L|A|W

Land Air Water Legal Solutions LLC

John P. Judge
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Mark
Ray
George

November 21, 2016

RECEIVED
NOV 23 2016
By ME

VIA U.S. MAIL
Williams Township Board of Supervisors
c/o Jennifer W. Smethers, Township Manager
Williams Township Municipal Office
655 Cider Press Road
Easton, PA 18042

Re: Chrin Brothers, Inc. Landfill Cell 3D and 3E Slope Failure Investigation

Dear Members of the Board:

On behalf of Chrin Brothers, Inc., I have enclosed a copy of the Amended Slope Failure Report prepared by Timothy D. Stark, Ph.D. The Amended Slope Failure Report supplements the investigation and analyses of the Slope Failure that was summarized in the Slope Failure Report dated July 14, 2014 and replaces that report. A copy of the letter to Roger Bellas, Waste Management Program Director for the Northeast Regional Office of the Pennsylvania Department of Environment Protection, dated November 18, 2016 is enclosed herein.

Sincerely,

John P. Judge

John P. Judge

JPJ:lsp
Enclosures
cc: Mr. Greg Chrin (w/o encs.)

L|A|W

Land Air Water Legal Solutions LLC

John P. Judge
610-898-3848
jjudge@landairwater.com

November 18, 2016

VIA ELECTRONIC MAIL AND FEDERAL EXPRESS
Mr. Roger Bellas
Waste Management Program
PADEP
Northeast Regional Office
2 Public Square
Wilkes-Barre, PA 18701-1915

Re: Chrin Brothers Sanitary Landfill ("Chrin")
Williams Township, Northampton County
Solid Waste Permit No. 100022
Cell 3D and 3E Slope Failure ("Slope Failure") Investigation

Dear Mr. Bellas:

On behalf of Chrin, I have enclosed a copy of the Amended Slope Failure Report prepared by Timothy D. Stark, Ph.D. The Amended Slope Failure Report supplements the investigation and analyses of the Slope Failure that was summarized in the Slope Failure Report dated July 14, 2014 and replaces that report.

As you know, subsequent to the completion of the Slope Failure Report, Chrin has made several submittals to the Department pertinent to the Slope Failure and/or in response to specific information requests made by the Department. These submittals were made under cover letter from this office dated:

1. August 4, 2016;
2. May 11, 2016;
3. October 23, 2015; and
4. October 1, 2015.

Copies of those letters of transmittal are attached to this letter.

In addition, as you know, Dr. Stark and Chrin representatives met with the Department and the Department's consulting engineers, AECOM at the Department's offices on August 14, 2015 and at the site on September 3, 2015, May 11, 2016 and September 1, 2016. AECOM representatives also toured the site on December 14, 2015. At the September 1, 2016 meeting Dr. Stark gave a Power Point presentation of the findings of the investigation. Copies of the presentation slides were distributed to the Department and AECOM at that meeting.

Chrin and Dr. Stark welcome the opportunity to respond to any of the Department's inquiries and comments concerning the Amended Slope Failure Report.

Via separate letter, Chrin is providing a courtesy copy of this letter and the Amended Slope Failure Report to Williams Township. Chrin will address any questions the Township Board of Supervisors and/or the Township Engineer may have.

Thank you for your consideration.

Very truly yours,

John P. Judge

JPJ:lsp
Enclosure
cc: via email only w/encl.:
David Buzzell, Esq.
Timothy Stark, Ph.D.
Gregory Chrin
Jason Dunham

Amended Slope Failure Report:

March 12, 2013 Chrin Brothers, Inc. Landfill Slope Failure

Submitted to the Pennsylvania Department of Environmental Protection Northeast Region Office

November 18, 2016

Timothy D. Stark, Ph.D., P.E., D.GE, F.ASCE
Stark Consultants, Inc.
P.O. Box 133
Urbana, IL 61801

SCI
Stark Consultants Inc.

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1. INTRODUCTION

This amended slope failure report has been prepared for the Pennsylvania Department of Environmental Protection (PADEP) in response to a directive to the Chrin Brothers Sanitary Landfill to prepare an assessment for the PADEP of the "root cause" of the landfill slope failure that occurred in Stages 3D and 3E of the Landfill on 12 March 2013. This report outlines my investigation, analyses, and conclusions regarding the "root cause" of the 12 March 2013 slope failure and summarizes information and analyses specifically requested by PADEP.

This report incorporates the additional work, observations, testing, and analyses that have been conducted as a result of the ongoing investigation of the slope failure since the Slope Failure Report that was published on 15 July 2014 ("Initial Report"). These activities have been conducted during the continuing excavation of the waste mass and removal of some of the liner system components. At the time of publishing this Amended Report, the entire length of the sideslope area in Stage 3E and a portion of the sideslope and waste bowl in Stage 3D have been excavated. A section that is about 400 feet wide from the Anchor Trench to the East was excavated all of the way down to the bottom of the waste bowl in Stage 3D. As a result, the bottom liner system, i.e., the liner system underlying the slide mass, has been exposed over the entire length of the slope along the southern side of the slide mass.[1] As of the date of this report, it is estimated that approximately 112,000 cubic yards of MSW of the estimated 812,000 cubic yards that comprised the slide have yet to be excavated. The remaining MSW (14 % of the total slide) is located in the "bowl" area.

The additional work that has been conducted since July 2014 confirm the Findings presented in Section 4.0 of the Initial Report that I prepared.

I have conducted over twenty landfill slope failure investigations. I have also investigated over 50 other failures of engineered slopes. My one-page *curriculum vitae* is attached in Appendix "A".

2. STAGE 3D AND 3E SLIDE AND BACKGROUND INFORMATION

The Chrin Brothers Landfill began in 1961 and has 108 acres permitted for solid waste disposal and support areas. The site is permitted to accept 2,000 tons of municipal solid waste (MSW) per day and a quarterly average of 1,500 tons of MSW per day. The landfill operates six days per week and 82% of its waste is generated in the Greater Lehigh Valley.

At some time after 20:00 hours on 12 March 2013, approximately 12.2 acres of the landfill slope in Stages 3D and 3E of the Chrin Landfill moved downslope to the northwest. On average, the slide mass has an average waste depth of 38 feet and moved about 73 feet downslope with a bearing of about 296 degrees. The magnitude and direction of movement was determined from the movements of existing gas wells as discussed below. The slide mass is estimated to involve approximately 812,000 cubic yards of MSW. An aerial photograph of the slide mass is shown in **Figure 1**.

Construction of Stages 3D and 3E started in 2002 and 2004, respectively, and was completed and certified in 2003 and 2005, respectively. At the bottom of the slope a bowl was excavated into bedrock using blasting. Stages 3D and 3E accepted an average of between 675 and 1,003

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[1] For the purposes of this report and to correlate with the terminology in Stark and Poeppel (1994), the bottom liner system consists of the liner system on the sideslope in Stages 3D and 3E and the nearly flat area at the bottom of the waste bowl in Stage 3D.

tons per day of waste on an annual basis from 2003 to 2008. The final geosynthetic composite cover system was installed over Stages 3D and 3E from 2006 to 2008. In December, 2009, a temporary cover for the area upslope of the Stage 3E slide area was installed to mitigate odors. This cover had the effect of inhibiting precipitation and runoff from entering the top of the landfill into the final covered waste in Stage 3E. The temporary cover extends 12 to 18 inches downslope of the anchor trench for the final cover system in Stages 3D and 3E. As a result, precipitation and runoff from the top of the landfill was inhibited from entering the waste in Stage 3E especially due to the compacted low hydraulic conductivity clayey soil used to backfill the anchor trench for the final cover system geosynthetics.

After the final cover installation was complete, the cover performed well and sealed the waste. After final covering some minor cracks and surface subsidence was observed, which is typically encountered in most landfills. No problem or failure in the final cover system was identified until mid-September 2011 as discussed below.

3. INVESTIGATION METHODOLOGY

This section outlines the methodology used to investigate the 12 March 2013 slope failure. The principal component of the investigation is the development of a slope stability model for Stages 3D and 3E that represents the slope conditions prior to failure on 12 March 2013. To develop the slope stability model, the following information was collected: ground surface topography; liner system elevations; location and geometry of the waste overlay area in Stages 3A, 3B, 3C, 3E, and 4; engineering properties of the waste, cover system and liner system components; various ground motion recordings created by the 2011 Central Virginia Earthquake; landfill gas properties and temperatures; and leachate levels.

Several cross-sections of the landfill slope (see Cross Sections 1 through 7 and F in **Figure 2**) were then developed to estimate the factor of safety for using a variety of failure surfaces and input parameters. Based upon field observations and interface shear strengths measured in laboratory testing of liner system components, a critical slip surface for each cross-section was identified in the area of principal slope movement to calculate the factors of safety. The laboratory interface shear tests were performed on the undisturbed samples of the geosynthetic liner system components and accompanying soils (compacted clayey subgrade and granular drainage media) that were obtained outside of the slide mass. The results of the interface shear testing and analyses were used in the development of the slope stability model discussed herein. Appendix B presents supporting information for the results and conclusions presented in this report. Appendix B contains **Figures B-1** through **B-26** all of which are specifically referenced below.

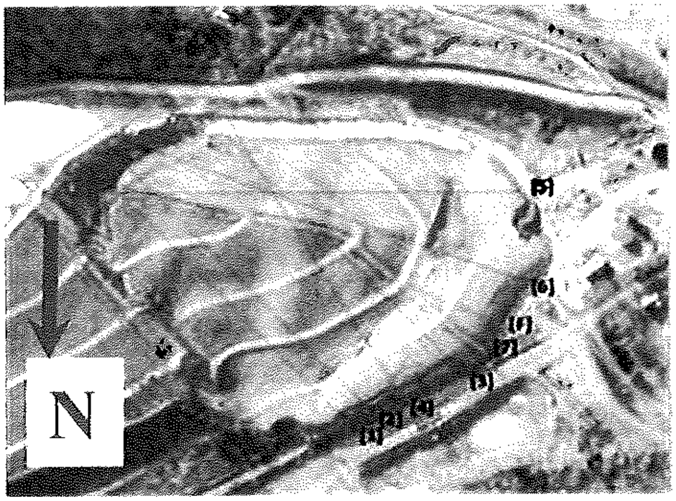

Figure 1: Aerial photograph of slide mass and cross-sections considered.

3.1. Liner Sampling and Analytical Methods

During waste excavation, the liner system geosynthetics were exhumed, inspected, and found to be significantly damaged within the slide area and adjacent to anchor trenches as shown in **Figure B-1**. Laboratory testing of the damaged geosynthetics would not yield meaningful results in the pre-failure slope stability model so undamaged geosynthetics were sought during the liner exhumation process. To obtain geosynthetics representative of pre-slide conditions, samples of the liner system components were obtained from areas just upslope and outside of the slide area and in the anchor trench along the toe of the slide mass. In the areas excavated to date, undamaged geosynthetics have been obtained just upslope of the slide mass and from the anchor trench along the northwest and northeast perimeters of Stage 3D. These locations are identified in **Figure B-2**. The process of obtaining undamaged samples just upslope of the slide mass is pictured in **Figure B-3**.

These undamaged samples of liner system geosynthetics and various soil samples, e.g., compacted clay subgrade and leachate collection and removal granular media, were tested by state-of-the-art and accredited testing laboratories for the following engineering properties: peak, large displacement, and residual geosynthetic interface and material shear strengths, asperity height, unit weight, and drainage media and subgrade soil index properties. The municipal solid waste excavated during the slide remediation effort was subjected to waste composition, moisture content, and unit weight testing.

Since publication of the Initial Report on 15 July 2014, PADEP has requested additional information and analyses of certain factors. Responsive information was provided to the PADEP under separate cover and is included in summary fashion in this Amended Report.

3.2. Slope Stability Model Development

Following review of the design and construction documents, site inspections, and laboratory testing, a slope stability model was developed to represent the slope conditions in Stages 3D and 3E prior to the 12 March 2013 failure. Data from the physical testing of the liner system components and waste mass were used to develop the input parameters for the slope stability model and confirm the conclusions drawn from the inverse analysis of the slope failure in my Initial Report dated 15 July 2014.

Static and dynamic limit equilibrium and continuum analyses were performed using the slope stability model to investigate the "root cause" of the slope movement and the factors that significantly contributed to the 12 March 2013 slope failure. Specifically, the effect of the following parameters has been investigated in the analysis: geosynthetic interface shear strength, subgrade soil and granular media stone, shear strength and unit weight, waste strength and unit weight for the wastes overlying and underlying the bottom liner system, leachate level, gas pressure, waste temperature, precipitation data, and slope geometry.

4. FINDINGS:

This section presents my findings of the "root cause" investigation for the 12 March 2013 slope failure. Appendix B presents supporting information for the results and conclusions presented in this section.

4.1. Slope Geometry and 12 March 2013 Slope Failure

The aerial photograph in **Figure 1** shows Stages 3D and 3E after the 12 March 2013 slope movement and the location of various cross-sections (labeled 1-7 and F) used to investigate the slope failure. (An enlarged version of **Figure 1** is reproduced in Appendix B as **Figure B-4**). **Figure B-5** illustrates the direction of movement of the slide mass as estimated from the comparison of pre- and post-slide movement of gas well heads and sideslope leachate primary collection risers, which guided the location and orientation of the cross-sections.

The slope cross-section shown in **Figure 2**, which is cross-section F in **Figure 1**, is indicative of the critical cross-section because it is in the direction of movement and yields the lowest static factor of safety. The green area in the cross-section in **Figure 2** is the 2013 slide mass. The waste in this area has been or is being excavated and relocated to the active area of the Landfill; the dashed red line is the 2013 failure surface that primarily parallels the geosynthetic bottom liner system in Stages 3D and 3E; the brown area is waste placed on the liner system that is still remaining above the slide area at the top of the slope; the olive green area is the old waste underlying the geosynthetic bottom liner system installed in Stages 3D and 3E; and the grey area is the bedrock and soil foundation underlying the above materials. **Figure 2** also shows the majority of the bottom liner system consists of a sideslope liner system and a small flat area at the bottom of the waste bowl in Stage 3D. The sideslope and flat portion are consistent with the terminology used in Stark and Poeppel (1994).

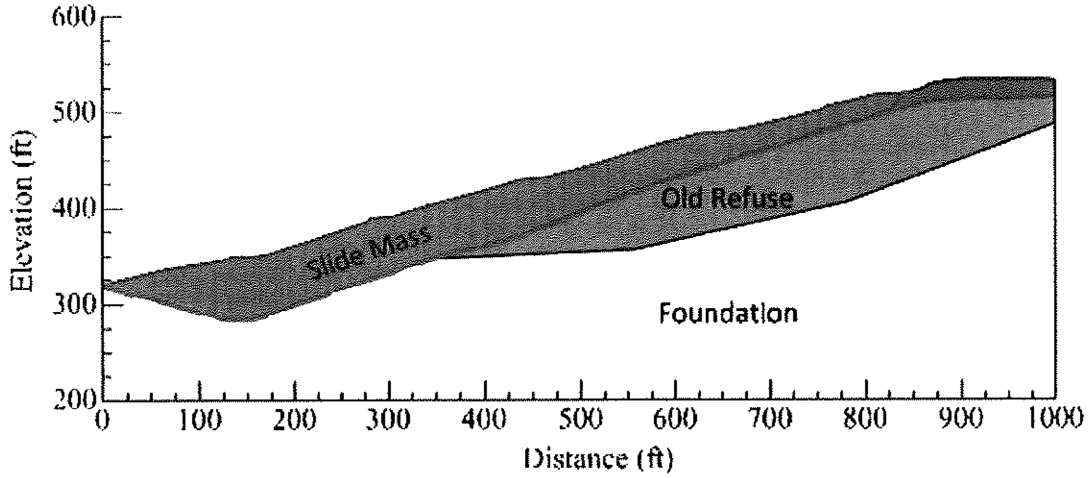

Figure 2: **Representative cross-section of slope prior to failure.**

A significant change in the liner system subgrade topography is present at the eastern edge of the slide mass and limited the slide from extending further east, i.e., into the remainder of Stage 3E. **Figure B-6** illustrates the subgrade topography in the eastern edge of the slide mass in Stage 3E flattens significantly so that the slide mass is confined to the areas of Stages 3D and 3E as shown in **Figure 1**. Bottom liner system contour elevations and subgrade topography used to construct the slope stability cross-sections 1 through 7 and F are shown in **Figures B-7(a)** and **B-7(b)**, respectively. **Figure B-8** shows that part of the slide mass overlies previously disposed waste in Stages 3A, 3B, 3C, 3E, and 4. However, none of this old waste was involved in the 2013 slope failure because the failure surface did not extend below the geosynthetic bottom liner system in Stages 3D and 3E.

4.2. Critical Failure Surface and Failure Mechanism

This section presents my findings on the critical failure surface for the 12 March 2013 slope failure.

4.2.1 Critical Failure Surface

Based on the slide investigation and exhumation of the geosynthetic bottom liner system, the primary 2013 slope movement occurred between the top of the secondary geomembrane and bottom of the overlying geosynthetic drainage composite within the slide area. Except as discussed below in Section 4.2.2, the failure surface is confined to the bottom liner system and this interface.

Figure 3 (also enlarged as **Figure B-9**) shows a cross-section and photograph of the geosynthetic liner system installed in Stages 3D and 3E. The secondary geomembrane is the bottom geosynthetic and is overlain by the leak detection geosynthetic drainage composite and was the critical interface for the slide mass (see red arrow in **Figure 3**). With proper design, a textured HDPE geomembrane and nonwoven geotextile interface (see red box in **Figure 3**) can be one of the strongest interfaces in a typical composite geosynthetic liner system due to the "Velcro" effect between the texturing and nonwoven fibers of the geotextile (Stark et al., 1996).

