USE OF DREDGED MATERIALS
FOR THE
CONSTRUCTION OF ROADWAY EMBANKMENTS

PREPARED BY:

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SUBMITTED TO:

NEW JERSEY MARITIME RESOURCES
NEW JERSEY DEPARTMENT OF TRANSPORTATION
NEW JERSEY DEPARTMENT OF ENVIRONMENTAL PROTECTION
NEW JERSEY PORT AUTHORITY OF NEW YORK AND NEW JERSEY
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INTRODUCTION

In 1998, the New Jersey Maritime Resources and the New Jersey Department of Transportation jointly sponsored a demonstration project to study the feasibility of beneficially reusing Stabilized Dredged Material (SDM) in the construction of road embankments (NJ Maritime Resources subsequently became part of NJDOT as the Office of Maritime Resources). The demonstration project was conducted by Sadat Associates, Inc. and Dr. Ali Maher[i], Geotechnical Consultant at Rutgers, the State University of New Jersey, on behalf of OENJ Corporation Inc. for the New Jersey Maritime Resources. The demonstration project included the construction of two embankments on the water front parcel (parcel G) of the OENJ Elizabeth Site (the Site). Between fifty to sixty thousand cubic yards of dredged material from Union Dry Dock were amended with Portland cement and placed at the Site for use in the construction of the two embankments. Geotechnical and environmental aspects of the use of dredge material for roadway construction were evaluated to assess 1) geotechnical manageability, strength, and workability of the material for the construction of roadway embankments and/or related structures and 2) the potential environmental impacts resulting from the use of SDM in roadway construction. Finally, the project included development of guidelines/recommendations for the use of SDM in NJDOT roadway construction projects.

BACKGROUND

The Port of NY and NJ is situated in the center of the Hudson Raritan Estuary complex. This estuary is naturally shallow, with an average depth of 19 feet at low tide. The Port is the largest on the East coast, with notable related businesses amounting to over $30 billion in annual regional benefits. Due to its strategic position in regional and international trade, the Corps of Engineers has provided over 200 miles of engineered waterways at depths ranging from 20 to 45 feet. Maintenance of these waterways, so crucial to safe navigation, requires annual maintenance dredging of 4-6 million cubic yards of sediment, or “dredged material”. Unfortunately, the proximity to heavily urban and industrial land use, coupled with historical mismanagement has resulted in a legacy of contaminated sediments.

Prior to 1996, dredged materials acceptable for ocean disposal were dumped at the USEPA designated ocean disposal site approximately 6 miles from Sandy Hook, New Jersey (the Mud Dump). In 1996, the United States Environmental Protection Agency (USEPA) closed the Mud Dump to dredged materials, and re-designated the area as the Historic Area Remediation Site (HARS). Since then, only dredged materials meeting the strict criteria of “remediation material” are permitted to be placed at the site. Since the 1996 USEPA ruling, the disposal of material not meeting the criteria of remediation material, so-called “non-HARS” material, has become a concern for Federal and State agencies.

The cost of non-ocean management of dredged materials is of particular concern to dredged materials managers. The current low-cost alternative for dredged material management is placement in sub-aqueous disposal pits. However the number of available sites for these pits is severely limited in the Harbor. Numerous studies have been conducted or are currently underway to further investigate alternatives to ocean dumping. One of the proposed alternatives is the beneficial use of non-HARS material in upland disposal sites. This entails the stabilization of non-HARS material with pozzolanic admixtures to create structural and non-structural fills and caps. The process of solidification of non-HARS material is more expensive than ocean dumping, but it has proven to be cost-competitive to aquatic disposal for large volume navigational dredging projects. For example, approximately 600,000 cubic yards of SDM was successfully used as structural fill for the construction of parking areas for the Jersey Garden’s Mall (former OENJ site, parcels A, B, and C). In this project, dredged material was amended with pozzolanic admixtures (Portland cement, cement kiln dust, lime kiln dust) to reduce

[i] The geotechnical consulting services provided by Dr. Ali Maher were rendered through Soiltek, Inc., a geotechnical consulting firm.

moisture and increase workability. Once the moisture content approached the optimum level, SDM was compacted using conventional construction equipment. In-situ testing was implemented for the SDM to ensure quality control.

The process of stabilizing problematic soils (such as high plastic clays and silts) by adding lime or cement goes back many decades. However, the natural moisture content of these soils is not nearly as high as that of dredged material. The use of dredged material as structural fill requires a significant reduction in moisture content and an increase in workability. Because of its high moisture content, the strength, compressibility, and durability of SDM present a major concern. Comprehensive laboratory analyses have been conducted to determine the engineering properties of SDM. These studies, in conjunction with full-scale field testing/monitoring of the two embankments in this study, have produced valuable data regarding the behavior of dredged material, particularly with respect to its use in roadway embankment applications.

CONSTRUCTION PHASE

Construction activities were initiated in September 1998 and completed in October 1999. About 81,000 cubic yards of the raw dredged material (RDM) was dredged and stabilized by mixing it with 8% (wet weight) Type II cement. The stabilized dredge material (SDM) was used for construction of the embankments at Parcel G of the OENJ Elizabeth redevelopment site.

Two embankments and an access roadway, designed to simulate typical highway configurations were constructed. Since the foundation soil at the site had potential for substantial and differential settlement, the embankments were constructed over a reinforced geosynthetic fabric to stabilize the foundation.

The construction of the embankments and the access roadway involved the use of excavators, loaders, dozers, disks and rollers. The material was spread in lifts and was left to dry for approximately one to two days. The material was frequently disked to accelerate and enhance the drying process. This disking-aeration-drying process was continued until acceptable moisture contents were achieved. The use of SDM having moisture levels similar to normal common fill is preferable since it allows the amended dredge to be handled in the same manner as normal common fill.

Upon completion of the two embankments and the access roadway, the contractor re-graded and applied final cover, consisting of six to eight inches of topsoil and vegetation on the slopes of the embankments, and recycled asphalt millings on top of the access roadway.

During the construction phase geotechnical and environmental monitoring devices were installed. Finally, a stormwater management system was installed consisting of one ditch around each embankment with stormwater runoff conveyed to a nearby wetlands transition area.

MONITORING, TESTING AND EVALUATION PHASE

GEOTECHNICAL

Geotechnical investigations undertaken as part of this project involved 1) the subsurface evaluation of the embankment foundations[ii], 2) laboratory analysis to study the geotechnical properties of soil matrices and 3) field monitoring of performance during construction and for approximately one year after the construction had been completed.

Laboratory Testing Program

The laboratory testing program focused on determining the geotechnical properties of the dredge material to

[ii] Due to site-specific geotechnical conditions, studies were conducted to design an appropriate foundation for the embankment.

assess its potential use in high volume applications, such as fills, embankments, and roadway base materials. The program included preparation of different recipes with raw dredge material (RDM), Portland cement and fly ash, and testing them after varying levels of curing and compaction. The laboratory testing classified the dredge material and assessed parameters of shear strength, swell pressure, consolidation, resilient modulus, permeability, compaction and durability of the SDM recipes, according to applicable ASTM or ASHTO standards.

The SDM used in this project is characterized as elastic silt (MH), with a moderate organic content (8% average). Moisture content of the RDM was 67% on an average. Compaction significantly influenced the engineering properties like shear strength, of the SDM. Admixtures did not influence the strength parameters significantly. The addition of cement increased the strength of the material significantly as long as the material was allowed to set gradually. However, the strength gain was reduced due to the continual breaking of cemented bonds in the SDM as a result of mixing and disking. Temperature had a major effect in the curing process of SDM, suggesting that SDM be placed during the warm seasons of the year (temperature above 40^{o}F).

The resilient modulus values for all the samples tested compared well with three sub-grade soils that are currently under New Jersey roadways. The Compression Ratio varied from 0.085 to 0.24, but did not exceed 0.19 for samples compacted to 83% or above MDD. The permeability of the compacted SDM was typically less than 10^{-7} cm/sec. Additional fly ash helped in reducing permeability.

The strain or swell percentage was not significant, ranging from 0.1% to 1.2%. However the swell pressure was high for samples compacted to 94% or higher of their MDD with moisture content to the dry side of the optimum. The samples were subjected to durability (freeze-thaw) tests and the results indicate that SDM is extremely susceptible to frost and shrinkage. This suggests that SDM should always be placed below frost line and proper soil cover needs to be provided.

Field Monitoring

The construction phase field monitoring included testing for the uniformity of mixes and in-situ compaction tests. Field compaction tests were performed in order to determine the dry density of in-situ SDM amended with Portland cement. The nuclear density gauge is commonly used for density control. For cement-stabilized soils, however, the nuclear gauge underestimates moisture contents resulting in overestimating dry density and strength parameters. In this study, in addition to nuclear gauge, the feasibility of using Humboldt Stiffness Gauge (HSG) and the Clegg Impact Hammer (CIG) to obtain rapid and accurate estimates of moisture content and dry density of SDM was evaluated. In the post construction phase monitoring, changes were recorded over a period of one year, of settlement, horizontal deformation and strength gain/loss.

The cement content of the mixes varied from 4% to 20%, the target cement content was 8%. The results indicate that the HSG measured compaction characteristics accurately, provided the samples were within a specific range of moisture content for which the HSG had been calibrated. The data analysis from CIH test was inconclusive.

The extensometer and settlement plate data indicated negligible vertical deformation within the SDM itself, but substantial settlement was recorded in the foundation soil. The inclinometer readings do not suggest any substantial lateral deformation. A series of CPT soundings were taken to monitor the integrity of the embankments over time. The results show no significant strength loss or gain over the course of one year.

ENVIRONMENTAL

Testing of environmental parameters was performed on RDM and SDM as well as on water percolated through the berm, stormwater runoff, ambient air, and air on personal samples. In addition, laboratory testing was done on RDM and SDM using laboratory simulations of acid rain. Test results were obtained for a wide range of chemical parameters for which criteria were established including the State's Residential and Non-Residential Soil Cleanup Criteria, Surface and Groundwater Criteria and OSHA PEL criteria for worker safety. Attachment

1 summarizes the results of testing in terms of parameters that may have impacted criteria to which they were compared. Other than soil cleanup criteria being slightly exceeded for a limited number of parameters (for which site specific approval can be allowed by NJDEP), the only issue was potential impact on surface and groundwater. Modeling calculations indicated that the detected concentrations of certain parameters in percolated water or stormwater after mixing with ambient water bodies will not adversely impact surface or ground water quality.

Other Impacts

The potential for corrosion of steel, reinforced concrete, and other structural materials by the SDM and associated liquids was evaluated through analysis of parameters such as acidity, chloride, pH, salinity, sulfate, sulfide, and resistivity.

Analysis of the data on potential corrosivity of the RDM and SDM suggest in general that the dredge material of the type used in demonstration project is potentially corrosive. Therefore suitable corrosion protection measures should be adopted for steel, reinforced concrete, and other structural materials that may come in direct contact RDM/SDM or which may come in contact with leachate or runoff from RDM/SDM embankments.

Total Organic Carbon (TOC) was analyzed in RDM and SDM as requested by the NJDEP to assess the suitability of SDM for upland beneficial use range. The TOC concentrations within both the RDM and SDM are typical of fine textured uncultivated soils. Proper geotechnical design of roadway structures using SDM can accommodate this level of organic content.

COST ANALYSIS

Typical construction costs for projects using SDM were analyzed. The analysis revealed that the incremental construction cost for utilizing SDM was approximately $1.50/cubic yard, assuming that the material was fully stabilized prior to be used as fill. The incremental costs beyond costs normally involved in placement of common fill in roadway construction were related to additional geotechnical engineering, field monitoring, installation of best management practices and permitting requirements.

CONCLUSIONS

The dredged material used in this Demonstration Project in its raw form is typical of that generated from maintenance dredging operations of the New Jersey Harbor areas, including the Hudson River, Kill Van Kull, Newark Bay, and Port Elizabeth. Due to its physical drainage and gradation characteristics, the RDM may not generally meet the existing NJDOT specifications for common fill. However, as shown by the results from this Demonstration Project, stabilizing the dredged material results in a material exhibiting strength, slope deformations, and settlement characteristics that would be satisfactory for NJDOT projects.

Results of the field testing and monitoring of SDM suggest that settlement in the SDM sub-grade is not significant. It is estimated that SDM embankments up to a height of 30 feet can be constructed with only minimal settlement within the SDM fill. The embankments were not subjected to dynamic loading. However, values of resilient modulus for all SDM samples compared well with three sub-grade soils that are currently under New Jersey roadways. It may be noted that laboratory resilient modulus values give a measure of the strength of sub-grade soils under dynamic vehicular loads.

The environmental screening analyses performed by SAI indicated the potential for stormwater runoff and percolated water to impact receiving water bodies. However, worst-case mathematical modeling results indicated that no significant impact on the receiving water body would result from the use of SDM, even before the application of BMPs.

The work performed during this demonstration project concluded that the impact to environment by using SDM is minimum. Furthermore, implementation of BMPs during construction would reduce any potential impact.

To assist the reader in understanding the environmental and construction issues involved in an SDM project, a hypothetical construction project is described in the report. As detailed within the hypothetical project, the use of SDM for roadway projects requires careful project planning and site selection. While the demonstration project showed that the use of SDM would result in minimal environmental impacts, in order to minimize any risks (as well as reduce the potential for public concerns) the most appropriate sites for similar SDM projects would be in existing Brownfield areas, and probably where a confining layer is present in the sub-soil strata.

RECOMMENDATIONS

Because the demonstration project did not involve dynamic loading conditions, additional studies of dredged material subjected to dynamic loading are recommended. These will evaluate the structural strength of SDM and environmental impacts under dynamic loading conditions (i.e. vehicular traffic). It is also recommended that the effect of additional admixtures be further studied.

Because properly conditioned SDM has geotechnical properties similar to fine grained soils (clay, silt etc), roadway structures utilizing SDM require appropriate design considerations such as protection from freeze/thaw and drainage measures that account for the low permeability of SDM.

In order to avoid introduction of contaminants present in SDM not meeting RDCSCC, roadway projects utilizing such SDM should be suggested for areas already having existing soil contamination. In general, Brownfield areas in need of remediation should be selected for SDM fill projects.

To minimize potential impacts to human health and the environment, to ensure structural stability, and to minimize construction costs, the use of environmental Best Management Practices (such as worker safety protection, stormwater runoff controls etc.) is recommended. The use of BMPs, required in all construction projects, as well as appropriate site selection, would further mitigate any potential environmental impacts associated with the use of SDM.

The comparison of results obtained from the analysis of MMEP leachates in the laboratory and field percolated water yield that MMEP may not be a representative technique of assessing potential leachability of contaminants from SDM. MMEP is a costly technique. An alternative method needs to be developed to predict more accurately the potential leachability of contaminants from SDM.

Attachment 1 – Instances of Criteria Impact

Parameter ▼	Dredge Material				Percolated Water		Stormwater Runoff	
	RDM		SDM		Laboratory Generated	Field Generated	During Construction	Post Construction
Standard/Criteria ▶	**RDCSCC**	**NRDCSCC**	**RDCSCC**	**NRDCSCC**	**GWQS** [iii]	**GWQS**[iii]	**SWQC**[iv]	**SWQC**[iv]
Alpha-BHC					x			
Benzo(a)anthracene	x	x	x	x				
Benzo(b)fluoranthene	x	x	x	x				
Benzo(k)fluoranthene	x	x	x	x				
Benzo(a)pyrene		x		x				
Dioxins							x	x
Aluminum					x	x		
Arsenic				x	x	x	x	x
Beryllium		x		x				
Cadmium							x	
Chloride					x	x	x	x
Copper							x	
Chromium							x	
Iron						x		
Lead			x				x	x
Manganese						x		
Mercury					x		x	x
Nickel						x		
Selenium							x	
Sodium					x	x		
Thallium						x	x	x
Zinc		x		x				

[iii] Potential impact prior to mixing in the aquifer.

[iv] Potential impact prior to mixing in receiving surface waters.

2.0 DEMONSTRATION PROJECT

2.1 INTRODUCTION

Section 2.0 of this report focuses on the activities conducted for the Demonstration Project and supplements the information previously submitted in the March 2000 Progress Report entitled "Use of Dredged Materials in the Construction of Roadway Embankments" (included as Appendix F). This section was prepared by Sadat Associates, Inc. ("SAI") and Dr. Ali Maher, Geotechnical Consultant at Rutgers, the State University of New Jersey ("Soiltek")[1] on behalf of OENJ Corporation Inc. ("OENJ") for the New Jersey Maritime Resources ("NJMR").

This project ("Demonstration Project") was established to assess the suitability of using dredged materials in roadway construction. The project involved the construction of two roadway embankments and an access road using stabilized dredged materials ("SDM") at the OENJ Redevelopment Site in Elizabeth, New Jersey. Geotechnical and environmental conditions were evaluated during the preparation of the construction materials (i.e., dredging and material stabilization), during construction of roadway embankments (i.e. material transport, drying, spreading, and compaction) and for the 13-month period after the construction of the embankment (post-construction period).

This Section 2.0 presents the construction and monitoring field activities performed until December 1, 1999, which were also presented in the March 2000 Progress Report. This section also presents the findings of the post-construction field activities performed from December 1, 1999 to October 28, 2000, when all field monitoring activities for the Demonstration Project were concluded. The activities performed since the submission of the March 2000 Progress Report include:

- the collection of two additional percolated water samples from Embankment Number 2;
- the collection of three additional stormwater samples from Embankment Number 2; and
- the completion of the air quality analyses and evaluation.

The samples collected during the post-construction period were analyzed by certified laboratories using appropriate QA/QC controls. All chemical data was then entered into a database system designed to facilitate the management of information during the preliminary data screening and evaluation efforts.

The environmental sampling data for dredged material, leachate, percolated water, and stormwater runoff were compared with existing medium specific standards and criteria, and were evaluated for potential impact on surface water and ground water systems. The comparisons were made for screening purposes only in order to identify potential parameters of concern, not for compliance purposes. Based on the screening evaluation, certain parameters and media were further evaluated via mathematical models to assess potential environmental impacts associated with the use of SDM in roadway construction projects.

2.1.1 Project Objective and Project Team

The Demonstration Project involved the construction of two embankments and an access roadway at Parcel G of the OENJ Redevelopment Site in Elizabeth, New Jersey. These structures were tested and monitored to evaluate the suitability of using SDM in NJDOT roadway construction projects.

The overall objectives of the OENJ / NJDOT Demonstration Project were:

- the collection of data on the geotechnical / engineering characteristics and behavior of the SDM in order to evaluate the manageability, strength, and workability of the material for the construction of roadway embankments and/or related structures;
- the collection and analysis of chemical data for the evaluation of the potential contaminant migration pathways and potential environmental impacts resulting from the use of SDM in roadway construction; and
- The development of guidelines for the use of SDM in NJDOT roadway construction projects.

The field testing and monitoring activities for this Demonstration Project consisted of the performance of:

- an environmental testing and monitoring program for air, soils, percolated water and stormwater; and
- a geotechnical testing and monitoring program.

The procedures for the performance of the environmental testing and monitoring programs followed the guidelines set forth in the following documents:

- NJDEP's May 1992 "Field Sampling Procedures Manual;"
- NJDEP's October 1997 "The Management and Regulation of Dredging Activities and Dredged Material in New Jersey Tidal Waters;" and
- US Army Corps of Engineers' February 1998 Technical Note DOER-C2, "Dredged Material Screening Tests for Beneficial Use Suitability."

The Project Team, consisting of OENJ, EE Cruz, SAI, and Soiltek, implemented the construction and testing activities. OENJ is the owner of the Demonstration Project Site and served as General Contractor. EE Cruz was responsible for stabilizing the dredge and constructing the embankments, access roadway, and associated improvements. SAI was the Project Manager and responsible for supervising the overall construction activities, performing the environmental monitoring, and evaluating the environmental data. Soiltek was responsible for installing the geotechnical instrumentation, performing the geotechnical monitoring, and evaluating the geotechnical data (see Section 2.2 for further details).

Results from all phases of the project have been submitted for review and comments to members of the following agencies and their consultants:

- New Jersey Maritime Resources (“NJMR”);

- New Jersey Department of Transportation (“NJDOT”) and Stevens Institute of Technology, consultant to NJDOT;

- New Jersey Department of Environmental Protection (“NJDEP”);

- The Port Authority of New York and New Jersey (“PANY/NJ”); and

- New Jersey Transit (“NJ Transit”) and its consultant, Dames & Moore.

These agencies and their consultants are referred to as “interested agencies” or “interested parties” in this report.

2.1.2 Site Location

Three different sites were used for the development of the Demonstration Project:

- Dredging Site: The Union Dry Dock in Hoboken, New Jersey was the source of the dredged sediments transported to the Sealand Facility for stabilization.

- Stabilization Site: The mixing of the dredged sediments with cement (stabilization) was conducted at the Sealand Facility in Elizabeth, New Jersey. Following stabilization, the material was transported to Parcel G of the OENJ Redevelopment Site in Elizabeth, New Jersey for construction.

- Construction Site: The embankment and roadway construction activities were conducted in Parcel G of the OENJ Redevelopment Site, including air-drying, compaction, and roadway construction. This 20-acre parcel comprises the undeveloped eastern portion of the OENJ Redevelopment Site and is situated on the western shore of the Newark Bay in Elizabeth, New Jersey.

Figure 2.1 shows the locations of the Union Dry Dock area, the Sealand Facility, and Parcel G.

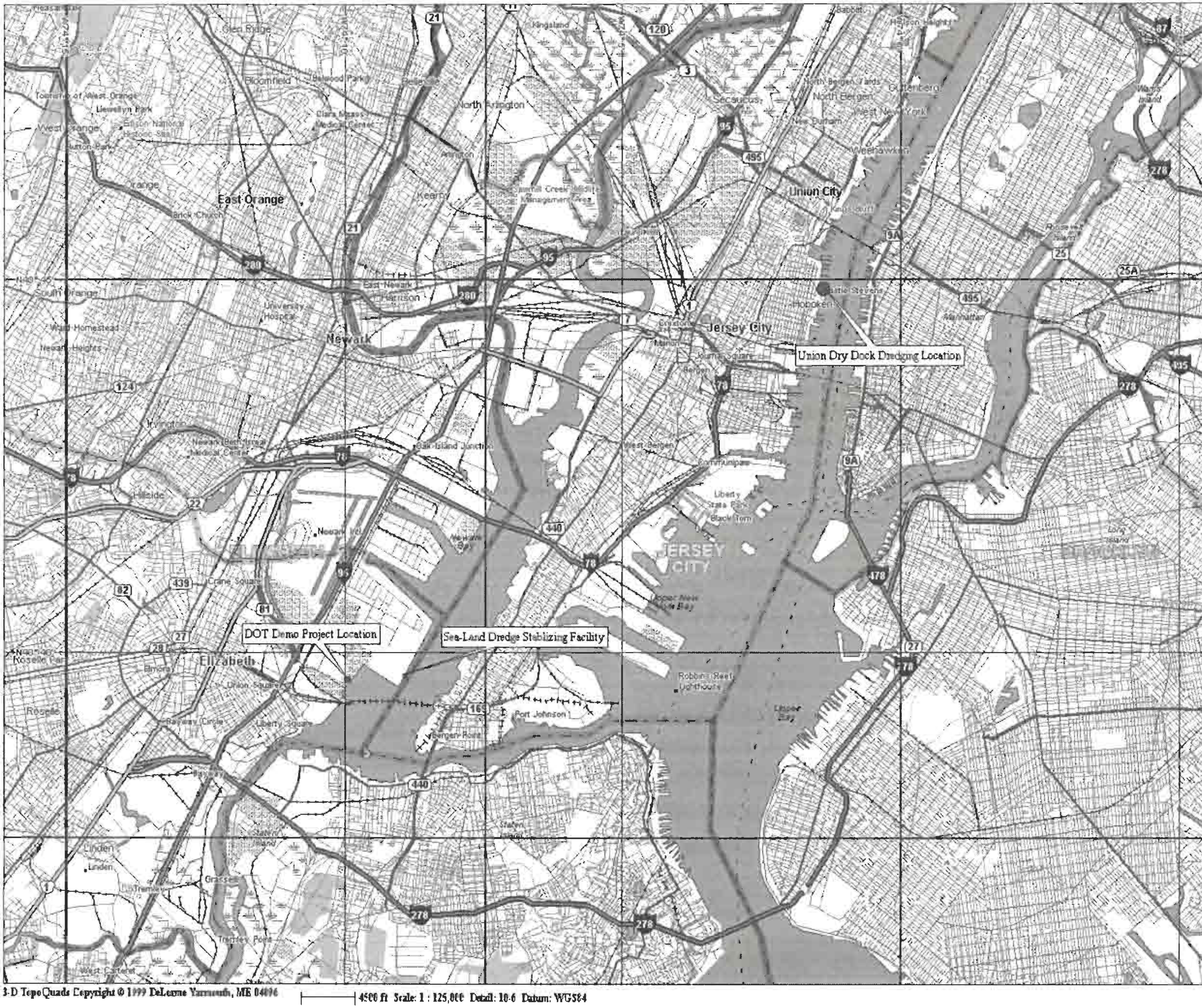


Figure 2.1 Site Plan

2.1.3 Project History

Between 1996 and 1998, stabilized dredged material ("SDM") was used at the OENJ Redevelopment Site as fill and/or capping material for the closure of a former landfill. In addition, SDM was used as structural fill to provide sub-grade support for vehicle access roadways and parking lots for the Jersey Gardens Mall. The SDM was used in accordance with an NJDEP-approved, site-specific "Protocol for Review and Certification of Recyclable Materials at the OENJ Site, Elizabeth, New Jersey." prepared by Sadat Associates, Inc.

On September 19, 1997, OENJ submitted a request for funding and a preliminary scope of work for a Demonstration Project to the NJMR. After several technical discussions with the NJMR and the NJDOT, the Demonstration Project was approved and funding was granted to the OENJ Corporation

In August 1998, a "Draft Geotechnical and Environmental Testing Work plan for the OENJ/NJDOT Roadway Embankment Pilot Project at Parcel G of the OENJ Redevelopment Site, Elizabeth, Union County, New Jersey" ("Draft Work plan") was prepared. This document included the scope of the field proposed monitoring activities. The Draft Work plan was presented to and discussed with interested agencies during a meeting held on September 8, 1998. Comments, questions and concerns related to the issues presented in the Draft Work plan were discussed and resolved during that meeting.

Several other meetings were held with the interested agencies to discuss technical and regulatory issues related to this project. Based on the decisions made during these meetings and further evaluation of the various technical issues, a "Final Work plan" was submitted to the interested agencies on February 22, 1999. In response to NJDEP's April 9, 1999 comments on the Final Work plan, a "Revised Final Work plan" was submitted to the interested agencies and parties on June 11, 1999. This Revised Final Work plan guided subsequent activities related to the Demonstration Project.

2.1.4 General Project Description

The Demonstration Project involved the construction of Embankment No. 1, Embankment No. 2, and an access roadway using SDM at Parcel G of the OENJ Redevelopment Site. Environmental and geotechnical field monitoring and tests were conducted prior to, during, and after construction of the two embankments and the access roadway.

The location and configuration of the two embankments and the access roadway were presented in the March 2000 Progress Report (Drawing No. 1 of Appendix A). Figure 2.2 below presents a flow chart indicating the main aspects of the construction phase of the project, and summarizes the environmental and geotechnical testing performed prior to, during, and after construction.

The construction and testing activities are summarized below.

Construction

The preparation of the dredged material, conducted prior to the construction of the embankments, consisted of the following activities:

- dredging at the Union Dry Dock site;
- material stabilization at the Sea-Land facility; and
- transport and stockpiling of the SDM at the construction site.

The embankment construction activities included:

- preparation of a platform and a foundation for construction of the embankments;
- construction of the embankments and access roadway;
- installation of geotechnical monitoring devices such as inclinometers and settlement plates; and
- installation of a collection system for percolating water and a stormwater conveyance system.

Monitoring

Geotechnical monitoring, which was conducted prior to, during, and after construction, included:

- cement content testing;
- subsurface investigation for design of the foundation;
- laboratory testing of SDM strength parameters;
- field compaction monitoring;
- settlement monitoring;
- inclinometer monitoring; and
- cone penetrometer testing for long-term strength evaluation.

Environmental monitoring activities included the sampling and characterization of:

- **Solids**
  raw dredged material (RDM)
  stabilized dredged material (SDM)
  soil cover

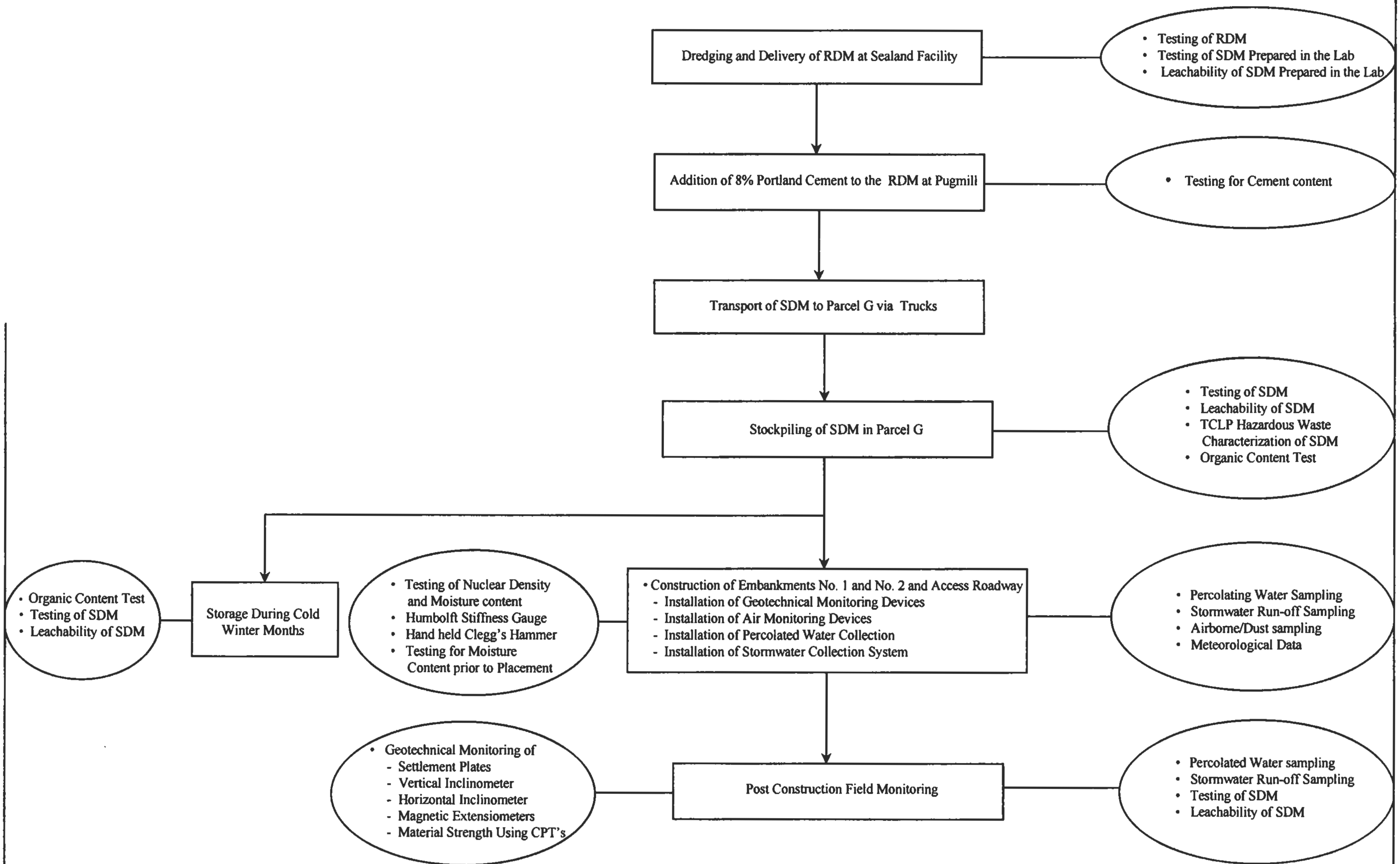
- **Liquids**
  leachate generated from SDM samples in the laboratory
  stormwater runoff
  percolated water

- **Air**
  airborne / dust samples collected during construction.

Figure 2.3 defines the engineering activities related to the performance of the project.

Figure 2.2 – Project Flow Chart

CONSTRUCTION & GEOTECHNICAL/ENVIRONMENTAL TESTING



ENGINEERING ACTIVITIES

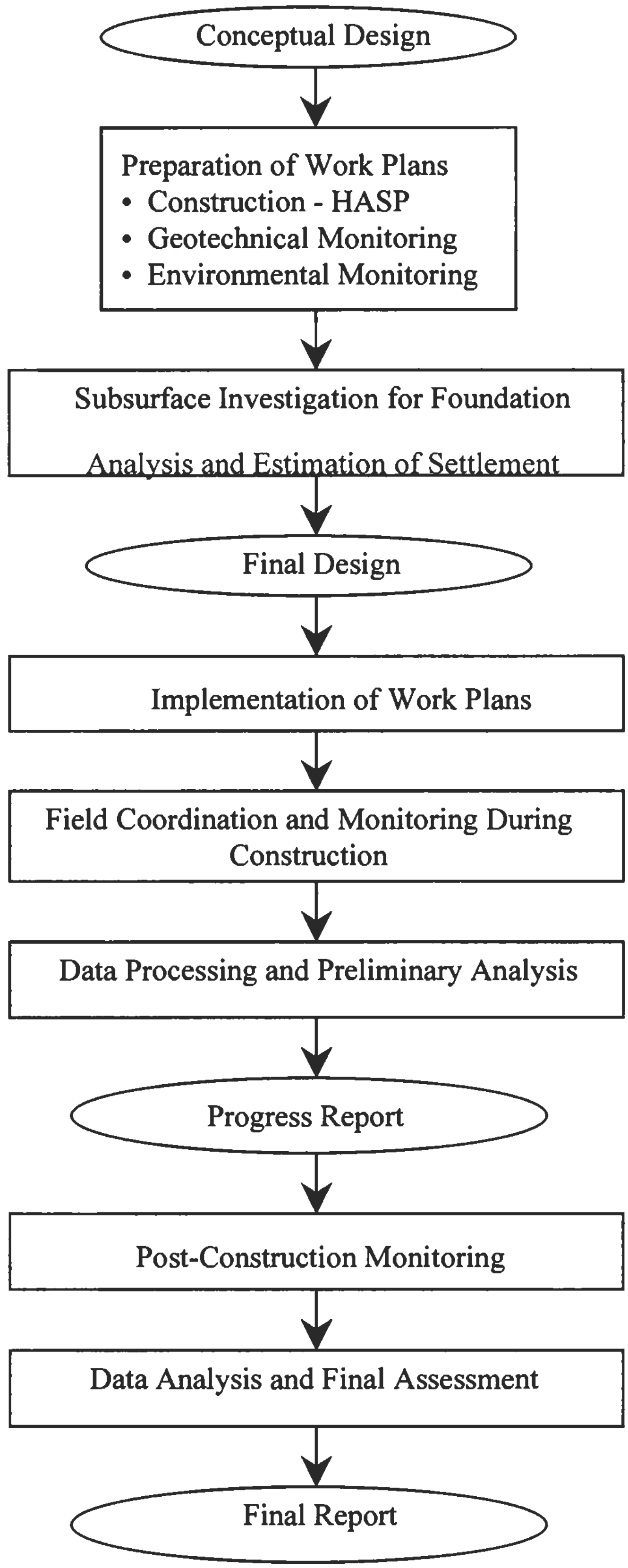


Figure 2.3

2.2 PROJECT TEAM, DOCUMENTATION, AND HASP

2.2.1 Demonstration Project Team

The Project Team involved in the construction and monitoring activities of the Demonstration Project included the following:

- **Project Owner and Grant Recipient:** OENJ Corporation responsible as project owner for grant application and grant administration;

- **Project Manager:** SAI - responsible for the overall preparation and development of the Workplan(s), project team management and coordination with project grant recipient, overall coordination of the construction and monitoring activities, proper documentation and records maintenance pertaining to the geotechnical and environmental monitoring programs, and preparation of the final report(s);

- **Geotechnical Consultant:** Soiltek (Dr. Ali Maher) - responsible for the oversight, installation, management, and execution of all geotechnical testing, monitoring, and evaluation activities;

- **Air Monitoring and Evaluation Consultant:** Environmental and Occupational Health Sciences Institute ("EOHSI," Dr. Paul Lioy and Dr. Clifford Weisel[2]) - responsible for the execution of the air monitoring activities and evaluation of the air quality data in conjunction with SAI;

- **Field Coordinator and Health and Safety Officer:** SAI - responsible for the management and oversight of the construction and field monitoring activities and for the implementation of the February 23, 1999 Health and Safety Plan ("HASP");

- **Construction Contractors:**
  E.E. Cruz Company, Inc. - responsible for the stabilization of the RDM, as well as construction of a portion of Embankment No. 1, the entire Embankment No. 2, the access roadway, and all associated appurtenances. E.E. Cruz was the Construction Contractor from September 29, 1998 until July 31, 1999, and

  KMC - responsible for the completion of the construction activities initiated by E.E. Cruz. KMC served as Construction Contractor starting August 1, 1999, and completed the construction phase of the Demonstration Project on October 19, 1999;

- **Surveying Subcontractor:** McCutcheon Associates, P.A. - responsible for all surveying activities and the collection of elevation readings from the settlement plates installed in the embankments;

- **Subcontractors for the Installation of Geotechnical Monitoring Devices:**
  Warren George, Inc. - responsible for the performance of drilling activities;

  E.E. Cruz - responsible for the installation of settlement plates and horizontal inclinometer; and

  Converse East Consultants - responsible for the installation of the vertical inclinometers;

- **Laboratory Subcontractors:**
  Aqua Survey, Inc. - responsible for the collection and testing of environmental samples until June 26, 1999. Testing of the samples was conducted by laboratories subcontracted by Aqua Survey,

including Intertek Testing Services,[3] Environmental Testing Laboratories, and Triangle Laboratories.

Environmental Testing Laboratories ("ETL") - responsible for the collection and testing of the SDM, percolated water, and stormwater samples after June 26, 1999.

2.2.2 Laboratories Used for the Project

The following laboratories were used during the various phases of the project:

- Analysis of raw and stabilized dredge material, percolated water, and stormwater samples for environmental parameters:

Aqua Survey, Inc. (until June 26, 1999)
499 Point Breeze Road
Flemington, New Jersey 08822
NJDEP Certification #10309

Intertek Testing Services (April 1998 Samples only)
55 South Park Drive
Colchester, Vermont 05446
NJDEP Certification # 85972

Environmental Testing Laboratories, Inc.
208 Route 109
Farmingdale, New York 11735
NJDEP Certification #73812

Triangle Laboratories (for Dioxin / Furans Analysis of April 1998 Samples only)
801 Capitol Drive
Durham, North Carolina 27713
NJDEP Certification #67851

PACE Analytical Services, Inc. (for Dioxin / Furans Analysis of Samples After April 1998)
1700 Elm Street - Suite 200
Minneapolis, MN 55414
NJDEP Certification #63002

- Analysis of airborne particulate samples from the personal monitoring program:

Princeton Analytical
47 Maple Avenue
Flemington, New Jersey 08822
AIHA Certification #509
NJDEP Certification #10003
NYDOH ELAO Certification #11586
NIOSH PAT Certification #7021

- Analysis of airborne particulate samples from area monitoring program:

Environmental and Occupational Health Sciences Institute, Rutgers University Laboratories

170 Frelinghuysen Road
Piscataway, New Jersey 08855-1179
Research Institute[4]

- Analysis of the engineering geotechnical properties of soil samples:

  Geotechnical Laboratory
  Civil and Environmental Engineering
  Rutgers, The State University of New Jersey
  Piscataway, New Jersey 08854

2.2.3 Documentation

The team member(s) performing a particular field monitoring program kept detailed field records within daily field logs. The field logs are presented as Appendix B-1. The daily field logs included records of:

- sampling / monitoring activities;
- daily weather conditions;
- field measurements;
- name of individual responsible for the monitoring / sampling, as well as activities being performed at the Site;
- on-site personnel;
- site-specific observations;
- type of equipment used;
- condition of the SDM; and
- required efforts to achieve the required density and moisture content of the SDM.

The documentation also contained any deviations from the protocol, visitors' names, and community contacts during the construction activities. Representative photographs of the different activities during the construction phase of the Demonstration Project are presented in Appendix B-2.

2.2.4 Health and Safety Requirements

The project team and subcontractors performed all field activities in conformance with a site-specific HASP, which was developed in accordance with the most recently adopted and applicable general industry (29 CFR 1910) and construction (29 CFR 1926) standards of the Federal Occupational Safety and Health Administration ("OSHA"), as well as other applicable Federal, State and local statutes and regulations. The Final HASP was submitted to the NJDEP on February 23, 1999.

The HASP was developed for use by SAI personnel during the performance of the construction and monitoring activities. All other members of the project team and its subcontractors were required to develop and follow their own HASPs, which followed the general guidelines of the SAI's February 23, 1999 HASP.

2.3 PRE-CONSTRUCTION ACTIVITIES

Prior to initiating the construction activities, some preliminary investigations and activities were deemed necessary. These investigations consisted of:

- preparation of work plan(s) and a preliminary design;
- characterization of the RDM and SDM;
- a foundation study for the evaluation of the physical and engineering characteristics of the sub base to be used for the two embankments; and
- preparation of a final design and work plan.

2.3.1 Work plans and Preliminary Design

Initial planning of the project involved the preparation of a preliminary design and work plans for construction and monitoring. The preliminary design was prepared to estimate work quantities, evaluate the configuration of the embankments, and determine the type and quantity of monitoring activities. The preliminary design was submitted to the interested agencies for review.

In August 1998, based on the preliminary design, a "Draft Geotechnical and Environmental Testing Work plan for the OENJ/NJDOT Roadway Embankment Pilot Project at Parcel G of the OENJ Redevelopment Site, Elizabeth, Union County, New Jersey" ("Draft Work plan") was prepared. This document included the scope of the field proposed monitoring activities. The Draft Work plan was presented to and discussed with interested agencies during a meeting held on September 8, 1998. Comments, questions and concerns related to the issues presented in the Draft Work plan were discussed and resolved during that meeting.

Several other meetings were held with the interested agencies to discuss technical and regulatory issues related to this project. Based on the decisions made during these meetings and further evaluation of the various technical issues, a "Final Work plan" was submitted to the interested agencies on February 22, 1999. In response to NJDEP's April 9, 1999 comments on the Final Work plan, a "Revised Final Work plan" was submitted to the interested agencies and parties on June 11, 1999.

The Revised Final Work plan included the final design for construction, incorporating the results of the foundation analysis. Activities related to the foundation analysis and the final design were presented in the March 2000 Progress Report, and are discussed in subsequent sections of this report.

Originally, the design for the Demonstration Project consisted of the construction of two embankments (Embankment No. 1 and Embankment No. 2) at Parcel G of the OENJ Redevelopment Site. Embankment No. 1 was to be constructed at the northernmost portion of the parcel, while Embankment No. 2 was to be situated at the southern portion of the site. The area between the two embankments was to be used for the temporary stockpiling of the SDM.

During a meeting with all the interested parties and agencies on September 8, 1998, the NJDOT requested that some of the dredged material be used for the construction of an access roadway. This item was added to the original design of the Demonstration Project.

In addition, material excavated during the installation of utilities at the OENJ Site and during the wetlands mitigation activities was placed at the southern portion of Parcel G. Hence, the southern embankment (“Embankment No. 2) was relocated towards the middle of Parcel G. This new location for Embankment No. 2 had less compressible material thickness than the original location, thereby reducing potential settlement. A portion of Embankment No. 2 was constructed on top of competent sand that was placed for the installation of a 10-foot reinforced concrete pipe that drains stormwater into the Newark Bay. This issue was presented to NJMR and the NJDOT during the meeting of November 13, 1998. Minor refinements and changes were made to the final design since then in order to accommodate various comments and concerns of the interested agencies. The final design of the Demonstration Project was presented in the Revised Final Work plan dated June 11, 1999.

2.3.2 Initial Sampling of the Raw and Stabilized Dredged Material

Sampling of the RDM and the SDM was discussed in detail in Section 7.0 of the March 2000 Progress Report, and is also included within Section 2.7 of this report.

The environmental sampling conducted prior to construction consisted of the following:

- sampling and analysis of RDM, laboratory-prepared SDM, and laboratory-generated leachate from SDM. The sampling was conducted prior to dredging as required for material acceptance at the site;
- sampling and analysis of SDM and leachate generated from SDM from samples collected at stockpiles in Parcel G;
- TCLP Hazardous Waste Characterization of SDM stockpiled at Parcel G; and
- organic content tests of SDM.

The geotechnical testing and monitoring conducted prior to actual construction included:

- collection of RDM to evaluate geotechnical characteristics of different admixtures in the laboratory;
- testing of cement content in RDM; and
- extensive subsurface investigation to specify the foundation of the embankment structures (as presented in Section 3.3 of the March 2000 Progress Report and Section 2.3.3 of this report).

2.3.3 Foundation Analysis and Final Design

As identified during the prior closure activities of the OENJ Redevelopment Site, the subsurface of Parcel G generally consists of one foot of soil cover over 8 to 23 feet of refuse material, which overlays a 5 to 10 foot thick peat layer. The peat layer rests on sands overlaying 30 to 40 feet of clay.

Due to the thickness of the compressible refuse layer, foundation improvement was considered necessary to minimize settlements in the substrata. Furthermore, measures had to be implemented to differentiate between settlements in the substrata (foundation settlements) and settlements within the embankments. The testing requirements for this investigation were summarized in Table 7 of Appendix A of the Revised Final Work plan.

Field activities required for the foundation analysis were conducted during September and October 1998 by Warren George, Inc. under the supervision of Soiltek. The results of the foundation study are detailed in the November 6, 1998 "OENJ / NJDOT Embankment Demonstration Project - Site Investigation and Foundation Analysis," ("Foundation Geotechnical Report"), which was previously submitted to the interested agencies. A copy of this report was included in Appendix C of the March 2000 Progress Report. The foundation investigations generally involved the performance of Cone Penetration Tests ("CPTs") at 15 locations. The information from the CPTs was used to determine the site's suitability for the proposed embankment load.

In addition, correlation of Standard Penetration Test ("SPT") with soil strength was conducted using data from four soil borings. All borings were thoroughly grouted and sealed after the completion of the work. Continuous soil samples were collected from each of the four borings for soil classification (as per ASTM D-1140, 422 and 4318) and to determine certain engineering properties (strength and consolidation) of the strata. In addition, samples were subjected to triaxial tests (as per ASTM D-4767 / ASTM D-2850-87) and consolidation tests (as per ASTM D-2435).

