B. The value of σ_{3i} shown in this Table is the initial confining pressure under which the sample was fully consolidated before the equilibrium permeability value ($K_{\sigma 3i}$) was measured. The value of σ_{3i} was calculated as the horizontal effective stress at the mid-depth of the respective Shelby Tube under the existing overburden conditions. Based on this discussion, it is evident that the value of $K_{\sigma 3i}$ represents the in situ permeability of the fine-grained soils at the Shelby Tube depth before the proposed landfill loadings are applied.

The value of σ_{3f} shown in Table 3-1 is the final confining pressure under which the sample was fully consolidated before the equilibrium permeability value ($K_{\sigma 3f}$) was measured. The value of σ_{3f} was calculated as the horizontal effective stress at the mid-depth of the respective Shelby Tube under the final overburden conditions (i.e., with the full landfill height in place). Based on this discussion, it is evident that the value of $K_{\sigma 3f}$ represents the permeability of the fine-grained soils after the full landfill loading has been applied and the material has fully consolidated and therefore densified in response to this loading.

An inspection of the results of Table 3-1 indicates the following:

1. The vertical permeability of the dredge spoils and recent deposits under the existing overburden conditions is slightly greater than the maximum regulated value of 1×10^{-7} cm/sec for two of the four values.

2. The vertical permeability of both the dredge spoils and the recent deposits under the final overburden conditions (i.e., full landfill height in place) is consistently less than the maximum regulated value of 1×10^{-7} cm/sec by a factor of approximately 5 to 10.

Table 3-1

Permeability Test Results

Test No.	Boring No.	Shelby Tube Depth (feet)	Substratum[1]	σ_{3i} (psi)	$K_{\sigma 3i}$ (cm/sec)	σ_{3f} (psi)	$K_{\sigma 3f}$ (cm/sec)
1	TB-11	16-18	Dredge Spoils	3.1	8.55×10^{-8}	30.8	1.35×10^{-8}
2	TB-12	30-32	Dredge Spoils	4.7	1.71×10^{-7}	31.8	2.28×10^{-8}
3	TB-15	50-52	Recent Deposits	7.2	8.22×10^{-8}	34.2	1.67×10^{-8}
4	TB-13	70-72	Recent Deposits	9.5	1.44×10^{-7}	36.5	2.42×10^{-8}

Based on WESTON's review of the DNREC regulations, it is our interpretation that the term "natural liner" is meant to connote low permeability soil or soil-like materials which directly underlie the leachate collection system of the landfill. Based on this definition, it is possible that the regulatory agencies may consider the dredge spoils alone and not the combined thickness of the dredge spoils and the geotechnically similar recent deposits as the "natural liner" for regulatory purposes. Based on this interpretation, the dredge spoils do not initially satisfy the "natural liner" requirements of the DNREC regulations since the TB-12 Shelby Tube indicates that this material does not presently possess a permeability of less than $1x10^{-7}$ cm/sec at its existing density condition. However, as discussed previously in the bearing capacity section of this report, at no time during active filling of the landfill will drained conditions (i.e., hydrostatic pore water pressure conditions) be attained within the dredge spoils/recent deposits stratum thickness. Instead, excess pore water pressures generated from the various waste lift loadings will exist within these fine-grained soils at all times until approximately 89 years after the final waste lift has been placed. Only after this time will excess pore water pressures induced by the landfill loadings be fully dissipated with hydrostatic pore water pressures re-established in the saturated zone of the fine-grained soil stratum. The minimum value of excess pore water pressure (u_e) within the dredge spoils/recent deposits stratum thickness at any time during the life of the landfill occurs after the first lift of waste has been in place for its calculated operational life (i.e, 3.52 years), but immediately before the second lift of waste is placed at this same location. This value of excess pore water pressure was calculated to be 482 psf. Excess pore water pressures within the dredge spoils/recent deposits will, in turn, induce flow in both the upward and downward vertical directions to drainage boundaries as the stratum consolidates under the landfill loadings. As part of the Phase V landfill's leachate collection system, the proposed design will incorporate a 12-inch thick granular soil drainage blanket of at least 1×10^{-2} cm/sec permeability over the entire Phase V landfill footprint. In addition to facilitating effective flow of leachate to the leachate collection piping system, this drainage blanket also represents a drainage medium atop the dredge spoils which will readily accept pore water which is being driven vertically upward from the upper half of the consolidating fine-grained soil stratum thickness. Therefore, upward flow of pore water from the dredge spoils into the drainage blanket will be induced by the consolidation process. That is, an upward vertical flow gradient will be developed during the consolidation process.

Recognizing that the consolidation process of the dredge spoil/recent deposit materials will create upward vertical flow of soil pore water, the minimum load induced excess pore water pressure of 482 psf within this stratum at any time during the active life of the landfill can be converted to an equivalent upward vertical head of leachate (h_L) using the expression.

$$h_L = u_e/\gamma_L \quad (18)$$

In this equation, the unit weight of leachate (γ_L) was assumed to be 66 pcf, that is, slightly greater than water to account for particulates in the liquid. Using this equation, the calculated equivalent minimum upward vertical leachate head is 7.3 feet. In addition, the selected landfill bottom slope (i.e., 2%) and leachate collection system piping configuration and spacing will limit the maximum leachate head buildup to 0.89 feet based on an equation determined by Giroud (1988). (Note that this head buildup is less than the design thickness of the granular soil drainage blanket so as to permit effective flow of leachate to collection pipes.) Therefore, the pressure head with which the leachate is being driven vertically downward is, at all times during active filling of the landfill, significantly less than the pressure head of the soil pore water which is being driven vertically upward from the upper half of the consolidating fine-grained soil stratum. Therefore, downward vertical migration of leachate cannot occur during active filling of the landfill. Even in the instance in which differential settlement may reduce the "sawtooth" surface slope from 2% to a flat condition (i.e., 0%), the maximum estimated leachate head buildup would be 1.4 feet. This value is still significantly less than the minimum equivalent upward vertical leachate head (7.3 feet) induced by the consolidating soil stratum, thereby also precluding downward vertical migration of leachate under this condition. Only after the final landfill height has been achieved and all excess pore water pressures have been fully dissipated can downward vertical migration of leachate occur. At this time, as shown in Table 3-1, the entire 80 to 100 foot dredge spoils/recent deposits stratum thickness has achieved a permeability of less than $1x10^{-7}$ cm/sec. Therefore, upon completion of active filling of the Phase V landfill, only after which time can downward vertical migration of leachate begin, the 80 foot thickness of the fine-grained soil stratum at this site is providing at least 16 times the minimum 5 foot thickness of natural soil liner required by the DNREC regulations.

The effects of permeability reduction as a function of increasing landfill height within the near surface dredge spoils was also investigated. In this regard, a fifth flexible wall permeability test was completed on a Shelby Tube sample of the dredge spoils obtained from Boring TB-12 at a depth of 12 to 14 feet below existing ground surface. This test determined the equilibrium vertical permeability value of these soils when fully consolidated under confining pressures which correspond to 0, 25, 50, 75, and 100 feet of landfill height using Cherry Island MSW leachate as the permeant. These five data points were subsequently plotted as shown in Figure 3-16. As is evident from this figure, a permeability of significantly less than $1x10^{-7}$ cm/sec is achieved in the near surface dredge spoils following partial consolidation of the fine-grained soil stratum at a very early stage during the active life of the landfill. This is well before the time period necessary to complete active filling of the landfill during which time, as noted above, vertical downward migration of leachate cannot occur.

3.6.4.2 Geochemical Properties of the Dredge Spoils/Recent Deposits in Support of the Subtitle D Approval Process

The results of the permeability tests presented in the previous subsection indicate that the proposed natural soil liner consisting of the dredge spoils/recent deposits meets the current DNREC Solid Waste Regulations (March 1990). To paraphrase the developed argument, a portion of the dredge spoils thickness has a measured permeability which is slightly greater than 1×10^{-7} cm/sec prior to waste placement in the Phase V area. However, once waste is placed atop these materials, an upward vertical flow gradient due to excess pore water pressures will be created as the dredge spoils consolidate in response to the landfill loadings. As landfilling continues, the consolidation/soil densification process reduces the permeability of these materials to less than 1×10^{-7} cm/sec. Excess pore water pressures are not totally dissipated until long after the active life of the landfill, thereby maintaining this upward flow

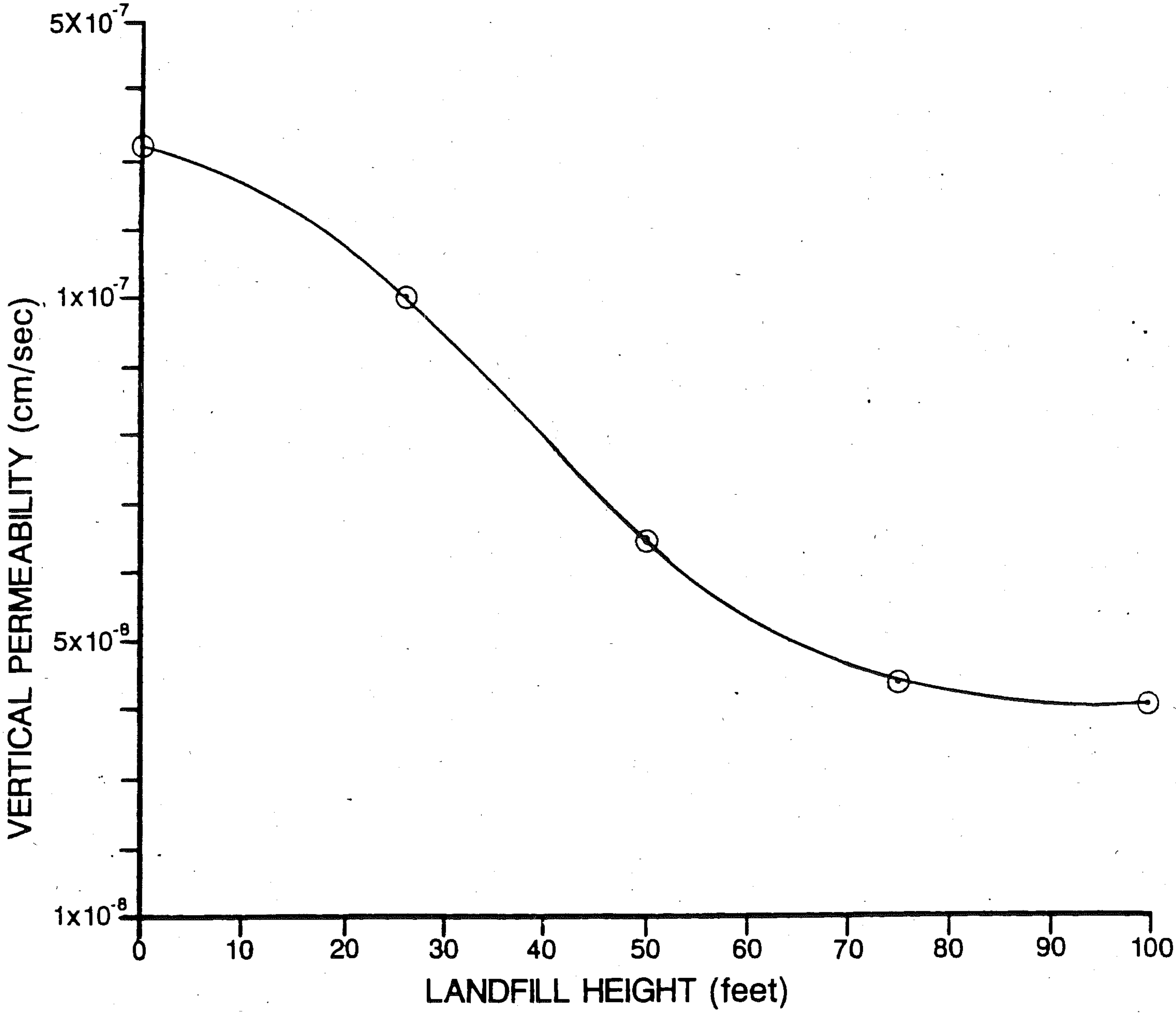

FIGURE 3-16
RELATIONSHIP OF VERTICAL PERMEABILITY AND LANDFILL HEIGHT

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gradient from the dredge spoils into the leachate collection system during this time period, and, in the process, prohibiting the downward migration of landfill leachate. Once excess pore water pressures have fully dissipated long after the active life of the landfill such that downward vertical migration of leachate can occur, the consolidation/soil densification process has reduced the permeability of the fine-grained soils to considerably less than the regulated 1×10^{-7} cm/sec minimum value.

