PERMEABILITY & DURABILITY TESTING
of
Soil/Bentonite Backfill Mix
St. Louis, Michigan

January, 1983
Ref. No. 0803

CONESTOGA-ROVERS & ASSOCIATES LIMITED
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1.0 INTRODUCTION

1.1 CONTAINMENT WALL CONSTRUCTION

Under the provisions of the Technical Appendix to the Consent Judgement for the environmental securement of its St. Louis, Michigan plant site, Velsicol Chemical Corporation (Velsicol) is required to construct a continuous soil/bentonite containment wall, having a permeability equal to or less than $1 \times 10^{-7}$ cm/sec, along the entire perimeter of the plant site property.

The containment wall has been subdivided into an upgradient and downgradient section. Figure 1 presents the proposed alignment of both the upgradient and downgradient containment walls.

As stipulated by the Technical Appendix within Section 6, Figures 2A and 2B, and Exhibit D entitled "Containment Wall Specifications", the containment wall must be constructed through a level clay working platform and must be a minimum of 21 inches (nominal 24 inches) wide and keyed into the underlying clay till a minimum of 30 inches (nominal
PLANT SITE CONTAINMENT WALL
St. Louis Plant Site

figure 1

LEGEND

- - - - - - - - - - - - UPGRADEnt CONTAINMENT WALL

- - - - - - - - - - - - DOWNGRADIENT CONTAINMENT WALL

- - - - - - - - - - FENCELINE
36 inches). Figures 2A and 2B, and Exhibit D are presented in Appendix A of this report.

Backfill material for the containment wall must be a soil/bentonite mix having as a minimum 25% plastic fines (minimum of 25% of soil particles passing a Standard U.S. #200 sieve). The backfill mix must maintain a permeability of not greater than $1 \times 10^{-7}$ cm/sec when exposed to the plant site groundwater.

1.2 TESTING PROTOCOL

Section 8 of the Technical Appendix outlines the testing procedures to be utilized to determine the adequacy of the containment wall backfill material with respect to durability and permeability subsequent to installation of the containment walls. These tests are to be performed on soil samples obtained from continuous cores collected from specified points along the line of the containment wall.
In addition, soil samples collected from the project borrow pit by continuous core sampling are to be tested for durability and permeability in a similar fashion. Material from the project borrow pit will be used as backfill to the containment wall in sections where native material is judged unsuitable for such a purpose.

Using the collected samples an optimum soil/bentonite mixing ratio is to be determined such that the designed backfill mix will have a permeability less than or equal to $1 \times 10^{-7}$ cm/sec. The ability of the soil/bentonite backfill mix to maintain the specified permeability will then be tested with the use of plant site groundwater to determine if the groundwater will have any adverse effect on the backfill mix permeability.

1.3 TESTING LABORATORY

Conestoga-Rovers & Associates Limited (CRA) retained the services of Michigan Testing Engineers Inc. (MTE) for all physical laboratory testing.
This report presents the laboratory results of the permeability and durability tests performed on soil/bentonite mixtures using soil samples obtained from the line of the proposed upgradient containment wall and the project borrow pit and using groundwater obtained from Plant Site monitoring wells.
2.0 SAMPLE COLLECTION

2.1 SOIL

Between May 20 and May 26, 1982 CRA conducted a sampling program along the line of the proposed upgradient containment wall to determine the depth to the underlying clay till and to determine the integrity of the upper 3 feet of till (absence of sand lenses having a thickness of 4 inches or greater) and to collect soil samples for physical and chemical analysis. Details of the sampling program and results are presented in the report entitled "Sampling Program - Upgradient Containment Wall - Plant Site, St. Louis, Michigan". This report was presented to the Michigan Department of Natural Resources (MDNR) and the United States Environmental Protection Agency (USEPA) in July, 1982.

As part of this sampling program soil samples from sampling stations UGW-4, UGW-9, UGW-15 and UGW-21 were collected by continuous split spoon sampling for permeability and durability tests for the design soil/bentonite backfill mix. The entire continuous core sample from UGW-4 and UGW-21 was retained for use in the permeability test. The continuous core sample from UGW-9 and UGW-15 was split
in the field. One half of each sample was retained for use in the permeability testing and the other half was retained for use in the durability testing. Figure 2 indicates the sampling locations along the line of the upgradient containment wall.

