Hsu, Benjamin

From: Madden, Melissa
Sent: Wednesday, July 18, 2018 11:56 AM
To: Hsu, Benjamin; Chamberlain, Justin
Subject: FW: WACS No. 41193 - Southeast County Landfill, Hillsborough County, Florida - Revised Corrective Action Plan
Attachments: R20180716 Updated CAP ver 3.0.pdf; R20180502 Updated CAP ver 3.0 TrackChanges.docx

Please feel free to contact me with any questions or concerns.

Thanks, Melissa

Melissa Madden
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From: Guilbeault, Ken [mailto:KGuilbeault@SCSEngineers.com]
Sent: Monday, July 16, 2018 4:34 PM
To: O'Neill, Joseph <ONeillJ@hillsboroughcounty.org>; Boatwright, Kelley M. <Kelley.M.Boatwright@dep.state.fl.us>; Morgan, Steve <Steve.Morgan@dep.state.fl.us>; Madden, Melissa <Melissa.Madden@dep.state.fl.us>; Dilmore, Cory <Cory.Dilmore@dep.state.fl.us>
Cc: Byer, Kimberly <ByerK@hillsboroughcounty.org>; Ruiz, Larry <RuizLE@HillsboroughCounty.ORG>; Susan <Susan@PelzEnvServices.com>; 'Townsend,Timothy G' <ttown@ufl.edu>; 'Laux,Steven J' <steven.laux@essie.ufl.edu>; Curtis, Bob <BCurtis@scsengineers.com>
Subject: RE: WACS No. 41193 - Southeast County Landfill, Hillsborough County, Florida - Revised Corrective Action Plan

Good Afternoon,
Re: Updated Corrective Actions Plan
Southeast County Landfill – WACS 41193
Hillsborough County, Florida

Please find attached to this email the revised Corrective Action Plan and track changes word document to ease your review.

Please note that item 8 on the email below has been revised to say:

> 8) The County will continue to follow the current Corrective Action plan (continue with measurements of the piezometers, supplemental pumping, and quarterly GW sampling) until the attached revised Corrective Action Plan has been approved by the FDEP.

Ken Guilbeault, P.G.
Project Director

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Sent: Friday, July 13, 2018 5:13 PM
To: Boatwright, Kelley M. <Kelley.M.Boatwright@dep.state.fl.us>; Morgan, Steve <Steve.Morgan@dep.state.fl.us>; Madden, Melissa <Melissa.Madden@dep.state.fl.us>; Cory.Dilmore@dep.state.fl.us
Cc: Byer, Kimberly <ByerK@hillsboroughcounty.org>; Ruiz, Larry <RuizLE@HillsboroughCounty.ORG>; Susan <Susan@PelzEnvServices.com>; 'Townsend,Timothy G' <ttown@ufl.edu>; 'Laux,Steven J' <steven.laux@essie.ufl.edu>; Guilbeault, Ken <KGuilbeault@SCSEngineers.com>; Curtis, Bob <BCurtis@scsengineers.com>
Subject: WACS No. 41193 - Southeast County Landfill, Hillsborough County, Florida - Supplemental Liquid Level Assessment Reports

Good Afternoon,
Re: Supplemental Reports & Updated Corrective Actions Plan
Southeast County Landfill – WACS 41193
Hillsborough County, Florida

Please find attached to this email three documents;
- i) The University of Florida Report – Evaluation of the readings from the piezometers and assessment of the system pumping efforts.
- ii) The Report from Susan Pelz – Pelz Environmental, Inc. – Completion of the Criteria #3 evaluation of the piezometers and readings.

As a brief summary of the technical reports provided above, the following overall findings have been provided;

1) There is liquid within the piezometers and the way it is being measured, with a standard water level indicator appears to be consistent and within a few tenths of foot of using other methods – transducers or sonic water level measurements.

2) The piezometer were flushed, are open, and do not appear to be clogged.

3) The liquid levels within the piezometer have remained static even though supplemental pumping continues from the Phase II areas. Since the levels have remained static, the levels may have reached an equilibrium point with the design of the system and liquid level removal rates.

4) The measurement of the liquid level within a piezometer does not correlate to a continuous phreatic (standing water level) that extends across the entire footprint of the landfill or within Phase I,II, and III.

5) The Series II piezometers can be effected by leakage around or adjacent to the borehole. This was confirmed by modeling and by the fact “measured” levels in the piezometer do not match the field conditions encountered during excavations.

6) Three separate excavations (one ~1,100 LF along the eastside of Phase II; one ~100 LF along the Phase III/VI, one ~100 LF along Phase II/III) had liquid levels measurements in the piezometers that were not encountered in the field. The “measured” levels in the piezometers would have indicated a standing liquid level in the sand layers; however, this was not encounter when the area was excavated.

7) If the liquid levels at the location of the piezometers was representative of condition at that specific location, then based upon slug and drawdown tests, the levels measured at these locations would potentially take more than a year to lower or would potentially require installation of dewatering points in very close proximity, within 100 ft., to have an effect these individual piezometer locations.

8) The County will continue to follow the current Corrective Action plan (continue with measurements of the piezometers, supplemental pumping, and quarterly GW sampling).

9) The County has successfully found and jet cleaned out two additional access laterals to the main collection header running through Phase II, III, and Phase VI to Permanent Pump Station B (the primary leachate removal point for Phase I-VI. One additional lateral was found one the Phase II/III boundary and one along the Phase III/Phase VI boundary. The County is evaluating these location for inclusion into the CAP or as within the Alternative Procedure.

10) Even with the heavy rains in June and July, the levels remained static with a slight increase (a few tenths of a foot and within the margin of error of measuring the liquid levels – See Criteria #1 finding Pelz Env) in the last part of July (Refer to Monthly Reports). We feel the system is functioning and keeping levels rising significantly.

11) Quarterly Water Quality Reports for the May sampling event is being compiled and will be sent to the Department for review.

We look forward to discussing the findings mentioned above and have an opportunity to explain this complex topic during our August 2 meeting.

Thank you

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Please note: All correspondence to or from this office is subject to Florida’s Public Records law.

SCS ENGINEERS

CORRECTIVE ACTION PLAN

Presented to:

Hillsborough County Public Works Department
Solid Waste Management Division
332 N. Falkenburg Road
Tampa, Florida 33619

Presented by:

SCS ENGINEERS
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July 16, 2018
File No. 09215600.06

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CORRECTIVE ACTION PLAN

Southeast County Landfill
Lithia, Florida

Presented To:

Hillsborough County Public Works Department
Solid Waste Management Division
332 N. Falkenburg Road
Tampa, Florida 33619

Presented by:

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July 16, 2018
File No. 09215600.06

KENNETH GUILBEAULT LICENSE No. 2907 STATE OF FLORIDA PROFESSIONAL GEOLOGIST

07/16/2018

Kenneth E. Guilbeault, P.G.
No. 2907

Note:
Initial Corrective Action Plan submitted on June 26, 2017 and revised November 27, 2017.

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1.0 INTRODUCTION

During the February 2016 groundwater monitoring event at the Southeast County Landfill (SCLF), elevated readings were observed by the Hillsborough County Public Works Department, Solid Waste Management Division (SWMD) for select parameters at monitoring well TH-67. TH-67 is a detection well approximately 45 feet east of Phase II and monitors shallow groundwater at the SCLF. Since that time, the SWMD and its engineering Consultant, SCS Engineers (SCS), have been conducting investigations of potential causes for the elevated readings and have installed additional measures to mitigate the concern.

The results of the on-going investigation have been shared with the Florida Department of Environmental Protection (FDEP) in multiple reports, weekly emails, and meetings.

This Corrective Action Plan (CAP) describes actions completed, ongoing and proposed to be taken by the SWMD to correct conditions that contributed to ground water impacts in the vicinity of monitoring well TH-67.

Condition 9a of the Consent Agreement dated July 28, 2017 between the SWMD and the FDEP required the SWMD to submit a CAP to the FDEP for review and approval.

An initial CAP was submitted on June 26, 2017 for FDEP review. A meeting with the FDEP was held on October 12, 2017 to discuss the CAP. As a result of the meeting, the SWMD is submitting this revised CAP.

2.0 BACKGROUND

Groundwater samples collected from TH-67 during the February 2016 monitoring event indicated elevated levels of indicator parameters. Although the exact cause cannot be definitively determined, the elevated levels in groundwater were thought to be related to a leachate discharge.

Accordingly, the SWMD responded with the following major activities:

1. Initiated additional leachate removal measures, such as installation of supplemental vertical dewatering wells, pumping from LFG extraction wells, construction of a cut-off trench, and jet-cleaning of leachate collection pipes, to assist with the removal of leachate from within the landfill;

2. Began quarterly collection of groundwater samples from monitoring wells and installed additional wells to monitor and evaluate the progress of groundwater quality restoration in the affected area;

3. Installed piezometers throughout the SCLF to assess the presence of liquid and its estimated depth at those locations (see **Figure 1**); and,

4. Removed an average of approximately 33,000 gallons per day (GPD) of leachate, from the supplemental locations mentioned above, since August of 2017. Approximately 11,100,000 gallons of leachate have been removed from the

supplemental locations mentioned above, since August of 2017. A table of supplement leachate removal is included in **Appendix A**.

Additional information is included in a detailed list of activities completed to date in **Appendix B**.

In addition to this CAP, the SWMD is preparing a Request for Alternate Procedure (Request) to establish an Approved Operating Level for leachate management at this site. The Request includes justification for the proposed operating level and describes how that level will be achieved and monitored. On December 8, 2017, a draft Request proposing a maximum leachate operating depth was provided to FDEP for comment. FDEP provided its initial comments on the draft Request on January 24, 2018. SCS and the SWMD are reviewing the FDEP's comments, and will be providing a revised Request that addresses those comments.

The Alternative Procedure will establish the "Approved Operating Level" referenced in this CAP. In the event that the Alternate Procedure is not granted, this CAP will be revised as necessary.

3.0 PURPOSE

The objectives of this CAP are to:

1. Reduce leachate levels within the landfill to an Approved Operating Level;
2. Monitor progress of leachate reduction efforts; and,
3. Monitor water quality in the area adjacent to Phase II for improvement and take necessary actions for the reduction in water quality parameters that exceed FDEP standards.

This CAP also includes the proposed metrics for confirming the stated goals have been achieved, a schedule for conducting the activities, and the estimated time for completion.

4.0 PROPOSED WORK PLAN

Since leachate management is complex and influenced by a variety of factors, the Work Plan is being developed, implemented and completed in Steps.

STEP 1 – INITIAL EVALUATION AND RESPONSE, 2016-2017

Work Plan Step 1 included initial evaluations, fieldwork, monitoring and recordkeeping, and installation of additional leachate management features.

Several activities completed in 2016 and 2017 are described in detail in the document titled, "Corrective Action Plan, Southeast County Landfill, Lithia, Florida" prepared by SCS Engineers, dated June 26, 2017. Also, see **Appendix B** for detailed list of completed activities.

STEP 2 – LEACHATE REMOVAL AND MONITORING SYSTEM DEVELOPMENT, JANUARY-JUNE 2018

Work Plan Step 2 includes additional fieldwork, ongoing monitoring, recordkeeping and data analysis to develop the long-term leachate removal system and controls necessary to meet the objectives of this CAP.

1. **Liquid Level Monitoring Evaluation:** Liquid levels in piezometers.

   To date, liquid levels have been measured in the Series-2 piezometers to attempt to demonstrate the progress of leachate removal activities. However, the analyses described below (Please see **Appendices C and D**) concluded that the Series-2 piezometers are not an accurate method of measuring liquid levels across the entire floor of the landfill. The liquid levels measured in the piezometers were evaluated as follows:

   a. **Effectiveness of Piezometers:** In order to be an appropriate monitoring metric, piezometers were evaluated to assess the accuracy and repeatability of measuring the liquid levels within the piezometer, as well as evaluating the liquid level monitoring as related to leachate removal locations. To date, this analysis has concluded that liquid level measurements using an electronic water level tape are reasonably accurate and liquids appear to move into and out of existing piezometers (Series-2). Piezometer locations relative to leachate removal locations are being evaluated to determine which, if any, piezometers are expected to be responsive to the liquid removal methods being utilized. See **Appendix C** for an evaluation of the piezometers completed by Pelz Environmental Services, Inc.

   b. **Influence of Other Site-Specific Conditions:** This evaluation by Dr. Tim Townsend and others from the University of Florida (UF) assessed the potential for other conditions within the landfill that could be influencing liquid levels measured in the piezometers. The analysis presented possible alternate interpretations of the recorded liquid levels. The following factors were examined:

      i. Piezometer construction methods

      ii. Perched leachate zones created by waste composition and layering

      iii. Leachate collection system design, e.g., gravel trench spacing, pipe spacing, bottom slopes, etc.

      The evaluation by Dr. Tim Townsend and others from the UF concluded the following:

      i. The presence of the piezometers is causing an artificially elevated liquid level at the piezometer locations.

      ii. Perched liquid conditions were present within the waste.

iii. The leachate collection system appears to be functioning properly.

iv. Piezometers are not an accurate or reliable method of determining liquid levels in a landfill leachate collection system.

2. **Compliance Metric:** Water balance.

   The metric for accomplishing the goal of reducing leachate levels in the landfill is based on liquid removed as calculated using the supplemental volume pumped compared to the estimated quantity of leachate above the Approved Operating Level. See **Appendix D** for detailed initial calculations.

STEP 3 – IMPLEMENTATION, MONITORING, EVALUATION AND REVISION

The SWMD proposes to conduct the following activities following FDEP acceptance of this plan through completion:

1. Continue supplemental pumping, or removal, of leachate from the Phase I and Phase II areas of the landfill as follows:

   a. Leachate removal via the Phase II header pipe;

   b. Pumping from the Phase I and II dewatering wells (DW 1-1, DW 1-2, DW 2-1, and DW 2-2);

   c. Pumping from Landfill gas (LFG) extraction wells (EW-38, EW-44, EW-48, and EW-66); and,

   d. Pumping from LFG condensate traps (CT-1, CT-2, and CT-3).

2. Equip the riser port in the leachate cut-off trench along the east side of Phase II with a level sensing device that will turn the pump on when the level reaches 30-inches in the trench.

3. Continue daily monitoring of the leachate level in the main sump (PS-B). This data will be included in the monthly progress report submitted to the FDEP.

4. Where absent, cleanouts are being installed on leachate collection system headers in landfill Phases I, II and III. As part of each cleanout installation, the leachate collection header pipe is being jet-cleaned and video recorded to assess its condition. If liquids do not appear to drain after jet-cleaning, a suction line will be temporarily placed in the leachate collection header to remove accumulated liquids. If sufficient accumulation persists, this location will be made part of the long-term leachate reduction system.

5. Per Condition 10 of the Consent Agreement, continue quarterly sampling of groundwater monitoring wells TH-20B, TH-38B, TH-66A, TH-67, TH-79, TH-80, TH-81, TH-82, and TH-83.

6. Provide a monthly progress and summary report to the FDEP of the activities in the CAP. Per the Consent Agreement, this report will be submitted by the 15th of the following month.

7. A detailed CAP objectives evaluation report will be prepared and provided to FDEP semi-annually (submitted dates to be determined). The evaluation will discuss:

   a. The effectiveness of the leachate removal, monitoring and controls;

   b. Supplemental pumping locations evaluation on a location specific basis and additional leachate removal points and methods will be added if needed;

   c. Pumpage rates;

   d. Unexpected conditions/results;

   e. Proposed changes to the CAP; and,

   f. Updates to schedule for completion.

STEP 4 – METRIC FOR CAP COMPLETION

Based on the metrics in place, completion of the CAP will be determined as follows:

1. Upon reaching the Approved Operating Level (as demonstrated by the approved metric described in Work Plan Step 2), the supplemental pumping locations will temporarily cease pumping while liquid levels within the area of concern will continue to be monitored.

2. If the liquid levels remain below the Approved Operating Level for twelve consecutive months, the CAP will be considered complete, and a final report will be submitted to FDEP requesting closure of the Consent Agreement.

3. In the event the liquid levels rise above the Approved Operating Level during the twelve-month period, supplemental pumping will resume at the time the level is recorded. Supplemental pumping will continue at least three months before ceasing supplemental pumping and beginning the twelve month monitoring period.

4. Schedule:

   a. SCS initially estimated that the leachate reduction be accomplished in approximately two years with an average supplemental leachate pumping rate of approximately 33,000 GPD. However, the estimated time to complete this work is highly dependent on several assumptions, including the actual volume of leachate in the landfill, the infiltration rate from rainfall, annual rainfall amounts, effectiveness of supplemental leachate pumping, days of pumping, and others.

   b. The semi-annual CAP objectives evaluation report will discuss if the estimated timeline will be achieved as planned or adjustments need to be made to the timeline. The schedule could be longer or shorter depending on how all of the variables come together over time; however, the CAP objectives will be measured based on the approved metrics.

5.0 GROUNDWATER MONITORING

The SWMD will continue to collect samples from surficial groundwater monitoring wells TH-20B, TH-38B, TH-66A, TH-67, TH-79, TH-80, TH-81, TH-82, and TH-83 on a quarterly basis (February, May, August, and November). SCS and the SWMD believe that the current monitoring network, which includes the recently installed TH-83, is sufficient to monitor the surficial aquifer groundwater. These samples will be analyzed for sodium, ammonia, chloride, and total dissolved solids. Field parameters will include temperature, pH, Conductivity, Turbidity, Dissolved Oxygen, and oxygen reduction potential (ORP). Results will be submitted to the FDEP within 60 days of completion of laboratory analysis.

Monitoring of these groundwater-monitoring wells will continue for one year following completion of the CAP. At that time, the SWMD will seek approval from the FDEP to discontinue quarterly monitoring at these locations. The SWMD will also discuss adding selected monitoring locations to the semi-annual groundwater monitoring and assessment program. Following completion of the CAP, additional assessment of groundwater will be implemented should a constituent of concern exceed regulatory limits and is confirmed in the same well during a monitoring event.

An evaluation of the water quality in monitoring wells referred to in this CAP, will be included with the semi-annual evaluation submittals (following approval of the CAP). This evaluation will compare quarterly groundwater quality results against historical and regulated groundwater standards.

6.0 CAP SUBMITTALS

The SWMD will continue to submit the following reports to the FDEP.

1. Monthly progress reports

    a. Leachate pumping data
    b. Supplemental pumping data
    c. Additional liquid removal activities, completed and proposed
    d. Submitted prior to the 15th of the following month

2. Quarterly supplemental groundwater quality reports

    a. Samples collected in November, February, May, and August
    b. Submitted within 60-days of completion of laboratory analysis

3. Semi-annual Evaluation of Objectives and Proposed Adjustments

    a. Evaluation of CAP objectives, milestone metrics, supplemental pumping locations, evaluation of water quality, and schedule

    b. Updated water balance reports
        i. Updated leachate volume estimate based on liquid levels in piezometers
        ii. Submitted every 6 months in May and November.

4. Final Report of Completion of the CAP
    a. A summary report for meeting the metrics for completion
    b. Boring logs
    c. Trend Analyses
    d. Groundwater summary tables
    e. Groundwater monitoring well installation
    f. Construction details
    g. Other information, as necessary

FIGURES

LEGEND:

SB-22D	SECOND SERIES PIEZOMETER LOCATION
SB-03	FIRST SERIES PIEZOMETER LOCATION
SB-27	REMOVED PIEZOMETER LOCATION
	PHASE LIMIT
	CUT-OFF TRENCH
	MONITORING POINT

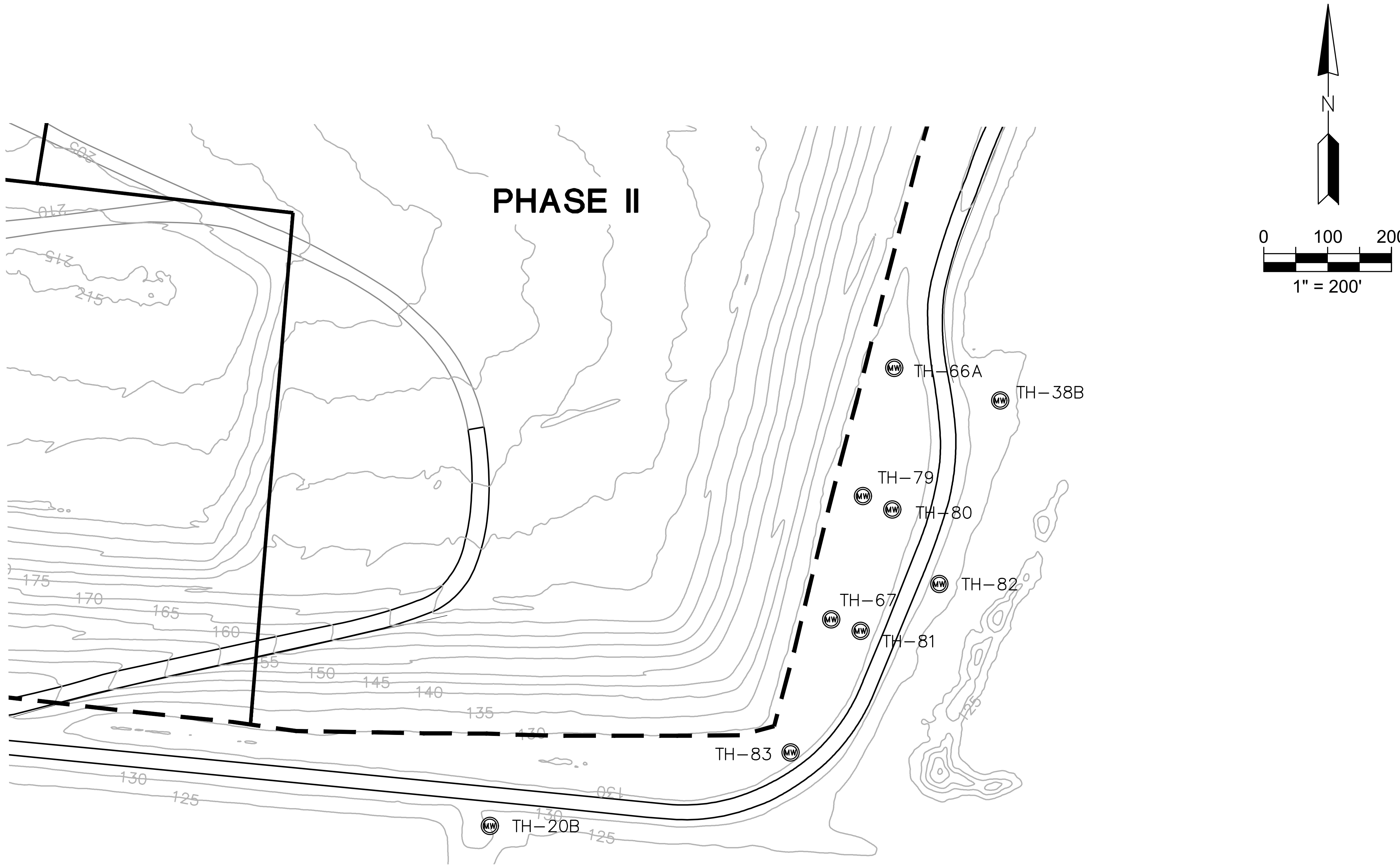
NOTE:

1. TOPOGRAPHIC SURVEY BY PICKETT, JANUARY 2018.

F:\PROJECT\HILLSBOROUGH\09215600.05 – ACTIVE LF\PHASE I\1110 – CORRECTIVE ACTION PLAN\MAY 2018 CAP\APPENDICES AND FIGURES\DWG\FIGURE 1 – MONITORING POINTS.DWG

SCS ENGINEERS

FIGURE 1. MAP OF PIEZOMETERS AND MONITORING POINTS
SOUTHEAST COUNTY LANDFILL
MAY 2018



LEGEND:

MW GROUNDWATER MONITORING WELLS

LANDFILL BOUNDARY

NOTE:
1. TOPOGRAPHIC SURVEY BY PICKETT, JANUARY 2018.

F:\PROJECT\HILLSBOROUGH\09215600.05 – ACTIVE LF\PHASE I\1110 – CORRECTIVE ACTION PLAN\MAY 2018\APPENDICES AND FIGURES\DWG\FIGURE 2 AND 3 – DEWATERING LOCATIONS.DWG

SCS ENGINEERS

FIGURE 2. MONITORING WELL LOCATIONS
SOUTHEAST COUNTY LANDFILL
MAY 2018

NOTE:
1. TOPOGRAPHIC SURVEY BY PICKETT, JANUARY 2018.

F:\PROJECT\HILLSBOROUGH\09215600.05 – ACTIVE LF\PHASE I\1110 – CORRECTIVE ACTION PLAN\MAY 2018 CAP\APPENDICES AND FIGURES\DWG\FIGURE 2 AND 3 – DEWATERING LOCATIONS.DWG

SCS ENGINEERS

FIGURE 3. MAP OF SUPPLEMENTAL DEWATERING LOCATIONS
SOUTHEAST COUNTY LANDFILL
MAY 2018

APPENDIX A
Supplemental Leachate Removal

Weekly Supplemental Leachate Pumping Data
Liquid Assessment Monitoring
Southeast County Landfill

Week Ending	Condensate Traps (gal)	LFG Extraction Wells (gal)	Dewatering Wells (gal)	Pump Stations (gal)	Weekly Total (gal)	Daily Average (gpd)
12/23/2016	-	4,296	-	-	4,296	1,074
12/30/2016	-	8,024	-	-	8,024	1,146
1/6/2017	2,518	7,614	-	-	10,132	1,447
1/13/2017	10,516	7,201	-	-	17,717	2,531
1/20/2017	15,952	9,104	-	-	25,056	3,579
1/27/2017	12,999	7,953	-	-	20,952	2,993
2/3/2017	13,991	8,072	-	-	22,063	3,152
2/10/2017	29,162	7,025	-	-	36,187	5,170
2/17/2017	64,513	8,404	-	2,000	74,917	10,702
2/24/2017	56,760	6,811	-	13,600	77,171	11,024
3/3/2017	16,376	5,872	-	14,600	36,848	5,264
3/10/2017	13,076	5,373	-	42,000	60,449	8,636
3/17/2017	14,365	5,969	-	84,000	104,334	14,905
3/24/2017	12,218	6,003	-	81,000	99,221	14,174
3/31/2017	9,808	5,199	-	63,000	78,007	11,144
4/7/2017	5,677	4,874	-	49,000	59,551	8,507
4/14/2017	3,292	5,685	-	42,000	50,977	7,282
4/21/2017	4,025	7,550	-	41,000	52,575	7,511
4/28/2017	3,529	6,954	-	34,600	45,083	6,440
5/5/2017	2,309	6,159	-	31,600	40,068	5,724
5/12/2017	1,279	5,845	-	27,000	34,124	4,875
5/19/2017	1,815	4,793	1,169	24,100	31,877	4,554
5/26/2017	2,168	5,792	7,374	34,140	49,474	7,068
6/2/2017	2,455	5,188	7,597	23,937	39,177	5,597
6/9/2017	2,900	4,639	7,551	24,033	39,123	5,589
6/16/2017	3,176	3,367	9,120	18,636	34,299	4,900
6/23/2017	2,587	4,111	2,063	22,735	31,496	4,499
6/30/2017	3,319	4,112	6,595	21,412	35,438	5,063
7/7/2017	2,369	4,303	7,156	35,711	49,539	7,077
7/14/2017	3,522	4,376	8,569	37,025	53,492	7,642
7/21/2017	3,272	8,131	8,059	51,131	70,593	10,085
7/28/2017	3,573	10,250	8,075	46,326	68,224	9,746

Weekly Supplemental Leachate Pumping Data
Liquid Assessment Monitoring
Southeast County Landfill

Week Ending	Condensate Traps (gal)	LFG Extraction Wells (gal)	Dewatering Wells (gal)	Pump Stations (gal)	Weekly Total (gal)	Daily Average (gpd)
8/4/2017 [1]	8,278	25,125	8,880	98,630	140,913	20,130
8/11/2017	6,541	64,449	7,701	170,324	249,015	35,574
8/18/2017	4,889	62,204	8,951	147,907	223,951	31,993
8/25/2017	4,852	62,896	9,397	139,376	216,521	30,932
9/1/2017	55,411	64,407	9,876	197,359	327,053	46,722
9/8/2017	62,183	75,863	9,912	132,878	280,836	40,119
9/15/2017 [2]	21,344	15,941	2,485	171,276	211,046	30,149
9/22/2017 [2]	21,062	24,538	7,088	152,090	204,778	29,254
9/29/2017	75,527	52,154	14,371	201,676	343,728	49,104
10/6/2017	60,611	57,347	12,037	285,947	415,942	59,420
10/13/2017	71,298	51,515	9,009	151,615	283,437	40,491
10/20/2017 [3]	78,470	57,889	1	154,888	291,248	41,607
10/27/2017	77,877	25,324	3,082	344,539	450,822	64,403
11/3/2017	93,276	52,784	15,743	295,219	457,022	65,289
11/10/2017	90,875	50,207	16,146	180,432	337,660	48,237
11/17/2017	96,443	53,486	14,756	177,071	341,756	48,822
11/24/2017	99,123	49,385	14,620	246,012	409,140	58,449
12/1/2017 [4]	100,387	48,906	14,013	75,732	239,038	34,148
12/8/2017 [4,5]	96,185	51,690	14,835	44,435	207,145	29,592
12/15/2017 [4]	96,010	45,467	14,758	37,714	193,949	27,707
12/22/2017 [4]	133,046	48,074	14,817	35,702	231,639	33,091
12/29/2017 [8]	189,864	48,139	14,646	55,554	308,203	44,029
1/5/2018 [6]	70,623	47,514	13,608	172,332	304,077	43,440
1/12/2018 [7]	72,915	33,406	9,817	123,399	239,537	34,220
1/19/2018 [8]	129,553	45,763	10,453	120,587	306,356	43,765
1/26/2018 [8]	163,579	46,519	10,942	101,490	322,530	46,076
2/2/2018	147,769	45,646	12,672	163,034	369,121	52,732
2/9/2018	76,459	29,950	13,106	126,081	245,596	35,085
2/16/2018	44,660	18,088	11,610	141,977	216,335	30,905
2/23/2018	627	17,140	10,827	138,050	166,644	23,806

Weekly Supplemental Leachate Pumping Data
Liquid Assessment Monitoring
Southeast County Landfill

Week Ending	Condensate Traps (gal)	LFG Extraction Wells (gal)	Dewatering Wells (gal)	Pump Stations (gal)	Weekly Total (gal)	Daily Average (gpd)
3/2/2018	1,125	22,122	6,227	118,247	147,721	21,103
3/9/2018	907	12,699	3,945	76,321	93,872	13,410
3/16/2018	884	22,354	12,456	109,885	145,579	20,797
3/23/2018	566	16,186	13,931	81,563	112,246	16,035
3/30/2018	1,037	2,959	9,899	109,604	123,499	17,643
4/6/2018	180	3,309	5,816	126,304	135,609	19,373
4/13/2018	288	5,539	5,056	135,041	145,924	20,846
4/20/2018	332	4,426	9,424	158,893	173,075	24,725
4/27/2018	1,211	8,176	5,154	134,289	148,830	21,261
5/4/2018	1,031	4,960	7,148	144,008	157,147	22,450
5/11/2018	603	811	5,227	115,756	122,397	17,485
5/18/2018	2,305	1,747	13,336	124,359	141,747	20,250
5/25/2018	4,339	5,693	13,481	144,579	168,092	24,013
6/1/2018	9,329	9,886	15,446	142,902	177,563	25,366
6/8/2018	1,978	8,266	15,229	106,707	132,180	18,883
6/15/2018	1,461	15,175	14,371	116,663	147,670	21,096
6/22/2018	617	6,684	18,438	109,495	135,234	19,319
6/29/2018	1,213	16,927	11,049	134,060	163,249	23,321
Total	2,602,664	1,738,784	589,120	7,636,588	12,567,156	

Notes

1. Installed suction line in Phase II header.
2. Pumps shut down during and following Hurricane Irma.
3. Dewatering wells shut down for maintenance 10/12/17 through 10/26/17.
4. PS-2 shut down for construction at cut-off trench from 11/27/17 through 12/28/17.
5. PS-2B shut down for construction at cut-off trench from 12/7/17 through 12/11/17.
6. PS-2B shut down to check liquid Levels in MP 2-2 and MP 2-3 from 12/28/17 through 1/5/18.
7. All supplemental dewatering pumps shut down for Phase II dye tracer test 1/9/18 and 1/10/18.
8. PS-2 shut down for maintenance 1/16, 1/19, 1/20, 1/24, and 1/25.