The most recent federal RCRA Subtitle D regulations (October 1991) require that the lining system of all new solid waste landfills consist of a composite liner or an alternative design that meets the performance standards outlined in these regulations. Due to the unique subsurface conditions at Cherry Island (i.e., a soft weak subgrade which will generate significant differential settlements when loaded), an effective composite lining system is not deemed feasible. Subtitle D allows for alternative lining systems if it can be demonstrated that the design meets the regulated performance criteria. The performance criteria requires that the lining system provide secure containment such that the regulatory concentrations (based on Federal Drinking Water Standards) of selected target analytes not be exceeded at a selected compliance point within the designated critical water bearing unit below the site. The critical water bearing unit that would most probably be monitored for this purpose is the Potomac Formation, since the quality of the groundwater within the Columbia Formation, which is the only other significant water bearing zone above the Potomac, is poor (i.e., non-potable) and is not used as a drinking water source. However, it is noted that the compliance point has not been delineated at this time. As has been discussed previously, a positive upward gradient will be established in the dredge spoils until well after the operating life of the landfill. At that time, leachate concentrations will be much lower than during the active life of the landfill, and the permeability of the dredge spoils/recent deposits will have decreased to less than 1.0×10^{-7} cm/sec. These factors are therefore believed to render the hydraulic characteristics of Cherry Island favorable to the development of the Phase V landfill using an alternative lining system design under the Subtitle D regulations by meeting the intent of the performance criteria.

In order to provide further data to support the conformance of the proposed alternative design to the Subtitle D regulations, geochemical tests were also performed. The purpose of these tests was to provide data on the general geochemical properties of the dredge spoils/recent deposits which define the ability of these materials to adsorb, retard and retain potential migration of contaminants. The geochemical testing which was completed included Cation Exchange Capacity (CEC) on dredge spoils/recent deposits samples. The results of these tests are summarized on Table 3-2. The results of the CEC tests indicate that the dredge spoils/recent deposits possess a CEC ranging from 26.5 to 34.0 meq/100g. These values are consistent with published values for clayey silts, silty loams, and low plasticity silts. CEC provides a qualitative geochemical parameter of a soil's potential to absorb positive charged contaminants such as heavy metals. For the CEC values determined for the dredge spoils/recent deposits at the Phase V landfill site, the exchange of metals at potential cation adsorption sites is highly favored. (It is noted as a point of reference that the pH values and organic carbon content of the dredge spoils/recent deposits measured as part of the Phase IV landfill design also indicated favorable retention of metals within these materials in this section of the Cherry Island site).

Table 3-2

Results of Geochemical Tests on Dredge Spoils/Recent Deposits

Boring No.	Sample No.	Depth (ft)	CEC meq/100g
TB-11	S12	60.5-62	26.5
TB-12	53	10-11.5	33.7
TB-13	56	25-26.5	34.0
TB-11	DUP	60.5-62	28.5

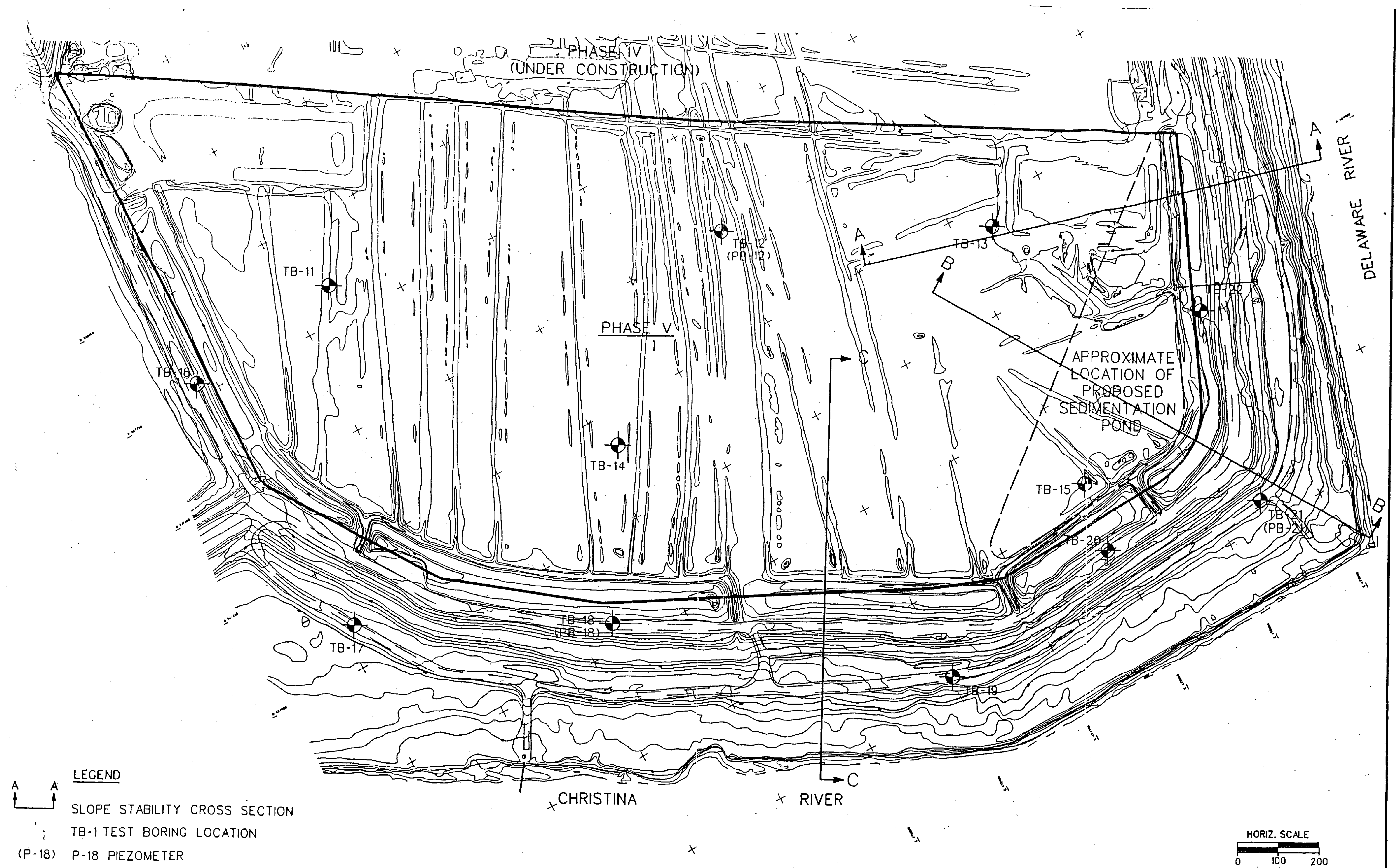
In summary, the geochemical test results indicate that, in addition to the favorable hydrogeologic conditions and low permeability of the dredge spoils/recent deposits, the proposed natural liner system materials favor the adsorption of heavy metals compounds. This data and that obtained for Phases III and IV can also be used to model the potential migration of these compounds to a compliance point if required under the Subtitle D State program approval process.

3.6.5 Slope Stability Analysis

The geotechnical and topographic data provided on both the soil boring logs and the topographic survey drawing were analyzed for the purpose of identifying and developing critical cross sections located along the perimeter of Phase V for slope stability analysis. A total of three (3) critical cross sections were identified at the locations shown on Figure 3-17. Two of the cross-sections are projected through the earthen perimeter berms along the Delaware and Christina Rivers. The third cross section is located in the southeastern portion of the Phase V area and is projected through the proposed landfill sideslope and sediment basin. The developed cross sections are shown on Figures 3-18 through 3-20. It is also noted that slope stability was not evaluated along the western portion of the Phase V landfill footprint due to the anticipated counter weight effect (i.e., resistivity force to a shear failure through the adjacent landfill mass) within the Wilmington Area of Cherry Island.

The slope stability analysis was completed using the computer program STABL4 which utilizes the Modified Bishop Method of Slices analysis procedure to calculate the minimum Factor of Safety value for the slope. This procedure defines a large number of potential circular arc failure surfaces through the slope and calculates the Factor of Safety of each failure surface by dividing the failure mass into an appropriate number of slices. The overall moment and force equilibrium for each slice is then statically analyzed for undrained, partially drained, or fully drained soil shear strength conditions. The generated Factor of Safety values for these conditions are then searched by the computer for the minimum values. These values are compared with minimum acceptable values for both short term (i.e., undrained or partially drained) and long term (i.e., drained) soil shear strength conditions within the landfill foundation soils. It should be noted that this analysis can predict the likelihood of failure via the computed Factor of Safety values as well as the location of the critical failure surface. However, it cannot predict the duration of the failure should it occur. That is, it cannot differentiate between a sudden failure and one that will gradually occur over a long time period as a result of "creep" movements.

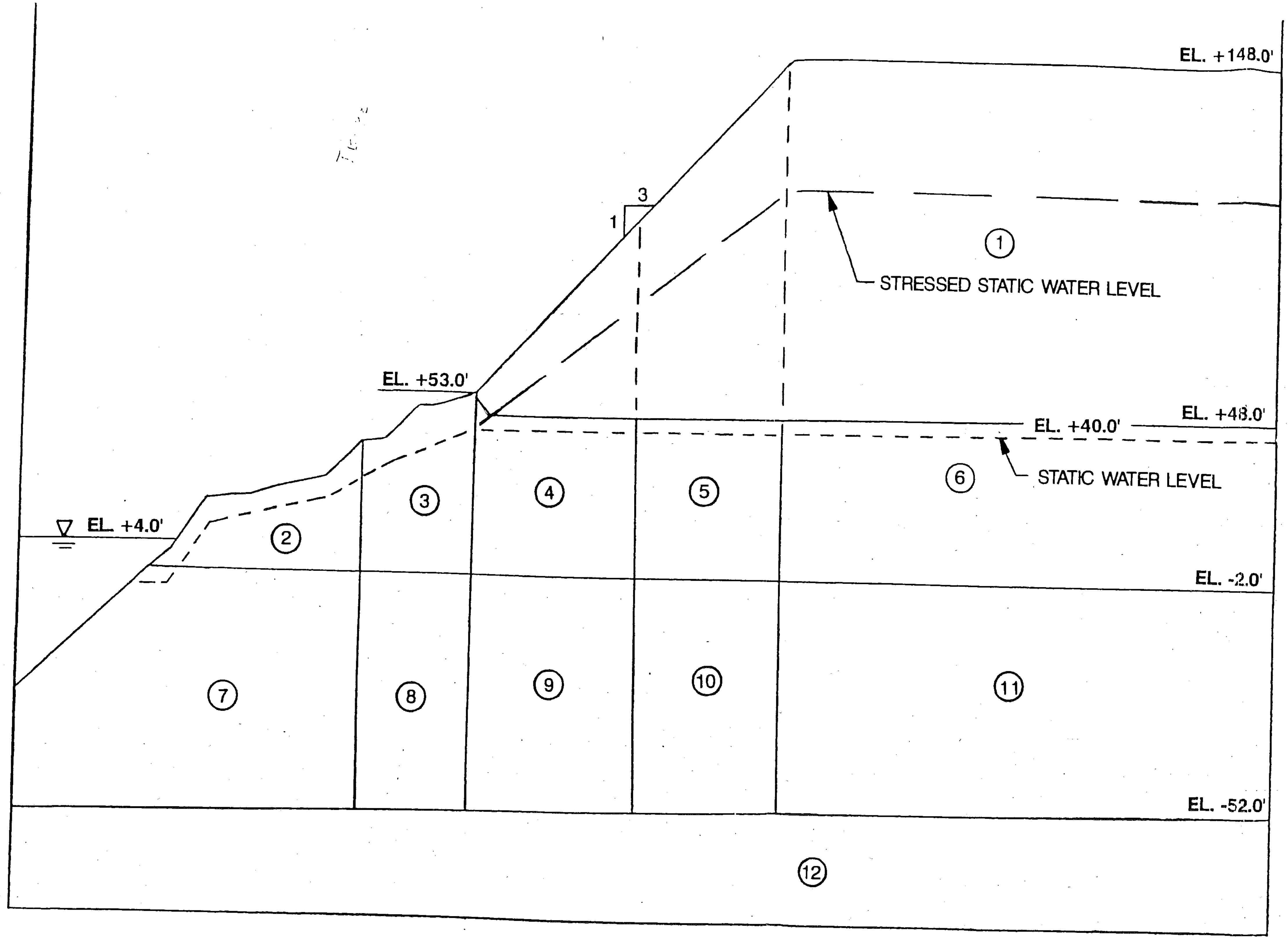
The remainder of this report section discusses in detail the referenced slope stability analysis. A discussion of the Modified Bishop Method of Slices computer program (STABL4) used to complete these slope stability analyses is presented in Appendix C of this report. Results (i.e., computer input and output data) of the various slope stability analyses which were completed are presented in Appendix D.



