ATTACHMENT 1

NOTES

1) THE MAPPING AND CONTOURS DEPICTED ON THIS MAP WERE CREATED BY PHOTOGRAMETRIC MAPPING USING AERIAL PHOTOS TAKEN IN APRIL OF 2013. THE MAPPING WAS COMPILED TO MEET THE NATIONAL MAPPING ACCURACY STANDARD FOR 50 SCALE MAPPING. THE CONTOUR ACCURACY FOR NON-OBSCURED AREAS IS +/- 0.5'.

2) THE ACTUAL GROUND MUST BE VISIBLE IN THE AERIAL PHOTOS IN ORDER TO ACCURATELY DETERMINE GROUND ELEVATIONS AND CONTOURS THROUGH PHOTOGRAMETRIC MAPPING. IN AREAS LABELED AND DEPICTED AS "OBSCURED", THE THICK VEGETATION DID NOT ALLOW FOR ACCURATE DETERMINATION OF ELEVATIONS. CONSEQUENTLY, IN THE "OBSCURED AREAS" THE CONTOURS MAY VARY FROM WHAT ARE DEPICTED AND ARE NOT GUARANTEED TO THE NEAREST 0.5'. IF MORE ACCURATE ELEVATIONS ARE DESIRED IN THESE AREAS, A SEPARATE CONVENTIONAL SURVEY SHOULD BE COMPLETED TO VERIFY AND ADJUST ELEVATIONS AS NECESSARY

3) EASEMENTS ARE SHOWN PER SG-19228, SHT 1, REV.C. NO TITLE WORK WAS PROVIDED

4) HISTORICAL BORINGS AND WELLS SHOWN IN GRAY COMPLETED BY OTHERS.

LEGEND

EXISTING MAJOR CONTOUR (5' INTERVAL)
COVENANT BOUNDARY
APPROXIMATE ROAD LOCATION
GOLDER CPT/SOIL BORING LOCATION & ELEVATION — GA-CPT-05/GA-B-05 617.14
EXISTING CLOSED AREA
SLOPE INCLINOMETER — SI-5

DATUM NOTES

THE VERTICAL DATUM FOR THE AERIAL SURVEY IS NAVD88 *EXTREME* CAUTION SHOULD BE TAKEN WHEN COMPARING THE ELEVATIONS ON THIS DRAWING TO OTHER RECORD DRAWINGS, BOTH SURVEY AND PLANT. IT IS IMPERATIVE THAT THE USER RECOGNIZE THAT DIFFERENT DATUMS HAVE BEEN USED AT THIS SITE. SEE CONVERSIONS AND DEFINITIONS BELOW.

MSPC = MICHIGAN STATE PLANE COORDINATE SYSTEM, NAD83(1994), SOUTH ZONE, INTERNATIONAL FEET.

PLANT = ORIGINAL PLANT DATUM AT TIME OF CONSTRUCTION. GROUND COORDINATES REPORTED IN FEET.

WP = WORLEY PARSONS DATUM USED FOR THE BAG HOUSE CONSTRUCTION PROJECT STARTING IN 2007. GROUND COORDINATES REPORTED IN FEET.

*NAVD88 = NORTH AMERICAN VERTICAL DATUM OF 1988
*NGVD29 = NATIONAL GEODETIC VERTICAL DATUM OF 1929
*USLS = UNITED STATE LAKE SURVEY 1935
*IGLD55 = INTERNATIONAL GREAT LAKES DATUM 1955 ADJUSTMENT
*IGLD85 = INTERNATIONAL GREAT LAKES DATUM 1985 ADJUSTMENT
* REPORTED IN UNITS OF FEET.

CONVERSIONS

NAVD88 TO USLS = +0.92'
NAVD88 TO IGLD85 = -0.11'
USLS TO IGLD55 = -1.754'
USLS TO NGVD29 = -0.297'
IGLD55 TO IGLD85 = +0.72'

NOTE: THE CONVERSIONS TO USLS AND TO IGLD DATUMS ONLY APPLY TO THE IMMEDIATE AREA AT THE KARN PLANT AND SHOULD NOT BE USED ELSEWHERE.