APPENDIX B
Completed Activities

Appendix B Completed Tasks Corrective Action Plan Southeast County Landfill	
Action Item	**Completion Date**
Stage 1	
Install piezometers SB-01 through SB-25	March 7, 2017
Install shallow groundwater monitoring well (TH-79)	November 28, 2016
Dewater extraction wells.	January 31, 2017
Install pneumatic pumps in condensate traps (CT-1, CT-2, and CT-3) and LFG extraction wells (EW-44 and EW-48)	January 15, 2017
Installed temporary well point system	March 10, 2017
Install temporary leachate pump station No. 2 (TPS-2)	February 17, 2017
Phase I cleanout installation	March 10, 2017
Jet clean Leachate Collection System Phase I	June 13, 2017
Install 3 shallow groundwater monitoring wells (TH-80, TH-81, and TH-82).	March 9, 2017
Survey wells, sample, and test water	March 29, 2017
Provide interim status reports to the FDEP	Findings reports dated December 16, 2016 and June 26, 2017
Draft CAP submittals to the FDEP	June 26, 2017 and November 27, 2017
Submit final CAP to the FDEP	May 2, 2018
Stage 2	
Design dewatering wells (DW-1 and DW-2)	May 5, 2017
Install dewatering wells (DW-1 & DW-2)/start pumping per FDEP.	May 19, 2017
Installed piezometers SB-26 through SB-30	April and May 2017.
Install Phase II Cut-Off Trench and begin monitoring	July 12, 2017
Phase II cleanout installation	July 12, 2017
Jet Clean Leachate Collection System Phase II	July 17, 2017
Weekly monitoring	On-going
Install GCL around all LFG extraction wellheads	September 30, 2017
Install 2 pneumatic pumps in LFG extraction wells (EW-38 and EW-66)	April 11, 2017
Phases I-VI fill sequence modification	Approved by FDEP July 17, 2017
Stage 3 – ACTIVELY IMPLEMENTING PER CAP	
Monthly Report Level Readings in all piezometers	On-going
Review and evaluate the project performance every 90 days (Piezometers, Dewatering Wells, Trenches, and Other Points)	Schedule pending FDEP approval of CAP
ADDITIONAL ACTIONS BEYOND INITIAL CAP	
Installation of Monitoring Well TH-83 at Southeast Corner of Phase II	December 28, 2017
Jet Clean All LCRS Headers with Access Cleanouts (Phases I, II, IV, V, and VI)	December 2017 Through January 2018
Tracer Dye Test of Phase II LCRS Header	January 9, 2018
Tracer Dye Test of Phase I LCRS Header	January 31, 2018
Installation of SB-31 and SB-32 Piezometers	March 6, 2018
Phase III LCRS Header Cleanout Installation	May 1, 2018
Jet Clean Phase III LCRS Header	May 1, 2018
Investigative Trenching for Northern Phase II Header	May 1, 2018
Evaluation of Series 2 Piezometers (Measurements, Slug Tests, Recharge, and Drawdown)	July 10, 2018

Notes:

Stage 1, 2, and 3 designation from initial Corrective Action Plan submitted on June 26, 2017

APPENDIX C
Piezometer Effectiveness Evaluation

Prepared by
Pelz Environmental Services, Inc.

Pelz Environmental Services, Inc.
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Brandon, FL 33509
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Piezometer Effectiveness Evaluation
Criterion #3

Southeast County Landfill
Lithia, Florida

Prepared for

Hillsborough County Public Works Department
Solid Waste Management Division
332 N. Falkenburg Road
Tampa, Florida 33619

July 13, 2018

Prepared by
Pelz Environmental Services, Inc.
Certificate of Authorization #30910

7/13/18

Susan J. Pelz, P.E.
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Executive Summary

Significant field work and assessment related to liquid levels in the Southeast County Landfill (SCLF) have been completed by the Hillsborough County Public Works Department, Solid Waste Management Division (SWMD) and SCS Engineers. Pelz Environmental Services, Inc. (PES) has reviewed pressure transducer data, water level readings, monthly progress reports and other relevant information provided by SCS Engineers to assist in our analysis of piezometer effectiveness. If liquid levels in piezometers (PZ) installed in the landfill are to be an appropriate metric to measure compliance with the Corrective Action Plan, the piezometers must effectively respond to the implemented corrective actions.

Based on our review of data from drawdown/recharge, pump and slug tests and other relevant information, the following conclusions can be made:

1. The water levels recorded in the piezometers vary based on location, and exhibit variable responses to dewatering activities.

2. Dewatering with pumps installed in each PZ generally achieved drawdown of liquids to depths between 2 and 3 feet, but is not likely a feasible long term solution given field and operational constraints.

3. Large dewatering wells (such as DW 1 and DW 2) have some effect on nearby piezometers. Although SB-29 is 11 feet from DW 1 and responds fairly well to pumping in DW 1, SB-30 that is 10 feet away from DW 2 shows only minimal effects from DW 2.

4. Recharge rates are significantly slower than drawdown rates. Based on the observed recharge rates, reduction of the liquid levels in the landfill may only be discernable in the PZ in the long term (e.g., years instead of months), see Table 4.

5. The piezometers appear to have a "steady state" water level. Since this "steady state" level may be a result of the landfill design (e.g., leachate collection spacing) or other uncontrollable factors (e.g., uneven clay settlement), reducing the liquids to below this level may not be possible using reasonably available methods.

6. Based on equipment limitations, PZ locations with liquid levels near or below two-foot (SB-17D, SB-18D, SB-20D, SB-21D, SB-22D, SB-23D and SB-24D) are not considered to be useful monitoring points.

Background

As required by Florida Department of Environmental Protection (FDEP) Consent Agreement #17-0058 (July 28, 2017), Hillsborough County Public Works Department, Solid Waste Management Division (SWMD) has completed several corrective actions and evaluations regarding leachate management at the Southeast County Landfill (SCLF).

As previously discussed in Pelz Environmental Services' (PES') Memorandum Report dated May 1, 2018, for piezometer (PZ) liquid level readings to be an appropriate indicator of Corrective Action Plan (CAP) compliance, the following questions must be answered affirmatively for each PZ that is proposed to be part of the monitoring system:

Criterion 1. Is the liquid level reading accurate and repeatable?

Criterion 2. Can liquid move into and out of the PZ?

Criterion 3. Can the PZ, or its location relative to a specific extraction point, effectively detect changes in liquid levels due to leachate removal (i.e., pumping)?

That report concluded that the electronic water level tape measurements are a reasonably accurate and repeatable method to determine the liquid level in the PZ (Criterion 1); and although there is variability in the responsiveness of each PZ, liquids can/do move into and out of each PZ (Criterion 2).

This report describes the actions completed to evaluate the existing (primarily Series 2) piezometers and dewatering locations specifically with respect to Criterion 3. Series 2 PZ include: SB-15D, SB-16D, SB-17D, SB-18D, SB-19D, SB-20D, SB-21D, SB-22D, SB-23D, SB-24D, and SB-28D.

Pressure transducer data, water level readings, monthly progress reports and other relevant information was provided by SCS Engineers and Hillsborough County SWMD for PES' review.

1. Field Activities

Field investigations conducted by the SWMD and SCS Engineers since late 2016 have produced an abundance of data that are useful to evaluate the dewatering actions at the SCLF. Field work most relevant to Criteria 3 is discussed briefly.[1] These activities generally consisted of removing liquids from various locations in the landfill and then observing the piezometer recharge responses.

[1] A detailed list of field activities is included in **Appendix B** of *the Corrective Action Plan,* dated May 2, 2018, prepared by SCS Engineers.

1.1. November 2016, Drawdown/Recharge tests

Liquid Assessment Findings Report, dated December 13, 2016, prepared by SCS Engineers. This report details drawdown/recharge tests conducted on landfill gas extraction wells (EW) and piezometers (SB) that existed at that time.

Locations included: EW-32, EW-39, EW-40, EW-44, EW-46, EW-48, EW-70, SB-01, SB-02, SB-03, and SB-05.

Summary: Pressure transducers and temporary submersible pumps were installed in each LFG EW and piezometer. Pumps removed liquids and the liquid levels were monitored with transducers and in-line data loggers that provided one-minute level measurements during drawdown and recovery periods. Testing was performed over approximately fifteen days.[2]

1.2. May 2017, Drawdown/Recharge tests

Locations included: SB-15D, SB-16D, SB-17D, SB-18D, SB-25D, SB-28D, SB-01, SB-29, and SB-30.

Summary: Pressure transducers were installed in each piezometer. Temporary submersible pumps placed in each piezometer were used to dewater the liquid. Liquid levels were monitored with transducers that provided level measurements (one-second intervals) during drawdown and recovery periods. Data was collected over approximately three days.

1.3. July 2017, Pump tests

Locations included: DW 1 and SB-29 (SB-29 is the PZ closest to DW 1).

Summary: After installation of dewatering wells (DW 1 and DW 2), initial field tests were conducted (DW 1 only) to ensure proper operation. Two permanent pumps were installed for normal operation in each DW. For the July 2017 test, one of the pumps was temporarily removed and a pressure transducer was installed. The other permanent pump was used to remove liquid. Liquid levels were monitored with temporary transducers installed in DW 1 and SB-29 that provided level measurements (one-second intervals) during drawdown and recovery periods. Data was collected for approximately five hours. As a result of this test, pump installation was adjusted to improve its operation.

1.4. March 2018, Pump tests

Locations included: DW 1, SB-29, DW 2, and SB-30.

Summary: For this test, one of the permanent pumps was removed from both DW 1 and DW 2, leaving one pump in each DW to remove liquid. Liquid levels were monitored with

[2] *Liquid Assessment Findings Report*, dated December 13, 2016, Section 2.3.2.

temporary transducers installed in each DW and adjacent piezometer (SB-29 for DW 1, SB-30 for DW 2). Level measurements (one-minute intervals) were recorded during drawdown and recovery periods. Data was collected over approximately fifteen days.

1.5. March/April 2018, Slug tests

"Piezometer Effectiveness Evaluation," dated May 1, 2018, prepared by Pelz Environmental Services, Inc. [Appendix C of *Corrective Action Plan,* dated May 2, 2018, prepared by SCS Engineers]. This report details slug tests conducted on Series 2 piezometers in March/April 2018.

Locations included: SB-15D, SB-16D, SB-17D, SB-18D, SB-19D, SB-20D, SB-21D, SB-22D, SB-23D, SB-24D and SB-28D.

Summary: Pressure transducers were installed in each piezometer. Clean water was pumped into each PZ. Liquid levels were recorded by the transducers (fifteen-second intervals) during liquid addition and while the added liquids dissipated through the PZ screen into the adjacent materials. Data was collected over approximately six days.

2. Results

For liquid levels measured in the PZ to be a reasonable metric for monitoring dewatering efforts, they must reflect changes within a reasonable timeframe. Drawdown rates are largely determined by pump selection and are expected to be significantly faster than recharge rates which are controlled by the characteristics of the porous media through which the liquid flows. Consequently, we focused our analysis on PZ recharge as the limiting factor.

Recharge rates estimated for the pump and drawdown/recharge tests are summarized in Table 1. The November 2016 results are as presented in SCS Engineers' report.[3] Recharge rates for the May 2017 drawdown/recharge tests and July 2017 pump tests are based on PES' review of the pressure transducer data.

The May 2017 tests generally included multiple drawdown/recharge cycles for each PZ, except for SB-01, SB-25D and SB-30 which exhibited only a single or partial recharge cycle. Figure 1 and Figure 2 illustrate a typical drawdown/recharge curve for the May 2017 tests. The rates listed in Table 1 for the May 2017 tests were determined by first graphing the data from each of the PZ. Peaks and low points that distinctly indicate pump on/pump off conditions were identified. Then for each cycle (pump on/pump off), starting and ending times, and depths were used to estimate the change in liquid depth per unit time (rate per drawdown/recharge cycle), assuming a linear relationship between liquid depth and time. Based on the average drawdown and recharge

[3] *Liquid Assessment Findings Report*, dated December 13, 2016, Table 1

times, a theoretical maximum number of cycles per day was calculated. Recharge rates based on those cycles are listed in Table 1 and Table 2.

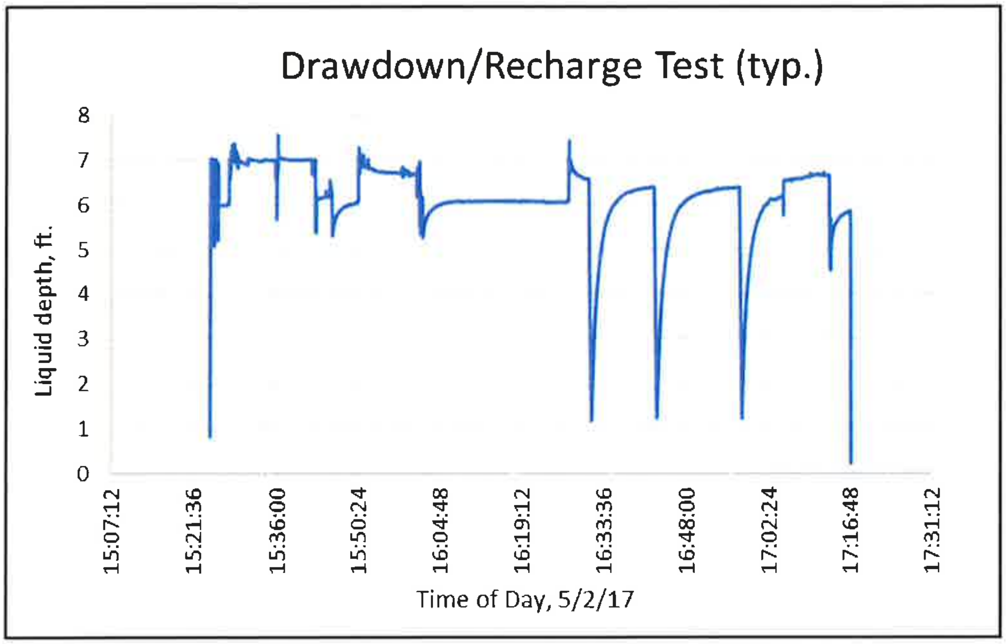

Figure 1 - May 2017 Drawdown/Recharge Test

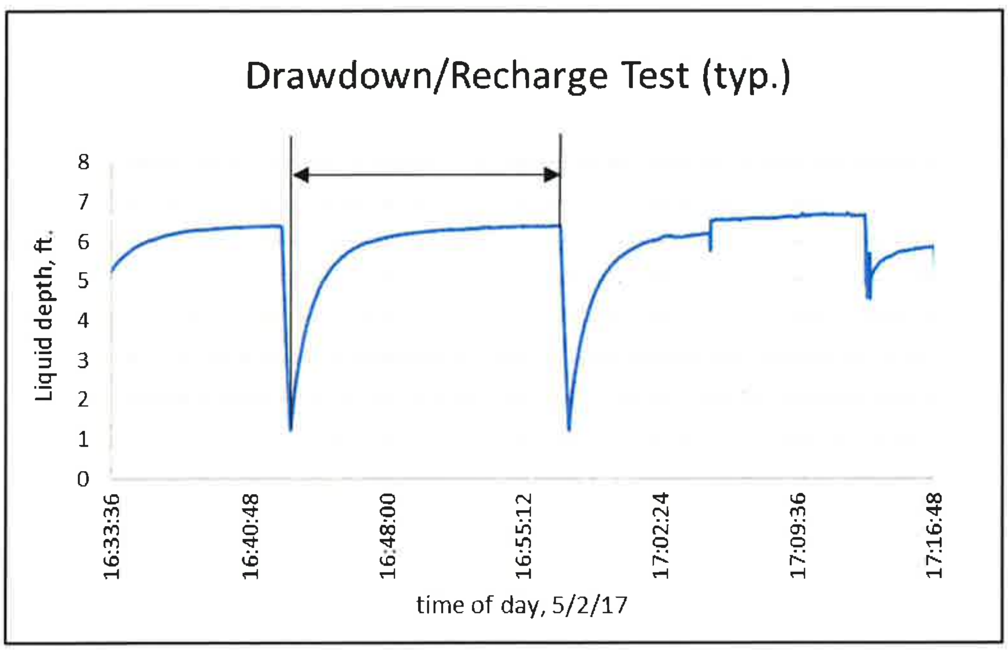

Figure 2 - May 2017 Drawdown/Recharge Test Detail

Table 1: Recharge Rate Summary			
	Nov-16 gal/day	May-17 gal/day	Jul-17 gal/day
SB-01	5	13	
SB-02	332		
SB-03	15		
SB-05	31		
SB-15D		436	
SB-16D		327	
SB-17D		111	
SB-18D		23	
SB-25D		*	
SB-28D		114	
SB-29		146	6
SB-30		230	
DW 1			1880
EW-32	419		
EW-39	83		
EW-40	180		
EW-44	828		
EW-46	161		
EW-48	735		
EW-70	154		
*	SB-25D abandoned in September 2017		

The July 2017 pump test included two cycles (two drawdowns, one recharge) for the DW 1/SB-29 locations. The March 2018 test allowed a direct comparison of SB-29 and SB-30 responses to pumping and showed that SB-29 responded more distinctly to pumping at DW 1 than SB-30 responded to pumping at DW 2. Since the March 2018 test only included one cycle (one drawdown, but incomplete recharge), recharge rates could not be accurately estimated for that test.

Table 2: Recharge Rate Calculation

		[A]	[B]	[C]	[D]	[E]	[F]	[G]
		recharge, min/cycle	drawdown, min/cycle	Total time, min/cycle	potential cycles per 24 hour day	ave recharge depth, ft/cycle	ave recharge volume, gal/cycle	ave recharge volume, gal/day
May-17	SB-01	79	0.30	79	18	0.50	0.74	13
	SB-15D	22	1.16	24	61	4.88	7.17	436
	SB-16D	27	0.37	27	53	4.19	6.16	327
	SB-17D	30	8.17	38	38	1.98	2.90	111
	SB-18D	20	8.80	29	50	0.31	0.46	23
	SB-25D	*	*	*	*	*	*	*
	SB-28D	18	13.50	31	46	1.69	2.48	114
	SB-29	36	4.23	40	36	2.79	4.09	146
	SB-30	30	4.95	35	41	3.83	5.62	230
Jul-17								
Cycle 1	SB-29	74	32	106	13	0.31	0.45	6
	DW 1	76	29	105	13	2.73	144.60	1880
Cycle 2[1]	SB-29	95	41	137	11	0.51	0.75	8
	DW 1	109	42	151	10	2.90	153.45	1461

Note 1	Recharge during July 2017 2nd cycle was incomplete.		
SB	6-inch dia. Borehole	1.469	gal/ft height
DW	36-inch dia. Borehole	52.873	gal/ft height
*	SB-25D abandoned in September 2017		

Table 2, cont'd

[A], [B]=	May 2017 average based on identified cycles; July 2017 based on single cycle
[C]=	recharge time + drawdown time
[D]=	(60*24)/[C]
[E]=	May 2017 average based on identified cycles; July 2017 based on single cycle
[F]=	[E]*1.469 for SB, [E]*52.873 for DW
[G]=	[F]*[D]

Reported Quantities	DW 1-1			DW 1-2		
	gal pumped	days	gal/day	gal pumped	days	gal/day
Jul-17	18,259	25	730	12,681	23	551
Aug-17	23,288	31	751	7,839	29	270
Sep-17	9,645	11	877	15,939	16	996
Oct-17	2,822	1	2,822	8,580	9	953
Nov-17	35,956	30	1,199	0	0	0
Dec-17	37,376	31	1,206	0	0	0
Jan-18	30,828	30	1,028	0	0	0
Feb-18	28,499	26	1,096	0	0	0
Mar-18	23,772	25	951	6,836	15	456
Apr-18	14,203	18	789	5,252	14	375
May-18	18,003	20	900	20,603	27	763
total	242,651	248		77,730	133	
	average gal/day		1,123		average gal/day	624
	DW 1 total	1,746	average, gal/day			

Table 3: Pump Test Cycles

	Jul-17					Mar-18
	Cycle 1			Cycle 2		Cycle 1
	Cycle time					
	Drawdown, min.	Recharge, min.	Ratio, Recharge/Drawdown	Drawdown, min.	Recharge[1], min.	Drawdown, min.
SB-29	32	74	2.32	41	95	775
DW 1	29	76	2.61	42	109	777
Ratio, SB-29/DW 1	1.09	0.97		0.98	0.87	1.00
SB-30						926
DW 2						848
Ratio, SB-30/DW 2						1.09
	Change in Liquid Depth					
	Drawdown, ft.	Recharge, ft.	Ratio, Recharge/Drawdown	Drawdown, ft.	Recharge[1], ft.	Drawdown, ft.
SB-29	0.40	0.31	0.77	0.66	0.51	3.05
DW 1	2.81	2.73	0.97	2.99	2.90	5.69
Ratio, SB-29/DW 1	0.14	0.11		0.22	0.17	0.54
SB-30						0.59
DW 2						3.17
Ratio, SB-30/DW 2						0.19
Note 1	Recharge during 2nd cycle was incomplete.					
	Values listed are calculated based on observed drawdown and ratio of recharge/drawdown.					

Figure 3 and Figure 4 show the July 2017 and March 2018 pump test results. Similar to the May 2017 drawdown tests, recharge rates were estimated for the July 2017 test and are included on Table 1 and Table 2.

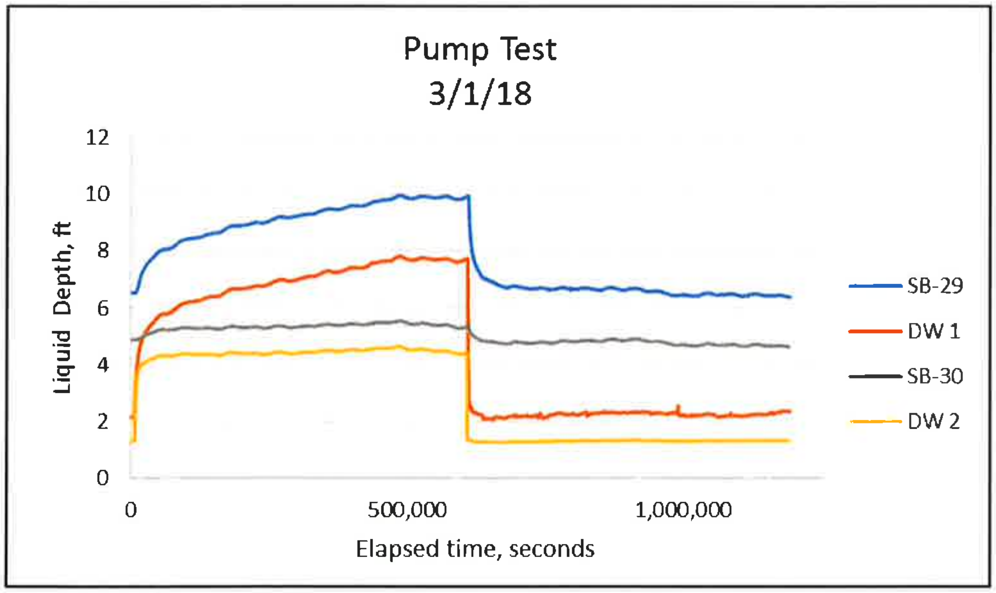

Figure 3 - March 2018 Pump Tests

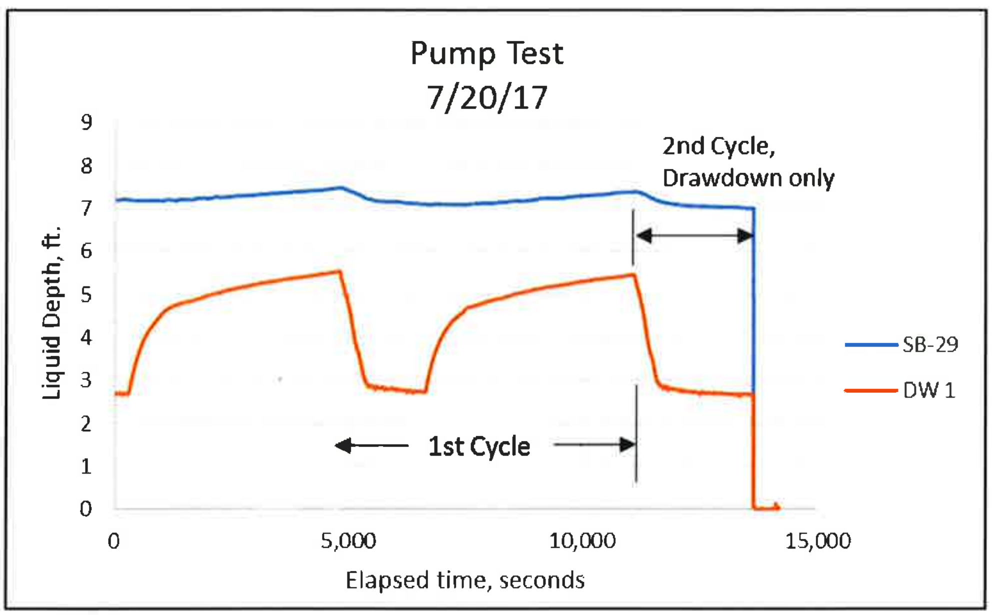

Figure 4 - July 2017 Pump Test

The March/April 2018 slug test data generally show an initial "steady state" water level, followed by a peak ("slug") and then a logarithmic decline in water level approaching a similar "steady state." Each of the PZs, except for SB-28D (discussed below) exhibited this behavior. Figure 5 shows a typical slug test curve for the March/April 2018 tests. The maximum liquid depth recorded (approximately 32 feet) is due to transducer limitations. During the test, each PZ was filled to the top of the casing. Consequently, some PZs experienced as much as 90 feet of water pressure during the slug test.

The slug tests were "slug-in" (i.e., water was added, not removed) so "recharge" rates were not determined. However, since the rate of water dissipation out of each PZ is also an indication of its ability to reflect changes in liquid levels, this response rate was estimated. Overall response rates for the slug tests are significantly influenced by the hydraulic pressure in each PZ. Since it is neither likely, nor desirable, to have the excessive hydraulic pressure (i.e., greater than 30 feet) experienced in the slug tests during normal operation, the response rate was estimated based on the linear (trailing) portion of the curve (instead of the entire curve) as more representative of long-term operation. These rates are summarized in Table 4.