DSWA PHASE V
CHERRY ISLAND LANDFILL
WILMINGTON DELAWARE

DCN: 02477-004-001-

DSWA PHASE V
SLOPE STABILITY PROFILE
LOCATION PLAN



SOIL LEGEND

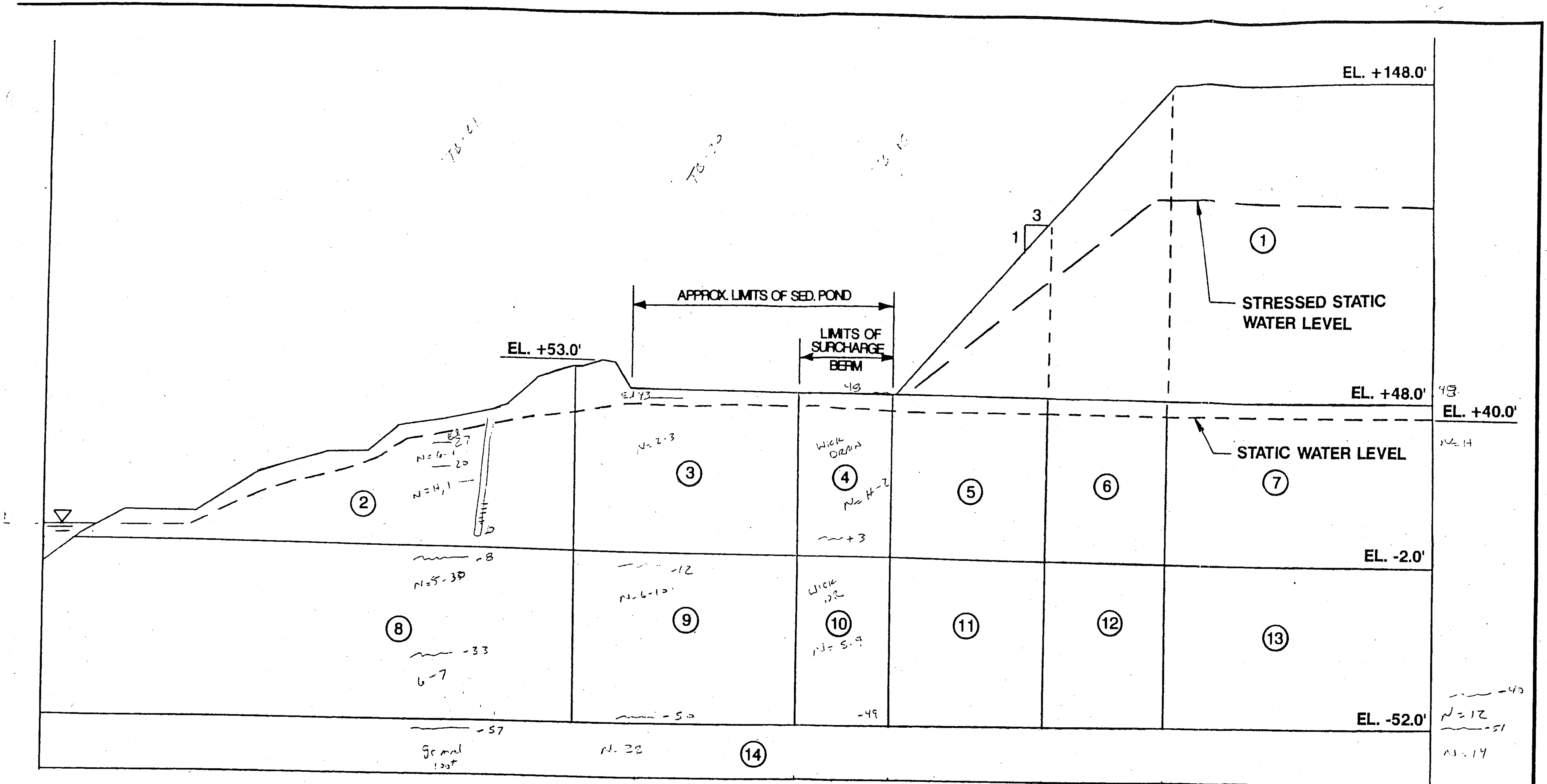
1. MUNICIPAL SOLID WASTE
2. PERIMETER BERM, UPPER SOILS
3. PERIMETER BERM, UPPER SOILS (WITH WICK DRAINS)
4. DREDGE SPOILS (FIRST PARTITION)
5. DREDGE SPOILS (SECOND PARTITION)
6. DREDGE SPOILS (THIRD PARTITION)
7. PERIMETER BERM, LOWER SOILS
8. PERIMETER BERM, LOWER SOILS (WITH WICK DRAINS)
9. RECENT DEPOSITS (FIRST PARTITION)
10. RECENT DEPOSITS (SECOND PARTITION)
11. RECENT DEPOSITS (THIRD PARTITION)
12. GRANULAR SOIL DEPOSITS

FIGURE 3-18
LANDFILL CROSS SECTION A-A
FOR SLOPE STABILITY ANALYSIS

DSWA
PHASE V DISPOSAL AREA
CHERRY ISLAND LANDFILL
WILMINGTON, DELAWARE

ROY F. WESTON, INC.
WESTON
MANAGERS DESIGNERS/CONSULTANTS

DRAWN	DATE	DES. ENG.	DATE	W. O. NO.
M HANSEN				



SOIL LEGEND

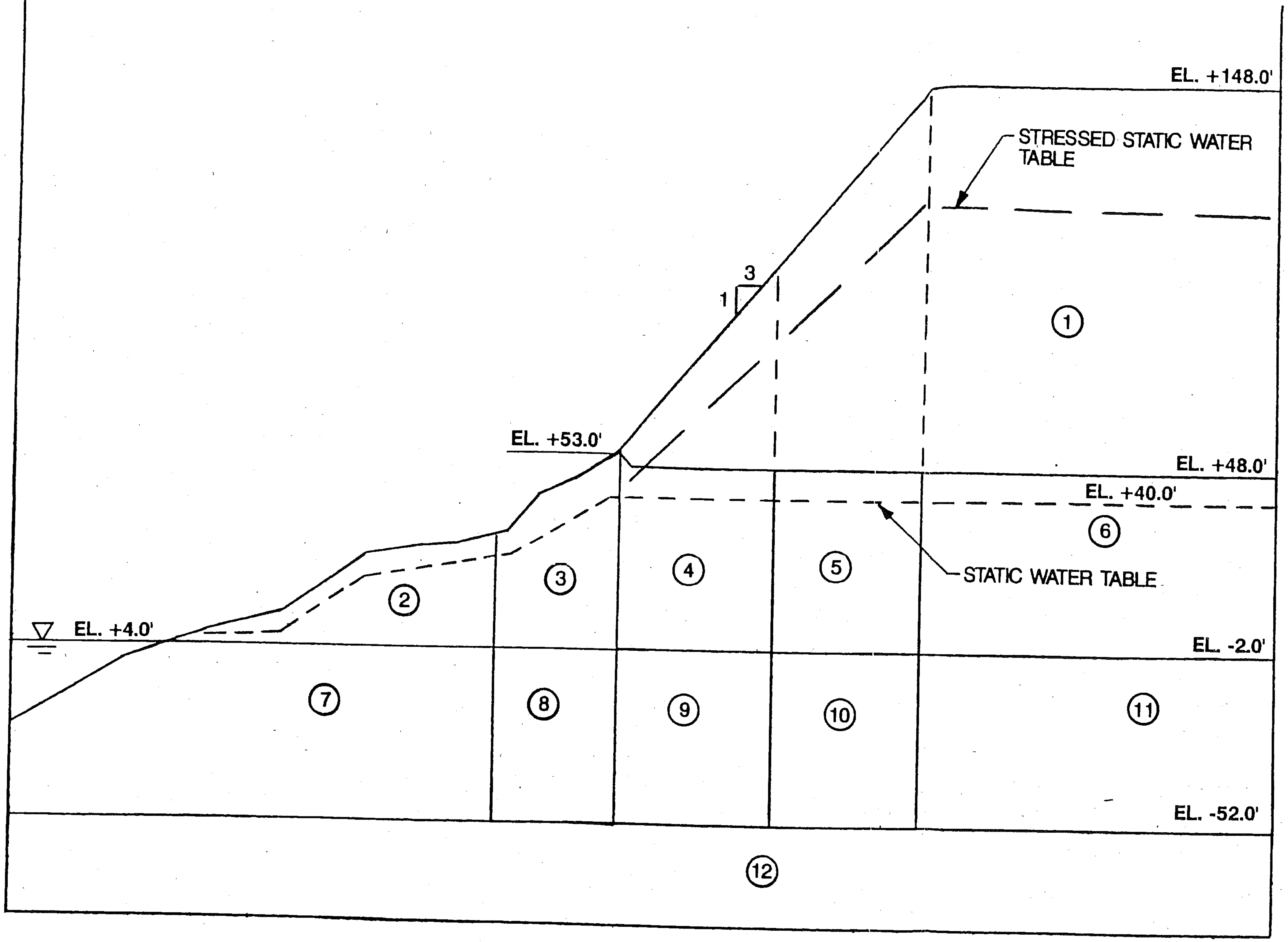
MUNICIPAL SOLID WASTE
PERIMETER BERM, UPPER SOILS
DREDGE SPOILS
DREDGE SPOILS (WITH WICK DRAINS)
DREDGE SPOILS (FIRST PARTITION)
[illegible]E SPOILS (SECOND PARTITION)
D[illegible]GE SPOILS (THIRD PARTITION)
PERIMETER BERM, LOWER SOILS
RECENT DEPOSITS
RECENT DEPOSITS (WITH WICK DRAINS)
RECENT DEPOSITS (FIRST PARTITION)
RECENT DEPOSITS (SECOND PARTITION)
RECENT DEPOSITS (THIRD PARTITION)
GRANULAR SOIL DEPOSITS

FIGURE 3-19
LANDFILL CROSS SECTION B-B
FOR SLOPE STABILITY ANALYSIS

DSWA
PHASE V DISPOSAL AREA
CHERRY ISLAND LANDFILL
WILMINGTON, DELAWARE

ROY F. WESTON, INC.
WESTON
MANAGERS DESIGNERS/CONSULTANTS

DRAWN	DATE	DES. ENG.	DATE	W. O. NO.
M. HANSEN	2/9/94	J. WARTMAN		2477-004-001



SOIL LEGEND

1. MUNICIPAL SOLID WASTE
2. PERIMETER BERM, UPPER SOILS
3. PERIMETER BERM, UPPER SOILS (WITH WICK DRAINS)
4. DREDGE SPOILS (FIRST PARTITION)
5. DREDGE SPOILS (SECOND PARTITION)
6. DREDGE SPOILS (THIRD PARTITION)
7. PERIMETER BERM, LOWER SOILS
8. PERIMETER BERM, LOWER SOILS (WITH WICK DRAINS)
9. RECENT DEPOSITS (FIRST PARTITION)
10. RECENT DEPOSITS (SECOND PARTITION)
11. RECENT DEPOSITS (THIRD PARTITION)
12. GRANULAR SOIL DEPOSITS

FIGURE 3-20
LANDFILL CROSS SECTION C-C
FOR SLOPE STABILITY ANALYSIS

DSWA
PHASE V LANDFILL
CHERRY ISLAND FACILITY
WILMINGTON, DELAWARE

ROY F. WESTON, INC.
WESTON
MANAGERS DESIGNERS/CONSULTANTS

DRAWN	DATE	DES. ENG.	DATE	W. O. NO.
M. HANSEN	2/8/94	J. WARTMAN		02477-004-001
CHECKED		APPROVED		DWG. NO.