Chemical analysis of the soil samples collected along the upgradient wall were performed as specified in Section 7 of the Technical Appendix. Results of the soil sample chemical analysis was presented to the MDNR and the USEPA in December, 1982, in the form of a report entitled "Upgradient Containment Wall - Chemical Analysis of Soil Samples - St. Louis, Michigan".

Between August 4 and August 12, 1982 CRA supervised a sampling program along the line of the downgradient containment wall. Soil samples were not collected for permeability and durability testing during this sampling program since a field inspection along the proposed alignment indicated that native soils were unsuitable for incorporation into the containment wall backfill. This necessitated the
LEGEND

- SAMPLE FOR CHEMICAL ANALYSIS ONLY
- AUGER HOLE FOR TILL ELEVATION DETERMINATION
- GROUNDWATER COLLECTION WELL
- UPGRADENT CONTAINMENT WALL
- DOWNGRADE NT CONTAINMENT WALL
- CONTINUOUS CORE SAMPLE (DURABILITY & PERMEABILITY TESTING)
- CONTINUOUS CORE SAMPLE (PERMEABILITY TESTING ONLY)

SOIL SAMPLING LOCATIONS

PLANT SITE
importation of backfill material from the project
borrow pit for the downgradient wall. The depth to the
underlying clay till was identified during this
sampling program. Details of the downgradient wall
sampling program are presented in the report entitled
"Sampling Program – Downgradient Containment Wall –
Plant Site, St. Louis, Michigan", presented to the MNDR
and USEPA in September, 1982.

In addition to sampling at the
plant site, four continuous core samples were collected
at the project borrow pit during the May, 1982 sampling
program. Permeability and durability testing for the
design soil/bentonite backfill mix was performed on
this material to determine compliance with
specifications. The entire continuous core sample was
retained from sampling stations BHS-1 and BHS-4 for use
in the permeability test. The continuous core sample
from sampling stations BHS-2 and BHS-3 was split in the
field longitudinally. One half of the sample was
retained for the permeability test and the other half
was retained for the durability test. Figure 3
presents the sampling locations at the project borrow
pit.
BORROW AREA FOR IMPORTED BACKFILL FOR UPGRADIENT & DOWNGRADIENT CONTAINMENT WALL

CONTINUOUS CORE SAMPLE (PERMEABILITY & DURABILITY TESTING)

CONTINUOUS CORE SAMPLE (PERMEABILITY TESTING ONLY)

figure 3
SOIL SAMPLE LOCATIONS
PROJECT BORROW PIT
All collected soil samples were delivered to the MTE testing laboratory in Detroit, Michigan by commercial courier under Chain of Custody protocol.

2.2 GROUNDWATER

Section 8 of the Technical Appendix specifies that plant site groundwater must be used during durability testing of the soil/bentonite backfill mix.

Groundwater for durability testing was obtained from two on-site wells developed during the upgradient wall sampling program of May, 1982. Figure 2 indicates the location of the two on-site wells.

Samples were composited on a 50%-50% basis from each well into a 5 gallon glass jars prior to shipping to the testing laboratory. The glass jars were cleaned with an acetone-hexane-acetone-distilled water wash and were air dried prior to sample collection.
Samples were composited on a 50%-50% basis from each well into 5 gallon glass jars prior to shipping to the testing laboratory. The glass jars used for sampling collection were cleaned with an acetone, hexane, acetone, distilled water wash and were air dried prior to sample collection.

A total of 20 gallons of groundwater was shipped to the laboratory for use in the durability testing of the backfill mix. Shipment was by commercial courier under Chain of Custody protocol.
TABLE 1
SUMMARY OF SOIL/BENTONITE BACKFILL TESTING