During the performance of the CPTs, at the locations of the originally proposed Embankments No. 1 and No. 2, the thickness of the refuse layer was found to be approximately 19 to 20 feet and 8 to 9 feet, respectively. The refuse material consisted primarily of wood, metal, tires, paper, construction debris and soil. Some waste material excavated during various closure activities at other areas of the OENJ Redevelopment Site was also found at the southern portion of Parcel G. Common sandy fill, rather than waste material, was encountered near the 10-foot reinforced concrete pipe ("RCP") that runs through Parcel G, which replaced the Great Ditch as part of the OENJ Redevelopment Site's closure activities.

Peat and soft elastic clayey silt were found below the refuse layer. The thickness of this soil stratum was found to range from 5 to 10 feet. Based on the CPT soundings, the silt layer underlays the peat layer, and consisted of silty sands to sandy silts with occasional clay. Previous investigations conducted at the OENJ Redevelopment Site encountered very stiff to hard red lean clay (approximately

30 to 40 feet thick) and hard red decomposed shale beneath the sandy formation. Finally, red brown bedrock of the Brunswick Formation was encountered at depths of 65 to 83 feet below ground surface.[5]

More information on the types of materials encountered and their engineering and physical characteristics are provided in the Final Geotechnical Report (Appendix D).

According to Soiltek's Foundation Geotechnical Report:

- settlement of approximately ten inches was estimated within the refuse layer after construction of Embankment No. 2, and,

- settlement of approximately 18 inches within the refuse fill layer was estimated after construction of Embankment No. 1.

Based on the geotechnical analysis, it was recommended that a reinforced synthetic fabric be placed at the base (one foot above the actual toe elevation) of Embankment No. 2 to potentially minimize the anticipated settlement of this embankment and allow for a more uniform settlement.

Pre-loading was originally selected to improve the foundation for Embankment No. 1. Due to time limitations and field conditions, it was concluded that a reinforced synthetic fabric should also be placed at the foundation of Embankment No. 1 to encourage even settlement and to minimize overall settlement.

Based on the results of the foundation analysis and on the comments made by the interested agencies, the final design was prepared and submitted. Appendix A presents the final construction drawings.

2.4 CONSTRUCTION ACTIVITIES

The construction activities performed for the Demonstration Project were initiated on September 14, 1998 and completed on October 16, 1999. As previously mentioned, the activities mainly included:

- the stabilization of the raw dredged material excavated from the Union Dry Dock site;
- the construction of the two roadway embankments (Embankment No. 1 and Embankment No. 2) and an access roadway which were designed to simulate typical highway configurations;
- the installation of geotechnical and environmental monitoring devices;
- the installation of a piping system to collect percolated water; and
- the construction of a stormwater management system to manage and monitor runoff from the embankments.

Environmental monitoring, sampling, and testing were conducted during the stabilization of the dredged materials and also during the construction of the embankments. During construction, the monitoring activities included the collection and analysis of air, dredged material, percolated water and stormwater samples. The evaluation of the air monitoring data obtained during the construction phase is described in Section 2.6 herein. The environmental monitoring / sampling activities conducted during construction are presented briefly in this section and more extensively in Sections 2.7 of this report.

Geotechnical testing and monitoring was performed to obtain information on the physical and engineering behavior of the material and the structures. Descriptions of the geotechnical activities are summarized in Section 2.5 of this report, and within the ‘Final Geotechnical Report by Soiltek (Appendix D).

Daily field reports were prepared during the construction activities. A copy of the daily field reports during the construction of the two embankments and the access roadway from February 16 to October 19, 1999 are included in Appendix B-1. In addition, representative photographs of the construction activities are presented in Appendix B-2.

2.4.1 Stabilization of the Raw Dredged Material (“RDM”)

The material used for the construction of the Demonstration Project structures was dredged from the Union Dry Dock Site by the Great Lakes Dredging Company. The dredging activities, which involved a total of approximately 81,000 cubic yards of sediments, were initiated on September 14, 1998 and completed on November 13, 1998.

Upon dredging, the RDM was loaded onto a barge and transported to a pugmill at the Sea-Land processing facility, where it was stabilized by mixing it with 8% (wet weight) Type II cement. The addition of cement to the RDM enhanced the workability of the material by decreasing its water content and creating a material easier to transport, spread, grade, and compact. The SDM was then loaded onto trucks and transported to designated areas at Parcel G, where it was stockpiled from October 1998 to February 1999, when the actual construction of the embankments began.

2.4.2 Construction of Embankments No. 1, No. 2 and Access Roadway

The construction of Embankment No. 2 was initiated on February 19, 1999 and completed on June 28, 1999. The construction of Embankment No. 1 was initiated on June 23, 1999, with the preparation of the structure's platform, and was completed on September 30, 1999.   The construction of the access roadway started on June 1, 1999 and finished on July 16, 1999. The location and final configuration of the embankments and the access roadway are presented on Drawing No. 1 of Appendix A.

All construction activities were conducted outside the 150-foot wide buffer zone (or wetlands transition area) of the existing wetlands located north of Parcel G, as well as at least 100 feet from the mean high water line of the Newark Bay. Prior to the initiation of the construction activities, all appropriate soil erosion and sediment control ("SESC") measures were implemented according to the existing approved SESC plan for the OENJ Site.

Embankment No. 1 is constructed along the northern portion of Parcel G (Drawing No. 1 of Appendix A). This structure is 620 feet long, 130 feet wide at the top and 180 feet wide at the base. The maximum height of the embankment is 10 feet above grade. The structure encompasses approximately 1.5 acres of land. The slopes of the embankment are 2:1 (horizontal: vertical) along its northeastern face and 1.5:1 along its southwestern face. The slopes at the access ramps are 15:1.

Embankment No. 2 was constructed south of Embankment No. 1, as shown on Drawing No. 1 of Appendix A. The structure is 580 feet long, 90 feet wide at the top and 150 feet wide at the base. The maximum height of the embankment is 13 feet above grade. Embankment No. 2 encompasses approximately one acre of Parcel G. This structure has slopes of 2:1 along its northeastern and southwestern sides, and slopes 15:1 along the slopes at the access ramps.

The access roadway was constructed west of the two embankments. It encompasses a total of approximately 1.4 acres, and has a top width of about 85 feet, a bottom width of approximately 90 feet and a final height of 3.5 feet above the ground surface.

The first structure to be completed was Embankment No. 2. The footprint of this embankment was surveyed and staked-out by McCutcheon Engineers and
Surveyors ("McCutcheon") on February 17, 18 and 19, 1999.   The footprints of Embankment No. 1 was surveyed and staked out by the same surveyors on May 26, 1999.

Prior to the actual construction of Embankment No. 2, a base platform was prepared to ensure a flat surface meeting the design elevations. Specifically, approximately one foot of crushed mixed clean masonry was placed and spread throughout the staked area. The construction of the platform involved some cutting and filling in order to meet the proposed contours. The material excavated from the platform area was stockpiled, and later transported and disposed of at a designated area on Parcel G outside of the embankment area. Finally, SDM was compacted on the platform to provide a smooth and level base for the embankment. The final elevation of the platform was approximately 12 feet above Mean Sea Level ("msl").

Similar activities were conducted for the preparation of the base of Embankment No. 1. Based on four test pits excavated by E.E. Cruz on May 1 and May 14, 1999, the interface between the waste and the soil cover was found at a higher elevation than expected (16' above msl). Hence, it was decided that the originally recommended base elevation of 14' msl be changed to 16' msl in order to avoid major cuts within the base of the embankment. Wastes excavated from the outlined base of the structure were transported to the restaging area in Parcel G, south of the RCP. The base of the embankment was leveled to the appropriate elevation before construction of the embankments began.

The footprints for the access roadway were cleared by E.E. Cruz on May 26, 1999, and construction on the southern portion of the access road started on June 1, 1999. The platform grades were cleared by OENJ, while E.E. Cruz rolled and leveled the platform top prior to hauling the dredged material for the construction. The cuts at the southern portion averaged 6 to 8 feet. Two large concrete slabs, located at the northern side of the access roadway, were left in place. These structures were sitting on piles previously used by Walsh (the prior dredge stabilization contractor) during other dredge process activities in this area.

According to the results of the Foundation Study conducted by Soiltek, it was estimated that the total long-term settlement for Embankment No. 1 and Embankment No. 2 would be approximately 27 inches and 22 inches, respectively. Taking into consideration the site and schedule constraints, it was recommended that a reinforced geosynthetic fabric be installed at the base of each embankment to arrest some of the anticipated settlements and allow for a more uniform settlement. The selected reinforced geosynthetic fabric was PET GEOTEX 6x6 GEOTEXTILE, which was provided by Synthetic Industries, Inc.. The fabric was installed according to the manufacturer's specifications, under the supervision of Soiltek, in Embankment No. 1 on July 9, 1999 at elevation 18' MSL and in Embankment No. 2 on April 27, 1999 at elevation 14' MSL.

The placement of the first 12-inch lift for Embankment No. 2 started on March 29, 1999. The initiation of the construction activities experienced some delays due to extensive rain, snow, and cold conditions. All of the lifts of Embankment No. 2 were 12 inches thick, with the exception of the third lift (14' - 15.5'), which was 18 inches to further protect the reinforcing fabric during the disking and compacting procedures.

The placement of the first 12-inch lift for the access roadway started on June 1 at elevation 15' MSL. All lifts were 12 inches thick.

The placement of the first 12-inch lift for Embankment No. 1 started on June 23, 1999 at elevation 16' MSL. All the lifts of Embankment No. 1 were 12 inches thick with the exception of the third lift (18' - 19.5'), which was 18 inches to further protect the reinforcing fabric.

The placement of each lift for both embankments and the access roadway involved the use of excavators, loaders, dozers, disks, and rollers. Initially, about 12 to 13 inches of SDM were transported from the stockpile area to the designated footprints. Using a dozer, the material was spread evenly throughout the appropriate area and was left to dry for approximately one to two days (as needed based on weather and material conditions). During this period, the material was frequently disked with a disking blade to accelerate and enhance the drying process. If rainy conditions were anticipated, the layer was sealed by rolling multiple times in order to prevent infiltration of water into the SDM. This disking-aeration-drying process was continued until acceptable moisture contents were achieved.

After aeration and drying, each lift was compacted with the use of a roller to a minimum of 86 percent of the maximum dry density (70.5 pcf). The optimum moisture content (50%) was confirmed by sampling at specific locations specified by a grid established over the embankment area. The wet density was determined at the center of each grid using the Troxler instrument (Nuclear Density Gauge). Then, a soil sample was taken at the same location to determine the moisture content and dry density. This was achieved by oven drying the sample at 60 degrees Celsius for 24 hours, as specified in ASTM D2216-71. The criteria of 50% and 86% of maximum dry density was established to "PASS" or "FAIL" the lift. If 80% of the tested locations met the established criteria, then the lift was determined "PASS" and the consolidation of new lift was permitted. If the test results did not meet the specified criteria, then the lift was determined "FAIL". In these cases, contractor was advised to re-open the lift, disk aerate and roll, until it met the criteria. In the instances where the failure was confined to few locations within the area, only that smaller area was re-opened and re-worked. Figures illustrating the approximate locations of the field compaction monitoring conducted by SAI and the associated geotechnical results are included in Appendix B-3.

A Humboldt Stiffness gauge and hand-held Clegg's Hammer were used by Soiltek to field test the moisture content and density of each lift. This was done in coordination with SAI's Troxler tests. A description of the field compaction monitoring using these methods is provided in Appendix D.

Furthermore, SDM samples were collected prior to the compaction of each lift to determine the moisture content of the material prior to its placement and aeration / drying phases. This monitoring activity was requested by the NJDOT during the May 26, 1999 Task Force meeting. The first time this test was performed was on May 28, 1999, during the construction of the seventh lift of Embankment No. 2. The moisture content results are included in the respective daily construction reports presented in Appendix B-1.

Embankment No. 1 reached its final elevation of 24.5' msl by the compaction of seven lifts. Eleven lifts were needed for the completion of Embankment No. 2, which was raised to elevation 24.5' msl. Six inches of asphalt millings were used as final cover on both embankments to reach the final elevation of 25' msl, 25' msl and 18.5' msl for Embankment No. 1, Embankment No. 2 and the access roadway, respectively. Six inches of soil were placed on the slopes of the embankments and slopes were hydroseeded.

A total of four lifts were needed to construct the access roadway, which reached the final elevation of 18.5' msl. The originally recommended final elevation of 20' msl was lowered, since the elevation of the parking lot bordering the roadway to the west was also lowered from its original elevation of 20' msl to 18.5' msl. The access roadway elevation needed to be lower than the parking lot elevation to prevent any surface runoff from flowing towards the parking area.

Table 2.1 details construction sequence and the compaction results for each of the lifts.

Table 2.1: Construction Sequence and Compaction Results

Lift	Elevation (feet msl)	Construction Start Date	Troxler Test Date	Results
1st - Embankment #1	17	06/23/99	06/29/99	Pass
2nd - Embankment #1	18	06/30/99	07/08/99	Pass
3rd - Embankment #1	19.5	07/12/99	07/16/99	Pass
4th - Embankment #1	20.5	07/19/99	07/26/99	Pass
5th - Embankment #1	21.5	08/15/99	08/18/99	Fail
			08/19/99	Pass
6th - Embankment #1	22.5	08/23/99	08/26/99	Fail
			08/31/99	Pass
7th - Embankment #1	23.5	09/01/99	09/14/99	Pass
8th - Embankment #1	24.5	09/14/99	09/23/99	Pass
1st - Embankment #2	13	03/09/99	03/29/99	Pass
2nd - Embankment #2	14	03/31/99	04/15/99	Fail
			04/21/99	Pass
3rd - Embankment #2	15.5	04/28/99	05/05/99	Pass
4th - Embankment #2	16.5	05/06/99	05/11/99	Fail
			05/12/99	Pass
5th - Embankment #2	17.5	05/13/99	05/17/99	Pass
6th - Embankment #2	18.5	05/18/99	05/21/99	Fail
			05/27/99	Pass
7th - Embankment #2	19.5	05/28/99	06/02/99	Fail
			06/07/99	Pass
8th - Embankment #2	20.5	06/07/99	06/09/99	Fail
			06/11/99	Pass
9th - Embankment #2	21.5	06/14/99	06/16/99	Pass
10th - Embankment #2	22.5	06/17/99	06/23/99	Pass
11th - Embankment #2	23.5	06/25/99	06/30/99	Pass
12th - Embankment #2	24.5	07/06/99	07/19/99	Pass
1st - Access Roadway	15	06/08/99	06/28/99	Pass
2nd - Access Roadway	16	06/28/99	07/06/99	Pass
3rd - Access Roadway	17	07/07/99	07/13/99	Pass
4th - Access Roadway	18	07/14/99	07/26/99	Pass

Upon completion of the construction of the two embankments and the access roadway, the contractor regraded and applied final cover to the embankments. Approximately six to eight inches of topsoil were placed on the slopes of the embankments and hydroseeded. This material had already been chemically analyzed, and met the site-specific "Protocol for Review and Certification of Recyclable Materials at the OENJ Site, Elizabeth, New Jersey.", prepared by Sadat Associates, Inc. In addition, recycled asphalt millings were spread on top of the access roadway and the embankments to simulate roadway conditions. Topsoil was also placed in the wetlands transition area, as well as in the stormwater ditches.

The construction of the Demonstration Project was completed on October 19, 1999.

In summary, the embankments and access roadway were constructed as indicated on Drawing No. 1 of Appendix A. Tables 2.2 and 2.3 present the final geometry of the structures and the construction start and completion dates, respectively.

Table 2.2: Geometry of Structures

Structure	**Initial Elevation** (ft MSL)*	**Final Elevation** (ft MSL)	**Toe Width** (ft)	**Top Width** (ft)	**Slopes**	**Number of Compacted Lifts**	**Total Height** (ft)
Embankment No. 1	16	25	180	130	2:1 NE Face 1.5:1 SE Face 15:1 ramps	8	9
Embankment No. 2	12	25	150	90	2:1 both faces 15:1 ramps	11	13
Access Roadway	15	18.5	90	85	2:1 both faces 15:1 ramps	4	3.5

* Elevation of top of platform

Table 2.3: Chronological Sequence of Construction

Structure	**Starting Date**	**Completion Date**
Embankment No. 2	February 19, 1999	June 28, 1999
Embankment No. 1	June 23, 1999	September 30, 1999
Access Roadway	June 1, 1999	July 16, 1999

2.4.3 Installation of Geotechnical Monitoring Devices

The following geotechnical monitoring devices were installed:

- two horizontal inclinometers (one in each embankment);
- four vertical inclinometers (two in each embankment); and

- fifteen settlement plates (six in Embankment No. 1 and nine in Embankment No. 2)

The monitoring equipment was installed under the supervision of Soiltek and SAI. The installation of the horizontal inclinometers involved the opening of a trench in the middle of each embankment's footprint and the placement of a 3-inch sand layer at the bottom of the trench. The horizontal inclinometer was placed in the middle of the trench. The trench was backfilled with 4" of sand overlain by dredged material. The horizontal inclinometers for Embankment No. 2 and Embankment No.1 were installed on April 26, 1999 at elevation 13' msl, and on July 8, 1999 at elevation 17' msl, respectively. On September 23, 1999, 6-foot diameter pipe sections were installed as protective casings for the exposed sections of the horizontal inclinometers in order to prevent any mud from flowing into the trenches. The approximate locations of the horizontal inclinometers are presented on Drawing No.5 of Appendix A.

The vertical inclinometers were installed on November 1 and 2, 1999. The approximate locations of these inclinometers are illustrated on Drawing No.5 of Appendix A. The locations of the settlement plates were surveyed by McCutcheon. A total of fifteen settlement plates (#1 through #15) were installed at both the embankments (Drawing No. 5 of Appendix A). The purpose of the settlement plates was to differentiate settlements occurring in the foundation of the embankments from those occurring within the embankments. In order to evaluate the latter, three additional settlement plates were installed within Embankment No. 2. The settlement base and support plates were manufactured of carbon steel meeting ASTM A36 standards. The telltale pipe was one of standard weight, Schedule 40, and carbon steel meeting ASTM A53, Grade B standards. The protective floating casing had a Schedule 80 and was made of Polyvinyl Chloride (PVC) meeting ASTM D1784, Type 1, Grade 1 standards. The telltale pipe was welded to the base of the settlement plates by E.E. Cruz. The protective casings were installed around the telltale pipe to provide frictionless and free vertical movement of the settlement plates. Precautions were taken during the construction of subsequent lifts to protect the settlement plates. The material surrounding the settlement plate riser was placed to prevent any damage and to avoid moving the riser pipe.

On April 27, 1999, the six settlement plates (#1 through #6) in Embankment No. 2 were installed at elevation 14' msl above the reinforcing fabric. On May 28, 1999, settlement plates #7 and #8 were installed in the same embankment at elevation 18.5' msl. On July 6, 1999, settlement plate #9 was installed in Embankment No. 2 at elevation 23.5' msl. On July 13, 1999, all six settlement plates (#10 through #15) were installed in Embankment No. 1 at elevation 18' msl.

The first readings on the settlement plates of Embankment No. 2 were taken by McCutcheon on May 17, 1999. The first readings on the settlement plates of Embankment No. 1 were taken by the same surveyors on July 13, 1999. Monitoring data of the settlement plates was collected on the following dates: May 17, June 1, July 9, July 14, July 21, July 30, August 16, August 30, September 13, October 4, October 18, November 15, and December 15, 1999, and January 21, 2000. The readings were submitted to Soiltek for review and evaluation.

Further information on the installation of the geotechnical monitoring devices and the associated monitoring data are provided in Appendix D. A summary on the information associated with the geotechnical monitoring equipment installed for the Demonstration Project is presented in Table 2.4.

Table 2.4: Summary Data for Geotechnical Monitoring Devices

Geotechnical Device	Installation Date	Location	Bottom Elevation (ft MSL)
Horizontal Inclinometer No. 1	4/26/99	Embankment No. 2	13
Horizontal Inclinometer No. 2	7/8/99	Embankment No. 1	17
Vertical Inclinometer VI-1	11/1/99	Embankment No. 2	NA
Vertical Inclinometer VI-2	11/1/99	Embankment No. 2	NA
Vertical Inclinometer VI-3	11/2/99	Embankment No. 1	NA
Vertical Inclinometer VI-1	11/2/99	Embankment No. 1	NA
Settlement Plate #1	4/27/99	Embankment No. 2	14
Settlement Plate #2	4/27/99	Embankment No. 2	14
Settlement Plate #3	4/27/99	Embankment No. 2	14
Settlement Plate #4	4/27/99	Embankment No. 2	14
Settlement Plate #5	4/27/99	Embankment No. 2	14
Settlement Plate #6	4/27/99	Embankment No. 2	14
Settlement Plate #7	5/28/99	Embankment No. 2	18.5
Settlement Plate #8	5/28/99	Embankment No. 2	18.5
Settlement Plate #9	7/6/99	Embankment No. 2	23.5
Settlement Plate #10	7/13/99	Embankment No. 1	18
Settlement Plate #11	7/13/99	Embankment No. 1	18
Settlement Plate #12	7/13/99	Embankment No. 1	18
Settlement Plate #13	7/13/99	Embankment No. 1	18
Settlement Plate #14	7/13/99	Embankment No. 1	18
Settlement Plate #15	7/13/99	Embankment No. 1	18

NA – Not Applicable

2.4.4 Installation of Air Monitoring Devices

As part of the air monitoring program, a meteorological (weather) station was installed by E.E. Cruz in April of 1999 in Parcel G of the OENJ Redevelopment Site. Daily meteorological data were recorded by SAI for temperature, wind speed and wind direction using a Weather Monitor II meteorological station.

The Weather Monitor was initially installed 30 feet above the ground surface near the footprint of Embankment No. 2. However, the final height of the Weather Monitor was approximately 22 feet above ground due to successive regrading of Parcel G. The weather station was used primarily to determine site-specific upwind and downwind directions for the positioning of area samplers, as well as to correlate the sampling data with site-specific meteorological events.

After the air sampling program was completed, the Weather Monitor was disassembled and removed from the Site.

2.4.5 Installation of Piping Systems for Collection of Percolating Water

Percolated water collection systems were installed at the base of Embankment No. 1 and Embankment No. 2 to collect any liquid that could percolate through the embankments. Each system consists of trenches 3 ft. wide and approximately 1.25 ft. deep, containing 3/8-inch crushed stone that direct the percolated water into a main 4-inch PVC perforated collection pipe which is connected to a site-wide leachate collection system. The collection systems for percolating water were designed and constructed to run along each of the embankments to a manhole and then to an existing 6-inch HDPE leachate clean-out pipe.

On April 6, 1999, McCutcheon laid out the location of the collection system for percolating water for Embankment No. 2. The installation of the collection system for percolating water for Embankment No. 2 started on April 16, 1999 at the elevation of 14' msl and was completed on April 26, 1999. A slope of 0.15 % was maintained both for the lateral trenches and the main pipeline.

The final layout and elevations of the collection system for percolating water for Embankment No. 2 are shown on Drawing No. 2 of Appendix A.

The installation of the collection system for percolating water for Embankment No. 1 was initiated on July 6, 1999 at the elevation of 18' msl and was completed on July 12, 1999. A slope of 0.15% was maintained both for the lateral trenches and the main pipeline. The pipe connecting the collection systems for percolating water from the two embankments was installed on July 23, 1999. On July 26, 1999, the collection system for percolating water from Embankment No. 1 and Embankment No. 2 were connected to a manhole. An outlet from the manhole was connected to an existing leachate clean-out (part of the site wide leachate collection system already installed for the OENJ redevelopment site).

The final layout and elevations of the collection system for percolating water for Embankments No. 1 and No. 2 are shown on Drawing No. 2 of Appendix A. A table summarizing the construction schedule and engineering data associated with the collection systems for percolating water is presented below:

Table 2.5: Collection Systems for Percolating Water

Percolated Water System	Location	Installation Start Date	Installation Completion Date	Peak Elevation (ft MSL)	Slope (%)
SystemNo. 1	Embankment No. 1	7/6/99	7/12/99	18	0.15
SystemNo. 2	Embankment No. 2	4/16/99	4/26/99	14	0.15

2.4.6 Installation of Stormwater Conveyance System

On September 28, 1999, McCutcheon surveyed the location of the stormwater ditches on the northern side of Embankment No. 2 and on the southern side of Embankment No. 1. The construction of the stormwater conveyance system was limited to the construction of one ditch around each embankment.

The installation of the stormwater ditches was initiated on October 14, 1999 and was completed on October 19, 1999. The work involved the excavation of the ditches at the base of the two embankments. The slopes for the ditches' sides were 1% and 0.5%, for Embankments No. 1 and No. 2, respectively. An additional ditch connecting the two stormwater ditches was built to carry the stormwater runoff into the northern wetlands transition area.

A total of six inches of topsoil was placed on the top and the sides of the stormwater ditches, which were then hydroseeded.

The configuration of the stormwater conveyance system and a typical detail of the stormwater ditches are presented on Drawing No. 2 and No.3, respectively, of Appendix A.

2.4.7 Environmental Sampling and Geotechnical Monitoring During Construction

A full description of the environmental monitoring and testing conducted during the construction phase is presented in Section 2.7 of this report.

The environmental sampling during construction consisted of the following:

- analytical sampling of the SDM and laboratory-generated leachate from SDM samples collected during the winter (material storage phase);
- organic content tests of SDM samples collected during the material storage in winter;
- analytical sampling of percolated water collected at the end of the collection systems;
- analytical sampling of stormwater runoff; and

- air / dust sampling during construction activities.

Geotechnical monitoring during construction included the following:

- Field compaction testing.
- Settlement monitoring.
- Embankment slope monitoring.

2.4.8 Construction Cost Estimate

As presented in the geotechnical section of this report, the SDM is sensitive to moisture (procedures for successfully addressing this issue are presented in Sections 2.5.4 and 3.0 herein). Cases in which the SDM initially failed the compaction criteria, it was usually due to excessive moisture content, rather than not reaching the criterion for maximum dry density. Consequently, considerable effort in the construction phase was dedicated to drying the SDM to acceptable water content levels.

During the May 26, 1999 Task Force meeting, the NJDOT suggested monitoring the moisture content of the SDM prior to construction of the embankments in order to compare the efforts and costs associated with handling of the SDM to those associated with the handling of conventional subbase construction materials. On May 28, 1999, SAI began collecting samples to determine initial moisture content. At least two SDM samples from each stockpile were collected before construction.

The following activities were initially considered for the evaluation of the construction efforts:

- trucking and hauling;
- spreading;
- disking and drying; and
- compaction.

Timing for the performance of these activities was monitored for each 12-inch lift. In addition, ambient temperature, rain events, and other associated factors, such as equipment downtime and HASP implementation, were observed and monitored.

The following assumptions were made in preparing this cost estimate:

- Material costs were not considered since the purpose of this evaluation was to assess incremental costs due to material workability. In addition, costs for trucking and hauling were not considered since these costs are generally similar to those associated with conventional materials.
- The equipment and labor cost for spreading, disking, and compaction were included in the cost estimate since these costs are directly associated with the handling of SDM exhibiting high water content. The costs of the equipment and labor are the actual charges by the subcontractors.
- No additional costs for geotechnical testing, engineering supervision, construction management, and overhead and profit were considered because these activities are similar to other construction

activities (i.e., compaction testing), or would be project-specific.

On average, each lift of SDM was spread in two days. To meet construction specifications, an additional two to four days of disking and compacting generally were needed. The number of days for the drying, aerating, and compacting efforts depended on initial moisture content and weather conditions.

The construction cost estimate is summarized in Table B-4-1 of Appendix B-4. The overall construction cost for placing and compacting one cubic yard of SDM was estimated to be approximately $8.10. As expected, the cost per cubic yard varied for each lift, depending on the volume of SDM, initial moisture content, and weather conditions, with rain increasing construction times.

A measurable correlation can be established between the construction cost and rain events. Based on the construction periods of rain events and no rain events, the cost analysis was further divided into two groups as presented in Tables B-4-2 and B-4-3 of Appendix B-4. The cost associated with lifts involving rain events during the construction period was estimated as $8.60 per cubic yard, as compared to $7.50 per cubic yard for lifts that experienced no rain events.

The costs associated with spreading and compacting a conventional material used for the construction of subbase in the roadway projects were estimated using MEANS Cost Works 1999 for a project site in the City of Elizabeth, New Jersey. The costs for placing and compacting one cubic yard of a conventional material were estimated to be approximately $2.00.

The costs associated with placing and compacting SDM are three to four times higher than the costs associated with the handling of a conventional material. The highest costs associated with the SDM can possibly be reduced by using different drying methods during the mixing and stabilization of the RDM. Temporary storage of the SDM during periods of dry, warm weather will help reduce the initial moisture content and minimize the equipment and labor needed for on-site aeration and drying of SDM.

The costs incurred in the preparation of the SDM, as well as the incremental cost associated with the dredging, stabilization, and transport of this material, has to be compared with the actual cost of using traditional fill material for any specific project where the use of SDM is considered. The benefits of using SDM can only be factored once specific conditions of a project are known.

2.5 GEOTECHNICAL INVESTIGATIONS

Comprehensive laboratory and field investigations were conducted to determine the geotechnical properties of the dredge material with respect to its potential use in roadway embankment applications. The investigations were conducted by Soiltek, Inc., under the supervision of Dr. Ali Maher, Ph.D.

The subsequent sections outline the methodology adopted and results of various tests performed as part of the investigation. The data generated by the study were analyzed for the overall feasibility of using SDM in roadway embankment projects. Detailed test results and analysis are included in the "Final Geotechnical Report" submitted by Soiltek, Inc. (Appendix D)

2.5.1 FOUNDATION INVESTIGATION

Prior to constructing the embankments, it was necessary to investigate the subsurface conditions and engineering properties of foundation soils at the two locations that had been proposed for construction of the two roadway embankments at Elizabeth Site. Embankment 1 was located North of Parcel G, near wetlands transition area and Embankment 2, bordering the ditch pipe with within Parcel G at the Elizabeth OENJ Development Site.

2.5.1.1 Scope and Methodology

Foundation investigation consisted mainly of the review of available data from previous studies and, field and laboratory investigations of the geotechnical properties of subsurface foundation layers.

Subsurface investigation to determine the required foundation for the embankments was based on the proposed design and location of the two embankments. The subsurface investigation was conducted from September 14 through October 20, 1998.

The field investigation included 6 exploratory borings using Standard Penetration Testing (SPT), and 14 Cone Penetration Test (CPT) soundings. Undisturbed soil samples of 2.8-inch diameter were obtained from the SPT borings. Soil samples were laboratory tested for physical properties. The borings and soundings penetrated 25 feet below the original grades of the landfill. The samples taken from the borings were classified in accordance with the Unified Soil Classification System.

2.5.1.2 Subsurface Composition and Soil Profiles

Based on the field investigations, subsurface conditions at the embankment foundations and the access road are as follows:

2.5.1.2.1 Stratum 1: Mixed refuse fill

Refuse fill, covered by approximately one foot of cover soil, was encountered in all of the borings and soundings, except in Boring B3. Based on the field data, the refuse layer extends to depths in the range of 19 to 23 feet within the footprint of embankment 1. At the location of Boring B3, in the vicinity of the 10-foot concrete pipe, the refuse fill had been removed and replaced by imported sandy fill.

In general, the refuse fill consists of varying quantities of wood, metal, tires, paper, construction debris, and soil. During previous construction activities, including the piping of the great ditch, a mixture of refuse fill and soft organic peat was placed on top of an older refuse layer. The newer refuse layer is approximately eight to nine feet in thickness. According to the CPT soundings, this refuse fill was placed with minimal compaction. . CPT soundings also identified layers of compacted sandy fill (about one foot in thickness) that had been placed as cover material on different occasions. A layer of sandy silt (dredged material) was encountered below the refuse fill at the soundings #9, #10, #11, and #12. The thickness of this layer varies from three to five feet.

2.5.1.2.2 Stratum 2: Soft Organic Peat (Pt) / Elastic Silt (MH)

Below the refuse fill a layer of Peat (Pt) and soft elastic silt (MH) marsh sediments were found. The thickness of this layer is in the range of five to ten feet. Based on the soundings, the elastic silt layer underlies the peat layer within the investigated areas. However, the organic peat layer was not encountered in all of the soundings. SPT numbers were in the range of 1 to 6.

2.5.1.2.3 Stratum 3: Silty Sand (SM), Sand with Silt (SP-SM)

Under the elastic layer, medium -dense to very-dense sandy soils of glacial origin were encountered. The soils in this stratum vary, but are predominantly made up of silty sand (SM). Other soil types, such as poorly, or well-graded, sand with silt (SP-SM) and (SW-SM), clayey sand (SC), and sandy silt (ML) were also found in this stratum. All of the borings and soundings were terminated after 10 feet of penetration into the sand stratum. SPT numbers ranged from 15 to refusal for this stratum. In general, the SPT numbers (N-values) were higher in the red-brown silty sand layer (SM) than in the gray sand with silt layer (SP-SM).

A summary of the compressible soil profile, which was used for the settlement analysis, is given in Table 2.6.

Table 2.6: Subsurface Soil Profiles at Embankments

Embankment	Mixed Refuse Fill	Pt / MH	SM - SP / SM
1	19-20 feet	5-10 feet	Min. 10 feet
2	8-9 feet	5-10 feet	Min. 10 feet

2.5.1.3 Engineering Properties of Soil Strata

Based on the field data obtained during the subsurface investigation, the strength and compressibility characteristics of the refuse, peat, and sand layers were evaluated and estimated as follows:

2.5.1.3.1 Stratum 1: Refuse Fill

Based on the analysis of SPT and CPT data soil borings and soundings, the friction angle within the refuse fill can be estimated as approximately 30 degrees to slightly higher. A nominal value of 30 degrees can be assigned to this layer along with a unit weight of 95 pcf.

Due to the heterogeneity of refuse fills, it is difficult to predict the short-term and long-term landfill settlement that would result from the construction of the proposed embankments. To date, most of the studies conducted on landfill settlements have been site-specific, and are not easily applied to other sites. Moreover, theories developed for determining soil settlements (specifically, granular or fine-grained soils) are not directly applicable to refuse fill.

A model presented by Holtz and Kovacs in 1981 assumes that the settlement behavior of refuse material is similar to the settlement behavior of a normally consolidated soil stratum. The model is presented by the following equation:

$$\Delta H_w = H_w CR \log[(\sigma_o + \Delta\sigma_s) / \sigma_o]$$

Where:

ΔH_w = Waste settlement (ft)

H_w = Waste thickness (ft)

CR = Compression Ratio, $CR = C_c /(1 + e_o)$

C_c = Compressibility Index,

e_o = In-situ void ratio of the waste before loading

σ_o = In-situ effective vertical overburden pressure at the mid-height of waste stratum (psf)

$\Delta\sigma_s$ =Applied surcharge loading at the mid-height of surcharge loading (psf)

Several investigators, such as Morris and Woods (1990), Landva and Clark (1990), Oweis and Khera (1998), have applied this model to waste and verified its validity with field data. The key to predicting settlement for refuse material is in selecting appropriate values for the compression ratio, the empirical constant (CR).

To estimate the compression ratio (CR) for the OENJ-Elizabeth site, all of the readings from the settlement plates that had been installed at the site prior to this investigation were reviewed. Based on this information, an average calculated CR value of 0.15 could be assigned to the refuse fill at the site.

The available data from the settlement plates at the OENJ site were not sufficient to determine the coefficient of secondary compression (C'_{α}). However, according to the published literature for similar types of landfills, a coefficient of secondary compression of 0.02 can be assigned to the refuse fill layer. Secondary compression will not occur during the lifetime of the proposed embankment.

2.5.1.3.2 Stratum 2: Peat (Pt) and Elastic Silt (MH)

The organic peat and the elastic silt layer have un-drained shear strength (S_u) in the range of 325 psf to 604 psf, according to the laboratory triaxial shear tests. The un-drained shear strength from laboratory tests was utilized to obtain the cone factor (N_{kt}) for piezocone point resistance.

Based on piezocone data, the in-situ un-drained shear strength of the stratum is in the range of 250 psf to 1,200 psf, although some lower values were recorded in CPT #13 and CPT # 14. Conservatively, an undrained shear strength (S_u) of 350 psf could be assigned to the organic peat and elastic silt layer. Based on laboratory tests, the unit weight of the stratum is approximately 85 pcf.

Four one-dimensional consolidation (oedometer) tests were performed on selected samples of the organic peat and silt to evaluate their compressibility characteristics. Based on the test results, the stratum is normally consolidated and the coefficient of primary compression for the samples tested is in the range of 0.62 to 0.83, with an average of 0.71. The compression ratio (CR) varies from 0.18 to 0.22. According to the C_v values, the estimated time within which 90% of the primary consolidation will be completed is 424 days (1.16 year).

2.5.1.3.3 Stratum 3: Silty Sand(SM), Sand with Silt (SP-SM)

Based on SPT results and piezocone data, a friction angle of 33 degrees can be assigned to this layer. Based on the CPT soundings, the relative density for the stratum is between 35 to 60 percent, with a dominant range of 40 to 50 percent. CPT results are in agreement with SPT results, which estimate that the relative density is in the range of 35 to 65 percent. The red-brown silty sand (SM) layer generally has a higher relative density than does the gray sand with silt (SP-SM) layer. A unit weight of 120 pcf can be assigned to this stratum.

As mentioned in previous sections of this report, the soundings and borings in the sand layer were terminated at a depth of ten feet. Therefore, the engineering characteristics of the sand layer at depths below ten feet cannot be evaluated without any further investigation.

2.5.1.4 Analysis of Settlement

Based on the investigations conducted at the proposed embankment locations, two separate soil profiles (profile A for embankment 1, and profile B for embankment 2) were developed for use in evaluating settlement.

2.5.1.4.1 Profile A at Embankment 1

The thickness of the refuse fill is approximately 20 feet. A 10-foot-thick layer of organic peat and elastic silt underlies the refuse fill layer. The maximum height of the embankment is 10 feet at the crown, and the embankment slopes down to existing ground elevation at the perimeter.

Using both the model and the estimated *CR* value discussed in the previous section, the anticipated settlement within the refuse fill for embankment 1, due to placement of 10 feet of compacted, stabilized dredged material ($\gamma_w = 105$ pcf), will be approximately 12 inches. The deformation is likely to be non-uniform due to the heterogeneous nature of the refuse fill layer.

For the organic peat and elastic silt layer, an average *CR* value of 0.2 was selected. Therefore, if the proposed embankment is constructed, the maximum settlement during the primary consolidation of the stratum will be approximately 9 inches. Settlement within this stratum is likely to be more uniform in nature than is the settlement in the refuse fill layer.

2.5.1.4.2 Profile B at Embankment 2

The refuse fill layer at embankment 2 (south embankment) is approximately eight feet, and this layer is covered by two feet of compacted, imported fill. The organic peat and silt layer has the same thickness as profile A (10 feet), according to the most recent subsurface investigations by Soiltek, Inc.

Using the same compression indices for both the refuse fill layer and underlying layer, the anticipated settlement for the refuse fill will be 9 inches, and for the peat/silt layer it will be approximately 8 inches.

A summary of the anticipated settlements within the proposed sites is given in Table 2.7.

Table 2.7: Estimated Settlements

Embankment	Refuse Layer Settlement	Peat Layer Settlement	Total Estimated Settlement
1	12 inches	9 inches	21 inches
2	9 inches	**8 inches**	17 inches

In both cases, the anticipated settlement is excessive for the proposed embankments. Moreover, the settlement is not likely to be uniform due to the heterogeneous nature of the refuse fill and the difference in height within various sections of the embankment. Techniques for improving the soil, such as pre-loading or deep dynamic compaction could significantly reduce final settlements. However, due to limited construction time and site-specific logistic issues, it was decided that high strength geosynthetic (SI 4x4 HT) fabric be used to induce uniform settlement and, to some extent, minimize deformation.

2.5.1.4.3 Post Construction Monitoring

After construction of the embankments with the recommended foundation improvements, settlements were measured in the field. The settlement modeling was relatively accurate in estimating embankment settlement and deformation. Moreover, the results of the field settlement data also reveal a relatively uniform settlement throughout the embankments, which indicates the effectiveness of geosynthetic liner in making the settlement more uniform. A comparison of data on predicted and actual settlements is presented in Table 2.8. Detailed discussion of the post construction settlement monitoring is provided in Section 2.5.3.3 and Appendix D of this report.

Table 2.8: Comparison of Estimated and Actual Settlements

Embankment	1	2
Anticipated Settlement	21 inches	17 inches
Measured (settlement plates)	15.6 inches	15.8 inches
Measured (horizontal. Inclinometer)	12.7 inches	13.4 inches

It should be noted that the footprint of Embankment 1 underwent partial and irregular preloading for a period of approximately four months prior to embankment construction due to heavy vehicular traffic on the site. This reduced the amount of post construction settlement and accounts for the fact that the discrepancy between the anticipated settlement and the actual settlement at Embankment 1 is considerably larger than the discrepancy between these values for Embankment 2.

2.5.2 LABORATORY TESTING PROGRAM

2.5.2.1 Scope and Methodology

The objective of the laboratory investigation was to determine the geotechnical properties of the dredge material to assess its potential for use in high volume applications, such as fills, embankments, and roadway base materials. In order to realistically determine the behavior of dredge material under field conditions, the selection of admixtures, the curing time and the placement process used in laboratory testing approximated field operations.

Controlling parameters for the laboratory investigation were the type and content, of admixtures (cement and fly ash) used in the field, as well as the sequence of mixing, curing and placement activities specific to the project. The soil-cement properties are used in order to provide a point of reference for the evaluation of laboratory results.

The laboratory testing included the preparation of three different mixtures; each using raw dredged material (RDM), Portland cement and fly ash. The recipes were all mixed on a wet-weight basis. The three recipes were as follows: 1) RDM with 4% Portland cement, 2) RDM with 8% Portland cement, and 3) RDM with 8% Portland cement and 10% fly ash.

Sample collection and preparation for testing was as follows: 1) RDM was collected from dredged material scows under OENJ supervision and stored in 5-gallon plastic containers; 2) The containers were transported to the laboratory for mixing with the admixtures; 3) RDM was mixed with cement and fly-ash, according to the work plan, in laboratory concrete mixers; 4) The mixtures were aerated in 3’x2’ holding pans for moisture reduction and curing; and 5) additional amended RDM was stored under field conditions outside of the laboratory as part of the six-month testing program. The testing plan as proposed in the geotechnical proposal is summarized in Table 2.9.

2.5.2.1 Soil Classification

Particle size distribution tests, including sieve analysis and hydrometer tests, were conducted on the three mixtures: RDM with 4% Portland cement, RDM with 8% Portland cement, and RDM with 8% Portland cement plus 10% fly ash. In addition, Atterberg limits, including plastic limit and liquid limit, were conducted on the same samples. Tests were conducted in conformance with ASTM D1140 and D422. The detailed laboratory test results and discussions are presented in Appendix D (Final Geotechnical Report).

Table 2.9: Laboratory Testing Plan

Laboratory Test Description	Number of Samples			
	85% Proctor - 1 Month Curing Time	90% Proctor – 1 Month Curing Time	85% Proctor – 6 Months Curing Time	90% Proctor - 6 Months Curing Time
Unified Classification (ASTM D-1140, 422, 4318)	3	3	3	3
Strength (Triaxial @ Points) (ASTM D-4767)	3	3	3	3
Swell Pressure (ASTM D-4546)	3	3	3	3
Consolidation (ASTM D-2435)	3	3	3	3
Resilient Modulus (MR AASHTO T74)	3	3	3	3
Permeability (ASTM D-5084)	3	3	3	3
Compaction (ASTM D-1557)	3	3	3	3
Durability (ASTM D-559)	3	3	3	3

A summary of gradation test results for three different types of SDM at two different curing times (1 month and 6 months) are presented in Table 2.10. The average SDM samples consisted of 66% silt, 14% clay and 16% fine and medium sand (12.1% fine, 3.9% medium). Gravel content was negligible except for one sample, which contained 6.5% gravel. The percentage of clay size particles was higher for those SDM samples that had been mixed with fly ash. This is due to the fine nature of fly ash particles. In general, the effect of increased curing time on particle size distribution was minimal.

In addition to the gradation test, SDM samples were also tested for plasticity index. The average liquid limit, plastic limit and plasticity index for SDM are summarized in Table 2.11.

The addition of Portland cement and fly ash reduced the Plasticity Index from 40 to 5, thus increasing the workability of the material and reducing the potential for volume change due to variations in moisture content. In addition, liquid limit and plastic limit values decreased with increasing curing time. This is primarily due to the ongoing hydration of cement, which results in a reduction of the mixture’s water-holding capacity.