In summary, **Figure B-10** shows the exposed secondary geomembrane is still intact after waste excavation and removal of the other liner system components that moved downslope. Some of the observations confirming the critical interface are the liner system components above the critical interface tore at the top of the slope (see **Figure B-11)** and along the anchor trench, significant striations were visible on the top of the textured secondary geomembrane, and the texturing of the secondary geomembrane was either significantly worn down or completely removed by the friction of the sliding layers above it (see photo on right in **Figure B-1**). This information reinforces that the critical interface is the bottom of the leak detection geosynthetic drainage composite/top of the secondary geomembrane interface. In other words, the liner system components and waste above the geosynthetic drainage composite/secondary geomembrane interface moved downslope leaving only the secondary geomembrane still on the slope and intact. This leads to the following important conclusions about the 12 March 2013 slope failure:

- Shear movement did not occur below the secondary geomembrane in the compacted clayey subgrade or the underlying old waste; otherwise the secondary geomembrane would have been disturbed;
- The old waste underlying Stage 3E and compacted soil and bedrock underlying Stage 3D were not involved in the slide so the factors of safety computed herein are independent of the shear strength of these materials;
- The secondary geomembrane is below the primary geomembrane, GCL, and leak detection drainage geocomposite so this interface is not directly impacted by hydraulic head within the leachate above the primary geomembrane. More importantly, the geosynthetic interface test results discussed below show the secondary geomembrane/leak detection geocomposite interface is not sensitive to soaking;
- The secondary geomembrane is also not directly impacted by precipitation because it is encapsulated by the underlying low hydraulic conductivity compacted clayey subgrade, the water levels in surrounding groundwater monitoring wells (EarthRes Engineering and Sciences (2016)) are below the bottom liner system, and the overlying primary geomembrane prevents most of the leachate generated within the overlying waste from reaching the top of the secondary geomembrane; and
- The secondary geomembrane is also not directly impacted by leachate generated from the underlying old waste because it is separated by a compacted low hydraulic conductivity clayey subgrade that prevents upward migration of the old leachate. This was confirmed at every location that the secondary geomembrane was removed or damaged because no leachate staining or sediment from either the witness detection zone or underlying old waste was found on the surface of the compacted clayey subgrade.

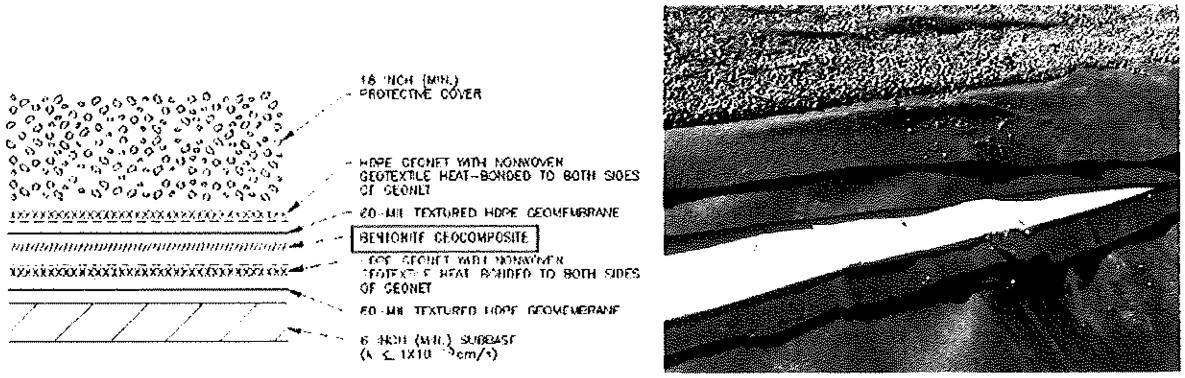

Figure 3: **Cross-section of liner system in slope failure area and photograph of liner system components after waste excavation.**

4.2.2 Limited Areas of Other Failure Surfaces

At the top of the slope, the failure surface also passed through the MSW overlying the bottom liner system (see scarp in **Figure 1** and failure surface in **Figure 2**). A close-up photograph of the exposed waste above the bottom liner system at the top of the slope is shown in **Figure B-12.** The waste was exposed at the top of the slope for a maximum height of about 40 feet and a width of about 530 feet across the upper portion of Section 3E. The critical failure surface in this area is still the secondary geomembrane/geosynthetic drainage composite interface. **Figure B-11** shows the torn geosynthetics above the secondary geomembrane at the top of the slope just below the scarp shown in **B-12.**

During the waste excavation and careful liner removal conducted since 15 July 2014, it was observed that in isolated areas, the shear movement may have shifted from the geosynthetic drainage composite/secondary geomembrane interface to another interface. These kinds of shifts typically occur due to slope geometry and liner system geometry effects, e.g., changes in subgrade topography, steepness and geometry of the excavated waste bowl, variability in geosynthetic properties, e.g., geomembrane texturing, changes in the overburden stress, among other factors. This is in agreement with observations presented in Stark and Poeppel (1994) that show the critical interface in a geosynthetic liner system can change due to slope geometry and changes in the applied normal stress on the failure surface.

Some of the interfaces where localized/isolated movement was observed during the exhumation process include: secondary geomembrane/compacted clayey subgrade, which locally damaged the secondary geomembrane (see **Figure B-13**), geosynthetic drainage composite/primary geomembrane interface (see **Figure B-14**), and primary geomembrane/geosynthetic clay liner (GCL) interface (see **Figure B-15**). Movement on these other interfaces was observed only as a localized phenomenon and limited to areas of Section 3D in the lower one-third of the slope and in areas along the anchor trench on the southern side of the slide mass. In all instances where this observation was made, the different shear movement interface was attributed to slope and liner system geometry effects, e.g., changes in subgrade at the sides of the waste bowl and slide mass, differences in texturing of the primary and secondary geomembranes, and the large downward force being applied by the sliding waste mass as it moved down slope and encountered significant changes in subgrade geometry. The excavated bowl at the bottom of the slope served as a buttress and caused the sliding waste mass to move clockwise, causing deformation, twisting, and tearing in all of the layers of the bottom liner system. As the last bit of remaining waste is excavated from the slide area (see **Figure B-16**), the critical interface will continue to be evaluated through the waste bowl at the toe of the slope. However, based on the observations to date, I do not expect that there will be any new findings related to the overall critical interface, i.e., geosynthetic drainage composite/secondary geomembrane interface.

4.3. Laboratory Interface Shear Test Results

Laboratory direct shear tests were conducted on undamaged geosynthetics obtained from just outside of the slide area to evaluate the shear resistance of the bottom liner system. **Figure B-2** shows the three locations where undamaged geosynthetics have been obtained. The laboratory direct shear tests were conducted in accordance with ASTM D5321 and ASTM D6243. Single and multi-interface tests were conducted on some of the samples. The direct shear tests were continued to a shear displacement of about three (3) inches so the mobilized strength at the end of the test is referred as a large displacement strength and not the residual strength (Stark and Choi, 2004). These test results indicate the leak detection geosynthetic drainage composite/secondary geomembrane interface exhibits a stress dependent strength envelope as do most geosynthetic interfaces.

The direct shear results for the leak detection geosynthetic drainage composite/secondary geomembrane interface are summarized in **Table 1** for a normal stress of 2,000 psf, which is close to the average normal stress acting along the critical interface. The data sheets from the Stage 3D and 3E specific direct shear testing are shown in **Figure B-17**.

The test results indicate a peak friction angle at an effective normal stress of 2000 psf of 22 to 35 degrees depending on the samples tested. The test results also indicate a large displacement (3 inches) friction angle at an effective normal stress of 2000 psf of 13 to 21 degrees. The large displacement test results were used to estimate the residual interface strengths for the secondary geomembrane/drainage composite interface for use in the stability analyses as described in Stark and Choi (2004).

Table 1: Summary of laboratory geosynthetic interface testing for Stages 3D and 3E.

Geosynthetic Interface Tested	Sample Number & Test Type	Moisture Condition	Normal Stress (psf)	Peak Friction Angle (degrees)	Large Displacement Friction Angle (degrees)
Geosynthetic drainage composite/secondary geomembrane	IF-7-02 – Single Interface	As-received	2,000	24	17
Geosynthetic drainage composite/secondary geomembrane	IF-7-05 – Single Interface	Soaked	2,000	24	15
Geosynthetic drainage composite/secondary geomembrane	IF-8-02 – Single Interface	Soaked	2,000	35	20
Geosynthetic drainage composite/secondary geomembrane	IF-4-6 – Multi-Interface	As-received	8,800	26	16

4.4. Possible Causes of Slope Failure

A number of possible causes of the 12 March 2013 slope movement were considered in this investigation including:

- Inadequate design, CQA/CQC material conformance testing, or construction
- Shear strength reduction of bottom liner system components
- Inadequate geosynthetic liner system materials
- Landfill operation and management
- Excavation along the slope toe
- Precipitation Runoff
- Precipitation
- Waste moisture content, unit weight, and shear strength
- Leachate generation
- Leachate recirculation
- Gas pressures
- Elevated waste temperatures
- Subgrade materials and geology
- Seismic events
- Placement of new waste over old refuse

Based on an evaluation of these possible causes of the 12 March 2013 slope movement, the root cause was determined and is presented in the next section.

4.5. Root Cause of Slope Failure

The root cause of the 12 March 2013 slope movement is attributed to inadequate static and seismic slope stability design, incorrect assessment of the critical geosynthetic interface strength for the bottom liner system, absence of testing and inadequate specification of the liner system components, and inadequate construction material conformance testing to ensure the materials provided achieved the parameters used in the static and seismic slope stability design. Specifically, the root cause of the slope movement was due to the issues identified below:

- Inadequate design and stability analyses for Sections 3D and 3E, which did not accurately model all possible failure modes for the installed liner system components, such as a failure surface remaining in the bottom liner system along the sideslope and waste bowl;
- Incorrect assessment of the geosynthetic interface strength(s) that would be mobilized along the sideslope and waste bowl for static and seismic slope design;
- No design shear testing was performed to measure and then model the appropriate liner system interface and material shear strengths in the original permit application stability analyses;
- Inadequate specification of geosynthetic materials, such as specification of geomembrane asperity height and/or interface shear strength, to achieve the slope design;
- Inadequate manufacture of geosynthetic materials, such as manufacturing geomembrane with insufficient asperity height, texturing, and/or interface shear strength, for this readily apparent steep sideslope;
- Inadequate construction conformance testing because of a lack of shear strength testing to determine whether or not the supplied geosynthetics would yield the assumed/required design shear strength parameters.

This opinion is based on my review of design and construction documents, site history, geologic setting, operational history, landfill performance, e.g., gas and leachate data, field observations, post-slide liner system investigation, exhumation, testing, static and dynamic analyses, and research on the stability of geosynthetic lined slopes.

4.6. Evaluation of other Possible Causes

Each of the following possible causes of the 12 March 2013 slope movement were evaluated and dismissed for the following reasons:

- **Landfill operation and management** – Stages 3D and 3E were closed areas. No significant operations had occurred or were occurring in this area following final closure in 2008. The only regular activity in this area was grass mowing and routine gas well monitoring;

- **Excavation along the slope toe** – Prior to the slope failure there is no recorded or observational evidence of a slope toe excavation. The final cover was installed and intact for over 5 years as shown in **Figure B-18**, which shows photographs taken in December 2012 and March, 2013, prior to the slide, along the access road at the slope toe and shows no excavation;

- **Precipitation Runoff and Infiltration**- Infiltration into waste mass prior to and after placement of final cover system was considered. **Figure B-19** shows the temporary cover for the area upslope of the slide area extending 12 to 18 inches downslope of the anchor trench for the final cover system in Stages 3D and 3E. As a result, precipitation and runoff from the top of the landfill could not enter the final covered waste in Stage 3E especially due to the compacted low hydraulic conductivity clayey soil used to backfill the anchor trench for the final cover system geosynthetics (see **Figure B-19**). This temporary cover was installed in December, 2009 or about 605 days prior to the 23 August 2011 earthquake and well before the 12 March 2013 slope failure. This temporary cover system is still in-place and functioning in areas above the slide mass. Saturation of the vegetative cover soil in the final cover system due to heavy rainfall and a consequential increase in the unit weight of the cover soil was considered. However, this potential small increase in unit weight of the final cover soil did not sufficiently reduce the overall factor of safety of the slope. This conclusion is supported by the absence of any observable sloughing failure of the vegetative cover soil after final closure was completed.

- **Precipitation** – Analysis of precipitation data for the two years prior to the 23 August 2011 earthquake through the date of the slide, and the recorded movement of the three survey hubs, described in Section 4.7 below, demonstrates that the slope movement observed between 23 August 2011 and 12 March 2013 is independent of precipitation events;

- **Waste moisture content, unit weight, and shear strength** – No large area of high moisture content or low shear strength waste has been found during waste excavation. Test pits with known volume have been excavated (see **Figure B-20**) to sample and measure the moisture content and unit weight of the waste in Stages 3D and 3E. **Figures B-21** and **B-22** provide tables of measured waste moisture content and unit weight, respectively. **Figure B-23** shows the various locations in the slide mass where the waste has been sampled and tested. The waste moisture content ranges from 12% to 55% with an average of 33% and the average unit weight of the waste is 83 pcf (47 to 120 pcf), both of which are typical for recently placed municipal solid waste (Eid et al., 2000). In addition, vertical, stable faces have been frequently excavated in the waste and readable newspapers and magazines dating back to 2003 have been regularly found during waste excavation. These analyses and observations confirm that little moisture was available in the waste to degrade the waste and that the final cover system "sealed" the new waste from precipitation. Further, no significant leachate was observed exiting the slide mass immediately after the slope failure and during the waste removal process. Finally, survey of the final cover system shows new waste settlement of only 1 to 2 feet from 2008 to 2012, which indicates good compaction and strength of the waste overlying the bottom liner system in Stages 3D and 3E;

- **Leachate generation** – The critical interface identified during the waste and bottom liner system removal process is the top of the secondary geomembrane. This interface strength is not directly impacted by leachate within the waste and/or precipitation because it is encapsulated between the underlying compacted clayey subgrade and overlying primary geomembrane. In addition, the shear resistance of the secondary geomembrane/leak detection geocomposite interface is not sensitive to soaking as discussed below using the results of laboratory interface shear tests shown in **Figure B-17**. **Figure B-24** presents the leachate data collected by Chrin personnel from 2007 to 2014. **Figure B-24** shows the flows from the leachate collection and removal system (LCRS) are not directly influenced by precipitation because there are two significant rainfall events in late 2010 but not a corresponding increase in leachate. This is due to the final cover system shedding the precipitation and not allowing it to enter the waste mass. This lack of correlation between rainfall and leachate removal is in agreement with a landfill where the final cover system has been installed successfully. As described above, during this investigation there was no evidence of infiltration or excessive moisture in the intermediate soil cover directly underlying the final cover system geosynthetics or in the waste mass that failed. There is an unexplained increase in the LCRS flow in 2010. However, this occurred without a significant increase in precipitation. The source of this leachate flow is not known but site plans reflect that the sump from which this leachate was being pumped is influenced by other areas of the landfill besides Stages 3D and 3E. As a result, this large increase in LCRS flow in 2010 without significant rainfall could be caused by liquid flowing to this sump from an open or operating area of the landfill. Regardless, the primary geomembrane properly contained the landfill leachate as the flows measured in the witness zone are at least two orders of magnitude lower than those observed above the primary geomembrane in the LCRS. There is a small amount of flow in the witness zone (less than 35 gallons/acre/day) prior to the 23 August 2011 earthquake. This small flow is below the accepted regulatory action leakage rate of 100 gallons/acre/day (USEPA, 1992) and is not unexpected. The historical flow in the witness zone was negligible until a short time after the earthquake, when the rate increased to 31.2 gallons/acre/day. It is probable that the final cover and bottom liner systems were damaged by the earthquake and progressive failure induced permanent deformations. Neither the pre or post- earthquake levels of flow in the witness zone) impacted the shear resistance of the drainage composite/secondary geomembrane interface, as the laboratory interface test results in **Table 1** (compare the test results for IF-7-02 – As Received and IF-7-05 – Soaked) show this interface is not sensitive to soaking. All of the data for the laboratory interface test results are presented in **Figure B-17** and show the interface shear resistance of the top of the secondary geomembrane is not sensitive to soaking (see tests IF-7-01, 7-02, 7-04, 7-05, and 7-06);

- **Leachate recirculation** – No leachate recirculation was performed in Stages 3D and 3E prior to or after final cover system installation;

- **Gas pressures** – Analysis of landfill gas data confirms there is no evidence of elevated gas pressures being present prior to the slope failure;

- **Elevated waste temperatures** – There is no evidence of elevated gas temperatures being present before the slope failure or during waste excavation (Jafari et al., 2015);

- **Subgrade materials and geology** – As mentioned above, no shear movement occurred in the subgrade materials because the failure surface occurred above the secondary geomembrane. With limited exceptions noted above, because all of the slope movement has only been observed above the secondary geomembrane, all of the subgrade materials exposed during the investigation have been intact and well compacted (see **Figure B-3(a), B-9, and B-13**);

- **Placement of new waste over old refuse** – The slide surface is located within the bottom liner system which is located above the previously disposed waste in Stage 3E. In addition, the settlement of the old waste in Stage 3E did not cause a significant reduction in the critical bottom liner system interface shear strength because a post-peak strength condition had already been mobilized before the slide. This post-peak strength loss occurred due to: shear displacement induced during construction and waste placement along the steep and long slope; thermal expansion of the geosynthetics; new waste settlement; and new waste post-closure behavior. (See, Stark and Poeppel, 1994). Each of these occurred above the bottom liner system. The subbase, subgrade, and old waste settlements predicted in the landfill permit application, Exhibit Q-2.4, (i.e., 2.3 to 7.4 ft depending on location), are in agreement with subgrade settlements measured after waste and liner system removal above the secondary geomembrane, (i.e., 2 to 9 ft). As a result, the magnitude of the old waste settlement observed after removal of the new waste and most of the bottom liner system after the slide in Stages 3D and 3E is within predictions and not unexpected. The settlement of the old waste resulted in a flattening of the upper portion of the slope, In addition, a berm or ridge developed near the bottom of Stage 3E, which is now visible on the slope. This was the location of a previously used access road. Both of these factors locally decreased the driving stresses and increased slope stability so settlement of the old waste is not the root cause of the 12 March 2013.