3.6.5.1 Subsurface Stratigraphy

Based on the available subsurface information, a total of five (5) subsurface strata were identified for slope stability analysis. These include the following:

a. Dredge Spoils: These materials include the upper approximately 40 to 50 feet of the fine-grained soil stratum thickness which exists behind the earthen perimeter dike. In the slope stability analysis, these soils, known to be thickest in the eastern portion of Phase V, were conservatively assumed to be 50 feet in thickness and extend from the ground surface (elev. 48.0 feet) to elevation -2.0 feet. These materials are Delaware River bed soils which were placed atop natural river bank materials (i.e., recent deposits) at a location behind the perimeter berm by dredging and pumping operations. Because of the operations used to place these very wet, slurry-like sediments, these materials were found to be very soft, weak and compressible in their in situ condition.

   The dredge spoils stratum was divided into three (3) partitions as shown on Figures 3-18 through 3-20 to permit more accurate modeling of the subsurface stratigraphy beneath the outslope of the landfill. The first partition extended from a point below the toe of landfill sideslope to a point below the mid-height of the sideslope. The second partition, located next to and "upslope" from the first partition, extended from a point below mid-height of the sideslope to a point below the top of slope. The third partition extended inward (i.e., towards the center of landfill) from a point below the top of landfill sideslope.

b. Recent Deposits: These materials include the bottom approximately 40 to 50 feet of the fine-grained soil stratum thickness which exists behind the earthen perimeter dike. In the slope stability analyses, these soils were conservatively assumed to be 50 feet in thickness and extend from elevation -2.0 feet to elevation -52.0 feet. These materials are believed to be natural river bank deposits which existed at this location before the perimeter dike was constructed and dredge spoils placed behind the dike. They are geotechnically similar to the overlying dredge spoils. Since these materials have a much longer geologic history at this site, and therefore had the benefit of consolidation/strength gain under both self weight and the weight of the overlying dredge spoils, the shear strength of these soils is considerably greater, and the compressibility significantly lower, than the overlying dredge spoils as shown in Figure 3-10. The recent deposits were also divided into three (3) partitions to permit more accurate modelling of the subsurface stratigraphy beneath the outslope of the landfill.

c. Delaware River Dike Soils (Upper): These materials include the upper approximately 45 feet of the Delaware River separation dike thickness. These soils were assumed to extend from an approximate elevation of +53.0 feet (top of dike) to elevation -2.0 feet for this analysis. These materials are generally fine-grained fill soils with granular inclusions which were placed by earthmoving operations to the geometrical configuration of the dike.

d. Delaware River Dike Soils (Lower): These materials include natural fine-grained river bank deposits (i.e., recent deposits) which lie between the dike fill soils and underlying granular soil deposits. These soils were assumed to extend from elevation -2.0 feet to elevation -52.0 feet from the Delaware or Christiania Rivers to a location beneath the inside edge of the top bench of the dike.

e. Granular Deposits: Sands and gravels underlie the recent deposits as well as the lower Delaware River dike soils. The assumed top elevation of this stratum corresponds to the bottom elevation of the two overlying strata as discussed above. These granular soil deposits were noted to be of significantly greater shear strength than the overlying fine-grained soils as evidenced by much higher "N" values.

3.6.5.2 Assumed Landfill Geometry

A 100 foot thickness of municipal solid waste was modelled in the slope stability analysis. This thickness was assumed to be constant beyond the top of the landfill sideslope. Based on conventional landfill design practice, the sideslope inclination was assumed to be 3H:1V. No benches were assumed in the slope stability analysis. Therefore, the configuration of the waste sideslope was assumed to extend from the top of the Delaware River perimeter dike (i.e., elevation +53 feet) to the landfill top of slope elevation of +148.0 feet (i.e., 100 feet above the existing top of dredge spoils elevation of approximately +48.0 feet) at this 3H:1V inclination as shown on Figures 3-18 through 3-20.

3.6.5.3 Soil Properties

Soil properties, including unit weight, cohesion, and angle of internal friction, are required as input to the STABL4 slope stability computer program for each soil layer or partition thereof. The selected values of these parameters for use in the stability analyses are presented in Table 3-3. The values of unit weight for the four fine-grained soil strata were directly measured from "undisturbed" Shelby tube samples during laboratory shear strength and/or consolidation testing of these materials.

The effective stress shear strength parameters ($\bar{c}$, $\bar{\phi}$) for the four fine-grained soil strata to be used in the slope stability analysis are presented in Table 3-3 and were selected from the $\overline{CIU}$ triaxial compression test results for these materials. The selected value of $\bar{\phi}$ was also cross-checked and conservatively modified, as appropriate, based on correlations with measured soil physical properties (i.e., plasticity index). Drained cohesive shear strength ($\bar{c}$) was conservatively neglected in the stability analysis. It is evident from Table 3-3 that the slope stability analysis was completed in its entirety using only drained, effective stress shear strength parameters. This is in contrast to conventional geotechnical engineering practice for applied fill loadings (e.g., embankments, landfilled materials, etc.) in which both a short-term stability analysis using undrained, total stress shear strength parameters, and a long-term stability analysis using drained, effective stress shear strength parameters are typically completed. The discrepancy is explained using Figure 3-21 which shows the variation of developed shear stress, developed excess pore water pressure, shear strength gain due to consolidation, and Factor of Safety against slope instability as a function of time for a

Table 3-3

Assumed Soil Unit Weight and Shear Strength Parameters

Soil	Soil Unit Weight γ_T (pcf)	Effective Stress Shear Strength Parameters	
		$\bar{c}$ (psf)	$\bar{\phi}$
Dredge Spoils	91.0	0	30°
Recent Deposits	100.0	0	30°
Delaware River Dike Soils (Upper)	77.0	0	34°
Delaware River Dike Soils (Lower)	100.0	0	28°
Granular Deposits	130.0	0	38°

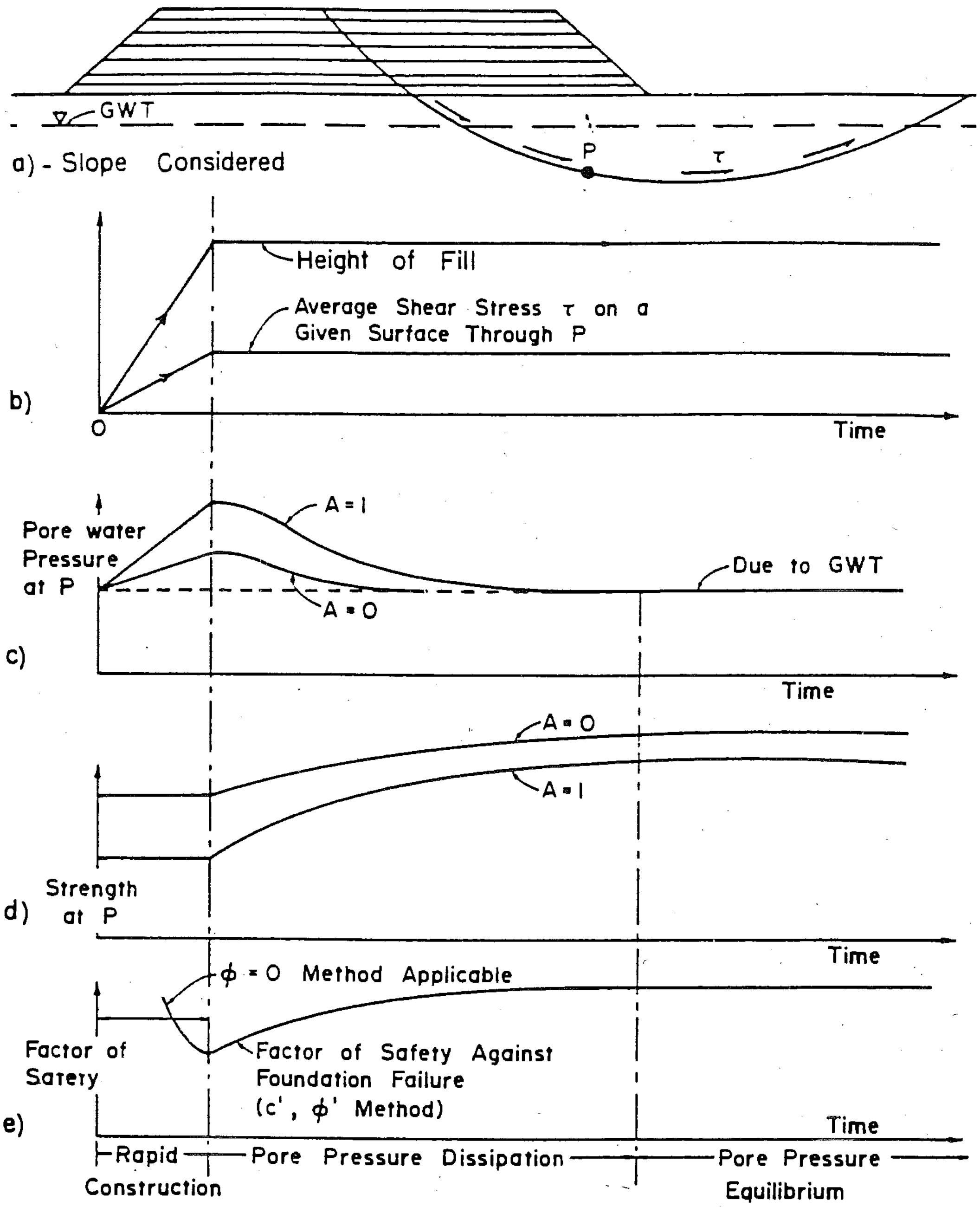


FIGURE 3-21

VARIATION WITH TIME OF SHEAR STRESS, PORE WATER PRESSURE, STRENGTH, AND FACTOR OF SAFETY FOR A SATURATED CLAY FOUNDATION BENEATH A FILL

DSWA PHASE V DISPOSAL AREA CHERRY ISLAND LANDFILL WILMINGTON, DELAWARE	ROY F. WESTON, INC. WESTON MANAGERS DESIGNERS/CONSULTANTS				
	DRAWN W.A. HARPUR	DATE	DES. ENG.	DATE 3/14/95	W. O. NO.
	CHECKED		APPROVED		DWG. NO.

saturated fine-grained soil stratum beneath an assumed rapidly applied fill loading. The Factor of Safety plot is most relevant to this discussion. Note that the Factor of Safety is a minimum at the end of the rapid construction time period, and increases with time thereafter consistent with consolidation and strength gain of the fine-grained soil materials as excess pore water pressures generated by the applied fill loading are dissipated due to soil pore water flow to the drainage boundaries. Note also from the Figure that this minimum Factor of Safety condition can be evaluated using either a $\phi = 0°$ analysis (i.e., an undrained, total stress stability analysis in which $c_u > 0$ and $\phi_u = 0°$), or a $\bar{c}$, $\bar{\phi}$ analysis (i.e., a drained, effective stress stability analysis in which $\bar{c} > 0$ and $\bar{\phi} > 0°$) in which the calculated excess pore water pressures generated by the loading are incorporated into the analysis. The Figure also conceptually illustrates that if full excess pore water pressure development due to the loading is incorporated into the analysis (i.e., no partial dissipation of excess pore water pressures is assumed), the minimum Factor of Safety condition can be quantified using the effective stress shear strength parameters. The manner in which this will be accomplished is discussed in detail in Section 3.6.5.7.1 of this report.

An internal friction angle of 38° was assigned to the granular deposits for both the drained and undrained stability analyses. This value was determined from correlations of this parameter to the average "N" value of this stratum. A unit weight of 130 pcf was also assumed for these materials consistent with the average "N" value of the stratum.

3.6.5.4 Municipal Solid Waste Properties

Undrained and drained shear strength conditions within the municipal solid waste (MSW) were evaluated in the slope stability analyses. The undrained properties of the waste correspond to the case of biodegraded, sludge-like material representative of older landfilled MSW. In this instance, the waste has high cohesive shear strength with low to zero internal friction similar to a soft clay. Drained shear strength properties of MSW correspond to the case of fresh, recently placed waste in which internal friction between the various waste components is prevalent. Numerical values of cohesion and internal friction for the MSW under undrained and drained shear strength conditions were determined from Figure 3-22.