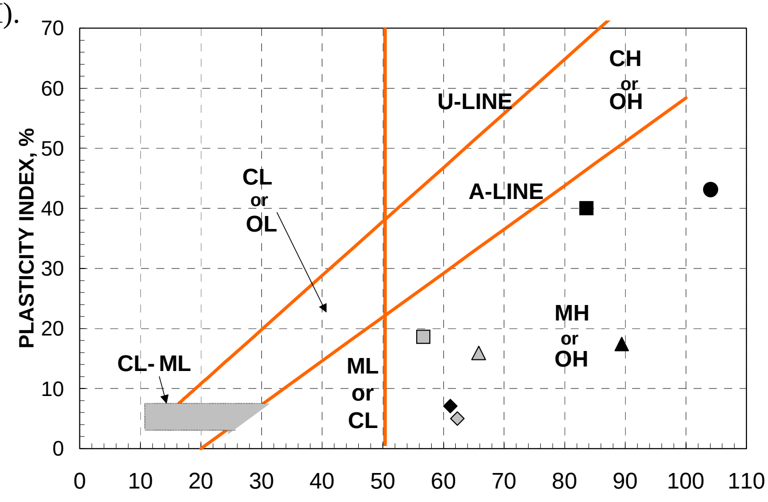
Table 2.10 Grain Size Summary (Sieve + Hydrometer Data)

Sample Type	Stockpiling Time	Sample #	% Gravel		% Sand			% Fines		D_{50}
			Coarse	**Fine**	**Coarse**	**Medium**	**Fine**	**Silt**	**Clay**	**(mm)**
4% PC	1 Month	1	0	0.8	0.8	3.3	9.4	71.6	14.1	0.0573
		2	0	1.8	0.8	3.4	5.9	74.1	14	0.0343
		3	0	0.7	0.7	2.9	10	73	12.7	0.0433
		Average	***0***	***1.1***	***0.7667***	***3.2***	***8.4333***	***72.9***	***13.6***	***0.045***
4% PC	6 Months	1	0	1.4	1.2	4.2	10.1	67.4	15.7	0.0355
		2	0	1.9	1.2	3.3	7.9	65.8	19.9	0.0261
		3	0	1.7	1.2	2.7	6.7	72.3	15.4	0.0348
		Average	***0***	***1.6667***	***1.2***	***3.4***	***8.2333***	***68.5***	***17***	***0.0321***
8% PC	1 Month	1	0	0	0.3	0.9	18.7	59.1	21	0.0146
		2	0	0	0.3	0.9	16.1	69.5	13.2	0.0234
		3	0	0	0.3	1.1	13.7	73.7	11.2	0.027
		Average	***0***	***0***	***0.3***	***0.96667***	***16.167***	***67.433***	***15.133***	***0.0217***
8% PC	6 Months	1	0	0.6	1.7	4.4	27.5	60.6	5.2	0.0556
		2	0	0.7	1.6	2.8	33.4	56	5.5	0.651
		3	0	0.5	1.8	3.1	25.6	62.7	6.3	0.0379
		Average	***0***	***0.6***	***1.7***	***3.43333***	***28.833***	***59.767***	***5.6667***	***0.2482***
8% PC + 10% FA	1 Month	1	3.8	6.7	5.4	6.6	5.4	64.1	8	0.0716
		2	0	10.4	8.8	9.2	7.3	56.8	7.5	0.0618
		3	3.4	2.5	4.2	5.5	4.5	70.2	9.7	0.0577
		Average	***2.4***	***6.5333***	***6.1333***	***7.1***	***5.7333***	***63.7***	***8.4***	***0.0637***
8% PC + 10% FA	6 Months	1	0	0.5	1.3	2.9	5.3	63.7	26.3	0.0289
		2	0	0.5	1	2.2	5.3	68.1	22.9	0.0251
		3	0	0.7	1.5	3.1	5.3	58.5	30.9	0.0147
		Average	***0***	***0.5667***	***1.2667***	***2.73333***	***5.3***	***63.433***	***26.7***	***0.0229***
Raw Dredge	N/A	1	0	0.9	1.1	1.6	4.5	66.7	25.2	0.0107
		2	0	0.8	0.7	2.6	6.3	68.4	21.2	0.0127
		Average	***0***	***0.85***	***0.9***	***2.1***	***5.4***	***67.55***	***23.2***	***0.0117***

Table 2.11 Average Atterberg Limits for SDM

Sample Type	Curing Time	Liquid Limit	Plastic Limit	Plasticity Index
Raw Dredge Material	NA	104	61	43
4% Portland Cement	1 Month	83.6	43.6	40
4% Portland Cement	6 Months	56.7	38.1	19
8% Portland Cement	1 Month	89.4	72	17
8% Portland Cement	6 Months	65.8	49.9	16
8% Portland Cement + 10% fly ash	1 Month	61.5	54	8
8% Portland Cement + 10% fly ash	6 Months	62.3	57.3	5

Based on the Atterberg Limits, all the samples tested are below the A-line and to the right of the LL=50 line on the Plasticity Chart, as shown in Figure 2.4. Therefore, the SDM could be classified as Elastic Silt (MH).



Atterberg Limit Data

Sample No.	Liquid Limit	Plastic Limit	Plasticity Index	Symbol
4% PC (1 Month)	83.6	43.6	40.0	■
4% PC (6 Months)	56.7	38.1	18.6	□
8% PC (1 Month)	89.4	72.0	17.4	▲
8% PC (6 Months)	65.8	49.9	15.9	△
8% PC + 10% FA (1 Month)	61.1	54.0	7.1	◆
8% PC + 10% FA (6 Months)	62.3	57.3	5.0	◇
Virgin Dredge Material	104.1	61.0	43.1	●

Figure 2.4. Atterberg limits for RDM and SDM

2.5.2.3 Moisture-Density Relationship

The three different mixtures of SDM were tested for moisture-density relationship. A summary of the test results is presented in Table 2.12.

Table 2.12: Compaction Data Summary

Sample Type	Stockpiling Time	Optimum Values		90% of Optimum		85% of Optimum	
		$\gamma_{d\ max}$ (pcf)	$w_{\%\ OPT}$ (%)	γ_d (pcf)	$w_{\%}$ (%)	γ_d (pcf)	$w_{\%}$ (%)
4% PC	1 Month	78.7	28.5	70.8	44.0	66.9	47.3
4% PC	6 Months	77.4	26.0	69.7	36.0	65.8	41.0
8% PC	1 Month	78.5	31.0	70.7	48.3	66.7	52.8
8% PC	6 Months	76.6	31.5	69.0	48.5	65.2	52.0
8% PC + 10% FA	1 Month	78.8	28.0	70.9	45.0	67.0	47.5
8% PC + 10% FA	6 Months	78.4	29.3	70.6	46.7	66.6	51.4
Sandy Silt+8%PC*	1 Month	119.2	10.5				
Fine Sand+8% PC*	1 Month	113.5	15.4				

* PCA, 1991

According to the test results, maximum dry densities ranged from 76.6 pcf to 78.8 pcf, and optimum moisture contents ranged from 26% to 31.5%. A slight reduction in maximum dry density was observed when the percentage of cement and the curing time were increased prior to compaction of the material.

2.5.2.3 Triaxial Shear Tests

The shear strength parameters, C and ϕ, were determined under both drained and undrained conditions to: 1) calculate the stability of the two embankments; and 2) to evaluate the effect of admixtures on shear strength parameters, thereby determining the suitability of SDM for re-use applications. A series of Unconfined Undrained (UU) and Confined Undrained (CU) tests were performed in samples from the recipes of SDM after varying levels of compaction and curing. The long-term behavior of SDM under load conditions is better modeled with effective stress parameters. In order to determine the effective stress parameters, CU tests were conducted on saturated SDM samples. Stress was applied to the material and the resulting pore pressures were measured. The difference between the total applied stress and the resulting pore pressure determines the level of effective stress. Soil samples were sheared approximately 24 hours after the samples were consolidated inside the triaxial chamber. In general, soils tend to show frictional behavior over the long term, as the pore pressure tends to dissipate.

Summaries of the UU and CU test results are presented in Table 2.13 and 2.14 respectively. A close examination of the data reveals no significant change or trend in the magnitude of the frictional angle, φ, as a result of the addition of admixtures. For both cases, an average value of approximately 32^o may be considered a good estimate for the stability analysis of slopes and embankment

A general comparison of SDM with typical soil-cement and cement-modified soils shows that with the same percentage of added cement, and similar compaction efforts (90% of optimum for SDM, and optimum for soil-cement) cement-modified soils are denser than SDM, have slightly higher friction angles, and have a much higher cohesion intercept under triaxial shear conditions. Table 2.13 summarizes these differences between SDM and typical soil-cement and cement-modified soils. One reason the SDM is less cohesive than soil-cement is that during the process of remolding the SDM for compaction, parts of cementitious bonds between hydrated cement particles and the soil matrix become broken.

Table 2.13: UU Triaxial Test Summary

Sample Type	Stockpiling Time	Compaction	Friction Angle	Cohesion (psf)
4% PC	1 Month	85%	28	1,958
		90%	31	3,312
4% PC	6 Months	85%	26	1,915
		90%	33	2,664
8% PC	1 Month	85%	12*	4,464
		90%	32	4,939
8% PC	6 Months	85%	30	3,643
		90%	35	4,744
8% PC + 10% FA	1 Month	85%	30	2,030
		90%	33	2,721
8% PC + 10% FA	6 Months	85%	23	1,195
* error		90%	34	2,203

In addition to UU tests, CU tests were also conducted on SDM. The effective C and ϕ or (C′ and ϕ′) were calculated after the Mohr circles for effective stresses were plotted. C′ is the cohesion intercept and ϕ′ is the angle of the tangent line with respect to the circles. Similar to the UU tests, no significant change or trend in the magnitude of the frictional angle, φ, with the addition of cement and fly ash could be observed. An average angle of 34^o can be estimated for long-term stability analysis of the embankments. These test results are summarized in Table 2.14.

Table 2.14: CU Triaxial Test Summary

Sample Type	Stockpiling Time	Compaction	Total Stress		Effective Stress	
			ϕ	C (psf)	ϕ'	C' (psf)
4% PC	1 Month	85%	35	1075	39	1094
		90%	37	1784	39	1490
4% PC	6 Months	85%	28	1343	46	707
		90%	34	1547	41	1205
8% PC	1 Month	85%	37	1526	40	1504
		90%	26	4826	30	4506
8% PC	6 Months	85%	35	2193	36	2330
		90%	36	3494	44	2832
8% PC + 10% FA	1 Month	85%	37	1512	30	1866
		90%	29	2266	34	2164
8% PC + 10% FA	6 Months	85%	26	847	36	655
		90%	39	1422	40	1500
Silt Loam+8% cement*	28 days	γ_d = 113,w=15%	37	21,888		
Silt Clay Loam+6% cement*	28 days	γ_d = 112,w=15.7%	36	14,352		

* PCA, Bulletin D32 (samples not saturated, no pore pressure measured)

The SDM samples were compacted to 85% and 90% of their maximum dry density, as determined by Modified Proctor (ASTM D1557). For all of the samples tested, a 5% increase in dry density resulted in increased strength. On average, the un-drained ϕ and C values increased by 32% and 35%, respectively. Moreover, the average increases in ϕ' and C′ were 1 % and 50%, respectively. On this basis, it can be concluded that compaction is the most effective method of increasing the strength of SDM.

2.5.2.3.1 Effects of Temperature on SDM Shear Strength

The hydration of pozzolanic materials, including Portland cement, is a temperature dependent reaction. The effects of low temperatures on Portland cement curing and the strength gain/moisture reduction of SDM were evaluated. The temperature effect data are presented in Table 2.15 and in Figures 2.5 and 2.6.

Table 2.15: Effect of Temperature on Shear Strength of SDM

Sample Type	Curing Temperature in F	Strength (psi) 1 day Curing	Strength (psi) 7 Day Curing	Strength (psi) 14 Day Curing	Strength (psi) 28 Day Curing
RDM+4%PC	40	--	--	--	--
RDM+4%PC	70	1.5	3.8	5.95	8.2
RDM+6%PC	40	1.1	2.5	4.6	4.3
RDM+6%PC	70	2.7	8.5	12.3	12.4
RDM+8%PC	40	1.8	3.5	3.9	4.2
RDM+8%PC	70	2.7	8.6	12.3	12.4
RDM+4%PC/ 5% FA	40	0.7	3.4	2.5	3.0

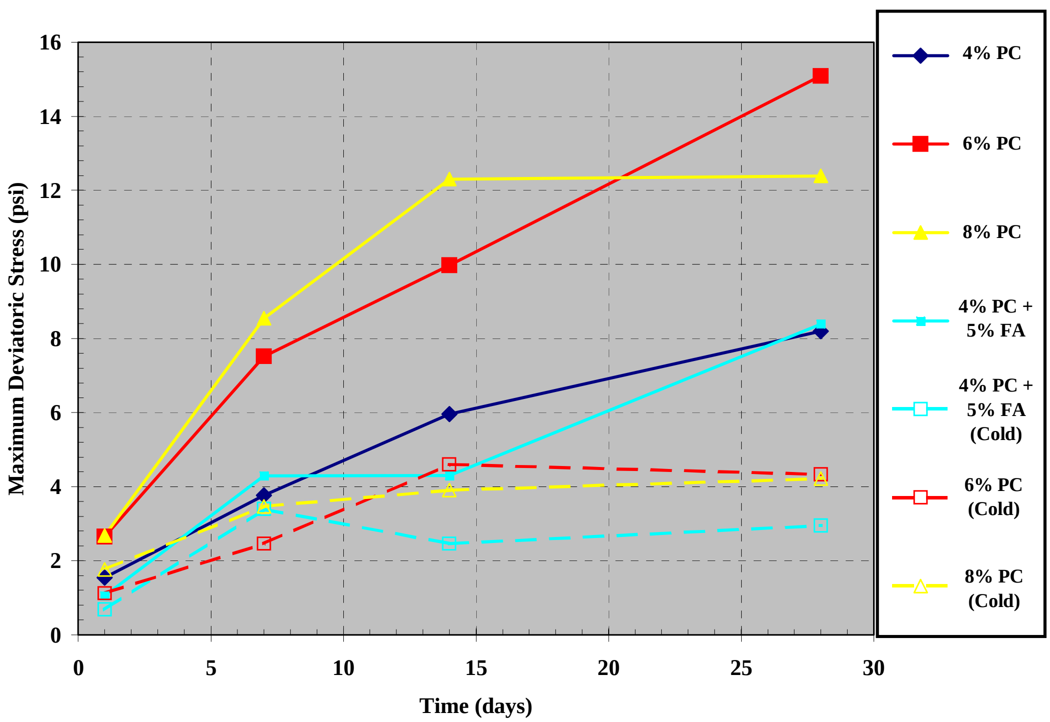


Figure 2.5 Effect of temperature on strength gain during curing period

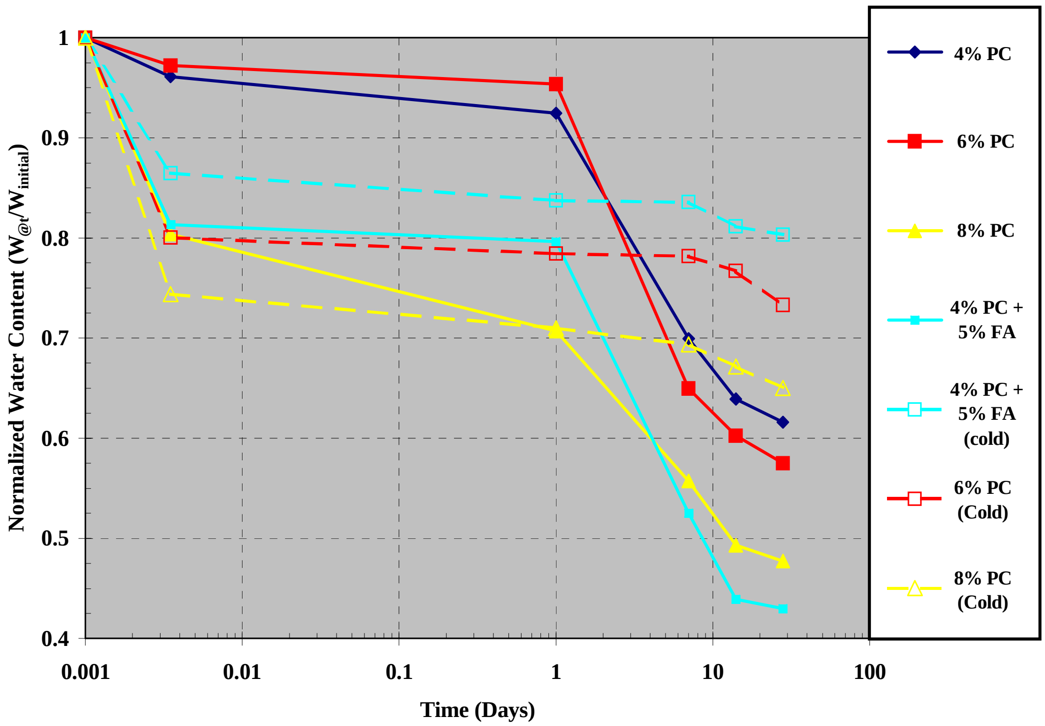


Figure 2.6. Effect of temperature on moisture reduction

According to the test results, temperature plays a significant role in the amount and rate of strength gain in dredged material that has been amended with cement and fly ash. Moreover, temperature affects the rate and degree of moisture reduction in SDM. Therefore, if economically feasible, dredged material should be amended during the warm seasons of the year.

2.5.2.4 Permeability

For permeability testing, the ASTM D-5084, or flexible wall, method was used. The results of permeability tests are presented in Table 2.16. The permeability results ranged from 1.25×10^{-6} cm/sec to 4.38×10^{-7} cm/sec. The lowest values were recorded for samples of RDM amended with 8% Portland cement and 10% fly ash. Also, samples amended with 4% Portland cement generally had lower permeability than did samples amended with 8% Portland cement. This may be due to the apparent effect of cementation on imposing a flocculated fabric arrangement in SDM.

Table 2.16: Permeability Results

Final Permeability (k) Results from Constant Head Tests

$$k = [(V(t_1, t_2)) \times L)/(P_B \times A \times t)]$$

$V(t_1, t_2)$ = Volume of Flow from t_1 to t_2 (cm^3)

L = Length of Sample (cm)

P_B = Bias Pressure (cm - H_2O)

A = Area of Sample (cm^2)

t = time from t_1 to t_2 (seconds)

Sample Type	Stockpiling Time	Compaction	Sample #	L	A	$V(t_1, t_2)$	P_B	t (seconds)	k (cm/sec)
4% PC	1 Month	85%	1	14.68	40.73	4.5	70.4	28810	8.00E-07
			2	14.73	41.16	3.0	63.3	29050	5.84E-07
								Average =	***6.92E-07***
4% PC	1 Month	90%	1	14.73	40.58	3.0	77.4	24300	5.79E-07
			2	14.76	40.87	2.5	70.4	24480	5.24E-07
								Average =	***5.52E-07***
4% PC	6 Months	85%	1	14.64	40.73	5.0	84.4	29040	7.33E-07
			2	14.73	41.01	5.5	77.4	29340	8.70E-07
								Average =	***8.02E-07***
4% PC	6 Months	90%	1	14.73	41.30	3.0	63.3	33180	5.09E-07
			2	14.73	41.16	5.5	84.4	33480	6.96E-07
								Average =	***6.03E-07***
8% PC	1 Month	85%	1	14.61	41.16	7.0	77.4	31080	1.03E-06
			2	14.63	40.87	10.0	77.4	31320	1.48E-06
								Average =	***1.25E-06***
8% PC	1 Month	90%	1	14.61	41.16	7.0	70.4	30600	1.15E-06
			2	14.63	40.87	5.0	84.4	30300	7.00E-07
								Average =	***9.27E-07***
8% PC	6 Months	85%	1	14.61	41.16	5.0	70.4	25920	9.73E-07
			2	14.57	41.16	4.0	84.4	26160	6.41E-07
								Average =	***8.07E-07***
8% PC	6 Months	90%	1	14.86	41.74	3.5	63.3	28440	6.92E-07
			2	15.01	41.45	3.0	70.4	28680	5.38E-07
								Average =	***6.15E-07***

Sample Type	Stockpiling Time	Compaction	Sample #	L	A	$V(t_1, t_2)$	P_B	t (seconds)	k (cm/sec)
8% PC + 10% FA	1 Month	85%	1	14.99	40.87	5.0	70.4	30960	8.42E-07
			2	14.76	40.58	3.5	63.3	31440	6.39E-07
								Average =	***7.40E-07***
8% PC + 10% FA	1 Month	90%	1	14.76	41.01	3.0	70.4	41120	3.73E-07
			2	14.73	40.58	4.5	70.4	42420	5.47E-07
								Average =	***4.60E-07***
8% PC + 10% FA	6 Months	85%	1	14.76	41.01	4.5	84.4	28260	6.79E-07
			2	14.73	40.87	3.0	63.3	28560	5.98E-07
								Average =	***6.38E-07***
8% PC + 10% FA	6 Months	90%	1	14.86	41.74	3.0	70.4	43920	3.46E-07
			2	15.04	41.45	5.0	77.4	44160	5.31E-07
								Average =	***4.38E-07***

A comparison between those samples compacted to 85% of the maximum dry density and those samples compacted to 90% of the maximum dry density indicates that with an increase in compaction there is a reduction in permeability ranging from 25% to 60%. For SDM amended with 4% Portland cement, the reduction in permeability ranged from 25% to 36%. For SDM amended with 8% Portland cement and for SDM amended with 8% Portland cement plus 10% fly ash, the reduction in permeability averaged from 33% to 53%, respectively. Samples tested after one month curing, when compared with samples tested after six months curing, indicate that there is no significant difference in permeability as a result of curing time.

2.5.2.5 Resilient Modulus

Resilient modulus is a dynamic soil property and is the ratio of axial cyclic stress to the recoverable strain. The resilient modulus test provides a means of characterizing base, sub-base and sub-grade materials for the design of pavement systems. The specimen preparation is accomplished in accordance with AASHTO TP46-94 Standard Test Method for Determining the Resilient Modulus of Soils and Aggregate Materials. This test method classifies sub-grade soils in two categories. Type 1 soil is classified by the following criteria: less than 70% of the material passes the number 2.00 mm sieve and less than 20% passes the 75-μm, and the material has a plasticity index of 10 or less. These soils are compacted in a 152-mm-diameter mold. Type 2 soils include all materials that do not meet the criteria for Type 1. These soils, such as SDM, are compacted in 71-mm-diameter mold. The test methodology, procedure and results are discussed in detail in the 'Final Geotechnical Report' (Appendix D).

Table 2.17 compares the resultant resilient modulus values for SDM with three New Jersey sub-grade soils that currently underlie roadways in New Jersey. According to the table, SDM compares favorably to the soil taken from Route 23 and the modulus for SDM is higher than that of the sub-grade soils taken from Route 206 and Route 295.

Table 2.17: Comparison of resilient modulus values between SDM and typical NJ base materials

Sample Type	Stockpiling Time	Compaction	Resilient Modulus (psi)
4% PC	1 Month	85% 90%	4827.5 7720.2
4% PC	6 Months	85% 90%	5167.9 8752
8% PC	1 Month	85% 90%	11,911 12.326.4
8% PC	6 Months	85% 90%	8432.3 8945.4
8% PC + 10% FA	1 Month	85% 90%	5610.4 9254.3
8% PC + 10% FA	6 Months	85% 90%	1498 6601.3
Rt. 23 (Medium to Fine Sand)		Max. Dry Density	9633.5
Rt. 295 (Medium to Fine Silty Sand)		Max. Dry Density	6405.8
Rt. 206 (Silt with Fine Sand)		Max. Dry Density	6554.3

2.5.2.6 Consolidation

Laboratory consolidation tests were conducted according to the ASTM D-2435 method. The results are summarized in Table 2.18

The compression index (C_c) values for SDM ranged from 0.22 to 0.9. In general, the compression index did not exceed 0.5 for any of the samples, once the samples had been compacted to 81%. Therefore, a P_c of 2 tsf or more should be expected. The compression ratio ($C_R = C_c/1+e_0$) varied from 0.085 to 0.24. This value did not exceed 0.19 for samples compacted to 83% or above.

Table 2.18. Consolidation Test Results

Sample Type	Curing Time	Moisture Content%		Dry Density*(psf)/	Pc (tsf)	Cc	Cr	e_0	Cc/(1+eo)
		Saturated	Remolded	Max. Dry Density					
SDM (4% PC)	1 month	69.1	68.4	(46.8/ 78.7)=59%	0.88	0.87	0.03	2.691	0.236
SDM (4% PC)	1 month	89.4	87.9	(47.7/ 78.7)=61%	4.14	0.88	0.04	2.674	0.240
SDM (4% PC)	6 month	89.8	55.7	(64.3/ 77.4)=83%	2.54	0.44	0.03	1.687	0.164
SDM (4% PC)	6 month	91.2	53.9	(67.6/ 77.4)=87%	8.7	0.39	0.02	1.608	0.150
SDM (4% PC)	6 month	70.6	40.6	(69.6/ 77.4)=90%	2.19	0.49	0.03	1.565	0.191
SDM (8% PC)	1 month	95.1	74.4	(53.7/ 78.5)=68%	2.51	0.51	0.02	2.057	0.167
SDM (8% PC)	1 month	92.9	63.3	(58.8/ 78.5)=75%	6.4	0.51	0.02	1.793	0.183
SDM (8% PC)	1 month	89	53.5	(63.6/ 78.5)=81%	7.45	0.22	0.02	1.582	0.085
SDM (8% PC)	6 month	62.1	64.4	(46/ 76.6)= 60%	1.41	0.9	0.03	2.717	0.242
SDM (8% PC)	6 month	82.7	76.7	(48.8/ 76.6)=64%	2.38	0.83	0.02	2.431	0.242
SDM (8% PC)	6 month	89.2	86.5	(47.8 76.6)=62%	2.83	0.83	0.02	2.542	0.234
SDM (8% PC,10% FA)	1 month	64.1	60	(50.7/ 78.8)=64%	2.64	0.72	0.03	2.623	0.199
SDM (8% PC,10% FA)	1 month	81.4	69.6	(53.8/ 78.8)=68%	1.92	0.54	0.02	2.397	0.159
SDM (8% PC,10% FA)	1 month	85.2	79.3	(52.9/ 78.8)=67%	0.97	0.58	0.03	2.605	0.161
SDM (8% PC,10% FA)	6 month	93	54.9	(64.2/78.4)=82%	7	0.33	0.02	1.546	0.130
SDM (8% PC,10% FA)	6 month	89.1	56	(67.9/78.4)=87%	8.27	0.41	0.02	1.766	0.148
SDM (8% PC,10% FA)	6 month	73.2	46	(67.4/ 78.4)=86%	1.32	0.43	0.02	1.766	0.155
Organic Silt, Bayonne, NJ*		75.1		58.9 pcf	0.15	0.54		1.86	0.189
Organic peat, Elizabeth, NJ*		90		46.5 pcf	1.38	0.7		2.6	0.194
Elastic Silt, Elizabeth, NJ*		70.4		54.3 pcf	1.17	0.69		2.14	0.220
Organic Silt, Woodbridge, NJ		158.8		27.3 pcf	0.89	3.5		6.08	0.494

*Remolded Dry Density (before consolidation)

* Obtained from OENJ Cherokee, Inc.

2.5.2.7 Swell Potential

Samples of SDM were tested for swell pressure in order to determine if SDM could be used in applications where the material would be in contact with structures sensitive to swell pressures and excessive deformations. Table 2.19, summarizes the findings for the swell pressure tests.

Table 2.19. Swell Pressure Test Results

Sample Type	**Age (Month)**	**Compacted Moisture %**	**% Max. Dry Density (on wet side)**	**Saturated Moisture %**	**Swell Pressure (tsf)**	**Percent Swell (%)**
4% PC	1	43.7	90	85.7	0.1	0.1
4% PC	1	25.9	97	58.8	0.88	1.0
4% PC	6	41.4	90	78.7	0.15	0.4
4% PC	6	22.6	96	48.8	0.44	0.8
8% PC	1	52.0	88	99.1	0.14	0.3
8% PC	1	22.8	95	50.6	1.95	1.1
8% PC	6	41.6	90	79.9	0.25	0.6
8% PC	6	28.2	97	62.3	0.76	1.0
8% PC + 10% FA	1	45.6	87	82.4	0.1	0.2
8% PC + 10% FA	1	27.9	94	56.8	1.2	1.2
8% PC + 10% FA	6	45	92	88.2	0.1	0.2
8% PC + 10% FA	6	21	96	44.8	0.8	0.6

The laboratory data indicate several trends. The strain or percent swell was not significant for any of the samples tested. The strain values ranged from 0.1 to 1.2 percent, with an average of 0.6. The maximum strain was recorded for the sample amended with 8% Portland cement plus10% fly ash (1.2%). This magnitude of volume change is considered low and, therefore, not detrimental to adjacent structures. The swell pressure, however, was high for samples compacted to 94% or higher of their maximum dry density with moisture contents on the dry side of optimum. For these samples, the overall average swell pressure was 1.005 tsf. The average for one-month old samples was slightly higher at 1.34 tsf, with an average strain of 1.1%. However, considering low associated strains, SDM would not have any detrimental effect on adjacent structures.

For samples compacted on the wet side of their optimum moisture content, much lower swell pressures and strains were measured. The average swell pressure for those samples was 0.14 tsf, and the average strain was 0.3%. This results from the fact that fine-grained soils have a flocculated structure at low moisture contents (below optimum moisture content). At moisture contents above optimum, the structure of the soil particles becomes more dispersed and layered. For these structures, additional moisture does not result in significant volume changes.

2.5.2.8 Durability

2.5.2.8.1 Freeze-Thaw Tests

Major durability concerns regarding SDM include potential strength loss due to freeze-thaw cycles and moisture variation. The freeze-thaw test simulates the internal expansive forces that result from the moisture in fine-grained soils. The freeze-thaw test avoids the accelerated cement hydration that is necessary to perform the wet-dry test.

According to test results, none of the samples could withstand more than three freeze-thaw cycles before failing. Significant volume change (ranging from 1.8% to 58%) was experienced during testing. Considering that the average volume change for the natural clay sample was 2%, it may be concluded that the freeze-thaw effect is several times more severe for SDM than it is for natural clay. As a result, all SDM should be protected against frost in order to maintain the cement contents within the percentages used for this project. Frost depth in New Jersey is approximately 2.5 to 3 feet. Under these conditions, SDM should be kept at least three feet below the surface. This should apply to both pavements and embankment slopes.

2.5.2.8.2 Wet-dry Tests

Wet-dry tests were conducted to simulate shrinkage forces in cement-modified or soil-cement specimens. All of the samples with the exception of one (8% PC at 90% Modified Proctor) collapsed before experiencing 12 wet-dry cycles. Volume changes were in the range of 10% to 48% of the original volume. Therefore, SDM should be protected against frequent wet-dry cycles. However, if SDM is compacted at moisture contents below the shrinkage limit, the potential for the development of tensile cracks and a consequent loss in strength could be minimized.

2.5.3 FIELD TESTING PROGRAM

The primary objectives of the field-testing program were 1) to check the uniformity of the mix by evaluating field cement contents during the mixing process, 2) to perform rapid in-situ compaction tests, such as Humboldt and Clegg hammer, for comparison with nuclear density gauge, 3) to instrument and monitor settlement and horizontal slope deformation and 4) to evaluate the long-term effects of cement/lime curing on the strength gain of the SDM.

2.5.3.1 Field Cement Content Evaluation

In order to evaluate the quality of the mixing, the cement content of samples collected from the site was measured for approximately six weeks: from September 29 to November 10, 1998. Grab samples of the SDM were collected on a daily basis and cement content was determined using the Standard Test Method for Cement Content of Soil-Cement Mixtures (ASTM D 806 – 96). The target cement content of 8% was used the basis for evaluating the test results.

As a quality assurance measure, laboratory prepared samples were also tested for cement content. These samples were prepared from a representative sample of RDM amended with Portland cement. The pug mill operator, E. E. Cruz, had provided the sample.

The cement content test results are presented in Figure 2.7. As the figure indicates, there is considerable variation with respect to the target cement content of 8%. Most of the variation can be attributed to problems associated with the original design of the processing plant. Specifically, the system was deficient in regulating the flow of cement into the pug mill. The system was later modified and properly instrumented with flow meters and aerators placed near the input orifice of the pug mill. This modification, which was implemented primarily as a result of this study, will help to better achieve the target cement contents.

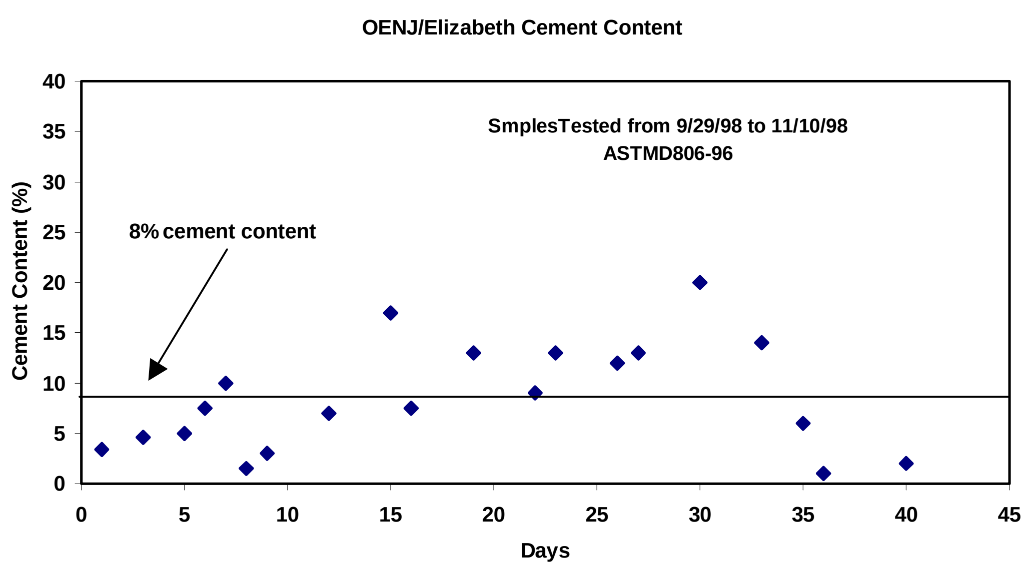


Figure 2.7- Field cement content data

2.5.3.2 Field Compaction Tests

Field compaction tests were performed in order to determine the dry density of in-situ SDM amended with Portland cement. To this end, the Humboldt Stiffness Gauge and the Clegg Impact Hammer tests were used. The traditional method of determining dry density with a Nuclear Density Gauge (Troxler test) requires a waiting period of at least 24 hours to determine the moisture content in the laboratory, before the in-situ dry density can be established. However, if a methodology could be developed to use either the Humboldt Stiffness Gauge (HSG) or the Clegg Impact Hammer (CIH) for determining dry density, the test could be performed in-situ, and the results would be immediately available.

The tests performed in this study used the manufacturer's procedures for the Humboldt Stiffness Gauge and the current standards for the Clegg Impact Hammer to predict the dry density, after field placement, of the SDM that had been amended with Portland cement. After this was accomplished, the predicted results were compared to the Troxler results, making the Troxler test the point of reference by which to evaluate dry density.

Once a methodology had been developed to determine the dry density of SDM and to ensure that the difference between the actual values and the predicted values were in agreement (% difference < 10 %), it was necessary to determine whether this methodology could be used to pass or fail an embankment lift under certain compaction criteria. Passing criteria were established for the embankment lifts as follows: 1) The dry density of the material should be more than 85% of the maximum dry density (MDD) and 2) the moisture content of the material should be less than 50%. If the material failed either of the criteria, then that particular section of the embankment was considered to have failed.

2.5.3.2.1 Humboldt Stiffness Gauge (HSG)

The Humboldt Stiffness Gauge (HSG) acts as a miniature plate load test. The stiffness is determined by the ratio of the force to displacement ($K=P/\delta$). The HSG does not measure the deflection that results from the weight of the HSG instrument itself. Instead, the HSG vibrates and produces small changes in the applied force that, in turn, produces small deflections that are measured.

The instrument was calibrated on the cement stabilized dredge material compacted in the field. This provided a realistic location for the density measurements; however, this created a narrow band of wet densities to calibrate the device. Figure 2.8 shows 412 tests that were conducted with the HSG and the Troxler Nuclear Density Gauge at exactly the same locations. The narrow calibration band led to sensitivity problems with the device. As can be seen from the figure, a majority of the predicted values fall within 60 to 65pcf, illustrating the lack of sensitivity of the instrument.

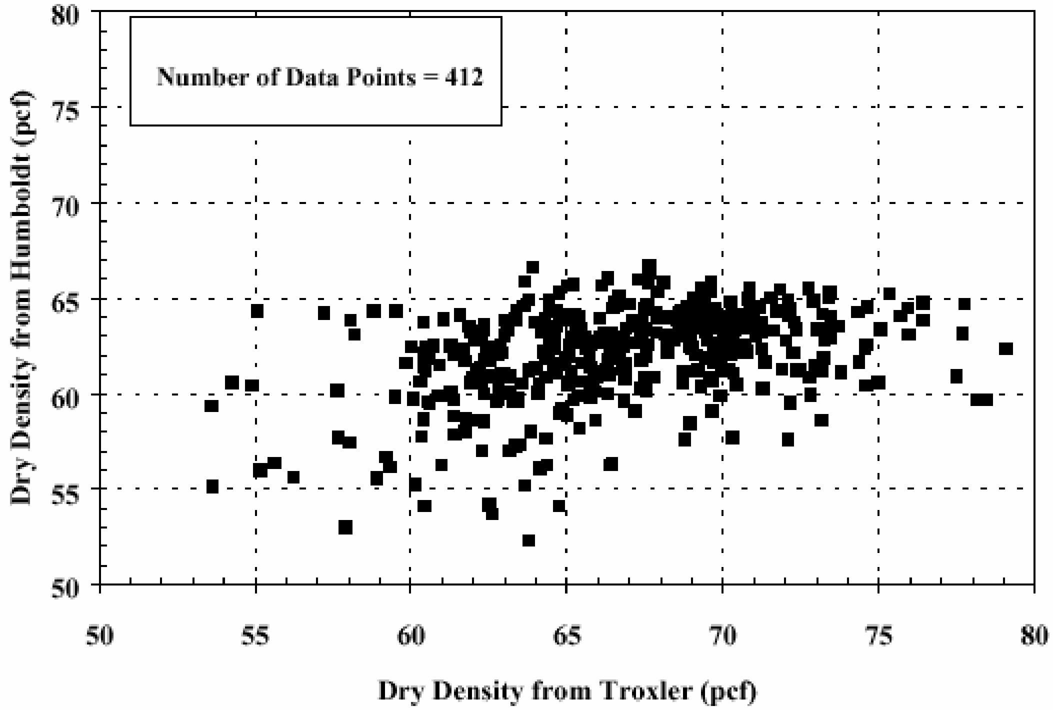


Figure 2.8- HSG Predicted Dry Density versus Nuclear Gauge

2.5.3.2.2 Clegg Impact Hammer (CIH)

The Clegg Impact Hammer (CIH) is a cylindrical hammer, similar in shape to a proctor compaction hammer. Inside the hammer is an accelerometer that measures the deceleration of the hammer as it falls from a designated drop height of 18 inches. The deceleration is then interpreted as a Clegg Impact Value (CIV). It is this CIV parameter that can be used to determine the dry density of soil. In laboratory the CIV was correlated to determine the dry density of SDM amended with Portland cement

Figure 2.9 shows the results of 383 field tests where the CIH test was used in conjunction with the Troxler test. As evident from the figure, the CIH is not sensitive and the majority of the points occur between 63 to 66pcf.

As shown in Figure 2.8 and Figure 2.9, the HSG and the CIH did not have the necessary sensitivity needed to accurately predict the dry density measured from the nuclear density gauge and oven drying. The results indicate that the HSG measured compaction characteristics accurately, provided the samples were within a specific range of moisture content for which the HSG had been calibrated. If the moisture content fell outside of this range, significant deviation was observed.

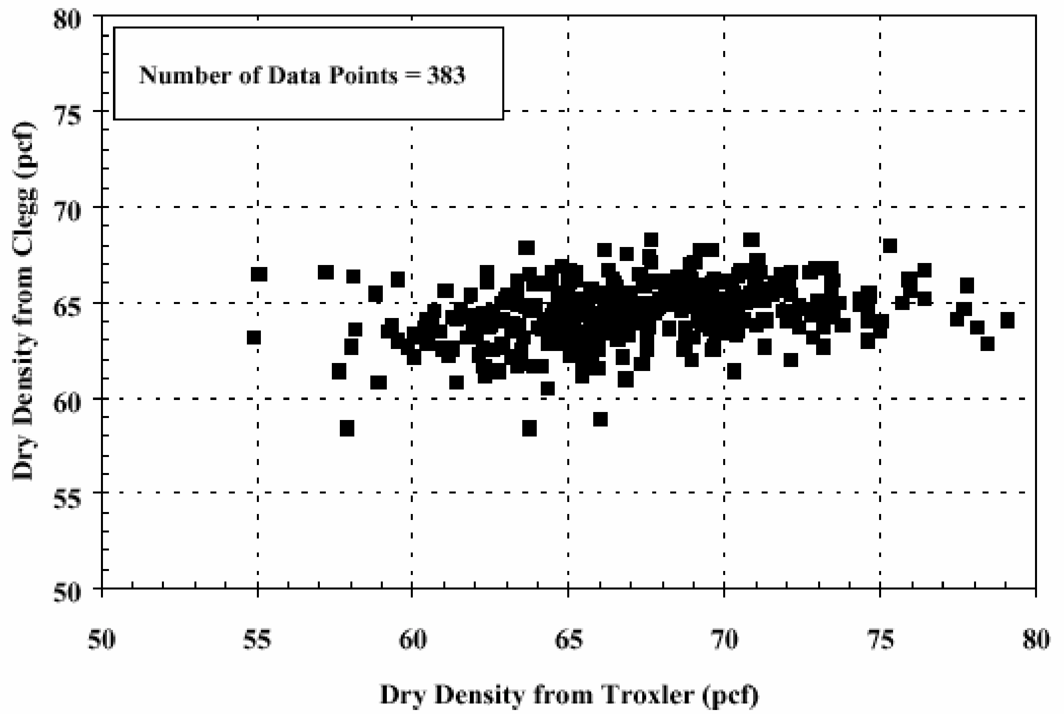


Figure 2.9- CIH Predicted Dry Density versus Nuclear Gauge

2.5.3.3 Field Settlement Monitoring

2.5.3.3.1 Settlement Plates

A total of 15 settlement plates were installed to monitor settlement of the foundation soil at the footprint of each embankment as well as the settlement within SDM that had been used in the construction of the embankments. Settlement plates are 3’ by 3’ steel plates with 10-foot steel riser rods welded to the center of the plate.

Of the 15 settlement plates, nine were installed within Embankment 2 (plates 1 to 9), and six were installed within Embankment 1 (plates 10 to 15). Settlement plates 1 - 6 and 10 - 15 monitored settlement within the foundation soil at the footprint of the two embankments Within Embankment 1; settlement plates 10 to 15 were installed at the base to monitor the embankment’s differential settlement. At Embankment 2, settlement plates 7 and 8 were installed five feet above the base and 20 feet to the west of plates 3 and 4, respectively. As a result, any differential settlement measured between plates 7 and 3 or between plates 8 and 4 could only be attributed to the settlement within the SDM, irrespective of base settlement. Additionally, plate 9 was installed ten feet above the base and 20 feet to the east of plate 3 to monitor the settlement within the bottom ten feet of the SDM.

The settlement of the embankments was monitored during a 500-day period: May 1999 to October 2000. During that time, 18 sets of readings, at various intervals, were taken by McCutcheon Associates, P.A., Secaucus, New Jersey. The elevations of the inner rods were recorded in reference to a benchmark within the Jersey Garden's Mall site. Readings were taken to within 0.01-foot accuracy. The results are further discussed in the 'Final Geotechnical Report' (Attachment L).

The report entitled, "Site Investigation & Foundation Analysis for NJDOT Embankment Demonstration Project" November 1998(Attachment C), predicted that the maximum settlement that would result from the placement of 20 feet of SDM at the location of Embankment 2 was 1.8 ft, or 22 inches. Using the primary consolidation model, assigning a compression ratio of 0.15 for refuse and 0.2 for the organic layer, and adjusting the loading to account for field conditions (placing 13 feet of SDM instead of 20 feet) the predicted settlement would be 1.4 feet. The actual measured settlement in the field averaged 1.2 feet. Therefore, the primary consolidation model gives a reasonably accurate value for settlement, considering the heterogeneous nature of waste material.

For similar projects, it is recommended that the primary consolidation model be used along with a site-specific coefficient of compressibility CR= $(C_c/1+e_o)$ for waste material. Settlement due to secondary consolidation, assuming a 0.02 – 0.03 for the Coefficient of Secondary Consolidation ($C\alpha$), is negligible.

According to the laboratory consolidation tests, SDM amended with 8% Portland cement and compacted to 60% - 81% of its modified maximum dry density has a Compression Ratio (C_c) in the range of 0.22 to 0.9. Void ratios range from 1.282 to 2.717. It should be noted that these values are highly dependent on the compaction applied during the remolding of laboratory samples. If the samples are compacted to 75% or more of their modified maximum dry density (as they were in the field), the pre-consolidation ratio will be higher than 6.4. This is equal to a surcharge twelve times greater than what the placed SDM experienced in the field. The C_c for the initial portion of the consolidation curve is approximately 0.08. Using this value and the applied load equivalent of 10/2=5 feet of SDM, or 0.25 tsf ($5x10^2$ pcf), the anticipated settlement is 0.01 feet, (0.12 inch). The field settlement measurement is in keeping with laboratory test results.

In addition to its own weight, the SDM used in embankments will experience the weight of overlying pavement and vehicular loads. These loads will add approximately 0.4 tsf to the applied loads, and will add 0.0075 ft (0.08 inches) to the settlement. Therefore, the anticipated total settlement would be 0.2 inches, assuming that ten feet of SDM were used. If, however, 20 or 30 feet of SDM were used, the total anticipated settlements could increase to 0.4 inches and 0.6 inches, respectively.

2.5.3.3.2 Horizontal Inclinometers

In addition to settlement plates, horizontal inclinometers were used to obtain high- resolution profiles of the settlement under Embankments 1 and 2. A summary of the relative deflection readings for both embankments is given in Table 2.20. There was also settlement for both reference points of approximately 7.2” for embankment 1 and 7.5” for embankment 2. So the maximum total settlement values were 12.7 and 13.4 inches for embankments 1 and 2, respectively.

Table 2.20: Measured vertical settlement

	Embankment 1	Max. Cumulative Displacement [in]	Embankment 2	Max. Cumulative Displacement [in]
1	10/01/99	“Zero level”	10/08/99	“Zero level”
2	11/23/99	2.5	11/25/00	Not successful
3	01/04/00	3.0	01/06/00	3.7
4	03/16/00	4.25	03/18/00	Not successful
5	05/16/00	4.75	05/19/00	5.1
6	09/02/00	5.5	10/26/00	5.9

2.5.3.3.3 Magnetic Extensometer

In order to determine the degree to which fill and foundation soils affected the total settlement values, a magnetic extensometer was installed on the crown of Embankment 1. Based on the readings, no noticeable settlement was observed within the fill of Embankment 1. This suggests that the foundation soils are primarily responsible for the overall settlements.

In summary, SDM that was compacted to 85% of its modified maximum dry density (according to field compaction specification) experienced little or no settlement under the given embankment loads. According to the settlement plate data and the magnetic extensometer, only 0.03 feet of settlement was measured within ten feet of SDM under its own weight. This degree of settlement would have little, or no, adverse effect on the integrity of pavement structures. Furthermore, the settlement would continue to remain negligible even if the height of embankment reached 20 or 30 feet.