4.7. Trigger of Slope Failure

The trigger of the slope failure is defined as the event that initiates a sequence of events that eventually results in the observed failure. This differs from the root cause, which is the factor(s) that allowed the trigger to initiate a sequence of events that resulted in non-uniform shear displacements and progressive failure of the slope. As stated above, the root cause of the 12 March 2013 slope movement is incorrect/inadequate design, mobilized geosynthetic shear strength, shear testing, geosynthetics specification, testing, and construction testing.

It continues to be my opinion the progressive slope movement leading to the 12 March 2013 slope failure was triggered by the Central Virginia Earthquake which occurred on 23 August 2011 (magnitude=5.8; acceleration~0.13g, depth 3.7 miles; distance 240 miles). This shaking induced an estimated peak horizontal acceleration at the top of Stage 3E of approximately 0.03g estimated using the Modified Mercalli Index based on Chrin personnel field observations. This shaking had a duration of 135 seconds in Philadelphia and 69 seconds in White River, Vermont. This magnitude and duration of shaking was sufficient to cause additional shear displacement along the critical interface and initiate and/or accelerate progressive failure mechanism in Stages 3D and 3E. This earthquake triggered some additional downslope movement that progressed with time until the slope failed on 12 March 2013 due to shear movement along the critical liner system interface, i.e., top of secondary textured geomembrane. If the slope had been properly designed and geosynthetics properly specified and confirmed for the anticipated horizontal peak bedrock acceleration of 0.15g and a static factor of safety that was actually greater than 1.5 as reported in the landfill permit application, this progressive failure mechanism would not have progressed to result in failure of the entire slope.

In mid-September, 2011, "subsidence issues" were observed by Chrin personnel in two swales near the top of the slope in the vicinity of the eventual slide scarp in Stage 3E. This is two to three weeks after the 23 August 2011 Central Virginia Earthquake. This cracking and settlement in the final cover system were initially attributed to normal landfill subsidence but continued to increase. By the end of September, 2011, consistent with normal maintenance practices, these cracks were filled and graded with soil to promote surface runoff and reduce infiltration.

This slope movement near the top of the slope continued and accumulated with time. As a result, Chrin personnel installed two survey hubs in July 2012 to monitor the magnitude and direction of movement. The movements continued and accelerated and a third survey hub was installed in January, 2013, about three months prior to the slope failure. The locations of these three survey hubs are shown in **Figure B-25**. **Figure B-26** presents the movement of these survey hubs since their installation (solid line) and an extrapolation of the movement back to mid-September and 23 August 2011 when movement was initially observed during the Central Virginia earthquake, respectively. **Figure B-27** shows the relative movement of these three survey hubs on the slide and a plan diagram of Stages 3D and 3E. The direction of movement of these survey hubs in **Figure B-27** are in excellent agreement with the eventual movement of the entire slide mass. Retrospectively, these cracks were the result of the progressive failure mechanism that was migrating through the slope causing additional shear movement and bottom liner system damage until the entire slope yielded on 12 March 2013.

Comparison of the precipitation data for the two years prior to the 23 August 2011 earthquake through the date of the slide and the recorded movement of the three survey hubs in **Figure B-26** is presented in **Figure B-28**. **Figure B-28** shows that the slope movement observed between 23 August 2011 and 12 March 2013 is independent of precipitation events. For example, there are two significant rainfall events in late 2010 but no evidence of slope movement in either the vegetative cover soil or the final cover system. In addition, after the survey hubs were installed there were periods of little rainfall but accelerating slope movement.

In my opinion with proper interface shear strength evaluation, slope design, specification, and manufacturing, the bottom liner system in Stages 3D and 3E would have been able to withstand the static and seismic forces induced before and after the 23 August 2011 earthquake and resisted the initiation and/or acceleration of this progressive slope failure.

5. LIMITATIONS:

SCI's professional services have been performed, findings obtained, conclusions derived, and opinions prepared in accordance with generally accepted geotechnical and geoenvironmental engineering principles and practices at the time of this report. This report and the opinions herein are based on site visits, documents reviewed, subsurface investigations, geosynthetics, waste, and soil testing, and analyses performed. The above evaluation, assessments, conclusions, and opinions constitute a reasonable degree of engineering certainty. SCI makes no warranties, either expressed or implied, as to the professional data, opinions, or recommendation contained herein. If additional data or information becomes available, these professional opinions are subject to revision.

6. CITED REFERENCES:

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APPENDIX A:

Brief Curriculum Vitae
Timothy D. Stark, Ph.D., P.E., D.GE

TIMOTHY D. STARK, Ph.D., P.E., D.GE, F.ASCE

Vice President, Stark Consultants, Inc. &
Professor of Civil and Environmental Engineering
University of Illinois at Urbana-Champaign

EDUCATION

Ph.D., Virginia Polytechnic Institute, Geotechnical Engrg., 1987 (advisor J.M. Duncan)
M.Engrg., U. of California at Berkeley, Geotechnical Engrg., 1984 (advisor J. M. Duncan)
B.S., University of Delaware, Civil Engineering, 1981

EXPERIENCE

Participated in a variety of geotechnical and earthquake engineering projects with Woodward-Clyde Consultants in San Francisco from 1981 to 1983. Has conducted academic research on waste containment facilities, geosynthetics, static and seismic stability of natural and manmade slopes, earthquake induced soil liquefaction, and performance of compacted structural fills and slopes.

EMPLOYMENT RECORD

Assistant Professor to Professor of Civil Engrg.: University of Illinois at Urbana-Champaign, 1/91 - date.
Assistant Professor of Civil Engineering: San Diego State University, 1/87-1/91.
Staff Engineer: Woodward-Clyde Consultants, San Francisco, CA, 6/81-9/83.

RECENT AWARDS AND RECOGNITIONS

"Best Geosynthetics International Paper for 2015", International Geosynthetics Society, 2016.
Excellence Faculty Scholar, Civil and Environmental Engrg. Dept., Univ. of Illinois, 2016-date
Best Paper Award, 13th International Railway Engineering Conference, Edinburgh, Scotland, June, 2015.
2015 James M. Hoover Lecturer, Iowa State University, Ames, IA, March, 2015.
R.S. Ladd D18 Standards Development Award, Standard Designation D6467, ASTM, 2014
Thomas A. Middlebrooks Award for "best" paper in Geotechnical Engineering, ASCE, 2013 and 1998
Selected Editor, Journal of Geotechnical and Geoenvironmental Engineering, ASCE, 2012
Associate Editor Award, Journal of Geotechnical and Geoenvironmental Engineering, ASCE, 2012
Journal of Legal Affairs and Dispute Resolution in Engineering Scholarly, Paper, ASCE, 2011
R.S. Ladd D18 Standards Development Award, Standard Designation D7608, ASTM, 2011
Elected Diplomate, Geotechnical Engineering, Academy of Geo-Professionals, ASCE, 2010
Classic Paper in Geosynthetics, Geo-Americas Conference, 2008
Elected Fellow, American Society of Civil Engineers (ASCE), 2006
R.M. Quigley Award, "best" paper in Canadian Geotechnical Journal, Canadian Geotech. Soc., 2003
Standards Development Award, Standard Designation D6467, ASTM, 2002
Walter L. Huber Civil Engineering Research Prize, American Soc, of Civil Engineers (ASCE), 1999
University Scholar, University Scholars Program, University of Illinois, 1998-2001
Arthur Casagrande Professional Development Award, ASCE, 1992

www.tstark.net

APPENDIX B:

Supporting Information

Appendix B – Supporting Information

Amended Slope Failure Report:

March 12, 2013 Chrin Brothers, Inc. Landfill Slope Failure

Submitted to the Pennsylvania Department of Environmental Protection Northeast Region Office

November 18, 2016

Timothy D. Stark, Ph.D., P.E., D.GE, F.ASCE
Stark Consultants, Inc.
P.O. Box 133
Urbana, IL 61801

SCI
Stark Consultants Inc.

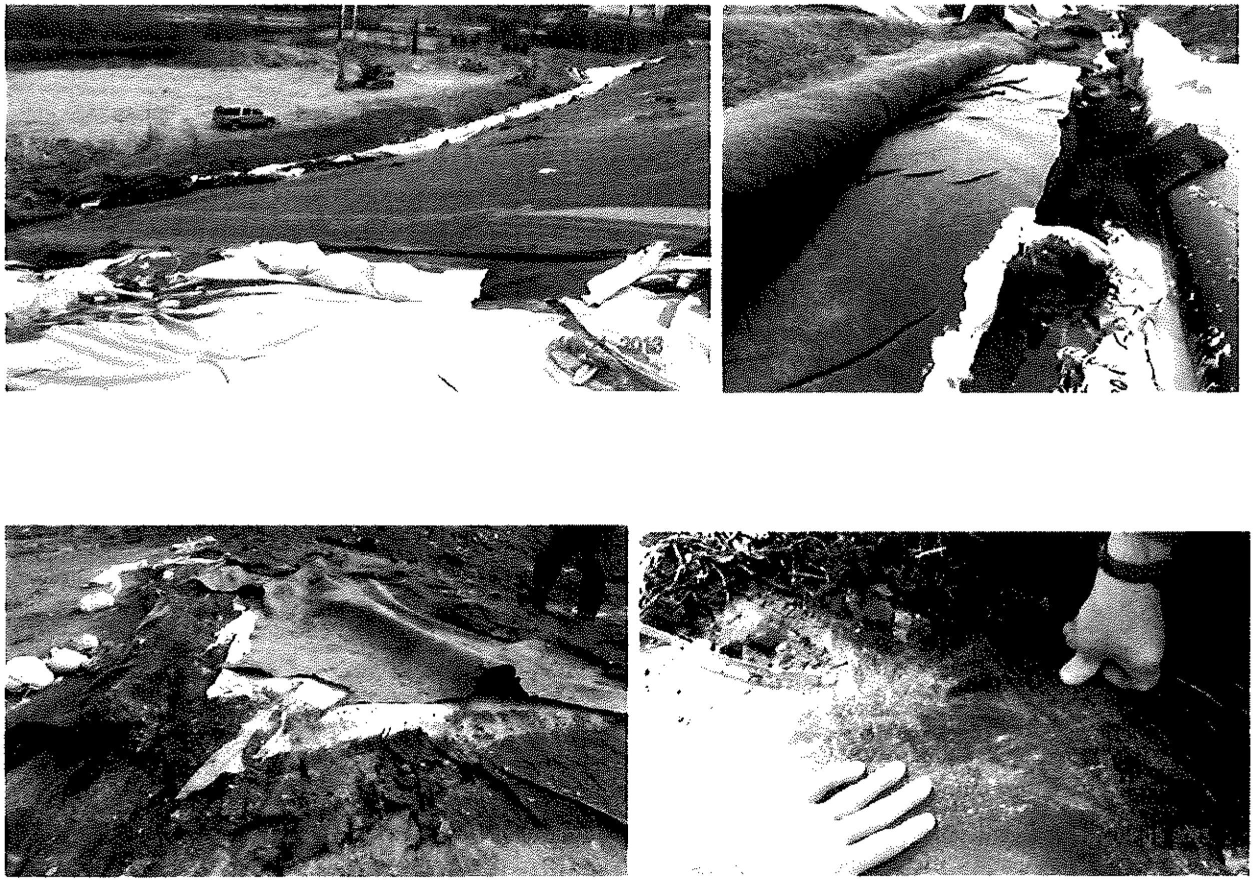
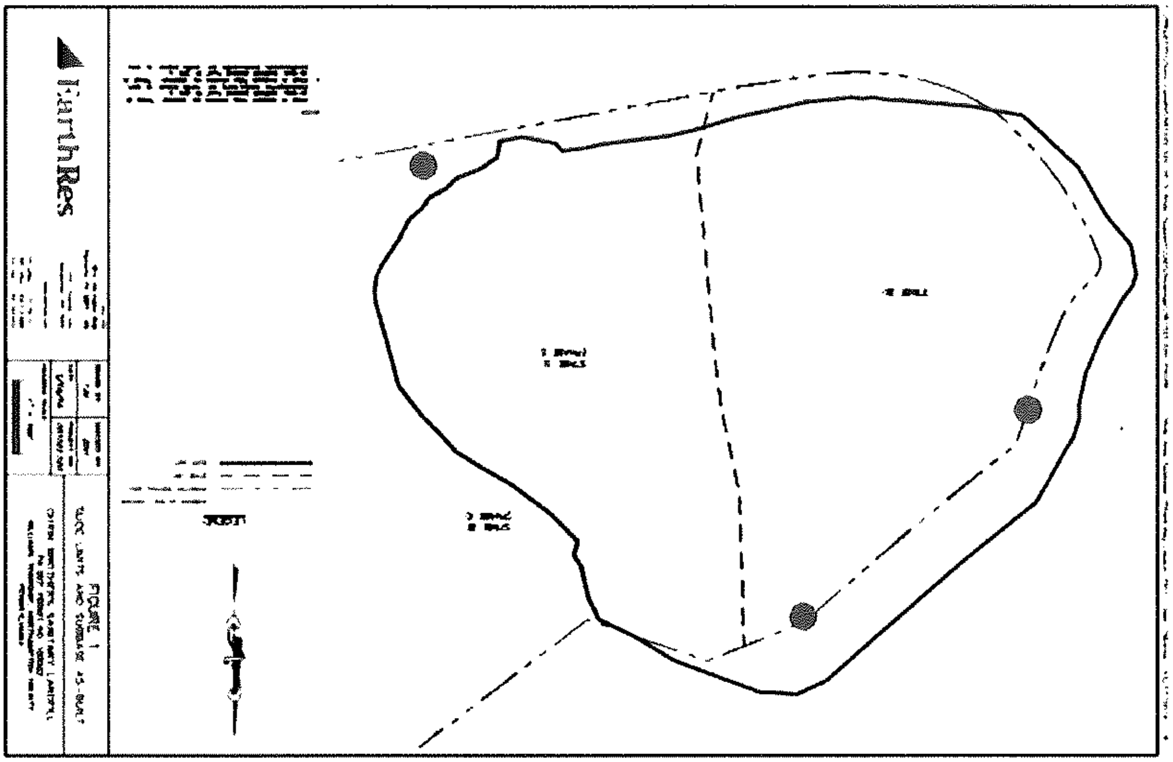
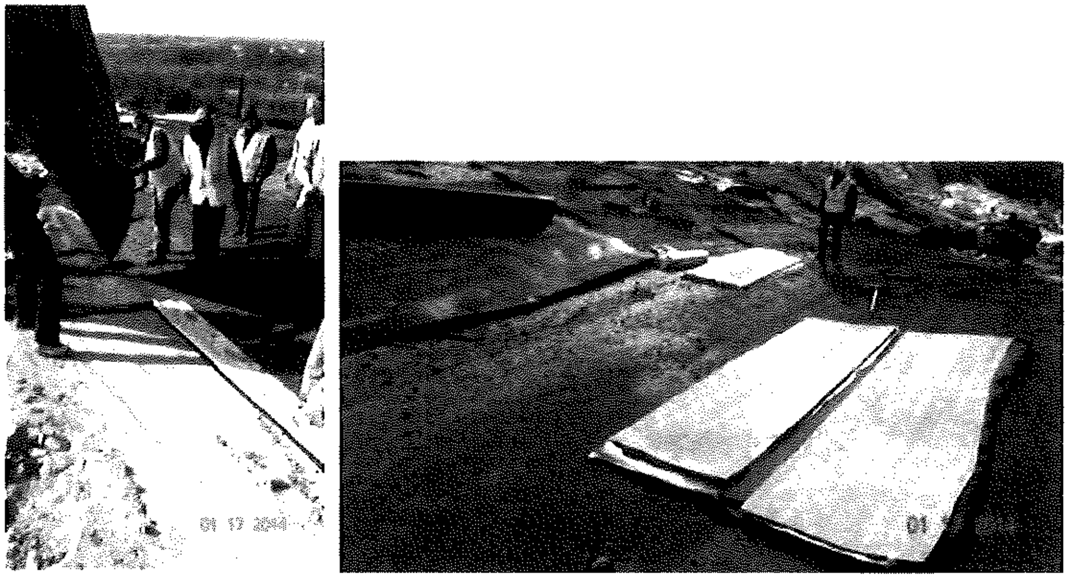


Figure B-1: Various photograph of damaged geosynthetics observed after waste excavation.