In particular, the undrained properties were selected as the average cohesion value for the $\phi = 0°$ condition. The drained properties were selected based on the results of recent research (Jessburger and Kockel, 1991). In summary, these values are:

Undrained Waste

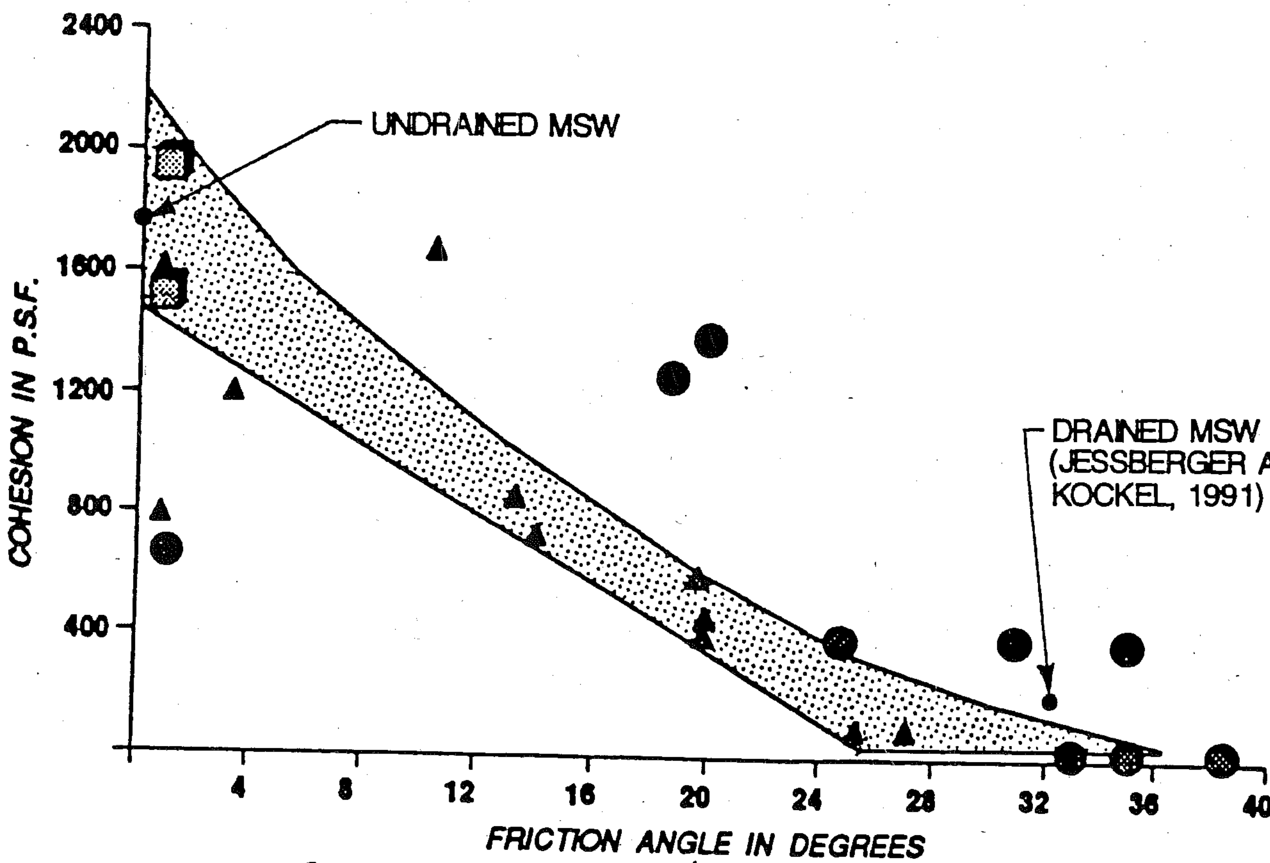
$c_u = 1825$ psf

$\phi_u = 0°$

Drained Waste

$c = 200$ psf

$\phi = 32°$



Summary Plot for All Tests with Recommended Parameters Shaded

FIGURE FROM: SINGH S. & MURPHY B., "A CRITICAL EXAMINATION OF THE STRENGTH AND STABILITY OF SANITARY LANDFILLS."

FIGURE 3-22
SHEAR STRENGTH PARAMETERS
FOR MUNICIPAL SOLID WASTE

DSWA PHASE V DISPOSAL AREA CHERRY ISLAND LANDFILL WILMINGTON, DELAWARE	ROY F. WESTON, INC. WESTON MANAGERS DESIGNERS/CONSULTANTS				
	DRAWN A. DELTUFFO	DATE	DES. ENG. J. WARTMAN	DATE	W. O. NO.
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It is noted that MSW shear strength properties were selected based on the results of empirical research as opposed to directly measured site-specific values as is the case for the landfill foundation soils. Because of this, it was believed appropriate to evaluate slope stability for each landfill height configuration and stability condition (i.e., short-term and long-term) using both undrained and drained MSW shear strength properties.

In addition, as previously discussed in Section 3.6.1 of this report, the unit weight of the composite MSW/daily cover material was assumed to be 70 pcf.

3.6.5.5 Static Water Level

The location of the static water level within the fine grained dredge spoils/recent deposits as well as the soils which comprise the perimeter berm was also required as input to the slope stability analysis. This water level was believed to be created by free, excess water recovered by the dredging operations which was impounded behind the perimeter dike along with the dredge spoils. This free water saturated the dredge spoils to a depth which generally ranged from 8 to 12 feet below the existing ground surface as measured in the test borings completed internal to the landfill footprint. Therefore, a conservative depth of 8 feet, which corresponds to an elevation of +40.0 feet, was selected as the static water level within the dredge spoils. This elevation was extended through the adjacent dike soils until this horizontal surface intersected an inclined surface which originated at the Delaware or Christiania Rivers water surface (assumed to be elevation +4 feet for this analysis). The geometry of this inclined water surface was estimated using a seepage analysis procedure for determining the phreatic surface within an earth dam. The final geometry of the assumed static water level used in the various slope stability analyses is presented on Figures 3-18 through 3-20.

3.6.5.6 Seismic Effects

Potential slope instability of the proposed landfill configuration under a design seismic event was also completed as part of the slope stability analysis. This requires selection of design seismic coefficients expressed as a percentage of the earth's acceleration due to gravity for both the vertical and horizontal directions. These values are subsequently input into the slope stability method of slices computer program for the seismic cases being analyzed. The computer program uses these coefficients to define two additional forces (one horizontal and one vertical) for each slice which are equal to the product of the weight of the slice times the horizontal and vertical seismic coefficients, respectively. These forces are applied in directions so as to enhance potential slope instability (i.e., vertically up and horizontally downslope) and, therefore, will always decrease the Factor of Safety to a value less than that for the nonseismic case. As documented in the Code of Federal Regulations, a minimum Factor of Safety of 1.0 (i.e., incipient failure) against potential slope instability is required under the design seismic event.

Slope stability analysis of landfill sideslopes under seismic conditions was recently impacted by the promulgation of 40 CFR Part 258 federal regulations. These requirements, commonly referred to as "Subtitle D Regulations," define "location restrictions" for new MSW landfills which lie within "seismic impact zones." The locations of seismic impact zones within the United States are based on "seismic hazard" mapping of horizontal ground accelerations due to earthquake induced shock waves for a 250 year recurrence interval/ 90% probability of nonoccurrence seismic event as developed by Algermissen, et al. Using this reference, it was determined that the Cherry Island site lies within a seismic impact zone. Under these conditions, the regulations further require that a new MSW landfill not be located within this seismic impact zone unless the landfill is either designed to resist the 250 year horizontal acceleration value from the "seismic hazard map," or "the maximum expected horizontal acceleration based on a site-specific seismic risk assessment" of the geographic area in which the site is located. In light of what is believed to be an extremely conservative horizontal seismic coefficient for this area of the country as determined from the "seismic hazard map", WESTON has instead proceeded to complete a site-specific seismic risk assessment based on the earthquake history of Wilmington, Delaware, and surrounding areas to statistically estimate the 250 year recurrence interval/90% probability of non-occurrence value. The remainder of this report section discusses the results of this assessment.

The database for the site-specific seismic risk assessment was created using EPIC retrieval computer software with the GLOBAL HYPOCENTER DATA BASE CD-ROM which was developed by the USGS. This computer database contains information from 40 earthquake catalog listings of over 700,000 seismic events which have occurred between 1500 AD and 1990 AD. The EPIC computer program searched seven individual earthquake catalogs and developed an 1100 earthquake database of all seismic events of Richter magnitude 3.0 and greater whose epicenters are located within 1000 kilometers (621 miles) of the Cherry Island Landfill (site coordinates: Latitude 39.73N, Longitude 75.52W). The site-specific database contains information on each earthquake's epicentral coordinates by latitude and longitude, Richter magnitude, focus depth, and time and date of occurrence. The database was compiled from the following earthquake catalogs (with the computer program's catalog designation in capital letters):

ABE - Catalog of large earthquakes, 1897-1980, from Abe (1981, 1982, 1984); Abe and Kanamori (1979); and Abe and Noguchi (1983a,b).

BCIS - Catalog of earthquakes listed in the publications of the Bureau Central International Seismologique for 1935, 1950-1963. File was supplied by the NOAA (Rinehart et. al., 1985).

BDA - Catalog of large earthquakes, 1897-1977, compiled by Bath and Duda (1979). File supplied by NOAA (Rinehart et. al., 1985).

DNAG - Catalog of North American earthquakes compiled for the Decade of North American Geology (Engdahl and Rinehart, 1991).

EPRI - Catalog of earthquakes of the United States east of the Rocky Mountains, 1627-1985, compiled by Electric Power Research Institute.

GREAT - Catalog of great (magnitude 7.9 and larger) earthquakes, 1904-1985, from Kanamori (1977).

GUTE - Catalog of hypocenters and magnitudes listed in Gutenburg and Richter (1954), 1904-1952.

A supplementary database of seismic events within the eastern half of the United States which occurred between January, 1990 and January, 1994 was compiled by WESTON from a search of USGS and Delaware State geologic records.

It is well established that the force of an earthquake diminishes with distance from the epicentral location of the quake. This phenomenon is quantified using earthquake attenuation theory. As part of the "site specific seismic risk assessment," an attenuation analysis was completed to determine the attenuated horizontal ground accelerations which were theoretically "felt" at the Cherry Island site for each earthquake in the database as a function of the epicentral Richter magnitudes of these quakes and their distances from the landfill. The procedures developed by Davenport were used for the attenuation analysis. This analysis resulted in attenuated horizontal ground accelerations which ranged between 0 (i.e., a non-felt quake) and .06g.

The attenuated seismicity database was subsequently analyzed using a statistical frequency analysis procedure entitled "Distribution of Extreme Values" (Gumbel). This procedure is appropriate for statistically predicting "worst case" events such as earthquakes, floods, droughts, etc. The frequency distribution of the database, as developed quantitatively from the analysis procedure, can be extrapolated to any recurrence interval event when plotted on probability graph paper. The plotted results of this analysis are shown on Figure 3-23 in the form of the statistical probability of nonoccurrence of a given earthquake (y axis) versus that earthquakes generated horizontal ground acceleration expressed as a percentage of the earth's acceleration due to gravity (x axis). This graphical relationship can then be used to estimate the horizontal ground acceleration which corresponds to the EPA Subtitle D recurrence interval standard (i.e. a 90% probability of nonoccurrence in a 250 year time period). As noted in the Algermision reference, this is statistically equivalent to an average return period of 2372 years (i.e. an earthquake with the noted ground acceleration has a 100% probability of occurring within this 2372 year time frame). The probability scale (P) of the Gumbel frequency distribution plot (Figure 3-23) is based on average return period (T_R) and the two variables are interrelated by the following equation:

$$T_R = \frac{1}{1-P} \tag{19}$$

For an average recurrence interval of 2372 years, the corresponding value of P as determined from this equation is 99.96%. As shown on Figure 3-23, this value of P corresponds to a horizontal ground acceleration of .041g. It is noted that this value is consistent with recommended design horizontal seismic coefficient values for slope stability analysis as presented in a widely accepted geotechnical reference (Huang) as documented in Figure 3-24. As noted on this Figure, a seismic coefficient of .03g to .07g is recommended for slope stability analyses for sites located within "Seismic Zone 1" such as the Wilmington, Delaware area. Since the high end of this range (i.e. .07g) exceeds the statistically estimated value of .041g as determined from the site specific seismic risk