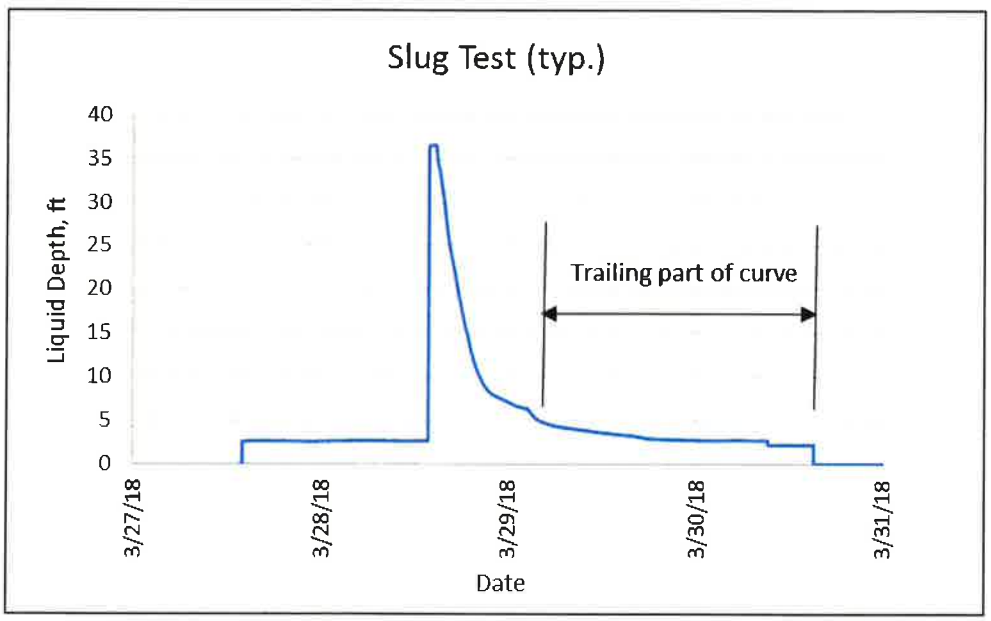

Figure 5 - Typical Slug Test Results

Table 4: Slug Test Response Rate								
	start depth (ft)	end depth (ft)	depth change (ft)	elapsed time (days)	dY/dX estimated rate (ft/day)	m	b	est. time to reach 2 ft (days)
SB-15D	8.004	6.858	1.147	0.83	-0.205	-0.17	8.2474	9.12E+15
SB-16D	6.498	6.414	0.084	2.04	-0.035	-0.07	6.422	1.12E+27
SB-17D	1.797	1.300	0.497	2.06	-0.037	-0.08	1.6598	n/a
SB-18D	2.393	2.010	0.384	2.06	-0.023	-0.05	2.2586	n/a
SB-19D	2.989	2.246	0.743	1.78	-0.414	-0.74	3.0781	n/a
SB-20D	2.302	2.049	0.253	2.05	-0.078	-0.16	2.0961	n/a
SB-21D	2.201	1.446	0.755	1.98	-0.378	-0.75	1.7641	n/a
SB-22D	2.204	1.998	0.206	2.03	-0.061	-0.12	2.0438	n/a
SB-23D	0.997	0.530	0.467	1.97	-0.012	-0.02	0.4871	n/a
SB-24D	7.000	5.778	1.222	2.06	-0.051	-0.11	5.7865	3.26E+15
SB-28D	5.999	5.381	0.618	0.11	-4.431	-0.49	4.2636	101

n/a levels were at or below 2 feet at end of test

3. Discussion

Volume estimations assume that the 2-inch PZs were constructed with 6-inch boreholes and dewatering wells (DW 1 and DW 2) were constructed with 36-inch boreholes. The formula for the volume is:

$$V = \pi\, r^2 h \qquad \text{[Eqn. 1]}$$

where,

V = volume (gal.)
h = liquid depth (ft.), and
r = radius of borehole (ft.).
$\frac{V}{h}$, the volume per foot of depth for each PZ is 1.469 gal/ft. Similarly, the volume per foot of depth in the DWs is 52.873 gal/ft.

3.1. May 2017 Drawdown/Recharge tests

In these tests, a small pump was placed in each PZ and liquids were removed and allowed to recharge for multiple cycles. Although the pumps were small, drawdown rates were (as expected) higher than recharge rates. The ratio of recharge time vs. drawdown time ranged from 72 (SB-16D) to 2 (SB-18D) minutes. In other words, depending on the PZ, for one minute of drawdown time, it took between 2 and 72 minutes for liquids to recharge the PZ sufficiently to begin the next drawdown cycle. SB-25D data was erratic, showing a single drawdown of 1.5 feet in 0.02 min., likely due to a transducer error. Consequently SB-25D results for this test are not included in our analysis.

The data also showed that the maximum recharge depth per cycle tended to slightly decrease over time. However, it is likely that these decreases are a result of field constraints (e.g., not enough time for levels to recharge fully) and not an indication of overall liquids reduction during the test. These tests were relatively short, ranging from 63 minutes (SB-18D) to 259 minutes (SB-15D). Some pumping cycles did not fully drawdown the PZ (i.e., the "pump off" liquid depth varied) possibly due to equipment issues such as pump overheating. As shown in Table 2, the average predicted recharge rates range from 13 gal/day (SB-01) to 436 gal/day (SB-15D). These results also suggest that SB-15D, SB-16D, SB-29 and SB-30 are relatively "productive" locations (recharge depths ranging from approximately 3 to 5 ft. per cycle) that could potentially be used for liquid extraction and/or monitoring.

These results are subject to notable limitations. Pump selection is limited due to the size of the PZ casing (2-inch dia.). Although the tests were conducted over a relatively short time, some of the pumps experienced operational issues such as overheating. Also, the extensive infrastructure (e.g., electrical power and liquid discharge piping) required for PZs to be used as extraction points would be difficult to protect and maintain in an operating landfill.

3.2. July 2017 and March 2018 Pump tests

The July 2017 and March 2018 pump tests were conducted using similar methodologies (discussed in Sections 1.2 and 1.3 above), and yielded similar results. Since these tests show the relationship between a dewatering location (DW 1, DW 2) and a nearby PZ (SB-29, SB-30), the effects, if any, of pumping can be more directly identified.

Figure 3 and Figure 4 show the responses of SB-29 and SB-30 to the pumping at DW 1 and DW 2. Although the magnitude is different, effects from pumping in DW 1 can be seen in SB-29 for both the July 2017 and March 2018 tests. As shown in Table 2, a drawdown of 2.81 ft. and 2.99 ft. in

DW 1 resulted in 0.40 ft. and 0.66 ft. drawdown in SB-29 in the July 2017 test. The March 2018 response was greater, with 5.67 ft. drawdown in DW 1 resulting in 3.05 ft. reduction in SB-29 water level.

In the July 2017 test, the initial increase seen in the graph appears similar to the recharge part of the cycle. However, since the pump on/off status and liquid level prior to data collection were unknown, it was not considered to be a recharge cycle. In other words, for the initial rise in depth to be "recharge," the pump would have to be off and the liquid level would have to be at a minimum prior to data collection. These conditions were not known. Thus, the first cycle begins with the first recorded pump "on" (decline in liquid levels) condition and ends just before then next pump "on" condition.

The cycle time for the initial cycle in July 2017 for SB-29 and DW 1 were approximately equal (between 105 and 106 minutes), potentially resulting in approximately 13 cycles per day. As expected, since the pump was located in DW 1, the liquid level decreased 2.73 ft. in DW 1, but only 0.31 ft. in SB-29 in the first cycle. Accounting for differences in the well sizes, the recharge rates were 0.45 gal/day for SB-29, and 144.60 gal/day for DW 1.

The second cycle included full drawdown, but only partial (if any) recharge. The drawdown for the second cycle was greater than the first cycle, and may be due to initial flushing of the dewatering well or other field adjustments.

Recharge data for the second cycle was not recorded. However, it is reasonable to expect that the recharge/drawdown characteristics for the second cycle would be similar to the first cycle. Assuming the ratio of recharge time to drawdown time (recharge/drawdown) is the same as the first cycle, the second cycle time and volume was estimated (see Table 2 and Table 3). Based on time recorded for Cycle 1, 13 cycles (drawdown and recharge) per day could be achieved, resulting in 1,880 gallons/day of liquid removal. Estimates for Cycle 2 were 10 to 11 cycles per day resulting in approximately 1,461 gal/day of liquid removal. As summarized in Table 2, liquid removal reported for DW 1 from July 2017 through May 2018 averaged 1,746 gal/day, which correlates reasonably well with our analysis.

In the March 2018 pump tests, the pumps in DW 1 and DW 2 were turned off and rising liquid levels were recorded for several days. The pumps were turned back on and drawdown data was recorded. The transducers were removed and normal automatic pumping operation resumed. Consequently, recharge data for the March 2018 tests is not available. Since it was necessary to allow liquids to accumulate over several days, daily cycle times could not be accurately estimated for this test.

As shown in Figure 2, SB-29 responded to DW 1 similar to its response in the July 2017 test. SB-30 showed a small response to DW 2 in the March 2018 test. Although the tests were conducted concurrently, initial liquid levels in SB-29 and DW 1 increased at a faster rate than SB-30 and DW 2. The liquid depths in SB-29 and DW 1 were also greater than in SB-30 and DW 2. This suggests that liquids flow to and are extracted more readily in the vicinity of SB-29/DW 1 than in the area of SB-30/DW 2. These results are confirmed by the monthly progress reports that consistently show more liquid is removed from DW 1 than from DW 2.

Although recharge behavior is the limiting factor in evaluating the PZs effectiveness, recharge data for March 2018 is not available. Examination of the drawdown data (see Table 3) shows that the time required to drawdown SB-30/DW 2 is slightly longer than SB-29/DW 1, but the difference in liquid depth drawdown is notable. The liquid level response for SB-29 to DW 1 was 0.54 ft./ft. In other words, for every foot of drawdown in DW 1, liquid depth in SB-29 decreased by approximately 0.54 ft. The response for SB-30 and DW 2 was significantly lower, at 0.19 ft./ft. Assuming the liquid level during drawdown has a linear relationship with respect to time, the rate (drawdown depth divided by time) in SB-29 is estimated to be 0.00394 ft./min and SB-30 is 0.00064 ft./min. Since recharge times may be conservatively estimated to be two to three times slower than drawdown times, the rate during recharge is estimated to be one-half to one-third the drawdown rate. Thus, SB-29 recharge could range between 0.00131 ft./min. [0.00394/3] and 0.00197 ft./min., and SB-30 recharge could range between 0.00021 ft./min. and 0.00032 ft./min. It should be noted that since the data show that dewatering activities typically follow logarithmic/exponential relationships, these values suggest faster recharge than would actually occur.

In the March 2018 test, the liquid level in SB-29 decreased 3.05 ft. in response to a decrease of 5.67 ft. in DW 1. This ratio, 0.54 indicates a much more significant influence on SB-29 from pumping than in the July 2017 test, but may be a result of the duration of the data collection (fifteen days in March 2018 vs. four hours in July 2017). A similar ratio for SB-30/DW 2 for March 2018 is 0.19. Based on the results from these pump tests, dewatering efforts in DW 2 may be minimally detected in SB-30, but DW 1 pumping is more easily identified in SB-29.

In both pump tests (July 2017 and March 2018), pumping reduced liquid levels until an apparent "steady state" level was achieved. As shown in Figure 4, the "steady state" (pump off) level for DW 1 and DW 2 is approximately two feet based on pump operational constraints. Consequently, liquid levels are not expected to fall below that level in DW 1 or DW 2. Based on Figure 4, the levels to which SB-29 and SB-30 appear to rebound, are approximately liquid depths of seven feet (SB-29) and five feet (SB-30). This apparent "steady state" liquid level is discussed in more detail in Section 4.4 below.

3.3. April/March 2018 Slug tests

Figure 4 shows a typical slug test curve. The rates are similar for all PZs except SB-28D. Due to a pressure transducer malfunction in the March test in SB-28D, the test was re-run on April 4th. During the April event, a slug of water was introduced into the PZ multiple times instead of only once as in the March tests. Figure 6 shows the results of the April re-test of SB-28D. Data was recorded the same as the March tests.

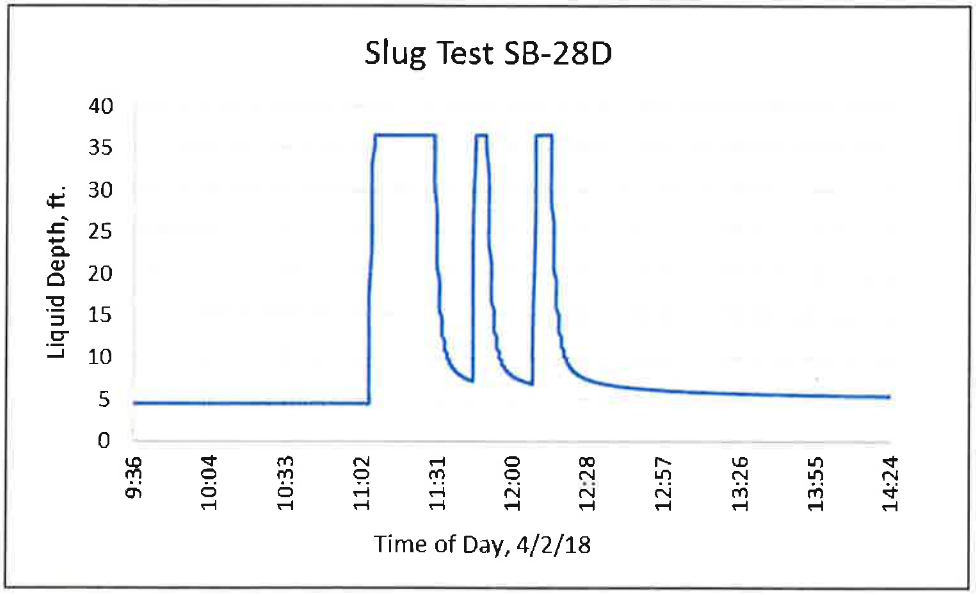

Figure 6 - SB-28D Slug Re-test

Each of the PZs generally responded to the slug with a logarithmic decline in liquid depth vs. time. The data for each test was graphed, and a best equation for the long-term decline was determined. The equations were of the form:

$$y_{slug} = m\,ln(x) + b \qquad \text{[Eqn. 2]}$$

where

y_{slug} = liquid depth (ft.)

x = elapsed time (days)

m, b = constants steepness of the curve and intercept.

Rearranging equation [2],

$$y_{slug} - b = m\ ln(x) \quad \text{[Eqn. 3]}$$

The derivative of the equation represents the instantaneous slope of the function at a given selected point. In this case, the rate of depth change with respect to time. Taking the derivative of liquid depth with respect to *x* (time), the equation can be rewritten as,

$$\frac{d}{dx}y_{slug} - \frac{d}{dx}b = m * \frac{d}{dx}(ln(x)) \quad \text{[Eqn. 4]}$$

Since *b* is a constant its derivative equals 0, leaving

$$\frac{d}{dx}(y_{slug}) = m * (\frac{d}{dx}\ln(x))$$

Since $\frac{d}{dx}\ln(x) = \frac{1}{x}$, the rate of change of liquid depth can be expressed as:

$$\frac{d}{dx}(y_{slug}) = \frac{m}{x} \quad \text{[Eqn. 5]}$$

Example:

For SB-15D, the best fit equation (R^2=0.9485), b=8.2474, m=-0.17 and x=0.83 days, so the long-term rate of liquid decline is,

$$y_{slug} = -0.17\ ln(x) + 8.2474$$

$$y_{slug} - 8.2474 = -0.17\ ln(x)$$

$$\frac{d}{dx}y_{slug} - \frac{d}{dx}8.2474 = -0.17 * \frac{d}{dx}(ln(x))$$

$$\frac{d}{dx}(y_{slug}) = \frac{-0.17}{0.83} = -0.205\ ft/day$$

Table 4 includes the calculated response rates and constants, *m* and *b*. The calculated rates represent the rate at the end of the slug test. Since the retest in SB-28D included multiple slugs, the time elapsed for each slug was relatively short resulting in the calculated rate for SB-28D being significantly skewed. The data show that liquid depths continue to decline logarithmically with time, approaching a horizontal asymptote. This "steady state" liquid level is discussed in Section 4.4 below.

4. Predicting Piezometer Liquid Levels

4.1. Darcy's Law

Assuming that the assumptions for Darcy's law are true for flow within the landfill drainage sand, the liquid levels in the PZ can be estimated. Darcy's law is the basis for fluid flow in a porous media, and is expressed as:

$$Q = kiA \qquad \text{[Eqn. 6]}$$

with

$$i = \frac{h_1 - h_2}{L} \qquad \text{[Eqn. 7]}$$

where,

Q = flow through porous media (ft.^{3}/s),
k = hydraulic conductivity of the porous media (ft./s),
i = hydraulic gradient (dimensionless)
h_1 = depth of liquid, location 1 (ft.)
h_2 = depth of liquid, location 2 (ft.)
L = distance between locations 1 and 2 (ft.), and
A = cross-sectional area of porous media perpendicular to flow (ft^2).

The flow velocity (also called the Darcy flux), $\frac{Q}{A}$ (ft./s) can be determined between locations, and travel time can be estimated. Based on surveyed locations, SB-29 is approximately 11 feet away from DW 1 and SB-30 is approximately 10 feet away from DW 2.[4] Recent tests[5] of the landfill drainage sand indicate that the hydraulic conductivity of the sand currently ranges from 3.5 x 10^{-3} cm/s (1.15 x 10^{-4} ft./s) to 5.8 x 10^{-3} cm/s (1.90 x 10^{-4} ft./s).

[4] Boring-Piezometer construction data provided and confirmed by SCS Engineers in April/May 2018
[5] Data provided by SWMD via email July 12, 2018

In the July 2017 pump test, recharge began at Cycle 1 "pump off." The liquid depth in SB-29 at this "pump off" time was 7.08 ft., and the depth in DW 1 was 2.72 ft. Since the distance between these locations is 11 ft., the gradient was 0.3969 [(7.08-2.72)/11]. Using an average (1.50×10^{-4} ft./s) of hydraulic conductivities noted above, *Q/A* is 3.57×10^{-3} ft./min. It would take approximately 2 days for liquid to travel from SB-29 to DW 1 (at gradient=0.3969) based on gravity drainage only and assuming no other influences (i.e., rainfall). Since the operating minimum liquid level in DW 1 is approximately two feet, the estimated time assumes the pumps are operating normally. Table 5 shows that based on the July 2017 and March 2018 pump tests, SB-29/DW 1 travel time is also estimated to be two days.

4.2. Radius of Influence

For the effects of liquid removal to be observable in the PZ, the pumping location must be within a certain distance of the PZ. This distance, the radius of influence (R_0), is the distance at which the drawdown from the pumping location is effectively zero. For our analysis, since the leachate collection system operation is based on flow through a porous media (i.e., drainage sand), fluids in the landfill are assumed to behave similarly, and were modelled using equations for flow in an unconfined aquifer. It is important to note that the radius of influence calculation is based only on the hydraulic conductivity of the porous media and the difference in the liquid levels at the points of interest. Time is not a factor.

To estimate the radius of influence, R_0, Sichardt's[6] equation provides a reasonable approximation.

$$R_0 = 3000\,(H_0 - h_w)\sqrt{k} \qquad \text{[Eqn. 8]}$$

where,
R_0 = Radius of influence (m)
H_0 = Liquid depth at R_0 (m)
h_w = Liquid depth at theoretical pumping location (m), and
k = hydraulic conductivity of the porous media (m/s).

[6] Referenced in "EXHIBIT III, CALCULATION METHODS FOR RADIUS OF INFLUENCE AND DEWATERING FLOW RATE FROM AQUIFER TEST DATA," Broward County Florida, Environmental Protection and Growth Management Department, Pollution Prevention, Remediation and Air Quality Division, found at [accessed May 17, 2018]: http://www.broward.org/Environment/ContaminatedSites/Documents/sopexhibitiii1209.pdf

Table 5: Travel Time Predictions

Based on pump tests

	Distance between L (ft)	Difference in depth H_0-h_w (ft)	Gradient i (-)	$\frac{Q}{A} = ki$ (ft/min)	Estimated time (days)	Difference in depth h_2-h_1 (ft)	Gradient i (-)	$\frac{Q}{A} = ki$ (ft/min)	Estimated time (days)
	July 2017 pump test					March 2018 pump test			
SB-29/DW 1	11								
Cycle 1		4.37	0.3969	3.57E-03	2	4.83	0.4394	3.95E-03	2
Cycle 2		4.26	0.3875	3.48E-03	2				
SB-30/DW 2	10					3.50	0.3501	3.15E-03	2

Based on radius of influence

Assume: Distance between PZ and pumping well, L = R_0

Liquid depth at theoretical pumping well (h_w) assumed to be 2 ft

Max. depth at PZ (H_0) based on monthly reporting for January through May 2018

k_{ave}= 4.57E-03 cm/s
1.50E-04 ft/s
8.99E-03 ft/min

	L (ft)	H_0 (ft)	H_0-h_w (ft)	i (-)	Q/A=ki (ft/min)	estimated time, L/ki (min)	estimated time, L/ki (days)
SB-15D	109	7.40	5.4	0.0493	4.44E-04	2.47E+05	171
SB-16D	93	6.60	4.6	0.0493	4.44E-04	2.10E+05	146
SB-17D	79	5.90	3.9	0.0493	4.44E-04	1.78E+05	124
SB-18D	18	2.90	0.9	0.0493	4.44E-04	4.11E+04	29
SB-19D	n/a, H_0 less than 2 ft						
SB-20D	32	3.60	1.6	0.0493	4.44E-04	7.31E+04	51
SB-21D	4	2.20	0.2	0.0493	4.44E-04	9.14E+03	6
SB-22D	4	2.20	0.2	0.0493	4.44E-04	9.14E+03	6
SB-23D	4	2.20	0.2	0.0493	4.44E-04	9.14E+03	6
SB-24D	77	5.80	3.8	0.0493	4.44E-04	1.74E+05	121
SB-28D	77	5.80	3.8	0.0493	4.44E-04	1.74E+05	121
SB-29	158	9.80	7.8	0.0493	4.44E-04	3.56E+05	248
SB-30	83	6.10	4.1	0.0493	4.44E-04	1.87E+05	130

Table 6: Radius of Influence

	H_0	h_w	H_0-h_w	H_0-h_w	R_0	R_0			
	ft	ft	ft	m	m	ft			
Pump test data:							k=	4.57E-03	cm/s
max. depth at PZ (H_0)							k=	4.57E-05	m/s
min. depth at DW (h_w)									
Jul-17									
SB-29/DW 1									
Cycle 1	7.48	2.72	4.76	1.45	29	97			
Cycle 2	7.39	2.47	4.92	1.50	30	100			
Mar-18									
SB-29/DW 1	9.95	2.06	7.89	2.40	49	160			
SB-30/DW 2	5.36	1.27	4.09	1.25	25	83			

Hypothetical Prediction:

Max. depth at PZ (H_0) based on monthly reporting for January through May 2018

Liquid depth (h_w) at theoretical pumping well (*DW_t*) assumed to be 2 ft

	H_0	h_w	H_0-h_w	H_0-h_w	R_0	R_0
	ft	ft	ft	m	m	ft
SB-15D	7.4	2	5.4	1.65	33.37	109
SB-16D	6.6	2	4.6	1.40	28.42	93
SB-17D	5.9	2	3.9	1.19	24.10	79
SB-18D	2.9	2	0.9	0.27	5.56	18
SB-19D	1.9	2	n/a, H_0 less than 2 ft			
SB-20D	3.6	2	1.6	0.49	9.89	32
SB-21D	2.2	2	0.2	0.06	1.24	4
SB-22D	2.2	2	0.2	0.06	1.24	4
SB-23D	2.2	2	0.2	0.06	1.24	4
SB-24D	5.8	2	3.8	1.16	23.48	77
SB-28D	5.8	2	3.8	1.16	23.48	77
SB-29	9.8	2	7.8	2.38	48.20	158
SB-30	6.1	2	4.1	1.25	25.33	83

Using this equation and the average hydraulic conductivity of the drainage sand ($k=4.57 \times 10^{-5}$ m/s), two conditions were examined. Table 6 includes the results of these calculations. First, using the July 2017 and March 2018 pump test data, R_0 for SB-29 and SB-30 were calculated. R_0

for SB-29 ranged from 97 to 160 ft., and SB-30 (only one data set) was estimated to be 83 ft. Although the data for SB-30 is limited, these results suggest that in order for SB-30 to effectively detect changes from pumping, it should be located no greater than 83 feet away from a dewatering well. Similarly, SB-29 may be located as much as 100 to 160 feet away from a dewatering well.

Next, the maximum distance (R_0) from a theoretical pumping well ("DW_t") to each piezometer was estimated. This calculation assumed the greatest liquid depth reported for each piezometer from January through May 2018 and that the pumping location would have a minimum of two feet of liquid based on pump intake constraints (such as in DW 1 and DW 2).

Not surprisingly, Table 6 shows that the R_0 for SB-29 and SB-30 based on maximum reported liquid depths are consistent with the R_0 calculated from the pump test data. Since the maximum liquid depths reported for SB-18, SB-19D, SB-21D, SB-22D and SB-23D are close to two feet (the minimum level in DW_t), those locations are not expected to provide meaningful information for measuring long-term compliance. SB-15D (109 ft.) and SB-16D (93 ft.) are within the range estimated for SB-29 and SB-30. SB-17D, SB-24D and SB-28D are similar and may respond to changes within 75-80 ft. of DW_t.

4.3. Time Considerations

The calculations presented in Table 6 suggest that certain PZs (SB-15D, SB-16D, SB-17D, SB-24D and SB-28D) may respond to pumping if DW_t is within a reasonable distance. However, when travel time is considered, the number of potentially useful locations is more limited.

Using the same assumptions as the radius of influence calculations (e.g., h_w=2 ft., H_0=max. reported liquid depth) and assuming that the distance between DW_t and the PZ is equal to R_0, the time for liquids to move between DW_t and the PZ were estimated and are shown in Table 5. Since R_0 and the gradient are based on differences in liquid depths and L is assumed to equal R_0, the gradient between each PZ and DW_t are all equal to 0.0493 ft./ft. The estimated times vary due to differences in R_0.

Based on pump tests, travel times between SB-29/DW 1 and SB-30/DW 2 are estimated to be two days. Based on radius of influence, the travel time between SB-29 and DW_t located 158 ft. away would be 248 days. Since the actual distances between these PZs and DWs are significantly less, the travel time is expected to be significantly less.

Travel times based on the slug test results were also estimated. These predictions assume the target liquid depth in the PZ is two feet (based on theoretical pump intake limitations), and that the liquid level follows a logarithmic decline with respect to time. Predictions were not necessary for the PZs for which liquid levels had already declined to two feet or less during the test. Table 4 shows that the estimated time for SB-28D was 101 days, and for all practical purposes, SB-15D, SB-16D and SB-24D cannot reach the two-foot level.

4.4. Apparent "Steady State"

Results of the each of the field investigations suggest that the liquid depths in the PZ have an apparent "steady state" level. To estimate this "steady state" level, several approaches were used.

First, for the slug tests, the starting (pre-slug) and ending liquid depths were compared for each of the piezometers. Although the depths were not the same for each PZ, the *differences* between the starting and ending depths were small (less than one foot) for all PZs except SB-15D (1.147 ft.) and SB-24D (1.222 ft.). This suggests that each PZ has a minimum liquid depth below which dewatering efforts would have limited success.

Next, examination of the data revealed that certain liquid depths (specific to the PZ) appear in the data much more frequently than other depths. Since these values could represent a "steady state," frequency distributions were created for each PZ for each of the tests (drawdown, pump, slug). Each data point was assigned to a "bin" based on the depth recorded at that point. The "bins" were in 0.1 ft. increments from 1.0 ft. through 11.9 ft. depths, and 1 foot increments from 12.0 ft. through 34 ft. depths. The "bin" with the most number of data points (i.e., highest frequency) is identified as the "steady state" based on this procedure. Table 7 shows that the apparent "steady state" for SB-17D, SB-18D, SB-19D, SB-20D, SB-21D, SB-22D and SB-23D is below 2 feet. In general, the other PZ show declining trends over time from May 2017 (drawdown) through April 2018 (pump and slug tests), except for SB-15D and SB-16D. When comparing the "steady state" predicted by the May 2017 pump tests and the March/April slug tests, a slight increase in "steady state" is seen for SB-15D and SB-16D. This may be due to the relatively short duration of the May 2017 test.