2.5.3.4 Slope Deformation Monitoring

In order to monitor the horizontal movement of the embankment fill, four vertical inclinometer ducts were installed. Specifically, one was installed at the top and at the toe of each embankment. Both toe ducts reached a depth of 28 feet, while both top ducts reached a depth of 38 feet. Five sets of readings were taken each on 11/23/99, 12/26/99, 3/16/00, 5/15/00 and 9/2/00. Summaries of inclinometer data and of the magnitudes of lateral deformations are presented in Appendix D. Lateral deformations were negligible for both embankments and were not a matter of concern. The maximum amount of lateral deformation, as measured from the inclinometer installed at the top of Embankment 1, was 0.83 inches, which occurred at the border of the embankment base and the top of the foundation soil (waste material). The maximum amount of lateral deformation in Embankment 2 (0.28") also occurred at the interface of the embankment base and the top of the foundation soil.

2.5.3.5 Monitoring of Strength Gain/Loss

In order to monitor the integrity of the embankments over time, CPT soundings were taken at various intervals throughout the course of the project. After embankment construction was completed, CPT soundings were taken at various times to determine whether or not the material experienced a gain or loss in strength over time. Soundings were conducted one month, three months, six months, and 12 months after the embankment construction was completed. The CPT soundings were conducted on top of each of the embankments in order to achieve the maximum possible penetration depth. For comparison purposes, soundings were taken from numerous locations within each embankment. To avoid the possibility of a CPT sounding being influenced by a previous test, a 15 foot diameter region was implemented. The CPT was set-up specifically to measure tip resistance and side friction, since the location of the water table was well below the base of the embankments.

The CPT tip resistance provides an excellent parameter for measuring strength gain or loss. To monitor strength gain/ loss, CPT soundings were conducted for a period of one year. The results do not show any evidence of a significant strength gain or loss in the embankment. This was true for all of the locations at each embankment.

In addition, for comparison purposes, the results of the SPT soundings were measured against the un-drained shear strength (S_U) of the material. The results were in good agreement with the Unconsolidated, Undrained, Triaxial shear strength results determined in the laboratory. Therefore, it can be concluded, based on the tip resistance and the un-drained shear strength analyses, that the SDM, once placed, experiences no significant loss or gain in strength over the course of one year.

2.6 AIR MONITORING ACTIVITIES

2.6.1 Introduction and Scope

This section describes the air monitoring program, discusses the results, and presents recommendations regarding air quality impacts from the use of SDM, including the results of the polycyclic aromatic hydrocarbons ("PAH's") and polychlorinated biphenyls ("PCB's") area-wide sampling that were previously reserved for additional data validation (see below).

2.6.1.1 Overview of Air Monitoring Program

The potential occupational and area-wide air quality impacts from the use of SDM in the construction of the embankments were assessed through the collection of personal and area samples of airborne particulate matter and vapor phase concentrations of target semi volatile compounds. The personal and area sampling programs were performed by SAI in association with EOHSI. The results of these efforts, presented by EOHSI, are included in Appendix E-1 of this report.

Air quality field studies were performed to determine the amount of airborne particulates generated and the concentration of selected contaminants within the particulate matter during the drying and aeration of SDM, and its subsequent use in the construction of the embankments.

Area-wide samples of airborne particulate matter were collected to evaluate the background airborne concentrations of contaminants within and around the work areas. The area samples were collected at upwind, downwind, and two crosswind locations perpendicular to the upwind and downwind samplers. Concentrations measured at each location were compared to each other to determine the difference in contaminant concentrations and to assess if work activity could be related to observed differences.

Samples of airborne particulate matter were also collected in the workers' breathing zones by fitting personal samplers to on-site workers. The results of the personal sampling were compared with occupational exposure limits defined by:

- Occupational Safety & Health Administration ("OSHA");
- National Institute of Occupational Safety & Health ("NIOSH"); and
- American Conference of Governmental Industrial Hygienists ("ACGIH").

The area samples were analyzed for the following:

- total suspended particulates ("TSP");
- selected metals;
- polycyclic aromatic hydrocarbons ("PAHs");
- polychlorinated biphenyls ("PCBs"); and
- pesticides.

The personal samples were analyzed for:

- respirable particulate matter ($PM_{10,}$ particles with an aerodynamic diameter of 10 microns or less);
- selected metals;
- PAHs;
- PCBs; and
- pesticides.

- To assess worst-case concentrations of airborne particulate matter that could be generated from the use of SDM during the construction of the embankments, sampling was performed during the spring and summer months when maximum dust generation was expected. Sampling was performed during Event 1, from April-May 199, and Event 2, from June-July 1999.

No sampling was performed on rainy days, since rain suppressed the generation of dust.

2.6.1.2 Overview of SDM Processing and Construction Activities

Field air sampling was performed during different types of construction activities. SDM was prepared at the Sea-Land dredge processing facility by mixing raw dredged material with 8% cement. The material was then transported by trucks and stockpiled at Parcel G of the OENJ Redevelopment Site. Since the SDM was too moist to be used directly for construction purposes, it was aerated/dried in discrete batches prior to use.

The SDM was loaded onto trucks from the stockpiles using an excavator/trackhoe and transported onto the embankment area, where it was spread using a dozer. Then, using disks attached to a dozer, the SDM was aerated and dried two to three times per day. At the end of each day, or when the SDM had dried to the required moisture content, the SDM was compacted using a roller. The operations of aeration/drying and construction were performed concurrently during the Demonstration Project. In this manner, the embankments/roadway were built by layering SDM in discrete lifts until the target elevations were attained.

Sampling Event 1 was conducted during the construction and aeration/drying of SDM at Embankment No. 2, while Sampling Event 2 was performed during the construction and aeration/drying of SDM at Embankment No. 1 and the temporary access roadway.

2.6.1.3 Parameters Selected for Analyses

The parameters selected for analyses in the area and personal samples were based on their potential presence in the RDM and laboratory-produced SDM. As indicated in the preliminary characterization data in Table 1 of Appendix E-2, RDM collected from the Union Dry Dock & Repair site contained low levels of PAHs, ranging from <0.01 mg/kg to 6.5 mg/kg.

The selected analytes for of airborne particulate matter were based on the following evaluation of previous SDM sampling results:

- Benzo(a)anthracene, benzo(a)pyrene, and benzo(b)fluoranthene were detected in the RDM above the Residential Direct Contact Soil Cleanup Criteria ("RDCSCC" used for comparison purposes only, not compliance). Benzo(a)pyrene was detected in one sample of laboratory-SDM at 0.69 mg/kg, which is above the RDSCC of 0.66 mg/kg, but it was also present in the laboratory blank.[6] All other PAHs in the RDM and laboratory-SDM were detected at concentrations below the RDCSCC.

- PCBs were found in the RDM and laboratory-SDM above the RDCSCC of 0.49 mg/kg, but were below the (non-residential) NRDCSCC of 2 mg/kg.

- Nominal concentrations of pesticides such as beta-BHC, heptachlor epoxide, dieldrin, DDE, DDD, DDT and gamma-chlordane were detected in the RDM and laboratory-SDM. However, none of the pesticide concentrations exceeded the RDCSCC.

- For metals, beryllium was detected at levels ranging from 1.1 to 3.4 mg/kg, exceeding the RDCSCC of 1 mg/kg in seven out of eight samples of RDM and laboratory-SDM. Lead was detected at 467 mg/kg, above the RDSCC of 400 mg/kg in one sample of laboratory-SDM, and zinc was detected at 2,190 mg/kg in one sample of RDM above the NRDCSCC of 1,500 mg/kg.[7] All other metals analyzed were detected at concentrations below the RDCSCC.

- Dioxins and furans in samples of RDM and laboratory-SDM ranged from 1.1×10^{-6} to 3.76×10^{-3} mg/kg.

Based on these data, certain PAHs, PCBs, pesticides and metals were selected to determine their presence in airborne particulate matter.

2.6.2 Methods and Materials

2.6.2.1 Meteorological Monitoring

On-site meteorological data was obtained for temperature, wind speed, and wind direction using a Weather Monitor II (Davis Instruments) meteorological station that was installed prior to any air sampling activities. The Weather Monitor was initially installed 30 feet above the ground surface near the footprint of Embankment No. 2. Over successive re-grading of the Embankment No. 2 area, the final height of the Weather Monitor was approximately 22 feet above ground surface.

The Weather Monitor was used primarily to determine site-specific upwind and downwind locations for the positioning of area samplers, and to correlate the sampling data with site-specific meteorological events. After the air sampling program was completed, the Weather Monitor was disassembled and removed from the demonstration site.

2.6.2.2 Area Samples

Area samples for the measurement of Total Suspended Particles (TSP's) in the ambient air around the SDM drying and construction areas were collected by drawing a measured quantity of air into a covered housing and through unpreserved, pre-weighed quartz fiber filters (Schleicher and Schuell No. 25, 20 x 25 cm). The apparatus used for this purpose was the Graseby General Metals Works High Volume Sampler. Samples were collected in accordance with the Reference Method for the Determination of Suspended Particulate Matter in the Atmosphere (High Volume Method; 40 CFR Part 50, Appendix B procedures).

The area samples were collected as composite samples over a period of three to six days. The number of high volume samplers used and their layout is described in Section 2.6.3.1 of this report. At the end of each sampling day, the quartz fiber filters were covered with plexiglass sheets while mounted in their holders, and stored in a refrigerator or icebox onsite. This was done to minimize any sample contamination or losses from volatilization between sampling periods. The filters were brought back to the sample housing in the construction area for the next sampling day, and were placed at appropriate locations based on the prevailing wind direction. The flow rates (nominally between 10-30 cubic feet per minute) were checked each day before and after the sampling, and at regular intervals, using a Magnehelic flow measuring device that had been calibrated using an instrument called a Rootsmeter[8].

TSP was measured gravimetrically based on the difference in filter weight before and after the sampling event. The filter was then split into two portions. One portion was analyzed for: 1) particulate matter for presence of PAHs using gas chromatography-mass spectrometry, and 2) PCBs and selected pesticides by gas chromatography with Ni^{63} electron capture detector.[9, 10] The analyses were performed at the Department of Environmental Sciences at Rutgers University, New Brunswick, New Jersey, under the direction of Dr. S. Eisenreich. The second portion of the filter was analyzed for metal particulates using a modification of EPA Method 200.8 for Inductively Coupled Plasma-Mass at the EOHSI, Piscataway, New Jersey, under the direction of Dr. B. Buckley.

It was anticipated that due to the low concentrations of metals, PAHs, PCBs, and pesticides in the RDM and SDM samples, only low concentrations, if any, of these parameters would be detected in the airborne particulates. Even with the three to six day compositing period, it was likely that the majority of the concentrations observed from this testing program would be less than the applicable method detection limits if the analyses were performed in strict accordance with NJDEP-approved methodologies. Therefore, to obtain lower detection limits (nanograms/m^3) during sample analysis, Rutgers University research laboratories used modified NJDEP analytical methodologies. This allowed the generation of more accurate analytical results and more accurate assessments of potential air quality impacts.

During the summer months (Event 2), when ambient temperatures were high enough to measure the volatilization of semi-volatile compounds in the SDM, the high volume area samplers were additionally fitted with a polyurethane foam ("PUF," 0.049 g/cm^3 density) adsorbent plug to collect vapor phase concentrations of PCBs, pesticides and PAHs. These analytes were measured using gas chromatography-mass spectrometry at Rutgers University.

In addition to the measurement of TSP, separate area samples for PM_{10} (upwind and downwind sets) were collected using low flow pumps. These samples were analyzed by Princeton Analytical Laboratories, Princeton, New Jersey, using the NIOSH 0600 method. Due to a sampling volume limitation of NIOSH Method 0600, samples for PM_{10} were collected for approximately two hours.

2.6.2.3 Personal Samples

Personal samples were collected using SKC Aircheck or Ametek Model MG-4 constant low-flow pumps fitted with analyte-specific sampling filters/media. The samplers were fixed onto construction personnel (operators of loaders, trucks, rolling, and disking equipment). The personal samplers were calibrated before and after each sampling day using a bubble flow meter. The NIOSH methods used for sampling and analyses, and the nominal flow rates at which the personal pumps were operated, were:

Analyte	Analytical Method	Nominal Flow Rate (L/min)
Respirable Particulate Matter (PM_{10})	NIOSH 0600	2.2
Metals	NIOSH 7300	1.91
Pesticides and PCBs	NIOSH 5503	0.08
PAHs	NIOSH 5506/5515	1.91

The personal samples were collected over an 8-hour work shift in accordance with applicable NIOSH methods, except the samples for $PM_{10,}$ which were collected for approximately two hours due to a sample volume limitation of the analytical method (NIOSH 0600). All personal samples were analyzed by Princeton Analytical Laboratories.

2.6.3 Area and Personal Sample Collection

2.6.3.1 Area Samples

Two to four high volume air samplers were used for the collection of area samples. An upwind air sampling location was used to establish background air quality and to assess potential upwind sources of airborne particulates (control sample), whereas downwind and crosswind samplers were used to collect airborne particulates within the construction area.

The wind direction was determined each morning from the on-site weather station, and upwind, crosswind and downwind samplers were accordingly positioned approximately 150 feet from the edge of the active drying and construction areas, where the potential for elevated concentrations of airborne particulates was the highest.

For screening purposes, only two high volume samplers were used during Event 1. If the wind direction changed during the day, the samplers were relocated according to the appropriate wind direction. However, on days when the wind direction fluctuated significantly, sampling was discontinued. Most days had a constant wind direction, so no major adjustments were necessary after the initial placement of the filter. For sampling Event 2, a total of four high volume samplers were used. In addition to the upwind control location, one sampler was placed directly downwind and two samplers were placed at crosswind locations, perpendicular to the upwind and downwind samplers. This was done to collect representative samples of airborne particulates generated during the sampling day, by accounting for changes in wind direction.

Sampling was performed during active drying and construction activities, which ranged from four to eight hours a day. The area samples were collected as composites over three to six days in order to obtain sufficient particulate loading on the quartz-fiber filter, and allow for the adequate detection of metals and target organic compounds in the particulates. Table 2 of Appendix E-2 summarizes the sampling frequency and the analytical parameters. As indicated on Table 2, two sets of composite area samples were collected; i.e., two pairs of upwind and downwind area samples during Event 1.

During Event 2, another two sets of area samples were collected; however, each set also consisted of two crosswind samples. A lower compositing interval (i.e., 2-3 days) was used during Event 2 because higher temperatures and drier days at this time were expected to favor greater dust generation, and sufficient particulate loading was observed on the quartz filters in a shorter time period. Furthermore, since it was summer, the daily work-shift had been extended to ten hours to expedite embankment construction. In addition, the upwind and downwind samplers were fitted with PUF adsorbent traps for the collection of vapor-phase concentrations of PAHs, PCBs and pesticides. Due to the limited availability of PUF samplers, the crosswind samplers were not fitted with the PUF backup.

Five sets of upwind and downwind area samples were collected for PM_{10} during Event 1. No additional area samples for PM_{10} were collected during Event 2.

2.6.3.2 Personal Samples

During the collection of area samples in sampling Events 1 and 2, two 8-hour work shifts were selected from each sampling event to perform personal sampling. Personal sampling was conducted on days when at least four construction personnel were available within the work area for an eight-hour sampling period. This was done so that all four of the target analytes, i.e., PAHs, PCBs/pesticides, metals and $PM_{10,}$ could be sampled on the same day under similar work and weather conditions. For reasons explained above, personal sampling for PM_{10} was performed for a two-hour period only. Each individual's activities and specific work areas were noted at the time of sampling. The personal monitoring pumps were provided to construction personnel at the start of the day's activities and retrieved from them during their lunch break. The same samplers were replaced on the same workers afterwards, and retrieved at the end of the day.

Because of the need to dry the SDM (alternate periods of disking and aeration) prior to the construction of a lift of the embankments, many work-shifts at the Demonstration Site required less than 8 hours of labor. As a result, several members of the construction crew split their daily work-shift between the Demonstration Site and the adjacent Jersey Gardens Mall construction site. Therefore, the availability of personnel who could wear a personal sampler and remain within the confines of the Demonstration Site for an entire 8-hour work-shift was limited. On an average construction day, only one to two personnel were available to dedicate 8 hours of work at the embankments. In addition, since it was cumbersome for active site workers to be equipped with more than one personal monitor, it was necessary to limit the number of samples that could be collected during each sampling event. The number of personal samples collected during Events 1 and 2 is indicated on Table 2 of Appendix E-2 of this report.

2.6.4 Results and Data Evaluation

2.6.4.1 Meteorological Data

Meteorological data collected during Events 1 and 2 are summarized in Appendix E-2 of this report. The actions taken to compensate for fluctuations in wind direction so that representative samples of airborne particulates could be collected included shifting the sampling locations whenever possible to re-orient the samplers according to the new prevailing wind direction, switching filters, and/or shutting down the samplers when wind directions changed frequently or by 90 degrees or more.

These measures are summarized in Appendix E-3 and were based on specific weather conditions observed during sampling.

2.6.4.2 Background Conditions and Potential Interferences

The OENJ Redevelopment Site, including the Demonstration Site, was a former landfill. Sections of the OENJ Redevelopment Site were concurrently being redeveloped to construct the Jersey Gardens Mall while the Demonstration Project was conducted. Therefore, it is possible that the air samples collected upwind and downwind of the embankments were impacted by activities unrelated to the Demonstration Project.

Specifically, one crosswind area sample (Sample ID# T070899J), collected during Event 2 (July 14-15, 1999), was significantly impacted by extraneous activities occurring near the Demonstration Site.

These activities involved heavy equipment traffic near one crosswind high volume sampler. Due to the topography of the Site and the limited space around the embankments, it was not possible to move this crosswind sampler to a location that would prevent the interference of nearby unrelated activities. As a result, Sample T070899J is noted to have higher dust loadings and, consequently, higher concentrations of metals, PCBs/pesticides, and PAHs.

Similarly, visual observations during the Event 1 sampling reveal that higher particulate loadings on upwind samplers were due to nearby mall construction activities, rather than embankment construction activities. During Event 1, dust from the mall construction site was observed to blow towards the upwind sampler (approximately 1,000 ft from the mall construction site), but did not get carried farther to impact the downwind sampler to the same extent (approximately 2,000 feet away from the mall construction site). As a result, upwind concentrations for Event 1 are marginally higher than downwind concentrations for all the parameters analyzed.

Further, the OENJ Redevelopment Site is located in a heavily industrialized area with several large manufacturing facilities that may potentially emit airborne contaminants. Other sources of potential air pollution include the heavy commercial traffic due to the Elizabeth Sea Port, the Newark Airport, and the New Jersey Turnpike, which are near the OENJ Redevelopment Site. Specific background impacts / interferences have been described, wherever observed, in the following sections of the report.

2.6.4.3 Area Samples

Visual observations of SDM used in embankment construction indicate that the material was generally moist, so dust generation from SDM was minimal when the material was stockpiled or compacted after construction of a lift. Minor amounts of SDM became airborne only when the material was transported or actively disked for the purpose of drying.

The concentrations of upwind / downwind and crosswind samples were evaluated with respect to each other. Apparent incremental increases in the concentration of downwind and crosswind samples have been identified herein. However, due to the contributing factors from nearby potential sources, it is difficult to determine if the apparent increases in contaminant concentrations are reflective of the SDM-related activities or other sources.

As shown in Tables 3 through 5 of Appendix E-2, the area samples showed measurable concentrations of metals, PAHs, and PCBs, since these parameters were analyzed using very low detection limits (ng/m^3). In general, the relative concentration differences between upwind and downwind / crosswind sampling locations for metals and PAHs are approximately ±1 order of magnitude. However, even with these relative differences in magnitude, the detected concentrations of these parameters indicate that the SDM used in embankment construction was not a major source of airborne metals or PAHs.

2.6.4.3.1 TSP and PM_{10}

Total Suspended Particles (TSP) observed in the area samples ranged from 0.10 to 1.16 mg/m^3. The differences in TSP during the spring and summer do not appear to be significant. During Event 1, the TSP and Respirable Particulate Matter (PM_{10}) concentrations were actually higher at upwind locations than at downwind locations (see Table 6 of Appendix E-2). Visual observations at the time of sample collection reveal that higher particulate loadings on upwind samplers were due to nearby mall construction activities, rather than embankment construction activities. During Event 1, dust from the mall construction site was observed to blow towards the upwind sampler. Dust from this background operation may have also impacted the downwind sampler, but at much lower levels. A comparison of the TSP and PM_{10} data shows that although sampling time-frames for the TSP and PM_{10} samples were different (16-36 hour composites v/s 2-hour composites), the PM_{10} results were within a factor of 2 to 4 of the TSP results. This indicates that a significant portion of the particulate matter in the air at the Demonstration Site was of respirable size.

During Event 2 (July 14 to 15, 1999), construction and heavy equipment traffic not associated with the use of the SDM was observed to generate dust plumes near one cross wind sampling location (T070899J), but did not appear to significantly impact other sampling locations. As a result, higher TSP loadings were observed at this crosswind sample compared to the other downwind / crosswind samples collected during this event.

The New Jersey Ambient Air Quality Standard for TSP (0.75 mg/m^3) and the National Primary Ambient Air Quality Standard for PM_{10} (0.05 mg/m^3) are based on 24-hour average concentrations measured during twelve consecutive months. Since the TSP and PM_{10} concentrations at the Demonstration Site represent worst-case concentrations determined very close to the source areas (within 150 feet of the drying and construction activities), over a much shorter time-frame than that for which air quality criteria are established. Direct comparisons of the TSP and PM_{10} worst-case concentrations with the ambient air quality criteria cannot be made.

2.6.4.3.2 Metals

Measurable concentrations of metals were detected in the area samples (See Table 3 of Appendix E-2). For reasons explained above, upwind metal concentrations for Event 1 were higher than downwind metal concentrations due to interferences from nearby sources unrelated to the Demonstration Project. In addition, metal concentrations were also higher in one crosswind sample (T070899J, Event 2) due to unrelated activities occurring near the high volume sampler. The most abundant metals detected were aluminum, barium, copper, magnesium, titanium and zinc.

Generally, except for instances where the upwind samplers were affected by activities unrelated to the Demonstration Project, the results for upwind and crosswind samples are within the same order of magnitude. No consistent trends are observed between the downwind / crosswind samples and the upwind samples, and based on the low concentrations (ng/m^3) detected in all the samples collected, the SDM does not appear to be a major source of target metals.

2.6.4.3.3 PCBs/Pesticides

PCB concentrations in the order of picograms/m3 were detected in all particulate and vapor phase area samples. As shown in Table 5 in Appendix E-2, relative differences in the concentrations of particulate phase PCBs between upwind, downwind, and crosswind samples were not significant, and within the same order of magnitude. However, vapor phase PCB samples collected using the PUF adsorbent trap revealed that PCB concentrations in the vapor phase range from 2,786 ppq to 2,969 ppq in the two upwind samples and 3,562 ppq to 5,567 ppq in the corresponding downwind samples. The overall concentrations of particulate and vapor phase PCBs (for both upwind and downwind samples) were the same order of magnitude as recently reported for a heavily industrialized area such as Chicago, but were found to be an order of magnitude higher than those detected in the vicinity of the Liberty Science Center, New Jersey.[11] The data indicate that vapor phase PCB concentrations are in general higher than those present in the particulate phase, but do not clearly indicate whether the SDM is a major source of airborne PCBs.

2.6.4.3.4 PAHs

Upwind PAH concentrations identified during Event 1 are marginally higher than the downwind concentrations, although both upwind and downwind concentrations are in the same order of magnitude (See Table 4 of Appendix E-2). As explained in Section 2.6.4.2, due to the location of the upwind samplers, mall construction activities apparently impacted the upwind samplers during Event 1.

For the July 14-15, 1999 sampling during Event 2, except for sample T070899J, which was impacted by activities unrelated to the Demonstration Project, the differences between downwind / crosswind samples and the upwind samples are marginal, and within the same order of magnitude. For the July 19-21, 1999 sampling, crosswind sample T0708991 was noted to have relatively higher PAH concentrations than the downwind/crosswind or upwind samples. The relatively higher concentration of PAHs in crosswind sample T0708991 than the downwind sample is attributed to fluctuations in the wind speed and direction for certain periods during the sampling.

In general, PAH vapor concentrations appear to be higher for certain PAHs than particulate phase concentrations, possibly due to relative differences in vapor pressure of the PAHs. The detected PAH concentrations (both particulate and vapor phase) are of such small magnitude (1 ng/m^3 for most compounds) that it cannot be conclusively determined whether the SDM is a primary source of PAHs or if significant background contributions exist. Based on the data, however, it can be concluded that PAHs are not emitted in large quantities from the use of SDM.

2.6.4.3.5 Overview of Area Sampling Results

The target particulate pollutants (metals, PAHs, PCBs/pesticides) measured in the ambient air around the embankment construction areas are similar to concentrations of each pollutant measured previously in New Jersey or other locations in the United States (Tables 7 to 10 of Appendix E-2).[12] [13] PCBs/pesticides and PAHs were generally higher in the vapor phase than the particulate phase for both the upwind and downwind samples, at levels approximately one order of magnitude higher at the Demonstration Site as compared to concentrations measured elsewhere in New Jersey. This finding confirms that because the Demonstration Project was performed in an industrial setting with ongoing, nearby construction activities, background conditions may have influenced some of the samples.

The results indicate that using the SDM in the manner done at the Demonstration Site does not have a significant effect on the air concentrations of compounds in the surrounding work place and community environment.

2.6.4.4 Personal Samples

The results for almost all metals, PCBs, pesticides, and PAHs were below the applicable detection limits for the personal air samples (see Tables 11 to 14 of Appendix E-2). The specific work activities of the individuals sampled apparently did not significantly impact the concentrations of airborne contaminants to which they were exposed. The airborne concentrations of the target contaminants in the workers' breathing zone were compared to the following applicable occupational exposure limits:

- <u>Occupational Safety and Health Administration ("OSHA"):</u> Maximum Permissible Exposure Limit ("PEL") expressed as a time-weighted average; the concentration of a substance to which most workers can be exposed without adverse effect averaged over a normal 8-hour workday or a 40-hour work week. The OSHA PEL is a regulatory exposure limit.

- <u>National Institute of Occupational Safety and Health ("NIOSH"):</u> Recommended Exposure Limits ("REL") for an 8-10 hour time weighted average.

- <u>American Conference of Governmental Industrial Hygienists (ACGIH):</u> Threshold Limit Value ("TLV") expressed as a time weighted average; the concentration of a substance to which most workers can be exposed without adverse effects.

2.6.4.4.1 Respirable Particulate Matter

The respirable particulate matter (PM_{10}) concentrations observed in personal samples were below the MDLs during the spring sampling. During the summer, when more airborne dust was present in the workers' breathing zones, the PM_{10} concentrations were measurable, but at least one order of magnitude below the PEL of 5 mg/m^3 and the TLV guideline of 3 mg/m^3 for $PM_{10,}$ and thus within the acceptable ranges for 8-hour exposure (See Table 11 of Appendix E-2). There are no RELs for respirable dust.

2.6.4.4.2 Metals

Measurable levels of chromium, lead, nickel, thallium, selenium, and zinc were noted in all six of the personal samples collected (See Table 12 of Appendix E-2). However, these air concentrations were well below the applicable PELs, RELs or TLVs.

2.6.4.4.3 PCBs and Pesticides

Concentrations of PCBs and pesticides were below the MDLs (<0.006 to <0.01 mg/m^3) in all seven personal samples collected for these parameters (See Table 13 of Appendix E-2). In general, PCB and pesticide concentrations were at least two orders of magnitude below the applicable PELs or TLVs. The NIOSH REL for PCBs is a conservative guideline used for 10-hour exposure to known human carcinogens (0.001 mg/m^3/10 hr). However in this case, a comparison of PCB concentrations with this REL cannot be made because the analytical detection limits for PCBs by Princeton Analytical are higher than the REL.

2.6.4.4.4 PAHs

Acenaphthene, acenaphthalene, and benzo(a)pyrene were detected at very low concentrations (from 0.0004 to 0.0039 ng/m^3), but no PELs, RELs or TLVs have been developed for these compounds. Naphthalene was also detected, but at concentrations well below the applicable PEL, REL or TLV.

2.6.4.4.5 Overview of the Personal Sampling Results

Concentrations of $PM_{10,}$ metals, PCBs, pesticides and PAHs were well below OSHA PELs, indicating that breathing zone concentrations of these potential contaminants did not pose adverse health risks to workers using SDM for construction purposes. However, in the absence of OSHA/NIOSH guidelines for acceptable exposure limits for PAHs and PCBs, it is recommended that a particulate mask be used to reduce potential exposure to particulate phase PCBs and PAHs.

2.6.5 Conclusions and Recommendations

Based on the results of the air sampling program described above, the potential impacts to ambient air quality and worker health are not significant for total and respirable airborne particulates, metals, PAHs, PCBs, and pesticides. However, in the absence of OSHA/NIOSH guidelines of acceptable exposure limits for PAHs and PCBs, it is recommended that a particulate mask be used to reduce potential exposure to particulate phase PCBs and PAHs.

2.7 ENVIRONMENTAL INVESTIGATIONS

2.7.1 Introduction

A comprehensive environmental monitoring plan was developed to assess the environmental characteristics of SDM used in the construction of the embankments. Based on this plan, air, stormwater, percolated water, and dredged material samples were collected to assess the behavior and chemical properties of SDM.

As presented in Section 2.1.4 of this report, environmental monitoring activities included the sampling and characterization of:

- **Solids**
  raw dredged material (RDM)
  stabilized dredged material (SDM)
  soil cover

- **Liquids**
  laboratory-generated leachate from SDM
  stormwater runoff
  percolated water

- **Air**
  airborne particulates / dust samples collected during construction

Sampling was performed in different phases of the project for various parameters in order to characterize the materials involved in the construction and assess potential adverse environmental conditions. The project phase at which the environmental sampling was performed is indicated in the Project Flow Chart presented in Figure 2.2 of Section 2.1.4 of this report.

The RDM and SDM were characterized according to NJDEP guidelines[14] set forth to determine the suitability of the material for upland beneficial use. In addition, the RDM and SDM were analyzed for other parameters recommended by the US Army Corps of Engineers[15] ("USACOE").

As requested by the NJDEP on March 17, 1998, SDM samples were subjected to a Modified Multiple Extraction Procedure ("MMEP"). The MMEP test is a modified version of the Multiple Extraction Procedure set forth in the EPA Method 1320,[16] which was previously used to evaluate material beneficially used at the OENJ-Elizabeth Site. For comparative purposes, the leachates produced by the MMEP were analyzed for the same parameters as the RDM and SDM, with the exception of those analyses that can only be performed on soil samples, such as cation exchange capacity or sodium adsorption ratio.

In addition to the laboratory testing, air, stormwater, and percolated water samples were collected from the field and analyzed for different parameters to evaluate the environmental conditions of the embankments during and after construction. The stormwater and percolated water samples were analyzed for the same parameters as the MMEP leachates.

The potential impacts to ambient air quality and worker health from the generation of airborne particles of the SDM were assessed by the collection of area and personal samples. The air quality study and its results are presented in detail in Section 2.6 of this report.

A detailed description of the environmental sampling is presented in the next sections. Table H-1 of Appendix H of this report summarizes the number of samples that were collected as per the environmental sampling plan. A screening evaluation of the results is presented in Section 2.7.4.

2.7.2 Environmental Sampling

Preliminary environmental investigations performed before the construction of the embankments included the characterization of RDM and SDM.

2.7.2.1 Environmental Sampling of the RDM

RDM used as source material for the Demonstration Project originated from the Union Dry Dock, located in Hoboken, New Jersey. The areas where samples were collected included Pier 1, Pier 2, and Pier 3, which are identified in Figure 2.14. Two rounds of sampling and analysis were performed to characterize the RDM.

<u>April 1998 Samples</u>

The first round of sampling was performed in April 1998. The locations and number of samples collected were based on the NJDEP's October 1997 "The Management and Regulation of Dredging Activities and Dredged Material in New Jersey's Tidal Waters," and in consultation with the NJDEP's Land Use Regulation Program. The sampling scheme was approved in a letter from the NJDEP dated March 17, 1998.

A total of 13 sediment core samples were collected at the Union Dry Dock Site as follows:

Location of Sediment Core Samples	Number of Core Samples	Sample ID	Composite ID
North of Pier 1	3	80418	A
Area between Pier 1 and Pier 2	3	80419	B
South of Pier 3	3	80420	C
Area between Pier 2 and Pier 3	4	80421	D

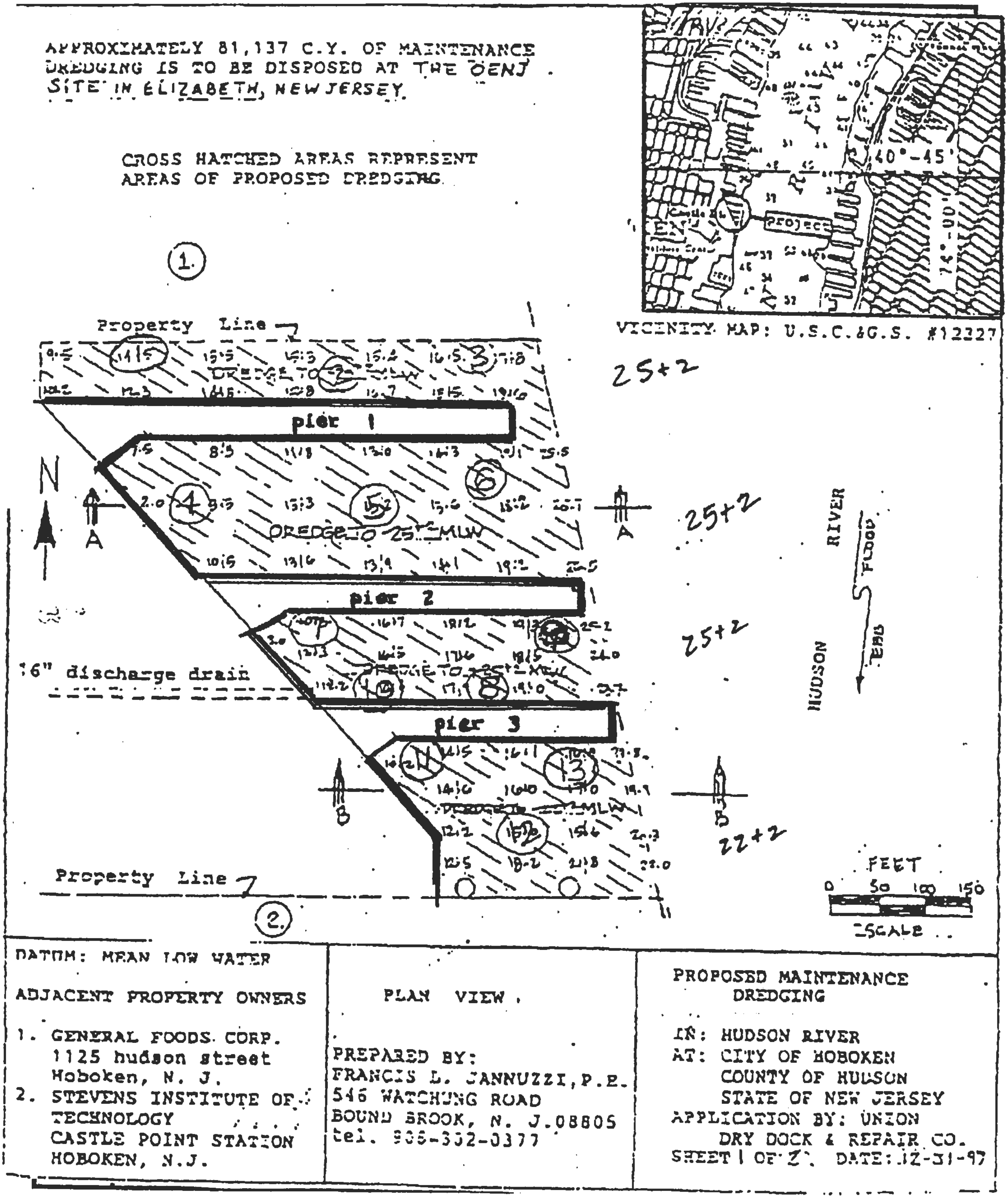


Figure 2.14 – Map of the Union Dry Dock Site

As indicated in the table above, the sediment core samples collected in each of the above areas were then composited into four composite samples. These samples were analyzed for:

- semi-volatile organic compounds on the USEPA's Target Contaminant List (SVOCs);
- PCBs/pesticides on the USEPA's Target Contaminant List;
- metals on the USEPA's Target Analyte List; and
- dioxins/furans and total organic carbon ("TOC").[17]

On June 12, 1998, NJDEP approved the use of this material as structural fill at the OENJ Redevelopment Site. However, by the time the material was available for use, it was no longer needed for the redevelopment site. As an alternative, the material was considered for use in the Demonstration Project.

October/November 1998 Samples

The environmental data previously collected to obtain NJDEP approval for use of dredged materials as structural fill was considered valuable to the project. However, it was necessary to complement the data with additional sampling to meet the requirements of the Demonstration Project work plans. Therefore, additional SDM/RDM sampling and analyses were conducted during October and November 1998.[18]

Approximately 81,000 cubic yards of RDM originated from the area between Pier 1 and Pier 2, and north of Pier 1, of the Union Dry Dock. Therefore, the supplemental environmental sampling focused on sample collection from these areas only. A total of six grab samples of RDM were collected from the area north of Pier 1 and the area between Pier 1 and Pier 2. The samples were collected and analyzed by Aqua Survey, Inc. during dredging operations by Great Lakes Dredge & Dock Co. These samples were obtained from the same approximate locations as the samples collected in April 1998, and were composited as follows:

Location of Sediment Core Samples	No. of Core Samples	Sample ID	Composite ID
North of Pier 1	3	H8788-1 [19]	A
Area between Pier 1 and Pier 2	3	H1760-1 [20]	B

All six core samples were composited into two composite samples as indicated in the table above. The two composite samples were analyzed for:

- volatile organic compounds ("VOCs") on the USEPA's Target Contaminant List;
- pH,[21] acidity, cation exchange capacity ("CEC");[22]
- sodium adsorption ratio ("SAR");[23]
- salinity[24], electrical conductivity [25], resistivity;
- sulfates, chlorides, and sulfides; and
- TOC[26] and other organic components,[27] and carbon:nitrogen ratio.[28]

Table 2.21 presents a summary of analytical sampling conducted for characterizing RDM:

Table 2.21 - Summary of RDM Sampling

Sample Date	No. of Samples	Analyses Performed	Sample ID	Reference
04/01/98	4	SVOCs, Pesticides, PCBs, Metals, Dioxins, Furans, & TOC	80418	Composite A
			80419	Composite B
			80420	Composite C
			80421	Composite D
10/10/98	2	VOCs	H8687-1	Complement of Composite A
			H8687-2 (dup)	Duplicate of H8687-1
			H8687-3 (FB)	Field Blank
10/16/98	2	TOC, and miscellaneous wet chemistry[29]	H8788-1	Complement of H8687-1
			H8788-1 (dup)	Duplicate of H8688-1
11/04/98	1	VOCs	H8920-2	Complement of Composite B
			H8920-1 (FB)	Field Blank
11/11/99	1	TOC & wet chemistry	H1760-1	Complement of H8920-2

A screening evaluation of results is presented in Section 2.7.4 of this report.

2.7.2.2 Environmental Sampling of SDM

The SDM consisted of RDM stabilized with 8% Portland cement in order to improve the construction-related characteristics of the SDM (not to reduce contaminant mobility). Samples of SDM were either: a) prepared in the laboratory by adding and mixing the selected cement admixture (laboratory SDM), or b) collected in the field after stabilization at the pug mill (field SDM). To characterize the SDM, these samples were analyzed for various chemical compounds.

Additionally, leachate samples were generated in the laboratory from some of the SDM samples using the MMEP, and analyzed for the same parameters as the SDM. Depending on the SDM sample from which leachate was generated, leachate samples are referred to as laboratory SDM MMEP leachate (i.e., SDM mixed with cement in the laboratory before testing) or field SDM MMEP leachate (i.e., SDM mixed with cement at the Sea-Land Facility pug mill and collected from the construction area).

April 1998 Samples

Each of the four composited RDM samples collected in April 1998 was stabilized in the laboratory with 8% cement (referenced as Samples 80422, 80423, 80424 and 80425). The laboratory

SDM samples were then analyzed for the same parameters as the RDM (pursuant to the sampling scheme approved by the NJDEP on March 17, 1998), namely:

- SVOCs;
- PCBs/pesticides;
- metals;
- dioxins/furans; and
- TOC.

In addition, the MMEP was conducted on each laboratory SDM sample. Seven leachate samples were generated by this procedure from each composite. Each of the leachate samples was analyzed for the parameters listed above, with the exception of dioxins, which were only analyzed in the first and seventh MMEP leachate samples. The leachate samples were labeled according to the source sample and the leachate number (e.g., 80422-5 refers to the fifth leachate generated from SDM sample 80422).

October/November 1998 Samples

Supplemental analysis was performed to generate data on field SDM samples. On October 1, 1998, two samples of SDM (Sample ID# H1354-1 and H1354-2) were collected from the stockpiles at Parcel G, and analyzed for the following parameters:

- VOCs;
- pH and acidity;
- CEC, SAR, salinity;
- electrical conductivity, resistivity;
- sulfates, chlorides, and sulfides; and
- TOC and components, and C:N ratio.

The MMEP was also conducted on these samples, and each of the seven leachate samples generated was analyzed for TOC and VOCs. The first and seventh leachate samples generated in each of the two samples were also analyzed for pH, salinity, electrical conductivity, sulfates, chlorides, sulfides, resistivity, and acidity. The first through seventh leachate samples generated from field SDM sample H1354-1 were identified as samples H1354-5 through H1354-11, respectively. The first through seventh leachate samples generated from field SDM sample H1354-2 were identified as samples H1355-1 through H1355-7, respectively.

February 1999 TCLP Samples

On February 19,1999, two more samples of SDM (Sample ID# I9695-1 and I9695-2) were collected from the stockpiles at the site. These samples were analyzed for the full RCRA/TCLP parameters (metals, VOCs, SVOCs, pesticides and herbicides, corrosivity, reactivity, and ignitability) to assess whether the SDM had any characteristics of a RCRA hazardous waste.

June 1999 Samples

On June 24, 1999, at the request of the NJDEP, three additional samples of SDM (sample numbers I4797-1[30], I4797-2[31], and I4797-3[32]) were collected during the construction of the embankments. These samples were analyzed for the full array of parameters, i.e., VOCs, SVOCs, pesticides/PCBs, metals, dioxin/furans, TOC and components, pH, salinity, electrical conductivity, sulfates, chlorides, sulfides, resistivity, acidity, CEC, SAR, and C:N ratio.

The three samples were also subjected to the MMEP for the extraction of a single leachate (samples numbers I4298-1, I4298-2, and I4298-3) from each SDM sample (samples numbers I4797-1, I4797-2, and I4797-3, respectively). The three extracts were analyzed for VOCs, SVOCs, pesticides/PCBs, metals, dioxin/furans, TOC, pH, salinity, electrical conductivity, sulfates, chlorides, sulfides, and resistivity.

Table 2.22 presents a summary of analytical sampling conducted for characterizing SDM, while Table 2.23 summarizes the analytical sampling performed on the laboratory and field SDM leachates.

Table 2.22: Summary of SDM Sampling

Sample Date	No. of Samples	Analyses Performed	Sample ID	Reference
04/01/98	4	SVOCs, Pesticides, PCBs, Metals, Dioxins, Furans, & TOC	80422	Composite A
			80423	Composite B
			80424	Composite C
			80425	Composite D
35804	2	VOCs, TOC & components, and miscellaneous wet chemistry[33]	H1354-1	Composite A/B
			H1354-2	Composite A/B
02/19/99	2	TOC & components, and hazardous characterization[34]	I9695-1	Composite A/B
			I9695-2	Composite A/B
			I9695-3 (FB)	Field Blank
06/29/99	3	VOCs, SVOCs, Pesticides, PCBs, Metals, Dioxins, Furans, TOC & components, CEC, SAR, and C:N Ratio	I4797-1	Composite A/B
			I4797-2	Composite AB
			I4797-3	Composite A/B
		pH, Salinity, Electrical Conductivity, Sulfates, Chlorides, Sulfides, Resistivity and Acidity	I4999-1	Complement of I4797-1
			I4999-2	Complement of I4797-2
			I4999-3	Complement of I4797-3
		VOCs	H4299-1 (FB)	Field Blank
11/11/99	1	TOC & components, and miscellaneous wet chemistry	H1760-1	Complement of Composite B & H8920-2

Table 2.23: Summary of SDM Leachate Sampling

Sample Date	No. of Leachates	Analyses Performed	Sample ID	Reference
04/01/98	7 per SDM Sample	SVOCs, Pesticides, PCBs, Metals, Dioxins[35], Furans, & TOC	80422-1 thru 80422-7	From SDM 80422 (Composite A)
			80423-1 thru 80423-7	From SDM 80423 (Composite B)
			80424-1 thru 80424-7	From SDM 80424 (Composite C)
			80425-1 thru 80425-7	From SDM 80425 (Composite D)
35804	7 per SDM Sample	Miscellaneous wet chemistry[36]	H1354-5 and H1354-11	1st and 7th Leachates from SDM H1354-1 (Composite A/B)
			H-1355-1 and H1355-7	1st and 7th Leachates from SDM H1354-2 (Composite A/B)
		VOCs and TOC	H1354-5 thru H1354-11	Seven leachates from SDM H1354-1 (Composite A/B)
			H1355-1 thru H1355-7	Seven Leachates from SDM H1354-2 (Composite A/B)
06/29/99	1 per SDM sample	VOCs, SVOCs, Pesticides, PCBs, Metals, Dioxins, Furans, TOC, and miscellaneous wet chemistry	I4798-1	1st leachate from sample I4797-1 (Composite A/B)
			I4798-2	1st leachate from sample I4797-1 (Composite A/B)
			I4798-3	1st leachate from sample I4797-1 (Composite A/B)

A screening evaluation of results is presented in Section 2.7.4 of this report.

Monthly Samples

Two monthly grab samples of SDM were collected from February to September 1999 during construction of the embankments. The samples were labeled as follows:

Date	Sample ID
February 19, 1999	I9695-1 & I9695-2
March 29, 1999	H2351-1, H2351-2 and H-2351-3 (duplicate of H2351-2)
April 27, 1999	H2354-1 and H2354-2
May 21, 1999	I1878-1 & I1878-2
June 29, 1999	I4299-2 & I4299-3
July 16, 1999	I5240-1 & I5240-2
August 24, 1999	I6638-1 & I6638-2
September 15, 1999	I7391-1 & I7391-2

These samples were analyzed for TOC and components. TOC is valuable for assessing three organic components that could be present in dredge material: total petroleum hydrocarbons, oils and greases, and degradable organic carbonaceous material. A discussion of this is presented in Section 2.7.4.8 of this report.