<table>
<thead>
<tr>
<th>Sampling Location</th>
<th>% Moisture</th>
<th>% Plastic Fines</th>
<th>Backfill Mix Permeability (cm/sec)</th>
<th>18 Days (Hydration)</th>
<th>18 Days (No Hydration)</th>
<th>90 Days (Hydration)</th>
<th>90 Days (No Hydration)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BHS-1</td>
<td>14.1</td>
<td>44</td>
<td>$7.6 \times 10^{-8}$</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>BHS-2</td>
<td>12.2</td>
<td>52</td>
<td>$9.9 \times 10^{-8}$</td>
<td>$1.1 \times 10^{-7}$</td>
<td>$1.1 \times 10^{-7}$</td>
<td>$7.0 \times 10^{-8}$</td>
<td>$6.7 \times 10^{-8}$</td>
</tr>
<tr>
<td>BHS-3</td>
<td>12.4</td>
<td>56</td>
<td>$7.9 \times 10^{-8}$</td>
<td>$9.0 \times 10^{-8}$</td>
<td>$9.0 \times 10^{-8}$</td>
<td>$7.0 \times 10^{-8}$</td>
<td>$7.0 \times 10^{-8}$</td>
</tr>
<tr>
<td>BHS-4</td>
<td>13.5</td>
<td>45</td>
<td>$7.7 \times 10^{-8}$</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>UGW-4</td>
<td>9.9</td>
<td>24</td>
<td>$8.0 \times 10^{-8}$</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>UGW-9</td>
<td>10.2</td>
<td>42</td>
<td>$9.2 \times 10^{-8}$</td>
<td>$2.1 \times 10^{-7}$</td>
<td>$8.8 \times 10^{-8}$</td>
<td>$7.0 \times 10^{-8}$</td>
<td>$7.4 \times 10^{-8}$</td>
</tr>
<tr>
<td>UGW-15</td>
<td>11.1</td>
<td>44</td>
<td>$8.9 \times 10^{-8}$</td>
<td>$1.05 \times 10^{-7}$</td>
<td>$1.1 \times 10^{-7}$</td>
<td>$7.6 \times 10^{-8}$</td>
<td>$6.0 \times 10^{-8}$</td>
</tr>
<tr>
<td>UGW-21</td>
<td>10.6</td>
<td>59</td>
<td>$8.0 \times 10^{-8}$</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Note: 1) Plastic Fines - particle sizes passing a Standard U.S. #200 sieve
3.0 LABORATORY ANALYSIS

The natural moisture content of each soil sample received from the line of the upgradient containment wall and from the project borrow was initially identified to determine the required bentonite concentration necessary to provide a backfill mix with a permeability of $1 \times 10^{-7}$ cm/sec. The moisture content for each sample is presented in Table 1.

From this data Slurry Gel #125 supplied by International Minerals and Chemical Corporation was added to the appropriate soil samples at a concentration of 3% by dry unit weight. Representative samples from each soil/bentonite mix were selected for grain size analysis. The percent plastic fines for each sample is presented in Table 1.

The soil/bentonite backfill mix of 3% slurry Gel #125, and native material was tested to determine permeability using the falling head permeability testing procedure as specified in ASTM D-2434. This testing procedure was in lieu of the triaxial permeability testing procedure specified in Section 8 of the Technical Appendix.
The consistency of the soil/bentonite mix was such that a suitable sample could not be formed to use in the triaxial test. Results of the permeability tests are presented in Table 1.

Durability testing was carried out on the soil/bentonite backfill mix using ASTM D-2434 procedures for falling head permeability testing. Initially, soil samples from BHS-2, BHS-3, UGW-9 and UGW-15 were prehydrated in clean water for 18 days with the permeability of each sample being monitored daily. At the completion of the prehydration period the clean water was drained from samples and replaced with groundwater from the plant site. The permeability of the soil/bentonite samples were monitored for an additional 72 days.

In addition to the prehydrated samples four duplicate samples were prepared which were exposed to the plant site groundwater without any prehydration period. Permeability of these samples were monitored for 90 days. The results of the durability testing are also presented in Table 1.

The soil laboratory testing report is presented in its entirety within Appendix B.
4.0 CONCLUSION

It is concluded that:

A) A blend of three percent bentonite (IMC Slurry Gel 125) by dry weight with native material obtained either from the line of the upgradient containment wall, or from the Project borrow pit, will produce a containment wall backfill matrix having an initial permeability no greater than $1 \times 10^{-7}$ cm/sec.

B) The bentonite/soil matrix as described in A) above exhibited a general decrease in permeability over time when Plant Site groundwater was used as the permeate. This is true for both no hydration and prehydration of the design soil/bentonite matrix prior to the addition of the Plant Site groundwater permeate.

C) The soil/bentonite containment wall design mix will meet the specifications of the Technical Appendix to the Consent Judgment for the environmental securement of the Velsicol Chemical Corporation Plant Site in St. Louis, Michigan.
All of Which is Respectfully Submitted,
CONESTOGA-ROVERS & ASSOCIATES LIMITED

Richard G. Shepherd, P. Eng.