Table 7: Apparent "Steady State" Liquid Depths							
	Frequency of Data				Weekly Liquid Level Reporting, Averages		
	May 2017 Drawdown tests (ft.)	Pump tests July 2017 (ft.)	Pump tests Feb/March 2018 (ft.)	Slug tests March/April 2018 (ft.)	June 2016-May 2017 (ft.)	June 2017-June 2018 (ft.)	January 2018-June 2018 (ft.)
SB-01	11				10.39	10.08	9.34
SB-15D	6.1			6.8	8.26	7.20	6.85
SB-16D	6.1			6.4	7.20	6.35	6.24
SB-17D	4.5			1.6	5.08	5.21	4.27
SB-18D	3.3			2.2	3.30	3.00	2.14
SB-19D				2.6	1.60	1.97	1.69
SB-20D				2.0	2.07	2.67	3.14
SB-21D				1.3	2.10	2.13	1.94
SB-22D				2.0	1.64	1.89	1.77
SB-23D				<1.0	2.34	2.23	2.08
SB-24D				5.7	4.47	5.78	4.90
SB-25D	*	*	*	*	*	*	*
SB-28D	5.9			4.5	4.57	5.04	4.86
SB-29	9.6	7.1	6.6		12.26**	8.48	8.39
SB-30	5.2		4.8		6.85	6.10	5.73

Average liquid depths for three time periods (June 2016 through May 2017; June 2017 through June 2018; and January 2018 through June 2018) were also reviewed. The initial liquid level assessments and much of the field work was completed between June 2016 and May 2017. June 2017 through June 2018 reflects liquid level reduction progress for the first year. Comparison of average liquid levels initially (June 2016/May 2017) to current levels (January 2018/June 2018) illustrates that average liquid levels in the majority of the PZs have declined. Also, current averages suggest the levels in SB-16D, SB-18D, SB-19D, SB-22D and SB-24D are near or below the estimated "steady state" level. Consequently, the levels in these PZs are not expected to decline significantly from the current levels. Average liquid levels in SB-15D, SB-17D, SB-21D, SB-23D, SB-28D, SB-29 and SB-30 are currently above, but are generally declining toward, the estimated "steady state." Although the average liquid levels in SB-20D appear to have increased from initial values, weekly readings (reported monthly to FDEP) show that the levels have been trending downward since March 2018 toward the “steady state” depth of two feet.

5. Conclusion

As proposed in our May 2018 memorandum, piezometer effectiveness (Criterion #3) has been evaluated with respect to the following:

1. What is the response rate for each PZ?
2. Which, if any, existing PZ respond to leachate removal by the existing system in a timeframe that would be reasonable for monitoring?
3. What dewatering system configuration is reasonable to meet the objectives of the CAP?

5.1. Response rate for each PZ

Drawdown/recharge, pump and slug test results show that liquid levels in the PZs respond variably to dewatering activities. Recharge occurs much slower than drawdown, and is therefore the controlling factor. SB-15D, SB-16D, SB-29 and SB-30 exhibited the highest recharge rates based on the May 2017 drawdown/recharge tests ranging from an average of 146 gal/day to 136 gal/day.

Pump tests showed that the SB-29 response to DW 1 pumping is more significant than the SB-30 response to DW 2 pumping. Radius of influence (R_0) was estimated for each PZ and a theoretical dewatering well. R_0 for SB-15D, SB-16D, SB-17D, SB-24D and SB-28D were estimated to be between 75 to 110 feet. The R_0 distances estimated for the other PZs were small.

Although the slug tests did not include “recharge,” the rate of change of liquid dissipation was estimated. Based on the logarithmic decline of liquid depth with respect to time, the response rates ranged from -0.378 ft./day (SB-21D) to -0.012 ft./day (SB-23D).

5.2. Response timeframes

Response timeframes were estimated for each PZ. Generally, the time required for recharge is two to three times as long as the drawdown time. Assuming a linear relationship between the liquid depth and time, the drawdown/recharge tests show that SB-15D, SB-16D, SB-28D, SB-29 and SB-30 exhibit the highest number of potential drawdown/recharge cycles per day, ranging from 36 cycles (SB-29) to 61 (SB-15D) cycles per day. Theoretically, the greater the number of cycles, the more liquid can be removed. However, it is important to note that these results are based on small pumps placed in each PZ that would not likely achieve these high number of cycles. The pump test results indicate that 10 to 13 drawdown/recharge cycles may be completed per day.

Experience from existing dewatering wells has shown that removal of liquids less than two feet deep is impractical based on equipment limitations. Assuming liquids below two-foot depth cannot feasibly be removed, the slug test data was used to estimate the time necessary for the liquid depth to decline to two feet in each PZ. PZs that had reached two-foot or less at the end of the slug test were not included. Liquid in SB-28D was estimated to reach two feet depth is approximately 100 days. Based on the assumptions used, liquid levels in SB-15D, SB-16D and SB-24D are not expected to reach two-feet.

Based on hydraulic gradient, drainage sand hydraulic conductivity, and estimated R_0, travel times from each PZ to a theoretical dewatering well placed at/near the R_0 (between 75-110 ft. of the PZ) were calculated. The PZs with liquid depths approximately two-feet were not included. The travel times ranged from 29 days (SB-18D) to 171 days (SB-15D), and are based on no other external influences occurring, e.g., rainfall.

5.3. Proposed configuration

Based on equipment limitations, PZ locations with liquid levels near or below two-foot are not considered to be useful monitoring points. Based on our analysis, SB-17D, SB-18D, SB-20D, SB-21D, SB-22D, SB-23D and SB-24D are not likely to provide information necessary to confirm compliance with the Consent Agreement.

Although SB-15D and SB-16D theoretically could be used for monitoring, response times are expected to be relatively long. Additionally, since the liquid depths are near or approaching their apparent "steady state," installation of an additional dewatering well is likely to have limited benefit.

Based on our analysis, while liquid levels in certain PZs respond in varying degrees to dewatering activities, the following significant limitations must be considered:

- The measurements may not reflect changes until extended periods of time have elapsed;
- It may not be reasonably feasible to remove liquids below a "steady state" level;
- The long-term monitoring and maintenance of the PZ may be difficult due to operational constraints (i.e., active landfilling); and
- The measurements may be subject to other factors (discussed by others).

APPENDIX D

Water Balance Initial Calculations

APPENDIX D
UPDATED LANDFILL WATER BALANCE

The execution of the liquids management plan has been a dynamic exercise. The accurate estimation of how much extra leachate needs to be removed and for how long, has been a moving target due to expected fluctuations in the leachate removal rates and variability of rainfall. Until better data is available, this estimate is based on liquid levels in existing Series-2 piezometers. Specifically, the quantity of leachate that must be removed to bring the leachate depth in the sealed Series 2 piezometer down to 30-inches.

The simplified water balance model that SCS is working with has the following components. Figure 1 below is a simplified graphic of the water balance components:

- The leachate currently stored in the landfill (Q_1),
- The added liquid contributed by infiltration of rainfall (Q_2),
- Normal leachate collection at PS-B (Q_3), and
- Supplemental pumping (Q_4).

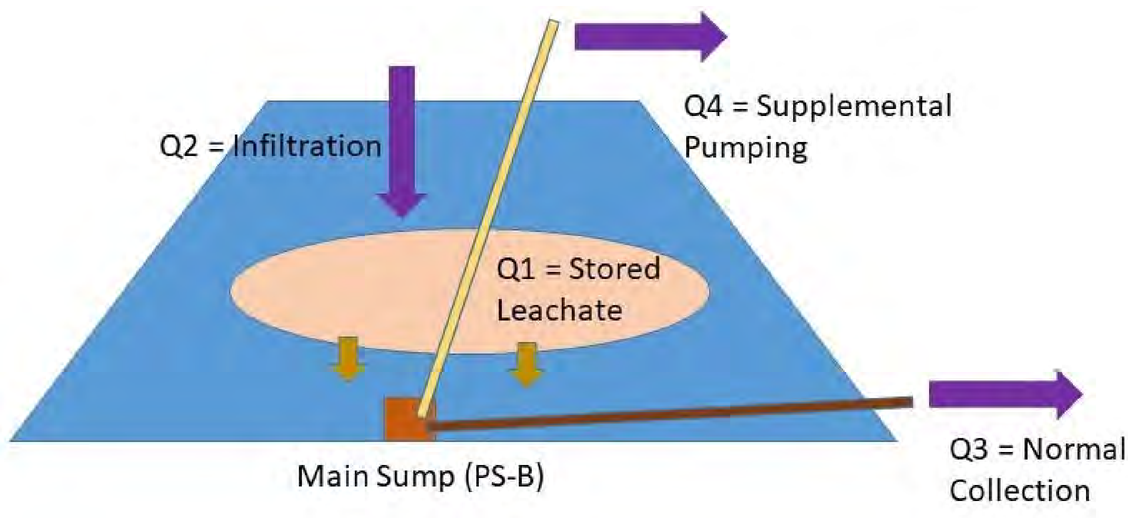

FIGURE 1. WATER BALANCE MODEL

46 acres (Phase II and parts of Phases I & III)

STORED LEACHATE

SCS used liquid level measurements from the Series-2 piezometers and AutoCAD software Civil 3D to update the stored leachate volume to be removed. This methodology will be used in future semi-annual water balance calculations. Based on the February 2, 2018 liquid levels and a target depth of 30-inches, the volume of leachate to be removed is now 11.83 MG. The key assumptions in this volume estimate include:

- Waste volume with leachate greater than 30-inches = 167,371 yd^3 or 33,804,608 gal.
  - Area = 2,014,302 s.f. (~46 acres)
  - Average thickness of perched leachate (above the 30-inch level) = 2.74 ft.
- Porosity of wastes = 50%
- Fraction of leachate held in pores by capillary action = 30%; so 70% of leachate can be released.
- Conversion factor of 7.48 Gal/ft^3

Equation: Q_1 = (33,804,608 gal.) (0.5)(0.7) = 11.83 MG

ADDED RAINFALL

The simplified water balance must also include additional leachate generated by infiltration of rainwater. This is conservative, since the normal infiltration over the entire 162-acre landfill will be collected by the current pump station PS-B.

- Average rainfall of 54 inches per year
- Site Area = 46 acres (Phase II and portions of Phase I and III)
- Estimated infiltration of rainfall equals 15% of total annual rainfall. Typical accepted values range from 10% to 15%.
- Conversion factor of 7.48 Gal/ft^3

Equation: Q_2 = (54 in)(1 ft/12 in)(46 ac)(43,560 ft^2/ac)(7.48 gal/ft^3)(0.15) = 10.12 MG

NORMAL LEACHATE COLLECTION

The simplified water balance must also include leachate that is currently being pumped from pump station PS-B on a daily basis.

- Average leachate pumped from main sump (Average daily of years 2015, 2016, and 2017) = 83,900 gpd
- Normal leachate collection by LCS from 46 acre area = 28 % of total (i.e. the LCS in Phase I, II and III is assumed to be only contributing 28% of total leachate)

Equation: Q_3 = (83,900 gpd)(0.28)(365 days/yr) = 8.57 MG (23,500 gpd)

SUPPLEMENTAL LEACHATE COLLECTION

The SWMD is currently pumping leachate from supplemental location is Phases I and II. The current pump system has been in place since completion of the Phase II cut-off trench in July 2017.

- Average supplemental leachate pumpage (removal) since early August (includes removal from the two vertical wells, and supplemental pump stations only) is 22,000 gpd
- Downtime factor = 0.95
- Pumping 6 days per week
- Determine daily pump rate with assumed downtime.

Equation: Q_4= (22,000 gal/day)(365 days/yr)(0.95)(6/7) = 6.54 MG or 18,000 gpd.

SUMMARY

The estimated total pumping time to bring the average leachate level down to the target level is calculated as follows.

- The current net leachate removal rate required is

  $Q = Q_1 + Q_2 - Q_3 = 11.83 + 10.12 - 8.57 = 13.38$ MG/year

- The approximate number of days to remove the total stored leachate at that rate is:

  - Days = 13,380,000 gals. / 18,000 GPD = 743 days. **(2 years)**

ADDITIONAL EVALUATIONS

The estimated schedule assumes that the pump rate will remain consistent. As discussed, the pumping rate is effected by rainfall, reduced liquid levels, and the flow of leachate from the target areas to the pump locations. It is anticipated that the average pumping rates will reduce over time.

These calculations may be revised based on the findings of Doctor Tim Townsend and others regarding site specific conditions that may affect the water balance.

APPENDIX E

Investigation of Landfill Leachate Removal at the Hillsborough County Southeast Landfill

Prepared by
University of Florida

Investigation of Landfill Leachate Removal at the Hillsborough County Southeast Landfill

Prepared for:

Hillsborough County Board of County Commissioners
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July 10, 2018

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EXECUTIVE SUMMARY

Hillsborough County (County) has been investigating the cause of a February 2016 groundwater exceedance event that was measured in several groundwater-monitoring wells along the east side of the Hillsborough Southeast County Landfill (SCLF) Phase I-VI disposal area. County staff has indicated that, based upon initial investigations, the exceedance event was most likely caused by a discharge of leachate from the Phase II disposal area. The County has implemented several supplemental leachate removal efforts to prevent further discharge and has been attempting to monitor the effectiveness of these efforts using piezometers to measure leachate levels in the landfill. There was an initial decline in leachate levels in some piezometers in the first quarter of 2017 after supplemental pumping began in December 2016. However, liquid levels in the piezometers in May 2018 were about the same as they were in May 2017, despite over 10 million gallons of supplemental pumping having occurred during this period.

Piezometers were initially installed by drilling a 6.25-inch borehole from the surface of the landfill through the waste mass into the underlying leachate collection system. A 2-inch diameter PVC pipe was then placed in the borehole (the pipe has perforations that correspond with the sand layer), and a sand pack was placed between the pipe and borehole wall. These piezometers are referred to in this report as “Series 1 piezometers.” The County determined that Series 1 piezometer leachate levels were being influenced by leachate from saturated perched zones in the overlying waste mass that was percolating downward through the piezometer sand pack. A modified piezometer was developed, designated as a Series 2 piezometer, where the sand pack in the upper portion of the LCS sand layer was replaced with a bentonite/grout mixture in an attempt to prevent seepage down the piezometer.

Because of the high liquid level readings measured in the Series 2 piezometers, the County installed dewatering pumps in landfill gas (LFG) wells and condensate traps, installed vertical dewatering wells, and a supplemental leachate collection trench along the east side of the Phase II area. After several months of pumping the levels dropped, but now have remained static.

The County retained the University of Florida to evaluate and provide an independent assessment of the piezometer readings and leachate removal efforts. This report documents the outcome of this investigation.

Long-term leachate pumping records for the Phase I-VI area were compared (on a gallons/acre/day basis) to leachate pumping rates of adjacent landfill cells (Sections 7-8 and Section 9). It was determined that per-acre leachate removal from the Phase I-VI area is consistently greater than, on a per-acre basis, than the leachate removal rates from Sections 7-8 and 9. These comparisons also indicate that leachate pumping rates in the Phase I-VI area fluctuate over time in a pattern similar to Sections 7-8 and 9, except during 2016 and 2017 where pumping rates in Phase I-VI increased more significantly than those of Sections 7-8 and 9. This comparison indicates that the leachate collection system is functioning and is at least as productive as the other landfill cells on this site, and indicates that recent supplemental pumping and piezometer drilling has increased leachate removal.

Phase I-VI leachate removal records and landfill leachate collections system configuration information were used to calculate theoretical maximum leachate levels based on leachate collection system configuration. These theoretical levels were significantly lower than the leachate levels measured in the Series 2 piezometers. Excavations performed in the Phase I-VI area adjacent to a piezometer found unsaturated conditions throughout the entire thickness of the sand drainage layer despite a liquid level being recorded in the adjacent piezometer.

It can be concluded from the information above that the Phase I-VI leachate collection system is at least as productive as the other landfill cells on this site and that liquid levels in the Series 2 piezometers are greater than calculated theoretical leachate collection system liquid levels. This report also explains why piezometers installed by drilling through the waste mass may not be a reliable method to measure actual liquid levels over landfill bottom liners.

Experience has shown that liquid in a landfill tends to migrate and accumulate in gas wells and piezometers that are installed in the landfill. Previous research has shown that drilling into a landfill disrupts the anisotropy of the waste, resulting in increased downward migration of liquid in the borehole. Although the boreholes around the Series 2 piezometers were sealed with grout and bentonite to prevent this from occurring, experience has shown that the heterogeneity of the waste does not allow an effective seal to prevent the downward migration of liquid.

The liquid then seeps downward in the borehole to the leachate collection system, where it causes localized mounding around the piezometer. This phenomenon, which is illustrated in this report using the two-dimensional finite element groundwater model SEEP/W, leads to higher “apparent” leachate level readings in the piezometers than the modeled level that is present in the sand drainage layer adjacent to the piezometer. It can be concluded that water levels measured in piezometers that have been installed through a waste mass into a landfill leachate collection system are influenced by liquids in the waste mass, and therefore do not necessarily represent liquid levels that would otherwise be in the leachate collection system or a continuous phreatic surface throughout the landfill.

1.0 INTRODUCTION

1.1 Summary of Issue

Hillsborough County has been investigating the cause of a groundwater impact that occurred at the Hillsborough Southeast County Landfill (SCLF). This event was the detection of elevated levels of total dissolved solids (TDS), chloride, and sodium in a monitoring well in the southeast corner of the landfill, east of Phase II in February and April of 2016. It was assumed that the groundwater impacts were caused by leachate that seeped from the side of the landfill above the top of the bottom liner system. Two possible mechanisms are hypothesized to have caused this. One possibility is the leachate collection system (LCS) was functioning poorly, resulting in an accumulation of leachate to the point where it overtopped the highest point of the landfill perimeter berm. The other possibility is that perched leachate present in the above-grade Municipal Solid Waste (MSW) regions of the landfill migrated laterally to the side slope because of anisotropic conditions within the waste. The leachate would have then seeped from the sides of the landfill and entered the underlying surficial groundwater. To evaluate the effectiveness of the LCS, the County installed piezometers at several locations through the waste mass and into the underlying sand drainage layer to monitor the leachate levels over the liner. The University of Florida was asked to examine the data collected from the piezometers and observe field investigations to evaluate if the piezometer readings are a representative indicator of actual leachate levels in the LCS.

1.2 Purpose and Organization of this Document

The purpose of this study is to evaluate whether the piezometers liquid level readings are representative of actual leachate levels in the landfill. This document is organized into eight sections. Section 2 provides some background information on the site, such as the overall layout, the leachate collection system (LCS) design, and corrective actions taken to-date.

An analysis of the site data is conducted in Section 3. This section compares normalized leachate generation rate in Phases I-VI to nearby landfills, estimates the leachate impingement rate in Phase I-VI, and summarizes the 2017 piezometer readings. Section 4 includes calculations of the maximum expected leachate levels in various locations of the Phase I-VI area based on actual impingement rates (determined in Section 3), LCS pipe spacing and bottom liner slopes. These levels are then compared to liquid levels measured in the Series 2 piezometers.

Section 5 presents the results of an excavation that was performed in the landfill (near one of the Series 1 piezometers) down to the bottom liner to compare actual liquid levels in the LCS to the Series 1 piezometer reading.

Section 6 provides a discussion on the observed piezometer readings and limitations of a piezometer's ability to measure leachate levels in a landfill LCS without influencing the reading. Computer simulations, performed using a two-dimensional finite-element model (SEEP/W), are presented in Section 7 to illustrate the concepts discussed in Section 6 (leachate flow in an anisotropic landfill and impact piezometer installation has on that flow). Conclusions and recommendations are provided in Section 8.

2.0 BACKGROUND

2.1 Overview of Site

The SCLF is comprised of two separate landfills: these are referred to as Phases I-VI and the Capacity Expansion Area (Sections 7, 8, and 9). A site map is shown in Figure 2-1. Sections 7, 8, and 9 were constructed more recently with a double liner system that conforms to current landfill liner standards (Chapter 62-701, FAC). Phases I-VI, were designed and constructed in the early to mid-1980s (before the current landfill design requirements were established) and do not have a synthetic bottom liner (the perimeter berm has a Hypalon geomembrane). Instead, the liner system for this landfill is composed of a thick layer of waste phosphatic clay. The thickness of the clay liner varies at different parts of the landfill, but averages about 5 feet, with the thickest clay located near the center of the landfill. Leachate is collected at the bottom of the landfill through a series of gravel trenches and pipes. More details on the LCS design is provided in Section 2.2. The current working face of this landfill is located in the eastern portions of Phases IV and VI. Between 2001 and 2007, annual piezocone tests were conducted by Ardaman & Associates at the site to measure the elevation, thickness and shear strength of the clay liner at different locations. These tests were performed by drilling through the waste to the underlying liner system.

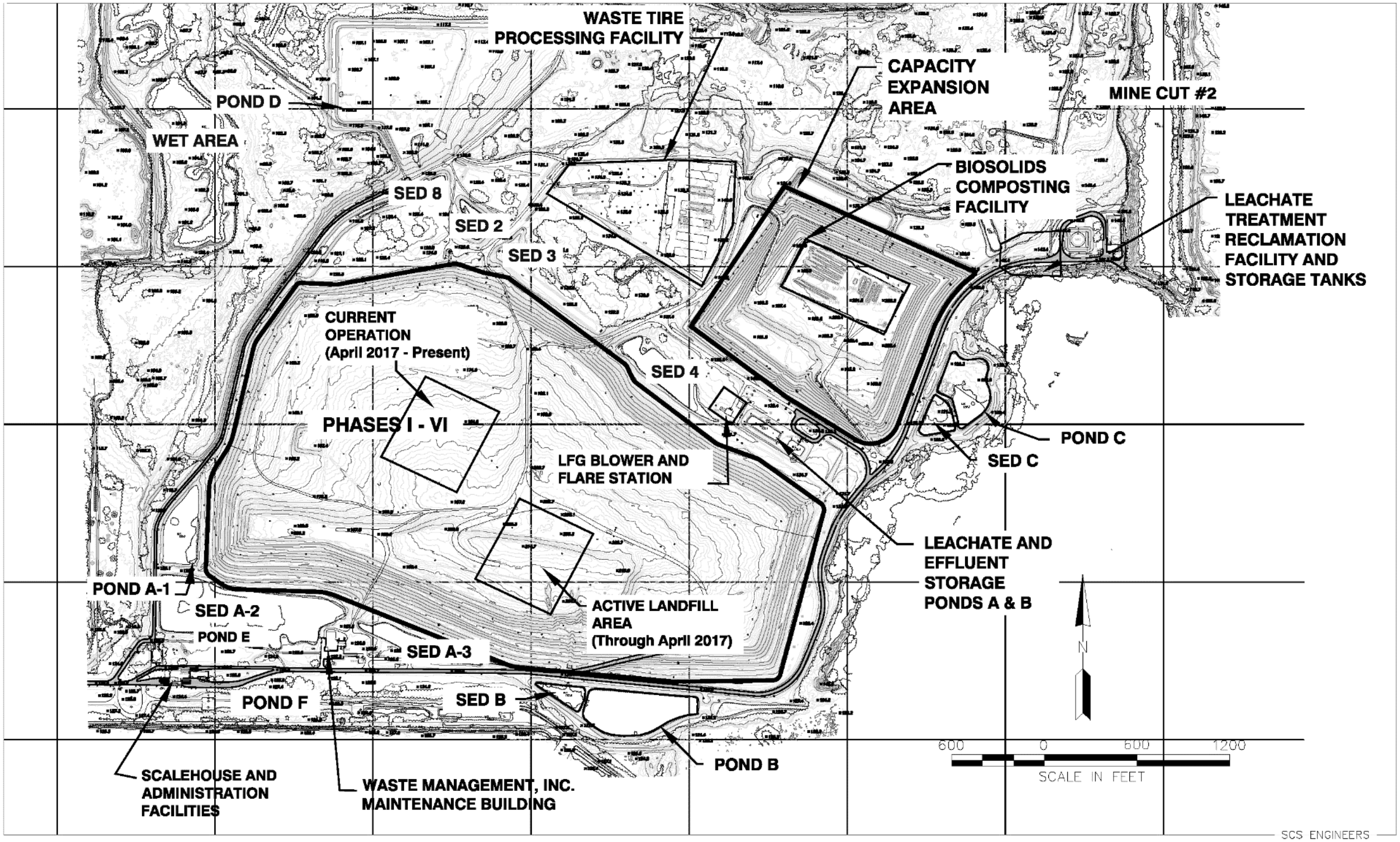

Figure 2-1. Site layout of SCLF. Phases I-VI are located in the southwest corner of the site near the scalehouse. Sections 7-9 (capacity expansion area) are located to the northeast of Phases I-VI. Figure was taken from the SCS corrective action plan from June 2017.

2.2 Design of the Leachate Collection System in Phases I-VI

The leachate collection system was designed in the early 1980s by Camp Dresser & McKee, in accordance with the landfill design standards that were in place at that time. A sand drainage layer was constructed over the top of the clay liner to drain leachate that percolates to the bottom of the landfill. The thickness of this layer ranges from 3 feet to 8 feet. A series of leachate collection trenches composed of gravel (in some cases, pipes are encased in the gravel) are spaced throughout the sand drainage layer. A cross section of one of these trenches is shown in Figure 2-2. The trenches have dimensions of approximately 2 feet by 2 feet and are covered above and below with a filter fabric. No filter fabric was placed along the sides of the trench. Leachate that enters the sand drainage layer eventually flows into the leachate collection trenches. From the gravel trenches, the leachate enters a leachate collection pipe (shown in Figure 2-3), which leads to a sump located in Phase VI. From the sump, collected leachate is pumped to the main leachate pump system (MLPS).

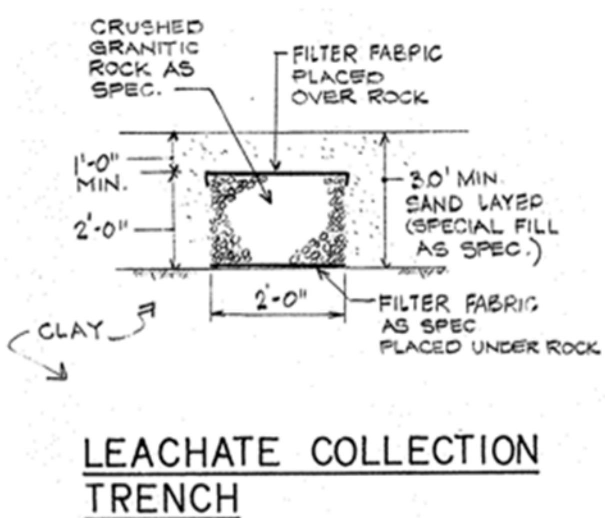

Figure 2-2. Cross section of the original CDM design of the gravel leachate collection trench.

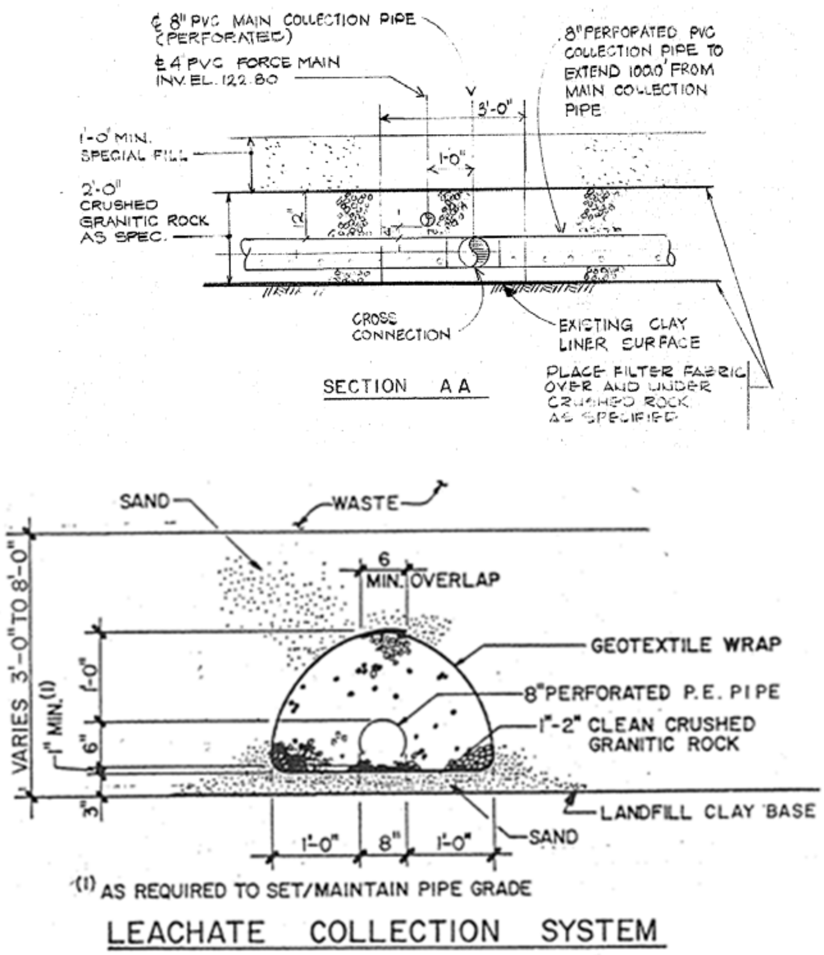

Figure 2-3. Cross sections of the original CDM design of the LCS pipes. Upper cross section shows Phases I through IV LCS PVC pipe surrounded with crushed granite and geotextile on top and bottom. Lower cross section shows Phases V and VI LCS PE pipe with crushed granite and geotextile wrap.

Figure 2-4 depicts the layout of the LCS in Phases I-VI. The system is comprised of a network of gravel collection trenches (green) and collection pipes (blue). The LCS slopes down to a low point in Phase VI (Pump Station B) where the leachate is pumped to a location outside the landfill.