2.7.2.3 Environmental Sampling of Percolated Water

Samples of percolated water were collected on July 23, 1999, September 15, 1999, and August 11, 2000 from Embankment No. 2 (Sample ID# I5297-1, I7390-1, and K4942-1, respectively). Percolated water samples were not collected from Embankment No. 1 since it was believed that percolated water would have the same quality as Embankment No. 2.

Each of these aqueous samples was analyzed for:

- VOCs;
- SVOCs;
- pesticides/PCBs;
- metals (total and dissolved);
- dioxin/furans;
- TOC;
- Total Dissolved Solids ("TDS");
- pH and acidity;
- electrical conductivity, resistivity, salinity; and
- sulfates, chlorides, and sulfides.

Metals were evaluated in both total and dissolved concentrations so as to better understand the qualities of the percolated water (e.g. whether fines were carried in the matrix, or were identified metals, if any, associated with the dissolution of soluble materials from the SDM).

2.7.2.4 Environmental Sampling of Stormwater

After three significant rain events, stormwater samples were collected while the two embankments were being constructed. Four additional samples were collected after the embankments were capped. The following table summarizes the stormwater sampling:

Date	Sample ID	Capped Embankment
September 24, 1999	J1039-1 & J1039-2	No
September 30, 1999	J1280-1 & J1280-2	No
October 6, 1999	H9120-1 & H9120-2	No
December 8, 2000	J4560-1	Yes
April 4, 2000	J9790-1	Yes
June 7, 2000	K1434-1	Yes
July 28, 2000	K3742-1	Yes

Each of these aqueous samples was analyzed for:

- VOCs, SVOCs;
- pesticides/PCBs;
- metals (total and dissolved);
- dioxin/furans;
- TOC, TDS;
- pH and acidity;
- salinity, electrical conductivity, resistivity; and
- sulfates, chlorides, sulfides

Stormwater sampled from September 24,1999 to October 6, 1999 from Embankment No. 1 (J1039-1, J1280-1 and H9120-1) represents stormwater which came into direct contact with the SDM, since Embankment No. 1 had not yet been capped with top soil or asphalt millings. The first three stormwater samples (J1039-2, J1280-2 and H9120-2) were collected from Embankment #2 when the embankment and stormwater swales were not fully capped. Therefore, these stormwater samples are also considered to have been in direct contact with the SDM. Stormwater samples collected after October 14, 1999 were collected when the embankments and stormwater swales were fully capped. Thus, stormwater samples (J4560-1, J9790-1, K1434-1, & K3742-1) did not come in direct contact with the SDM.

As previously indicated, the tops of the embankments were covered with approximately six inches of asphalt millings, whereas the side-slopes of the embankments, the stormwater conveyance swales, and the area between the two embankments were covered with approximately six inches of topsoil and hydroseeded. For this evaluation, all stormwater samples collected before October 14, 1999 are considered to have been in contact with SDM, while all stormwater samples collected after this date are considered not to have been in direct contact with the SDM.

2.7.3 Data Processing and Basis for Data Screening

2.7.3.1 Database system

All samples collected during the pre-construction, construction, and post-construction periods were analyzed by certified analytical laboratories using proper QA/QC procedures. The laboratory data was also reviewed and validated by SAI's QA/QC personnel.

All validated data was entered into a database system[37] designed to facilitate the management of information during the preliminary data screening and evaluation. Fields within the database system included the following information:

- sample date;
- dredging source;
- sample ID;
- composite ID;
- media and matrix;
- leachate number;
- parameter name;
- CAS number;
- type of chemical;
- concentration value;
- units of concentration;
- method detection limit; and
- applicable criteria for screening evaluation

The database system includes results for approximately 261 different parameters and 111 different samples. The data entered in the database system as of December 1, 1999 (collected until October 6) was presented in Appendix H of the March 2000 Progress Report, which is reproduced in Appendix H1 of this report. Data collected since that presented in the March 2000 Progress Report, for a total of 991 new entries, are included as Appendix H2 of this report. Screening analysis was performed to sort the data according to their criteria.

2.7.3.2 Environmental Standards used for Data Screening

The analytical data related to dredged material, leachate, percolated water, and surface water sampling were compared to selected benchmarks. Specifically, the analytical results were compared with chemical-specific Federal and State criteria/standards that are established for different media. This comparison was performed as a screening tool to identify those parameters that could be considered of potential concern, not for compliance purposes.

2.7.3.2.1 Soil Samples

RDM, SDM, and soil cover samples were compared with the following NJDEP Soil Cleanup

Criteria ("SCC")[38]:

- Residential Direct Contact Soil Cleanup Criteria ("RDCSCC");
- Non-Residential Direct Contact Soil Cleanup Criteria ("NRDCSCC"); and
- Impact to Groundwater Soil Cleanup Criteria ("IGWSCC").

The RDCSCC and NRDCSCC are based on land use, and were developed based on an evaluation of unacceptable risks of exposure to both carcinogenic and non-carcinogenic contaminants. Most of the RDCSCC and NRDCSCC were developed using an incidental ingestion exposure pathway, such that incidental ingestion of soil containing a chemical at the RDCSCC or NRDCSCC concentration would pose no more than a "one-in-a-million" incremental cancer risk to the population. In some cases, the criteria are based on ecological considerations or chemical-specific factors that suggest increased risk through other exposure pathways.

The IGWSCC are to be used when there is a potential for the soil to either make direct contact with groundwater, or indirect contact via percolation of surface water through the soil strata. The IGWSCC are also human-health based criteria, developed with the same risk considerations as the RDCSCC and the NRDCSCC, with the end-point generally being potable water standards. However, generic threshold values for IGWSCC have only been developed for organic contaminants. For inorganic compounds, IGWSCC values must be determined on a site-specific basis, when required.

2.7.3.2.2 MMEP Leachates and Percolated Water Samples

Aqueous sample results from laboratory-generated leachate from SDM and from percolated water that infiltrated through the embankments were compared with the New Jersey Groundwater Water Quality Standards ("GWQS") for Class IIA Aquifers. The GWQS are based on human-health risk assessments, considering ingestion of groundwater as the primary exposure pathway. These standards are protective of Class IIA Aquifers or Groundwater for Potable Water Supply[40] (NJAC 7:9-6.5 c). It should be noted that these standards are used to assess the overall quality of the groundwater, not of the potential discharges to groundwater. Once the potential discharge reaches groundwater, the concentration will be significantly less, as contaminant mass will be absorbed to the soil matrix it travels through or diluted in the aquifer. The comparison for SDM percolated water to GWQS is for purposes of potential impact assessment only. SDM is not considered to be discharge regulated by NJDEP.

2.7.3.2.3 Stormwater Samples

Stormwater sample results were compared to the New Jersey Surface Water Quality Criteria ("SWQC") for freshwater designated as FW-2 and saline waters designated SE/SC. As per NJAC 7:9B, the SWQC for FW-2 waters protect surface water bodies so that water may be used as a source of potable water for industrial and agricultural purposes, for primary and secondary recreation, for the maintenance, migration and propagation of natural biota, and for potable water supply after conventional filtration treatment. The surface water criteria for SE/SC waters protect surface water bodies so that water may be used for shellfish harvesting, the migration of diadromous fish, the maintenance of wildlife, the maintenance, migration, and propagation of the natural and established biota, and primary and secondary contact recreation. These criteria are human-health based and consider ingestion as the primary exposure pathway. In addition, the criteria are also protective of aquatic life, and are based on acute and chronic toxicity effects to aquatic biota.

Several criteria have been established by the NJDEP for the evaluation of FW-2 or SE/SC waters depending upon exposure and carcinogenic effects:

- criteria labeled in this report as "FW2-A"or "SE/SC-A" represent criteria identified for acute (as a one-hour average) aquatic life;
- criteria labeled as "FW2-C" or "SE/SC-C" represent criteria identified for chronic (as a four-day average) aquatic life;
- criteria labeled as "FW2-H"[41] or "SE/SC-H" refer to criteria defined for non-carcinogenic effects based on a 30-day average with no frequency of exceedence at or above the design flows specified in NJAC 7:9B-1.5(c)2. These criteria are based on a risk level of one-in-one million;
- criteria labeled as "FW2-HC" or "SE/SC-HC" refer to criteria defined for carcinogenic effects based on a 70 year average with no frequency of exceedence at or above the design flows specified in NJAC 7:9B-1.5(c)2. These criteria are also based on a risk level of one-in-one million.

For the screening evaluation, stormwater sample results were compared against the most conservative of these four criteria for each type of surface water body (i.e., FW-2 or SE/SC). It should be noted that the SWQC, like the GWQS, are used to assess the quality of the surface water, not of the potential discharges to surface water. Once the potential discharge reaches surface water, the concentration will be significantly less, as contaminant mass will be diluted through dispersion and mixing in the surface water.

2.7.3.2.4 Dioxins Analysis

As defined in the 1989 International Scheme, I-TEFs/89, for this analysis, dioxin compounds include those compounds that have nonzero Toxicity Equivalency Factor ("TEF") values. This procedure was developed under the auspices of the North Atlantic Treaty Organization's Committee on Challenges of Modern Society (NATO-CCMS, 1988a; 1988b) to promote international consistency in addressing contamination involving chlorinated dibenzo-p-dioxins (CDDs) and chlorinated dibenzofurans (CDFs).

The USEPA has adopted the I-TEFs/89 as an interim procedure for assessing the risks associated with exposure to complex mixtures of CDDs and CDFs. The TEF scheme assigns nonzero values to all CDDs and CDFs with chlorine substitute in the 2, 3, 7, and 8 positions. By relating the toxicity of the CDDs and CDFs to the highly-studied 2, 3, 7, 8-TCDD, the approach simplifies the assessment of risk involving exposures to mixtures of CDDs and CDFs.

In general, the assessment of the human health risk to a mixture of CDDs and CDFs, using the TEF procedure involves the following steps:

- analytical determination of the CDDs and CDFs in the sample;
- multiplication of congener concentrations in the sample by the TEFs to express the concentration in terms of 2, 3, 7, 8-TCDD equivalents (TEQs);
- summation of the products in Step 2 to obtain the total TEQs in the sample;
- determination of human exposure to the mixture in question, expressed in terms of TEQs; and
- combination of exposure from Step 4 with toxicity information on 2, 3, 7, 8 -TCDD to estimate risks associated with mixture.

EPA has established action levels for dioxin in soils. The preliminary remediation goals ("PRGs") or starting points for setting cleanup levels for dioxin in soil at Comprehensive Environmental Response, Compensation and Liability Act ("CERCLA") and Resource Conservation and Recovery Act ("RCRA") corrective action sites, are as follows:

- one ppb (TEQs) is to be generally used as a starting point for setting cleanup levels for CERCLA removal sites and as a PRG for remedial sites with dioxin in surface soil involving a residential exposure scenario.
- for commercial/industrial exposure scenarios, a soil level within the range of 5 ppb to 20 ppb (TEQs) should generally be used as a starting point.
- for the dioxin screening evaluation of dredged materials and the soil cover material, the levels of 1ppb (TEQs) for residential soils and 5 ppb (TEQs) for nonresidential soils were used.

For groundwater screening evaluations, the following criteria were used:

- the dioxin standard for Class II GWQS of 0.01 ppb was used for MMEP and percolated water sample results.

For surface water screening evaluations, the following criteria was used:

- the dioxin standard for FW-2 SWC of 0.013 ppq was used for stormwater sample results;

- the dioxin standard for SE/SC SWC of 0.014 ppq was used for stormwater sample results;

- the dioxin standard for NJPDES discharges to either FW-2 or SE/SC surface water bodies of 10,000 ppq was used for stormwater sample results.

For the dioxin samples in all media discussed above where the concentration was reported as non-detect, the concentration was conservatively estimated to be equal to the detection limit. The measured and estimated concentrations were used in the TEQ determination.

2.7.4 Screening Evaluation of Analytical Data

This section presents the results of the screening evaluation performed on the RDM, SDM, MMEP extracts (SDM leachates), percolated water, and stormwater samples collected as described in previous sections. All results generated from sample analysis were included into the database system to facilitate and streamline the data evaluation. Appendix H of the March 2000 Progress Report presented all tabulated data collected prior to December 1, 1999. Appendix H of this report presents all data gathered since December 1, 1999, which compliments data presented in the March 2000 Progress Report.

In the screening evaluation of data, sample results were divided into those that were "detected" and those that were "non-detected" by the laboratory analyses. Commonly reported detection limits include the following:

- Method Detection Limit (MDL)[42]
- Instrument Detection Limit (IDL)[43]
- Sample Quantification Limit (SQL)[44]
- Practical Quantification Limit (PQL)[45]

The procedures set forth in the "EPA Region III Guidance on Handling Chemical Concentration Data Near the Detection Limit in Risk Assessments" were used to evaluate non-detected metal concentrations when the MDLs were higher than the selected criteria. In the EPA document, it is recommended that the non-detects be treated as half of the MDLs when the chemicals are believed to be present.[46] Similarly, the EPA document recommends that undetected chemicals be reported as zero when there is reason to believe that the chemical is not present.

The screening evaluation of non-detected concentrations for samples collected prior to December 1, 1999 was presented in Appendix I of the March 2000 Progress Report. Appendix I of this report presents the screening evaluation of non-detected concentrations for samples collected after December 1, 1999. This section addresses parameter concentrations reported by the laboratories as positive values by comparing them with the criteria previously presented in Section 2.7.3 of this report.

2.7.4.1 RDM - Screening Results

Because RDM is not intended for use in construction, comparisons of RDM analytical results to the soil cleanup criteria are not directly relevant. However, solid-phase RDM was tested in order to assess the suitability of this material for different management options and to provide general information regarding the potential quality of the SDM. The RDM testing data can also facilitate the evaluation of potential exposures to contaminants during the mixing, transport, storage, and construction phases. The RDM sample results obtained in this study are compared with the selected criteria because these data provide some basis for future SDM evaluation, not for compliance purposes.[47]

2.7.4.1.1 RDM - Comparison to Soil Cleanup Criteria

As discussed throughout this document, the RDM samples were analyzed for VOCs, SVOCs, pesticides, PCBs, metals, dioxins/furans, and miscellaneous wet chemistry parameters. Table G-1 in Appendix G presents all chemical parameters, except dioxins, detected in the RDM above the RDCSCC. The dioxin/furans results are discussed in detail in Section 2.7.4.1.2.

A summary of the screening evaluation for RDM is presented below:

- The concentrations of all VOCs, pesticides, and PCBs were below the RDCSCC.
- Of the semivolatile parameters analyzed in the RDM sampling, only the following were detected above the RDCSCC:

SVOC	No. Samples Above the SCC	Range of Concentrations (ppm)	RDCSCC (ppm)	NRDCSCC (ppm)	IGWSCC (ppm)
benzo(a)anthracene	2 / 4	1.0 - 3.5	0.9	4	500
benzo(a)pyrene	4 / 4	0.67 - 2.4	0.66	0.66	100
benzo(b)fluoranthene	3 / 4	1.0 - 3.9	0.9	4	50
benzo(k)fluoranthene	2 / 4	1.0 - 2.8	0.9	4	50

- the following metals were detected above the RDCSCC[48]:

Metal	No. Samples Above the SCC	Range of Concentrations (ppm)	RDCSCC (ppm)	NRDCSCC (ppm)	IGWSCC (ppm)
beryllium	2 / 4	3.4 - 3.9	2	2	-
zinc	1 / 4	2190	1500	1500	-

2.7.4.1.2 RDM - Comparison to Dioxin Criteria

The results of dioxin analyses performed on the RDM samples are summarized in Table G-3 of Appendix G. The TEQs for all four samples were determined following the procedure described in Section 2.7.3.2.4. The calculated TEQs in four samples are 45.66 ppt, 38.13 ppt, 33.52 ppt and 36.55 ppt. All the TEQs are lower than the action level concentrations of exposure under residential scenario (1 ppb) and non-residential / industrial scenario (5 ppb).

2.7.4.2 SDM - Screening Results

- As a first screening procedure, SDM was tested using the Toxicity Characteristic Leaching Procedure ("TCLP"). In addition, SDM samples were collected to evaluate potential environmental impacts resulting from its use. As with the RDM, the SDM sample results were compared to the RDCSCC, NRDCSCC, and IGWSCC.

2.7.4.2.1 SDM - Comparison to Hazardous Waste Criteria

Section 1004(5) of RCRA defines hazardous waste as solid waste that may "pose a substantial present or potential threat to human health and the environment when improperly treated, stored, transported, or otherwise managed." RCRA Section 3001charged EPA with the responsibility of defining which specific solid wastes would be considered hazardous waste either by identifying the characteristics of hazardous waste or listing particular hazardous wastes. In response, the Agency identified four characteristics of hazardous waste: 1) toxicity, 2) corrosivity, 3) reactivity, and 4) ignitability. EPA also developed standardized procedures and criteria for determining whether a waste exhibited one of these characteristics. These characteristics and criteria are codified at 40 CFR Part 261; testing procedures are generally detailed in SW-846.[50]

To define whether the SDM being used in the Demonstration Project would be classified as a hazardous waste under RCRA, two samples (I9695-1 and I9695-2) were collected on February 19, 1999. These samples were subjected to a full TCLP analysis as recommended by the NJDEP's November 1998 "Guidance for Sediment Quality Evaluation." The results are summarized in Table G-4 of Appendix G.

The following is a summary of the TCLP results for SDM:

- All TCLP results for VOCs, SVOCs, metals, pesticides, and herbicides were below the hazardous characterization levels. Only barium, mercury, and selenium were even detected above the MDLs.

- The samples were not ignitable, corrosive, or reactive.

The TCLP results indicate that SDM is not a hazardous waste.

2.7.4.2.2 SDM - Comparison to Soil Cleanup Criteria

The SDM samples were analyzed for VOCs, SVOCs, pesticides, PCBs, metals, dioxins/furans, and miscellaneous wet chemistry parameters. Table G-5 of Appendix G presents all chemical parameters, except dioxins, detected above the RDCSCC. The dioxin/furans results are discussed in detail in Section 2.7.4.2.3.

A summary of the screening evaluation for SDM is presented below:

- The concentration of all VOCs, pesticides and PCBs were below the RDCSCC.
- Of all SVOCs analyzed, only the following were detected above the RDCSCC:

SVOC	No. Samples Above the SCC	Range of Concentrations (ppm)	RDCSCC (ppm)	NRDCSCC (ppm)	IGWSCC (ppm)
benzo(a)anthracene	2 / 7	1.18 - 1.43	0.9	4	500
benzo(a)pyrene	4 / 7	0.69 - 1.28	0.66	0.66	100
benzo(b)fluoranthene	1 / 7	1.16	0.9	4	50
benzo(k)fluoranthene	2 / 7	0.977 - 1.36	0.9	4	50

As previously presented in Section 2.7.4.1.1, these SVOCs were also identified above the RDCSCC in the RDM. However, the number of times SDM results exceeded the RDCSCC for these SVOCs is reduced by a factor of approximately 2.

- The following metals were detected above the RDCSCC in the SDM:

Metal	No. Samples Above the SCC	Range of Concentrations (ppm)	RDCSCC (ppm)	NRDCSCC (ppm)	IGWSCC (ppm)
arsenic	4 / 7	23.3 - 42.6	20	20	-
beryllium	3 / 7	2.1 - 2.3	2	2	-
lead	1 / 7	467	400	600	-

Both arsenic and lead were detected above RDCSCC, in the SDM but not in the RDM. This is most likely due to normal sampling variations that occur whenever a limited number of grab samples are collected from soils or sediments. It should also be recalled that the stabilization of the dredge is being performed due to construction requirements, not for the purposes of contaminant binding, so the detectable presence of these analytes in the material is not unexpected. Regardless of whether the stabilization process was successful in binding the contaminants, theoretically, the analytical method would be able to detect the presence of the above metals in the matrix (e.g., if the above seven samples had been collected from the exact raw materials prior to stabilization, the identified contaminant levels would have been similar).

The presence of low levels of the above metals above RDCSCC should not represent a concern provided that the material is used at an appropriate site and contained by capping as discussed further in Section 2.4.2.

2.7.4.2.3 SDM - Comparison to Dioxin Criteria

The results of analyses performed on the seven amended dredge material samples are summarized in Table G-7 of Appendix G. The TEQs for all seven samples were determined following the procedure outlined in Section 2.7.3.2.4. The calculated TEQs for all seven samples are 43.65 ppt, 36.86 ppt, 23.972 ppt, 29.58 ppt, 0.057 ppt, 0.061 ppt, and 0.048 ppt. All the TEQs are lower than the action level concentrations of exposure under residential scenario (1 ppb) and non-residential / industrial scenarios (5 ppb).

2.7.4.3 SDM MMEP Leachate - Screening Results

To assess the potential for impacts to groundwater, MMEP leachate samples derived in the laboratory from SDM were evaluated against the Class IIA GWQS. The MMEP leachate samples are generated over seven days. A total of four SDM samples were used to generate leachate samples. Seven leachate samples were generated from each of four SDM samples. Only the first leachate sample was generated from each of the remaining three SDM samples. As previously indicated, SDM MMEP leachates were generated from both laboratory prepared SDM samples (lab MMEP) and from SDM mixed at the Sea-Land Facility Pug mill (field MMEP).

2.7.4.3.1 SDM MMEP Leachate - Comparison to Groundwater Quality Standards

The leachates extracted from the SDM samples were analyzed for VOCs, SVOCs, pesticides, PCBs, metals, dioxins/furans, and miscellaneous wet chemistry parameters. Table G-8 of Appendix G presents all chemical parameters detected above the GWQS. *Again, it should be noted that the GWQS are not in fact an applicable criteria for the laboratory-generated leachate; the comparisons made below are intended to support an evaluation of potential impacts, (which are further discussed in section 2.7.6) not to determine compliance with applicable criteria.*

The following analytes were detected within the leachate samples above the GWQS:

Analyte (No. SDM-leachate samples above the GWQS)	*SDM Sample**	No. Leachate Samples Above the GWQS	Range of Concentrations (ppb)	GWQS (ppb)
alpha-BHC (3 / 7)	80422 L	2 / 7	0.05 - 39	0.02
	80423 L	3 / 7	0.061 - 0.17	
	80424 L	1 / 7	0.11	
aluminum (7 / 7)	80422 L	7 / 7	650 - 1570	200
	80423 L	7 / 7	617 - 2720	
	80424 L	7 / 7	765 - 1510	
	80425 L	7 / 7	604 - 1620	
	I4297-1 F	1 / 1	2040	
	I4297-2 F	1 / 1	200	
	I4297-3 F	1 / 1	880	
arsenic (3 / 7)	I4297-1 F	1 / 1	31	8
	I4297-2 F	1 / 1	25	
	I4297-3 F	1 / 1	20	
chloride (3 / 7)	H1354-1 F	1 / 2	2,380,000	250,000
	H1354-2 F	1 / 2	3,800,000	
	I4297-2 F	1 / 1	263,000	
mercury (1/7)	80422 L	2 / 7	3.6 - 6.1	2
sodium (7 / 7)	I4297-1 F	1 / 1	140,000	50,000
	I4297-2 F	1 / 1	143,000	
	I4297-3 F	1 / 1	122,000	
	80422 L	1 / 7	157,000	
	80423 L	1 / 7	162,000	
	80424 L	1 / 7	171,000	
	80425 L	1 / 7	160,000	

*L = sample stabilized in the laboratory; F = sample stabilized in the field (Sea-Land facility)

Based on the above comparison, the following can be observed / concluded:

- The presence of sodium and chloride is attributable to the marine nature of the sediment samples.
- Aluminum, an abundant, naturally occurring element, was found above the GWQS in all analyzed SDM leachate samples.

- Arsenic and mercury concentrations exceeded GWQS only in laboratory SDM MMEP leachate samples. In the field SDM MMEP leachate samples, arsenic and mercury did not exceed GWQS.

- Alpha-BHC exceeded GWQS in three of the four laboratory SDM leachates. In the field SDM leachate samples, alpha-BHC did not exceed GWQS.

2.7.4.3.2 SDM MMEP Leachate - Comparison to Dioxin Criteria

Dioxin analyses were performed on the first and seventh leachate samples generated from four SDM samples (ID # 80422, 80423, 80424, and 80425) and the first leachate sample generated from three SDM samples (ID # 14798-1, 14798-2, and 14798-3). The results of dioxin analysis of the seven SDM samples are summarized in Table G-9 of Appendix G.

The TEQs for all the samples were determined following the procedure outlined in Section 2.7.3.1.4. The calculated TEQs were then compared with the Ground Water Quality Criteria of 0.01 ppb. This analysis indicated that the dioxin TEQs are below the GWQS.

2.7.4.4 Percolated Water - Screening Results

Percolated water samples were collected and analyzed to assess the actual quality of the liquids percolating through the SDM embankments. As with the MMEP leachate samples, the sampling results of percolated water samples were compared to the GWQS as a screening tool only, not for compliance purposes. The sampling results for percolated water samples collected on July 23, 1999 and September 15, 1999 were presented in the Progress Report of March 2000. As previously indicated, only one additional percolated water sample (K4942-1) was collected since December 1999. The analytical results for this additional percolated water sample, collected on August 11, 2000, were incorporated into the evaluation previously presented in the March 2000 Progress Report. Thus, this section supercedes that presented in the March 2000 Progress Report.

2.7.4.4.1 Percolated Water - Comparison to Groundwater Quality Standards

Percolated water samples were analyzed for VOCs, SVOCs, pesticides, PCBs, metals, dioxins/furans, and miscellaneous wet chemistry parameters. The metals were evaluated on both a total and dissolved basis so as to better understand the qualities of the percolated water (e.g. whether fines were carried in the matrix, or were identified metals associated with dissolution of soluble metals from the SDM).

Table G-10 in Appendix G of this report presents all chemical parameters detected above the GWQS. This table supersedes that presented in the March 2000 Progress Report.

The following represents the preliminary findings of percolated samples:

- The concentrations of all VOCs, SVOCs, pesticides, PCBs, and dioxins/furans were below the GWQS. As presented in Table G-10 of Appendix G, the following metals were detected at levels exceeding the GWQS:

Metal	No. of Samples Above the GWQS	Range of Concentrations (ppb)	GWQS* (ppb)
aluminum, total	1 / 3	1960	200
aluminum, dissolved	1 / 3	290	
arsenic, total	1 / 3	39	20
arsenic, dissolved	1 / 3	30	
chloride	3 / 3	1.01E6 - 1.88E8	250,000
iron, total	3/ 3	840 - 4300	300
iron, dissolved	3/ 3	500 - 3520	
lead, total	2 / 3	20 - 35	10
lead, dissolved	2 / 3	15 - 19	
manganese, total	3 / 3	950 - 3280	50
manganese, dissolved	3 / 3	950 - 3400	
nickel, total	2 / 3	110 - 220	100
nickel, dissolved	2 / 3	120 - 220	
sodium, total	3 / 3	3.53E6 - 6.57E6	50,000
sodium, dissolved	3 / 3	3.37E6 - 7.92E6	
thallium, total	1 / 3	16	10
thallium, dissolved	2 / 3	70-130	

The GWQS are determined based on total concentrations. The above comparisons are not provided for compliance purposes.

The following can be observed / concluded from the above data:

- Slight discrepancies exist between the total and dissolved concentrations measured for most metals due to the sampling procedures followed. If both the dissolved and total concentrations were to be measured from the same exact water sample, the total concentration would be greater than the dissolved concentration. In practice, this was not the case, since the samples to be analyzed for dissolved metals were immediately preserved while samples to be analyzed for total metal concentration remained unpreserved. This resulted in the collection of two distinct samples, which does not allow for establishing a definitive quantitative relation between total and dissolved concentrations.

- The presence of sodium and chloride are attributable to the marine nature of the dredge.

- In all of the analyzed percolated water samples, manganese and iron were found above the GWQS.

- Aluminum, arsenic, lead, nickel, and thallium were found in some of the percolated water samples, although their respective concentrations only marginally exceeded the GWQS.

Based on the above screening evaluation, contaminants in the percolated water exceeding the GWQS were modeled, to assess the potential impact of the percolated water on groundwater This additional evaluation is presented in Section 2.7.6.

The sampling of percolated water allowed for the evaluation of potential differences between leachate generated in the laboratory and leachate collected in the field. A distinction can be also made between leachate samples generated from SDM material prepared in the laboratory (laboratory SDM MMEP leachate) and leachate samples generated in the laboratory from SDM material collected in the field after actual cement mixing (field SDM MMEP leachate). These comparisons are discussed in Section 2.7.5.2.

2.7.4.4.2 Percolated Water - Comparison to Dioxin Criteria

Dioxin analyses were performed on all percolated water samples (I5297, K4942, I7390). The results of the dioxin analyses are presented in Table G-11 of Appendix G of this report. This table supercedes that presented in the March 2000 Progress Report. Following the procedure outlined in Section 2.7.3.2.4, the TEQs for percolated water samples (I5297, I7390, K4942,) were calculated to be 6.19 ppq, 19.05 ppq, and 28.81 ppq, respectively. As with the MMEP extracts, the calculated TEQs were compared with the GWQS of 0.01 ppb. The analysis indicated that the dioxin TEQs for all percolated water samples are below the GWQS.

2.7.4.5 Stormwater During Construction - Screening Results

Stormwater samples were collected during construction of the embankments and analyzed to assess the quality of the stormwater runoff that came into direct contact with the SDM embankments. Stormwater samples collected during construction of the embankments represent a worst-case scenario, since the SDM is exposed to rainfall without a protective cover. The results presented in this section are for samples collected prior to the installation of the topsoil and asphalt covers.

As previously noted, the stormwater sampling results were compared to the most stringent of the SWQC for both FW-2 freshwaters and SE/SC saline waters. For dioxins, the FW-2 criterion of 0.013 ppq and the SE/SC criterion of 0.014 ppq were used.

2.7.4.5.1 Stormwater During Construction - Comparison to FW-2 Surface Water Criteria

Stormwater samples collected during construction activities (prior to capping) were analyzed for VOCs, SVOCs, pesticides, PCBs, metals, dioxins/furans, and miscellaneous wet chemistry parameters. The metals were evaluated on both a total and dissolved basis so as to better understand the qualities of the stormwater (e.g. whether fines were carried in the stormwater, or were any identified metals associated with dissolution of soluble metals from the SDM).

Table G-12 of Appendix G presents all chemical parameters detected above the FW-2 surface water criteria in the stormwater from an uncapped embankment. The following is a summary of the findings based on the screening evaluation performed for stormwater samples collected during the construction of the embankments:

- The concentration of all VOCs, SVOCs, pesticides, and PCBs were below the FW-2 surface water criteria.

With the exception of dioxin, which will be discussed in detail in Section 2.7.4.5.4, of all parameters analyzed, only the following inorganics were detected at levels exceeding the FW-2 surface water criteria in the stormwater from an uncapped embankment:

Metal	No. Samples Above the SWQC	Criteria Exceeded	Range of Concentrations (ppb)	FW2 SWQC (ppb)
antimony, total	6 / 6	FW2-H	17 - 300	12.2 (H)
antimony, dissolved	4 / 6	FW2-H	27 - 120	
arsenic, total	6 / 6	FW2-HC	180 - 1330	0.017 (HC)
arsenic, dissolved	6 / 6	FW2-HC	240 - 1520	
cadmium, total	1/ 6	FW2-H	11	10 (H)
chloride	6 / 6	FW2-C	0.874E6 - 10.2E6	253,000 (C)
chromium, total	1 / 6	FW2-H	170	160 (H)
lead, total	5 / 6	FW2-H	11 -670	5 (H)
lead, dissolved	4 / 6	FW2-H	9 - 35	
mercury, total	3 / 6	FW2-H	0.2 - 0.49	0.144 (H)
selenium, total	3 / 6	FW2-H	14 - 39	10 (H)
selenium, dissolved	4 / 6	FW2-H	11 - 18	
thallium, total	6 / 6	FW2-H	2-30*	1.70 (H)

* Includes concentrations that were estimated by the laboratory and concentrations that were estimated from the MDL as described in Appendix I, since the MDL was above the SWQC

- As indicated in the previous section, slight discrepancies exist between the total and dissolved concentrations measured for some metals due to the sampling procedures followed.

- Arsenic exceeded the FW2-HC criteria by approximately four orders of magnitude.

- Lead and antimony exceeded the FW2-H criteria by approximately one order of magnitude.

- Cadmium, chromium, mercury, selenium, and thallium marginally exceeded the FW2-H criteria.

- As previously discussed, the detected chloride concentrations (six orders of magnitude above the SWC) are attributable to the marine nature of the dredged materials.

  It must be emphasized that the above comparisons between criteria and detected results are for evaluation purposes only. Section 2.7.6 further discusses the relationship between detected results and potential impact to the environment.

2.7.4.5.2 Stormwater During Construction - Comparison to SE/SC SWQC

To assess the viability of using SDM near marine surface water bodies, all surface water quality data gathered during construction of the embankments was also compared to the SWQC for water bodies designated as SE/SC. "SE" refers to the general surface water classification applied to saline waters of estuaries, while "SC" refers to the general surface water classification applied to coastal saline waters. Table G-14 in Appendix G of this report presents all chemical parameters detected above the SE/SC surface water criteria in the stormwater from an uncapped embankment.

The following table summarizes the results of this screening evaluation:

Metal	No. Samples Above the SWQC	SE/SC Criteria Exceeded	Range of Concentrations (ppb)	SWQS (ppb)
arsenic, dissolved	6 / 6	HC	290 - 1,520	0.136
arsenic, total	6 / 6	HC	180 - 1,330	
copper, dissolved	6 / 6	**	180 - 410	5.6
copper, total	6 / 6	**	170 - 1,170	
mercury, total	3 / 6	H	0.2 - 0.49	0.146
thallium, total	5 / 6	H	30*	6.22

*The levels of concentration for this parameter were below the MDL. Concentrations for this metal were estimated to be half of their MDL.

** Criteria established for New York/ New Jersey Harbor Estuary waters, which include Newark Bay, the New Jersey portion of Raritan Bay, Upper Newark Bay, Arthur Kill, Kill Van Kull, saline portions if the Passaic, Hackensack, and Hudson Rivers and saline portions to all tributaries to these waters.

The following are observed / concluded from the above comparison:

- Arsenic (total and dissolved) exceeded the SE/SC-HC surface water criteria in all the samples by three to four orders of magnitude.

- Even though as previously noted, the concentration of total thallium was estimated to be half of the MDL or 30 ppb, five of the six thallium samples exceeded the SE/SC surface water criteria by one order of magnitude.

- Total mercury only exceeded the SE/SC-HC surface water criteria in three out of four samples.

A comparison of those parameters exceeding the FW-2 SWQC with those parameters detected above the SE/SC SWQC shows that the frequency of arsenic and mercury exceedences did not vary between the separate criteria. Thallium, which was either detected or estimated at concentrations above the FW-2 criteria in all samples, was also estimated to be above the SE/SC criteria in five out of six samples. Antimony and total chromium, which were detected above the FW-2 criteria, were found below the SE/SC criteria.

It should be stated that the NJDEP has not established a SE/SC standard for cadmium, selenium, lead, and chloride, parameters that were detected in the stormwater collected during construction above the FW-2 surface water criteria. In addition, the NJDEP has not established an FW-2 surface water criterion for copper, a parameter detected above the NY/NJ Harbor Estuary Criteria.

It must be emphasized that the above comparisons between criteria and detected results are for evaluation purposes only. Section 2.7.6 further discusses the relationship between detected results and potential impact to the environment.

2.7.4.5.3 Stormwater During Construction - Comparison to Dioxin Criteria

The results of the dioxin analyses performed on the six stormwater samples collected during construction are summarized in Table G-13 of Appendix G. The TEQs for all the samples were determined following the procedure outlined in Section 2.7.3.2.4. The calculated TEQs were then compared to the SWQC of 0.013 and 0.014 ppq established for FW-2 and SE/SC surface waters, respectively, and the NJPDES 10,000 ppq standard for discharge to FW-2 and SE/SC waters.

The dioxin analysis results for stormwater samples indicate that the although SWQC for both FW-2 and SE/SC water bodies were exceeded in all samples (with calculated TEQs ranging from 19.41 ppq to 52.20 ppq), none of the six samples exceeded the NJPDES criteria for discharge into FW-2 or SE/SC surface waters. Again, the above comparisons are presented for impact evaluation purposes, not for compliance. Section 2.7.6 further discusses the relationship between detected results and potential impact to the environment.

2.7.4.6 Post-Construction Stormwater - Screening Results

- Four stormwater samples were collected after the capping of Embankment No. 2 to assess the effectiveness of the final cover. As with stormwater samples collected during construction, the results obtained from the post-construction sample analyses were compared to the most stringent of the SWQC for FW-2 freshwater and SE/SC saline waters. For dioxins, the FW-2 criterion of 0.013 ppq and the SE/SC criterion of 0.014 ppq were used.

2.7.4.6.1 Post-Construction Stormwater - Comparison to FW-2 SWQC

The post-construction stormwater samples were analyzed for VOCs, SVOCs, pesticides, PCBs, metals, dioxins/furans, and miscellaneous wet chemistry parameters. The metals were evaluated on both a total and dissolved basis so as to better understand the qualities of the stormwater.

Table G-16 in Appendix G of this report presents all chemical parameters found in the post-construction stormwater above the FW-2 SWQC. The following is a summary of the findings from this screening evaluation:

- The concentration of all VOCs, SVOCs, pesticides, and PCBs were below the FW-2 surface water criteria.
- With the exception of dioxins, which will be discussed in detail in Section 2.7.4.6.4, out of all the parameters analyzed, only the following inorganics were detected at levels exceeding the SWQC:

Metal	No. Samples Above the SWQC	FW2 Criteria Exceeded	Range of Concentrations (ppb)	SWQC (ppb)
arsenic, dissolved	4 / 4*	FW2-HC	1.9* -6.7	0.017 (HC)
arsenic, total	4 / 4*	FW2-HC	1.9* - 10.0	
chloride	2 / 4	FW2-C	3.19E5 - 1.84E6	230,000
lead, dissolved	1 / 4	FW2-H	16.0	5 (H)
lead, total	1 / 4	FW2-H	30.0	
mercury, total	1 / 4	FW2-H	0.27	0.144 (H)
thallium, dissolved	1 / 4	FW2-H	39.0	1.70 (H)
thallium, total	1 / 4	FW2-H	90.0	

*The concentration level for one sample was below the MDL. Concentrations for this sample were estimated to be half of the MDL.

The following are observed / concluded based on the above data:

- As indicated in previous sections, slight discrepancies exist between the total and dissolved concentrations measured for some metals due to the sampling procedures followed.

- Arsenic (total and dissolved) exceeded the FW2-HC criteria by approximately two orders of magnitude while thallium (total and dissolved) exceeded the FW2-H criteria by approximately one order of magnitude

- Lead (total and dissolved) and mercury marginally exceeded the FW2-H criteria.

- As previously discussed, the detected chloride concentrations (six orders of magnitude above the SWC) are attributable to the marine nature of the dredged materials

Sampling of the stormwater during construction and during the post-construction period was performed to evaluate the potential beneficial effects of capping the SDM embankments with soil cover.

It must be emphasized that the above comparisons between criteria and detected results are for evaluation purposes only. Section 2.7.6 further discusses the relationship between detected results and potential impact to the environment

2.7.4.6.2 Post-Construction Stormwater - Comparison to SE/SC SWQC

As previously noted, a total of four stormwater samples were collected after the embankments were capped. As with stormwater samples collected during construction, the post-construction stormwater samples were compared to the SWQC for saline waters designated as SE/SC to evaluate the viability of the use of SDM near marine surface water bodies. Table G-17 in Appendix G of this report presents all chemical parameters detected above the SE/SC surface water criteria in the post-construction stormwater.

The following table summarizes the results of this screening evaluation:

Metal	No. Samples Above SWQC	SE/SC Criteria Exceeded	SE/SC Criteria (ppb)	Range of Concentrations (ppb)
arsenic, total	4 / 4*	HC	0.136	1.9* - 10.0
arsenic, dissolved	4 / 4*			1.9 *- 6.7
copper, total	4 / 4	**	5.6	36 -120
copper, dissolved	4 / 4			39 -110
mercury, total	1 / 4	H	0.146	0.27
thallium, total	1 / 4	H	6.22	90.0
thallium, dissolved	1 / 4			39.0

* Includes concentrations that were estimated by the laboratory and concentrations that were estimated from the MDL as described in Appendix I, since the MDL was above the SWQC.

** Criteria established for New York/New Jersey Harbor Estuary, for waters which include Newark Bay, the New Jersey portion of Raritan Bay, Upper Newark Bay, Arthur Kill, Kill Van Kull, saline portions if the Passaic, Hackensack, and Hudson Rivers and Saline portions to all tributaries to all these waters.

The following are observed / concluded based on the above data:

- Arsenic (total and dissolved) exceeded the SE/SC surface water criteria in all samples by two orders of magnitude.

- Total and dissolved thallium exceeded the SE/SC surface water criteria in one out of four samples by an order of one magnitude.

- Total mercury marginally exceeded the surface water criteria in one out of four samples.

- Although not specifically a SE/SC SWQC, copper (dissolved and total) exceeded the criteria established for protection of the New York/New Jersey Harbor Estuary in all samples.

A comparison of those parameters exceeding the FW-2 SWQC with those parameters detected above the SE/SC SWQC shows that the frequency of exceedences for arsenic (total and dissolved), total mercury, and thallium (total and dissolved) did not vary with the specific SWQC. It should be noted that the NJDEP has not established SE/SC standards for chloride and lead, parameters that were detected in the post-construction stormwater above the FW-2 surface water criteria. In addition, the NJDEP has not established an FW-2 SWQC for copper, a parameter detected above the NY/NJ Harbor Estuary Criteria.

It must be emphasized that the above comparisons between criteria and detected results are for evaluation purposes only. Section 2.7.6 further discusses the relationship between detected results and potential impact to the environment.

2.7.4.6.4 Post-Construction Stormwater - Comparison to Dioxin Criteria

Dioxin analyses were performed on the four stormwater samples collected during the post-construction period. The results of the dioxin analyses for these samples are summarized in Table G-19 of Appendix G of this report. The TEQs for all the samples were determined following the procedure outlined in Section 2.7.3.2.4. The calculated TEQs were then compared to the SWC of 0.013 and 0.014 ppq established for FW-2 and SE/SC surface waters, respectively, and the NJPDES 10,000 ppq standard for discharge to FW-2 and SE/SC surface waters.

The dioxin analysis results for stormwater samples indicate that although the SWC for both FW-2 and SE/SC water bodies was exceeded with calculated TEQs of 11.23 ppq, 20.39 ppq, 24.59 ppq, and 8.72 ppq, none of the six samples exceeded the NJPDES criteria for discharge into FW-2 or SE/SC surface waters.

2.7.4.7 Soil Cover - Screening Results

A total of ten soil cover samples were collected and analyzed for Priority Pollutants plus a forty-compound library search (VOCs, SVOCs, pesticides, PCBs, and metals). All parameters tested were found to be below the RDCSCC.

2.7.4.8 Total Organic Carbon (TOC) Evaluation

TOC was analyzed in RDM samples 80418, 80419, 80420, 80421, H1670-1, and H8788. The results indicate that the representative TOC concentrations in the RDM samples (80418, 80419, 80420, 80421) collected to assess the suitability of the dredged material for upland beneficial use ranged from 15,000 ppm to 45,000 ppm. The TOC in the supplemental RDM samples collected in October/ November 1998 (H1670-1 & H8788) were reported to range between 10,000 ppm and 30,000 ppm. The average value for TOC found within the RDM samples was calculated to be 24,679 ppm, or 2.5%. These TOC concentrations are comparable to the range of organic carbon content typically found in fine textured uncultivated soils.

Likewise, TOC was analyzed in SDM samples 80422, 80423, 80424, 80425, H1354-1 through 4, H2351-1 through 3, H2354-1 through 2, I1878-1 through 2, I4297-1 through 3, I4299-2 through 3, I5240-1 through 2, I6638-1 through 2, and I7391-1 through 2. In April 1998, initial samples (80422, 80423, 80424, and 80425) were collected to characterize the concentrations of TOC within the SDM. These initial concentrations ranged between 20,000 ppm and 25,000 ppm. TOC concentrations in supplemental samples (H1354-1 through 4), collected in October 1998 ranged from 13,500 ppm to approximately 14,600 ppm. Two monthly TOC samples were collected between March 1999 and September 1999 (H2351-1 through 3, H2354-1 through 2, I1878-1 through 2, I4297-1 through 3, I4299-2 through 3, I5240-1 through 2, I6638-1 through 2, and I7391-1 through 2) to evaluate potential variations in TOC within the SDM with time. The concentrations in the monthly samples ranged from 7,000 to 26,000 ppm and showed no discernible variation with time. The average TOC concentration in the SDM was calculated to be 12,842 ppm, or 1.3%. Furthermore, these TOC concentrations are similar to that of uncultivated fine textured soils.

The average value for TOC found within the RDM was calculated to be 24,679 ppm or 2.5%, whereas the average TOC concentration in the SDM was 12,842 ppm or 1.3%. Although the average TOC concentrations measured in the RDM and SDM are slightly different, a Student's T-Test with a 95% confidence interval indicated that there is no overall statistical difference between the TOC concentrations in RDM and SDM.

2.7.4.9 Corrosion Potential

A measurement of the corrosive effects of SDM on steel and reinforced concrete roadway systems is necessary to determine the need for corrosion protection measures for these materials. Corrosion of such materials is caused by an electrochemical process that requires the flow of electric current and various chemical reactions, which may be accelerated by certain components of the SDM. The corrosion potential of the SDM was evaluated using the following indicators: pH, chlorides, total acidity, sulfate, sulfide, and resistivity. Although the actual corrosivity of a material is site dependent, generalizations regarding corrosivity can be made based on these parameters.

2.7.4.9.1 Data on Potential Corrosivity of Dredge Material

RDM

Although RDM will not be used in its unamended form in roadway construction projects, it is necessary to estimate its corrosive potential for two reasons. First, it provides a preliminary indication of the potential for corrosivity of the SDM. Second, since the RDM will be used in its natural form in the stabilization plant, the potential for corrosion of the stabilization equipment can be assessed.

The following table presents the data gathered to assess the potential corrosivity of RDM:

Potential Corrosion Contributors	Range of Concentrations (ppm)	Average Concentration (ppm)
Acidity	0.5* - 28	9.96
Chloride	5,186 - 9,510	8,025
PH	7.31 - 7.42	7.38
Salinity	2.1E-5	2.1E-5
Sulfate	411 - 1,730	1,227
Sulfide	0.008* - 0.075*	0.053
Resistivity	250 - 1,120 ohm-cm	631 ohm-cm

*Since the concentrations of these parameters were reported as below the MDL, their concentrations were estimated to be half of their respective MDLs.