Frank A. Rovers, P. Eng.
APPENDIX A

SECTIONS 6, 7, AND 8
AND
FIGURES 2A & 2B

TECHNICAL APPENDIX

CONSENT JUDGMENT
6. Velsicol shall submit, for review and subject to approval by EPA and Michigan, plans, specifications and methods and techniques of emplacement for continuous containment walls along the entire boundary of the main Plant Site to control the infiltration of groundwater through, and abate the further migration of contaminants from, the main Plant Site. The containment walls shall be constructed within Velsicol property lines of the main Plant Site, as shown in attached Figures 1 and 2. Upon approval Velsicol shall construct and install said containment walls in accordance with such plans, specifications and methods and techniques of emplacement. Such plans and specifications shall include but not be limited to the provisions detailed in Exhibit D, Containment Wall Specifications. The containment walls shall be constructed to a minimum thickness of twenty-one (21) inches (nominal 24 inches) of suitable bentonite soil mixture, or equivalent, achieving a permeability of $1 \times 10^{-7}$ cm/sec, or less, and shall be keyed a minimum of thirty (30) inches (nominal 36 inches) into the underlying till layer. If sand lenses having a minimum thickness of 4 inches are found along the containment wall route, the wall shall be keyed to a minimum of thirty (30) inches (nominal 36 inches) into the underlying till layer beneath such sand lenses. Soils excavated along the containment wall route shall be visually examined by the supervising Engineer in consultation with representatives of EPA or Michigan and, if determined to be unsuitable for slurry wall construction, shall be removed for disposal upon the plant site within the containment walls.

7. The plans and specifications which Velsicol is required to develop pursuant to Paragraph 6, above, shall include provisions for pre-construction borings and core samplings (or backhoe excavation and sampling), chemical testing along the line of the upgradient wall, and construction quality control and field testing methods. Such activities shall be designed to locate sand lenses, to locate contaminated soils on the line of the upgradient wall, and to assure proper design and construction of the containment walls. Chemical testing of soil for HBB, PBB, total DDT and Tris shall be conducted along the line of the upgradient wall at one hundred and fifty (150) foot intervals at depths below one (1) foot, using the protocols defined in Exhibit C, Analytical Protocols for HBB, DOT, PBB and Tris. The top of the till and consistency of the till to a depth of thirty-six (36) inches shall be defined by bore hole testing with visual definition and logging of the spoon sampling (or backhoe excavation with visual definition and logging of the open excavation) at 150 foot centers along the line of containment wall construction.
Velsicol shall excavate that soil lying between the containment wall and adjacent roadways owned by the City of St. Louis (Watson Street, Center Avenue, Washington Avenue and North Avenue) to a one (1) foot depth and shall dispose of such soils upon the plant site within the containment walls. Soil below such one (1) foot depth lying between the containment wall and adjacent roadways owned by the City of St. Louis, shown on Figure E-1 to Exhibit E, Storm Sewer System, which is assumed to contain significant levels of chemical contamination (as determined by EPA, Michigan and Velsicol following chemical testing along the line of the upgradient containment wall), shall be excavated and disposed of by Velsicol upon the plant site within the containment walls. The maximum depth of excavation shall be to the top of the water table.

In the area where private property abuts the main Plant Site, Velsicol shall, if granted permission by the owner of such property, excavate that soil lying within the drainage area of the storm sewer on the private property on Watson Street, and that soil lying within the limit of fifty (50) feet outside the Plant Site on the private property adjacent to the northeast corner of the main Plant Site, as shown on Figure E-2, Exhibit E, Storm Sewer System, to a depth of one (1) foot and shall dispose of such soil upon the plant site within the containment walls. Soil below such one (1) foot depth lying between the containment wall and both the limit of drainage of the storm sewer and the limit of fifty (50) feet outside the main Plant Site, as shown on Figure E-2 to Exhibit E, Storm Sewer System, which is assumed to contain significant levels of chemical contamination (as described by EPA, Michigan and Velsicol following chemical testing along the line of the upgradient containment wall) shall be excavated by Velsicol, if it is granted permission by the Owner of such property, and disposed of by Velsicol, within the containment walls. The maximum depth of excavation shall be to the top of the water table.

All such excavated areas shall be backfilled with imported fill, and where appropriate, with topsoil, and shall be seeded or sodded.