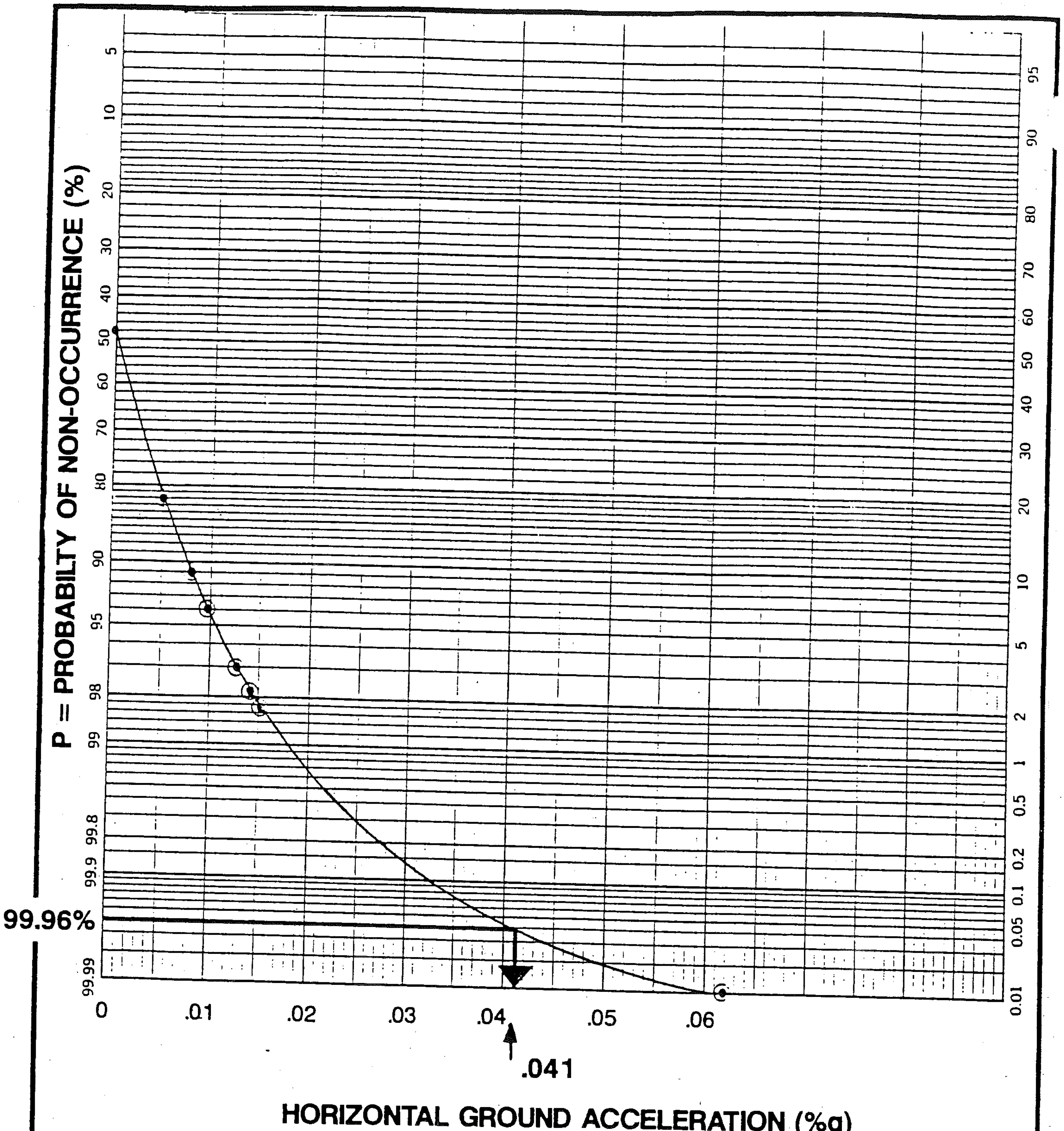

FIGURE 3-23
EARTHQUAKE MAGNITUDE AS A FUNCTION
OF PROBABILITY OF NON-OCCURRENCE

DSWA
PHASE V DISPOSAL AREA
CHERRY ISLAND LANDFILL
WILMINGTON, DELAWARE

ROY F. WESTON, INC.
WESTON
MANAGERS DESIGNERS/CONSULTANTS

DRAWN M. HANSEN	DATE 2/10/94	DES. ENG. J. WARTMAN	DATE	W. O. NO. 02477-004-001
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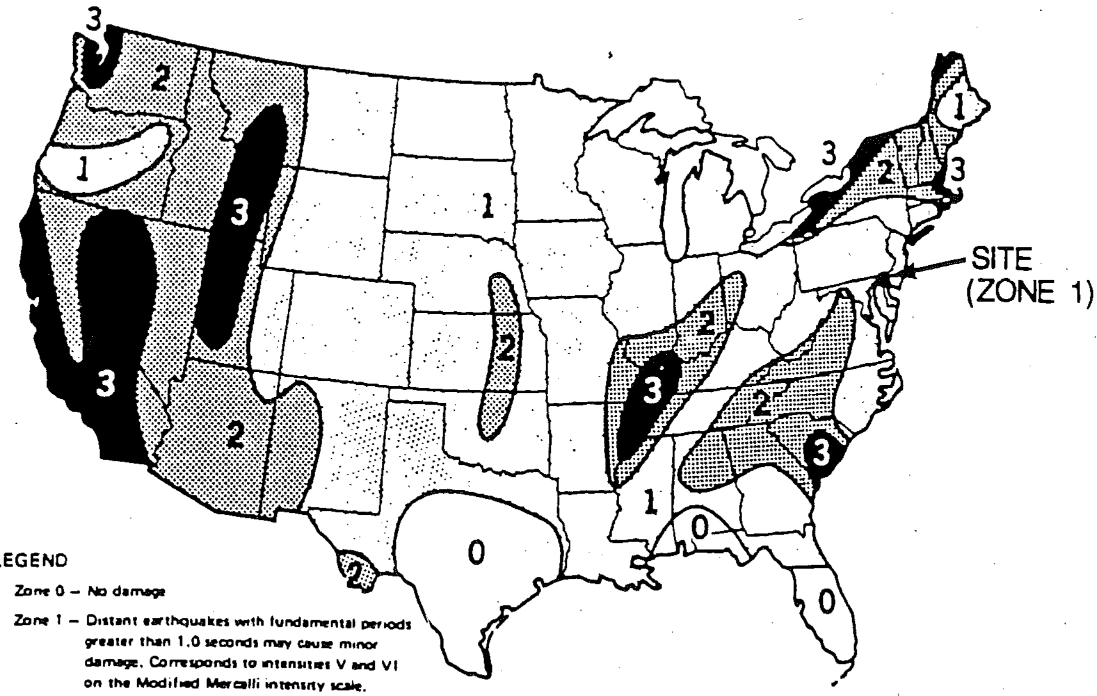


LEGEND

Zone 0 – No damage

Zone 1 – Distant earthquakes with fundamental periods greater than 1.0 seconds may cause minor damage. Corresponds to intensities V and VI on the Modified Mercalli intensity scale.

Zone 2 – Moderate damage; corresponds to intensity VII on the Modified Mercalli intensity scale.

Zone 3 – Major damage; corresponds to intensity VIII and higher on the Modified Mercalli intensity scale.

Seismic zone map of continental United States (After Algermissen, 1969)

Table 2.2 Seismic Coefficients Corresponding to Each Zone.

ZONE	INTENSITY OF MODIFIED MERCALLI SCALE	AVERAGE SEISMIC COEFFICIENT	REMARK
0	—	0	No damage
1	V and VI	0.03 to 0.07	Minor damage
2	VII	0.13	Moderate damage
3	VII and higher	0.27	Major damage

REF: HUANG Y.H., "STABILITY ANALYSIS OF EARTH SLOPES."

FIGURE 3-24
SEISMIC COEFFICIENTS
FOR SLOPE STABILITY ANALYSIS

DSWA
PHASE V DISPOSAL AREA
CHERRY ISLAND LANDFILL
WILMINGTON, DELAWARE

ROY F. WESTON, INC.
WESTON
MANAGERS DESIGNERS/CONSULTANTS

DRAWN	DATE	DES. ENG.	DATE	W. O. NO.
A. DELTUFFO	11/19/93	J. WARTMAN		02477-004-001
CHECKED		APPROVED		DWG. NO.

assessment, WESTON has conservatively elected to use .07g as the design horizontal seismic coefficient for the Cherry Island, Phase V landfill slope stability analyses. In accordance with conventional geotechnical engineering practice, a vertical seismic coefficient of 1/2 of the horizontal value (i.e. .035g) has also been used in the analysis.

3.6.5.7 Short-Term and Long-Term Slope Stability Analyses

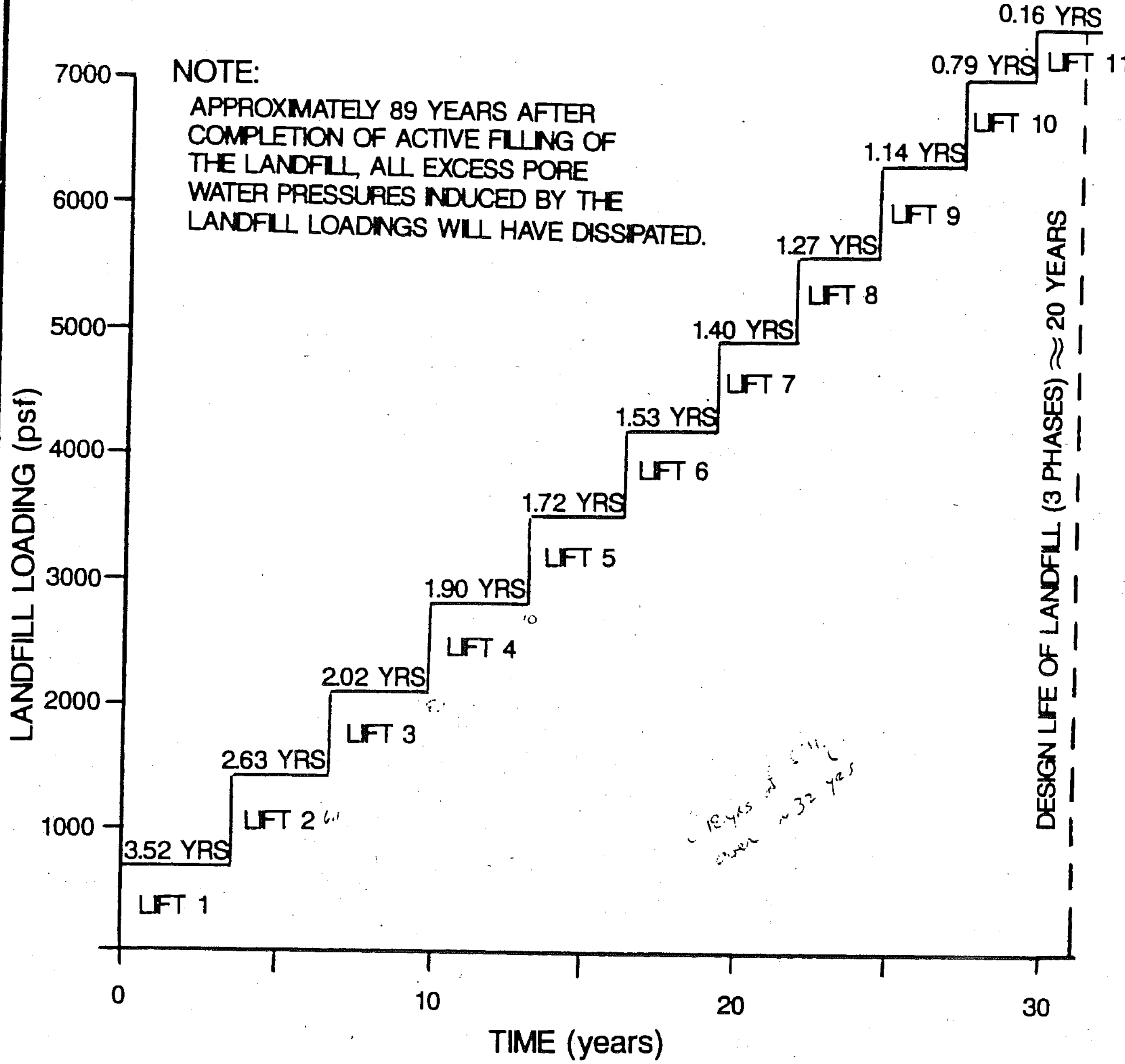
Both short-term and long-term slope stability analyses were completed as part of the geotechnical evaluation of the proposed Phase V landfill design. The short-term analysis considers full development of excess pore water pressures without dissipation consistent with the end of the rapid construction time period shown on Figure 3-21. This in turn quantifies the minimum Factor of Safety condition as shown in this same Figure. This case is applicable to all of the various landfill height configurations corresponding to the various waste lifts. A minimum Factor of Safety of 1.3 is required under this short-term stability condition per the 1977 Federal Register. The long-term or fully drained stability condition will govern slope stability of the landfill mass once all excess pore water pressures generated by the landfill loadings have been fully dissipated. As discussed in previous sections of this report, this case is only applicable to the finished landfill configuration (i.e., 100 feet of waste height), and occurs approximately 89 years after the final waste lift has been placed. A minimum Factor of Safety of 1.5 is required under this long-term stability condition per the 1977 Federal Register. These two slope stability analyses are discussed in the following subsections of this report.