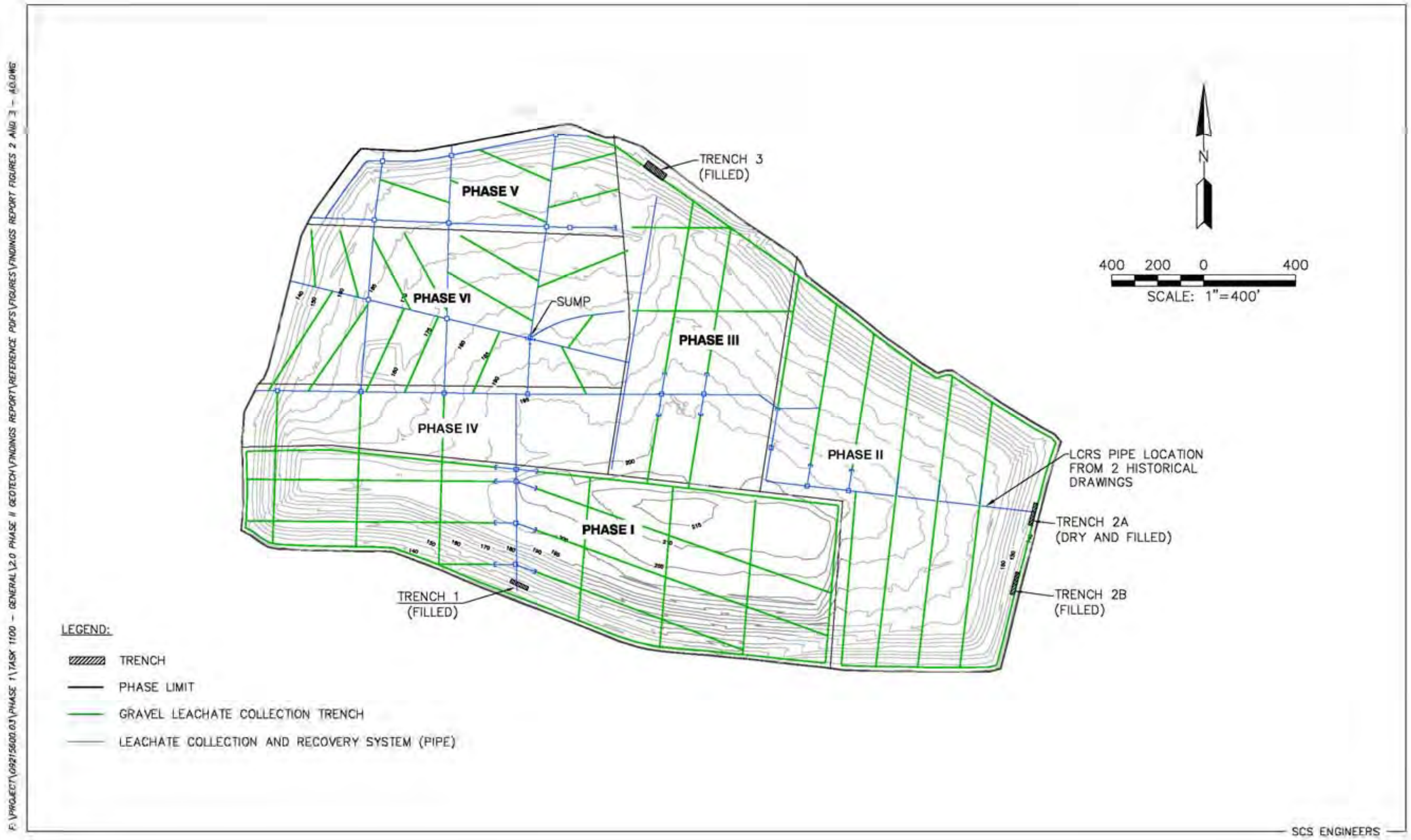

Figure 2-4. Design of the leachate collection system (LCS). The LCS is located above the clay liner in the sand drainage layer. Green lines represent gravel trenches and blue lines represent leachate collection pipes. The LCS slopes down to a collection point, located in Phase VI. Figure was taken from the SCS corrective action plan from June 2017.

2.3 Issues of Concern and Steps Taken

Beginning in February 2016, groundwater impacts were identified at monitoring well TH-67, located to the east of the Phase II landfill cell. It was determined that some of the nearby landfill gas (LFG) extraction wells in the waste mass contained liquid, and it was suspected that the landfill was saturated, causing leachate to seep from the side of the landfill and impact the surficial aquifer. To better understand the cause of these impacts, piezometers were installed to determine if leachate levels had accumulated to the point that leachate would have overtopped the bottom liner system perimeter berm. The locations of these piezometers are indicated in Figure 2-5. High liquid elevations in some of the piezometers have raised concerns about the effectiveness of the LCS and elevated leachate levels above the bottom liner.

To address the apparent leachate levels measured in the piezometers, a cut-off trench was constructed and a supplemental pumping program was initiated as a part of the corrective action plan. Seven pneumatic pumps were installed in four LFG extraction wells and three condensate traps to remove liquid. In addition, two dewatering wells and three temporary pump stations were installed on the eastern edge of the landfill to provide further liquids removal from the LCS. To determine if the LCS in Phase II had connectivity with the main pump station in Phase VI, a dye test was conducted in January 2018. From this, it was found that dye injected into the header pipe in Phase II was quickly able to reach the main pump station in Phase VI, minimizing the possibility of a blockage in the main header pipe.

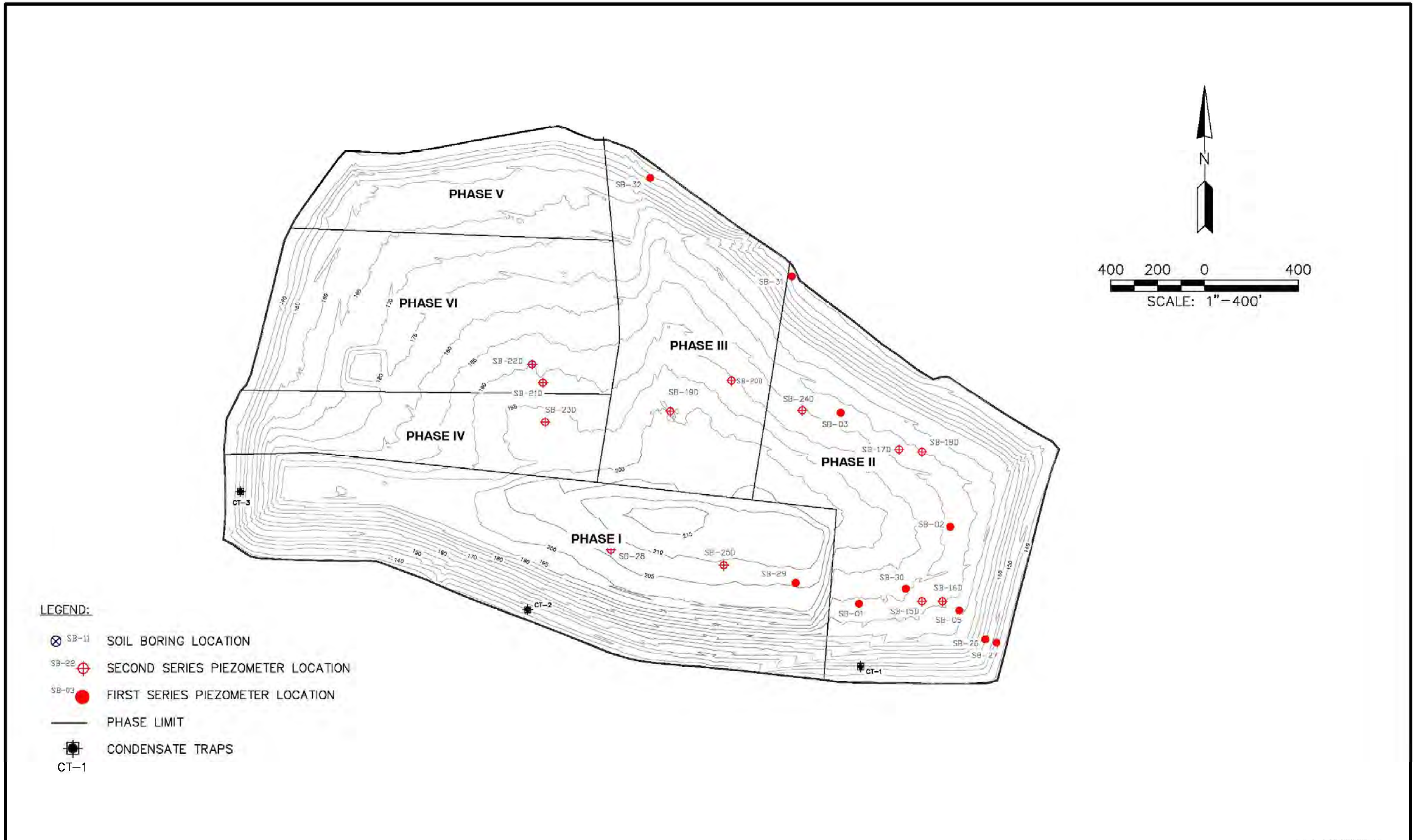

FIGURE 2. PIEZOMETER LOCATION PLAN
SOUTHEAST COUNTY LANDFILL
JUNE 2017

Figure 2-5. Map of the piezometer location plan.

3.0 ANALYSIS OF SITE DATA

3.1 Leachate Removal Rate

Daily leachate removal data for the period January 1, 2005 through December 31, 2017 for the lined landfill areas at the SCLF (Phases I-VI, Sections 7-8, and Section 9) was provided by Hillsborough County. This data was used to calculate leachate removal on a gallon/acre/day (GPAD) basis to allow comparison between these different sized landfill areas. Average monthly and average annual GPAD leachate removal rates are presented in Table 3-1, Figure 3-1 and Figure 3-2.

Table 3-1. Average GPAD leachate removal rates calculated for each year from 2005 to 2017 based on reported daily pumping rates.

	Phases I-VI (gal/acre*day)	Sections 7-8 (gal/acre*day)	Section 9 (gal/acre*day)
2005	299	110	-
2006	238	128	-
2007	206	98	-
2008	273	122	-
2009	275	89	524
2010	274	137	101
2011	274	140	46
2012	322	208	114
2013	380	217	57
2014	397	233	100
2015	374	319	185
2016	549	325	198
2017	595	301	274
Average	343	187	179*

- Indicates the landfill was not constructed at the time

* Excludes years before the landfill was constructed

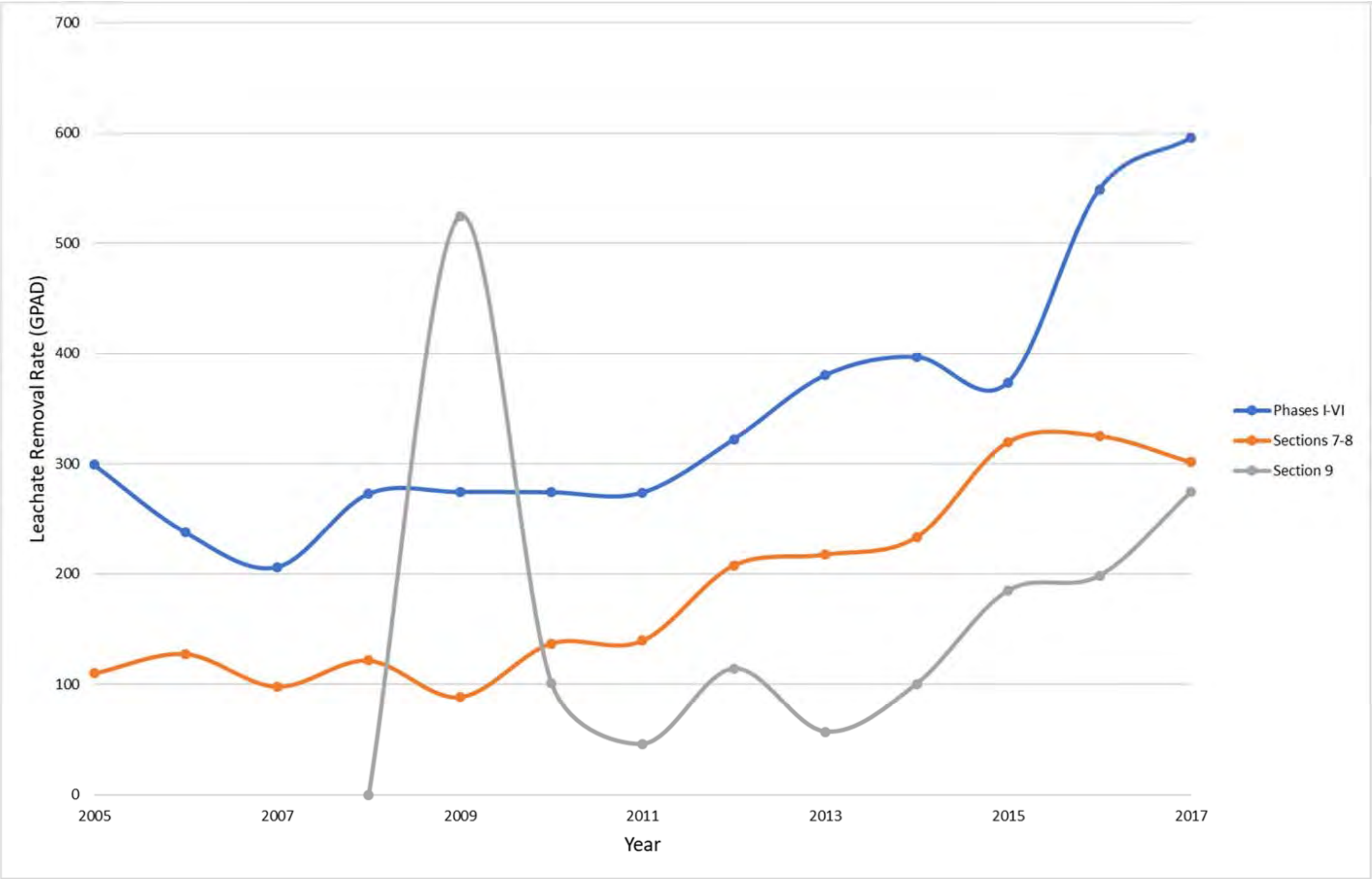

Figure 3-1. Average annual leachate removal rates (GPAD) for all three landfills from 2005 to 2017

From the results obtained, the leachate removal rate for Phases I-VI is observed to be much greater than the leachate removal rates for Sections 7-8 and Section 9 in almost every year (the high removal rate for Section 9 in 2009 was likely due to direct rainfall on the LCS before the newly constructed landfill cell was covered with solid waste). All three landfill sections showed a similar increase in removal rate from 2005 to 2015. Phases I-VI deviated from this trend in 2016 and 2017 when a significant increase in leachate removal was observed. Sections 7-9 did not show a similar increase. The increase in leachate removal in Phases I-VI could have been caused by the supplemental pumping procedure that began soon after the groundwater exceedance in February 2016. Figure 3-2 was constructed show how the impingement rates changed on a monthly basis from 2005 to 2017.

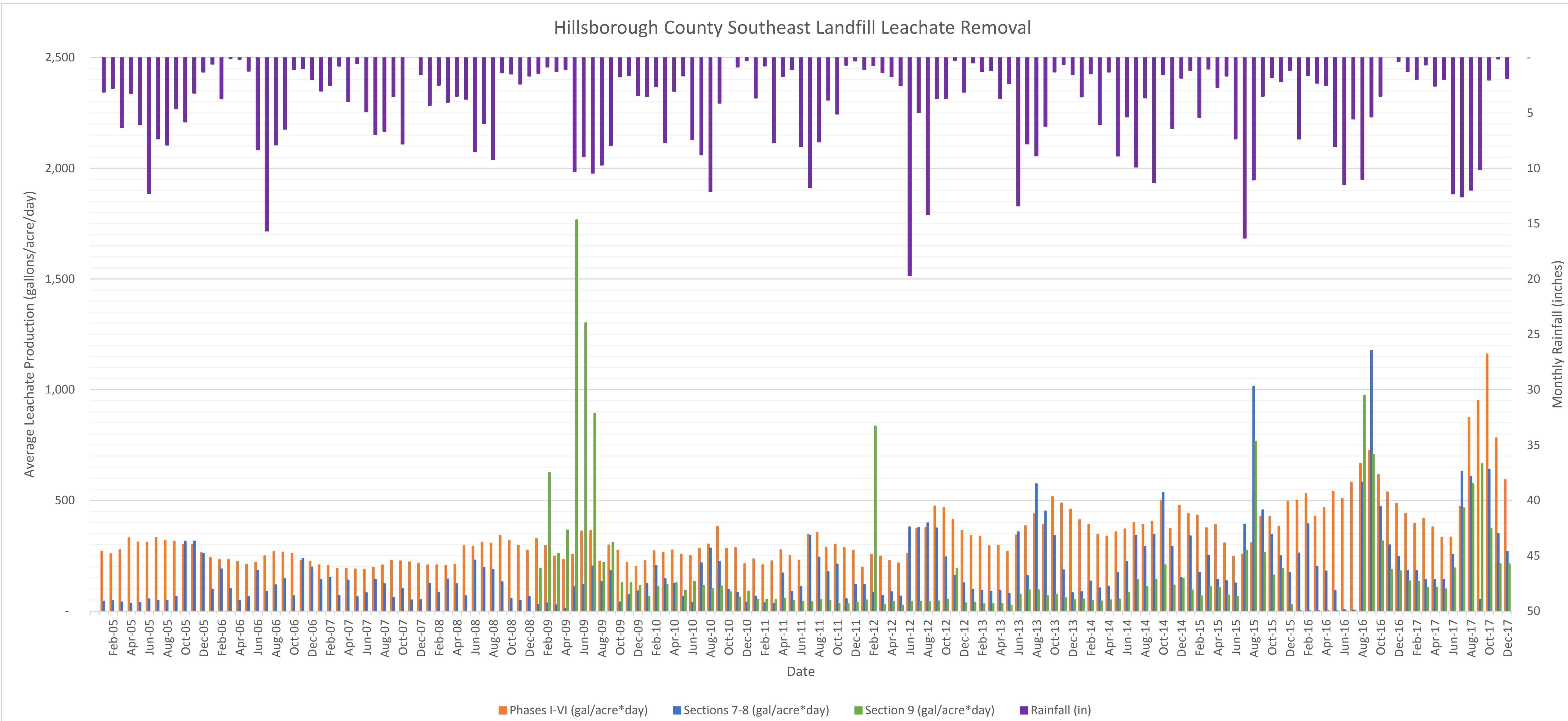

Figure 3-2. Graph of monthly average leachate removal rates from January 2005 to December 2017. Leachate removal rates for Phases I-VI are shown in orange. Monthly rainfall totals are shown in purple.

3.2 Piezometer Data

To estimate the leachate level above the liner, Hillsborough County installed several piezometers throughout the landfill. Two categories of piezometers were used, referred to as Series 1 and Series 2 piezometers. Four Series 1 piezometers were installed during the summer of 2016. One concern with the Series 1 piezometers, depicted in Figure 3-6, was that perched leachate and any accumulated moisture in the waste mass could migrate down the open borehole around the PVC pipe to the sand drainage layer. This additional liquid could cause a localized liquid mound around that piezometer that would not exist without the piezometer, and therefore giving a reading that is not representative of leachate levels that would otherwise be in the LCS. Beginning in 2017, several Series 2 piezometers were installed. The design of these piezometers differs from the Series 1 piezometers in that the open borehole is replaced with grout and a bentonite seal is incorporated at the top of the sand drainage layer. This design was intended to impede the downward migration of leachate that would affect the reading.

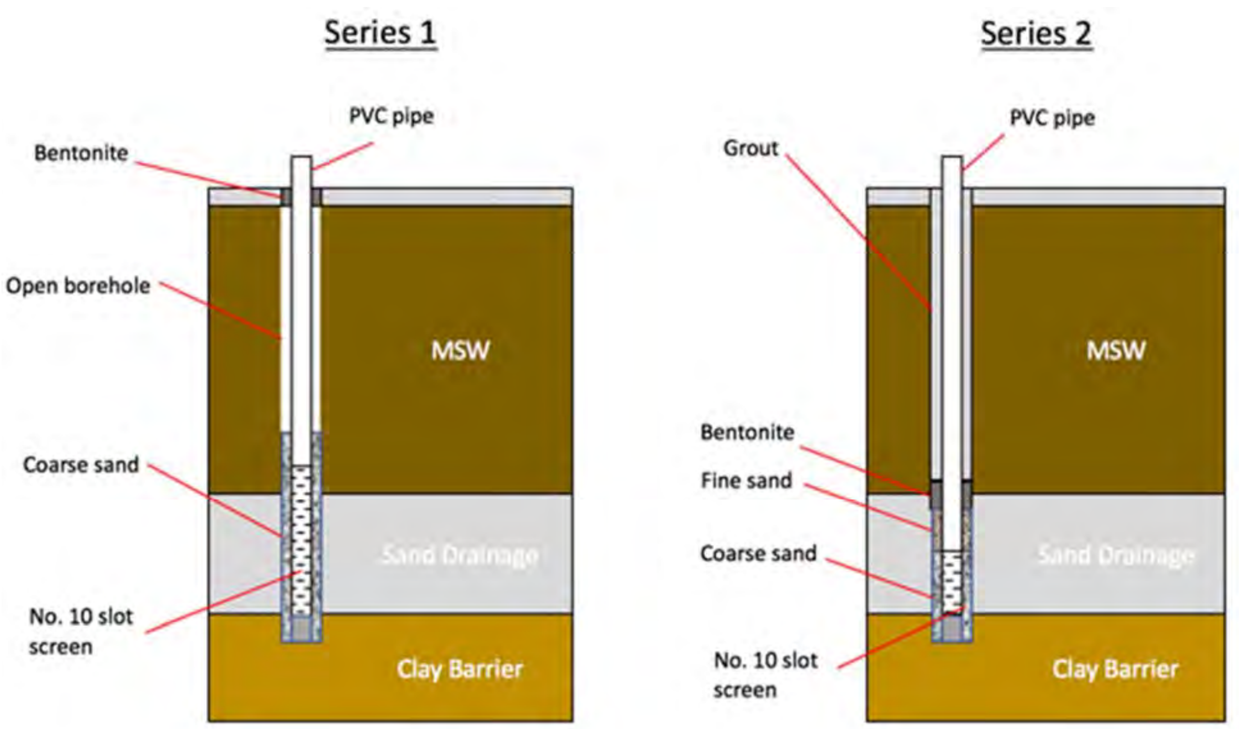

Figure 3-6. Design of the Series 1 and 2 piezometers.

3.2.1 Measurements from 2017

During 2017, weekly liquid level measurements were taken from each piezometer. The Series 1 readings were excluded in this analysis because they were not believed to be as accurate, as discussed in the previous section. Figure 3-7 depicts the location of each Series 2 piezometer and how the liquid level readings changed throughout the course of the year. A liquid level spike in most of the piezometers was observed during September, which was preceded by three months of relatively high rainfall and Hurricane Irma in early September.

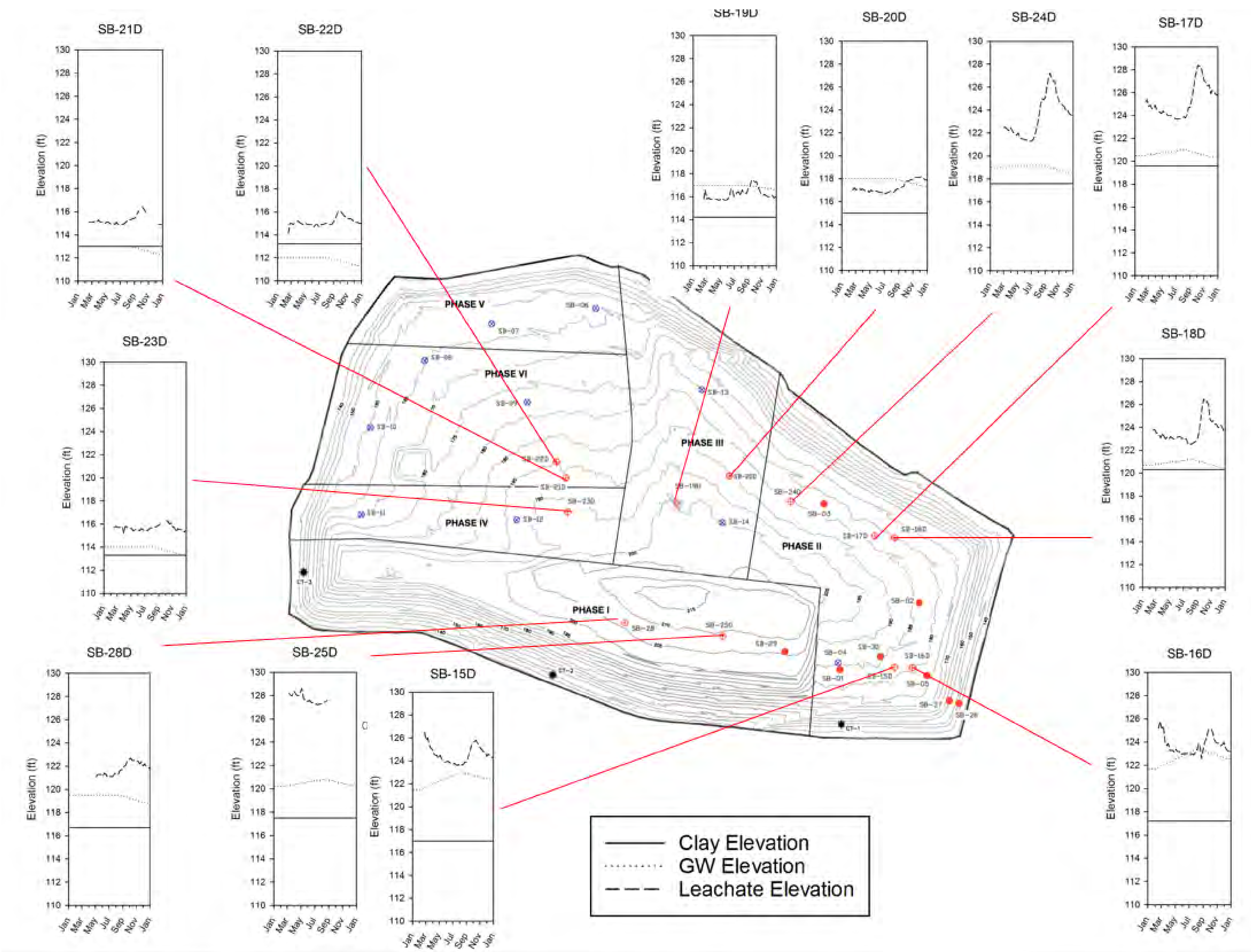

Figure 3-7. Line graphs for all Series 2 piezometers during 2017. Dashed lines indicate the liquid elevation in each piezometer as a function of time. Solid and dotted lines indicate the estimated clay and groundwater elevations at each piezometer, respectively. Groundwater data was only available for February and August.

4.0 PREDICTED LIQUID LEVEL ON THE LINER FROM THE LCS DESIGN

4.1 Methodology

The leachate collection system design can be used to calculate the maximum leachate level that is likely to occur over different regions of the liner. See Figure 2-4 for the LCS design in Phases I-VI. The LCS rests on top of the clay liner, which slopes downward to a leachate collection point in Phase VI - Pump Station B (see Figure 4-1 for a schematic of the LCS superimposed over a clay contour map of Phases I-VI). Leachate that infiltrates the sand drainage layer will move laterally until it reaches a gravel collection trench. From the gravel collection trench it eventually reaches a collection pipe, which conveys it to Pump Station Blocated in Phase VI.

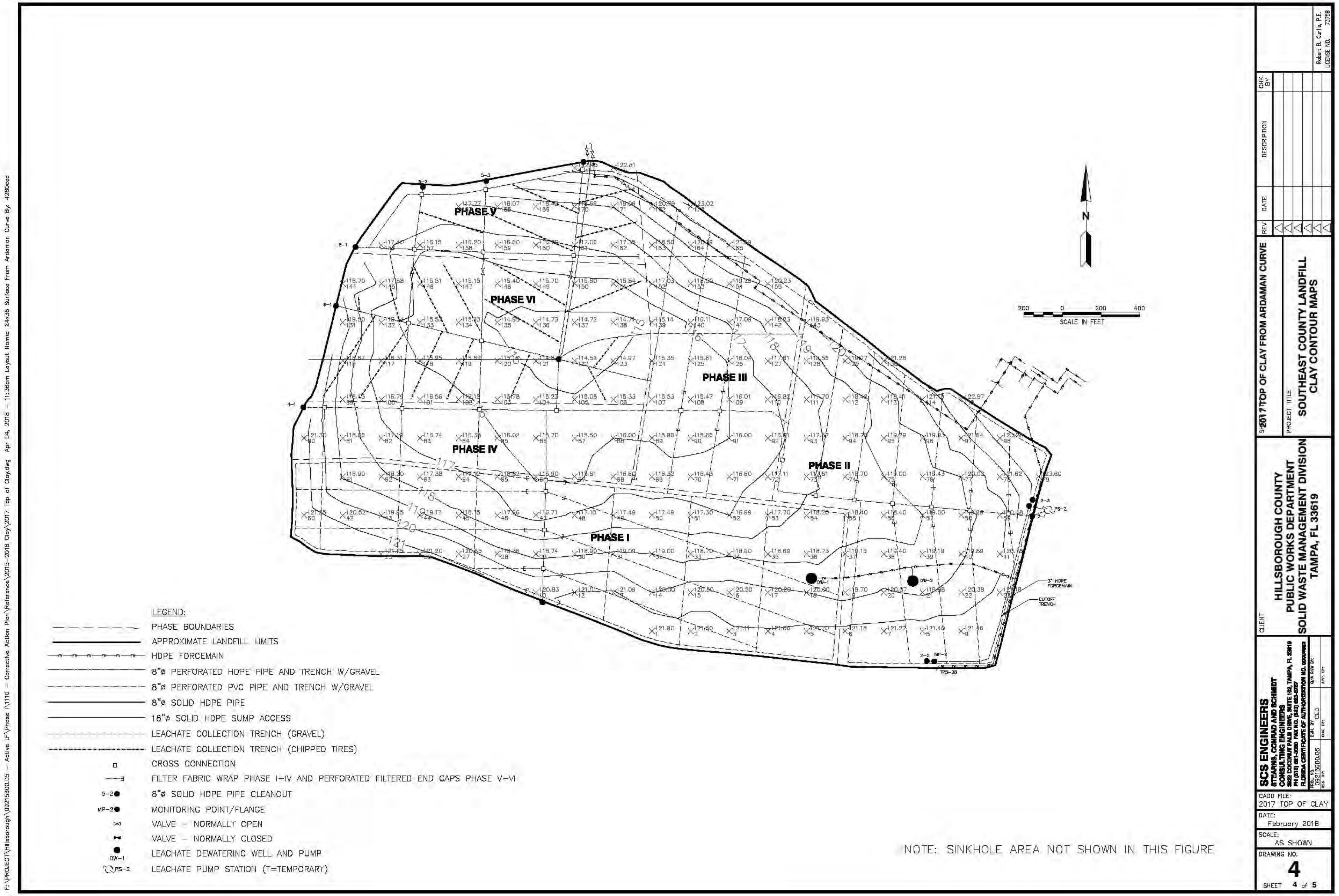

Figure 4-1. Schematic of the LCS superimposed over a clay contour map of Phases 1-VI.