8. The following testing procedures shall be utilized to determine the adequacy of the containment wall material with respect to durability and permeability both during and subsequent to installation, and to ensure that proper mixture ratios, blending and injection rates are maintained during containment wall installation:

a) Durability Testing

The testing procedure to determine the durability of the containment wall material to maintain a permeability of
1 \times 10^{-7} \text{ cm/sec}, \text{ or less, as well as predict the expected in situ life of the containment wall shall be as follows:}

1) Prepare four permeameter specimens: two by mixing the selected grade of bentonite at the design mix ratio with native material obtained from borings taken along the line of the containment wall, and two by mixing the selected grade of bentonite with the imported fill.

2) Prepare permeameter specimens of 1) by dehydrating with water for 13 days.

3) Prepare duplicate permeameter specimen of 1) without prehydration with water as per 2).

4) Under the falling head permeability test, set up in accordance with ASTM D 2434, add groundwater from the main Plant Site to the permeameter specimens of 1), 2), and 3) and monitor the permeability for 90 days. Analysis of the data shall be carried out as outlined in the reference text "Laboratory Soils Testing", Department of Army Engineering Manual EM-1110-2-1906.

5) Native material from the route of the containment wall, where native material is to be used in containment wall construction, shall be obtained from two bore hole locations jointly agreed to by Velsicol and EPA/Michigan. Imported fill material from the imported fill site location for use in containment wall construction shall be obtained from two bore hole locations jointly agreed to by Velsicol and EPA/Michigan. At each location at the main Plant Site, continuous split spoon samples shall be taken from the surface to a point three feet below the top of the clay till. At each location at the imported fill site continuous split spoon samples shall be taken through the depth of the soil deposit to be used. The material contained with each continuous sample shall be thoroughly blended prior to the addition of bentonite.

6) Plant site groundwater shall be collected from existing on-site wells. The groundwater to be used in this testing procedure shall be approved by EPA/Michigan prior to initiation of the test.

b. Permeability Testing

The testing procedure to determine the permeability of the design mix for the containment wall backfill shall be as follows:
1) From four locations agreed to by Velsicol and EPA/Michigan, along the route of the containment wall continuous samples of native material shall be obtained. In addition, imported fill samples shall be obtained from four locations at the imported fill site. The soil samples shall be continuous from the ground surface to a point three (3) feet below the top of the clay till at the main Plant Site, and from the surface through the depth of the soil deposit to be used at the imported fill site.

2) Each continuous sample shall be thoroughly blended prior to addition of bentonite. A grain size analysis shall be performed on each blended sample in accordance with ASTM D 422-63 as reapproved in 1972.

3) Bentonite shall be blended with each sample at the specified design ratio.

4) One triaxial consolidation test, set up in accordance with ASTM D 2580 with samples saturated, shall be performed on a portion of each sample to determine permeability. Calculations of test results shall be carried out as outlined in the reference text "Laboratory Soils Testing", Department of Army Engineering Manual EM-1110-2-1906.

c. Construction Testing

1) From each 500 lineal feet of installed containment wall, a triaxial consolidation test to determine permeability, set up in accordance with ASTM D 2850 with samples saturated, shall be performed. Well corings for testing purposes shall be collected within seven to ten days of backfill placement. Calculations of test results shall be as specified in subparagraph 8.b.4, above.

2) Slump cone tests, carried out in accordance with API-RP-13B, shall be performed during construction at the rate of one test for each twenty-five (25) cubic yards of backfill mix.

3) Gradation tests for determination of plastic fines contents (passing the #200 sieve) shall be performed at the rate of four (4) tests per eight (8) hour shift.

4) A Methylene Blue Test, carried out in accordance with API-RP-13B, shall be performed four (4) times each eight (8) hour shift on backfill mixture samples selected at the same time as the gradation test.
5) Slurry samples which shall be pumped from the bottom of the trench, and backfill samples from mix being added to the trench, shall be tested for unit weight, in accordance with API-RP-13B, at least once each hour of the working shift.

d. Post Construction Testing

Following installation, falling head laboratory testing, set up in accordance with ASTM D 2434, on a single collected sample of the installed containment wall shall be done every three (3) months for thirty-six (36) months to evaluate maintenance of a permeability of $1 \times 10^{-7}$ cm/sec., or less. Analysis of the data shall be carried out as specified in subparagraph 8.a.4, above.
SECURITY FENCE ON VELSICOL EASTERN PROPERTY LINE

PRIVATE PROPERTY

VELSICOL PROPERTY

CLAY SEAL

CLAY WORKING PLATFORM (PERM. 4 x 10^{-7} cm/sec.)