3.6.5.7.1 Short-Term Slope Stability Analysis

The drained soil shear strength parameters used in this analysis are presented in Table 3-3. These values are based on assumed effective stress conditions within the stratigraphic profile. Landfill height configurations of 10, 50, and 100 feet were analyzed. Both undrained and drained shear strength properties were assumed for the MSW. Additionally, both seismic and non-seismic conditions were also considered for each case. This resulted in a total of 12 cases being completed for each of the 3 cross sections which were evaluated so as to define the stability condition of the slope during and up to approximately 89 years following completion of active filling of the landfill.

The assumed loading condition for the landfill at any given plan location within the three phase landfill footprint is shown on Figure 3-25. As is evident from an inspection of this Figure, a given landfill lift loading of 10 foot thickness (i.e., 700 psf) is assumed to be applied instantaneously at any given point within the footprint, followed by the lapse of a certain time period during which this loading remains constant until the next lift is placed at this same location. The referenced time periods were calculated from the Phases III, IV and V Landfill volumes and the placement rate at which the MSW will be landfilled.

As discussed in Subsections 3.6.2.1 and 3.6.4.1 of this report, a time rate of settlement analysis has shown that the dredge spoils/recent deposits stratum thickness will not reach full consolidation during any of the various time intervals required to place the 10 waste lifts. Therefore, excess pore water pressures will exist within this stratum at all times during



NOTE:

LOADING DIAGRAM ASSUMES 70 pcf UNIT WEIGHT FOR LANDFILLED MSW AND A LIFT HEIGHT OF 10 FEET.

FIGURE 3-25

RELATIONSHIP OF LANDFILL LOADING AND TIME

DSWA PHASE V DISPOSAL AREA CHERRY ISLAND LANDFILL WILMINGTON, DELAWARE	ROY F. WESTON, INC. WESTON MANAGERS DESIGNERS/CONSULTANTS				
	DRAWN A. DELTUFFO	DATE 2/9/94	DES. ENG. J. WARTMAN	DATE	W. O. NO. 02477-004-001
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active filling of the landfill. These excess pore water pressures must therefore be incorporated into the short-term stability analysis since their effect is to reduce the drained shear strength of the soil and, therefore, the minimum Factor of Safety of the slope. The method by which this effect was incorporated into the analysis was to increase the existing static water level elevation of +40.0 feet to some higher elevation which is a function of the average excess pore water pressure which exists within the fine-grained soil stratum at the time the designated MSW lift for which stability is being evaluated is placed. This increased water level is designated as the "stressed static water level" for purposes of this discussion. For example, based on Figure 3-25, at the time at which the third MSW lift (i.e., 30 foot landfill height condition) is instantaneously placed at a given plan location, the first waste lift has been in place a total of 6.15 (i.e., 3.52 years + 2.63 years) years while the second waste lift has been in place a total of 2.63 years at this same location. Therefore, the "stressed static water level" head increase (Δh_{TOT}) at this time is calculated as follows:

$$\Delta h_{TOT} = (1 - U_1)\ \Delta p_1/\gamma_w + (1 - U_2)\ \Delta p_2/\gamma_w + (1 - U_3)\ \Delta p_3/\gamma_w \qquad (20)$$

in which:

$\Delta p_1 = \Delta p_2 = \Delta p_3$ = the loading of the first, second and third MSW lift (i.e., 700 psf)

γ_w = unit weight of water

U_1, U_2, U_3 = average degree of consolidation of the fine-grained soil stratum based on time periods of 6.15, 2.63, and 0 years respectively as calculated from conventional consolidation theory assuming double drainage conditions. (Double drainage of excess pore water pressures from the fine-grained soil stratum is assured by the placement of a high permeability granular soil drainage blanket atop the dredge spoils as discussed in Subsections 3.6 and 3.6.4.1 of this report). The value of the coefficient of consolidation (c_v) used in this analysis was calculated as a function of the permeability of these soils and differs for each waste lift as discussed in Subsection 3.6.2 of this report.

The values of Δh_{TOT} were then added to the elevation of the static water level (+40.0 feet) to determine the "stressed static water level elevation" (SSWLE). The geometry of the "stressed static water level" for each analyzed landfill height condition was assumed to be horizontal and equal to the SSWLE beneath the top of the landfill where the waste height is constant, followed by a linear decrease of this stressed water table to elevation +40.0 feet beneath the toe of the landfill slope where the waste height is zero.

The results of the short-term slope stability analysis are presented in Table 3-4. This Table presents the calculated minimum Factor of Safety values for the various conditions of waste height, SSWLE, MSW shear strength (drained or undrained) and seismic conditions discussed previously. The footnotes to this Table show that the minimum required Factor of Safety values for short-term slope stability analyses under nonseismic and seismic conditions are 1.3 and 1.0 as documented in the 1977 Federal Register. Based on this

Table 3-4

Results of Short-Term Slope Stability Analysis

			Drained Waste Shear Strength Analysis				Undrained Waste Shear Strength Analysis			
Profile	Waste Height (Feet)	Stressed Static Water Level Elev. (Feet)	Non-Seismic Factor of Safety	Status[1]	Seismic Factor of Safety	Status[2]	Non-Seismic Factor of Safety	Status[1]	Seismic Factor of Safety	Status[2]
A	10	51.2	1.590	Satisfactory	1.043	Satisfactory	1.590	Satisfactory	1.043	Satisfactory
A	50	81.2	1.594	Satisfactory	1.042	Satisfactory	1.594	Satisfactory	1.042	Satisfactory
A	100	111.5	1.571	Satisfactory	1.041	Satisfactory	1.575	Satisfactory	1.041	Satisfactory
B	10	51.2	1.892	Satisfactory	1.201	Satisfactory	1.892	Satisfactory	1.201	Satisfactory
B	50	81.2	1.899	Satisfactory	1.202	Satisfactory	1.899	Satisfactory	1.202	Satisfactory
B	100	111.5	1.839	Satisfactory	1.201	Satisfactory	1.825	Satisfactory	1.201	Satisfactory
C	10	51.2	1.551	Satisfactory	1.059	Satisfactory	1.551	Satisfactory	1.059	Satisfactory
C	50	81.2	1.551	Satisfactory	1.059	Satisfactory	1.551	Satisfactory	1.059	Satisfactory
C	100	111.5	1.522	Satisfactory	1.055	Satisfactory	1.520	Satisfactory	1.059	Satisfactory

[1]Based on a minimum required Factor of Safety of 1.3 per the 1977 Federal Register.
[2]Based on a minimum required Factor of Safety of 1.0 per the 1977 Federal Register.

criteria, all 36 cases considered in the short-term slope stability analysis resulted in acceptable Factor of Safety values.

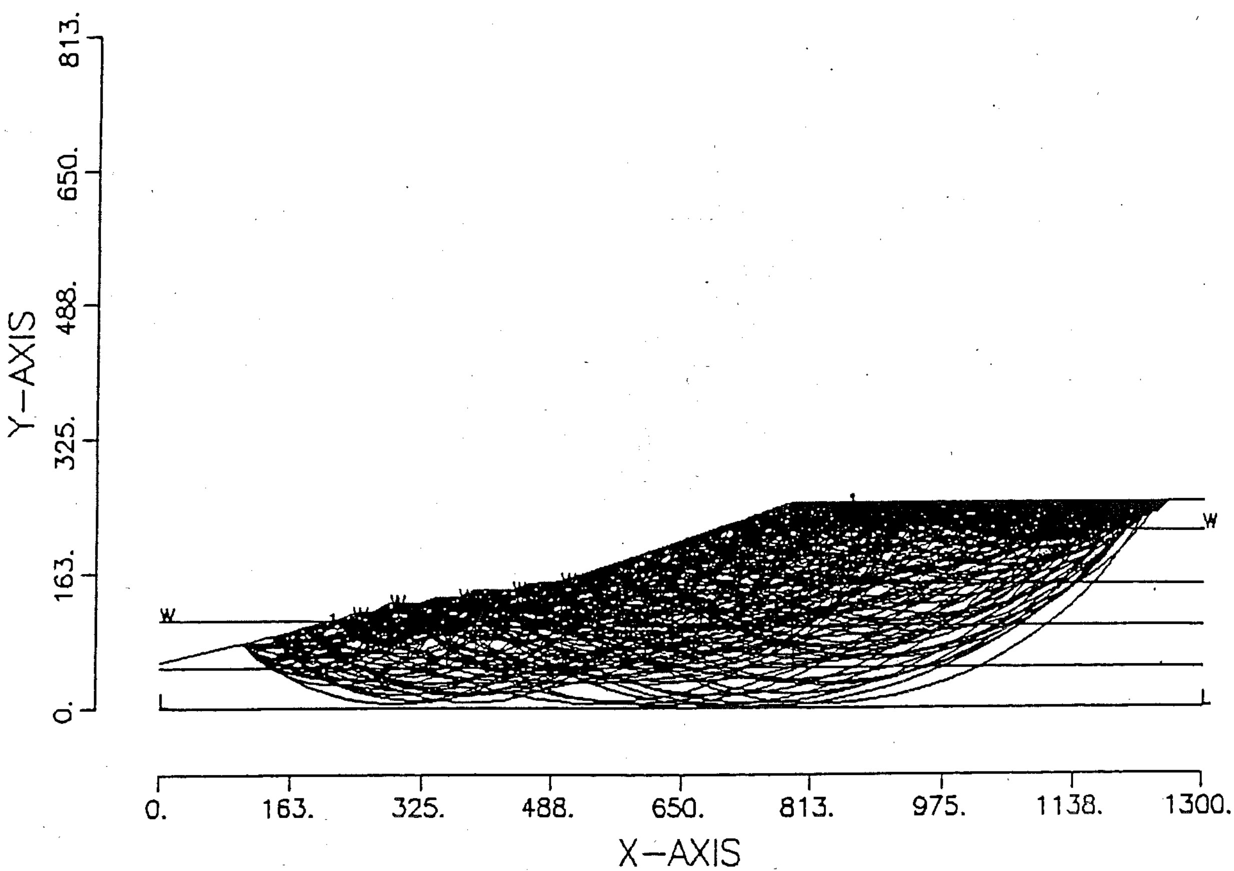
Computer input and output data which documents each of the 36 short-term stability cases is presented in Appendix D. The output data includes a graphical plot of the slope cross section which shows the landfilled mass, the SSWLE, and the assumed subsurface stratigraphy. These plots also indicate the locations of the 10 most critical failure surfaces identified by the computer search as well as the location of the most critical failure surface which is identified by hatch marks. The minimum Factor of Safety value which corresponds to the critical failure surface is also shown on these output plots. Note also that these plots indicate that a very extensive search routine consisting of hundreds of circles was completed for each analysis. Figure 3-26 has been prepared to graphically illustrate the extensive and thorough nature of this search for one of the 100-foot high landfill cases. It is evident from this Figure that circles of varying radii and center points which define the orientation of virtually every conceivable failure surface are selected by the search routine.

It is also evident that the minimum required Factor of Safety values for all 36 cases of the short-term slope stability analysis have been achieved without the use of high strength, high modulus reinforcing geosynthetics on the landfill floor along the eastern and southern perimeter of the landfill footprint. Therefore, it is concluded that, based on the short-term stability analysis, no reinforcing geosynthetics of this nature are required for the Phase V design.

3.6.5.7.2 Long-Term Slope Stability Analysis

A long-term slope stability analysis was also completed using effective stress shear strength parameters. However, this analysis assumed that the water table elevation was +40.0 feet (i.e., the static water table elevation) consistent with the assumption that all excess pore water pressures induced by the landfill loadings have fully dissipated at this time. Both undrained and drained shear strength properties were assumed for the MSW. The completed landfill configuration of 100 feet of waste thickness is the only landfill configuration pertinent to this case. Both seismic and nonseismic conditions were analyzed, resulting in a total of four (4) cases requiring analysis for each of the 3 profiles.