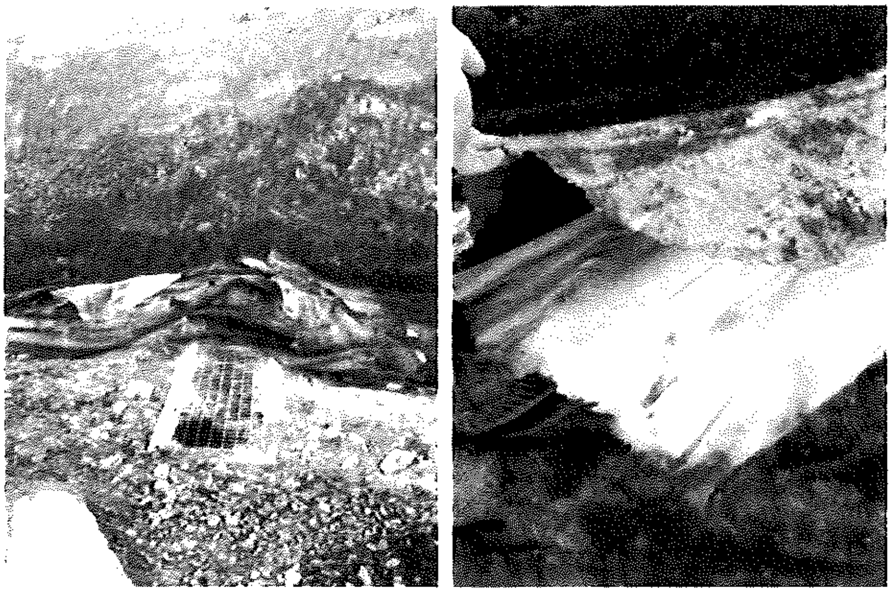
● Liner Sample Locations

Figure B-2: Locations where samples of the pre-slide geosynthetics were obtained for testing.



(a)

(b)



(c)

Figure B-3: **Photographs of: (a) Southern Liner System Samples obtained on 17 January 2014, (b) Northeast Toe of Slope Liner System Samples on 18 March 2014, and (c) Northwest Toe of Slope Liner System Samples – 18 March 2014**

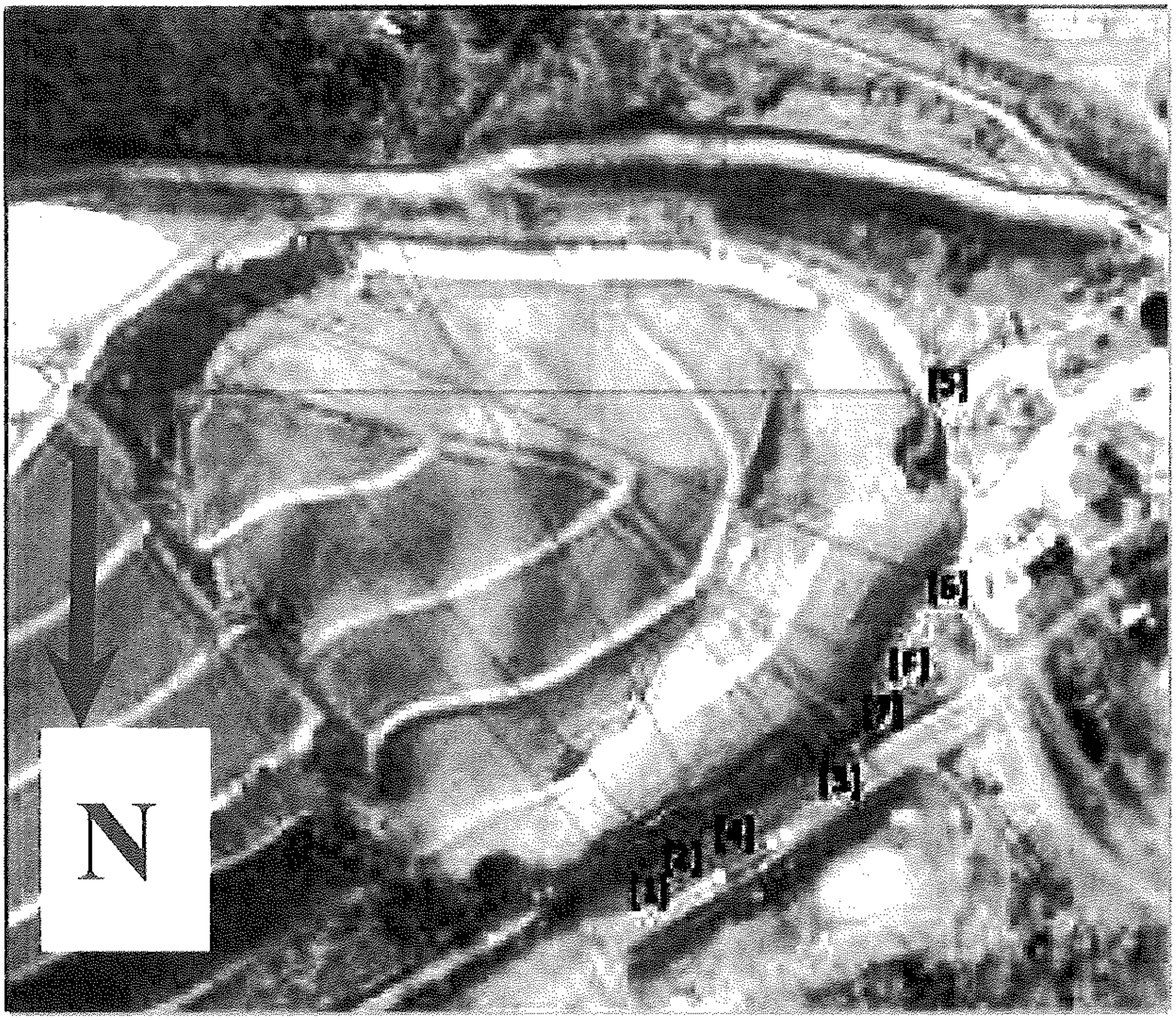


Figure B-4: Aerial photograph of 12 March 2013 Slide mass slope failure and cross-sections used for stability analyses.

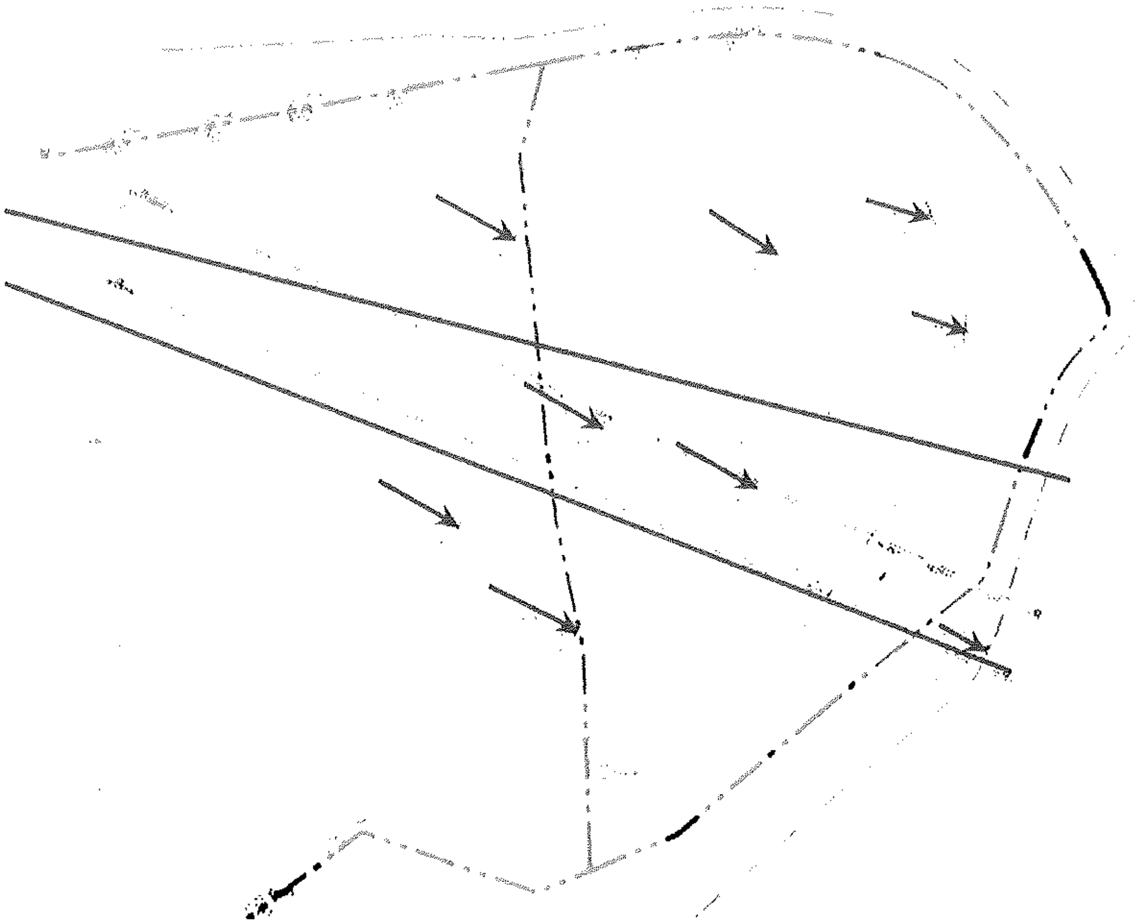


Figure B-5: Movement vectors for gas wellheads showing direction of slide movement.

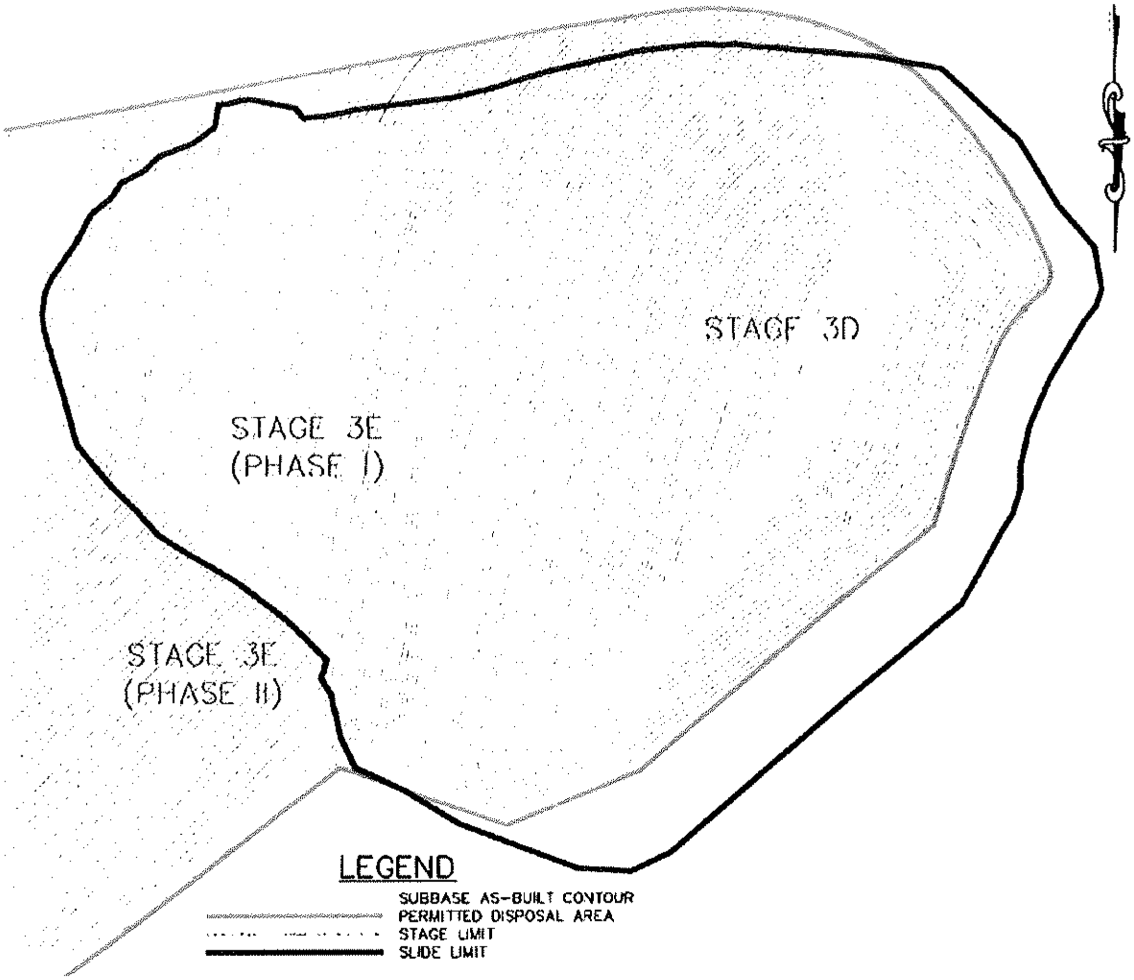
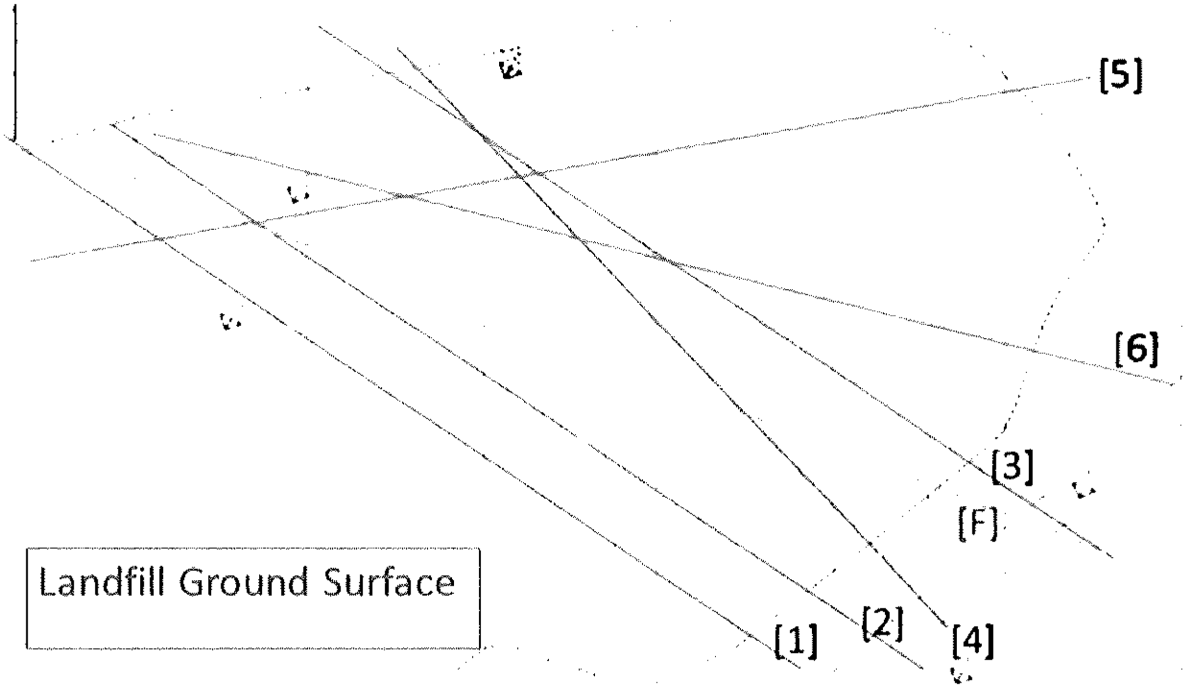
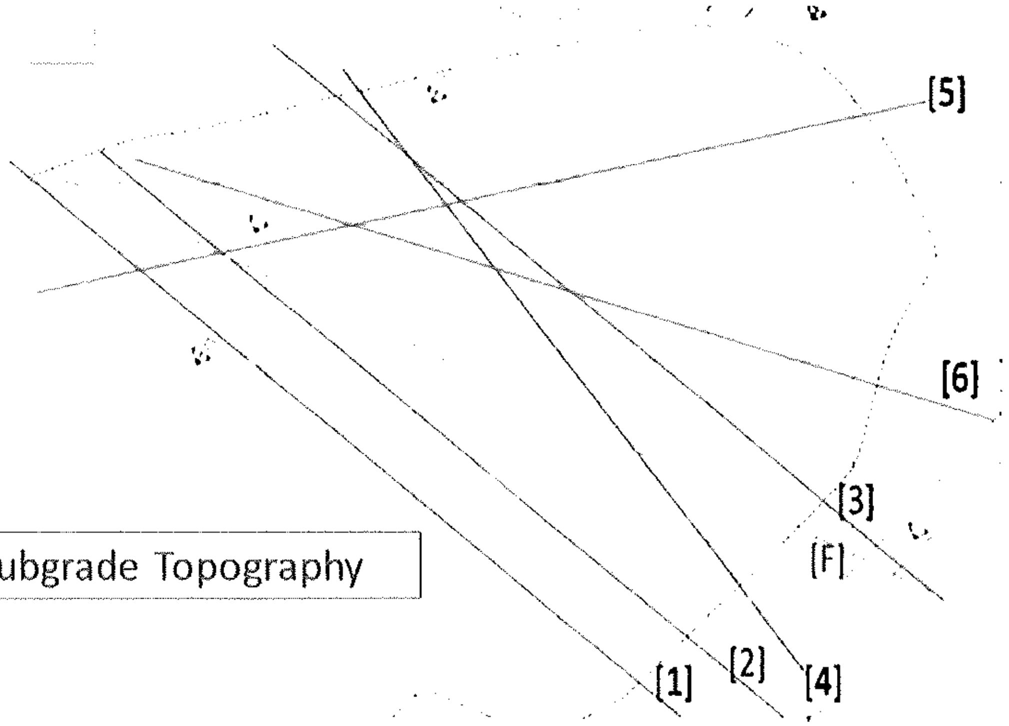


Figure B-6: Limits of 12 March 2013 slide mass and subbase as-built contours (map prepared by ERG).



(a)



(b)

Figure B-7: Contour maps showing: (a) ground surface topography and (b) compacted clayey subgrade topography.