12' MIN.

6' MIN.

ALLUVIAL DEPOSITS OR FILL

MATERIAL OF PERMEABILITY EQUAL TO 1 x 10^{-7} cm/sec. OR LESS

TRENCH LINE FOR CONTAINMENT WALL

18" to 21" Ø STORM SEWER

GRANULAR FILTER BEDDING & BACKFILL

TILL

24" NOMINAL

figure 2A
UPGRADIENT CONTAINMENT WALL & STORM SEWER CROSS SECTION
St. Louis Plant Site
CLAY WORKING PLATFORM (PERM. $\leq 1 \times 10^{-7}$ cm/sec.)

TRENCH LINE FOR CONTAINMENT WALL

MATERIAL OF PERMEABILITY EQUAL TO $1 \times 10^{-7}$ cm/sec. OR LESS

ALLUVIAL DEPOSITS OR FILL

figure 2B

DOWNGRADIENT CONTAINMENT WALL

St. Louis Plant Site
Conestoga-Rovers & Associates Limited
651 Colby Drive
Waterloo, Ontario, Canada N2V 1C2

Attn: Mr. Rick Shepard

Subject: Bentonite Study
Velicol Chemical Corporation
St. Louis, Michigan

Gentlemen:

As requested, we have completed a study on the bentonite materials proposed for use during the containment wall construction on the above project.

The results of our study are to be found in the accompanying report, three copies of which are being transmitted herewith.

If there are any questions, please do not hesitate to call.

Very truly yours,

MICHIGAN TESTING ENGINEERS, INC.

Randall K. DeRuiter
Branch Manager

James H. Standen, P.E.
Division Manager

RKD/dgd
BENTONITE STUDY
PROPOSED CONTAINMENT WALL CONSTRUCTION
VELICOL CHEMICAL CORPORATION
ST. LOUIS, MICHIGAN

CONESTOGA-ROVERS & ASSOCIATES LIMITED
651 COLBY DRIVE
WATERLOO, ONTARIO, CANADA N2V 1C2

NOVEMBER 9, 1982
BY
MICHIGAN TESTING ENGINEERS, INC.
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Report of Soil Analysis - Figures 1 thru Figure 8
Permeability Graphs - Figure 9 thru Figure 16
SYNOPSIS

An evaluation of the proposed bentonite-soil mixture to be utilized for construction of the containment wall at the Velicol Chemical Company in St. Louis, Michigan has been conducted. This testing was conducted by Michigan Testing Engineers with the cooperation of International Minerals and Chemical Corporation.

Soil test borings have been drilled and the soil samples subjected to laboratory tests. The data has been carefully analyzed and the following conclusions made.

1) Addition of 3% Slurry Gel #125, produced by International Minerals and Chemical Corporation, to both the native material from the alignment of the containment wall and the proposed borrow materials from the project borrow pit will produce a containment wall backfill material with a permeability of less than $1.0 \times 10^{-7}$ cm/sec.

2) Prehydration of the soil-bentonite mixture prior to addition of plant site ground water has no apparent effect on the permeability of the mixture.

3) There is a decline in the permeability of the soil-bentonite mixture with time and therefore, it is not expected that the plant site ground water will have a detrimental effect on the permeability of proposed containment wall.

Detailed description of test methods are found on the following pages of this report.
INTRODUCTION

Authorization

This report presents the results of a laboratory investigation conducted on the proposed soil-bentonite mixture to be utilized as a backfill for the containment wall construction at the Velicol Chemical Corporation Plant Site in St. Louis, Michigan. This report was conducted for Conestoga-Rovers & Associates Limited.

Authorization to perform this investigation was in the form of a verbal agreement on May 29, 1982 between Conestoga-Rovers & Associates and Michigan Testing Engineers, Inc.

The purpose of this study was to determine the following:

A. If the proposed bentonite-soil design mix will provide a containment wall backfill material having a permeability of less than $1 \times 10^{-7}$ cm/sec.

B. If the proposed design soil-bentonite backfill material will provide a long term permeability of less than $1 \times 10^{-7}$ cm/sec when in contact with onsite ground water.

General

The conclusions submitted are based on the available soil information and the preliminary design details furnished by the Conestoga-Rovers & Associates for the proposed containment wall. Any revision in the plans for the proposed containment wall should be brought to the attention of the engineer to determine what effect the changes may have on the proposed wall.
If deviations in the subsurface conditions are encountered during construction, they should also be brought to the attention of the soils engineer.