When leachate infiltrates the sand drainage layer, it will typically form a mound in the space between each leachate collection trench. The highest point in this mound is equivalent to the highest liquid level over that section of the liner. Different equations for calculating the maximum liquid level over the liner are applicable for different situations. The two main situations that were applicable to Phases I-VI were a sloped case and a flat case.

The sloped case is shown in Figure 4-2. In this case, the clay liner and LCS are sloped at an angle. The leachate that infiltrates into the sand drainage layer will flow down the sloped surface to the nearest gravel collection trench, from where it will be channeled to the pump station. The Giroud equation is most commonly used for calculating the maximum liquid level over the liner for a sloped case.

$$h_{max} = L * \left(\frac{\sqrt{1 + 4\lambda} - 1}{2} \; x \; \frac{\tan(\alpha)}{\cos(\alpha)} \right) * j \qquad \text{(Eq. 4 − 1)}$$

The Giroud equation, shown in Eq. 4-1, is dependent on four parameters: the drainage path length (L), the slope of the sand drainage layer (α), the leachate removal rate (e), and the hydraulic conductivity of the sand (k). Once these four parameters are known, the maximum theoretical liquid level that should develop over that region of the liner can be calculated. The other parameters, λ and j, can be solved with Eq. 4-2 and 4-3 respectively.

$$\lambda = \frac{e}{k * tan^2\alpha} \qquad \text{(Eq. 4 − 2)}$$

$$j = 1 - 0.12 * exp\left\{ -\left[log\left(\left(\frac{8\lambda}{5} \right)^{\frac{5}{8}} \right) \right]^2 \right\} \qquad \text{(Eq. 4 − 3)}$$

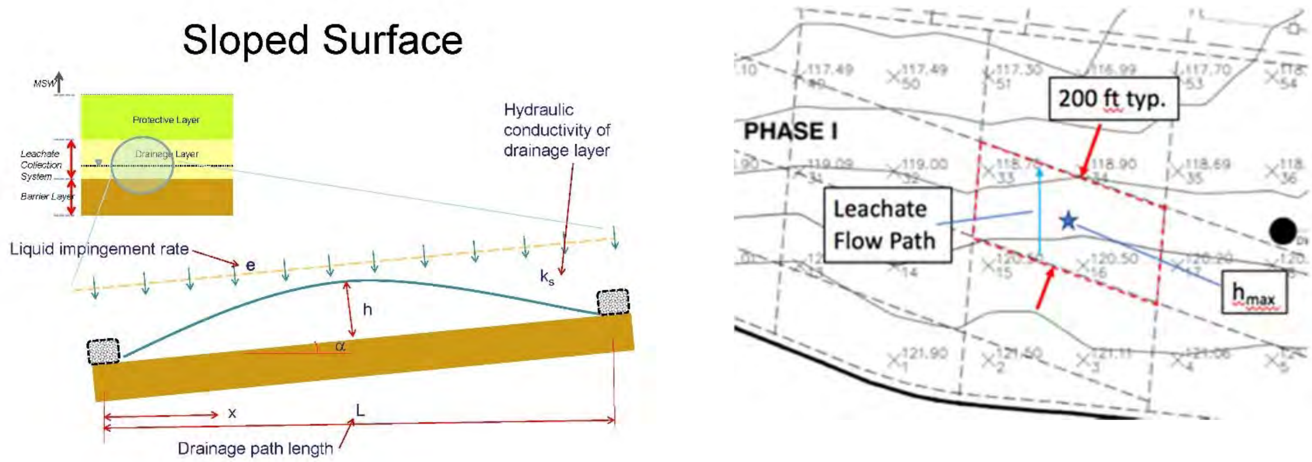

Figure 4-2. Diagram of the sloped drainage surface (left). In this case, leachate will flow from a higher elevation to a gravel trench at a lower elevation (right). A mound of leachate will develop at the point farthest from the nearest gravel collection trenches. This represents the maximum liquid level that should develop over the liner and is indicated by the star in the right-hand figure.

Figure 4-2 was used as an example to show how the Giroud equation can be applied to a sloped surface case. The right-hand figure shows one specific region of the landfill in Phase I. The gravel collection trenches are outlined in red. The highest leachate level would be expected to occur close to where the star is. When leachate infiltrates into the sand drainage layer, the leachate would be expected to flow in the direction indicated (down slope). The flow path, L, is about 225 feet (measured from the gravel trench up slope to the gravel trench down slope). The slope along the flow path was estimated to be about 0.8% based on the clay contour map in Figure 4-2. The leachate removal rate was set at 595 GPAD, based on the results obtained from Table 3-1 for 2017. The hydraulic conductivity of the sand drainage layer, k, was estimated at 0.0058 cm/s based on test results provided by AREHNA Engineering for samples collected from the sand drainage layer. After determining these parameters and using them in Eqs. 4-1 to 4-3, the maximum liquid level that should develop over this region of the clay liner was estimated to be 1.45 feet.

In some instances, a flat surface case is more appropriate than a sloped surface case for estimating the liquid level over the liner. An example of this is shown in Figure 4-3 below. Eq. 4-4 is used for the flat drainage case.

$$h_{max} = \left[\frac{e * L^2}{4k}\right]^{\frac{1}{2}} \qquad \text{(Eq. 4 − 4)}$$

Eq. 4-4 is only dependent on three parameters: the drainage path length (L), the leachate removal rate (e), and the hydraulic conductivity of the sand (k). Once these three parameters are known, the maximum theoretical liquid level that should develop over that region of the liner can be calculated.

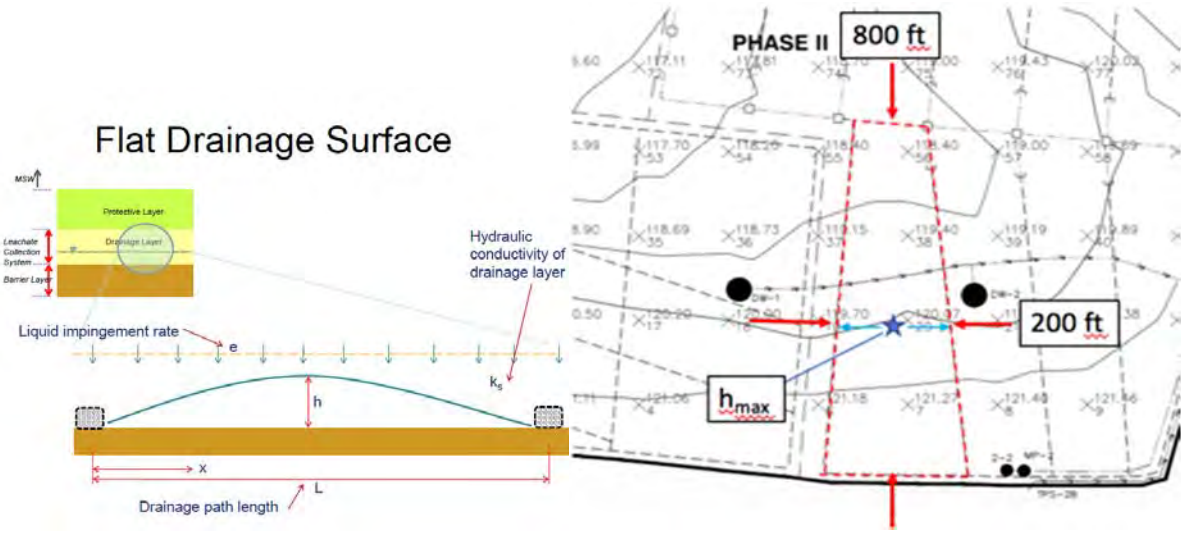

Figure 4-3. Diagram of the flat drainage surface (left). In this case, leachate will flow to the nearest gravel collection trench from either of two directions (right). A mound of leachate will develop at the point farthest from the nearest gravel collection trenches. This represents the maximum liquid level that should develop over the liner and is indicated by the star in the right-hand figure.

Figure 4-3 was used as an example to show how the Eq. 4-4 can be applied to a flat surface case. The right-hand figure shows one specific region of the landfill in Phase II. The gravel collection trenches are outlined in red. The highest leachate level would be expected to occur close to where the star is. When leachate infiltrates into the sand drainage layer, the leachate would be expected to flow in the directions indicated (toward the nearest gravel trenches). In this case, it would not flow down slope because the leachate is more likely to take the shortest path possible to the gravel collection trench, which happens to be nearly flat. The average flow path, L, is about 200 feet (measured as the distance between gravel trenches). The leachate removal rate was set at 595 GPAD, based on the results obtained from Table 3-1 for 2017. The hydraulic conductivity, k, was estimated at 0.0058 cm/s based on test results for samples collected from the sand drainage layer. After determining these parameters and using them in Eq. 4-4, the maximum liquid level that should develop over this region of the clay liner is estimated to be 1.05 feet.

4.2 Theoretical Maximum Liquid Level near Each Piezometer

The methodology discussed in Section 4.1 was used to calculate the maximum liquid level that should occur nearest to each piezometer. If the piezometers are accurate, then the readings should not be higher than the expected maximum liquid level in the region of the landfill they are located. Figure 4-4 shows the average liquid level measured from each piezometer throughout the course of 2017. Most of the piezometers read a much higher liquid level over the liner than would be expected based on the design of the LCS and leachate removal rate. These higher-than-expected readings may be caused by reasons discussed in Section 6 and modeled in Section 7.

Table 4-1. Maximum Theoretical Liquid Level Calculation Input & Output

Piezometer	Equation	Slope (%)	L (feet)	h_{max} (feet)
SB-15D	Flat		194	1.02
SB-16D	Flat		184	0.97
SB-17D	Giroud	0.56	210	1.54
SB-18D	Giroud	0.54	237	1.76
SB-19D	Flat		218	1.15
SB-20D	Giroud	0.50	377	2.70
SB-21D	Flat		204	1.05
SB-23D	Flat		507	2.67
SB-24D	Giroud	0.50	216	1.64
SB-25D	Giroud	0.80	225	1.45
SB-28D	Giroud	0.50	204	1.55

e = 595 GPAD

k = 0.0058 cm/sec

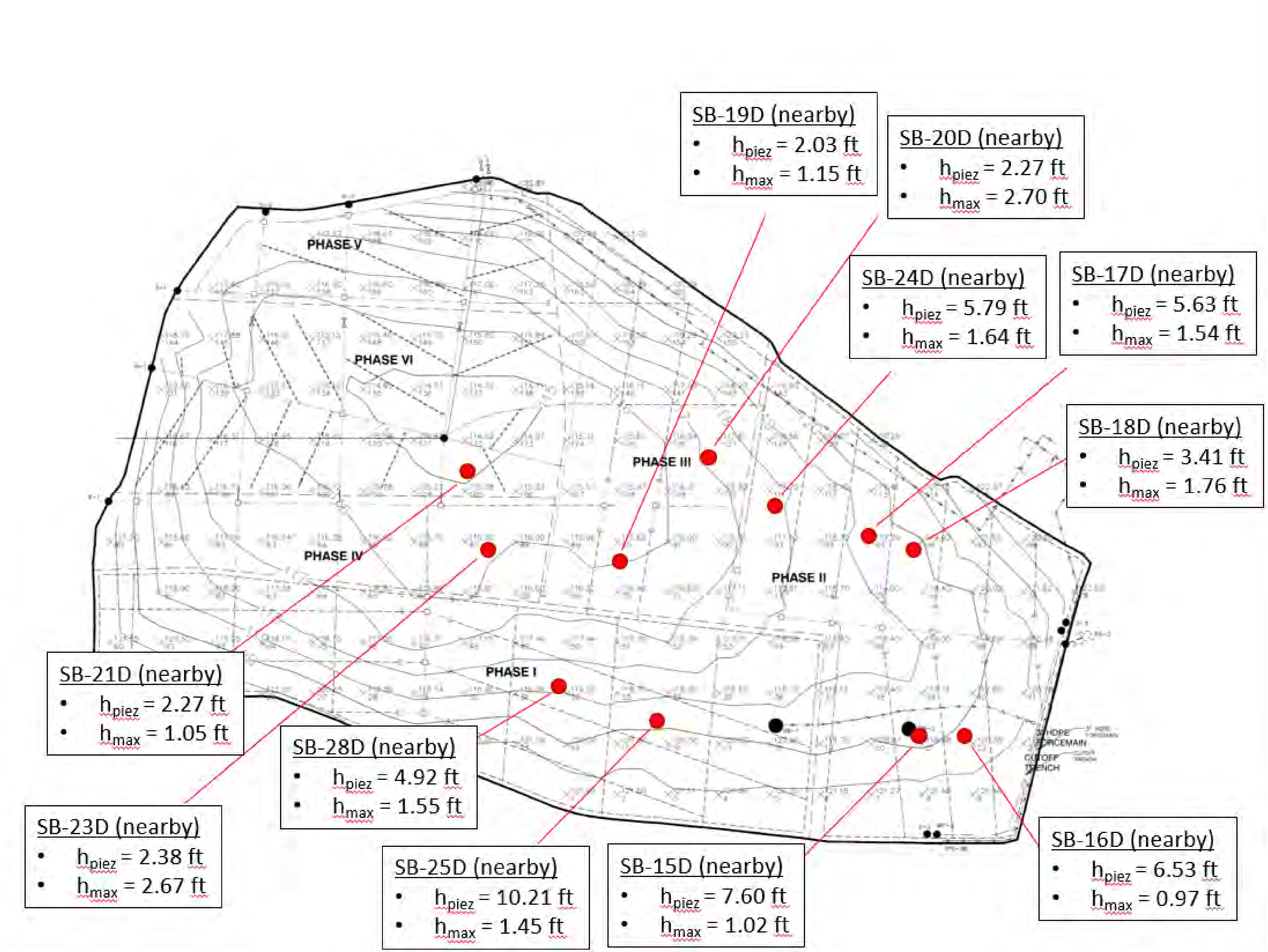

Figure 4-4. Map indicating the average leachate level measured in each Series 2 piezometer during 2017 and the maximum liquid level that would be expected near each piezometer.

5.0 FIELD EXCAVATION AT SCLF

From April 23-26, 2018, a field excavation was conducted at SCLF near piezometer SB-32 in Phase III. The purpose of the excavation was to locate the LCS header pipe so that a cleanout pipe could be installed. This excavation was also used as an opportunity to observe soil moisture contents and actual leachate levels in the LCS sand drainage layer to compare with a nearby piezometer. The trench was excavated about 5-10 feet to the south of the piezometer (Figures 5-1 and 5-2); construction progressed from east to west and the trench extended through the waste mass and underlying sand drainage layer to the top of the clay layer. During excavation, the piezometer indicated there 0.4 feet of leachate above the liner, but the surrounding sand that was excavated was not saturated with moisture as the piezometer predicted. Personnel on site observed the excavation (which had been excavated to the top of the clay layer) to initially be dry, but then noticed liquid flowing from waste layers higher up in the sidewall into portions of the bottom of the trench (see Figure 5-3, 5-4, and field observations made by Pelz Engineering Services). A surveying level was used to compare the levels recorded from the piezometer to the elevations in the adjacent trench (see Figures 5-5, 5-6 and 5-7). Using the top of the piezometer casing, previously determined as EL 146.9 feet by a registered land surveyor, as a reference point, the bottom of the excavation trench was measured to be EL 122.23 feet. At the same time, the leachate level in the piezometer was measured with a water level tape and determined to be at EL 122.62 feet (0.4 feet above the bottom of the trench).

As the excavation progressed, the trench appeared to be dry all the way down to the bottom of the drainage sand. Samples of the drainage sand were collected, stored in a sealed bag and transported to the laboratory to determine the moisture content.

The laboratory results are displayed in Table 5-1. Saturated water content (porosity) was determined by taking a known volume of the completely dried sample and adding a known volume of water to it over a funnel with wetted filter paper. The volume of water retained in the sand was used to calculate the porosity. The field capacity (moisture content where water will no longer drain) was estimated by allowing the covered sample to drain freely for 1.5 days and recording the volume of water that was still retained in the sand. The volumetric moisture content of the original sample was determined by taking a known mass and volume of sand and drying it for 24 hours. The weight after drying was recorded, and the difference between the two measurements was used to calculate the volume of water that left the sample.

The degree of saturation (volume of water divided by the volume of voids) of the sand sample taken from the bottom of the LCS sand layer (just above the clay liner) at the time of excavation was 0.82, which indicates that it was unsaturated. Unsaturated sand does not exert positive liquid pressure (head). In fact, capillary forces cause unsaturated sand to produce a negative pressure.

Table 5-1. Laboratory test results of drainage sand samples collected from the excavation.

Parameter	% of Total Volume	Degree of Saturation
Saturated Water Content	31.0%	1.0
Field Capacity	24.1%	0.78
Sample Moisture Content	25.5%	0.82

One key observation that was made following the excavation of the section of the trench closest to the piezometer was that perched water higher up in the waste mass began to seep through the side of the waste and pond in the trench (see Figure 5-1This observation provides further evidence that leachate may be building up around the piezometer for the reasons described in Section 6. Another observation made during the excavation process was that the buried waste exhibits a high degree of heterogeneity (see Figures 5-3 and 5-4). A wide range of materials, such as plastics, metals, bulky items, and soil, were found in the MSW layer. As can be seen from these trench excavation photographs, the walls of the trench are very rough and uneven. Drilling a borehole through this MSW would likewise produce a similar pattern. Completely sealing the piezometer with bentonite would therefore be very difficult because of the many empty spaces that can develop along the sides of the borehole.

Figure 5-1. Trench dug near piezometer SB-32 on April 26, 2018. The piezometer is shown in the top left hand corner of the picture. The sand drainage layer was initially dry when it was excavated. A significant buildup of leachate occurred when the section of the trench nearest to the piezometer was dug up. This leachate originated from the middle layers of the MSW, not the sand drainage layer. About 0.4 feet of leachate developed in that area of the trench.

Figure 5-2. Picture of piezometer SB-32.

Figure 5-3. Looking down the trench in the section closest to the piezometer. The sidewall of the trench shows the 4-foot sand layer at the bottom with MSW on top of it. Note the heterogeneity in the MSW layer. When this section of the landfill was excavated, the sand was originally reported to be dry. However, water soon began to seep from the side wall, where the black agricultural plastic is located (the water did not originate in the sand layer). The water ponded at the bottom of the trench, as can be seen in the figure above.

Figure 5-4. Photo illustrating the heterogeneity of the MSW layer.

Figure 5-5. Surveying equipment used to determine elevations above the ground surface.

Figure 5-6. Determining the height of the piezometer above the ground surface with a surveying level.

Figure 5-7. Measuring the depth to the top of the clay liner.

6.0 EXAMINATION OF THE OBSERVED PIEZOMETER READINGS

6.1 Possible Explanations

The results presented in Section 3.2 indicate there are potentially significant leachate levels above the liner. There are two explanations that may be able to provide an interpretation of these results. One possibility is that the piezometers provide an accurate representation of the actual level above the liner. However, based on the design of the leachate collection system and the calculations that were presented in Section 4, this may not be a realistic estimation. The levels measured in the piezometers exceed the calculated design calculations for the actual system and this was not seen in the excavations. Another explanation for the observed piezometer readings is that they are not representative of the area wide liquid levels that would exist in the absence of the piezometer. One hypothesis for why this might be true is presented in Section 6.2. This second hypothesis is more reasonable and was confirmed since the liquid levels measured in the piezometers prior to excavation, in all three separate locations in Phase II and III, exceeded the calculated design level (Refer to Section 4.2) and would have indicated a standing liquid level at the location of the excavation; however, based upon actual field observations of the conditions of the sand and waste layers within the excavations, these “measured” levels were not encountered as a static, free standing liquid level. The sands were only moist and liquids were observed flowing horizontally in the waste layer. The liquids entered the trench from the above waste layers and possibly into, or influencing, the piezometers measurements.

6.2 Sources of Inaccuracy

It is hypothesized that the piezometer data presented in Section 3.2 will lead to an overestimation of the leachate level above the liner. The cause of these higher-than-expected leachate levels would originate from the piezometer itself. Under normal conditions, the hydraulic conductivity of waste within a landfill exhibits anisotropy, leading to 10 to 100 times greater permeability in the horizontal directions than in the vertical direction (Singh et al., 2014).

This is the result of the compaction process employed at most landfills, which creates layers of low vertical hydraulic conductivity. This anisotropy can be disturbed if a borehole is drilled through these layers, which forms a zone where leachate can percolate downward to the sand drainage layer. A similar situation can occur when a piezometer is installed; the anisotropy is disturbed immediately around the newly installed piezometer, forming a region of greater isotropy. This isotropic region around the piezometer acts as a drain for the surrounding waste. Because the surrounding waste has higher horizontal hydraulic conductivity, leachate can seep horizontally towards the piezometer, where it will then flow downward in the isotropic region around the piezometer casing. This would create a drawdown effect in the upper regions of the landfill under steady-state conditions, resulting in the mounding of leachate in the sand drainage layer immediately around the piezometer. This mounding effect would influence piezometer readings that are used in determining the level above the liner; in this case, the liquid levels in the piezometer would be higher at the piezometer than what would otherwise be in the LCS if the piezometer did not exist. The piezometer would therefore not be representative of water levels in the region around the piezometer.

Although a grout and bentonite seal was installed between the borehole wall and piezometer casing in the Series 2 piezometers, the seal would not be able to effectively prevent water from seeping into the borehole. This is because compacted waste exhibits a high degree of heterogeneity (see Figures 5-3 and 5-4). Hundreds of different types of materials can be present in a given sample of MSW, with each material having different sizes, shapes, and properties. Drilling through a layer of MSW would therefore be expected to result in pockets of empty space and regions of isotropy around the outer edges of the borehole. As can be seen from Figures 5-3 and 5-4, effectively establishing a complete seal around this material would be extremely difficult. See Section 5 for further discussion.

Figures 6-1, 6-2, and 6-3 visually describe the phenomenon discussed above. In an ideal case where the installation of a piezometer does not disturb the surrounding anisotropy of the waste, the readings from the piezometers should be accurate. Section 7 will discuss the results from modeling different scenarios of these phenomena in SEEP/W.

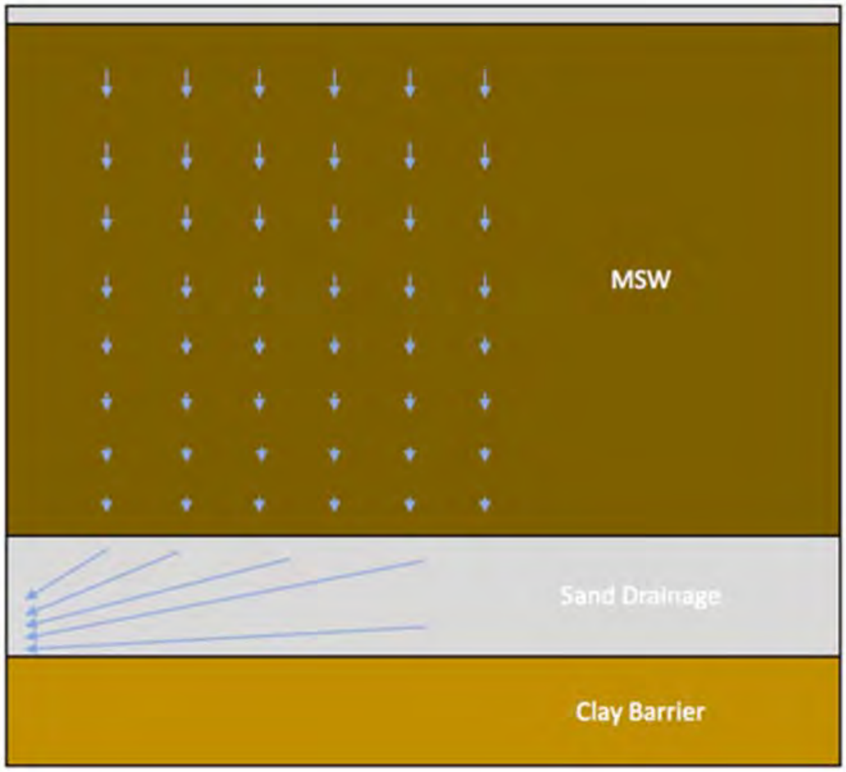

Figure 6-1. Flow vectors depicting leachate movement within a landfill before a piezometer is installed. Although there is greater hydraulic conductivity in the horizontal direction than in the vertical direction (anisotropy), the average movement of the leachate is downward since there is nowhere for leachate to travel horizontally. The vertical hydraulic conductivity of the MSW decreases with depth because of greater compaction.

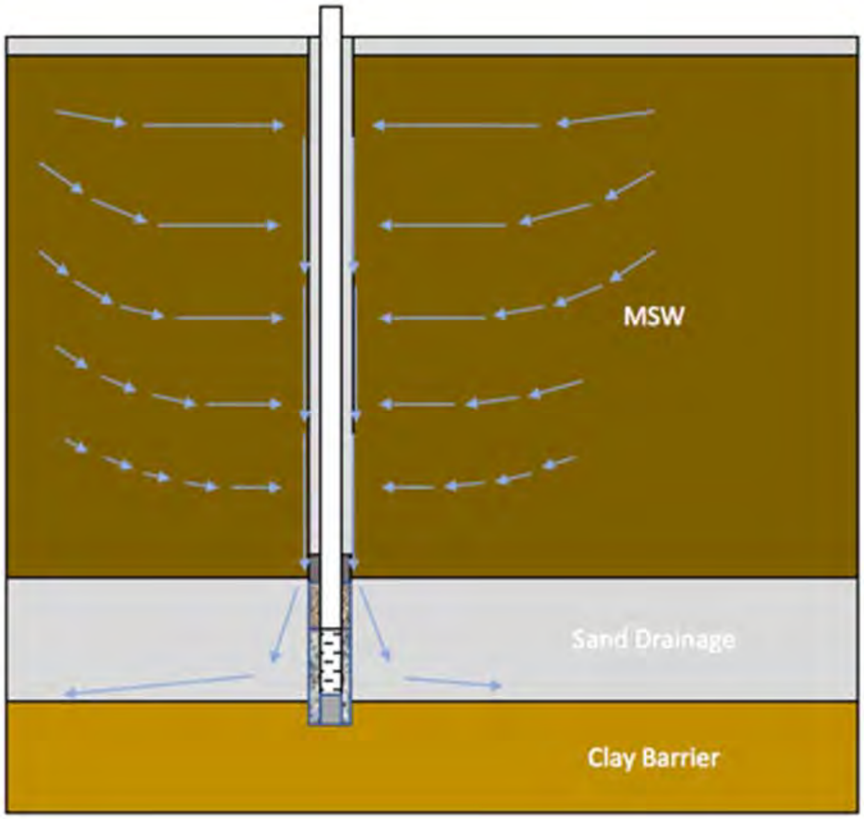

Figure 6-2. Flow vectors depicting leachate movement within the landfill after a piezometer is installed. The installation of the piezometer disturbs the anisotropy of the surrounding waste, creating a thin layer around the casing that has a high vertical hydraulic conductivity. Leachate in the surrounding area of the MSW will flow horizontally in all radial directions toward the piezometer casing, which provides a pathway of least resistance to the sand drainage layer. This leads to a buildup of leachate immediately around the piezometer.