SDM

The following table presents the data collected on potential corrosivity of SDM:

Potential Corrosion Contributors	Range of Concentrations (ppm)	Average Concentration (ppm)
Acidity	0.5* - 4.85*	2.91
Chloride	3,005 - 11,900	7,875
pH	9.31 - 11.2	10.3
Salinity	2.0E-6	2.0E-6
Sulfate	2,140 - 3,020	1,283
Sulfide	50.2 - 667	242
Resistivity	242 - 432 ohm-cm	350 ohm-cm

*Since the concentrations of these parameters were reported as below the MDL, their concentrations were estimated to be half of their MDL.

When the RDM and SDM data are compared, it is noted that four of the indicators of corrosion increased (i.e., pH, salinity, sulfate and sulfide), while the remaining indicators (i.e., acidity and resistivity) decreased. These changes are attributable to the thorough mixing of the RDM with 8% cement. Ostensibly, the addition of the cement increased the concentrations of ions, which results in a decrease in acidity and resistivity. Although the acidity of the SDM is low, and therefore should exhibit low corrosivity, the resistivity of the material is less than 1000 ohm-cm, which is indicative of materials with very high corrosivity.[v] Therefore, because of the low resistivity of the material it is assumed that the SDM could potentially be corrosive.

MMEP Leachates & Percolated Water

Considering the possibility that rainwater could infiltrate through the SDM and come into contact with steel or reinforced concrete structures, it is important to investigate the potentially corrosive characteristics of the infiltrating liquids. To assess the potential leachability of the SDM, both MMEP leachates and percolated water samples were collected as part of this project. The following table summarizes the data gathered to assess the potential corrosivity of infiltrating or leaching liquids:

Potential	MMEP Leachates (ppm)	Percolated Water (ppm)

[v] Corrosivity classes range from very low to very high based on resistivity values of >10,000 ohm-cm and <1,000 ohm-cm, respectively as cited in: Escalante, E., Underground corrosion, ASTM STP 741, Baltimoire MD, 1981, pp.3-23.

Contributors of Corrosion	Range of Concentrations	Average Concentration	Range of Concentrations	Average Concentration
Acidity	0.5*	0.5*	16.2 - 510	194
Chloride	0.4 - 3,800	984	7.02 - 18.8	8.94
pH	9.77 - 11.7	10.9	7.21 - 7.84	7.52
Salinity	8E-7 - 1E-6*	8.7E-7	1.33E-5 - 2.03E-5	1.7E-5
Sulfate	4 - 142	62.4	1,800 - 5,640	2,140
Sulfide	0.008* - 9.2	5.83	0.008* - 0.8	0.408
Resistivity	408 - 7820 ohm-cm	2,288 ohm-cm	32.4- 35.8 ohm-cm	34.1 ohm-cm

*Since the concentrations of these parameters were reported as below the MDL, their concentrations were estimated to be half of their MDL.

Individual indicators of corrosivity were found to vary significantly between leachate generated in the laboratory through the MMEP and percolated water samples collected in the field. The differences between the MMEP leachates and percolated water samples can be attributed to quality of cement mixing, variability on cement curing, and differences between the field conditions and the conditions imposed by the MMEP extraction (i.e., extractant to SDM mass ratio, pH of extractant, contact area, and contact time). In addition, as with all grab samples from large amounts of media, the chemical composition and general characteristics of the discrete SDM samples from which the leachate was generated may not adequately represent the large amount of SDM used at the site. Specifically, the MMEP is performed on a 100-gram aliquot, which likely did not fully represent the 30,000 cubic yards of material used for this embankment. Nonetheless the results for both the MMEP and the percolated water were generally consistent with the results for SDM.

It should be emphasized that percolated water samples resulted from actual field conditions (i.e., quality of cement mixing in the SDM and potential variability on chemical fixation after complete cement curing), actual atmospheric and rain conditions (i.e., actual acidity and advective / erosive forces), and actual water retention time within the soil matrix.

As mentioned in Section 2.7.3.2.2, the available data indicate that the MMEP may not be an acceptable technique for evaluating contaminant leaching from SDM until steady state conditions are achieved.

Stormwater

The potential corrosivity of stormwater in contact with the SDM was investigated, since runoff could come in contact with steel reinforced roadway structures as it travels through the stormwater management system. The following table summarizes the data gathered to assess the potential corrosivity of stormwater before and after capping of the SDM structures:

Potential Corrosion Contributors	During Construction (ppm)		Post-Construction (ppm)	
	Range of Concentrations	Average Concentration	Range of Concentrations	Average Concentration
Acidity	0.5* - 26.5	9.5	0.5*-18.5	10.5
Chloride	874 - 10,200	5,424	177 - 1,840	641.5
pH	7.27 - 8.88	8.17	7.14 - 7.3	7.23
Salinity	2.1E-6 - 1.45E-5	7.0E-6	6.0E-7 - 5.0E-6	1.925E-6
Sulfate	681 - 3,280	1,730	196 - 1,520	738.5
Sulfide	0.008* - 15.2	2.870	8* - 800	272
Resistivity	41.7 - 254 ohm -cm	113.9 ohm -cm	115 - 674 ohm -cm	424 ohm -cm

*Since the concentrations of these parameters were reported as below the MDL, their concentrations were estimated to be half of their MDL.

Comparisons between stormwater collected during construction (uncapped embankment) and post-construction (capped embankment) indicate that two contributors of corrosion (sulfide and resistivity) increased after capping of the embankment. All other indicators of potential corrosion of reinforced concrete and steel structures decreased.

2.7.4.9.2 Discussion

Corrosion is a phenomenon of concern with many naturally occurring soil types. Data discussed in the preceding sections on corrosion potential of RDM/SDM suggest that suitable corrosion protection measures be adopted for structures in direct contact with RDM/SDM or which may come in contact with leachate or runoff from RDM/SDM embankments.

2.7.4.9.3 Methods of Corrosion Protection

The need for corrosion protection must be evaluated on a case-by-case basis, depending on the corrosive properties of the material being used and the intended use and service life of the structure. Corrosion protection methods will not completely prevent the corrosion of steel, but will retard potential corrosive effects.

The U.S. Department of Transportation has identified and grouped corrosion prevention strategies for concrete into four general categories:

- **<u>Design</u>**
  Provide additional concrete cover over steel
  Control reinforcement distribution to prevent crack formation

- **<u>Concrete</u>**
  Adjust the water-cement ratio
  Use of pozzoleans (silica fume, fly ash, slag)
  Addition of latex, epoxy, and polymer additives
  Control the aggregate size
  Selection of adequate cement types

- **<u>Corrosion Inhibitors</u>**
  Use of organic, inorganic, or other mixed common inhibitors
  Use of sacrificial cathodes or cathodic protection

- **<u>Reinforcement Type</u>**
  Epoxy coat the reinforcing bars
  Galvanize the reinforcing bars
  Use nickel clad, copper clad, and stainless steel bars
  Use stainless steel, alloyed or non-metallic bars

Any of the above recommendations, or combinations of the above, might be selected for specific projects based on the material being used and intended use and service life of the structure. Other corrosion protection methods would be required for metal structures.

2.7.5 Overall Findings of the Screening Evaluation

The discussion presented in Section 2.7.4 of this report is based on the comparison of data gathered between April 1, 1998 and September 1, 2000 to environmental benchmarks established by the NJDEP for soil, groundwater, and surface water quality. This comparison was performed as a screening tool to identify of those parameters that could potentially cause environmental impacts. The screening evaluation was not performed for compliance purposes; in fact, none of the selected benchmarks are directly applicable.

Based on the initial screening results, supplemental evaluations were performed for stormwater and percolated water. Specifically, a contaminant mass transport analysis was performed for chloride and selected metals (antimony, arsenic, cadmium, chromium, copper, silver, selenium, and thallium) in the stormwater and chloride and selected metals (aluminum, arsenic, iron, lead, manganese, nickel, sodium, and thallium) in the percolated water. These analyses are presented in Section 2.7.6.

To assess the potential environmental benefits that could result from the stabilization of the RDM with cement and/or the placement of a protective soil cover over the embankments, it was necessary to compare the analytical data gathered in different stages of this project. To evaluate the environmental effect of cement stabilization, the RDM and SDM analytical data in exceedence of NJDEP standards was compared. Similarly, to assess the environmental effect of placing a cover over the SDM, stormwater sample results before and after the placement of the soil cover were compared.

To evaluate the leachate and percolated water data, and the effectiveness of the MMEP testing, the leachates from laboratory-generated SDM and field-mixed SDM were compared to each other, and to the percolated water that had been collected in the field. The following sections present the conclusions of these evaluations.

2.7.5.1 RDM and SDM

The RDM and SDM sediment samples were compared to the RDCSCC, NRDCSCC, and IGWSCC. As discussed previously, RDM analytical results are not directly comparable to the SCC because RDM is not intended for direct use as construction fill. However, through testing the RDM, the potential quality of the associated SDM can be better understood, and potential contaminant exposures during the mixing, transport, and construction phases can be evaluated.

The stabilization activities performed on the RDM were conducted to improve the construction qualities of the material, not to provide contaminant stabilization. However, the potential for contaminant stabilization exists, so results from the RDM and SDM samples were compared to determine whether the stabilization process also provided environmental benefits.

The following list identifies those analytes that exceeded the SCC in at least one RDM and/or SDM sample:

Analyte	RDM		SDM	
	RDCSCC	NRDCSCC	RDCSCC	NRDCSCC
benzo(a)anthracene	exceeds		exceeds	
benzo(a)pyrene	exceeds	exceeds	exceeds	exceeds
benzo(b)fluoranthene	exceeds		exceeds	
benzo(k) fluoranthene	exceeds		exceeds	
beryllium	exceeds	exceeds	exceeds	exceeds
zinc	exceeds	exceeds		
arsenic			exceeds	exceeds
lead			exceeds	

As noted in the table, lead and arsenic were detected above the SCC in the SDM but not the

RDM, and zinc was detected in the RDM but not the SDM. This finding is not believed to be associated with the stabilization process, but is instead due to typical variations observed between individual soil and/or sediment grab samples.

The comparison of the SDM and RDM data indicates that the stabilization of RDM with 8% cement may not significantly affect contaminant binding. However, this does not present any particular concern due to the following:

- in theory, the laboratory analytical method would be able to detect the presence of the metals within the RDM / SDM regardless of whether the contaminants were bound sufficiently to prevent environmental impacts via leaching or other exposure routes. Thus, the comparison may have little validity (a comparison of leachates generated from RDM and SDM might be more appropriate);

- the stabilization is performed for construction purposes, rather than environmental purposes, so the 8% cement is not optimized for contaminant binding and does not indicate a failure;

- the highest contaminant concentrations identified in the RDM and SDM are comparable to those found in industrial settings, and are well below those concentrations typically found in historic fill material (see NJAC 7:26E Table 4.2). Soils containing these contaminants at much higher concentrations are frequently approved for onsite containment by the NJDEP with minimal engineering and/or institutional controls, such as capping (which would be performed regardless as part of any construction project using SDM); and

- because the use of SDM for roadway construction projects is only recommended in industrialized and/or brownfield areas, the contaminant concentrations within the RDM and/or SDM would not be appreciably different from background conditions.

2.7.5.2 Field SDM Leachate and Laboratory SDM Leachate

Leachate samples generated from SDM following the MMEP procedure were evaluated against the GWQS to assess potential contaminants of concern. Two distinct sets of SDM leachate samples were generated. These included “laboratory SDM MMEP leachates” generated in the laboratory from RDM cores, and “field SDM MMEP leachates” generated in the laboratory using SDM obtained from the Sea-Land Facility Pug mill. To assess potential differences between lab and field leachate samples, those chemicals exceeding the GWQS were compared, as shown below:

Parameter Found Above GWQC	Incidence in Laboratory SDM MMEP Leachate	Incidence in Field SDM MMEP Leachate
alpha-BCH	3 / 4 SDM samples 6 / 21 leachate samples	none
aluminum	4 /4 SDM samples 8 / 28 leachate samples	3 / 3 SDM samples • / 3 leachate samples
arsenic	none	3 / 3 SDM samples • / 3 leachate samples
chloride	not tested	3 / 3 SDM samples • / 3 leachate samples
mercury	1 / 4 SDM samples 2 / 7 leachate samples	• one
sodium	4 / 4 SDM samples 4 / 28 leachate samples	3 / 3 SDM samples • / 3 leachate samples

The following are concluded based on the above comparison:

- The presence of sodium and chloride in the field and laboratory SDM MMEP samples is attributable to the marine nature of the sediment samples (although chloride was not tested for in the lab SDM MMEP samples, it is presumed to be present).

- Aluminum concentrations exceeded the GWQS in all laboratory and field SDM leachate samples. Aluminum is an abundant, natural element found within fine-grained soils and sediments.

- Mercury and alpha-BCH only exceeded GWQS in some of the laboratory SDM leachate samples. These chemicals were not detected in the field SDM leachate samples.

- Arsenic was detected above the GWQS in all the field SDM leachate samples, but none of the laboratory SDM leachate samples.

Although sample preparation could be a contributing factor in the discrepancies found between the field and laboratory SDM MMEP leachate data, it is presumed that these differences are due to localized variations in the quality of the sediments (artifact of grab sampling).

Because the field SDM leachate was generated from SDM stabilized outside the laboratory, it is believed to be more representative of the potential leachability of SDM.

2.7.5.3 SDM Leachate and Percolated Water

To supplement the leachability tests described above, which are required within the NJDEP's October 1997 "The Management and Regulation of Dredging Activities and Dredged Material in New Jersey's Tidal Waters," samples of liquids that percolated through the SDM embankments were collected to evaluate actual contaminant leaching. This Demonstration Project provided a unique opportunity to compare the quality of leachate generated from the MMEP with that of actual percolated water, and to thus assess the appropriateness of the MMEP for evaluating contaminant leaching potential.

Like the leachate samples, the percolated water samples were compared to the GWQS to identify potential contaminants of concern. The following table summarizes the results of a screening evaluation comparing the constituents within the percolated water against both laboratory and field SDM leachates:

Parameter exceeding GWQS	Incidence in Laboratory SDM MMEP Leachate	Incidence in Field SDM MMEP Leachate	Incidence in Percolated Water
alpha-BCH	3 / 4 SDM samples 6 / 21 leachate samples	none	none
aluminum	4 / 4 SDM 28 / 28 leachate	3 / 3 SDM 3 / 3 leachates	2 / 6 samples
arsenic	none	3 / 3 SDM 3 / 3 leachates	2 / 6 samples
chloride	not tested	3 / 3 SDM 3 / 3 leachates	3 / 3 samples
iron	none	none	5 / 6 samples
lead	none	none	4 / 6 samples
manganese	none	none	6 / 6 samples
mercury	1 / 4 SDM 2 / 7 leachates	none	none
nickel	none	none	4 / 6 samples
sodium	4 / 4 SDM 4 / 28 leachates	3 / 3 SDM 3 / 3 leachates	6 / 6 samples
thallium	none	none	3 / 6 samples

The following are concluded based on the above comparison:

- The presence of sodium and chloride in the MMEP leachates and percolated water samples is attributable to the marine nature of the sediment samples.
- The GWQS for aluminum was exceeded in both the MMEP leachates and percolated water samples, although the incidence in the percolated water samples was significantly less than in the laboratory and field SDM leachates. As noted above, aluminum is an abundant, naturally occurring element.
- Mercury and Alpha-BCH only exceeded GWQS in the laboratory SDM leachate.
- Arsenic was detected above GWQS in all field SDM leachate samples, but in just one-third of the percolated water samples.

- Lead, thallium, nickel, manganese and iron were detected above GWQS only in the percolated water samples.

The data gathered from this project indicate that the laboratory-generated SDM leachates generally underestimate the concentrations of analytes found in the field samples (percolated water samples). The higher occurrence of metals within the percolated water samples can be attributed to the quality of cement mixing and variability of cement curing. The results found in the percolated water samples also reflect actual atmospheric and rain conditions (e.g. actual acidity and advective / erosive forces) and actual water retention time within the soil matrix.

The observed differences may have also been due to differences between the field conditions and the conditions imposed by the MMEP extraction (i.e., extractant to SDM mass ratio, pH of extractant, contact area, and contact time). The SDM MMEP leachate is generated by combining a measured mass of SDM (100 grams) with 20 times as much synthetic acid rain (pH = 4.2), and agitating over a 24-hour period. Similar to the EPA's TCLP method 1311, seven extracts (leachate samples) are generated from each soil sample. The SDM and extractant (synthetic acid rain) have maximized contact areas due to the agitation, relatively large contact time between soil and extractant particles, and the large extractant to SDM ratio (20 to 1). Therefore, the concentration of chemicals in the MMEP leachate could represent chemical equilibrium conditions between the extractant and the SDM.

Alternatively, the percolated water samples were obtained from rainwater that permeated through the embankment layers into the percolated water collection system. Since the contact area is restricted to the limited areas that the extractant (rain water) percolates through, and the ratio of extractant to SDM is very small (approximately 1000 gallons of water have been collected from the percolated water system in 14 months, and the volume and density of the SDM in the embankment are 30,000 cubic yards and approximately 75 pounds per cubic foot, respectively), the concentrations of contaminants measured in the percolated water samples may represent a concentrated solution of the most easily extractable fraction of contaminants present in the SDM.

These hypotheses are supported by comparison of the metal concentrations in successive extracts and the changes in the metal concentration with time in the percolated water samples. Careful review of the laboratory-generated SDM leachate data indicates that, in general, the concentration of the detected metals decreased with successive extractions. In many cases, the successive extractions resulted in contaminant concentrations below the detection limits, leading to conclusion that there is a small, finite, easily extractable fraction of metals within the SDM. Such results are consistent with the general decrease over time in the concentration of parameters detected in the percolated water samples.

As with all discrete sampling events, it is also possible that the discrete SDM samples from which the leachates were generated did not fully represent the large amount of SDM used at the site.

Although more research may be necessary to adequately evaluate the discrepancies observed in this project, and the adequacy of the MMEP extraction process to evaluate chemical leachability from SDM, the available data indicate that the MMEP might not be the optimal technique for evaluating contaminant leaching from SDM until steady state conditions are achieved. However, given the alkaline pH conditions of the SDM, once steady state is reached, metal leaching is expected to be quite low.

2.7.5.4 Comparison of Stormwater Runoff from Uncapped and Capped Embankments

After significant rain episodes, samples consisting of runoff from the embankments were obtained from the stormwater collection system. Six stormwater samples were collected prior to the placement of the protective cover over the embankments, and four samples were collected after the capping of the embankments. Samples collected during construction of the embankments represent "worst-case" stormwater that came in direct contact with the SDM, since the protective cover was not completely in place. Stormwater samples collected during the post-construction period did not come into direct contact with the SDM due to protective caps consisting of six inches of asphalt millings on top and twelve inches of clean fill on the sides of the embankment.

To evaluate the soil cover as an environmental control for surface water runoff, the samples collected during and post-construction can be compared. For the purpose of this analysis, only those parameters detected in the stormwater above the FW2-SWQC have been evaluated. The following table presents the comparison of these distinct stormwater samples.

Summary Results for Stormwater Samples During And After Construction

Parameters Found Above SWQC	Lowest FW2 SWQC (ppb)	Stormwater Quality During Construction (SDM exposed)		Stormwater Quality After Construction (SDM capped)		Log Reduction
		Frequency above SWQC	Range of Concentration (ppb)	Frequency above SWQC	Range of Concentration (ppb)	
antimony, dissolved	12.2	4 / 6	17 - 300	none	<5.7 - <11.0	1 to 2
antimony, total		6 / 6	27 - 120	none	<5.7 - <6.7	1 to 2
arsenic, dissolved	0.017	6 / 6	240-1520	3 / 4	5.0 - 6.1	1 to 2
arsenic, total		6 / 6	180 - 1330	3 / 4	9.3 - 10.0	1 to 2
cadmium, total	10	1 / 6	11	none	< 1.1 - <3.3	1
chloride	230,000	6 / 6	0.874E6 - 10.2E6	2 / 4	0.319E6 -1.84E6	No Reduction
chromium, total	160	1 / 6	170	none	2 - 6.5	2
copper, total	5.6	6 / 6	170 - 1170	3 / 4	36.0 - 120.01 to 2	1 to 2
copper, dissolved		6 / 6	180 - 410	3 / 4	39.0 - 110.0	0.5 to 1
lead, dissolved	5	3 / 6	9 - 35	1 / 4	16.0	No Reduction
lead, total		5 / 6	11 - 670	1 / 4	30.0	0 to 1
mercury, total	0.144	1 / 6	0.2 - 0.49	1 / 4	0.27	No Reduction
selenium, dissolved	10	4 / 6	11 -18	none	<2.0 - <5.6	1
selenium, total		3 / 6	14- 39	none	<2.0 - <5.6	1
thallium, dissolved	1.7	6 / 6*	30*	4 / 4*	30.0 - 39.0*	No Reduction*
thallium, total		6 / 6**	2**- 30	1 / 4**	90.0***	No Reduction

* Includes concentrations estimated by the laboratory and concentrations estimated from the MDL, since the MDL was above the SWQC.

** The thallium concentration of 2 ppb was estimated by the laboratory. In the remaining five samples, the concentration was estimated to be 30 ppb, half of the MDL.

*** In the remaining three samples, the concentration was estimated to be 1 ppb, half the MDL.

The following points are relevant to the above data comparison:

- No net reductions in the concentrations of chloride, dissolved lead, total mercury, and thallium (total and dissolved) were observed before and after the embankments were capped.

- As discussed in Appendix I, dissolved concentrations of thallium in all stormwater samples collected during construction were estimated to be half the MDL (60 ppb). These estimated concentrations are above the SWQC of 1.7 ppb. In a similar manner, the dissolved concentration of thallium in three of the four stormwater samples collected after the capping of the embankments were estimated to be 30 ppb (half the MDL). The dissolved concentration of thallium in the fourth post-construction stormwater sample was estimated to be 39 ppb by the analytical laboratory. Therefore, the estimated concentrations of dissolved thallium before and after the capping of the embankments were essentially the same, and no net effect was observed due to the capping of the embankments.

- A net reduction (0.5 to 2 orders of magnitude) in the concentrations of antimony (total and dissolved), arsenic (total and dissolved), total cadmium, total chromium, copper (total and dissolved), total lead, and selenium (total and dissolved) was observed after the embankments were capped.

- Of all the chemicals experiencing a net reduction in concentration (see above), only arsenic and copper remained above their detection limits after capping.

- Arsenic, chloride, copper, and lead were detected 25% to 50% less frequently after capping of the embankment.

- Capping did not affect the frequency in which total mercury and dissolved thallium were encountered. Dissolved thallium was never detected above the laboratory MDL.

- Antimony (total and dissolved), total cadmium, and selenium (total and dissolved) were not detected after the capping of the embankment.

As previously indicated, during the construction of the embankments, rainwater could come into direct contact with the SDM. Therefore, the stormwater samples collected during construction are expected to represent a worst-case scenario. Following capping, the stormwater would be expected to exhibit lower contaminant concentrations, since the protective asphalt, soil and vegetative covers prevent direct contact with the SDM, and the capping material was found to contain lower contaminant concentrations than the SDM.

The following table compares contaminant concentrations within the SDM and soil cover for those parameters detected in the stormwater above the SWQC:

Parameters Detected in the Stormwater above SWQC	Range of Concentrations in SDM (ppb)	Range of Concentrations in Protective Soil Cover (ppb)
Antimony	1,600 - 8,200*	500*
Arsenic	23,300 - 42,600	1000*
Cadmium	40* - 3,930	300 - 600
Chromium	87,200 - 139,000	7850 - 15,000
Chloride	3,005,000 - 11,900,000	Not tested
Copper	164,000 - 268,000	23,400 - 65,400
Lead	467,000	13,200 - 61,500
Mercury	1,000 - 2,200	20 - 53
Selenium	490* - 1,500	500*
Thallium	870* - 1,540*	250*

*The concentrations for these parameters were below the MDLs, and thus were estimated to be half of their respective MDLs.

As shown in the above table, the soil cover concentrations for the inorganics detected in the stormwater above SWQC are significantly lower than in those observed in the SDM. Although this capping material is considered clean (complies with the RDCSCC), naturally occurring metals exist in the soil cover in sufficient amounts to impact associated stormwater. Nonetheless, the availability of extractable chemicals is significantly reduced with the presence of the soil cover. Thus, the levels of metals associated with runoff from the soil cover would be expected to be less than those associated with the SDM. Also, the net available amount of easily extractable parameters within the SDM and/or soil cover would be reduced with each subsequent rain event, so concentrations of metals within the stormwater will be further reduced over time.

In practice, the use of Best Management Practices (“BMPs”), which are required for all road construction projects, would limit the potential for stormwater to both come into contact with potentially contaminated materials, and to discharge to surface water bodies (or groundwater).

The above screening analysis, while extremely conservative, did indicate that certain metals within the SDM (and possibly the soil cover) could potentially cause environmental impacts. As such, additional analyses were performed to evaluate potential impacts on receiving waters, as presented in Section 2.7.6.

2.7.6 Evaluation of Impacts on Receiving Water

2.7.6.1 Introduction

Mathematical models were applied to predict the possible environmental impacts of stormwater and groundwater discharges from the constructed embankments upon the local receiving water body. The models used a series of conservative, simplifying assumptions to provide worst-case scenarios. More realistic scenarios including more complex governing processes would produce results that would fall below the range of these worst-case scenarios. The actual environmental impacts of the embankments would therefore be less than the worst-case scenarios predicted by these models.

Two different models are presented that describe separate mechanisms and governing equations for the transport of contaminants detected in the SDM. The models are used to evaluate impacts on Newark Bay via advection of percolated groundwater and via stormwater runoff directly into the Bay.

2.7.6.2 Percolated Water Entering into the Groundwater System

This section of the report evaluates the potential environmental impact on the groundwater system underlying the embankments and the impact on its final destination in the Newark Bay.

The entrance of percolated water from the embankments into the groundwater system was modeled as if the soil directly underneath the embankment was very porous and had a very high hydraulic conductivity. This assumption represents the worst-case scenario, as it allows the concentrations of contaminants found in the percolated water to enter into the saturated zone without any retardation or dispersion. The contaminant concentrations were assumed to be the same entering into the groundwater aquifer system as found in the percolated water.

The embankment under study is approximately 140 meters (460 ft) long and 35.6 meters (117 ft) wide, having an interfacial area with the aquifer of 4977.65 m^2 (53,579 ft^2). During the study, 700 gallons of percolated water were collected in an underlying collection system over a 10-month time period. This equates to 8.712 x 10^{-3} m^3/d (2.3 gpd, 3.561 x 10^{-6} cfs). Over the given interfacial area, this is equivalent to an average downward velocity through the embankment of $\acute{\upsilon}_E$ = 1.75 x 10^{-6} m/d (5.74 x 10^{-6} ft/d) or 2.03 x 10^{-9} cm/s (2.39 x 10^{-7} ft/h).

The parameters for the aquifer system were selected to be representative of the groundwater aquifer system in the region where the embankments were constructed. The top aquifer layer in this region is typically a soil comprised of a mixture of gravel, clay and sand.[51] The typical hydraulic gradient is less than 10 ft/mile (1.89 x 10^{-3} ft/ft), with an average thickness of 25 ft (7.6 m) and a permeability of 1000 gpd/ft^2 (5.57 ft/h; 4.72 x 10^{-2} cm/s). Using these parameters and Darcy's Law (EQN 2.7.6.1),

$$v = \frac{q}{A} = K\left(-\frac{\Delta h}{\Delta l}\right)$$

where: v = specific discharge [L/T]
q = flow rate [L^3/T]
A = cross-sectional area [L^2]
K = hydraulic conductivity [L/T]
$\Delta h/\Delta l$ = hydraulic gradient [L/L]

The specific discharge through the aquifer can be estimated as:

$$v_A = \left(5.57\ {ft}/{h}\right)\left(1.89 \times 10^{-3}\right) = 0.011\ {ft}/{h}$$

or 0.080 m/d. Assuming a typical porosity of n = 0.45, then the average velocity, $\bar{v}$, is given by

$$\bar{v} = v/n$$

and the average velocity of the aquifer is $\bar{v}$ = 0.024 ft/h (0.178 m/d).

The system to be modeled is the groundwater flowing through the aquifer underlying the dredge embankment. The worst-case scenario is one in which the groundwater flows in a direction parallel to the length of the embankment. A two-dimensional formulation of the cross-section along the length of the embankment is therefore modeled to predict the concentration profile as the groundwater leaves the region underneath the embankment.

A two-dimensional steady state advection-dispersion groundwater equation was used to model this system (EQN 2.7.6.3).

$$0 = D_x \frac{\partial^2 C}{\partial x^2} + D_y \frac{\partial^2 C}{\partial y^2} - v_x \frac{\partial C}{\partial x} - v_y \frac{\partial C}{\partial y}$$

Here, $c(x,y)$ = contaminant concentration at location (x,y) at time, t [M/L^3]
D = dispersivity in the x or y direction [L^2/T]
v = velocity in the x or y direction [L/T]
x = distance from start of embankment [L]
y = depth from embankment/aquifer interface [L]

Retardation by soil retention and ion exchange are not included in this model because the ultimate goal is to understand the final steady-state scenario. In a steady-state scenario, retardation is eventually overcome and has no bearing on the final solution.

The velocities of the flow field were defined using the average velocities described in the previous section (i.e. $v_x = \bar{v}_A$ and $v_y = \bar{v}_E$). Because there is no information on the dispersivities of the porous medium, dispersivities were estimated using EQN 2.7.6.4 and EQN 2.7.6.5:

$$D_x = \alpha_L v$$

$$D_y = \alpha_T v$$

where, a_L = longitudinal dispersivity of the medium [L]
a_T = transverse dispersivity of the medium [L]
v = velocity in the direction of flow [L]

The dominant flow is in the x-direction (i.e. $\bar{v}_A >> \bar{v}_E$), so $v = v_x$.

Estimation of dispersivities has been an area of much debate. Column experiments have suggested longitudinal dispersivities ranging from 0.0001 to 0.01 m, with field experiments giving a range of 0.1 to 2 m.[52] Field studies have suggested that the ratio of longitudinal to transverse dispersivity fall in the range of 6 to 20, although there are not many reports in the literature.[53] The values selected were a_L = 0.1 m and a_T= 0.01 m, which were chosen to fall in the middle of the range of reported values. This gives D_x = 0.0178 m^2/d (0.00798 ft/h) and D_y = 0.00178 m^2/d (0.000798 ft/h).

For the purposes of the model, the system is defined as having negligible concentrations of the contaminants of concern in the underlying aquifer. Therefore, the upgradient (i.e. x = 0) boundary condition has zero concentrations everywhere. The boundary condition, representing the interface with the embankment (i.e., y = 0) has a constant concentration everywhere equal to the measured contaminant concentration of the percolated water. There is assumed to be no concentration flux across the aquifer bottom. The solution provided by the model of this system represents the contaminant concentration profile with depth at the downgradient end of the embankment (i.e. x = L = 140 m).

The boundary conditions for this model are:

$$\left.\frac{\partial C}{\partial y}\right|_{y=b} = 0$$

where b = base of aquifer = 7.6 m

The solution of this problem was carried out using an extension of the method of characteristics (MOC). The flow in this problem is primarily advective in the x-direction. The major point of interest, however, is how the concentration profile penetrates orthogonal to the primary direction of flow. The method of characteristics essentially isolates the advective and diffusive segments of the solution. Dispersion of contaminants is tracked along the flow path $y = v_y\ t = v_y\ (v_x/x)$. In order to simplify the solution, dispersion in x direction is set equals to zero because the relative magnitude of the associated component in the governing equation is negligible.

The time it takes the advective front to get to the edge of the embankment represents the length of time the concentration profile has to penetrate into the aquifer. This time can be calculated simply by knowing that the front is moving at 0.178 m/d and needs to cover 140 m. Therefore, it takes 786.5 days for the groundwater to travel from the beginning of the embankment to the end of the embankment during which time the containment plume spreads out due to dispersion. By solving the transient diffusion equation at t = 786.5 days will give the concentration profile at x = 140 m.

The corresponding diffusion equation is given by EQN 2.7.6.6 for concentration as a function of y and t, i.e. c(y, t).

$$\left.\frac{dC}{dt}\right|_{y=v_y\frac{x}{v_x}} = D_y \frac{\partial^2 C}{\partial y^2}$$

and is solved as a one-dimensional contaminant transport equation for the profile of $C(y,t=786.5d)$ with an initial condition of $C(y,0) = 0$ and a boundary condition of $C(0,t) = C_{in}$.

The analytical solution for this problem is given by:

$$C = \frac{C_{in}}{2}\left[erfc\left(\frac{y - v_y t}{\sqrt{4D_y t}}\right) + \exp\left(\frac{v_y t}{D_y}\right) erfc\left(\frac{y + v_y t}{\sqrt{4D_y t}}\right)\right]$$

2.7.6.3 Stormwater Runoff into Newark Bay

As discussed in previous sections, stormwater runoff should be collected via side ditches and retention ponds before it is discharged into a surface water body. Nevertheless, the impact of stormwater runoff that came in contact with the SDM needs to be understood and estimated. This section describes the mathematical approach to understand the impact, if any, on the receiving surface water body (Newark Bay). Impacts on the surface water body have been estimated using a worst-case scenario on an average annual basis for chronic exposure. In this model, all water that precipitates onto the embankment is assumed to contribute to the runoff, and infiltration is considered negligible. The contaminants present in the soil matrix of the embankment are then mobilized with the runoff and are transported to Newark Bay via stormwater runoff. This runoff then mixes with the upstream bay water to result in a new volumetric flow and concentration downstream. This simple dilution model can be described by EQNs 2.7.6.8 and 2.7.6.9.

$$Q_w C_w + Q_r C_r = Q_{out} C_{out} \qquad \text{(EQN 2.7.6.8)}$$

$$Q_w + Q_r = Q_{out} \qquad \text{(EQN 2.7.6.9)}$$

In these equations:

Q_w	=	volumetric flow rate of the runoff (m^3/sec)
Q_r	=	volumetric flow rate of the river before mixing (m^3/sec)
Q_{out}	=	volumetric flow rate of the river after mixing (m^3/sec)
C_w	=	concentration of constituent in runoff (ug/L)
C_r	=	concentration of constituent in river before mixing (ug/L)
C_{out}	=	concentration of constituent in river after mixing (ug/L)

By substituting EQN 2.7.6.8 into EQN 2.7.6.9 and rearranging we find:

$$Q_r = Q_w\left(\frac{C_{out} - C_w}{C_r - C_{out}}\right)$$

Through this equation, the amount of upstream volumetric flow necessary so that the downstream concentration of the mixed inflows meet the SWQC (Surface Water Quality Criteria) can be calculated. This is done by calculating Q_r , which represents the necessary average annual flow into Newark Bay. This necessary flow, Q_r , can then be compared to actual flow. To solve this equation, several parameters must be known. First, Q_w , the volumetric outflow from the embankment, must be known. The amount of runoff can be calculated by taking the average annual depth of rainfall of 40" multiplied by the area draining from the embankments (approximately 120,000 ft^2). This total annual volume of runoff is based on the conservative assumption that there is no loss via infiltration, evapotranspiration and adjacent drainage from the construction site. The resulting annual volumetric flow rate from the embankment is therefore 400,000 ft^3 per year. This contribution is intermittent, however, the average annual value (0.0127 cfs.) will be used for analysis of chronic effects but not acute effects.

For analysis using SE/SC criteria for acute loading a similar analysis has been performed for the 24-hour storm event with a recurrence frequency of 10 years. Depth of rainfall for this recurrence is 5.3" for Union County. Total volume of runoff assuming no infiltration was multiplied by the maximum concentration for samples, C_W, during and after construction.

The assumption that the maximum concentration would occur with a significant rainfall (5.3”) is extremely conservative and exaggerates the total mass of contaminants that could be transported from the embankments. Worst case concentrations of pollutants in stormwater usually occur in the “first flush,” that is, the amount of rainfall needed to mobilize the contaminants.

Typically the “first flush” is around 1” of total rainfall. Therefore, the use of a 5.3” rainfall and the highest contaminant concentration observed, could exaggerate pollutant loading by a factor of five. However, the purpose of this analysis is to conservatively predict potential for environmental impact.

For both acute and chronic SWQC, upstream pollutant contributions have been assumed to be negligible in the mathematical model. The highest allowable concentration in the output surface water is the SWQC. Therefore, C_{out} was chosen to be equal to the SWQC.

2.7.6.4 Mathematical Modeling Results

Stormwater Runoff

The ability to meet the SWQC in Newark Bay was evaluated based upon a simple mathematical model for stormwater runoff and percolated water from the embankments entering into Newark Bay. Worst-case scenarios were used for the analysis, using both chronic and acute SWQC. Chronic impacts were evaluated based upon estimated average annual loads and dilution factors (Q_r/Q_W) for both stormwater and percolated water. Acute impacts were evaluated for stormwater runoff based upon estimated loads and dilution factors associated with a storm with a 10% annual probability of occurrence.

In order to compare the inflow to Newark Bay required to provide adequate dilution of the runoff from the embankment to meet the SWQC, long-term historical records from 3 USGS gauging stations have been obtained.[54] The three stations are located on the three main rivers that discharge into Newark Bay. Station numbers, gauging station locations, upstream drainage areas and the number of years of record (POR) are included in Tables 2.7.6.1- 2.

Average annual discharges for each gauging station are also included in Table 2.7.6.1. Additional flow into Newark Bay from these three rivers is expected from more downstream locations in their respective drainage areas. The total area of each river's drainage basin are estimated and included in Table 2.7.6.1. Total flow into Newark Bay for each river is then calculated based upon the total drainage area. The sum of these flows is used as the estimate of total inflow to Newark Bay, Q_r, which is used for comparison to SWQC for chronic effects.

Table 2.7.6.2 presents a similar analysis of flows associated with a 10-year recurrence interval. Annual peak values at the three gauging stations were obtained digitally for the period of record (POR) for each gauging station from the USGS. The flow associated with the 10-year recurrence interval (i.e. 10% chance) was estimated using the Weibull plotting position method. These 10-year recurrence interval flows were used to estimate the 10-year flow into Newark Bay for each river. Flow for each river was calculated for total drainage area. Total flow into Newark Bay for the 10-year recurrence interval was then estimated as the sum of the 10-year flows from the three rivers. This value *(Q_r* 10 yr) was used for comparison to the flow required for dilution associated with the acute SWQC. The necessary minimum values for the volumetric flow rates as determined by the mathematical model to meet the SWQC for the construction and post-construction phases are summarized in Tables 2.7.6.3 and 2.7.6.4. For each contaminant, Table 2.7.6.3 presents the calculations of the flows required for dilution of the maximum concentration from stormwater samples, C_W, for the embankment during construction. The first and second columns of the table present the contaminant name and the maximum stormwater sample concentration, C_W. Columns 3 through 5 present the mass loading rate, SWQC, and flow required for dilution (Q_r) for the chronic SWQC conditions. Similarly, columns 6 through 8 present mass loading rate, SWQC and Q_r for the acute SWQC. Table 2.7.6.4 presents the same set of calculations for stormwater samples collected from the embankment after construction was completed in an identical format.

In table 2.7.6.3, for example, the maximum concentration of the stormwater samples during construction was 1,170 ppb for total copper. Using runoff for the average annual rainfall, the mass loading rate is 13.25 kg/year. The chronic SWQC is 5.6 ppb for Newark Bay. As a result, the average annual flow in Newark Bay required to meet the chronic SWQC is 2.65 cfs. In comparison to the average annual flow in Newark Bay of 1576 cfs presented in table 2.7.6.1, it is clear that dilution alone will bring concentrations in Newark Bay resulting from stormwater runoff from the embankment far below chronic SWQC. Similarly, the mass loading rate calculated for total copper using the extremely conservative assumptions described earlier for the 10 year storm is 0.0048 kg/day. The acute SWQC, which must be met in Newark Bay, is 7.9 ppb. As a result, the average 24 hour flow for the 10 year storm in Newark Bay required to meet the acute SWQC is 0.249 cfs. In comparison to the average flow of the 10 year storm in Newark Bay of 22,861 cfs presented in Table 2.7.6.2, it is clear that dilution alone will bring concentrations in Newark Bay resulting from stormwater runoff from the embankment for the 10 year storm is to 100,000 times smaller than the acute SWQC for total copper. Tables 2.7.6.3 and 2.7.6.4 also indicate that total and dissolved arsenic are the contaminants which provide the most stringent dilution requirements.

Table 2.7.6.1: Estimated Average Inflow to Newark Bay

USGS Station Number	River	Location of Station	Drainage Area * (sq. mi)	POR (yrs)	Avg. Flow at Station (cfs)	Estimated Total Basin Area (sq mi)	Estimated Avg. Flow (cfs)
1389500	Passaic	Twin Rivers	762	88	1160	935	1423.4
1378500	Hackensack	New Milford	113	64	101	135.6	121.2
1393450	Elizabeth	Ursino Lake	16.9	64	25.9	20.28	31.08
Total Estimated Average Inflow to Newark Bay							**1575.68**

* Upstream of gauging station

Table 2.7.6.2: Estimated Inflow to Newark Bay for 10-Year Recurrence Interval

USGS Station Number	River	Location of Station	Drainage Area * (sq. mi)	Start of Record	POR (yrs)	10 yr Flow at Station (cfs)	Estimated Total Basin Area (sq mi)	Estimated 10-Year Flow (cfs)
1389500	Passaic	Little Falls	762	1892	103	11983	935	14704
1378500	Hackensack	New Milford	113	1922	77	3691	135.6	4429
1393450	Elizabeth	Ursino Lake	16.9	1973	26	3107	20.28	3728
Total Estimated 10-Year Peak Inflow to Newark Bay								**22861**

* Upstream of gauging station

Table 2.7.6.3: Minimum Q_r for Embankment During Construction

Contaminant of Concern	CW (ppb)	Mass Loading (kg/yr)	SWQC (chronic) (ppb)	Q_r (cfs)	Mass Loading (kg/d)	SWQC (acute) (ppb)	Q_r (10yrs) (cfs)
antimony, total	300	3.40	43000	0.000088	0.0012	43000	0.000012
antimony, dissolved	120	1.36	43000	0.000035	0.0049	43000	0.000005
arsenic, total	1330	15.06	0.136	124.041	0.0055	0.136	16.435
arsenic, dissolved	1520	17.22	0.136	141.761	0.0063	0.136	18.783
cadmium, total	11	0.12	10*	0.01395	0.00005	10*	0.0018
chloride	1.00E+07	113267	2.30E+05*	0.55147	41.12	8.60E+05*	0.020
chromium, total	170	1.93	3260	0.00066	0.0007	3230	0.000088
copper, total	1170	13.25	5.6	2.65003	0.0048	7.9	0.249
copper, dissolved	410	4.64	5.6	0.92864	0.0017	7.9	0.087
lead, total	670	7.59	5	1.70	0.0028	5	0.225
lead, dissolved	35	0.40	5*	0.089	0.00014	5*	0.012
mercury, total	0.49	0.01	0.146	0.04	0.000002	0.146	0.006
selenium, total	39	0.44	10*	0.05	0.00016	10*	0.007
selenium, dissolved	18	0.20	10*	0.02	0.00007	10*	0.003
thallium	2	0.02	6.2	0.004	0.00001	6.2	0.002
Maximum of all required flows				**141.76**			**18.78**

** FW-2 criteria are used for these parameters because SE/SC criteria are not available.*

Table 2.7.6.4: Minimum Q_r for Embankment Post-Construction

Contaminant of Concern	CW (ppb)	Mass Loading (kg/yr)	SWQC (chronic) (ppb)	Q_r (cfs)	Mass Loading (g/d)	SWQC (acute) (ppb)	Q_r (10yrs) (cfs)
arsenic, total	10.00	0.11	0.136	0.93	0.041	0.136	0.124
arsenic, dissolved	6.10	0.07	0.136	0.57	0.025	0.136	0.075
chloride	1.80E+06	20388	230000*	0.10	7401	860000*	0.004
copper, total	120.00	1.36	5.6	0.27	0.49	7.9	0.026
copper, dissolved	110.00	1.25	5.6	0.25	0.45	7.9	0.023
lead, total	30.00	0.34	5*	0.08	0.12	5*	0.010
lead, dissolved	16.00	0.18	5*	0.04	0.066	5*	0.005
mercury, total	0.27	0.003	0.146	0.02	0.0011	0.146	0.003
thallium, total	90.00	1.019	6.2	0.18	0.37	6.2	0.024
thallium, dissolved	39.00	0.442	6.2	0.08	0.16	6.2	0.011
Maximum of all required flows				**0.93**			**0.124**

** FW-2 criteria are used for these parameters because SE/SC criteria are not available.*

Percolated Water

Figures 2.7.6.1 - 9 present the calculated penetration depths into the underlying aquifer for each contaminant at the far edge of the embankment (x = 140 m). The figures plot the concentration (y-axis) versus depth (x-axis) below the embankment (the line of x = 0 is the interface of aquifer and embankment, depth increases with increasing x). Concentration profiles represent both the total concentration and dissolved concentration for each compound. The groundwater quality standard for each compound is presented as a horizontal line to clearly demonstrate where the concentration exceeds the standard and where it falls below the standard. The graphs are all plotted on a linear scale except for sodium and chloride. These two plots have logarithmic y-axes because the concentrations span several orders of magnitude, and log-space helps clarify where the concentrations intersect the groundwater quality standards.

The modeling results were used to delineate the zone of potential contamination in the underlying groundwater system. For all of the compounds of concern, the amount of penetration, where the aqueous concentration is greater than the groundwater quality standards, ranges from 1 m to 5.3 m. The total depths into the aquifer that exceeds the standards for each compound are listed in Table 2.7.6.5. A more in-depth analysis that includes dispersion and retardation due to sorption and ion exchange appears in Appendix C. The in-depth analysis of Appendix C indicates that the GWQC would not be exceeded at the SDM Demonstration Project.