The soil engineer warrants that the findings, recommendations, specifications or professional advice contained herein, have been prepared in accordance with generally accepted professional engineering practice in the fields of foundation engineering, soil mechanics and engineering geology. No other warranties are implied or expressed.

This report has been prepared for the exclusive use of Conestoga-Rovers & Associates, Limited for the specific application to the proposed containment wall construction, in accordance with generally accepted soil and foundation engineering practices.
General Discussion

Materials

Soil samples, designated S-1, S-2, S-3, S-4, UGW-4, UGW-9, UGW-15 and UGW-21 were collected by Conestoga Rovers & Associates Limited within the plant site property and the project borrow pit. The plant site ground water was supplied to Michigan Testing Engineers and was sampled from onsite wells by Conestoga-Rovers & Associates. The samples were labeled as composite samples from UGW-9 and UGW-15. The proposed bentonite product, Slurry Gel #125 produced by International Minerals and Chemical Corporation was supplied to Michigan Testing Engineers by the producer.

Preparation of Test Specimens

At the start of the testing program, the natural moisture content of each soil sample was determined. This test was conducted in accordance with ASTM D-2216. The moisture content of each samples are listed below:

<table>
<thead>
<tr>
<th>Sample</th>
<th>% Moisture</th>
</tr>
</thead>
<tbody>
<tr>
<td>S-1</td>
<td>14.1</td>
</tr>
<tr>
<td>S-2</td>
<td>12.2</td>
</tr>
<tr>
<td>S-3</td>
<td>12.4</td>
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<td>10.2</td>
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<td>11.1</td>
</tr>
<tr>
<td>UGW-21</td>
<td>10.6</td>
</tr>
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</table>

Utilizing this data, 3% Slurry Gel #125 was added to the test specimens based on a dry soil weight. Representative samples of the soil-bentonite mixture were selected for grain size analysis. Grain size
distribution curves for each specimen are presented in the Appendix, Figures 1 through 8. The grain size distribution of each sample was determined in accordance with ASTM D-422.

Sufficient water was added to the soil-bentonite mixture to obtain a 4 inch slump as measured by ASTM C-143. The soil-bentonite mixture was then placed in a PVC permeameter and permeability tests were conducted.

Permeability Determinations

Each soil-bentonite mixture was placed in a permeameter and the flow monitored. The testing was set-up and the permeability calculated as outlined in ASTM D-2434. The specifications for the project suggested utilizing the triaxial method of determining the permeability of the mixture. However, due to the consistency of the soil-bentonite mixture, we were unable to form a test specimen. Therefore, methods outlined in ASTM D-2434 were utilized. Results of permeability tests are tabulated below.

<table>
<thead>
<tr>
<th>Specimen</th>
<th>Permeability Of Soil-Bentonite Mixture cm/sec</th>
</tr>
</thead>
<tbody>
<tr>
<td>S-1</td>
<td>$7.6 \times 10^{-8}$</td>
</tr>
<tr>
<td>S-2</td>
<td>$9.9 \times 10^{-8}$</td>
</tr>
<tr>
<td>S-3</td>
<td>$7.9 \times 10^{-8}$</td>
</tr>
<tr>
<td>S-4</td>
<td>$7.7 \times 10^{-8}$</td>
</tr>
<tr>
<td>UGW-4</td>
<td>$8.0 \times 10^{-8}$</td>
</tr>
<tr>
<td>UGW-9</td>
<td>$9.2 \times 10^{-8}$</td>
</tr>
<tr>
<td>UGW-15</td>
<td>$8.9 \times 10^{-8}$</td>
</tr>
<tr>
<td>UGW-21</td>
<td>$8.0 \times 10^{-8}$</td>
</tr>
</tbody>
</table>
Durability Determinations

During this portion of the testing program, the effects of prehydration on the slurry was studied. Also, the long term effects of plant site ground water on the soil-bentonite slurry was investigated. This testing was conducted on samples S-2, S-3, UGW-9 and UGW-15 only. Permeabilities were determined in accordance with ASTM D-2434 and the following test procedure followed.

1. Four test specimens were prepared as described above and allowed to hydrate for 18 days. During this period, the permeability of the sample was calculated. A graph of the permeability vs-time characteristics of the specimen have been presented on Figures 9, 11, 13 and 15.