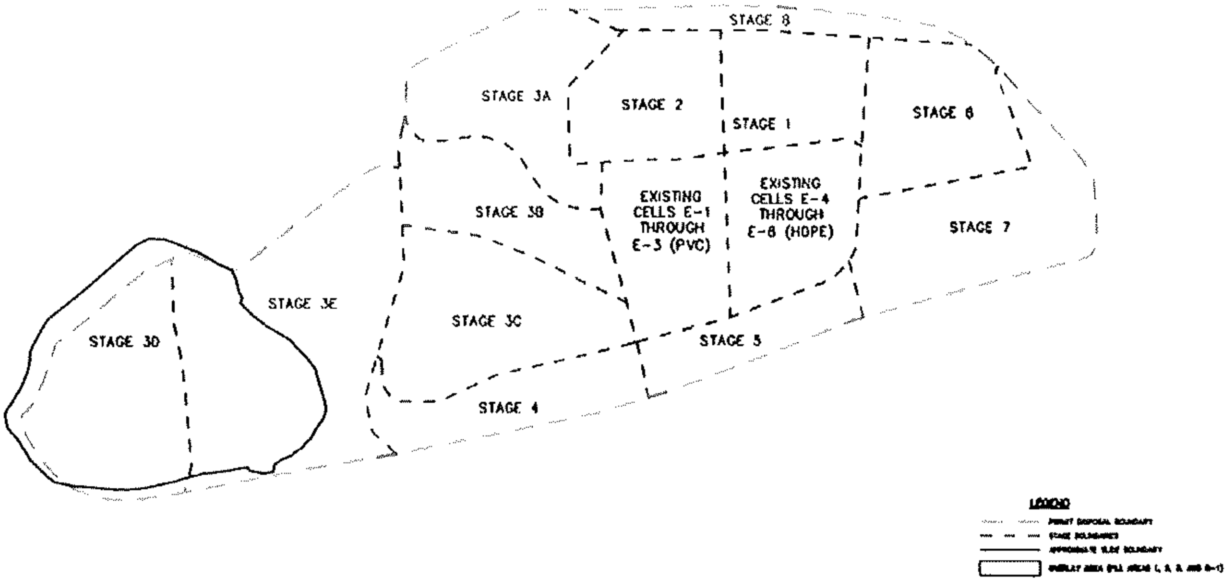


Figure B-8: **Plan view of the Chrin Landfill showing location of underlying old waste (map prepared by ERG).**

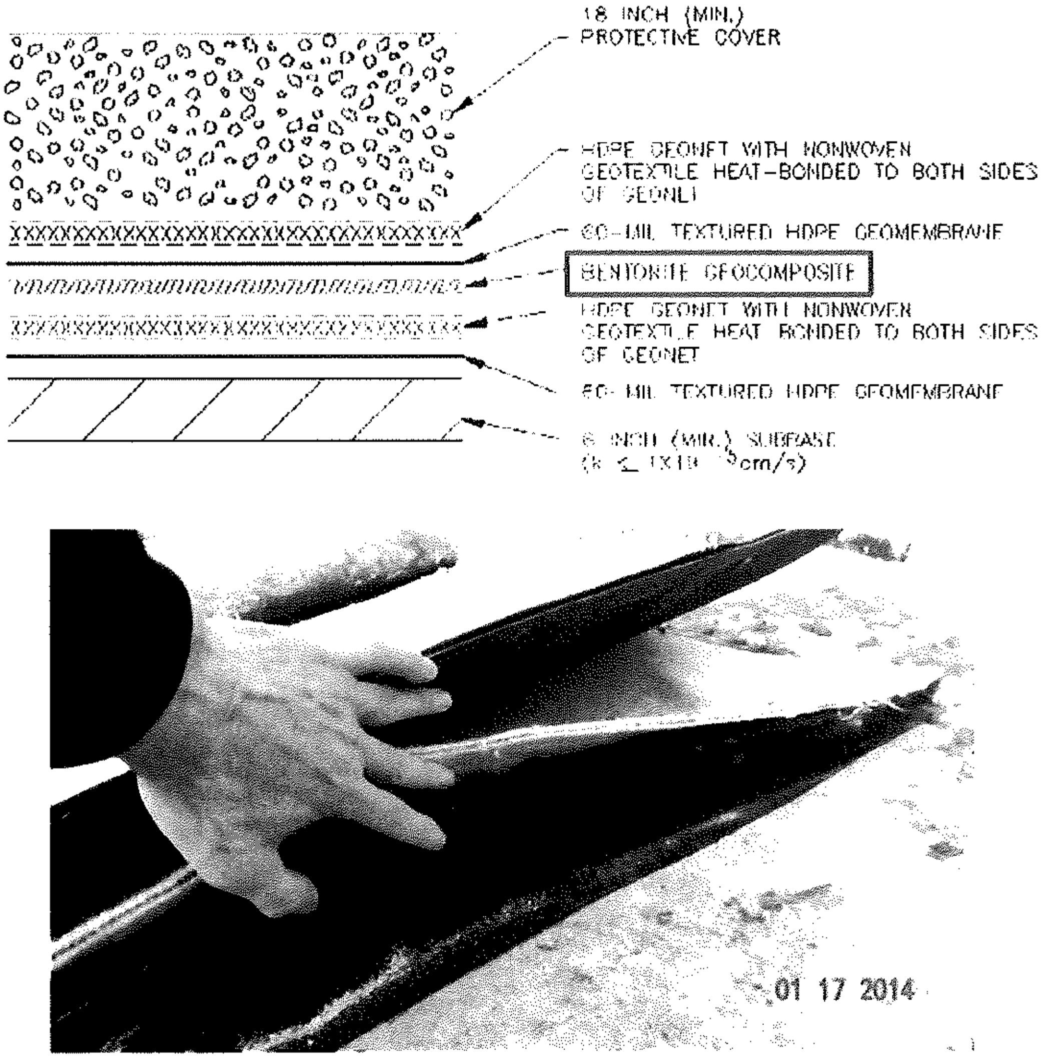


Figure B-9: **Cross-section of liner system in slope failure area and photograph of liner system components after waste excavation.**

Figure B-10: Photograph of secondary geomembrane still present and intact on the slope in Stage 3E and a portion of Stage 3D.

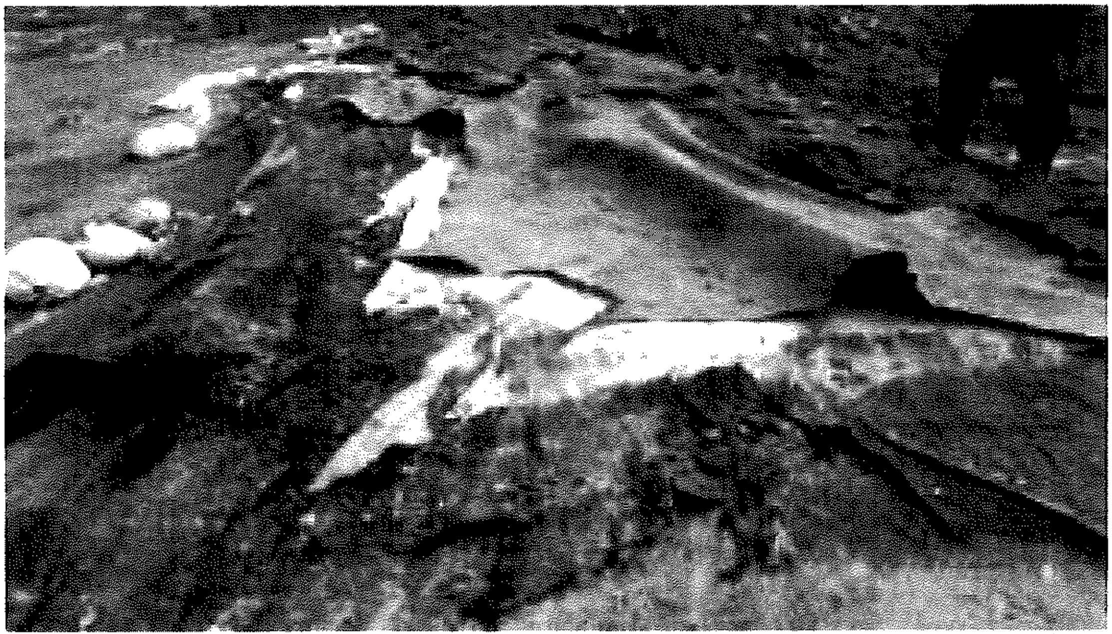


Figure B-11: Close-up of torn geosynthetics above the secondary geomembrane at the top of the slope.

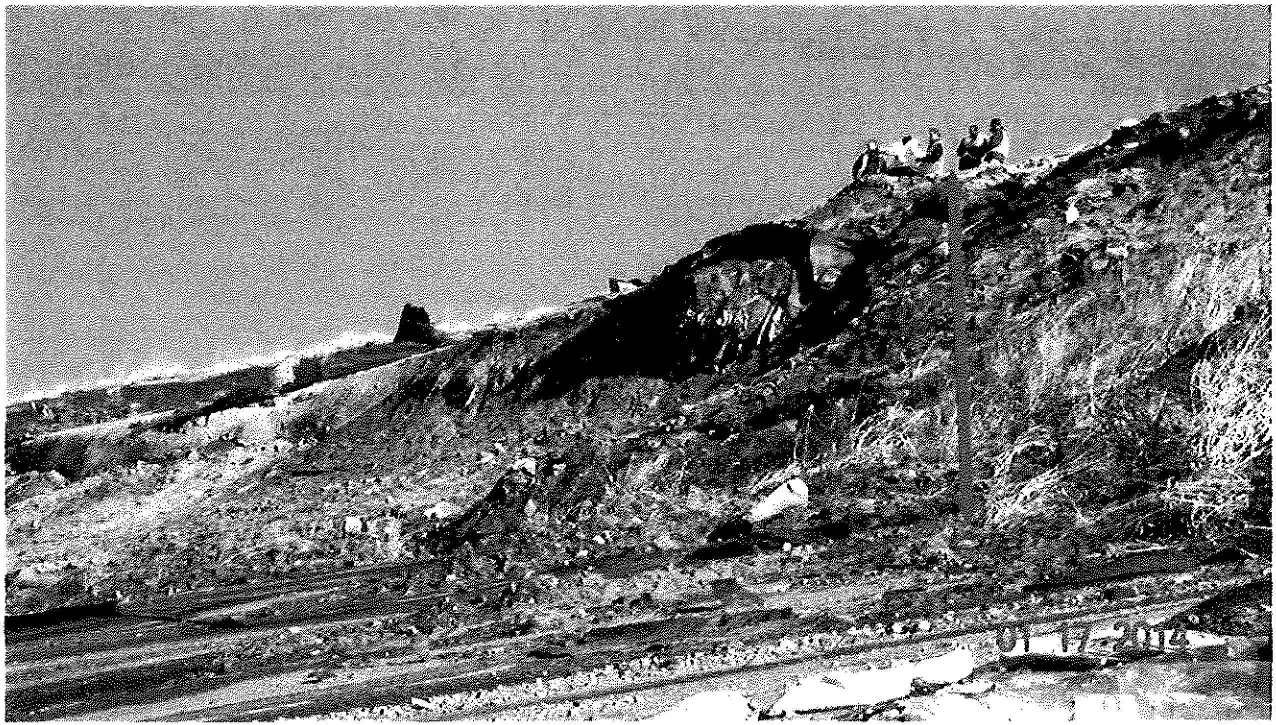


Figure B-12: Close-up of exposed waste and cover soil at top of slope (see red arrow) where failure surface exited the bottom liner system and passed through the waste.

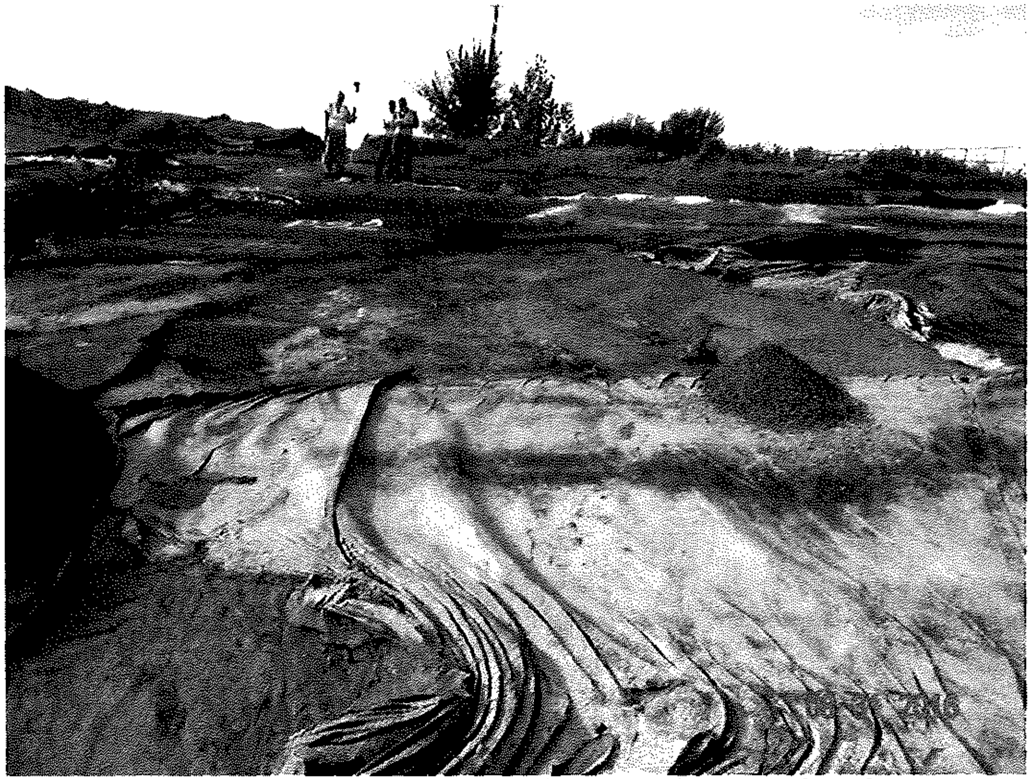


Figure B-13: Photograph of secondary geomembrane/compacted clayey subgrade interface movement.

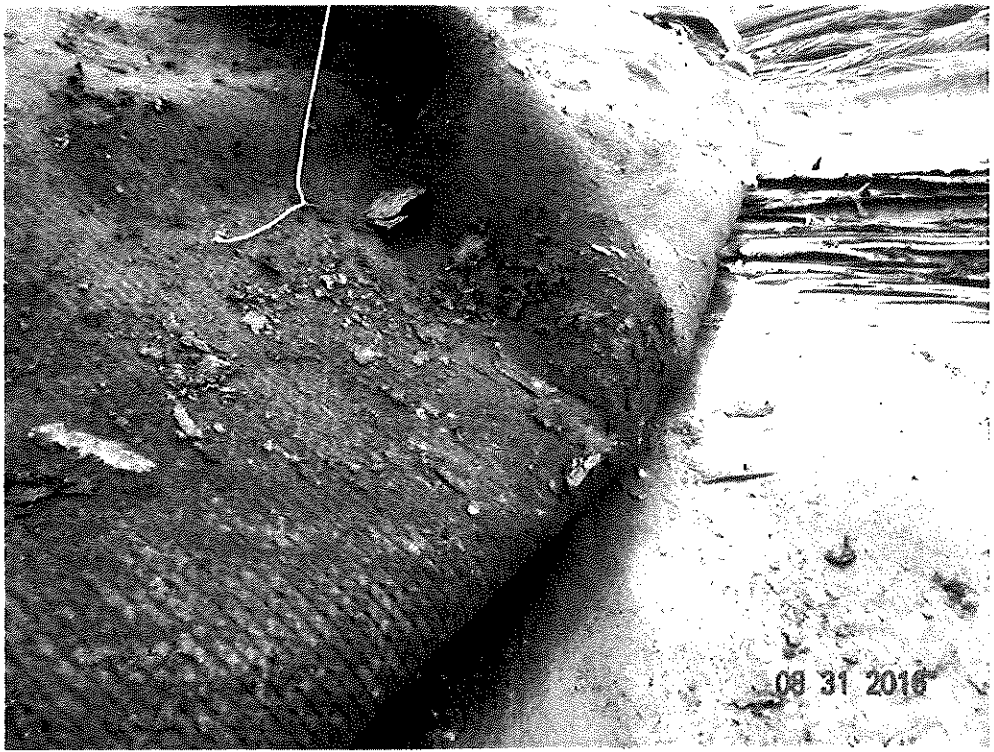


Figure B-14: **Photograph of geosynthetic drainage composite/primary geomembrane interface interface movement.**

Figure B-15: **Photograph of primary geomembrane/GCL interface interface movement.**

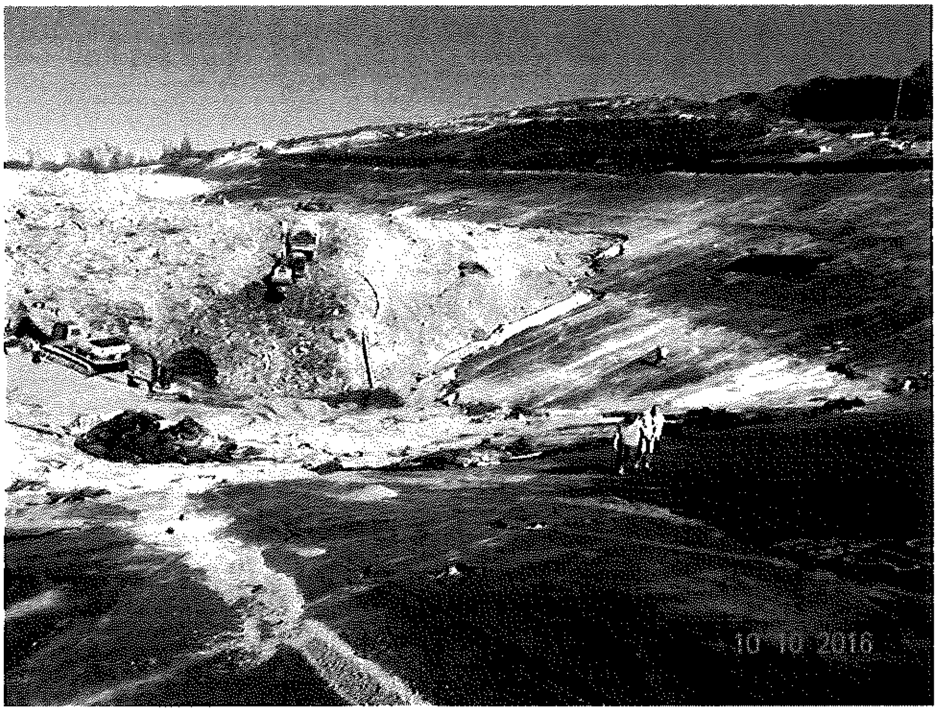


Figure B-16: Photograph of intact secondary geomembrane on slope after waste removal and removal of the damaged liner system components.