Table 2.7.6.5: Depth into Aquifer where Concentration Exceeds GWQC

Compound of Concern	Depth where C > GWQC	
	for total	for dissolved
Aluminum	8.86 ft (2.7 m)	1.97 ft (0.6 m)
Arsenic	6.89 ft(2.1 m)	5.91 ft (1.8 m)
Chloride	17.39 ft (5.3 m)	--
Iron	9.84 ft (3.0 m)	9.19 ft (2.8 m)
Lead	5.58 ft (1.7 m)	3.28 ft (1.0 m)
Manganese	13.12 ft (4.0 m)	13.12 ft (4.0 m)
Nickel	3.94 ft (1.2 m)	3.94 ft (1.2 m)
Sodium	14.44 ft (4.4 m)	14.76 ft (4.5 m)
Thallium	11.81 ft (3.6 m)	15.75 ft (4.8 m)

As discussed earlier in this section, the concentration at the interface of the embankment and the aquifer is assumed to be equal to that of the percolated water everywhere. The percolated water is relatively concentrated. Although the percolation rate is quite small, the substantial length of the embankment allows for an appreciable amount of penetration via dispersion into the underlying aquifer.

As this front of potential contamination passes beyond the embankment edge, the concentration will continue to diffuse. Past the embankment ($x > 140$ m) there is no longer a constant source of contamination at the top of the aquifer, so the concentration profile will begin to disperse. The concentration profile will then slowly flatten and spread across the entire cross-section of the aquifer. This process will decrease the maximum concentration. This will serve to spread out the concentration profile, until it becomes one concentration throughout the aquifer. This contaminant front will proceed along via advection until it reaches Newark Bay.

If the concentration profile at the edge of the embankment (Figures 2.7.6.1-9) is integrated, the total mass leaving the aquifer can be calculated by multiplying the concentration by the total discharge (velocity x cross-sectional area). Then using a similar approach as outlined for the stormwater, the necessary flow rates at Newark Bay to have concentrations at or below the GWQC have been estimated and are presented in Table 2.7.6.6

Table 2.7.6.6: Minimum Q_r for Percolation

Compound of Concern	C_W (ppb)	Mass Loading (kg/yr)	GWQC (ppb)	Q_r (cfs)
aluminum, total	1960	6.23	200	0.0000484
aluminum, dissolved	290	0.92	200	0.000024
arsenic, total	39	0.12	8	0.003714
arsenic, dissolved	30	0.10	8	0.000071
Chloride	1.88E+08	597792	250000	0.000017
iron, total	4300	13.67	300	0.00032
iron, dissolved	3520	11.16	300	0.000011
lead, total	35	0.11	10	0.000649
lead, dissolved	19	0.06	10	0.00016
manganese, total	3280	10.43	50	0.0000072
manganese, dissolved	3400	10.81	50	0.000019
nickel, total	220	0.70	100	0.000058
nickel, dissolved	220	0.70	100	0.0000094
sodium, total	6.57E+06	20891	50000	0.00034
sodium, dissolved	7.92E+06	25184	50000	0.000011
thallium, total	16	0.05	10	0.000782
thallium, dissolved	130	0.41	10	0.00128
Maximum of all required flows				**0.003714**

2.7.6.5 Discussion and Conclusions

Impacts on Receiving Water by Demonstration Project

Mathematical models were used to evaluate the impact of stormwater runoff and percolated water generated at the construction site of embankments built with SDM. The results obtained from modeling efforts indicate that stormwater runoff and percolated water have minimal impact on the nearby receiving surface water body, the Newark Bay. For stormwater, both chronic and acute SWQC were considered using average flows and the ten year storm, respectively. The average mass loading rates, M(t), for each of these scenarios are summarized in Tables 2.7.6.3, 2.7.6.4 and 2.7.6.6. Results for all cases are summarized in Table 2.7.6.7.

Table 2.7.6.7: Summary of Receiving Water Impact Results

Scenario	Contaminant with Greatest Flow Requirement	Maximum Required Inflow to Newark Bay (cfs)	Estimated Inflow to Newark Bay (cfs)	Predicted Concentration in Newark Bay (ppb)	SWQC (ppb)	Ratio of SWQC to Predicted Concentration
Chronic - During Construction	arsenic, dissolved	141.76	1575.68	0.0122356	0.136	1.1E+01
Chronic - Post Construction	arsenic, total	0.93	1575.68	0.0000803	0.136	1.7E+03
Chronic - Percolated Water	arsenic, total	0.003714	1575.68	0.0000003	0.136	4.2E+05
Acute - During Construction	arsenic, dissolved	18.78	22861	0.0001117	0.136	1.2E+03
Acute - Post Construction	arsenic, total	0.124	22861	0.0000007	0.136	1.8E+05

In Tables 2.7.6.3, 2.7.6.4 and 2.7.6.6, the inflow to Newark Bay required to provide dilution to meet the chronic and acute SWQC is reported for each contaminant species. In each of these tables, the maximum of these required flows is presented on the last line. The last line therefore represents the critical species associated with the most stringent dilution requirements. These critical species result in the highest ratio of the concentration after dilution in Newark Bay relative to the SWQC.

Tables 2.7.6.3 and 2.7.6.4 indicate that dilution of runoff from the demonstration project in Newark Bay will result in ambient concentrations below SWQC. For the estimated average annual loads, the maximum required flow for dilution for the construction case is 141.76 cfs, and for the post-construction case it is 0.93 cfs. The average flow into the Newark Bay is 1575.68 cfs. For the construction case, the flow required for dilution is an order of magnitude smaller than the average flow, and for the post-construction case it is three orders of magnitude smaller. For the 10-year storm event case, the maximum required flow for the construction case is 18.78 cfs, and for the post-construction case it is 0.124 cfs. The 10-year storm event flow rate into Newark Bay is 22861 cfs. For this acute loading, only a flow three orders of magnitude lower than actual flows likely to occur in Newark Bay is required for dilution. Similarly the post-construction case requires five orders of magnitude less flow. For the groundwater case, the maximum required flow is 0.00371 cfs, which is five orders of magnitude smaller than the average flow into Newark Bay.

The results of Tables 2.7.6.3, 2.7.6.4 and 2.7.6.6 are summarized for each of the scenarios in Table 2.7.6.7. A description of the scenario is presented in the first column. For each of these scenarios, the contaminant species associated with the maximum required flow presented on the last line of Tables 2.7.6.3, 2.7.6.4 and 2.7.6.6 is presented in the second column. The maximum required flow and the estimated actual inflow to Newark Bay are presented in the third and fourth columns. Comparisons between the third and fourth columns indicate that dilution alone is more than sufficient to meet SWQC for all scenarios even when the conservative assumptions regarding concentrations and runoff coefficients are applied. The resulting concentrations for these critical contaminant species after dilution in Newark Bay appear in the fifth column, which can be directly compared, to the SWQC listed in the sixth column. Finally, the ratio of these concentrations appears in the last column of Table 2.7.6.7. *Review of these ratios indicates that the predicted concentrations of contaminants in stormwater from the demonstration project after dilution range between 1 order of magnitude to 5 orders of magnitude smaller than the chronic and acute SWQC for the critical species.* Therefore, for the environmental conditions of the demonstration project, there is more than adequate dilution in the receiving waters to accommodate even the worst case potential impact from the project without the use of BMP's to control the mass loading of contaminants in the runoff.

For the groundwater case, though the resulting concentrations of percolating water do not meet the GWQC directly beneath the embankment area, there is minimal impact on the receiving surface water. In this analysis, a worst-case scenario of the percolated water entering directly into groundwater system without any retardation or dispersion in the unsaturated zone was assumed. This worst-case scenario is not representative of the system at the embankment site. The embankments have been constructed on top of a ten-foot layer of solid waste overlying a five-foot meadowmat (organic clay) layer. These two layers lie upon the base aquifer and provide significant protection to the aquifer. Additional layers present would result in a much lower impact than the results obtained for modeled scenario presented herein had they been incorporated into the analysis. A more in depth analysis is presented in Appendix C: *Impact of Embankment Percolate into Underlying Aquifer System Groundwater*. The analysis in Appendix C uses a three-layer model with dispersion and retardation due to sorption and ion exchange. Results presented in Appendix C indicate that the GWQC is not, by a factor of approximately two, exceeded by the SDM Demonstration Project. The Embankment would have to be more than twice as long before GWC are exceeded in the conservative analysis of Appendix C.

Management of Impacts to Receiving Water of Future SDM Embankment Projects

The above analysis relates only to field conditions at the demonstration project and cannot be generalized directly to future projects due to the expected variability between project sites. The receiving water body associated with the demonstration project is relatively large having an average flow of approximately 1560cfs. It is additionally influenced by tides, which enhances the mixing process significantly. This allowed the use of a simple dilution model using field data related to loading rates (i.e. concentration and volumetric flow rates) and the relative flow in the receiving water body available for dilution. It is valuable to note, however, that flows in the receiving water bodies required for dilution of contaminants from the embankments, were very low. Many rivers and streams would have had sufficient flow for dilution for this demonstration project, particularly during the post-construction phase when requirements were less than 1 cfs for the chronic and acute SWQC.

Information on the receiving water body will be critical to the evaluation of potential impacts of future projects. In general, for more sensitive receiving water bodies such as streams and lakes, more complex modeling of the fate and transport of the contaminants present in runoff and percolated groundwater flow will be appropriate. Based upon the nature of the contaminants and the receiving water body, a variety of Best Management Plans (BMPs) can be used to control contaminants from runoff before allowing it to move offsite. The choice of BMPs will be dependent on the types of contaminants expected, the sensitivity of the receiving water body, the available space at the site and the geophysical characteristics of the site. A wide variety of BMPs are currently available which have variable costs, constraints, and expected removal rates. It is again important to note that for this demonstration project, mass loading rates and the required flows for dilution during construction are more than 100 times greater than post construction. This suggests that temporary BMP's during construction will be critical to protecting receiving water quality for future projects.

2.8 SUMMARY OF FINDINGS

The overall objectives of the Demonstration Project have been fulfilled. Specifically, pre-construction, during construction, and post-construction monitoring activities were conducted in accordance with the work plans and other documents prepared for the project and reviewed by the interested parties/agencies. Two embankments and an access roadway were designed and constructed to simulate typical highway configurations. These structures were properly instrumented to monitor the geotechnical and environmental parameters of SDM.

Geotechnical and environmental data were collected to determine the characteristics and behavior of the SDM prior to, during, and after construction. Analytical data for RDM, SDM, stormwater runoff, percolated water, and air was collected throughout the project duration. A preliminary screening analysis consisting of comparing the contaminant concentrations with benchmark standards was performed. The objective of this exercise was to identify potential contaminants of concern, not to determine compliance. The contaminants that did not meet the selected benchmarks were further evaluated using mathematical models. This effort was directed to evaluate the potential impact on media, including groundwater aquifer systems and surface water bodies.

2.8.1 Geotechnical

Geotechnical data collection and analysis focused on, subsurface investigation for design of the foundation, laboratory testing of SDM strength parameters and field monitoring of embankment construction and performance. The findings of the geotechnical data collection and analytical efforts are presented in the 'Final Geotechnical Report' prepared by Dr. Ali Maher, Soiltek, Inc. (attached as Appendix D)The findings are summarized in this section.

2.8.1.1 Foundation Investigations

Foundations for both the embankments included three consecutive layers; 8'-20' refuse fill, 19' to 23' of peat and elastic silt, and 5' to 10' of sand. The initial settlement estimates indicated excessive settlements; up to 21'' for Embankment 1, and up to 17" for Embankment 2, each with the potential for differential settlements. The results of the field settlement monitoring program, which included settlement plates, horizontal inclinometers and a magnetic extensometer, showed settlement values (over a period of one year) of approximately 15.6" for Embankment 1, and 15.8" for Embankment 2. The extensometer data showed no noticeable settlement within the SDM fill and thus attributed most of the settlement to foundation soil. Settlement plate data indicated minimal differential settlement for both embankments

Settlement and other issues related to the foundation layers are site specific in nature and should be addressed by appropriate design procedures depending on that particular application.

2.8.1.2 Laboratory Investigations

Laboratory studies were conducted to assess the strength and durability parameters of various SDM recipes. The findings of various tests are as follows.

2.8.1.2.1 Classification

The SDM used in this project is characterized as elastic silt (MH) with a moderate organic content (8% average). It also contains low percentages of fine sand and clay. With respect to the Plasticity Chart, SDM lies below the A-line and to the right of the LL=50 line.

2.8.1.2.2 Compaction

The moisture content of raw dredged material is highly variable, however RDM is, on average, one-third solids and two-thirds liquid. Compaction greatly improved the engineering properties of SDM. A comparison between samples compacted to 85% and 90% of their maximum dry density showed a considerable increase in shear strength. Moreover, samples amended with 4% Portland cement and compacted to 85% of their maximum dry density had shear strength sufficient for embankment slope stability. A slope stability analysis for proposed embankment structures indicated safety factors of 2 and above, even for 1V: 1.5H slopes. Field inclinometer readings also indicated only minimal movement or instability within the slopes, confirming the findings.

2.8.1.2.3 Shear Strength

The addition of admixtures produced no significant change or trend in the magnitude of frictional angle, φ. A general comparison of SDM with typical soil-cement and cement-modified soils indicated that for the same amount of cement, and approximate compaction effort (90% of optimum for SDM, and at optimum for soil-cement) soil-cement or cement-modified soils are denser than SDM, have a slightly higher friction angle, and have a much higher cohesion intercept under triaxial shear conditions. One reason for the reduced cohesion of SDM is that, during the process of compaction, parts of cementitious bonds between hydrated cement particles and the soil matrix were brocken. Unlike typical soil-cement or cement-modified soils where hydration and curing take place immediately after compaction, and where compaction prior to curing causes soil grains to be forced into direct contact with the cement grains. The sequence of sample preparation in the case of SDM is reversed and some of the previously gained strength is lost during the break-up upon compaction. Temperature had a major effect on the curing process of SDM. At temperatures below 40°F, pozzolanic reactions slow down and, as a result, the rate and amount of moisture reduction and strength gain became insignificant.

2.8.1.2.4 Resilient Modulus

Resilient modulus measures the strength of sub-grade soils under dynamic vehicular loads. The resilient modulus values for all of the samples tested compared well with three sub-grade soils that are currently under New Jersey roadways. The test results indicated that SDM compares well with the sub-grade soil used on Route 23 and that SDM has a slightly higher modulus than the sub-grade soils in Route 206 and Route 295.

2.8.1.2.5 Consolidation

The compression index (C_c) values for SDM ranged from 0.22 to 0.9. In general, the compression index did not exceed 0.5 for any of the samples, once the samples had been compacted to 81%. Therefore, a P_c of 2 tsf or more should be expected. The compression ratio ($C_R = C_c/1+e_0$) varied from 0.085 to 0.24. This value did not exceed 0.19 for samples compacted to 83% or above.

2.8.1.2.6 Permeability

The permeability of the compacted SDM was typically less than 10^{-7} cm/sec. On the wet side of the optimum, additional compaction further reduced the permeability of SDM. Additional fly ash also helped in reducing permeability.

2.8.1.2.7 Swell Potential

The strain or swell percentage was not significant for any of the samples tested. The strain values ranged from 0.1% to 1.2% , with an average of 0.6%. This magnitude of volume change is considered to be low and, therefore, not detrimental to adjacent structures. The maximum strain (1.2%) was recorded for the samples amended with 8% Portland cement and 10% fly ash. The swell pressure, however, was high for samples compacted to 94% or higher of their maximum dry density with moisture contents on the dry side of optimum. For these samples, the average swell pressure was 1.005 tsf. The average for one-month old samples was slightly higher, at 1.34 tsf, with average strain of 1.1%. Although strains were not high for any of the samples tested, the swell pressure generated was moderate. For SDM that was mixed with 8% Portland cement and compacted to 95% of its maximum dry density, the swell pressure was measured as high as 1.96 tsf. However, for samples compacted on the wet side of optimum moisture content, much lower swell pressures and strains were measured. The average swell pressure for these samples was 0.14 tsf, and the average strain 0.3%.

2.8.1.2.8 Durability

The three different recipes of SDM were subjected to durability (freeze-thaw) tests. The results from these tests indicate that SDM is extremely susceptible to frost (several times more susceptible than natural clay) and should be placed below frost line. The three SDM recipes were also subjected to wet-dry tests to evaluate the material's potential for shrinkage. Based on the wet-dry tests, proper soil cover needs to be provided at all times to minimize strength loss and erosion. Compacting SDM at moisture contents below the shrinkage limit would minimize the potential for tensile cracks and thereby minimize any further strength loss in the material.

2.8.1.3 Field Investigations

The main objective of the field investigation was to monitor the integrity of the embankments over a period of one year and to record changes in settlement, horizontal deformation, and strength gain/loss over time. The filed investigation also included testing and evaluation of Humboldt Stiffness Gauge and Clegg Hammer device as compaction control tools for large-scale placement of SDM.

2.8.1.3.1 Field Determination of Cement Content

SDM samples were collected during processing and tested for cement content, which ranged from 4% to 20%. Although the target cement content was 8%, samples with 4% were laboratory tested to determine how the SDM would behave if the target cement content was not achieved. The results indicate considerable variation with respect to the target cement content of 8%. Most of the variation can be attributed to problems associated with the original design of the processing plant.

2.8.1.3.2 Field Compaction Control

Field compaction tests were performed in order to determine the dry density of in-situ SDM amended with Portland cement. The nuclear density gauge is commonly used for density control. For cement-stabilized soils, however, the nuclear gauge underestimates moisture contents resulting in overestimating dry density and strength parameters. For this study in addition to nuclear gauge, Humboldt Stiffness Gauge (HSG) or the Clegg Impact Hammer to determine dry density was evaluated. The objective was to determine whether these tests could provide rapid and accurate estimates of SDM's moisture content and dry density.

The results indicate that the HSG and CIH did not have the necessary sensitivity needed to accurately predict the dry density measured from the nuclear density gauge and oven drying. The HSG measured compaction characteristics accurately, provided the samples were within a specific range of moisture content for which the HSG had been calibrated. If the moisture content fell outside of this range, significant deviation was observed.

2.8.1.3.3 Settlement and Lateral deformation Monitoring

The field settlement-monitoring program consisted of installing settlement plates, horizontal inclinometers and extensometers for measuring vertical deformations in Embankments 1 and 2. For both embankments, the measured vertical settlement was in the range of 15 to 16 inches from settlement plates, and 12 to 14 inches from horizontal inclinometers (transverse centerline). These were lower than the predicted values estimated from initial foundation investigation study, which ranged from 17 to 21 inches for embankments, 1 and 2, respectively. The differential settlement was minimal for both cases, ranging from 1 to 2 inches. The extensometer reading and settlement plate data indicated negligible vertical deformation within the SDM itself, which demonstrates that the foundation soil is the primary cause of vertical settlement.

Vertical inclinometer ducts were installed to monitor the lateral movement of the embankments. The inclinometer readings indicate that lateral deformations were negligible for both embankments and were of no concern. The maximum lateral deformation (approximately 0.83") was at the top of Embankment 1 and had no impact on the stability of the slope.

2.8.1.3.4 Strength Gain/Loss Monitoring

In order to monitor the integrity of the embankments over time, a series of CPT soundings were taken at various intervals during the course of the project. The monitoring data were used to provide evidence of either a gain or loss of strength over time. The CPT soundings were conducted on top of each of the embankments in order to achieve the maximum possible penetration depth.

Based on the CPT soundings, there was no significant strength loss or gain within the embankments over the course of one year. This was observed for all locations on both embankments. In addition, for comparison purposes, the results of the SPT soundings were measured against the un-drained shear strength (S_U) of the material. The results show that the SDM, once placed, experiences no significant loss or gain in strength over the course of one year.

2.8.2 Environmental

Environmental monitoring and sampling were performed at different phases of the project for various parameters in order to characterize the materials involved in the construction and to assess potential adverse environmental conditions. Environmental monitoring activities included the sampling and characterization of:

<u>Solids</u>

RDM, SDM, and soil cover material.

Liquids
laboratory-generated leachate from SDM samples, stormwater runoff, and percolated water generated at the project site.

Air
airborne / dust samples collected during construction.

Screening Analysis of RDM, SDM and Leachate

All analytical data collected during the pre-construction, construction, and post-construction periods were analyzed with proper QA/QC by certified analytical laboratories. After these evaluations, all data were entered into a Database system designed to facilitate the management of information during the preliminary data screening and evaluation.

The findings of the screening evaluation are summarized below.

- The comparison of the SDM and RDM data indicates that the stabilization of RDM with 8% cement does not appear to have a significant effect on contaminant binding. However, this does not present any particular concerns due to the following:
  - the stabilization is performed for construction purposes, rather than environmental purposes;
  - the highest contaminant concentrations identified in the RDM and SDM are comparable to those found in industrial settings, and are well below those concentrations typically found in historic fill material (see NJAC 7:26E Table 4-2). Soils containing these contaminants at much higher concentrations are frequently approved to be contained on site within industrial areas with minimal engineering and/or institutional controls, such as capping (which would be performed regardless as part of any construction project using SDM); and
  - because the use of SDM for roadway construction projects is only recommended in industrialized and/or brownfield areas, the contaminant concentrations within the RDM and/or SDM would not be appreciably different from background conditions.

- The analysis of results of SDM/MMEP leachate samples indicates that one pesticide, aluminum, mercury, and sodium were detected above the GWQS. The pesticide and mercury were not detected in the field SDM percolated water samples. On the other hand, arsenic was detected above the GWQS in the field SDM percolated water sample only.

  Although sample preparation could be a contributing factor in the discrepancies found between the two sets of analytical results, (field percolated water and laboratory SDM MMEP leachates), it is presumed that these differences are due to the potential localized variations in the quality of the sediments, which are typically observed in soil or sediment grab samples. The observed differences may also have been due to differences between the field conditions and the conditions imposed by the MMEP extraction (i.e., extractant to SDM mass ratio, pH of extractant, contact area and contact time). Since the field SDM percolated water was generated from SDM stabilized at the site, as opposed to being generated from SDM prepared in a laboratory, field SDM percolated water samples are believed to better represent the potential leachability of SDM.

- The results of the screening evaluation indicated that aluminum, arsenic, chloride, iron, lead, manganese, nickel, sodium, and thallium were found in the percolated water above the selected benchmark of the GWQS. The GWQS are in fact not directly applicable to the concentrations within the percolated water, since this discharge would be significantly diluted once it reaches groundwater, and the use of best management practices ("BMPs"), as required for all construction projects, would reduce the infiltration of groundwater. In any case, the presence of these chemicals is not unexpected due to the nature of the SDM. Also, the presence of at least aluminum, chloride, and sodium are unquestionably due to naturally occurring metals within the sediments.

- Based on the data gathered in this project, the MMEP did not adequately predict the field gathered percolated water metal concentrations. It should be emphasized that percolated water samples account for actual field conditions (i.e., quality of cement mixing in the SDM and potential variability on chemical fixation after complete cement curing), actual atmospheric and rain conditions (i.e., actual acidity and advective/ erosive forces), and actual water retention time within the soil matrix, so are considered more reliable.

  In addition, as with all discrete sampling events, the chemical composition and general characteristics of the discrete SDM samples from which the leachate were generated may not have been fully representative of the large amount of SDM used at the site.

- Careful review of the laboratory-generated SDM leachate (MMEP extract) data leads to the conclusion that, in general, the concentrations of the detected metals decreased with successive extractions. In many cases, the successive extractions resulted in contaminant concentrations below the detection limit, leading to conclusion that there is a small, finite, easily extractable fraction of metals in the dredge material. Such results are consistent with the general decrease over time in the concentration of parameters detected in the percolated water samples.

  Although, more research is necessary to adequately evaluate the discrepancies observed in this project and the adequacy of the MMEP leachates to evaluate chemical leachability from SDM, the available data seem to indicate that the MMEP might not be an acceptable technique for evaluating contaminant leaching from SDM until steady state conditions are achieved. This notwithstanding, given the alkaline pH conditions present in the stabilized dredge material, once steady state is reached the potential for metal leaching is expected to be quite low.

<u>Screening Analysis of Stormwater</u>

Stormwater samples were collected during construction of the embankments, when rainwater could come into direct contact with the SDM, and during the post-construction period, when a clean soil cover prevented contact between rainwater and the SDM. As preliminary screening evaluation, stormwater sample results were compared with the SWQC to identify those parameters that could potentially impact either freshwater surface water bodies (FW-2) or saline surface waters (SE/SC).

- The stormwater samples collected during construction and post-construction were compared. The data indicated that the detection frequency of arsenic (total and dissolved), total thallium, and total mercury did not vary. Antimony (total and dissolved) and total chromium, which were detected above the FW-2 criteria, were found to comply with the typically less stringent SE/SC criteria. Cadmium, selenium, lead, and chloride were detected in the stormwater during construction above the FW-2 SWQC; however, no SE/SC criteria have been established for these contaminants. Similarly, the NJDEP has not established an FW-2 SWQC for copper, which was detected above the NY/NJ Harbor Estuary Criteria.

- An analysis of potential storm water impact by the application of empirical model revealed that the large flow in nearby receiving waters would generally be sufficient to allow runoff from a project similar to the demonstration project to meet applicable water quality criteria.

- The use of Best Management Practices (as further described in Section 3.0) would be adequate to further mitigate potential impact of storm water on receiving water bodies.

<u>Screening Analysis for Air</u>

The potential occupational and area-wide air quality impacts from the use of SDM in NJDOT construction projects were assessed by collecting personal and area samples of airborne particulate matter. Air quality studies were performed by measuring the amount of airborne particulates generated and the concentration of various contaminants associated with the particulate matter during the use of SDM. The samples were analyzed for TSP, PM10, selected metals, PAHs, PCBs, and pesticides. The results were then compared to various occupational exposure limits defined by OSHA, NIOSH, and ACGIH. The findings were as follows:

- The potential impacts to both ambient air quality and worker health are not expected to be significant for total and respirable airborne particulates, metals, or PAHs and PCBs/Pesticides in the particulate phase.

- Vapor phase concentrations of PCBs and PAHs were generally two orders of magnitude higher than the corresponding particulate phase concentrations of PCBs and PAHs. The vapor phase PAHs are within concentration ranges previously measured in New Jersey; however, the vapor phase PCBs are an order of magnitude higher than those measured elsewhere in New Jersey. Due to potential background influences / interferences, including construction within unrelated portions of the site and the proximity of both the New Jersey Turnpike and Newark Airport, it cannot be conclusively determined whether the dredged material is a source of vapor phase PCBs and/or PAHs.

- Because regulatory guidelines and worker exposure limits are not available for PAHs, PCBs, and pesticides, it is recommended that particulate masks be used as respiratory protection when handling SDM.

<u>Other Analyses</u>

Corrosivity

To control potential corrosivity resulting from the use of SDM and its resultant percolated water on steel, concrete, and other structural materials, corrosion protection might be required. The need for corrosion protection should be evaluated on a case-by-case basis, depending on the corrosive resistance of the material being used and the intended use and service life of the structure. Corrosion protection methods will not prevent corrosion of steel, but should be adopted in order to retard the potential corrosive effects of the dredged materials.

Corrosion is a naturally occurring phenomenon applicable to any soil type, not only potentially contaminated materials such as SDM. As a result, the USDOT has already explored a wide variety of useful corrosion prevention strategies, which have been grouped into the general categories of Design, Concrete, Corrosion Inhibitors, and Reinforcement Type. Any one or any combination of these common protection strategies might be required when using dredged materials in roadway construction projects, based on site and project-specific conditions.

Based on the corrosion data gathered for the demonstration project, the following observations were made:

- Four of the potential indicators of corrosivity, (pH, salinity, sulfate, and sulfide) increased after the addition of cement to the RDM, while acidity and resistivity decreased. These changes may be attributed to the thorough mixing of the RDM with 8% cement or possible localized variations in the quality of the sediments.

- The parameters considered to be indicators of corrosivity were found to vary significantly between MMEP leachates generated in the laboratory and percolated water samples collected in the field. But no trends were discernible. As with other environmental data gathered from discrete samples, the difference between the MMEP leachate and percolated water samples can be attributed to quality of cement mixing, variability on cement curing, as well as differences between the field conditions and the conditions imposed by the MMEP extraction (i.e., extractant to SDM mass ratio, pH of extractant, contact area and contact time). In addition, as with all discrete sampling events, the chemical composition and general characteristics of the discrete SDM samples from which the leachate was generated may not fully represent the large amount of SDM used at the site.

- The stormwater quality data collected during and after the construction (uncapped versus capped embankment), showed that sulfide and resistivity increased in concentration after capping of the embankment, confirming that these and possibly other indicators of corrosivity are associated more with natural conditions than with the use of SDM.

- Analysis of the data on potential corrosivity of the RDM and SDM suggest in general that the dredge material of the type used in demonstration project is potentially corrosive. Therefore suitable corrosion protection measures should be adopted for structures in direct contact with RDM/SDM or which may come in contact with leachate or runoff from RDM/SDM embankments

Total Organic Carbon

TOC was analyzed in RDM and SDM as requested by the NJDEP to assess the suitability of the dredged material for upland beneficial use range.

- The TOC within the RDM ranged from 10,000 to 45,000 ppm. The TOC concentrations within the SDM ranged from 7,000 to 26,000 ppm, and showed no discernible variation with time.

- The average value for TOC concentration in RDM was calculated to be 24,679 ppm or 2.5%, whereas the average TOC concentration in the SDM was 12,842 ppm or 1.3%. Although the average TOC concentration measured in the RDM and SDM are slightly different, a Student's T-Test with a 95% confidence interval indicated that there is no overall statistical difference between the TOC concentrations in RDM and SDM.

- The TOC concentrations within both the RDM and SDM are typical of fine textured uncultivated soils. Proper geotechnical design of roadway structures using SDM can accommodate this level of organic content.

Mathematical Modeling of Impact Evaluation

Simple mathematical models were developed to predict the possible worst-case environmental impacts of both percolated water and stormwater runoff on the local receiving water bodies, i.e. groundwater aquifer system and Newark Bay. More realistic scenarios, which would be modeled using more complex governing processes, would have produce results far below the range of these worst-case scenarios.

Despite the conservative modeling parameters, the results of the mathematical model indicate that the Newark Bay surface and ground water systems would not be impacted by either percolated water or stormwater runoff associated with the embankments.

3.0 BEST MANAGEMENT PRACTICES

During performance of this demonstration project, certain Best Management Practices ("BMPs") were identified which should be applied in SDM construction projects to protect the environment and human health, ensure structural stability, and minimize construction costs. In addition, SAI observed that to meet some environmental, construction, and/or cost objectives, different BMPs may be appropriate under different conditions. It is beyond the scope of this document to provide an exhaustive list of specific conditions and accompanying BMPs; in fact, it would be necessary for project design engineers to complete this process for each individual construction project.

Thus, to provide the most complete description of BMPs, SAI elected to organize this section into "objectives" with accompanying generic BMPs, where applicable, and performance/design criteria, where specific BMPs could not be assigned.

Please note that in addition to the appropriate selection and use of BMPs, appropriate siting criteria should always be considered when using SDM. SAI recommends that through restricting the use of SDM to brownfield areas (see Section 4.0 below), sensitive areas will be prevented from being adversely affected due to unforeseen events occurring during road construction and/or the ongoing maintenance and usage of the road.

3.1 ENVIRONMENTAL / HUMAN HEALTH OBJECTIVES

The following BMPs and performance/design criteria are recommended to ensure the protection of air, water, and soil resources:

Objective: Understand the Chemical Characteristics of the SDM

The SDM used for this Demonstration Project, while believed to be typical, may be somewhat cleaner than SDM used for similar NJDOT projects (e.g., other sources of RDM / SDM may contain higher concentrations of metals, PAHs, and other contaminants). As such, one cannot assume that the testing data described within this report is representative of all SDM.

It is expected that SDM arriving at the site for construction use will have been previously amended and dried (e.g. not raw dredge). In fact, prior to use of the material, the supplier will have completed the testing needed to comply with NJDEP's requirements for dredge management and will have obtained appropriate results. However, to provide the information needed for worker protection, permitting, runoff control, and other activities, the chemical constituents of the amended SDM should be confirmed prior to construction activities.

The following testing is suggested, based on the results of this study and the NJDEP's October 1997 document, "The Management and Regulation of Dredging Activities and Dredged Materials:"

- Grain size, total organic carbon ("TOC"), and percent moisture;
- Priority pollutant metals ("PP metals"), semi-volatile organic compounds ("SVOCs"), pesticides, polychlorinated biphenyls ("PCBs"), and dioxins/furans;
- Toxicity Characteristic Leachate Procedure ("TCLP"); and
- A modified Multiple Extraction Procedure ("MMEP"), using local rainwater for the extraction process.

A sampling frequency of approximately one sample per 25,000 cubic yards of SDM is recommended for grain size, TOC, percent moisture, PP metals, SVOCs, pesticides, PCBs, and dioxins/furans. For TCLP and MMEP analyses, a frequency of one sample per 50,000 cubic yards is recommended. These test results become the basis for design of the BMP.

Objective: Ensure Worker Safety During Construction Activities

The use of SDM may present safety issues in addition to those normally associated with a construction site.

SAI recommends the development of a site-specific HASP for each project that addresses both the chemical quality of the SDM and the physical activities to be performed. This document should be prepared in accordance with all OSHA requirements by the engineer prior to the start of activities, and all contractors should be required to adhere to the HASP. This HASP should also include details regarding area and personnel monitoring (see items below)

Although air quality was shown to be acceptable during the demonstration project, air monitoring is suggested to ensure worker health and safety. Monitoring should include both area samples and personal samples; the criteria to be analyzed should be based upon those contaminants present in the SDM, but should include at least total suspended particles and respirable particulate matter. The parameters to be monitored should be determined by the engineer prior to site work; the locations for area monitoring locations should be determined on a day-to-day basis subject to site conditions (e.g. location of activities, wind speed / direction, precipitation).

If monitoring indicates excess particulate matter in the working area, use of dust masks is suggested. Cessation of work during windy conditions may also be recommended as needed. Misting is recommended to wet the surface under dusty conditions so long as extreme wetting is avoided (this results in problem of placement/compaction of SDM).

Objective: Minimize Contaminated Stormwater Runoff During Construction

The generation of contaminated stormwater runoff is anticipated to be the most significant environmental issue associated with the use of SDM.

To minimize infiltration of rainwater into the SDM, and associated volumes of contaminated stormwater run-off and/or percolated water, all SDM should be either covered with a water resistant tarp or sealed by rolling at the close of the workday when precipitation is anticipated, or if rain begins during the workday. SAI recommends that the project designer prescribe intensity of tarping/sealing to be followed by the contractor based on site-specific conditions.

To divert and control stormwater run-off, the construction of (or connection to existing) stormwater management systems is recommended. Specific stormwater handling techniques may include swales, detention basins, controlled flow to a POTW, or other engineering controls. The design engineer should select the appropriate system based on the final stormwater management system to be constructed for the structure, location, anticipated precipitation, the presence/absence of existing systems, and other factors. It is recommended that necessary stormwater conveyance systems be constructed before the SDM is stored and/or applied at the project site.

Stormwater management with projects involving SDM, as for other road construction projects, may require Appropriate Acceptable Use Determination permits, permits, Soil and Sediment Erosion Plan approvals, local approval, POTW approval, and/or other notifications. The engineer should address permitting requirements prior to the initiation of site work, and should plan for worst-case stormwater quality and volumes (see Section 4.4 for permitting details). Stormwater should be analyzed after generation to determine the most appropriate disposal point (e.g. discharge to a surface water body or a POTW); preliminary laboratory leaching tests can assist in predicting the discharge point for permitting purposes.

Handling requirements for SDM are different than those for clean fill. To minimize the efforts associated with proper handling, good housekeeping practices are recommended. These practices include maintaining a separate storage area for SDM, minimizing spillage of SDM material between the storage area and the site of the end use, preventing mixing with other types of fill, use of dedicated equipment, and adherence to appropriate equipment decontamination procedures. Appropriate housekeeping practices will be determined on a site-specific basis, and will result in lower costs associated with stormwater management and, potentially construction.

Many published BMPs are available for stormwater management. The reader is referred to the following:

- The "National Stormwater Best Management Practices Database," provides access to standardized BMP performance data for over 70 studies conducted over the past fifteen years. This database, which is sponsored by the USEPA and ASCE, can be accessed at www.bmpdatabase.org;

- The USEPA's "Stormwater Management for Construction Activities: Developing Pollution Prevention Plans and Best Management Practices," September 1992, EPA #832/R-92-005, provides an overview of suggested practices related to pollution prevention and regulatory requirements;

- The NJDEP Division of Water Quality's "Technical Manual for Stormwater Permitting" contains detailed descriptions of stormwater permit options/requirements and a list of applicable BMPs for both general and individual permits.

- The Maryland Stormwater Design Manual is a two-volume document which provides comprehensive instructions describing the types, uses, and implementation of stormwater BMPs;

- The Pollution Prevention Information Clearinghouse ("PPIC") is a component of the USEPA's Pollution Prevention Office dedicated to reducing or eliminating pollutants through technology transfer, education, and public awareness. PPIC is accessible via EPA hotline (202-260-1023) or mail, and includes a reference library of more than 2000 documents and materials. Staff serving the hotline are also available to answer questions and share information.

Objective: Minimize the Generation and Effects of Percolated Water

Percolated water will be generated as moisture trapped within the SDM drains through the material, and/or rainwater infiltrates the SDM during construction. To prevent groundwater contamination, and/or soil/surface water contamination via seeps, the percolated water must be properly planned for and addressed. It should be noted that the quantities of percolated water will decrease over time, at a rate dependent on the moisture content of the SDM, the permeability of the compacted material, the type of cap applied to the structure, and other factors. The potential for contamination of the percolated water will vary depending on the constituents of the SDM, the acidity of the local precipitation, etc.

The exposure of the SDM to precipitation, during both material storage and application, will largely determine the amount of percolated water that will be generated. To minimize the volume of percolated water generated, the SDM should be covered with a tarp. Additionally, when the SDM is placed, it may be appropriate to delay work during extremely rainy conditions.

Generation of percolated water will significantly decrease once a cap (e.g. asphalt, grass cover, or other) has been applied, so efforts should be made to place a cap as soon as practical. Root intrusion into the SDM should be avoided.

Generally a leachate collection and management system is not necessary to handle percolated water. Project specific design to address potential of percolated water to adversely impact ground water is recommended to assess the need, if any, for collection/management of percolated water.

3.2 CONSTRUCTION OBJECTIVES

The following BMPs and performance/design criteria are recommended to facilitate road construction, including minimizing associated construction costs.

Objective: Minimize Moisture Content in SDM

Excessive moisture content may result in SDM failing compaction criteria, and results in higher construction costs and increased potential for environmental damage. While it is anticipated that the SDM will be dried prior to transport and usage at construction sites, efforts must be taken to determine and monitor moisture content, as well as minimize wetting of the material. These efforts will be determined on a site-specific basis, but may include use of a covered storage area, tarping, appropriate housekeeping and handling practices, and/or other activities.

Objective: Maintain Structural Strength of SDM

Excessive disking of the SDM to aid its drying is suspected to have an adverse impact on the cementation of the material, as the cement bonds were continually broken. As such, when the material was recompacted, some of the cementation effect had dissipated. To address this problem, it is advisable to allow the material to hydrate and compact in place, to provide greater strength prior to use as fill.

The SDM should be applied/compacted in one-foot thick lifts to provide sufficient strength while minimizing costs. Twelve-inch thick lifts were found to be as strong as eight-inch thick lifts during the demonstration project. Subsequent lifts should not be placed until the previous lift has met moisture content and compaction criteria.

Each lift should be sloped to facilitate drainage towards stormwater collection systems to minimize ponding and infiltration of any precipitation, as well as to ensure appropriate stormwater management.

Use of a geomembrane under embankments (where needed to address unstable soils) can minimize differential settlement.

While the presence of foreign matter is not anticipated in the SDM, if rebar, bricks, or other objects are found in the material, these items should be removed via hand picking. Loads of SDM containing significant quantities of unacceptable material, while not anticipated, should be screened or returned to the supplier if encountered.

Routine monitoring is required to confirm or obtain new information regarding the engineering characteristics and behavior of the SDM. These include:

- Cement content testing (or lime, fly ash, or other additives);
- Subsurface investigation for foundation design (if needed);
- Laboratory material strength testing;
- Field compaction monitoring;
- Settlement monitoring (if needed);
- Movement (horizontal and vertical) monitoring; and
- Cone Penetrometer Testing ("CPT") for long-term strength evaluation.

3.3 OPERATIONS & MAINTENANCE OBJECTIVES

The following BMPs are recommended to ensure the ongoing protection of the environment and personnel throughout the lifetime of structures containing SDM

Objective – Ensure Worker Safety during O&M

Appropriate organizations must be notified of the presence of SDM within the construction project. It is suggested that the NJDOT's Property Management group be advised via a Deed Notice – type mechanism of the need for appropriate O&M activities and safety controls.

A Health and Safety Plan for ongoing operations and maintenance should be developed and provided to personnel who may need to perform invasive work in affected areas (e.g. for repairs, utility installations, etc.). This HASP must be site-specific based on the quality of the SDM, potential for contact with percolated water or other contaminated media, the configuration of the structure, and other factors.

4.0 HYPOTHETICAL PROJECT

4.1 DESCRIPTION

A hypothetical project including the use of the stabilized dredge material ("SDM") in a roadway construction project is described herein to help understand the main issues involved in a typical SDM material application: siting, permitting requirements, environmental concerns, construction methods, and associated costs. The components incorporated in this hypothetical project are based on the experience gained after the performance of the one-year testing program at the Demonstration Project presented in detail in Section 2.0 of this report. The hypothetical project assumes that 100,000 cubic yards of SDM will be used.

It is assumed that the dredge material will be stabilized at an offsite location with an additive(s), such as Portland cement, at a predetermined ratio. The initial stabilization of the dredge material will produce a soil-like material, and improve workability during construction. The SDM will be kept in a stockpile at the construction site. Best management practices ("BMPs") as described in Section 3.0 of this report will be employed to minimize the exposure of SDM to precipitation and reduce the potential for increase in the moisture content.

The hypothetical project will maximize the use of the material on the smallest possible land area, thereby minimizing the potential for generation of a large volume of impacted runoff requiring control during construction. This would also minimize the exposed surface area of the SDM, and would also minimize the contact of construction workers to any contaminated material. Therefore, the hypothetical project would involve sections of the roadway, including roadbed and embankment of approximately 10-20 ft. in height. The project could involve excavation and placement of material below existing grade, or could be constructed at existing grade. Figures 4A and 4B provide two typical roadway sections for the hypothetical project. Sections 4.2 through 4.4 discuss pre-construction planning, siting factors, and permitting requirements. Section 4.5 discusses construction methods and sequences. Section 4.6 discusses required geotechnical and environmental tests. Section 4.7 discusses environmental concerns and controls both during and after construction, including application of BMPs. Section 4.8 discusses the cost of the hypothetical project, including a comparison with use of standard construction fill.

4.2 PRECONSTRUCTION PLANNING AND DESIGN

Preconstruction planning and design are important components needed to provide a thorough understanding of the advantages and limitations of the use of SDM for construction projects. This phase of the project involves project evaluation, siting factors, permit requirements, determination of the availability of SDM, working with local government and communities, an awareness program for the construction crew, selection of BMPs, and scheduling.

In the project evaluation phase, compliance with technical and regulatory requirements is determined. The technical requirements, i.e. environmental considerations and geotechnical specifications, are explained in detail in Sections 5.1 and 5.3 of this report. The regulatory requirements are explained in detail in Sections 4.4 and 5.5 of this report. Rough construction costs and a time line can be included to aid in the planning before the construction starts.

Stormwater runoff control must be considered during project planning phase. The primary stormwater runoff control objectives during project planning are to:

- identify potential stormwater quality impacts and develop/evaluate options to avoid, reduce, or minimize the potential for stormwater runoff impacts where possible;
- ensure that the programmed project includes sufficient right-of-way and budget for required stormwater controls; and
- identify project-specific permanent and temporary BMPs that may be required to mitigate impacts.

During the early project planning phase, stormwater activities focus on identifying and avoiding impacts where practical and, if necessary and cost effective, incorporating permanent treatment BMPs into the project that may require additional right-of-way. This identification, avoidance, and incorporation process continues in additional detail during the environmental studies phase, to determine if treatment controls or additional mitigation-type BMPs will be required.

4.3 SITING FACTORS

One of the critical decisions to be made when determining the use of the SDM for a roadway project is selecting the location of the project. Siting factors for the use of SDM need to be established to ensure that potential environmental impacts are minimized and the controls to mitigate any impacts are cost effective. Siting factors should address critical environmental and other technical concerns, as well as important social concerns. Once again, failure to consider these factors may result in an increase in cost and, potentially, public concern.

Following are certain factors that should be considered in selecting a site for the use of SDM in roadway projects:

- site acreage and configuration;
- subsurface soil;
- topography;
- drainage patterns;
- depth to groundwater;
- direction and rate of ground water flow;
- ecological areas;

- drinking water wells in the area;
- receiving streams (lakes, rivers, etc.);
- level of existing contamination; and
- nearest sensitive receptor

As a general guideline, SDM should not be used in public open spaces or resource protection areas, agricultural lands or agricultural development areas, exceptional value watersheds, or State or Federal natural or historic places. The use of SDM is most appropriate in areas where a certain degree of contamination already exists., e.g. brownfields, because the presence of the SDM will not elevate any environmental concerns and will help reduce potential remedial costs.

The following information should be reviewed for the site selection process:

- an inventory of existing site conditions should be used to evaluate relevant environmental and geotechnical characteristics;

- existing topographic maps (e.g. USGS or local government topos) should be obtained;

- existing drainage patterns on the site should be determined;

- areas adjacent to the site which could be of any significance and/or concern should be determined; and

- Federal, State, and local agencies that regulate land-disturbing activities should be contacted to determine any permit or approval requirements.

Once a site has been selected, a foundation analysis needs to be performed as part of the preconstruction design. The foundation analysis will focus on the type of substrata soil at the site, remedial measures for potential differential settlements, and other required foundation improvements.

Environmental permitting related to the dredging operation and stabilization activities would already have been secured for the stabilization site. Environmental controls would be in effect at the stabilization site to prevent any adverse impacts at that site. However, permits for the use of SDM at a roadway construction site would be the responsibility of the project for roadway construction. Section 4.4 outlines the typical permits required for the hypothetical project.

4.4 PERMITTING

Several permits from regulatory agencies, including the NJDEP, USEPA, and/or County and local agencies may be required for typical dredge projects. The potential applicability of these permits to the use of SDM in roadway projects should be determined on project-by-project basis. The following permits might be required:

Permit	Applicability
Acceptable Use Determination	Definitely
Local POTW Discharge Permit	Only if discharge to surface water is not feasible
Soil Erosion and Sediment Control Plan	Definitely, if above 5000ft^2 disturbance
Local/County Site Plan Approval Plan	Not required for state DOT projects
Air Pollution Control Permit	Only at the stabilization site.