2. After the hydration period, the fluid in the permeability apparatus, fresh water, was drained and replaced with plant site ground water. The test was continued for about 72 additional days. The permeability was calculated at regular intervals. Results of the extended testing have also been present on Figures 9, 11, 13 and 15.

3. At the end of the hydration period explained in Point 1, four duplicate samples were prepared. In these tests, plant site ground water was added to the system at the start of the test and the sample not allowed to prehydrate. Flow was monitored and permeability calculated at regular intervals for a period of 90 days. Figures 10, 12, 14 and 16 present results of the testing on the unhydrated samples.
The following conclusions have been made from the results of this portion of the testing:

1. No significant variations were noted in the permeability characteristics of the hydrated -vs- unhydrated soil samples.

2. The general trend for the permeability of the samples was to decrease with time. Therefore, the plant site ground water does not appear to adversely affect the permeability of the soil-bentonite mixture.
REPORT OF SOIL ANALYSIS

Boring No.  S-1  Classification  Sandy Clay with 3% Slurry Gel #12% added

<table>
<thead>
<tr>
<th>Component</th>
<th>Coarse</th>
<th>Fine</th>
<th>Coarse</th>
<th>Fine</th>
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<tr>
<td>CUMULUS</td>
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</tr>
<tr>
<td>GRAVEL</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SAND</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Silt or Clay</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Project: Proposed Containment Wall

File No.  406-25027  Date: November 1982

Figure 1
REPORT OF SOIL ANALYSIS

Boring No. Classification  Nat w %  LL  PL  PI  Project  Proposed
S-2  Sandy Clay with 3%  —  —  —  —  Containment Wall

File No. 406-25027
Date November 1982

Figure 2
REPORT OF SOIL ANALYSIS

<table>
<thead>
<tr>
<th>Sieve No</th>
<th>Classification</th>
<th>Fine w%</th>
<th>LL</th>
<th>PI</th>
<th>PI</th>
</tr>
</thead>
<tbody>
<tr>
<td>S-3</td>
<td>Sandy Clay with 3%</td>
<td>Slurry Gel #125 added</td>
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</table>

Project: Proposed Containment Wall

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Date: November 1982

Figure 3
REPORT OF SOIL ANALYSIS

<table>
<thead>
<tr>
<th>Percentage of Material</th>
<th>COBBLES</th>
<th>GRAVEL</th>
<th>SAND</th>
<th>SALT OR CLAY</th>
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<tr>
<td>CORR.</td>
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<td>FINE</td>
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<td>MEDIAN</td>
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</tbody>
</table>

S-4
Sandy Clay with 3%
Slurry Gel #125 added

Figure 4
U. STANDARD SIEVE OPENING IN INCHES U. STANDARD SIEVE NUMBERS HYDROMETER

GRAIN SIZE IN MILLIMETERS COBBLES GRAVEL SAND Silt or Clay

PER CENT PASS BY WEIGHT

PER CENT PASS BY WEIGHT

PER CENT PASS BY WEIGHT

PER CENT PASS BY WEIGHT

Classification

Clayey Sand with 3%
Slurry Gel #125 added

Project

Proposed

Containment Wall

Boring No.

UGN-4

Nat w% LL PL FI

- - -

REPORT OF SOIL ANALYSIS

File No. 406-25027 Date November 1982

Figure 5
**REPORT OF SOIL ANALYSIS**

<table>
<thead>
<tr>
<th>Boring No.</th>
<th>Classification</th>
<th>Nat. %</th>
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<th>PL</th>
<th>PI</th>
<th>Project</th>
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</thead>
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<td>UGH-9</td>
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</table>

**File No.:** 406-25027  
**Date:** November 1982  

**Figure 6**
<table>
<thead>
<tr>
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<th>PI</th>
<th>Project</th>
</tr>
</thead>
<tbody>
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<td>UCM-15</td>
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<td>Slurry Gel #128 added</td>
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</table>

**REPORT OF SOIL ANALYSIS**

File No. 406-25027
Date November 1982

Figure 7
REPORT OF SOIL ANALYSIS

<table>
<thead>
<tr>
<th>Boring No.</th>
<th>Classification</th>
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<th>FI</th>
<th>Project</th>
<th>Date</th>
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</thead>
<tbody>
<tr>
<td>UGM-21</td>
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<td>Proposed Containment Wall</td>
<td>November 1982</td>
</tr>
</tbody>
</table>

Figure 8