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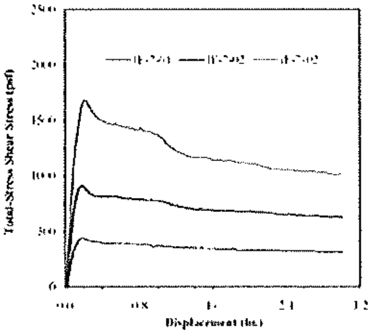
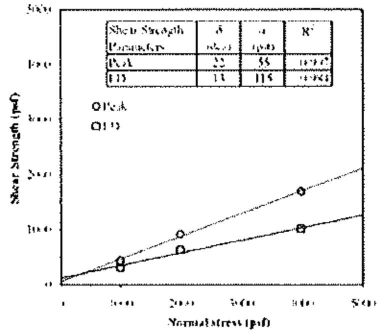
INTERFACE DIRECT SHEAR TEST SERIES #8

Upper Shear Box: Concrete sand
As-received witness geocomposite clamped to the upper shear box with bottom side down/
As-received secondary GSE 60-mil textured HDPE geomembrane clamped to the lower shear box with bottom side down
Lower Shear Box: Concrete sand





Shear Strength Parameters	δ (deg)	a (psf)	R²
Peak	22	55	0.997
LD	13	115	0.998

Interface Sample No.	Shear Box Size (in. x in.)	Normal Stress (psf)	Shear Rate (in./min)	Soaking Stress (psf)	Soaking Time (hours)	Consolidation Stress (psf)	Consolidation Time (hours)	Subbase Soil γ_d (pcf)	ω_0 (%)	ω_f (%)	[illegible] γ_d (pcf)	ω_0 (%)	ω_f (%)	GCL ω_0 (%)	GCL ω_f (%)	Shear Strength τ_P (psf)	τ_{LD} (psf)	Failure Mode
IF-7-01	12 x 12	1000	0.04			1000	48									440	311	(1)
IF-7-02	12 x 12	2000	0.04			2000	48									914	621	(1)
IF-7-03	12 x 12	4000	0.04			4000	48									1683	1011	(1)

NOTE:
(1) Sliding (shear failure) occurred at the interface between the bottom of the witness geocomposite and top of the 2nd textured geomembrane

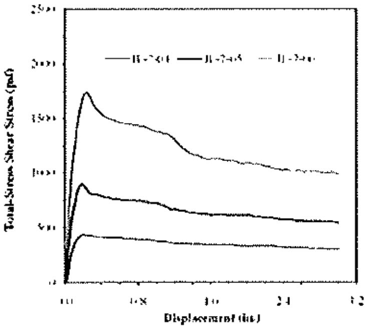
DATE OF REPORT	3-5-2014
FIGURE NO.	8
PROJECT NO.	SGI13023
DOCUMENT NO.	
FILE NO.	

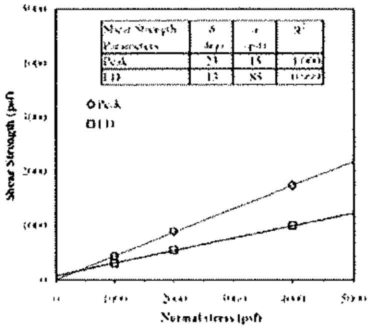
SGI TESTING SERVICES, LLC

S13023 08 Tests.xls

UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN - CHRIN LANDFILL
INTERFACE DIRECT SHEAR TEST SERIES #9

Upper Shear Box: Concrete sand
Soaked witness geocomposite clamped to the upper shear box with bottom side down
Soaked secondary GSE 60-mil textured HDPE geomembrane clamped to the lower shear box with bottom side down
Lower Shear Box: Concrete sand





Shear Strength Parameters	δ (deg)	a (psf)	R²
Peak	21	15	1.000
LD	13	85	0.999

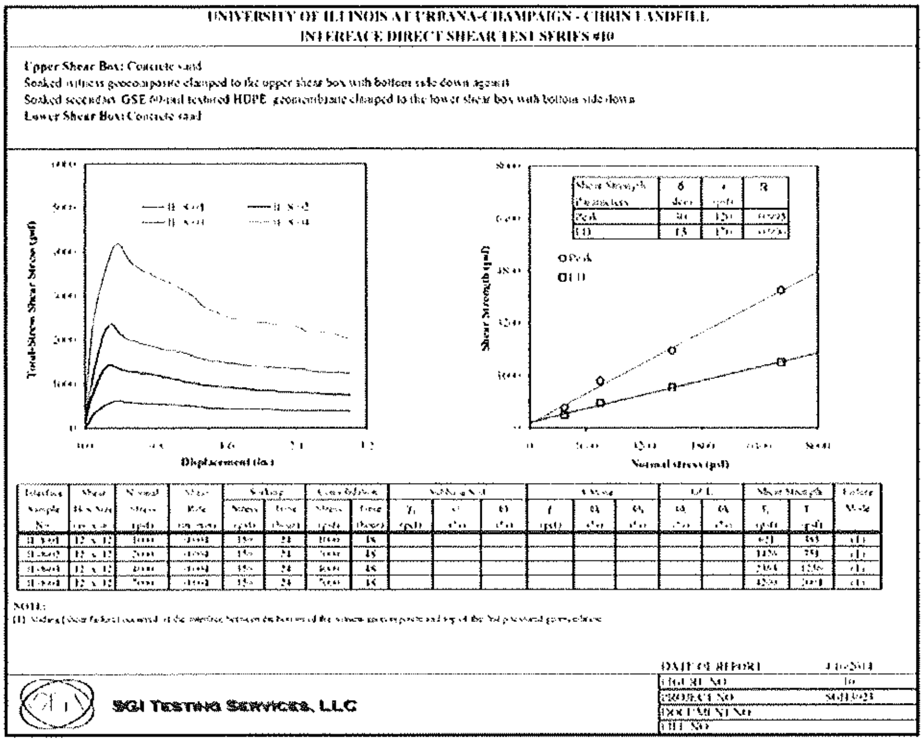
Interface Sample No.	Shear Box Size (in. x in.)	Normal Stress (psf)	Shear Rate (in./min)	Soaking Stress (psf)	Soaking Time (hours)	Consolidation Stress (psf)	Consolidation Time (hours)	Subbase Soil γ_d (pcf)	ω_0 (%)	ω_f (%)	[illegible] γ_d (pcf)	ω_0 (%)	ω_f (%)	GCL ω_0 (%)	GCL ω_f (%)	Shear Strength τ_P (psf)	τ_{LD} (psf)	Failure Mode
IF-2-04	12 x 12	1000	0.04	0	24	2000	48									435	345	(1)
IF-2-05	12 x 12	2000	0.04	0	24	2000	48									896	551	(1)
IF-2-06	12 x 12	4000	0.04	0	24	2000	48									1740	921	(1)

NOTE:
(1) Sliding (shear failure) occurred at the interface between the bottom of the witness geocomposite and top of the 2nd textured geomembrane

DATE OF REPORT	3.5.2014
FIGURE NO.	9
PROJECT NO.	SGI13023
DOCUMENT NO.	
FILE NO.	

SGI TESTING SERVICES, LLC

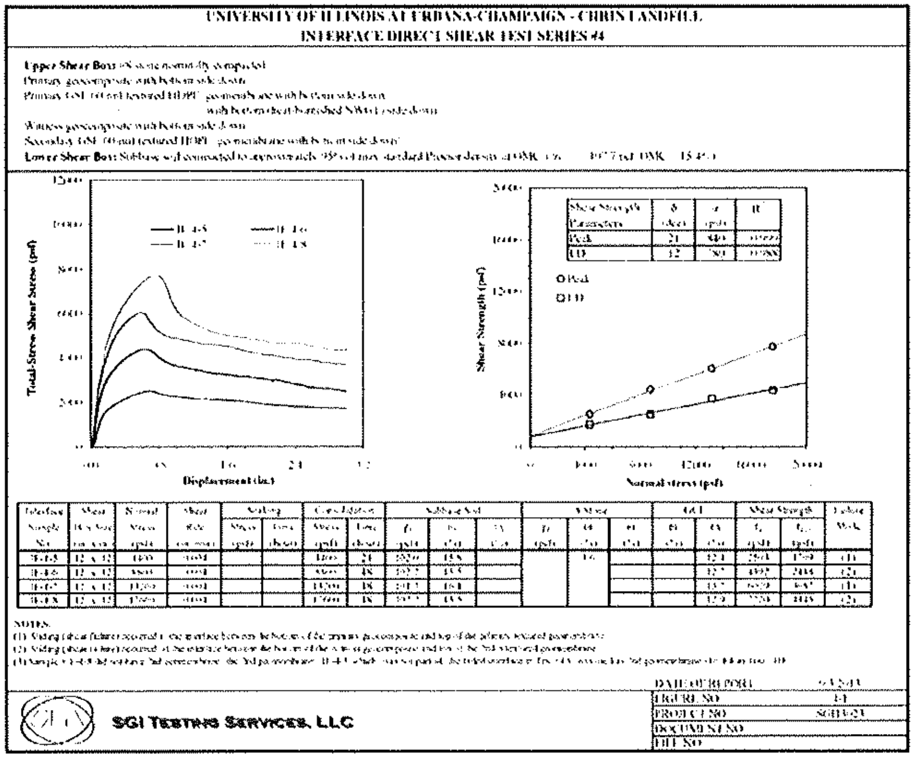
S13023 09R calib.xls



UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN - CHRIN LANDFILL
INTERFACE DIRECT SHEAR TEST SERIES #10

Upper Shear Box: Concrete sand
Soaked witness geocomposite clamped to the upper shear box with bottom side down against
Soaked secondary GSE 60-mil textured HDPE geomembrane clamped to the lower shear box with bottom side down
Lower Shear Box: Concrete sand

SGI TESTING SERVICES, LLC



UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN - CHRIN LANDFILL
INTERFACE DIRECT SHEAR TEST SERIES #4

SGI TESTING SERVICES, LLC

Figure B-17: SGI Interface Test Results Summarized in Table 1 for Secondary Geomembrane Interface.

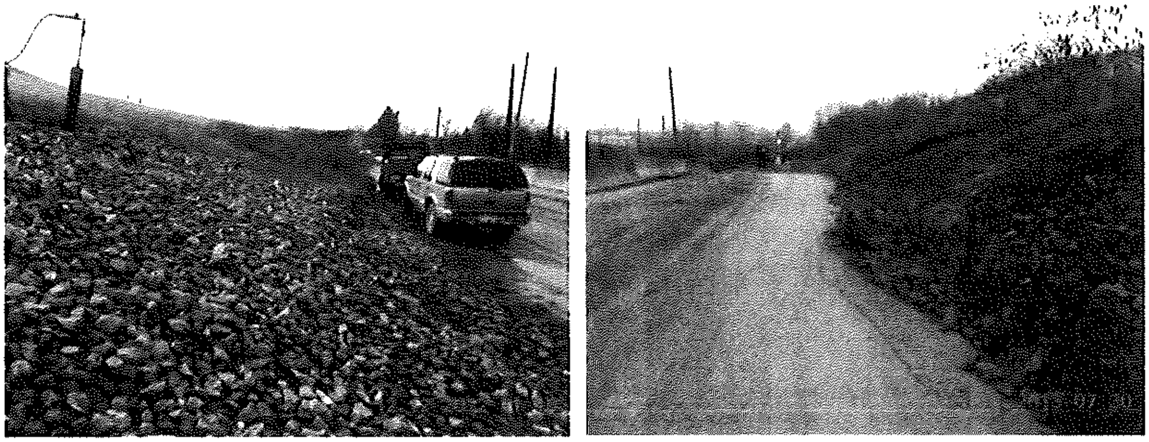


Figure B-18: Photographs along slope toe showing no toe excavation looking: (a) northwest on 12 December 2012 and (b) northeast on 11 March 2013.

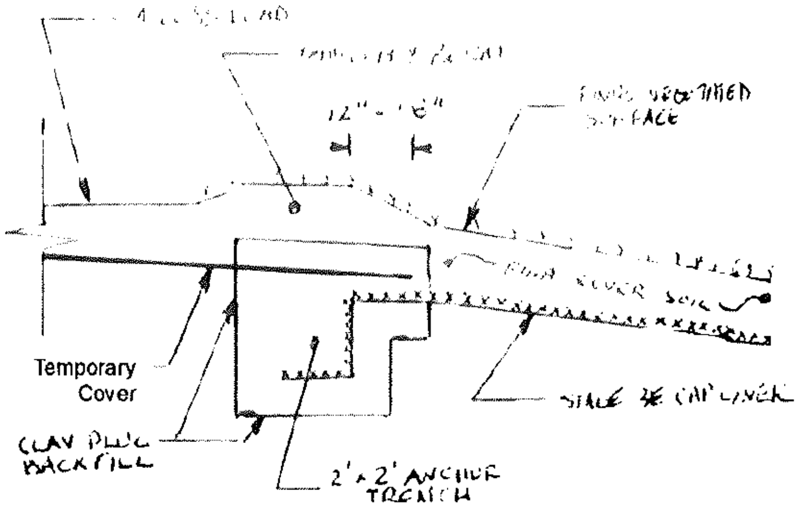


Figure 2 –Stage 3E Anchor Trench Sketch

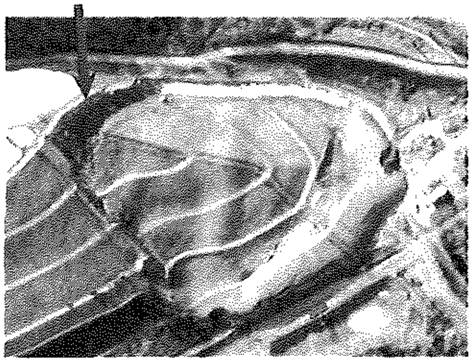


Figure B-19: Schematic diagram of the tie-in for temporary cover system with final cover system for Stages 3E and 3D and photograph showing the location of the buried Temporary Cover below the access road (see red arrow).

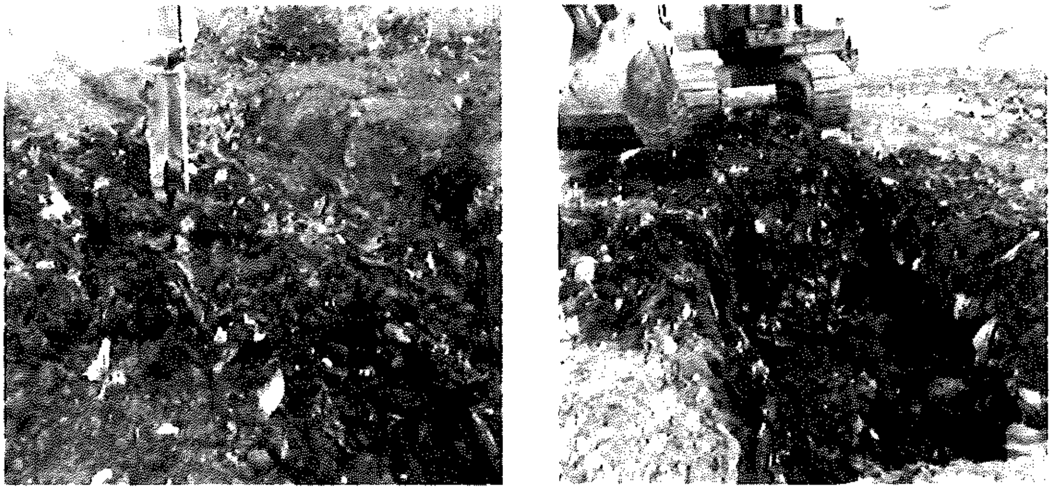


Figure B-20: Excavations in waste to measure moisture content and unit weight.

Sample ID	SAMPLE NO.	DEPTH (FT)	WATER CONTENT (%)
W-1	Bucket 1		26.7
W-1	Bucket 2		31.0
W-2			46.8
W-3			31.6
W-4			55.3
W-5			17.7
FC-1			0.3
IC-1			1.1
Subbase-1			16.9
W-6			40.5
W-7			40.8
W-8			36.4
W-9			36.6
W-10			20.0
W-11			12.5
W-12			33.3

Figure B-21: Summary of measured waste moisture contents in Stages 3D and 3E.