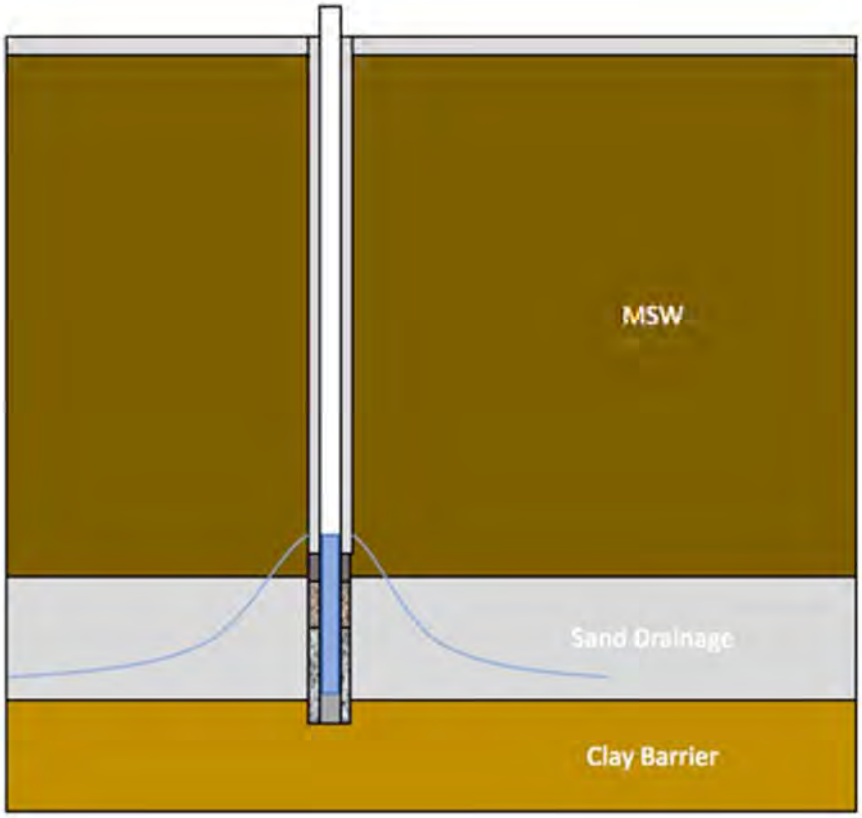

Figure 6-3. Depiction of the average leachate level above the liner. A mounding effect is observed in the sand drainage layer immediately around the piezometer due to influx of leachate from above (as described in Figure 4-2, leading to a greater liquid elevation in the piezometer than would be expected.

7.0 MODELING OF THE LEACHATE LEVEL ABOVE THE LINER WITH SEEP/W

The landfill leachate flow concepts described in Section 6 can be best-illustrated using computer simulations of subsurface flow within a landfill. A computer model was constructed to demonstrate that, even in unsaturated conditions and because of anisotropy of the waste mass, leachate moves horizontally to eventually fill boreholes drilled into a landfill (landfill operators who install landfill gas extraction wells are familiar with this phenomenon). The computer model also simulates movement of the leachate downward in the borehole and the groundwater mounding that occurs where the leachate accumulates at the bottom of the borehole (in the LCS). This section includes both steady-state and transient computer simulations of boreholes installed in unsaturated landfills and landfills that have perched liquid zones.

7.1 Description of SEEP/W

SEEP/W is a finite element software product for modeling groundwater flow in porous media. The software can model simple saturated steady-state problems or sophisticated saturated / unsaturated transient analyses with atmospheric coupling at the ground surface. The SEEP/W model is constructed to solve two-dimensional flow situations with multiple soil layers (see Figure 7-1). Flow directions of groundwater can also be analyzed. Under steady state conditions, the difference between input flux and output flux is zero at all times. For finite element calculation, the SEEP/W model is divided into nodes. The software calculates the water level elevation at each node.

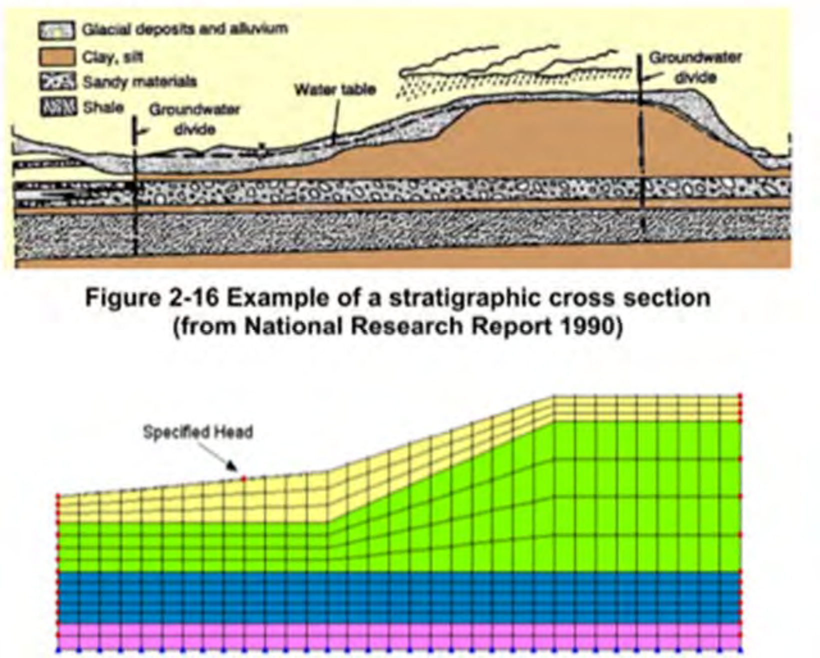

Figure 7-1. Example of finite element mesh generation with different soil layers (adopted from SEEP/W manual).

Richards equation (Eq. 7-1) is the governing equation used in this model.

$$\frac{\partial}{\partial x}\left(k_x \frac{\partial H}{\partial x}\right) + \frac{\partial}{\partial y}\left(k_y \frac{\partial H}{\partial y}\right) + Q = \frac{\partial \theta}{\partial t} \qquad (\text{Eq. } 7-1)$$

where, H is the total head, K_x and K_y is the hydraulic conductivity in the x and y directions, respectively, Q is the applied boundary flux, θ is the volumetric water content, and t is time. This equation states that the difference between the flow (flux) entering and leaving an elemental volume at a point in time is equal to the change in storage of the soil systems. More fundamentally, it states that the sum of the rates of change of flows in the x- and y-directions plus the external applied flux is equal to the rate of change of the volumetric water content with respect to time.

Under steady-state conditions, the flux entering and leaving an elemental volume is the same at all times. The right side of the equation consequently vanishes and the equation reduces to:

$$\frac{\partial}{\partial x}\left(k_x \frac{\partial H}{\partial x}\right) + \frac{\partial}{\partial y}\left(k_y \frac{\partial H}{\partial y}\right) + Q = 0 \qquad \text{(Eq. } 5-2)$$

The solution of governing equation depends on the model geometry as well as the initial and boundary conditions, which will be discussed in the following section.

7.2 Types of Runs Performed in SEEP/W

In this study, a series of transient to steady-state simulations were conducted with two different scenarios; 1) without and 2) with a perched water table in the waste layer, to investigate the effect of the installation of the piezometer and how this influences the observed readings. The simulation results are presented using a degree of saturation profile. Degree of saturation is the volume of water in a segment of material divided by the total volume of that material. This profile shows the simulated degree of saturation of the waste and soil layers in the simulated landfill. Soil or waste with a degree of saturation less than 1.0 is considered unsaturated. Soils or waste with a degree of saturation equal to one is considered saturated. The figures in this report use colors to show various degrees of saturation between 0 and >0.9. A blue line is shown to delineate between unsaturated (degree of saturation < 1.0) and saturated (degree of saturation = 1.0) areas of the model. This line is known as the phreatic surface, or liquid level.

7.2.1 Geometry of modeled landfill segment

Figure 7-2 represents a schematic model of an axisymmetric landfill segment that contains a well on the left-hand side along the y-axis (geometry as in Figure 7-3). Note that five different MSW layers are considered where the hydraulic conductivity and anisotropy decrease and increase respectively in vertical direction due to compaction. Detailed dimensions including hydraulic conductivities are listed in Table 7-1.

7.2.2 Description of boundary conditions

As previously mentioned, assigning a proper boundary condition plays an important role in solving the governing equation. In SEEP/W unless otherwise specified, all boundaries that contact with no adjacent cell (outer boundaries) has “no flow” boundary. Therefore, in this study, all flow within the MSW layers occurs in either the vertical direction or horizontal direction toward the piezometer (left end); the sand layer has a drainage boundary at the right side (i.e., leachate collection system). An impingement rate of 6.6×10^{-9} $m^3/sec/m^2$ (610 GPAD) at the top layer was assumed based on the results from Table 3-1. Later, a perched water table scenario was considered by adding a highly impermeable layer at the bottom of layer 4.

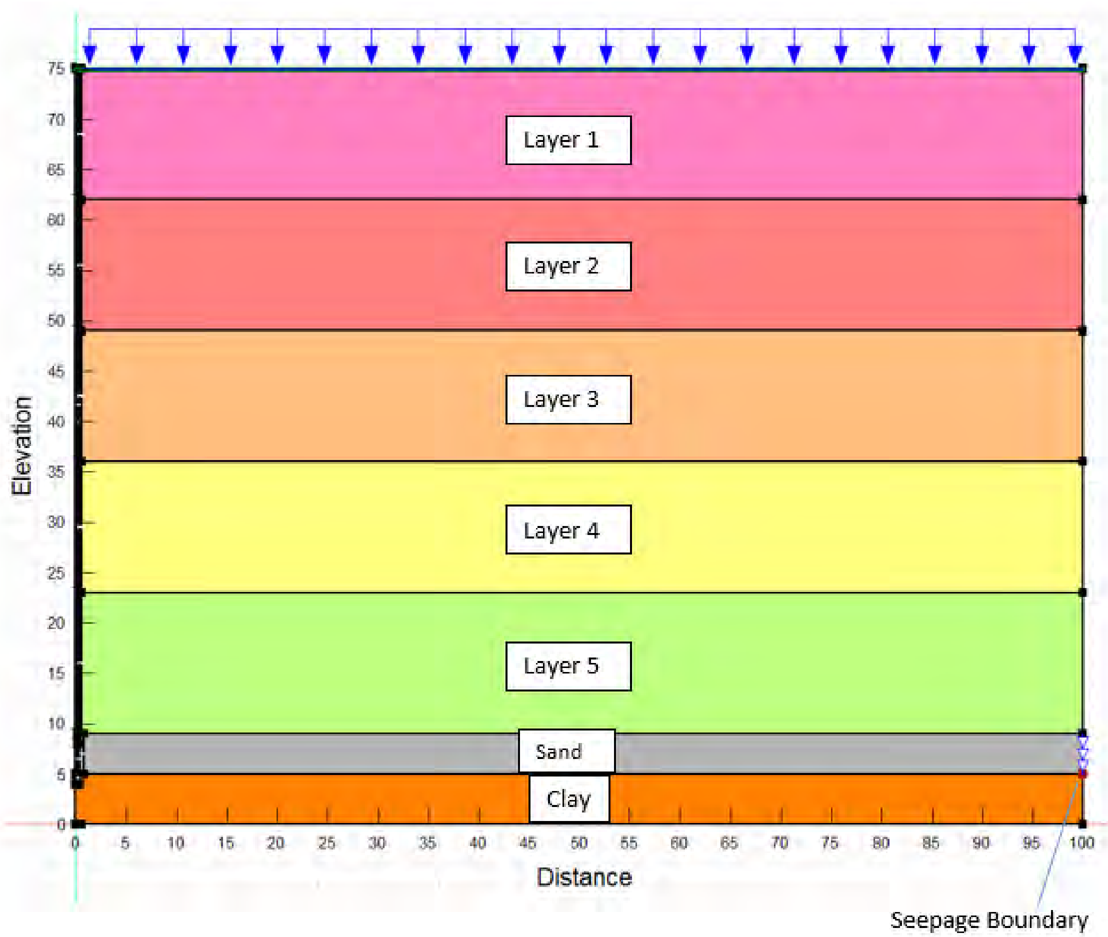

Figure 7-2. Schematic model of the landfill segment around the piezometer. The radial distance (x-axis) is 100 feet and the total height from the bottom of the clay to the top of the landfill is 75 feet.

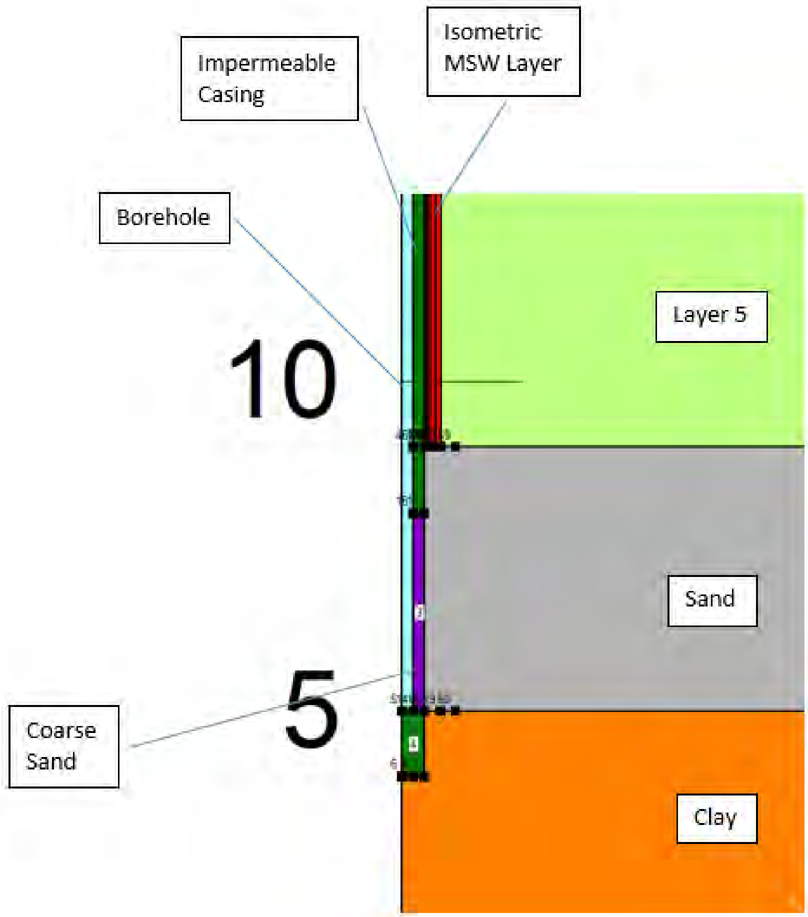

Figure 7-3. Schematic model of landfill segment. The piezometer is shown on the left-hand side.

Table 7-1. Dimensions and hydraulic properties at each layer.

		Ky/Kx	Ky (cm/s)	Kx_{sat} (cm/s)	Residual WC	Sat. WC	Height (ft)
MSW	Layer 1 (top)	0.08	1×10^{-4}	1.25×10^{-3}	0.1	0.5	13
	Layer 2	0.04	5×10^{-5}	1.25×10^{-3}	0.1	0.5	13
	Layer 3	0.02	1×10^{-5}	5×10^{-4}	0.1	0.5	13
	Layer 4	0.01	5×10^{-6}	5×10^{-4}	0.1	0.5	13
	Layer 5 (bottom)	0.005	1×10^{-6}	2×10^{-4}	0.1	0.5	14
	Isometric Layer	1	10	10	0.1	0.5	N/A
Sand (LCS)		1	1.5×10^{-3}	1.5×10^{-3}	0.1	0.45	4
Clay liner		1	1.8×10^{-8}	1.8×10^{-8}	0.1	0.5	5
Impervious Material (grout and bentonite)		1	1×10^{-20}	1×10^{-20}	0	0.5	N/A

7.3 Results

The following simulation results show how the saturation profile and leachate level on liner changes from transient to steady-state with and without a perched water table in the MSW layer.

7.3.1 Simulation result without the perched water table

A steady-state simulation was first conducted without the piezometer to provide an initial condition for the following transient analysis. In this simulation water moves vertically thorough the landfill waste layers until it reaches a highly permeable LCS sand layer. A degree of saturation profile is shown in Figure 7-4. Degree of saturation gradually increases with depth in this profile (from 0.3 to 0.4 near the surface to >0.9 at the bottom of the waste layers) due to the gradually decreasing hydraulic conductivities of the waste layers with depth. Degree of saturation abruptly drops to 0.3 to 0.4 in the sand layer. This is caused by the higher hydraulic conductivity of the sand layer compared to the lower hydraulic conductivity in the overlying waste layer; the sand layer has greater capacity to transmit liquid than the waste layer has to provide liquid. This liquid then accumulates to a maximum depth of about 0.5 feet on the low hydraulic conductivity clay layer at the bottom of the sand layer. In this simulation, water will flow from left to right toward the seepage boundary, so the maximum depth of 0.5 feet is on the left side.

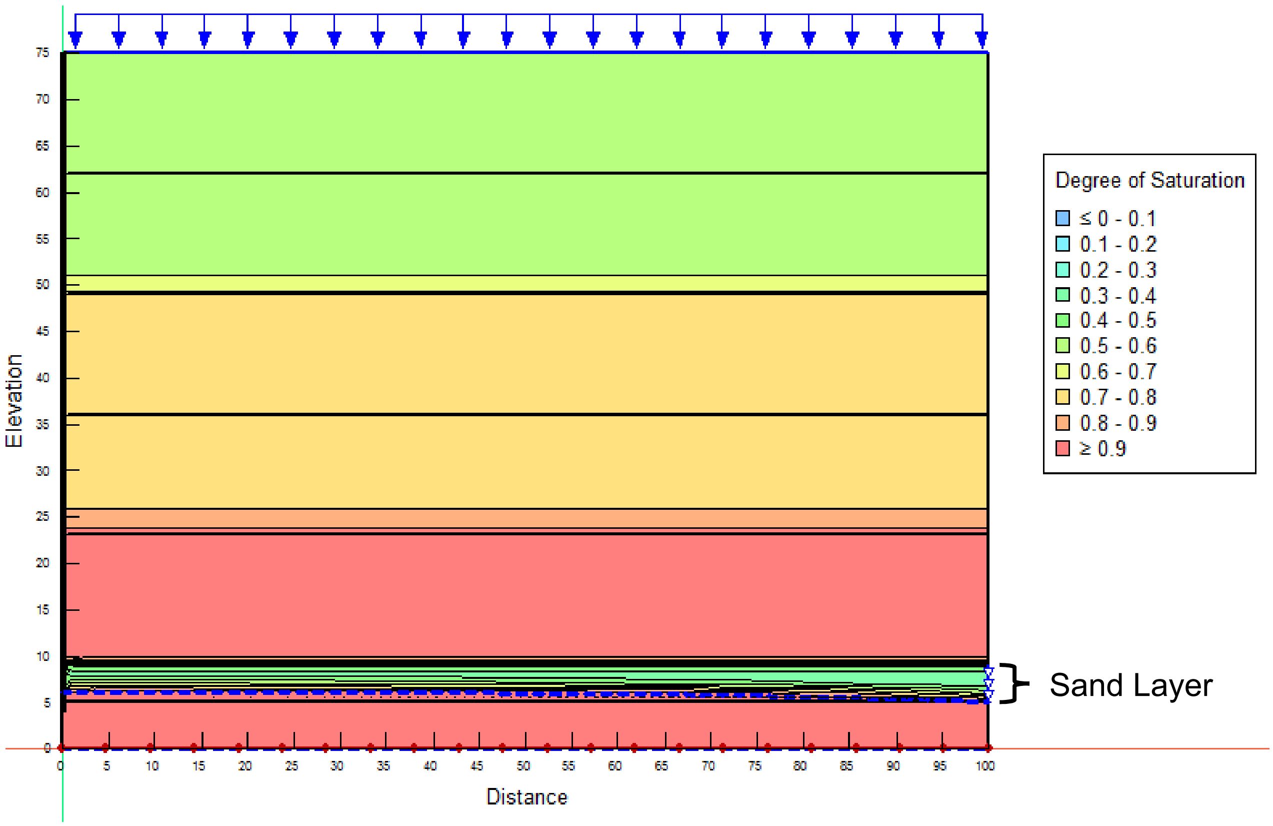

Figure 7-4. Degree of saturation profile before installation of the piezometer (without the perched water table).

Figure 7-5 represents the simulated saturation profile one day after installing the piezometer. The piezometer is installed by drilling a hole through all of the waste layers, removing the low permeability waste material and replacing it with a higher permeability material that represents a poorly sealed borehole annulus. Liquid then begins to move laterally from the waste layers to the piezometer. This causes the degree of saturation in the waste layers around the well to decrease. The liquid then enters the borehole and flows downward to the sand layer, where it accumulates around the piezometer.

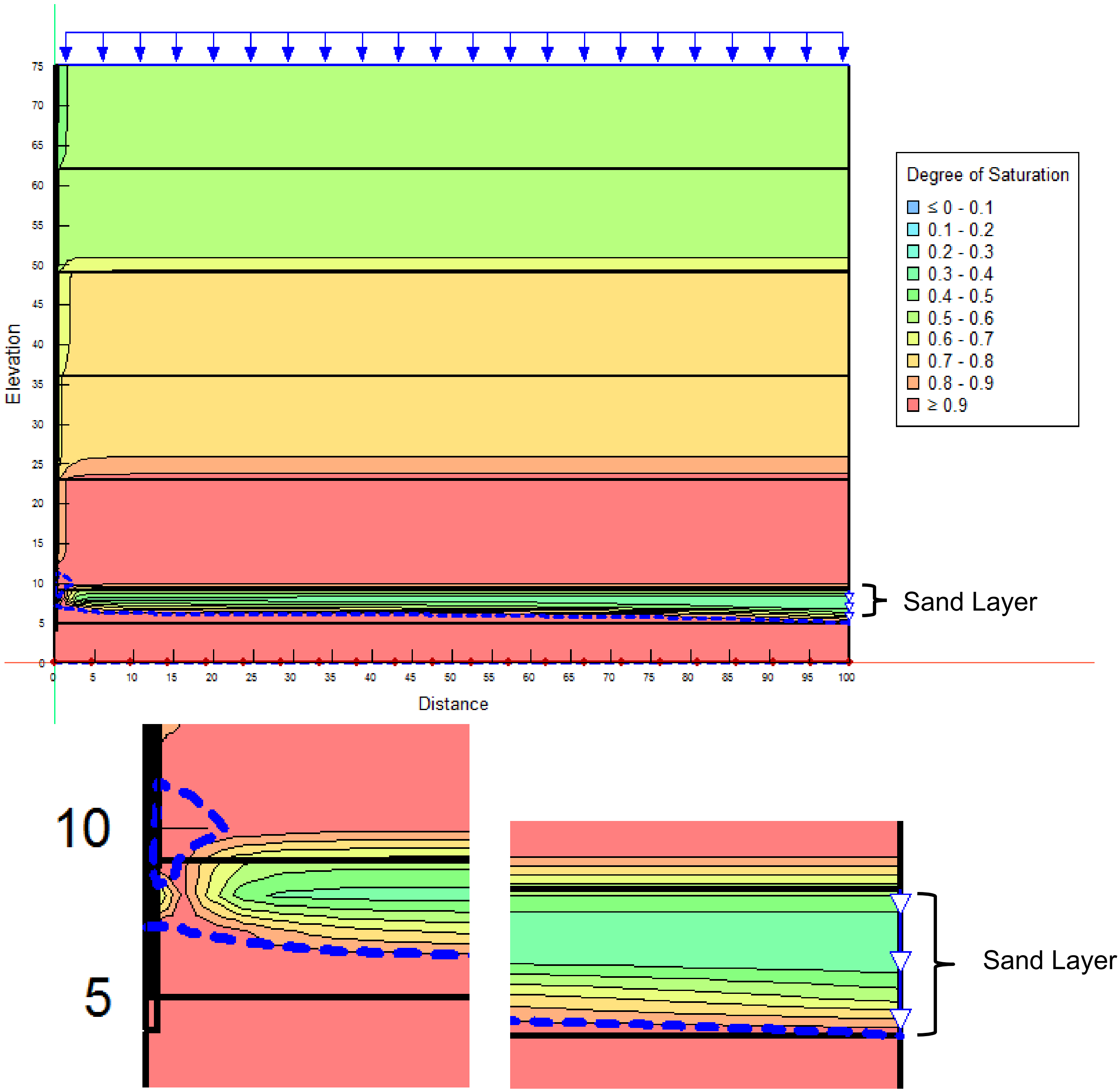

Figure 7-5. Degree of saturation profile and leachate level on the liner at the both ends of sand one day after installation of the piezometer (without the perched water table).

This trend continues until it reaches steady state (after about five years). Figure 7-6 represents the saturation profile five years after installing the piezometer; the leachate level on the clay liner was about 2.3 feet near the piezometer.

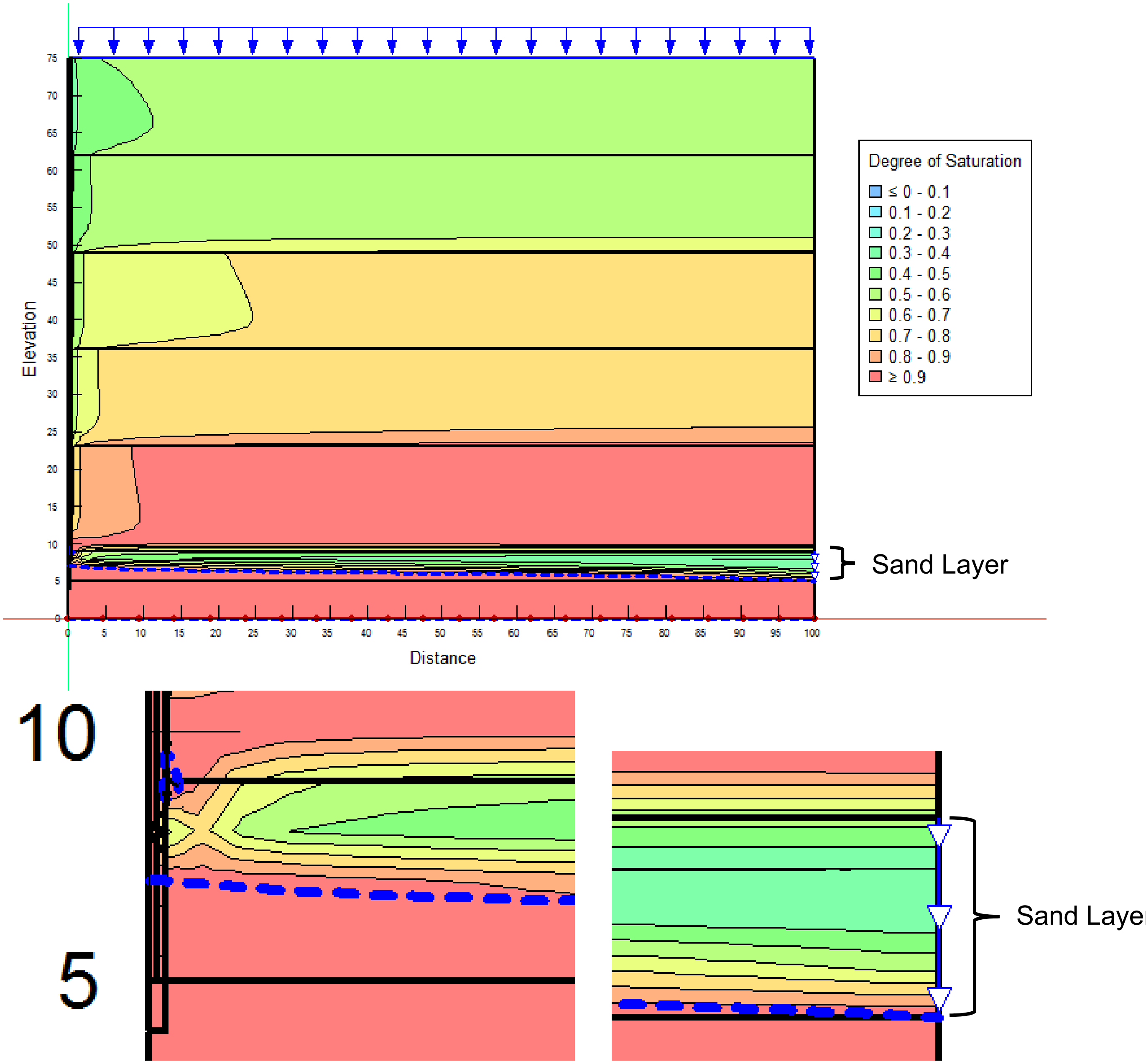

Figure 7-6. Degree of saturation profile and the leachate level on the liner at the both ends of sand layer five years after installation of the piezometer (without the perched water table).

7.3.2 Simulation result with perched water table

A similar series of simulations were conducted by creating a perched water table at the bottom of layer 4 to model the possibility of perched conditions within the waste mass. Figure 7-7 shows the steady-state saturation profile before installation of the piezometer. Note that there are two different phreatic water surfaces (blue dotted lines) in the middle of waste layer as well as in the sand layer. The steady-state level on the liner was almost zero, which indicates that the drainage system operates properly under the moderate impingement rate (610 GPAD).