The results of the fully drained slope stability analysis are presented in Table 3-5. This Table presents the calculated minimum Factor of Safety values for the various conditions of MSW shear strength (i.e., drained or undrained) and seismic conditions discussed above. Footnotes to this Table also show that the minimum required Factor of Safety values for long-term stability analyses under non-seismic and seismic conditions are 1.5 and 1.0, respectively, as documented in the 1977 Federal Register. Based on these criteria, all 12 cases considered in the long-term stability analysis resulted in acceptable Factor of Safety values. Computer input and output data which documents each of the analyzed cases is presented in Appendix D.



NOTE:

PROFILE - A SHOWN ABOVE.

FIGURE 3-26

SLOPE STABILITY ANALYSIS :
SEARCH ROUTINE

DSWA PHASE V DISPOSAL AREA CHERRY ISLAND LANDFILL WILMINGTON, DELAWARE	ROY F. WESTON, INC. WESTON MANAGERS DESIGNERS/CONSULTANTS			
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Table 3-5

Results of Long-Term Slope Stability Analysis

Profile	Waste Height (Feet)	Drained Waste Shear Strength Analysis				Undrained Waste Shear Strength Analysis			
		Non-Seismic Factor of Safety	Status[1]	Seismic Factor of Safety	Status[2]	Non-Seismic Factor of Safety	Status[1]	Seismic Factor of Safety	Status[2]
A	100	1.600	Satisfactory	1.041	Satisfactory	1.600	Satisfactory	1.041	Satisfactory
B	100	1.909	Satisfactory	1.201	Satisfactory	1.909	Satisfactory	1.201	Satisfactory
C	100	1.552	Satisfactory	1.059	Satisfactory	1.552	Satisfactory	1.059	Satisfactory

[1]Based on a minimum required Factor of Safety of 1.5 per the 1977 Federal Register.
[2]Based on a minimum required Factor of Safety of 1.0 per the 1977 Federal Register.

It is also noted that the minimum required Factor of Safety values for each of the analyzed cases of the long-term slope stability analysis have been achieved without the use of high strength, high modulus reinforcing geosynthetics on the landfill floor along the eastern and southern perimeter of the landfill footprint. Therefore, it is concluded that, based on the long-term stability analysis, no reinforcing geosynthetics of this nature are required for the Phase V design.

3.7 CONCLUSIONS

Based on the results of the geotechnical investigation/analysis of the Cherry Island Phase V landfill site, the following has been concluded:

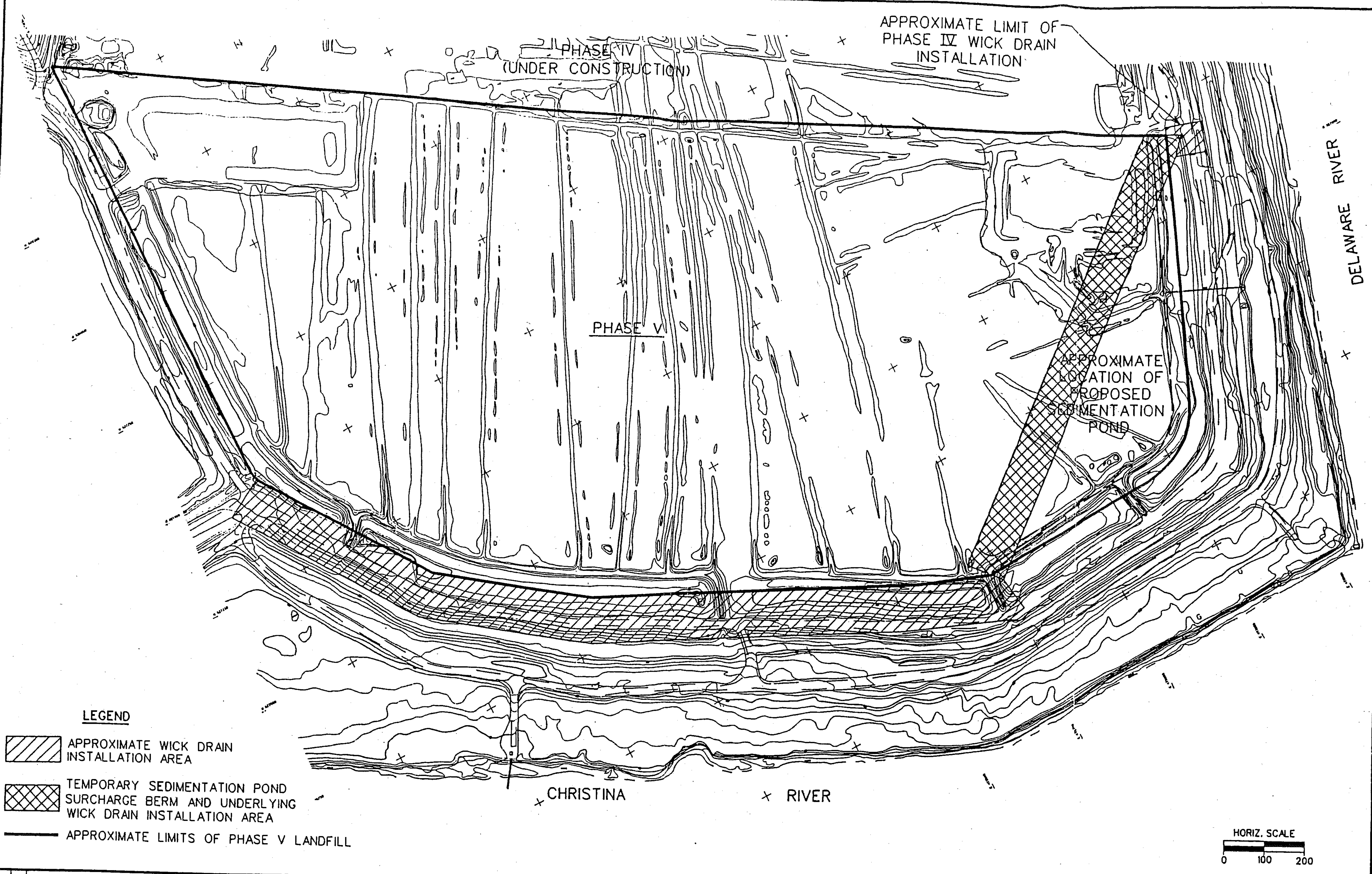
1. The Phase V landfill may be safely constructed from the inside top of slope of the Delaware River perimeter dike (i.e. at approximately elevation +53 feet) at a maximum 3H:1V inclination without benching to the design top elevation of this slope as discussed subsequently.

2. A waste thickness of 100 feet at the top of the 3H:1V waste sideslope was assumed in the bearing capacity and slope stability analyses. This thickness corresponds to a maximum permissible landfill top elevation of +148 feet at the top of the 3H:1V sideslope. It is understood that crowning of the landfill at a 2% grade will be required beyond the top of slope for proper drainage of the landfill flattop. This grading configuration should be designed consistent with achieving an elevation no greater than elevation +148.0 feet at the top of the 3H:1V landfill sideslope.

3. No high-strength, high-modulus reinforcing geosynthetics are necessary on the floor of the landfill along the eastern or southern perimeter berms based on the slope stability analyses. However, reinforcing geosynthetics will be required under, and to an adequate length beyond the footprint of the temporary surcharge berm of the sediment basin. These reinforcing geosynthetics are required to provide an adequate factor of safety against bearing capacity failure of the underlying foundation soils and to separate the surcharge berm fill from the underlying dredge spoils. The surcharge berm should be constructed of well compacted, stable granular fill soils which must remain in place permanently.

4. To preclude the development of excess pore water pressures within the Delaware River and Christina River perimeter dikes during active filling of the landfill, a pore water pressure relief, control, and monitoring system will be necessary as part of the design and construction of Phase V. The details of this design will be presented in the construction plans and specifications. This system will consist of the following:

   a. Installation of lines of wick drains along the eastern and southern perimeter of Phase V as shown on Figure 3-27. The wick drains will extend approximately 100 feet outward from the toe of the landfill slope. The spacing, depth, and number of these drains will be determined during final design of the system. A near surface drainage system will be constructed within the limits of the wick drains and



DSWA PHASE V
CHERRY ISLAND LANDFILL
WILMINGTON DELAWARE

WESTON

FILE NO.:DSW5220.DGN

DCN: 02477-004-001-

DSWA PHASE V
PROPOSED WICK DRAIN
INSTALLATION AREA

DATE 11-19-93	DWG. NO.	Figure 3-27
SCALE 1" = 100'	W.O. NO. 02477-004-001	

consist of a 1 foot thick high-permeability granular soil drainage blanket sloped to perforated collection pipes.

b. Controlled preloading of the outslope benches of the perimeter dike with common borrow materials as part of the specified landfill construction activities to be completed before waste placement begins. This process will facilitate internal drainage, consolidation and strength gain of these materials in a very controlled manner. The rate of application of these preloading lifts will be controlled by a system of installed piezometers which will monitor the dissipation of excess pore water pressures through the wick drains as induced by the various preload lift loadings.

c. Construction of a permanent surcharge berm to be constructed of carefully controlled, well compacted granular fill soils and located within the limits of the installed sedimentation pond wick drain field. The purpose of this berm will be to:

    1. Increase the undrained shear strength (i.e., c_u) of the dredge spoils and underlying recent deposits through consolidation of these materials.

    2. Increase the drained internal friction (i.e., $\bar{\Phi}$) of the dredge spoils and recent deposits through densification of these materials.

    3. Preclude the development of excess pore water pressures near and approximately 100 feet beyond the toe of the landfill slope during MSW filling operations.

    4. Serve as a counterweight to resist slope instability through the adjacent landfill mass.

d. Continued maintenance of the wick drain pore water pressure relief system during active filling of the landfill as well as continuous monitoring of the dissipation of excess pore water pressures within the perimeter dikes during this time using the installed piezometer system.

5. To design for the significant differential settlement potential of the site (to the extent possible), the features of the landfill floor grading plan and leachate collection system presented in Figure 3-15 will be incorporated into the design.

6. To permit effective leachate transmission to the leachate collection piping system, as well as to preclude leachate head buildup greater than the upward pore water pressures induced by the dredge spoils consolidation process, it is necessary to install a 12-inch thick, high-permeability granular soil drainage blanket of at least $1x10^{-2}$ cm/sec permeability over the entire Phase V landfill footprint. In addition, in order to maintain the continuity and thickness of this drainage blanket, a medium duty separation geotextile will need to be placed beneath the granular soil layer over the

entire Phase V footprint. This geotextile will also help safeguard against excessive localized differential settlement as well as bearing capacity failures near the working face of the waste, thereby facilitating more efficient landfill operations during placement of the first waste lift. The required properties of this geotextile will be determined as part of final design of this facility.

7. To preclude leachate migration into the Delaware and Christina River perimeter dike soils, a geosynthetic clay liner (GCL) with overlying soil protective cover should be placed along the inside slope of both perimeter dikes, and should extend from the top of the dike to the floor of the landfill (i.e., the surface of the dredge spoils). The details of this system, including proper anchorage of the GCL at the top of the dike, will be developed during the final design of the Phase I landfill.

8. Based on the results of the permeability and geochemical testing programs and the technical analyses of Subsections 3.6.4.1 and 3.6.4.2 of this report, it is concluded that the dredge spoils/recent deposits will satisfy the DNREC requirements of a natural soil liner at this site.

9. An operations plan must be developed and stringently followed for landfilling the three-phase footprint which conforms to technical assumptions 1 through 4 of Subsection 3.6.1 of this report. In this regard, it is critical that landfilling of each waste lift progress across the three-phase footprint in a rigidly defined and directionally similar manner so as to maximize the time interval between placement of various waste lifts at any given location within the landfill footprint. In addition, strict conformance to the minimum time intervals between sequential waste lift loadings placed at any given point within the Phase V footprint as documented in Figure 3-25 of this report is required by this design. It is also critical that the amount of waste placed along the eastern and southern perimeter of the site within any given time interval be minimized to avoid loadings of large areal footprint at this location from excessively surcharging the Delaware and Christina River perimeter dikes.

SECTION 4

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