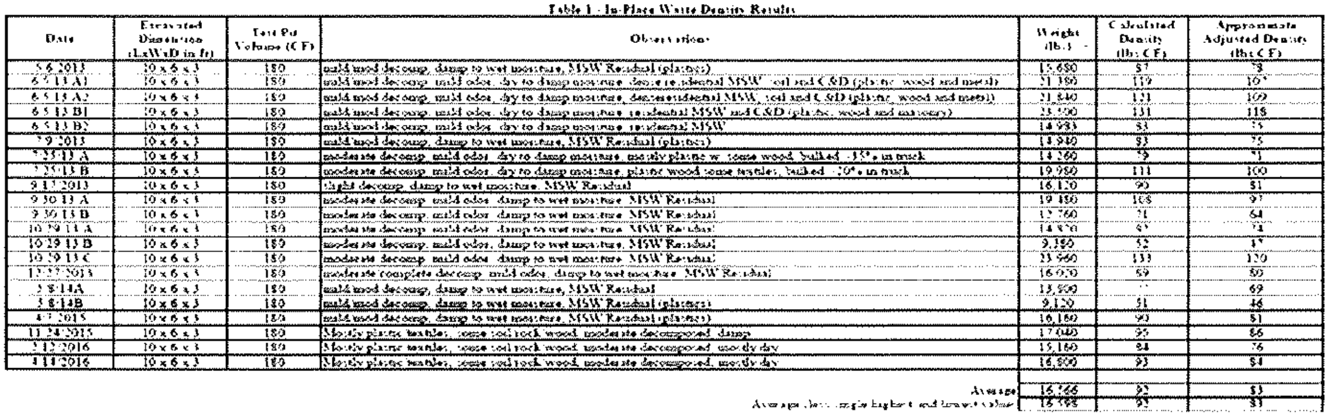


Table 1 - In-Place Waste Density Results

Date	Excavated Dimension (LxWxD in ft)	Test Pit Volume (CF)	Observations	Weight (lbs.)	Calculated Density (lbs/CF)	Approximate Adjusted Density (lbs/CF)
5/6/2013	10 x 6 x 3	180	mild/mod decomp, damp to wet moisture, MSW Residual (plastics)	15,680	87	73
6/5/13 A1	10 x 6 x 3	180	mild/mod decomp, mild odor, dry to damp moisture, dense residential MSW, soil and C&D (plastic, wood and metal)	21,380	119	107
6/5/13 A2	10 x 6 x 3	180	mild/mod decomp, mild odor, dry to damp moisture, dense residential MSW, soil and C&D (plastic, wood and metal)	21,840	121	109
6/5/13 B1	10 x 6 x 3	180	mild/mod decomp, mild odor, dry to damp moisture, residential MSW and C&D (plastic, wood and masonry)	23,590	131	118
6/5/13 B2	10 x 6 x 3	180	mild/mod decomp, mild odor, dry to damp moisture, residential MSW	14,933	83	75
7/9/2013	10 x 6 x 3	180	mild/mod decomp, damp to wet moisture, MSW Residual (plastics)	14,940	83	75
7/25/13 A	10 x 6 x 3	180	moderate decomp, mild odor, dry to damp moisture, mostly plastic w/ some wood, bulked ~15% in truck	14,260	79	71
7/25/13 B	10 x 6 x 3	180	moderate decomp, mild odor, dry to damp moisture, plastic wood some textiles, bulked ~20% in truck	19,980	111	100
9/17/2013	10 x 6 x 3	180	slight decomp, damp to wet moisture, MSW Residual	16,120	90	81
9/30/13 A	10 x 6 x 3	180	moderate decomp, mild odor, damp to wet moisture, MSW Residual	19,480	108	97
9/30/13 B	10 x 6 x 3	180	moderate decomp, mild odor, damp to wet moisture, MSW Residual	12,760	71	64
10/29/13 A	10 x 6 x 3	180	moderate decomp, mild odor, damp to wet moisture, MSW Residual	14,870	83	74
10/29/13 B	10 x 6 x 3	180	moderate decomp, mild odor, damp to wet moisture, MSW Residual	9,350	52	47
10/29/13 C	10 x 6 x 3	180	moderate decomp, mild odor, damp to wet moisture, MSW Residual	23,960	133	120
12/27/2013	10 x 6 x 3	180	moderate/complete decomp, mild odor, damp to wet moisture, MSW Residual	16,070	89	80
3/8/14A	10 x 6 x 3	180	mild/mod decomp, damp to wet moisture, MSW Residual	13,900	77	69
3/8/14B	10 x 6 x 3	180	mild/mod decomp, damp to wet moisture, MSW Residual (plastics)	9,120	51	46
4/7/2015	10 x 6 x 3	180	mild/mod decomp, damp to wet moisture, MSW Residual (plastics)	16,160	90	81
11/24/2015	10 x 6 x 3	180	Mostly plastic textiles, some soil rock wood, moderate decomposed, damp	17,040	95	86
2/12/2016	10 x 6 x 3	180	Mostly plastic textiles, some soil rock wood, moderate decomposed, mostly dry	15,160	84	76
4/11/2016	10 x 6 x 3	180	Mostly plastic textiles, some soil rock wood, moderate decomposed, mostly dry	16,800	93	84
			Average	16,566	92	83
			Average (less single highest and lowest value)	15,595	92	83

Figure B-22: Summary of measured waste unit weights in Stages 3D and 3E.

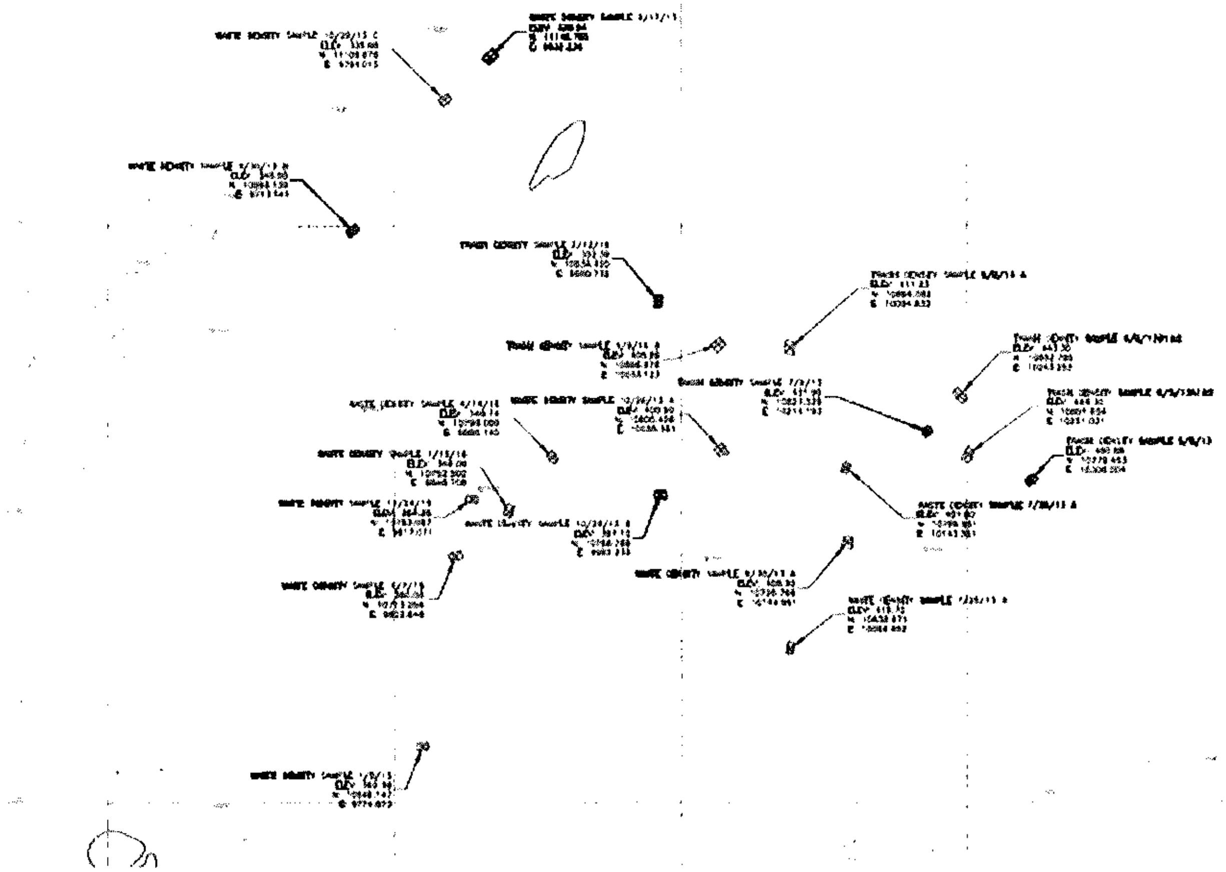


Figure B-23: Locations in Stages 3D and 3E where waste moisture content and unit weight were measured.

Chrin Landfill PS-6, WZ-6 (Witness Zone), and Precipitation Data (2007-2013)

SOURCE OF DATA: Landfill historical pumping records 2007-2013, Lehigh Valley International Airport historical precipitation 2007-2013

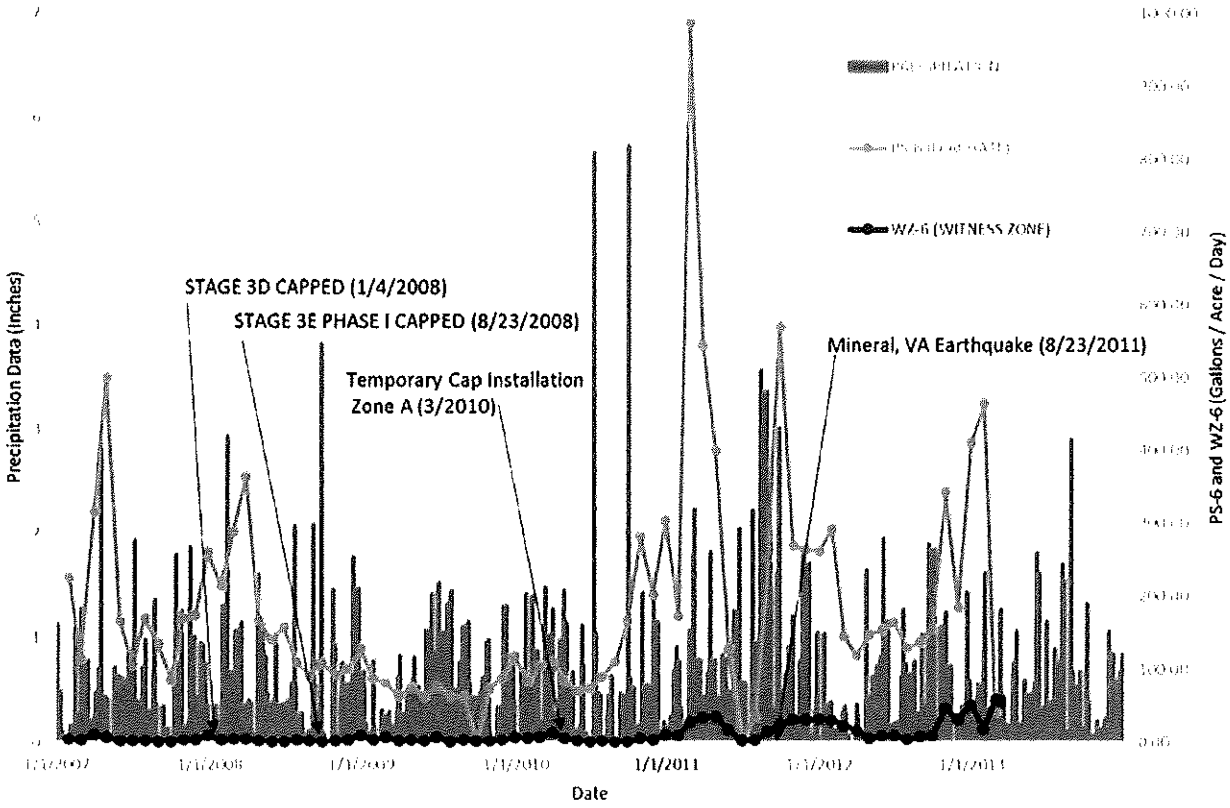


Figure B-24: Summary of leachate data in Stages 3D and 3E including witness zone between the primary and secondary geomembranes.

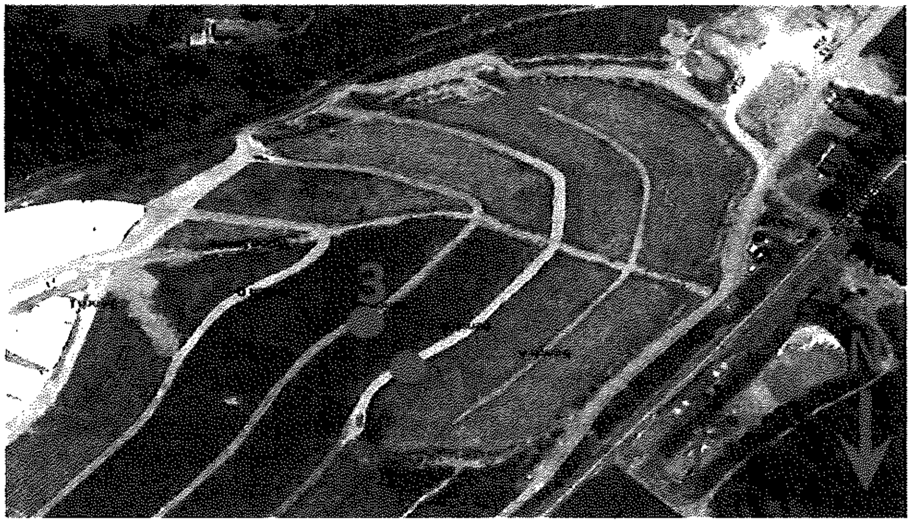


Figure B-25: Location of survey hubs installed after July 2012 to monitor slope movement in Stages 3E and 3D.

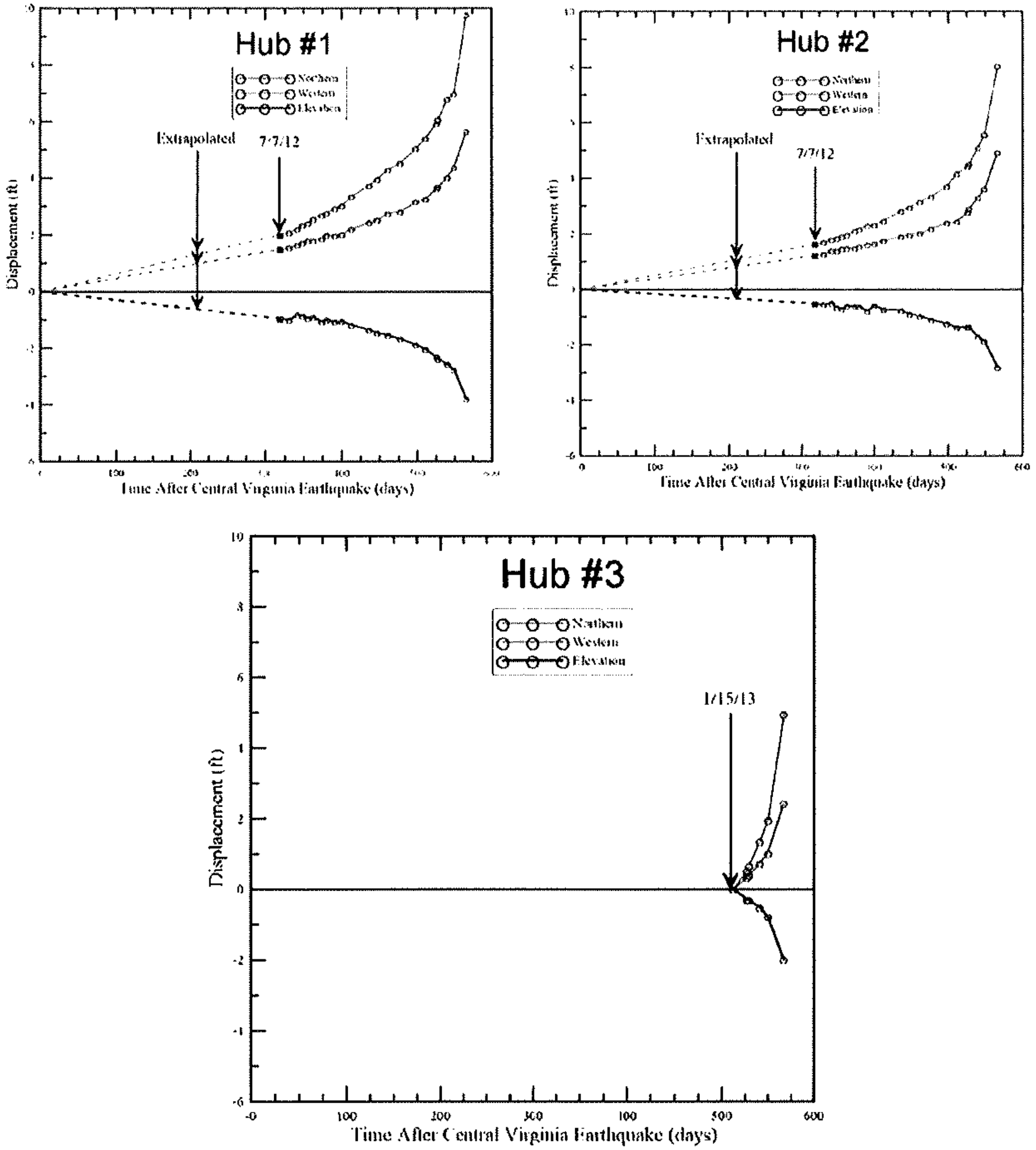


Figure B-26: Measured and extrapolated movement of three survey hubs installed after July 2012 to monitor slope movement in Stages 3E and 3D.