The following permits could potentially be required depending on site-specific factors:

- Freshwater Wetlands Permit;
- Waterfront Development and/or Coastal Wetlands Permit; and
- Stream Encroachment Permit.
- Other site specific permits

4.5 CONSTRUCTION SEQUENCE

This section describes the construction components that should be considered as construction proceeds. As discussed previously, the hypothetical project will be constructed where a certain degree of contamination already exists. Therefore the site is presumed to have been characterized for pre-existing contaminants and may be undergoing some type of remediation for pre-existing contamination. If remediation includes capping, the hypothetical project can be used as part of the capping system. As such, the presence of existing contamination and the potential need for foundation improvement may require additional measures before construction using SDM could be initiated. These additional measures include foundation stabilization, instituting BMPs, and isolating those areas where construction workers could potentially be exposed to contamination. Once these measures have been taken, then the use of the SDM for the construction could start.

The construction of a roadway using the SDM involves preparation of subbase and the placing and spreading of the SDM. As mentioned above, the stabilized dredge material would be stockpiled adjacent to the construction site to minimize the transportation efforts.

The type of equipment required for the construction includes: an excavator or loader for loading the SDM from stockpile to the trucks, trucks for transporting the SDM from the stockpile to the footprint of the proposed roadway, a dozer for spreading the SDM in one foot lifts[[i]], a smooth roller or sheep foot

[vi] One foot lifts were used for the construction of embankments at the Demonstration Project. NJDOT recommends using placement of eight-inch lifts. The experience with the use of SDM material at the OENJ Redevelopment Site (a.k.a Jersey Gardens Mall Site) and Demonstration Project shows that one foot lifts result

roller for compaction. Disking for the additional drying is assumed to be unnecessary since drying would have been completed at the stabilization site.

The SDM material should be spread with the mechanical spreader or dozer except in the limited restricted areas. The SDM should be spread so as to eliminate segregation and all ruts and ridges caused by dumping or hauling over the material.

Compaction of each layer should continue until the SDM complies with the compaction acceptance testing requirements recommended in Section 5.0 of this report. The in-place dry density of each compacted lift should be determined by using recommended testing methods. To check conformance to the compaction requirements, the represented number of locations (preferably 60 ft. x 60 ft. grid locations) should be tested. To be acceptable a lift must have at least 75% of tested locations meet the compaction requirements (i.e., dry density and moisture content). If a lift fails to meet this requirement, it should be reworked, opened, recompacted, and retested for the compliance with compaction requirements.

The use of SDM during rainy events should be minimized. As discussed earlier, the SDM is very sensitive to moisture content. If rain is expected, relevant BMPs should be implemented in order to minimize potential increases to construction costs.

4.6 ENVIRONMENTAL CONCERNS

The results of the Demonstration Project indicated that the use of SDM for roadway projects does not pose significant environmental concerns, based on extensive data collected for air, soil, percolating water, and stormwater. The data generated from the analyses were compared with existing Federal and State benchmarks for each specific compound. This comparison was employed as screening tool to determine the need for further media-specific evaluations (modeling).

The screening analyses for percolated water indicated that some of the metals and chloride exceeded the groundwater quality standards ("GWQS"). Further evaluation via mathematical models was performed to assess the impact of the percolated water on the groundwater aquifer system and nearest surface water body. The mathematical model assumed the worst-case scenario of percolated water concentrations of same magnitude entering into the groundwater aquifer system.

The results generated from the groundwater model indicated that the contaminant concentrations in the groundwater aquifer system right beneath the embankment do not meet the GWQS. However, the model used was simplified, and does not represent the actual conditions. The mathematical modeling of a refined scenario representing the real conditions of the aquifer system, including dispersion in vandose

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in the expected geotechnical characteristics.

zone, would yield significantly lower concentrations.

The screening analyses for stormwater indicated that some of the metals exceed various surface water criteria (“SWQC”) used. Further evaluation via mathematical models indicates that these compound do not have any impact on surface water bodies.

The results of the air monitoring program indicate that the concentrations detected in dust via area and personal samplers did not pose any significant impact on either worker health or ambient air quality.

Based on the screening and modeling activities summarized above, it could be concluded that the potential impact of SDM on the environment is minimal. However, project-specific measures (such as personal protection for workers and BMP’s for storm water) could be taken prior to and during construction to minimize the potential for impact.

For illustration, it is assumed that the quality of the SDM used in the hypothetical project is worse than the quality of that used in the demonstration project. Under this assumption, the potential for higher levels of contamination would require that the stormwater runoff that comes in contact with exposed SDM should be managed through appropriate BMP’s prior to discharge into any surface water body (i.e. swales, detention basins etc). A representative number of stormwater runoff samples should be collected for chemical analysis. Based on the analytical results, the appropriate location for discharge of the stormwater could be determined.

The personal protection equipment level for the construction crew should be Level D. However, it is recommended that particulate masks be used to reduce potential exposures to contaminants in associated dust.

4.7 CONSTRUCTION COST ESTIMATE

As concluded in the demonstration project, the SDM is very sensitive to moisture. Most of the time when the dredge material failed compaction criteria, it was due to excessive moisture content rather than not meeting the dry density criteria.

For the hypothetical project, it is assumed that 100,000 cubic yards of SDM will be used to construct the roadway embankment, as shown on Figures 4A and 4B. For the purposes of cost estimation, the typical shape presented on Figure 4A will be assumed, specifically, a 45,000-foot long embankment with side slopes of 2:1 (H:V), 60 feet wide at the bottom, 40 feet wide at the top, and 10 feet in height.

Based on the experience gained from the Demonstration Project, it is estimated that a production rate of 500 cubic yards a day could be achieved using one excavator, one dozer and one roller. This assumption takes into account that exposure to rain will be minimized with the use of BMPs. The cost estimates presented in the following tables for this hypothetical project may vary with different site

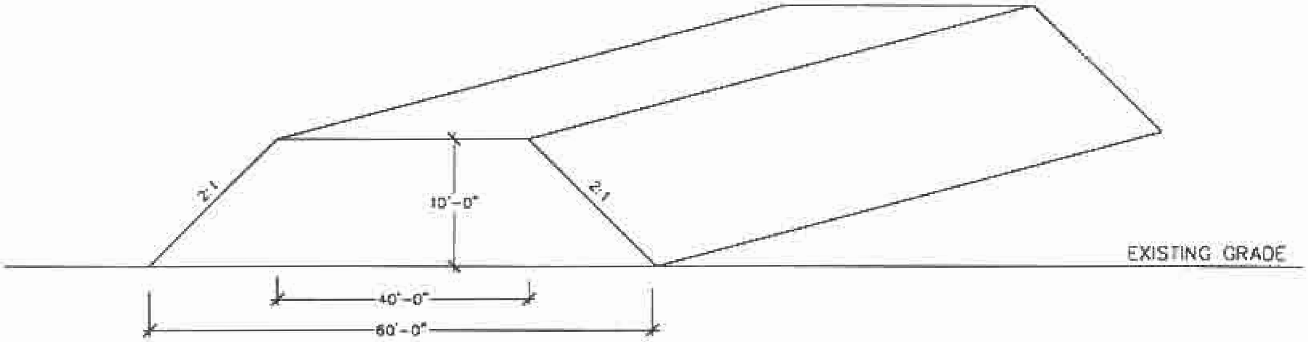

FIGURE4 A: USE OF SDM IN ROADWAY AT EXISTING GRADE

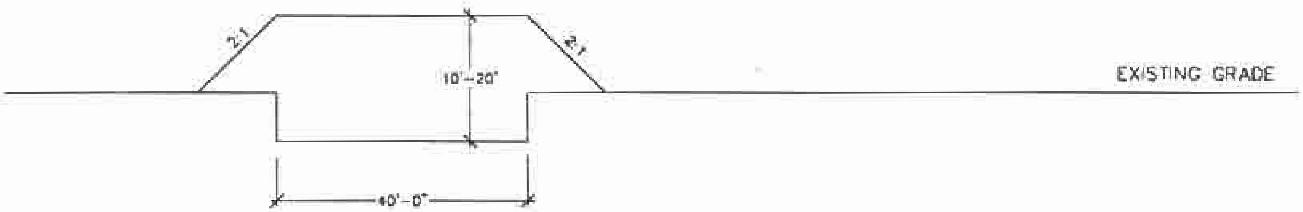

FIGURE4 B: USE OF SDM IN ROADWAY BELOW EXISTING GRADE

Sadat Associates, Inc. PRINCETON, NEW JERSEY	
HYPOTHETICAL PROJECT	
PROPOSED SHAPE OF ROADWAY	
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NC	H:\98069\ 8X11.DWG

conditions, bigger and/or more equipment used, and the embankment configuration.

Construction Cost Estimate for Handling 500 cubic yards/day of SDM

Construction Item	Equipment Needed	Personnel	Estimated Cost
Pushing and Spreading	Dozer/spreader	Labor/Foreman	$2,250.00
Disking	Dozer	Labor/Foreman	$1,050.00
Compaction	Roller	Labor/Foreman	$850.00
Total Estimated Cost for 500 cubic yards			**$4,150.00**

The total cost of placement for this hypothetical project is estimated to be $830,000. Material costs are not added to the estimate, as the material will be available from a stockpile in the vicinity of the construction site. In addition, the costs for trucking and hauling are not included since these activities will not cause a difference in the cost, when compared to traditional construction materials. Additional costs associated with the review of analytical data, the implementation of BMPs (such as constructing swales or side channels to collect the stormwater runoff and a temporary or permanent detention basin), and installing the plastic cover or other measures to prevent the exposure of the SDM to precipitation for anticipated rainy days, are project specific and should be taken into consideration.

For this hypothetical project, which will use 100,000 cubic yards of the SDM, following additional management costs are estimated.

Item	Estimated Cost ($)
Review of Analytical Data on SDM	8,000 - 12,000
Additional permitting – environmental [a]	10,000 – 25,000
Additional design - environmental	10,000 – 15,000
Additional design - geotechnical	10,000 – 15,000
Preparation/modification of Health and Safety Plan	1,000 – 1,500
Implementation of Health and Safety Plan [b]	1,000 – 40,000
Additional environmental oversight/engineering	5,000 – 10,000
Construction of stormwater side channels/swales	10,000 – 15,000
Construction of retention pond	15,000 – 20,000
Stormwater runoff sample collection and analysis (samples during two events)	6,000 – 10,000
Additional efforts for compaction testing requirements	10,000 – 15,000
Sealing/Tarping to prevent from rain exposure	8,000 – 10,000
TOTAL ADDITIONAL COST	**94,000 – 188,500**

[a] - Depends on site conditions

[b] - Depends on properties of dredge and possible need for air monitoring.

The total additional costs for the hypothetical project works out to be approximately $ 0.9/cy - $1.9/cy. All other costs for engineering supervision, construction management, and overhead and profit are similar to those for any conventional material used for the embankment projects.

4.8 CONCLUSIONS

The use of the SDM for roadway projects requires careful pre-construction project planning. Due to the fact that the SDM may contain low levels of contamination, selection of a site where it is environmentally safe to use is an important component of the project. The most appropriate sites for using SDM have existing levels of contamination (e.g. brownfields) and a confining layer in the foundation soil.

Once the construction site has been determined, Federal, State and local government permits will be required to proceed with the construction of roadway. To minimize the potential impact to the environment, the use of BMPs such as stormwater runoff control measures, plastic cover on the surface, and use of dust masks for the construction workers are strongly recommended.

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 GEOTECHNICAL CONSIDERATIONS

- The dredge material used in this Demonstration Project, in its raw form is typical of that generated from maintenance dredging operations of the New Jersey Harbor areas. Due to its drainage and gradation characteristics, the RDM may not generally meet the existing NJDOT specifications for common fill. However, as shown by the results from this Demonstration Project, stabilizing the dredge material results in a material exhibiting strength, slope deformations, and settlement characteristics that would be satisfactory for NJDOT projects.

- The foundation improvement by the use of geomembranes minimized differential settlement under the embankments. However, design of suitable foundation for embankments is a site-specific issue and should be addressed accordingly.

- Results of the geotechnical investigation suggest that the embankments have a fairly high factor of safety against slope failure. This is verified by laboratory test results and computer models used to predict the slope stability of the embankment, as well as the field monitoring (inclinometer) data gathered during the Demonstration Project.

- As long as the SDM meets construction compaction criteria, consolidation effects in the SDM layers are minimal. This has been confirmed by laboratory testing and by review of field monitoring data collected from the settlement plates.

- Addition of cement increased the strength of the dredge material significantly. However, the strength gain was reduced due to the continual breaking of cemented bonds in the SDM due to mixing and disking. SDM can be hydrated and compacted in place to provide greater strength gains and avoid the continual mixing and disking of the dredge material, which aids in drying but tend to break the cement bonds. However, for highway projects, it can be assumed that SDM will be dried and fully stabilized at specialized facilities and be made available to contractors for construction.

- Temperature plays a significant role in the strength gain and moisture reduction of SDM. At temperatures below 40^{o}F, the pozzolanic reactions between the cement and soil particles slow down. As a result, the improvements associated with the addition of cement, i.e., moisture content reduction and improved strength are minimized. Therefore, it may be prudent to limit the placement of SDM to warm seasons of the year. The processing and curing of the material, however, can take place throughout the year.

- The permeability of the compacted SDM was typically less than 10^{-7} cm/sec. Addition of fly ash further helped in reducing permeability. Based on the findings of this study, SDM could be effectively used for impermeable caps in landfills or other contaminated sites.

- Laboratory scale durability tests conducted on SDM suggest that it is extremely susceptible to frost and shrinkage. Based on the findings it is suggested that SDM should be placed below the frost line and with proper soil cover at all times. Compacting SDM at moisture contents below the shrinkage limit would minimize the potential for tensile cracks. Field monitoring data available for the course of one year show that the SDM once placed properly, experiences no significant loss or gain of strength.

- The embankments were not subjected to dynamic loading. However, values of resilient modulus for all SDM samples compared well with three sub-grade soils that are currently under New Jersey roadways. It may be noted that laboratory resilient modulus values give a measure of the strength of sub-grade soils under dynamic vehicular loads.

- Humboldt Stiffness Gauge and the Clegg Impact Hammer were evaluated as alternatives to Nuclear Density Gauge for more time-efficient determinations of dry density in cement SDM. The results indicate that the HSG and CIH did not have the necessary sensitivity needed to accurately predict the dry density measured from the nuclear density gauge and oven drying. The HSG measured compaction characteristics accurately, provided the samples were within a specific range of moisture content for which the HSG had been calibrated. If the moisture content fell outside of this range, significant deviation was observed

- Field monitoring of SDM cement content show considerable variation with respect to the target cement content of 8%. This variation is attributed to problems associated with the processing plant. Design modifications and improved instrumentation is expected resolve this.

5.2 ENVIRONMENTAL CONSIDERATIONS

5.2.1 General

As discussed in Section 2.7, SDM varies widely in chemical and physical composition. SDM from dredge sites in the Hudson, Hackensack, and Passaic River watersheds often has certain contaminants exceeding the State's NRDCSCC. The demonstration project indicates that some release of mobile constituents takes place by percolation of rainwater through properly placed and compacted structural fills. Stormwater runoff from structural fills also has the potential to mobilize certain chemical constituents that require proper stormwater management practices to prevent potential adverse water quality impacts. Based on the chemical nature of the SDM, it is important for projects utilizing dredge from certain areas of the State to be carefully planned to properly manage potential ground and surface water impacts. Section 3.0 outlines the need for Best Management Practices for Stormwater Runoff. Section 2.7.6 discusses the need for evaluation of the potential for ground and surface water impacts in the design process to account for potential migration of contaminants. Based on the above considerations, the following evaluation process is recommended in the design phase of projects utilizing SDM in highway construction:

- Obtain chemical characterization data on the SDM to assess the need for site-specific environmental design considerations.

- For SDM exceeding the State's RDCSCC, hereinafter referred to as "impacted SDM", the following planning/design considerations are advisable:

    - Evaluate potential for groundwater impact by assessing area specific groundwater quality criteria and analyzing potential impact of specific parameters that could be mobilized in the percolated water from SDM. Results from leading tests (MMEP testing), required as part of the State's AUD process, could be used as a rough approximation of concentrations that could be present in actual project conditions. As shown in the demonstration project, actual concentrations of certain parameters may be higher in percolated water than those resulted in MMEP analyses. A comparison of variability of concentrations between SDM leachate in laboratory testing and the field demonstration showed the following:

Parameters	Exceeding GWQS	Exceeding GWQS
alpha BHC	2.5 - 19.5	not exceeding
arsenic	2.5 - 3.9	3.8 - 4.9
mercury	1.8 - 3.1	not exceeding
lead	not exceeding	1.5 - 3.5
nickel	not exceeding	1.1 - 2.2
thallium	not exceeding	1.6 - 13.0

- Therefore, the analyst should use an appropriate safety factor based upon the specific parameters of concern.
- The designer should consider site specific factors in evaluating potential stormwater impact, including depth of SDM fill, overburden thickness and soil characteristics, groundwater elevation, potential rate of groundwater movement, background groundwater quality (if known) and GWQS. Simplified calculations, similar to those presented in Section 2.7.6, can be used to identify potential for groundwater impact.

- Based upon the results of the groundwater evaluation site-specific engineering and designs, approaches may be needed to properly design the project to avoid potential impact. Such measures could include avoidance of sensitive aquifer areas, placement in areas with adequate overburden/depth to groundwater to mitigate impacts, and in certain cases, collection and off-site management of percolated water.

- In the case of potential stormwater impact, a similar evaluation process can be followed. Potential for contamination of stormwater can be ascertained using data from the demonstration project or other literature sources. Site-specific BMPs should be considered for potential to mitigate impact of stormwater. Simplified calculations similar to those presented in Section 2.7.6 can be used to evaluate potential impact on recessing water. This evaluation process requires consideration of concentration of contaminants in runoff impact of BMP's to mitigate contaminant transport, flow of runoff from the project. and site specific flow of receiving waters under varying conditions and applicable surface water quality standards.

- Based on the results of the surface water impact evaluation process, specific engineering and design approaches may be needed to properly address potential surface water impact. Such measures may include, variation of BMP's to achieve greater control of contaminant migration, design of detention/retention basins, avoidance of discharge to sensitive ecosystems, and other site-specific design approaches.

- Based on the need to consider potential SDM impact on ground and surface water, certain planning considerations for selection of project sites most amenable to use of SDM are also appropriate. Planning/siting considerations for SDM projects are discussed in Section 5.2.2

5.2.2 Planning and Siting Considerations

Projects utilizing dredge with contaminants exceeding RDCSCC should consider locations where background soil concentrations of parameters of concern are similar to the characteristics of the dredge material and/or in areas where surface and groundwater criteria are most appropriate.

5.2.3 Areas of Historic Soil Characteristics Exceeding RDCSCC

Certain areas of the State have surface and subsurface soils that often do not meet RDSCC. There areas include sites considered to be brownfields, i.e., abandoned, contaminated sites, as well as properties in active use but having soils impacted by past industrial practices. Generally, the older urban or industrial areas of the State often have such soil conditions. Contaminants and their potential sources in urban or industrial areas in concentrations often exceeding RDCSCC include:

Typical Urban/Industrial <u>Parameters</u>	Typical Sources of <u>Contaminant</u>
Arsenic	coal combustion, industrial activity
Lead	paint, industrial activity
Beryllium	coal combustion
Various PAH’s	coal processing, chemical manufacturing

The above relationships may be highly simplified since there are many potential causes of exceedences of the above parameter. The above patterns are often found in site-specific remedial investigations in which specific parameters can be traced to prior site activities. In addition, movement of fill from one site to another, or prior disposal practices, often results in soil having exceedences of RDCSCC, and in many cases, exceedences of NRDSCC. In cases in which the exceedences are not clearly traceable to prior site history, the presence of contaminants is often referred to as “historic fill”. Historic fill is often recognized by the presence of non-native soils, construction debris, ash or slag or other visible forms of waste material.

The parameters in dredge from the urban/industrial areas of New Jersey are obviously related to the nature of typical soil contamination in life source areas. The parameters in dredge from the Hudson, Passaic and Hackensack basins, that often do not meet NRDSCC, are also very typical of “historic fill” contaminated sites and urban soils in general.

5.2.4 Use of SDM in Areas of Prior Urban/Industrial Activity

The rationale for use of SDM for highway structural fill in areas of prior urban/industrial activity is as follows:

- Areas in which background soils are not pristine require environmental studies that reveal specific patterns of contamination.
- Once prior contamination is identified, appropriate design measures for proper managing impacted soils are included in the highway design project. Management can include off-site relocation/disposal or on-site containment and capping.
- Because areas of impacted soils will require special environmental design, the addition of another impacted material (i.e., SDM over RDSCSS) does not result any additional burdens to the environment that cannot be accounted for in an overall design.
- SDM exhibits high degrees of impermeability and can be used as an impermeable layer for sites requiring capping. While the impacted site will require clean material at the surface, this is easily accomplished by the placement of structures paving or clean soil and vegetation.
- Management of impacted SDM at sites undergoing study/remediation provides economies of scale in the remediation process. In addition, the beneficial use of impacted SDM at brownfields or sites undergoing remediation is consistent with overall State policy goals of avoiding the introduction of new development or introducing contamination in pristine areas. This goal is an overall theme of the following State/Federal programs:

5.2.5 Avoidance of Areas with Sensitive Ground/Surface Water Resources

Areas of the State with groundwater classified as Class IIA require groundwater to be usable without treatment for potable purposes. It is possible to design projects with impacted SDM so as to not adversely impact groundwater potable quality. However, wherever possible, it is preferable to avoid projects utilizing impacted SDM in such areas.

Similarly, areas of the State with the most sensitive surface waters, i.e., FW-1 and FW-2 can potentially accommodate impacted SDM. However, the additional environmental design, use of more elaborate BMP's and uncertainty in predicting potential impact, suggest that it is preferable to avoid impacted SDM projects in such areas.

5.2.6 Other Sensitive Resources

Areas of the State that have groundwater classifications of Class -I and surface water classified as FW – I often have valuable natural ecosystems along streams and estuaries. These ecosystems are particularly notable in wetlands, flood plains, and stream corridors. Project specific design should be undertaken to avoid potential adverse impact on sensitive ecosystems that may be present in urban/industrial areas of the State.

5.2.7 State Plan

The State Plan (March 2001) encourages revitalization of cities and towns and specifically calls for Brownfields development (State Plan p128). The State Plan also encourages materials reuse and recycling (State Plan p128).

5.2.8 Water Quality Management Act

The State of New Jersey has enacted ground and surface water quality standards pursuant to the Water Quality Planning Act (N.J.S.A. 58:10A-1 et seq.) and Water Pollution Control Act (N.J.S.A. 58:11A-1 et seq.). As part of the standards, “anti-degradation” policies have been established for ground and surface waters. These standards call for no further degradation of existing groundwater quality (N.J.A.C. 7:9 - 6.8) or change to surface water quality that would impair or preclude attainment of designated waterway uses (N.J.A.C. 7:9B1.5(d).

In order to meet the State’s anti-degradation policies it can be presumed that introduction of new sources of soil contamination in areas exceeding current minimum groundwater quality criteria would be potentially problematic with respect to the overall goals of the anti-degradation policy.

5.2.9 Brownfields Act of 1998

The Brownfields Act (PL 1997 Ch. 278) contains many provisions related to the issues involved in SDM management. For example, Section 3 calls for NJDEP to identify areas of existing aquifer contamination. Section 4 requires NJDEP to identify areas of the state where historic fill exists. The Act also provides processes for onsite contaminant or contamination at Brownfield sites through legal and institutional controls. Finally Section 26 mandates that NJDEP “Encourage and aid in coordinating Water Quality Management Act, State, regional and local plans, efforts and programs concerning the remediation and lease of former industrial or commercial properties that are currently underutilized or abandoned and which there has been a discharge....”

5.3 PLANNING AND DESIGN

SDM projects that involve dredge materials with some contamination require special planning and design considerations that would not be necessary in typical roadway fill projects. Section 5.2 discusses locational aspects for selecting SDM projects and emphasizes sites with a history of prior contamination. Section 5.2 also explains the need for analyzing the potential for impacted SDM to migrate to surface or groundwater. Section 3.0 explains the need for various Best Management Practices to be considered in the design of projects utilizing impacted SDM. Section 5.4 discusses permits that may apply to impacted SDM. The combination of the above factors makes it important for the roadway planning and design process to incorporate a series of issues to address the best use of SDM.

5.3.1 Planning Phase

When roadway projects are being planned, it is helpful to consider the use of SDM early in the planning process. Projects located in areas of prior contamination that need substantial volumes of fill due to the particular configuration of the project are logical choices for consideration of impacted SDM. For such projects it is prudent to consider availability of processed SDM locations and volumes of SDM that are available. It is presumed that one or more stockpiles of processed SDM will be established in the northern New Jersey waterfront area and that significant volumes of processed SDM will be available for use as fill in roadway projects. This assumption should be checked for each specific project.

There are economies of scale in using SDM because special planning and design for environmental factors have relatively fixed costs. Therefore the greater the volume of fill that may be needed, the lower the incremental unit cost for utilizing impacted SDM. As explained in Section 4.7, projects with volume exceeding 100,000 cubic yards are of a scale that should allow incremental unit costs for SDM to be minimized.

In the planning phase the following additional considerations should be evaluated for projects that could benefit from SDM:

- proximity to surface water.
- proximity to sensitive ecological receptors.
- ability to utilize BMPs/sufficient space to construction of needed swales and detention facilities.
- need for impermeable capping material to address prior site contamination.
- site specific permits for use of SDM.
- geotechnical needs of the projects and ability of SDM to meet geotechnical design parameters.
- schedule (i.e. need to allow sufficient time for permitting and special planning and design considerations).

If the above factors are favorably evaluated, the project for use of impacted SDM can proceed to the design phase.

In the design phase additional details should be developed to address environmental issues evaluated in the planning phase. Design considerations generally include:

- geotechnical design, including stabilization of underlying soils
- fill configuration

- subsurface drainage.
- surface drainage
- detailed analysis of potential surface and groundwater impact
- BMPs for stormwater runoff
- BMPs for placement of material (rolling and/or tarping to avoid rewetting)
- geotechnical and environmental monitoring requirements during fill placement
- final cost estimate
- value engineering to address cost minimization detailed logistical planning to obtain source of SDM.

5.4 PERMITTING

5.4.1 General

Several permits from regulatory agencies, including the NJDEP, USEPA, and/or County and local agencies may be required for typical dredge projects. The potential applicability of these permits to the use of SDM in roadway projects is described in this section. It is assumed that the SDM will only be used at Brownfields sites, which have a certain level of existing contamination.

Following is a list of permits and approvals, which could be applicable to the use of SDM in roadway projects:

- Site Remediation Approval;
- Acceptable Use Determination;
- Freshwater Wetlands Permit; (site specific)
- Waterfront Development and Coastal Wetlands Permits; (site specific)
- Stream Encroachment Permit; (site specific)
- Stormwater Discharge Permit;
- Discharge to Groundwater Permit;
- Soil Erosion and Sediment Control Plan;
- Federal Agency Approval; e.g. Corps of Engineers (site specific)
- Local/County Approval; (site specific) and
- Air Pollution Control Permit. (site specific)

5.4.2 Site Remediation Program Approval

The Site Remediation Program ("SRP"), through the Office of Dredging and Sediment Technology, coordinates the review and permitting of all coastal projects which involve dredging and the reuse of dredge material in New Jersey. It is recommended that a pre-application be held with this office in conjunction with appropriate LURP staff.

In addition, depending on the particular project site, it may be necessary to comply with the Technical Requirements for Site Remediation (NJAC 7:26E). The SRP oversees compliance with these rules in accordance with either a mandatory (i.e., Administrative Consent Order) or voluntary (i.e., Memorandum of Agreement) arrangement with the responsible party. This includes, at a minimum, a Preliminary Assessment ("PA") to identify potential areas of concern ("AOCs"). Depending on the findings of the PA, a Site Investigation ("SI") may be needed to further investigate potential AOCs, and a Remedial Investigation ("RI") may be necessary if contamination is identified during the SI. Any planned remedial action for the site, as well as the results of the PA, SI, and RI, must be reviewed and approved by the SRP.

5.4.3 Acceptable Use Determination

An Acceptable Use Determination ("AUD") is required for the beneficial reuse of dredge material, and is coordinated through the Office of Dredging and Sediment Technology. A request for an AUD must be submitted for the project in accordance with the requirements specified in the document entitled "The Management and Regulation of Dredging Activities and Dredge Material in New Jersey's Tidal Waters" (October 1997). A request for an AUD should contain the following required documentation:

- A description of all admixtures to be combined with the dredge material, including source location;
- Evidence that the dredge material and each admixture used is used directly as a product or as substitute for a raw material that is incorporated into a product;
- A contaminant profile and evaluation of the general quality of all dredge material, admixtures and products;
- A description of any past or ongoing regulatory activities at the site of origin for each admixture;
- A description of any treatment or processing of the dredge material, admixtures and product prior to shipment to acceptable use project;
- A description of measures which will be implemented to minimize or eliminate environmental and health impacts;
- A description of the design capacity of the acceptable use project;
- A detailed description of the acceptable use project;

- A schedule for initiation and completion of the acceptable use project; and
- A description of the destination of all admixtures, products or wastes that will move from the site of use.

The detailed requirements for an AUD request are specified in Appendix E of "The Management and Regulation of Dredging Activities and Dredge Material in New Jersey's Tidal Waters" (October 1997).

5.4.4 NJDEP Land Use Regulation Program

The NJDEP Land Use Regulation Program ("LURP") has jurisdiction over coastal areas, freshwater wetlands, and tidal wetlands in New Jersey, including any transition areas adjacent to these wetlands, and stream corridors.

It is recommended that a pre-application meeting be held early in the project development process to discuss permit applicability with NJDEP for the specific project. A Site Plan including project boundaries, wetlands and the mean high water line should be presented at that time. It is also recommended that all LURP applications be submitted simultaneously.

In addition, since the project involves the reuse of dredge material, it will be coordinated through the SRP's Office of Dredging and Sediment Technology. (See section 4.4.1).

5.4.4.1 Freshwater Wetlands

Certain specific activities are authorized by Freshwater Wetlands General Permits as specified by NJAC 7:7A-9.2. The NJDEP will issue a General Permit to an applicant, which meets the conditions and requirements of the Permit. General Permits can be obtained for activities including reconstruction of existing roadways and for filling up to one acre of isolated (non-tributary) wetlands. Transition Area Waivers are required for activities within the buffer zone adjacent to intermediate and exceptional resource value wetlands.

To obtain a wetlands permit, wetlands must be delineated on the subject property. A Letter of Interpretation ("LOI") is not required, but can obtained by application to NJDEP. An LOI is a mechanism for NJDEP review and concurrence with the wetlands boundaries, as well as a determination of resource value. After receiving the LOI, an application for a wetlands permit can be submitted and must include the appropriate form with signatures, signed and sealed drawings, photographs, and evidence of notification to adjacent property owners, and local and regional officials.

5.4.4.2 Coastal Wetlands and Waterfront Development

The Coastal Permit Rules (NJAC 7:7) apply to those Hackensack Meadowlands District areas in New Jersey specifically designated as Coastal Zone, as well as all other waterfront areas, including up to 500 feet from the mean high water line. Specifically, NJDEP requires that an Upland Waterfront Development Permit ("UWD") be obtained prior to development activities within this waterfront area. Activities that may affect mapped coastal wetlands will require a Coastal Wetland Permit under these rules.

A Coastal Permit Application requires the appropriate form with signatures, signed and sealed drawings, photographs, and evidence of notification to adjacent property owners and local and regional officials. In addition, a statement of compliance with the Rules on Coastal Zone Management (NJAC 7:7E) is required.

5.4.4.3 Stream Encroachment

Stream Encroachment Permits are required for projects which involve construction, grading or other disturbance within the 100-year flood plain, or within a stream buffer, or construction of a point discharge within or discharging to a 100-year flood plain.

A Stream Encroachment Permit Application includes appropriate form with signatures, signed and sealed drawings, photographs, environmental report, and evidence of notification to adjacent property owners and local and regional officials. The application may require net-fill, hydrologic or hydraulic calculations, water quality analyses, stability analyses, stormwater management, and soil erosion and sediment control plans.

5.4.5 Soil Erosion And Sediment Control Plan

Any construction project disturbing more than 5000 ft^2 requires that a Soil Erosion and Sediment Control ("SESC") Plan be prepared and submitted for approval to the appropriate Soil Conservation District. Generally, other permits for this project will require that such an approval be documented.

5.4.6 Federal Agency Review

The USEPA and United States Army Corp of Engineers ("US ACOE") may become involved in review of the project if comments are solicited by NJDEP during review of LURP permit applications. Otherwise it is assumed that since the project does not involve dredging, permits form these agencies are not required.

5.4.7 Other Permits And Approvals

Project Review by the Local and/or County Planning Board may be necessary if the project affects existing local/county properties. The municipality/county in which the project site is located should be consulted.

5.4.8 Air Quality

In addition, if dredge material is to be amended at the project site, an Air Pollution Control Permit may be required for the amendment and storage process.

5.5 RECOMMENDATIONS FOR FUTURE RESEARCH

- The work performed during this demonstration project concluded that the impact to environment by using SDM is minimum. Furthermore, implementation of BMPs during construction would reduce any potential impact. However, it should be noted that the SDM used in this project was relatively clean and was approved as fill material at the Jersey Gardens Mall site. This material meets the NRSDCC. The use of contaminated dredge material may bring different results.

- The comparison of results obtained from MMEP analyses in lab and percolated water analyses yield that MMEP may not be a representative technique of assessing potential leachability of contaminants from SDM. MMEP is a costly technique. An alternative method needs to be developed to predict more accurately the potential leachability of contaminants from SDM.

- The geotechnical findings as described in geotechnical report included as Appendix D are for the work performed during the demonstration project. This demonstration project only included one admixture and was not subjected to dynamic loading. Additional demonstration of dredged material subjected to dynamic loading needs to be performed. This will evaluate the structural strength of SDM and environmental impacts under dynamic loading (i.e. vehicular traffic)

APPENDIX A

Drawings

LIST OF DRAWINGS

APPENDIX B

Field Data During Construction

APPENDIX B-1

Daily Construction Reports

APPENDIX B-2

Construction Photographs

APPENDIX B-3

Troxler Results and Locations

APPENDIX B-4

Construction Cost Estimates

APPENDIX C

Impact of Embankment Percolate into Underlying Aquifer System Groundwater

APPENDIX D

Final Geotechnical Report

APPENDIX E

Air Study

APPENDIX E-1

Report by Dr. Clifford P. Weisel and Dr. Paul J. Lioy, University of Medicine and Dentistry of New Jersey. for Sub-Contract Agreement for OENJ / NJDOT
Roadway Embankment Pilot Project
dated January 5, 2000

APPENDIX E-2

Tables on Air Quality Data

APPENDIX E-3

Wind Data for Sample Collection Days

APPENDIX F

March 2000 Progress Report "Use of Dredged Materials in the Construction of Roadway Embankments"

APPENDIX G

Screening Evaluation and Environmental Data

APPENDIX H

Tabulated Analytical Data

APPENDIX H1

Data Collected Until October 6 1999

APPENDIX H2

Data Collected After October 6 1999

APPENDIX I

Screening Evaluation of Non-Detects

ENDNOTES

[1]The geotechnical consulting services provided by Dr. Ali Maher are rendered through Soiltek, Inc. ("Soiltek"), a geotechnical consulting firm.

[2]Environmental and Occupational Health Sciences Institute ("EOHSI") is a joint venture of Rutgers-The State University of New Jersey and The University of Medicine and Dentistry of New Jersey.

[3]Intertek Testing Services performed some of the analyses on the raw and laboratory SDM collected/created in April 1998 for the evaluation of the RDM and SDM for uplands beneficial use. These analyses were conducted for the Port Authority of New York and New Jersey to determine if the material was suitable for use at the OENJ Redevelopment Site, prior to the conception of the NJDOT Embankment Project.

[4]EOHSI Laboratories were selected for the performance of the analyses, since very low detection limits were required for certain parameters.

[5]"Report of Preliminary Geotechnical and Foundation Study, Kapkowski Road Site", prepared by Converse Consultants East, dated January 29, 1993; and, "Report of Geotechnical Investigation Pipe Support - Great Ditch, Metromall Site, Elizabeth, New Jersey", prepared by Converse Consultants East, dated May 31, 1995.

[6]Under the approved Remedial Action Workplan (RAWP) and Closure Plan, Site Specific Alternate Criteria for these parameters have been established and were met.

[7]Under the approved Remedial Action Workplan (RAWP) and Closure Plan, Site Specific Alternate Criteria for these parameters have been established and were met.

[8]EPA, July 1983, APTI Course 435 - Atmospheric Sampling, US Environmental Protection Agency, Air Pollution Training Institute, MD 20, Environmental Research Center, Research Triangle Park, NC 27711, 1983, EPA 450/2-80-005.

[9]Franz, T.P., and Eisenreich, S., "Snow Scavenging of Polychlorinated Biphenyls and Polycyclic Aromatic Hydrocarbons in Minnesota", Environ. Sci. Technol., 1998, 32 (12), 1771 - 1778.

[10]Simcik, M.F., Franz, T.P., Zhang, H., Eisenriech, S., "Gas-Particle Partitioning of PCBs and PAHs in the Chicago Urban and Adjacent Coastal Atmosphere: States of Equilibrium", Environ. Sci. Technol., 1998, 32 (2), 251 - 257.

[11] Eisenreich, S.J. et al, "Persistent organic pollutants in the coastal atmosphere of the Mid-Atlantic States - USA." In Persistent Bioaccumulative Toxic Chemicals, R. Lipnick and D. Mackay (Eds.), ACS Symposium Book Series: Washington, D.C., 2000

[12]Sweet, C.W., Vermette, S.J, "Sources of Toxic Trace Elements in Urban Air in Illinois", Environmental. Science. and Technology, 1993, 27 (12), 2502 - 2510.

[13]Cari Lavorgna Gigliotti, Environmental Sciences, "Polycyclic Aromatic Hydrocarbons in the New Jersey Coastal Atmosphere", Thesis submitted January 1999.

[14]The Management and Regulation of Dredging Activities and Dredged Material in New Jersey's Tidal Waters, October 1997.

[15] USACOE Technical Note DOER-C2, February 1998.

[16]The Multiple Extraction Procedure (MEP) is designed to simulate the leaching that a waste will undergo from repetitive precipitation of acid rain. The repetitive extractions reveal the highest concentration of each constituent

that is likely to leach in a natural environment. Method 1320 is applicable to liquid, solid, and multiphase samples.

[17]Pursuant to the February 3, 1998 letter from the NJDEP to Mr. Robert Ferrie of the Union Dry Dock and Repair Company, analysis of the composite samples for volatile organics was not required.

[18]Samples were collected on October 9, October 10, October 15, November 4, and November 10, 1998. The samples collected in October and November were composited on October 16, 1998 and November 11, 1998, respectively.

[19]Sample H8687-1 and Sample H8788-1 complement each other. Sample H8687-1 represents one of three grab samples, which were composited into Sample H8788-1. This grab sample (H8687-1) was analyzed for TCL-VOCs instead of the composite sample (H8788-1) in order to avoid the loss of volatile organic compounds, which may occur during the compositing of samples.

[20]Sample H8920-2 and H1760-1 complement each other. Sample H8920-2 represents one of three grab samples, which were composited into Sample H1760-1. This grab sample (H8920-2) was analyzed for TCL-VOCs instead of the composite sample (H1760-1) in order to avoid the loss of volatile organic compounds, which may occur during the compositing of samples.

[21]It has been found that a high pH is needed for stabilization. In addition, the pH affects the chemical properties of dredged material including, but not limited to, corrosivity, solubility, mobility, and toxicity of contaminants.

[22]Cation exchange reactions can alter soil physical properties and chemical composition of percolating waters. The CEC is pH dependent and directly proportional to the clay concentration, organic matter content, and particle size distribution.

[23]The SAR indicates the tendency for sodium to adsorb the cation exchange sites at greater concentration than calcium or magnesium. SAR values are generally used to indicate dispersivity in soil and permeability.

[24]Salinity is a measure of the concentration of soluble salts. Salt accumulations in soil can adversely affect its structure (decrease in the cohesiveness of particles), inhibit water and air movement, and increase the osmotic potential.

[25]Electrical conductivity will be used to measure the ionic strength present in the dredged material.

[26]The organic content in a soil can contribute to mobility and fixation of chemical compounds. In addition, it affects plasticity, shrinkage, compressibility, permeability, and strength of the SDM. High organic contents impede the necessary reactions for stabilization.

[27]The value of the total organic carbon is separated into three components: total petroleum hydrocarbons, oils and greases, and the degradable organic carbonaceous material. The collection of this information will allow for the investigation of potential changes in chemical fixation and strength of the stabilized material due to changes in the organic content (e.g., as a result of biodegradation). Existing literature (Clare and Sherwood, 1956) suggests that the unconfined compressive strength of sand-cement mixes is affected by the organic content of the soil, and more specifically, by the type of compounds encountered in the mix.

[28]The C:N ratios present in dredged material help determine the potential for growth of soil microbes and plants.

[29]Miscellaneous wet chemistry for RDM samples refers to the analyses for pH, salinity, electrical conductivity, sulfates, chlorides, sulfides, resistivity, acidity, CEC, SAR, coliforms, and C:N Ratio

[30]Samples I4797-1 and I4999-1 are derived from the same parent sample, i.e., a single sample was divided into these two portions, which were analyzed separately for different parameters. Sample I4797-1 has also been referred to as Sample I4297-1.

[31]Samples I4797-2 and I4999-2 are derived from the same parent sample, i.e., a single sample was divided into these two portions, which were analyzed separately for different parameters. Sample I4797-2 has also been referred to as Sample I4297-2.

[32]Samples I4797-2 and I4999-2 are derived from the same parent sample. Sample I4797-3 has also been referred to as Sample I4297-3.

[33]Miscellaneous wet chemistry for SDM samples refers to the analyses for pH, salinity, electrical conductivity, sulfates, chlorides, sulfides, resistivity, acidity, CEC, SAR, and C:N Ratio

[34]Hazardous characterization refers to the analyses for TCLP-VOCs, TCLP-SVOCs, TCLP-Pesticides, TCLP-Herbicides, TCLP- Metals, Corrosivity, Ignitability, Explosivity, and Reactivity.

[35]Dioxins were only tested in the first and seventh leachates generated from each of the SDM samples.

[36]Miscellaneous wet chemistry for liquid samples refers to the analyses for pH, salinity, electrical conductivity, sulfates, chlorides, sulfides, resistivity, and acidity

[37]The actual database program used was Microsoft Access® which is a relational Database system. A relational database is a collection of data items organized as a set of formally-described tables from which data can be accessed or reassembled in many different ways without having to reorganize the database tables. The standard user and application program interface to a relational database is the *structured query language* (SQL). SQL statements are used both for interactive queries for information from a relational database and for gathering data for reports. In addition to being relatively easy to create and access, a relational database has the important advantage of being easy to extend. After the original database creation, a new data category can be added without requiring that all existing applications be modified. The definition of a relational database results in a table of "metadata" or formal descriptions of the tables, columns, domains, and constraints.

[38]Last revised May 12, 1999.

[40]These criteria are used for evaluation purposes only. Typical Brownfields Sites where SDM may be used are not in areas in where groundwater is used for potable purposes.

[41]The applicability of these criteria to typical Brownfields Sites may not be appropriate since such sites are normally in watersheds in which surface waters are not used for potable supply.

[42]USEPA's commonly used definition for the detection limit for non-isotope methods has been the method of detection limit (MDL), as promulgated in 40 CFR Part 136, Appendix B (USEPA 1995i). A level above the MDL is the level at which reliable quantitative measurements can be made; generically termed the "quantification limit" or "quantification level"

[43]The IDL is the smallest signal above background that an instrument can reliably detect but not quantify. Also, commonly described as a function of the signal-to-noise ratio.

[44]SQL is a quantification level that is sample-specific and highly matrix dependent because it accounts for sample volume or weight, aliquot size, moisture content, and dilution. SQLs for the same compound generally vary between samples as moisture content, analyte concentration, and concentrations of interfering compounds vary. The SQL is generally 5 to 10 times the MDL, however, it is often reported at much higher levels due to matrix interferences.

[45]PLQ is a quantification level that is defined in 50 FR 46908 and 52 FR 25699 as the lowest level that can be reliably achieved with specified limits of precision and accuracy during routine laboratory operating conditions (USEPA 1992g; 195i). The PQL is constructed by multiplying the MDL by a factor usually in the range of 5 to 10. This factor is subjective and variable between laboratories and analysis performed. However, PQLs with multipliers as high as 50 have been reported (USEPA 1995i).

[46]The EPA document does not recommend that non-detects be handled as DLs. The EPA document states that: "this method always produces a mean concentration which is biased high, and is not consistent with Region III's policy of using best science in risk assessments."

[47]The impact to groundwater soil cleanup criteria for inorganics is to be determined on a site-specific basis. Site-specific criteria are generally performed for those inorganic constituents that exceed the residential and nonresidential soil cleanup criteria.

[48]The project site had Alternate Criteria approved under the RAWP and Closure Plan that allowed the parameters exceeding NRSCC or RDCSCC to be accepted at the Site.

[50]U.S. Environmental Protection Agency, Test Methods for Evaluating Solid Waste, Volumes I and II (SW-846), 3rd Edition, November 1986. Updates are available through Revision 2B, published April 4, 1995.

[51]State of New Jersey Department of Conservation and Economic Development, Division of Water Policy and Supply with United States Department of the Interior Geological Survey. 1968. Special Report No. 27 Geology and Ground-Water Resources of the Rahway Area, New Jersey. By Henry R. Anderson.

[52]Domenico, P.A. and F. W. Schwartz. 1990. Physical and Chemical Hydrogeology. John Wiley & Sons. New York.

[53]Anderson, M. P. 1979. "Using models to simulate the movement of contaminants through groundwater flow systems." Critical Reviews in Environmental Controls 9, no. 2:97-156 and Klotz, D., K. P. Seiler, H. Moser, and F. Neumaier. 1980. Dispersivity and velocity relationship from laboratory and field relationships. Journal of Hydrology 45. no. 3:169-184 as cited by Fetter, C. W. 1993. Contaminant Hydrogeology. Prentice Hall. Upper Saddle River, New Jersey.

[54]USGS Water-Data Report NJ-85-1. 1986. Water Resources Data New Jersey Water Year 1985. Volume 1. Atlantic Slope Basins Hudson River to Cape May.