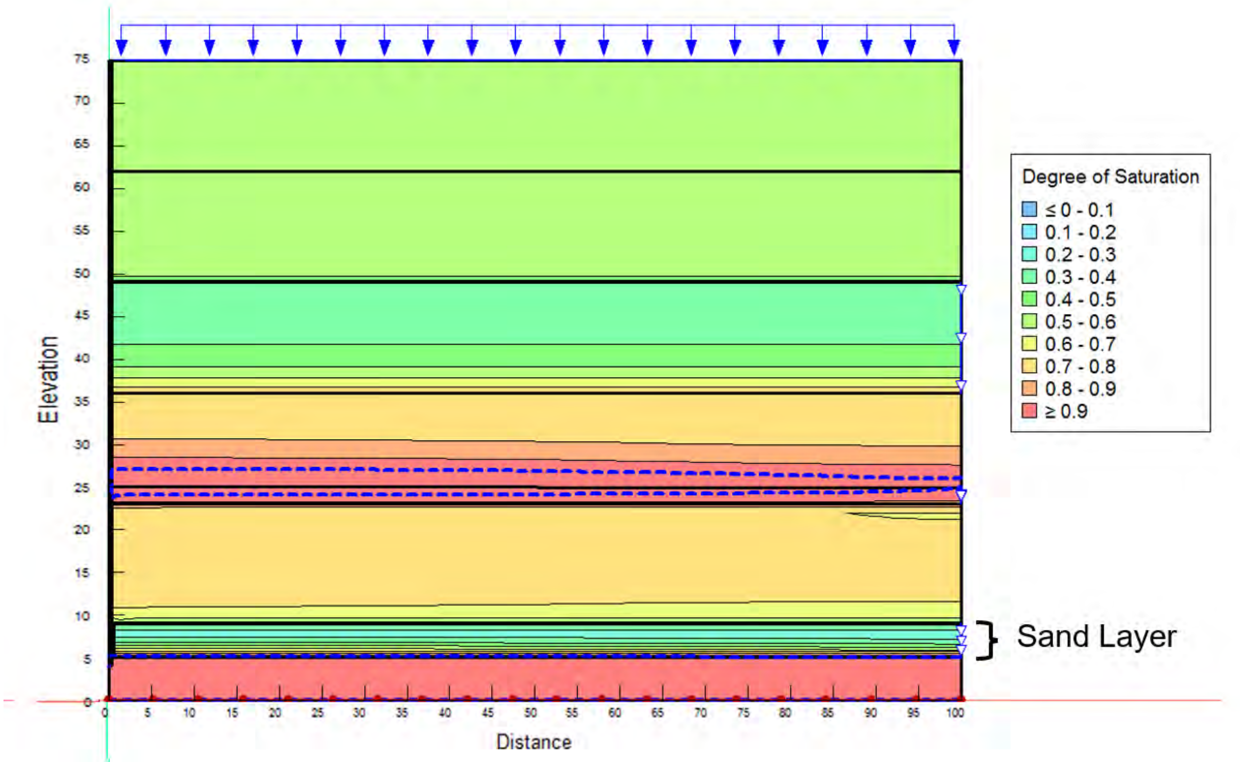

Figure 7-7. Degree of saturation five years after the installation of the piezometer (with the perched water table).

Figure 7-8 represents the saturation profile one day after the installation of the piezometer. Similar to the previous case, water near the piezometer starts to move in the MSW toward the piezometer and the degree of saturation in the waste layers around the well decreased. In this case, free water in the perched layer also began to flow to the piezometer. This increased quantity of liquid then enters the borehole and flows downward to the sand layer, resulting in an abrupt increase in the liquid levels in the sand layer.

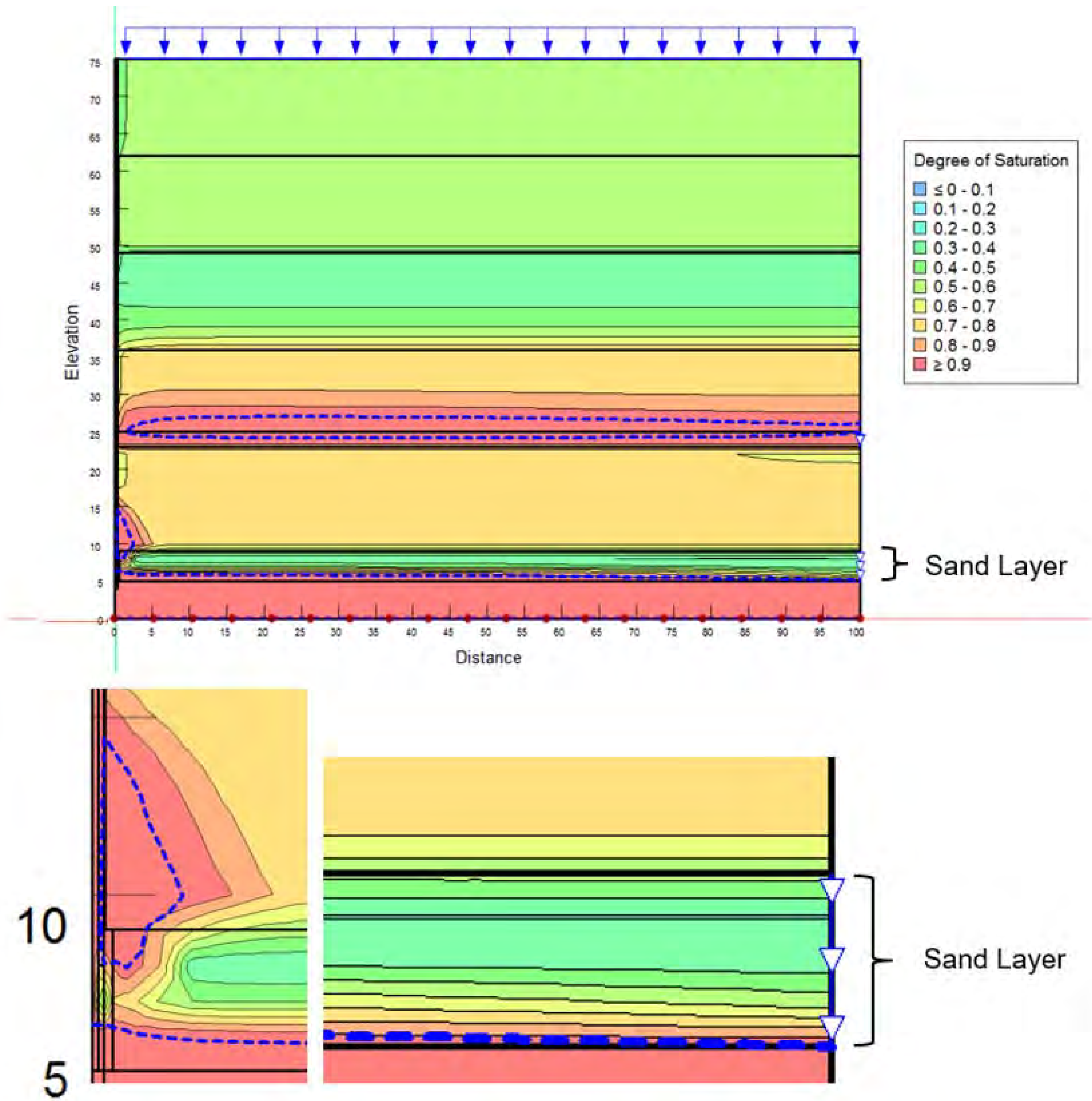

Figure 7-8. Degree of saturation and the leachate level on the liner at the both ends of sand layer five days after the installation of the piezometer (with perched water table).

Figure 7-9 represents the saturation profile at steady-state conditions 6.5 years after the installation of the piezometer. Note that the water elevation inside the piezometer increased up into the MSW layer (approximately 7.9 feet above the bottom of the sand layer), and the subsequent build-up of liquid was observed in the LCS around the piezometer, which gradually decreased towards the drainage boundary at the end of the sand layer.

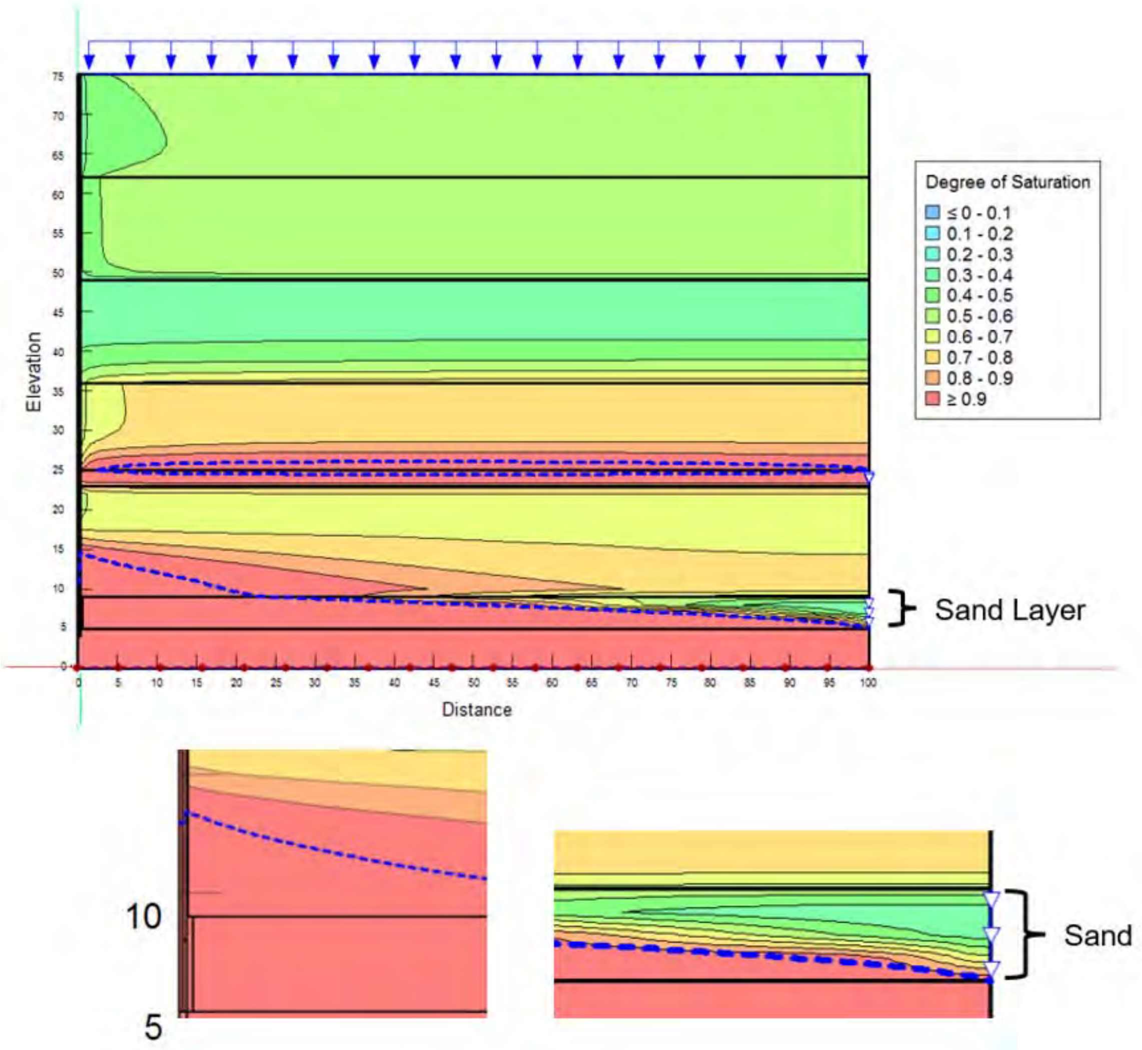

Figure 7-9. Degree of saturation and the leachate level on the liner at the both ends of sand layer 7 years after the installation of the piezometer (with perched water table).

7.4 SEEP/W Summary

Based on the SEEP/W simulation results, the installation of a piezometer, like the Series 2 piezometers at the SCLF, can draw moisture and free liquids from the waste layers around the piezometer (the anisotropic properties of the surrounding waste directs the moisture horizontally) to the piezometer borehole. This liquid can then flow down the borehole and accumulate in the sand layer at the bottom of the landfill, resulting in a build-up of leachate above the clay liner around the piezometer. This localized mounding of leachate around the piezometer can persist indefinitely.

8.0 CONCLUSIONS AND RECOMMENDATIONS

Several methods were used in this investigation to determine if the readings from the piezometers in the Phase I –VI cells of the SCLF provide an accurate representation of the actual liquid level over the clay liner. The major findings from this report support the case that they do not.

Based on a review of 13-years of leachate pumping data, the per-acre leachate removal rate in the Phase I-VI cells has been significantly higher than the other, more modern landfill cells that have operated on this site for many years. The leachate removal rate also fluctuates seasonally in a pattern similar to these other landfills. This indicates that the LCS sand layer, gravel trenches and leachate collection laterals are successfully transmitting leachate that is percolating from the waste layers in response to seasonal precipitation variation, and that the pumps are keeping up with the quantities of leachate that are being delivered to them. This is an indication that the LCS is functioning properly. One interesting observation is that the Phase I-VI cell leachate removal rate has dramatically increased in the past two years compared to the Section 7, 8 and 9 cells, which could be a result of piezometer installation and/or with the addition of the supplemental pumping.

Using the most recent leachate removal rate and the original LCS design plans, it was calculated that the leachate levels in the sand drainage layer should be much lower than most of the piezometer readings indicate. A field investigation was also conducted to measure the presence of moisture in the sand drainage layer to compare with the readings in a nearby piezometer. The drainage sand in the trench was observed (and later confirmed through laboratory testing of soil samples) to be unsaturated down to clay liner. However, the adjacent piezometer reading indicated there were several inches of leachate over the liner, which contradicts conditions documented in the trench excavation. During the excavation, perched leachate was observed to seep from the sides of the trench nearest to the piezometer, which supports the idea that the piezometer has an effect on the flow of moisture in the area. This would explain why there was liquid present in the piezometer while the surrounding drainage sand was unsaturated. An additional observation made was that the waste along the sides of the trench were ragged and exhibited a high degree of heterogeneity. These characteristics make it very difficult to attain a complete seal around the piezometer. As a result, moisture would be able to easily migrate to the sides of the piezometer casing.

It was hypothesized that the installation of a piezometer disturbs the surrounding anisotropy, and results in a thin region around the outer piezometer casing that exhibits much greater vertical hydraulic conductivity than the surrounding waste. This provides a pathway of least resistance for leachate to flow vertically downward. The leachate that flows down the piezometer casing can accumulate in the immediate area around the piezometer in the sand drainage layer, leading to high water level readings inside the piezometers relative to the rest of the sand drainage layer. To demonstrate the plausibility of this hypothesis, this phenomenon was simulated using the computer model SEEP/W. The results support the hypothesis that the piezometers have an effect of the flow of moisture within the landfill. A mounding effect around the piezometer was also observed, which was particularly pronounced when perched leachate conditions were present.

A key conclusion of this study is that the act of installing a piezometer through a waste mass disrupts the anisotropy of the waste mass and creates a preferential flow path (the piezometer borehole) to the underlying LCS. The leachate that flows from the waste layers to the LCS sand layer at the bottom of the landfill can then accumulate in and around the piezometer (mounding), influencing the leachate levels in the piezometer. Piezometers installed through a waste mass are therefore not an accurate or reliable means to determine liquid levels in a landfill LCS, and that the installation of the piezometers can result in an increased leachate impingement on the LCS since the piezometer acts as a drain for the surrounding waste. We recommend against installing any more piezometers in the landfill.

REFERENCES

Singh, K., Kadambala, R., Jain, P., Xu, Q., & Townsend, T. G. (2014). Anisotropy estimation of compacted municipal solid waste using pressurized vertical well liquids injection. *Waste Management & Research*, *32*(6), 482-491.

SCS ENGINEERS

CORRECTIVE ACTION PLAN

Presented to:

Hillsborough County Public Works Department
Solid Waste Management Division
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Tampa, Florida 33619

Presented by:

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~~May 2~~July 16, 2018
File No. 09215600.06

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CORRECTIVE ACTION PLAN

Southeast County Landfill
Lithia, Florida

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Solid Waste Management Division
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No. 2907

Note:
Initial Corrective Action Plan submitted on June 26, 2017 and revised November 27, 2017.

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Appendix E **Investigation of Landfill Leachate Removal at the Hillsborough County Southeast Landfill (prepared by University of Florida)**

1.0 INTRODUCTION

During the February 2016 groundwater monitoring event at the Southeast County Landfill (SCLF), elevated readings were observed by the Hillsborough County Public Works Department, Solid Waste Management Division (SWMD) for select parameters at monitoring well TH-67. TH-67 is a detection well approximately 45 feet east of Phase II and monitors shallow groundwater at the SCLF. Since that time, the SWMD and its engineering Consultant, SCS Engineers (SCS), have been conducting investigations of potential causes for the elevated readings and have installed additional measures to mitigate the concern.

The results of the on-going investigation have been shared with the Florida Department of Environmental Protection (FDEP) in multiple reports, weekly emails, and meetings.

This Corrective Action Plan (CAP) describes actions completed, ongoing and proposed to be taken by the SWMD to correct conditions that contributed to ground water impacts in the vicinity of monitoring well TH-67.

Condition 9a of the Consent Agreement dated July 28, 2017 between the SWMD and the FDEP required the SWMD to submit a CAP to the FDEP for review and approval.

An initial CAP was submitted on June 26, 2017 for FDEP review. A meeting with the FDEP was held on October 12, 2017 to discuss the CAP. As a result of the meeting, the SWMD is submitting this revised CAP.

2.0 BACKGROUND

Groundwater samples collected from TH-67 during the February 2016 monitoring event indicated elevated levels of indicator parameters. Although the exact cause cannot be definitively determined, the elevated levels in groundwater were thought to be related to a leachate discharge.

Accordingly, the SWMD responded with the following major activities:

1. Initiated additional leachate removal measures, such as installation of supplemental vertical dewatering wells, pumping from LFG extraction wells, construction of a cut-off trench, and jet-cleaning of leachate collection pipes, to assist with the removal of leachate from within the landfill;

2. Began quarterly collection of groundwater samples from monitoring wells and installed additional wells to monitor and evaluate the progress of groundwater quality restoration in the affected area;

3. Installed piezometers throughout the SCLF to assess the presence of liquid and its estimated depth at those locations (see **Figure 1**); and,

4. Removed an average of ~~a total average of~~ approximately ~~42~~33,000 gallons per day (GPD) of leachate, from the supplemental locations mentioned above, since August of 2017. Approximately 11,100,000 gallons of leachate have been removed from the

supplemental locations mentioned above, since August of 2017. A table of supplement leachate removal is included in **Appendix A**.

Additional information is included in a detailed list of activities completed to date in **Appendix B**.

In addition to this CAP, the SWMD is preparing a Request for Alternate Procedure (Request) to establish an Approved Operating Level for leachate management at this site. The Request includes justification for the proposed operating level and describes how that level will be achieved and monitored. On December 8, 2017, a draft Request proposing a maximum leachate operating depth was provided to FDEP for comment. FDEP provided its initial comments on the draft Request on January 24, 2018. SCS and the SWMD are reviewing the FDEP's comments, and will be providing a revised Request that addresses those comments.

The Alternative Procedure will establish the "Approved Operating Level" referenced in this CAP. In the event that the Alternate Procedure is not granted, this CAP will be revised as necessary.

3.0 PURPOSE

The objectives of this CAP are to:

1. Reduce leachate levels within the landfill to an Approved Operating Level;
2. Monitor progress of leachate reduction efforts; and,
3. Monitor water quality in the area adjacent to Phase II for improvement and take necessary actions for the reduction in water quality parameters that exceed FDEP standards.

This CAP also includes the proposed metrics for confirming the stated goals have been achieved, a schedule for conducting the activities, and the estimated time for completion.

4.0 PROPOSED WORK PLAN

Since leachate management is complex and influenced by a variety of factors, the Work Plan is being developed, implemented and completed in Steps.

STEP 1 – INITIAL EVALUATION AND RESPONSE, 2016-2017

Work Plan Step 1 included initial evaluations, fieldwork, monitoring and recordkeeping, and installation of additional leachate management features.

Several activities completed in 2016 and 2017 are described in detail in the document titled, "Corrective Action Plan, Southeast County Landfill, Lithia, Florida" prepared by SCS Engineers, dated June 26, 2017. Also, see **Appendix B** for detailed list of completed activities.

STEP 2 – LEACHATE REMOVAL AND MONITORING SYSTEM DEVELOPMENT, JANUARY-JUNE 2018

Work Plan Step 2 includes additional fieldwork, ongoing monitoring, recordkeeping and data analysis to develop the long-term leachate removal system and controls necessary to meet the objectives of this CAP.

1. **Liquid Level Monitoring Evaluation:** Liquid levels in piezometers.

   To date, liquid levels have been measured in the Series-2 piezometers to attempt to demonstrate the progress of leachate removal activities. However, ~~if~~ the analyses described below (Please see **Appendices C and D**) concluded that the Series-2 piezometers are not an accurate method of measuring liquid levels across the entire floor of the landfill. ~~an alternate or additional metric is more appropriate to measure the effectiveness of the leachate removal efforts, the SWMD will provide a revised CAP to incorporate those changes for FDEP review and approval.~~ The liquid levels measured in the piezometers ~~will be~~were evaluated as follows:~~;~~

   a. **Effectiveness of Piezometers:** In order to be an appropriate monitoring metric, piezometers ~~are~~ were ~~being~~ evaluated to assess the accuracy and repeatability of measuring the liquid levels within the piezometer, as well as evaluating the liquid level monitoring as related to leachate removal locations. To date, this analysis has concluded that liquid level measurements using an electronic water level tape are reasonably accurate and liquids appear to move into and out of existing piezometers (~~Series~~ Series-2). Piezometer locations relative to leachate removal locations are being evaluated to determine which, if any, piezometers are expected to be responsive to the liquid removal methods being utilized. See **Appendix C** for an evaluation of the piezometers completed by Pelz Environmental Services, Inc.

   b. **Influence of Other Site-Specific Conditions:** This evaluation by Dr. Tim Townsend and others from the University of Florida (UF) ~~will~~ assessed the potential for other conditions within the landfill that could be influencing liquid levels measured in the piezometers. The analysis ~~will~~ presented possible alternate interpretations of the recorded liquid levels. The following factors ~~are being~~were examined:

      i. ~~PZ~~ Piezometer construction methods

      ii. Perched leachate zones created by waste composition and layering

      iii. Leachate collection system design, e.g., gravel trench spacing, pipe spacing, bottom slopes, etc.

      The evaluation by Dr. Tim Townsend and others from the UF concluded the following:

      i. The presence of the piezometers is causing an artificially elevated liquid level at the piezometer locations.

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ii. Perched liquid conditions were present within the waste.

iii. The leachate collection system appears to be functioning properly.

~~i.~~iv. Piezometers are not an accurate or reliable method of determining liquid levels in a landfill leachate collection system.

2. **Compliance Metric:** Water balance.

The metric for accomplishing the goal of reducing leachate levels in the landfill is based on liquid removed as calculated using the supplemental volume pumped compared to the estimated quantity of leachate above the Approved Operating Level. ~~This metric may be revised based on the findings of Doctor Tim Townsend and others from the University of Florida regarding site specific conditions that may affect the water balance.~~ See **Appendix D** for detailed initial calculations.

STEP 3 – IMPLEMENTATION, MONITORING, EVALUATION AND REVISION

The SWMD proposes to conduct the following activities following FDEP acceptance of this plan ~~rom June 2018~~ through completion:

1. Continue supplemental pumping, or removal, of leachate from the Phase I and Phase II areas of the landfill as follows:

   a. Leachate removal via the Phase II header pipe;

   b. Pumping from the Phase I and II dewatering wells (DW 1-1, DW 1-2, DW 2-1, and DW 2-2);

   c. Pumping from Landfill gas (LFG) extraction wells (EW-38, EW-44, EW-48, and EW-66); and,

   d. Pumping from LFG condensate traps (CT-1, CT-2, and CT-3).

2. Equip the riser port in the leachate cut-off trench along the east side of Phase II with a level sensing device that will turn the pump on when the level reaches 30-inches in the trench~~if leachate appears in the riser~~.

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3. Continue daily monitoring of the leachate level in the main sump (PS-B). This data will be included in the monthly progress report submitted to the FDEP.

4. Where absent, cleanouts are being installed on leachate collection system headers in landfill Phases I, II and III. As part of each cleanout installation, the leachate collection header pipe is being jet-cleaned and video recorded to assess its condition. If liquids do not appear to drain after jet-cleaning, a suction line will be temporarily placed in the leachate collection header to remove accumulated liquids. If sufficient accumulation persists, this location will be made part of the long-term leachate reduction system.

5. Per Condition 10 of the Consent Agreement, continue quarterly sampling of groundwater monitoring wells TH-20B, TH-38B, TH-66A, TH-67, TH-79, TH-80, TH-81, TH-82, and TH-83.

~~6. Continue weekly measurements of piezometers within Phases I, II and III of the landfill and track liquid level trends. Measurements will be reported with the monthly progress report submitted to the FDEP.~~

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~~7.~~6. Provide a monthly progress and summary report to the FDEP of the activities in the CAP. Per the Consent Agreement, this report will be submitted by the 15th of the following month.

~~8. Provide an updated landfill estimated water balance to the FDEP. This will assess what the additional supplemental leachate pumping and removal volumes should be to reduce the liquid levels in the piezometers and landfill.~~

~~9.~~7. A detailed CAP objectives evaluation report will be prepared and provided to FDEP semi-annually (submitted dates to be determined). The evaluation will discuss:

a. The effectiveness of the leachate removal, monitoring and controls;

b. Supplemental pumping locations evaluation on a location specific basis and additional leachate removal points and methods will be added if needed;

c. Pumpage rates;

d. Unexpected conditions/results;

e. Proposed changes to the CAP; and,

~~f.~~ Updates to schedule for completion.

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STEP 4 – METRIC FOR CAP COMPLETION

~~The above metrics for completion may be revised based on the outcomes and/or conclusions in Steps 2 and 3.~~

Based on the metrics in place, completion of the CAP will be determined as follows:

1. Upon reaching the Approved Operating Level (as demonstrated by the approved metric described in Work Plan Step 2), the supplemental pumping locations will temporarily cease pumping while liquid levels within the area of concern will continue to be monitored.

2. If the liquid levels remain below the Approved Operating Level for twelve consecutive months, the CAP will be considered complete, and a final report will be submitted to FDEP requesting closure of the Consent Agreement.

3. In the event the liquid levels rise above the Approved Operating Level during the twelve-month period, supplemental pumping will resume at the time the level is recorded. Supplemental pumping will continue at least three months before ceasing supplemental pumping and beginning the twelve month monitoring period.

4. Schedule:

    a. SCS initially estimated that the leachate reduction be accomplished in approximately ~~2~~ two years with an average supplemental leachate pumping rate of approximately ~~42~~33,000 GPD. However, the estimated time to complete this work is highly dependent on several assumptions, including the actual volume of leachate in the landfill, the infiltration rate from rainfall, annual rainfall amounts, effectiveness of supplemental leachate pumping, days of pumping, and others.

    b. The semi-annual CAP objectives evaluation report will discuss if the estimated timeline will be achieved as planned or adjustments need to be made to the timeline. The schedule could be longer or shorter depending on how all of the variables come together over time; however, the CAP objectives will be measured based on the approved metrics.

5.0 GROUNDWATER MONITORING

The SWMD will continue to collect samples from surficial groundwater monitoring wells TH-20B, TH-38B, TH-66A, TH-67, TH-79, TH-80, TH-81, TH-82, and TH-83 on a quarterly basis (February, May, August, and November). SCS and the SWMD believe that the current monitoring network, which includes the recently installed TH-83, is sufficient to monitor the surficial aquifer groundwater. These samples will be analyzed for sodium, ammonia, chloride, and total dissolved solids. Field parameters will include temperature, pH, Conductivity, Turbidity, Dissolved Oxygen, and oxygen reduction potential (ORP). Results will be submitted to the FDEP within 60 days of completion of laboratory analysis.

Monitoring of these groundwater-monitoring wells will continue for one year following completion of the CAP. At that time, the SWMD will seek approval from the FDEP to discontinue quarterly monitoring at these locations. The SWMD will also discuss adding selected monitoring locations to the semi-annual groundwater monitoring and assessment program. Following completion of the CAP, additional assessment of groundwater will be implemented should a constituent of concern exceed regulatory limits and is confirmed in the same well during a monitoring event.

An evaluation of the water quality in monitoring wells referred to in this CAP, will be included with the semi-annual evaluation submittals (following approval of the CAP). This evaluation will compare quarterly groundwater quality results against historical and regulated groundwater standards.

6.0 CAP SUBMITTALS

The SWMD will continue to submit the following reports to the FDEP.

1. Monthly progress reports

    ~~a. Piezometer liquid level data~~
    ~~b.~~a. Leachate pumping data
    ~~c.~~b. Supplemental pumping data
    ~~d.~~c. Additional liquid removal activities, completed and proposed
    ~~e.~~d. Submitted prior to the 15th of the following month

2. Quarterly supplemental groundwater quality reports

    a. Samples collected in November, February, May, and August
    b. Submitted within 60-days of completion of laboratory analysis

3. Semi-annual Evaluation of Objectives and Proposed Adjustments

    a. Evaluation of CAP objectives, milestone metrics, supplemental pumping locations, evaluation of water quality, and schedule

    b. Updated water balance reports
        i. Updated leachate volume estimate based on liquid levels in piezometers

ii. Submitted every 6 months in May and November.

4. Final Report of Completion of the CAP
    a. A summary report for meeting the metrics for completion
    b. Boring logs
    c. Trend Analyses
    d. Groundwater summary tables
    e. Groundwater monitoring well installation
    f. Construction details
    g. Other information, as necessary

FIGURES

APPENDIX A
Supplemental Leachate Removal

APPENDIX B
Completed Activities

APPENDIX C
Piezometer Effectiveness Evaluation

Prepared by
Pelz Environmental Services, Inc.

APPENDIX D

Water Balance Initial Calculations

APPENDIX E

Investigation of Landfill Leachate Removal at the Hillsborough County Southeast Landfill

Prepared by
University of Florida

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