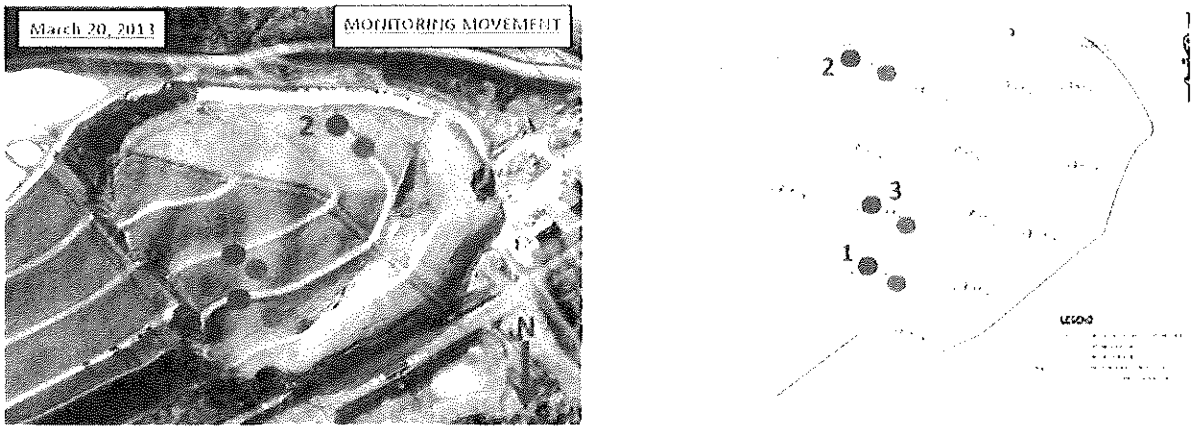


Figure B-27: Movement of the three survey hubs superimposed on an aerial photo of the slide mass and a plan diagram of Stages 3D and 3E.

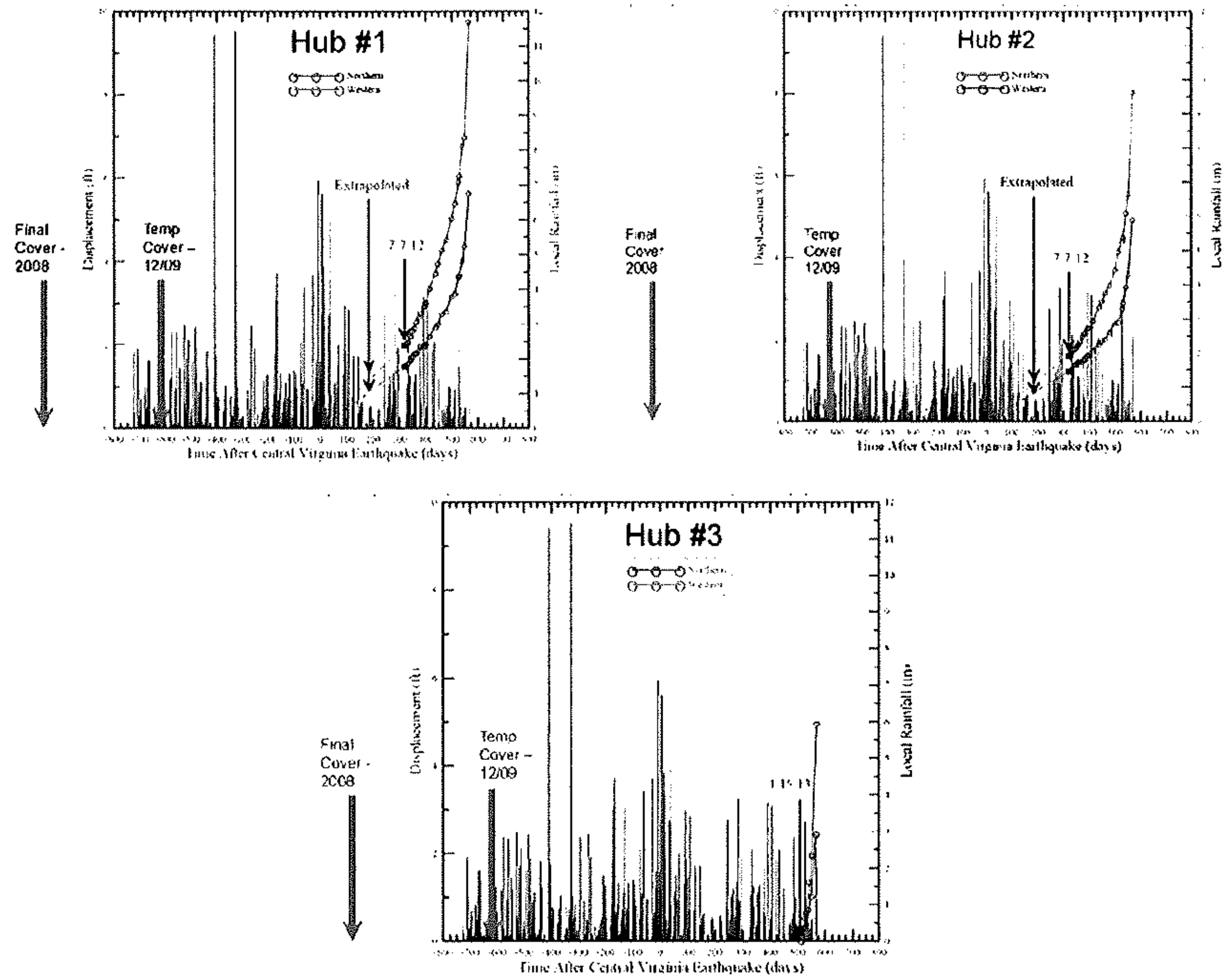


Figure B-28: Measured and extrapolated movement of three survey hubs installed after July 2012 to monitor slope movement in Stages 3E and 3D.

L | A | W

Land Air Water Legal Solutions LLC

David W. Buzzell
610-898-3860
dbuzzell@landairwater.com

August 4, 2016

VIA FEDERAL EXPRESS
Mr. Roger Bellas
Waste Management Program
PADEP
Northeast Regional Office
2 Public Square
Wilkes-Barre, PA 18701-1915

Re: Chrin Brothers Sanitary Landfill
Williams Township, Northampton County
Solid Waste Permit No. 100022
Cell 3D and 3E Slope Failure ("Slope Failure") Investigation

Dear Mr. Bellas:

On behalf of the Chrin Brothers Sanitary Landfill, this letter is provided in response to the additional document request made by the Department and Mr. Volk at our site meeting on May 11, 2016, and supplements our prior submissions. (On October 1, 2015, October 23, 2015, and May 11, 2016, you were provided documents responsive to previous requests, which were bates-stamped CHDEP000001 – CHDEP022128, CHDEP022129 – CHDEP022134, and CHDEP022135-CHDEP022536, respectively.) Enclosed herewith, please find three compact disks (CDs) each containing the supplemental production of documents, bates-stamped CHDEP022537 – CHDEP022613 responsive to your May request. For ease of review, the following is an outline of the documents:

1) Chrin Rain Tarp to Cap Anchor Trench Excavation Stage 3E (CHDEP022564 – CHDEP022568);

2) Chrin Hydrograph of Rainfall/Leachate/Witness Zone flows and levels:

    a. Chart (CHDEP022569 – CHDEP022570); and
    b. Excel Database Spreadsheet (Placeholder: CHDEP022571; see "Native Files" folder on CD for Excel Spreadsheet);

3) Chrin Groundwater Table with Cross-Sections in Stage 3E/D (CHDEP022572 – CHDEP022574);

4) Chrin Depth of Old Waste:

   a. Electrical Resistivity Survey for Stage 3E Results (CHDEP022575 – CHDEP022591); and
   b. Settlement Plan (Actual/Predicted) (CHDEP022592);

5) In-place Density Calculations Update (CHDEP022593 – CHDEP022603);

6) Stage 3C Development Plan for Closure Areas 1,2, and 3 Overlay (CHDEP022604); and

7) Pre-slide hub data (graphs) (CHDEP022605 – CHDEP022613).

In addition, also included on the disk is the document containing historical aerial photographs which was handed over at the May meeting, titled Chrin Brothers Landfill Site Investigation, prepared for U.S. EPA Region 3 and OERR, dated December 1983, and bates-stamped in this production as CHDEP022537-CHDEP022563;

If you have any questions or concerns, please contact me.

Sincerely,

David W. Bozzell

DWB:mmm
Enclosures
cc: John Judge, Esq. (w/o encl.)
    Sean Robbins, Esquire (w/o encl.)
    Chrin Landfill (w/encl.)
    EarthRes Group Inc. (w/encl.)

L | A | W

Land Air Water Legal Solutions LLC

David W. Buzzell
610-898-3860
dbuzzell@landairwater.com

May 11, 2016

VIA HAND DELIVERY
Mr. Jeffrey Spaide
Waste Management Program
PADEP
Northeast Regional Office
2 Public Square
Wilkes-Barre, PA 18701-1915

Re: Chrin Brothers Sanitary Landfill
Williams Township, Northampton County
Solid Waste Permit No. 100022
Cell 3D and 3E Slope Failure ("Slope Failure") Investigation

Dear Mr. Spaide:

On behalf of the Chrin Brothers Sanitary Landfill, I am writing to in response to your email requests sent to Joe Klobusicky of Chrin dated April 25, 2016 and April 29, 2016 to provide supplemental documents concerning the above referenced matter. (On October 1, 2015, and October 23, 2015, you were provided documents responsive to previous requests, which were Bates Stamped CHDEP000001 – CHDEP022128 and CHDEP022129 – CHDEP022134, respectively.) Enclosed herewith, please find two compact disks (CDs) each containing the supplemental production of documents, Bates Stamped CHDEP022135 – CHDEP022536 responsive to your April requests. For ease of review, the following is an outline of the documents requested and Chrin's responses thereto:

1) **Historical aerial photos from 1900's to present.**

   Documents will be provided at the meeting.

2) **Test borings that indicate thickness of older MSW below liner in Stages 3D, 3E, and 3C. If borings were not performed, please document how bottom of older MSW was judged.**

   a. Boring Location Plan (CHDEP022135)

3) **Relevant slope stability analyses and files.**

   a. Section 1 through Section 7 and Section F Reports, as well as elevation by distance charts (CHDEP022136-CHDEP022196)
   b. Electronic files are available on the CD provided (Placeholder: CHDEP022197)

4) **Survey data and plots from the post-failure investigation of hubs.**

    a. Settlement Displacement Monitoring spreadsheet and Figure (CHDEP022198-CHDEP022370)

5) **Movement data of riser pipes before and after failure.**

    a. Stage 3D Riser Locations Model (CHDEP022371)

6) **Relevant DMOD and FLAC electronic files – both input and output.**

    a. Electronic files are available on the CD provided. (Placeholders: CHDEP022372-CHDEP022373)
    b. FLAC text files were Bates Stamped (CHDEP022374-CHDEP022491)

7) **PDF copy of design plans for Stages 3D, 3E, and 3C.**

    a. Liner Details for Closure Areas 1, 2, and 3 Overlay, Sheets 1 to 5 of 5 (CHDEP022492-CHDEP022496)
    b. Stage 3D Development Plan for Closure Areas 1, 2, and 3 Overlay (CHDEP022497)
    c. Stage 3E Development Plan for Closure Areas 1, 2, and 3 Overlay (CHDEP022498)

8) **Plans/specs of details of rain flap/tarp of covered MSW above escarpment.**

    a. Chrin Temporary Cap Update Memoranda (CHDEP022499-CHDEP022507)
    b. Form No. 13-A Modification to Solid Waste Disposal and/or Processing Permit, effective 12/28/2009 (CHDEP022508-CHDEP022510)
    c. Photographs relating to the rain flap/tarp (CHDEP022511-CHDEP022534)

9) **A limited instrumentation program be implemented including inclinometers and piezometers and settlement monitoring points.**

    a. These documents will be supplemented.

10) **CAD Files**

    a. C-10: Form 6 – Geology Map (CHDEP022535)
    b. Electronic files are available on the CD provided (Placeholder: CHDEP022536)

If you have any questions or concerns, please contact me.

Sincerely,

David W. Buzzell

Enclosures
cc: John Judge, Esq. (w/o encs.)
Roger Bellas (w/o encs.)
Sean Robbins, Esquire (w/o encs.)

L|A|W

Land Air Water Legal Solutions LLC

John P. Judge
610-898-3848
jjudge@landairwater.com

October 1, 2015

VIA EMAIL AND FEDERAL EXPRESS
Mr. Jeffrey Spaide
Waste Management Program
PADEP
Northeast Regional Office
2 Public Square
Wilkes-Barre, PA 18701-1915

Re: **Chrin Brothers Sanitary Landfill ("Chrin")**
Williams Township, Northampton County
Solid Waste Permit No. 100022
Cell 3D and 3E Slope Failure ("Slope Failure") Investigation

Dear Mr. Spaide:

On behalf of the Chrin Brothers Sanitary Landfill ("Chrin"), I am writing in response to your email request to Joe Klobusicky of Chrin dated September 3, 2015 to provide information concerning the above referenced matter. It is Chrin's understanding that this request was prompted by inquiries from the consultant retained by the Department, John Volk of AECOM. The text of those requests appears in bold below. For ease of review, each page of the responsive documents have been Bates Stamped with the prefix CHDEP and all documents have been copied onto one 32 gb flash drive.

1) **Geotechnical borings and lab data and groundwater data from the entire site from all years.**

   a. All historical geotechnical borings and lab data from those borings are enclosed.

      Chrin submission to Williams Township **(CHDEP000001-000711)**
      Citizens submission to Williams Township **(CHDEP000712-001061)**
      Additional Geology Documents **(CHDEP001062-001232)**
      This information has been previously provided to the Department.

   b. Landfill groundwater monitoring data is presented as follows:

      1997 – 1999 **(CHDEP001233-003796)**
      2000 – 2002 **(CHDEP003797-006813)**
      2003 – 2005 **(CHDEP006814-010190)**
      2004 – 2015 **(CHDEP010191-010686)**

This information has been previously provided to the Department.

2) **Design report and calcs from this area that was constructed 2003-2008.**

3) **Bid documents from this area.**

4) **Construction QA/QC documents from construction of this area**

Due to the overlap in topics covered and the nature of these documents, we have consolidated the documents that are responsive to these three requests.

a. Form 24 and Stage 3D Design, Bid and Construction **(CHDEP010687-013409)**

b. Stage 3E Documents **(CHDEP013410-016002)**

c. Stage 3D Documents **(CHDEP016003-016308)**

d. Stage 3E – Phase I **(CHDEP016309-016401)**

e. Stage 3E – Phase II **(CHDEP016402-016438)**

f. Report-Construction Certification and Record Documentation – Stage 3D Final Closure, May 15, 2007 **(CHDEP016349-016902)**

g. Report-Construction Certification and Record Documentation Seep Mitigation System Stage 3D, October 10, 2003 **(CHDEP016903-016982)**

h. Certification of Construction Stage 3E – Phase I Subgrade, Subbase and Liner System, November 5, 2004 **(CHDEP016983-017095)**

i. Report-Construction Certification and Record Documentation Stage 3E Phase I – Area 2 Final Closure, March 2009 **(CHDEP017096-017583)**

j. Stage 3E Cap 2007 Stage – 3E Cap 2008 **(CHDEP017584-018285)**

5) **Any historical info/ data on existing MSW that goes back to 1960s.**

a. Annual Tonnage 1961 – 2014 **(CHDEP018286)**

b. Permit Modification 1997 **(CHDEP018287-018291)**

c. Quarterly PADEP reports for years 1989 to 1998 **(CHDEP018292-018332)**

d. Industrial Lane CERCLA Site RI/FS. At pp.1-1 through 1-15.

http://loggerhead.epa.gov/arweb/public/pdf/107442.pdf

6) **Photos and survey data from Sept 2011 when movement first observed and following.**

a. Site photos and locations taken by Chrin employee, David Chismar; site survey data. **(CHDEP018333-018725)**

7) **Photos and survey data from March 2013 at failure and following.**

a. Photographs taken by Earth Res Group during slide excavation and investigation activities March 2013 through September 2015. **(CHDEP018726-021663)**

b. Using the Bookmark function, the date of the photographs can be viewed.

c. Aerials and Autocad images can be found at **(CHDEP020921-020967)**

d. Chrin is not in possession of photographs taken by Chrin's former engineers, Civil & Environmental Consultants, Inc. following the slide.

8) **Investigation data (test pits, samples taken, etc) from post-failure.**

a. Waste Density Calculations and table prepared by Earth Res Group **(CHDEP021664-021673)**

b. Waste Density test pit locations map prepared by EarthRes Group. **(CHDEP021674)**

9) **Timeline of activities pre and post-failure.**

a. Interim Stabilization Plan (ISP) prepared by Civil and Environmental Consultants, Inc. - submitted to the Department in March 2013. **(CHDEP021675-021700)**

b. Daily and weekly reports to PADEP regarding the slide investigation and remediation. **(CHDEP021701-021927)**

c. EarthRes Group 30 Day Report submitted to the Department in April 2013. **(CHDEP021928-022070)**

10) **Lab test data post-failure.**

   a. Slope Failure Report prepared by Timothy D. Stark and submitted to the Department July 15, 2014. **(CHDEP022071-022110)**

11) **Detailed stability analyses output.**

   a. Printouts of stability analyses conducted by Timothy Stark Ph.D., on critical cross section, No. 7. **(CHDEP022099-022110)**

12) **Dynamic response (DMOD) and FLAC deformation analyses output and electronic files.**

   a. The outputs from the DMOD is enclosed. **(CHDEP022111-022128)** FLAC deformation analyses will be produced before October 15, 2015.

Sincerely,

John P. Judge

Enclosures
cc: David Buzzell, Esq. (w/o encs.)
Maryanne Garber, Esq. (w/o encs.)
Roger Bellas (via electronic mail only, w/o encs.)
Sean Robbins, Esquire (via electronic mail only, w/o encs.)