Golder Associates
Great Lakes
Engineering & Environmental Solutions, LLC
400 136th Avenue, Building 100, Suite B, Holland, Michigan 49424
Phone/Fax: (616) 994-6541
www.goEESolutions.com

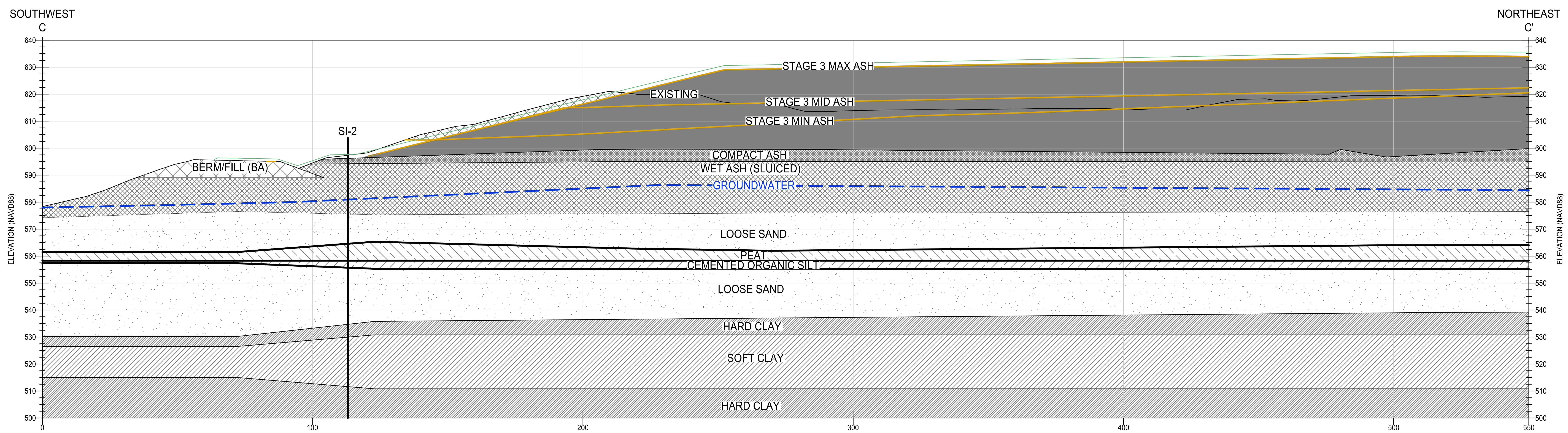
GEOTECHNICAL INVESTIGATION
D.E. KARN ASH LANDFILL
SECTIONS 1 & 2, T. 14 N., R. 5 E., HAMPTON TOWNSHIP, BAY COUNTY
CONSUMERS ENERGY COMPANY
2742 N. WEADOCK HWY, ESSEXVILLE, MI 48732

MARK	DATE	DESCRIPTION
	06-17-2013	ISSUED FOR 25% REPORT
	11-08-2013	ISSUED FOR 100% REPORT

DESIGNED BY: ----
DRAWN BY: DJS
CHECKED BY: BAL
PROJECT NO: 094-13-001
SHEET TITLE
BORING LOCATION PLAN

FIGURE 2

C:\Civil 3D Projects\Vault\094-13-001\094-13-001 - BORE-A.dwg 11/18/2013 2:37 PM



CROSS SECTION C-C'

SCALE: 1" = 20'

LEGEND

EXISTING TOPO (EX) (ROWE APRIL 2013)	
PROPOSED COVER (MAX. SHOWN ONLY)	
PROPOSED SDA/ FLY ASH COMMINGLE	
DRY ASH (DA)	
COMPACT ASH (CA)	
WET ASH OR SLUICED FLY ASH (WA)	
GROUNDWATER (GW)	
LOOSE TO MEDIUM DENSE SAND (L)	
MEDIUM COMPACT TO COMPACT SAND (D)	
PEAT (PT)	
CEMENTED ORGANIC SILT (OH)	
HARD CLAY (H)	
SOFT TO STIFF CLAY (SC)	

Golder Associates Great Lakes

Engineering & Environmental Solutions, LLC
400 136th Avenue, Building 100, Suite B, Holland, Michigan 49424
Phone/Fax: (616) 994-6541
www.goEESolutions.com

GEOTECHNICAL INVESTIGATION
D.E. KARN ASH LANDFILL
SECTIONS 1 & 2, T. 14 N., R. 5 E., HAMPTON TOWNSHIP, BAY COUNTY
CONSUMERS ENERGY COMPANY
2742 N. WEADOCK HWY, ESSEXVILLE, MI 48732

MARK	DATE	DESCRIPTION
	06-17-2013	ISSUED FOR 25% REPORT
	11-08-2013	ISSUED FOR 100% REPORT

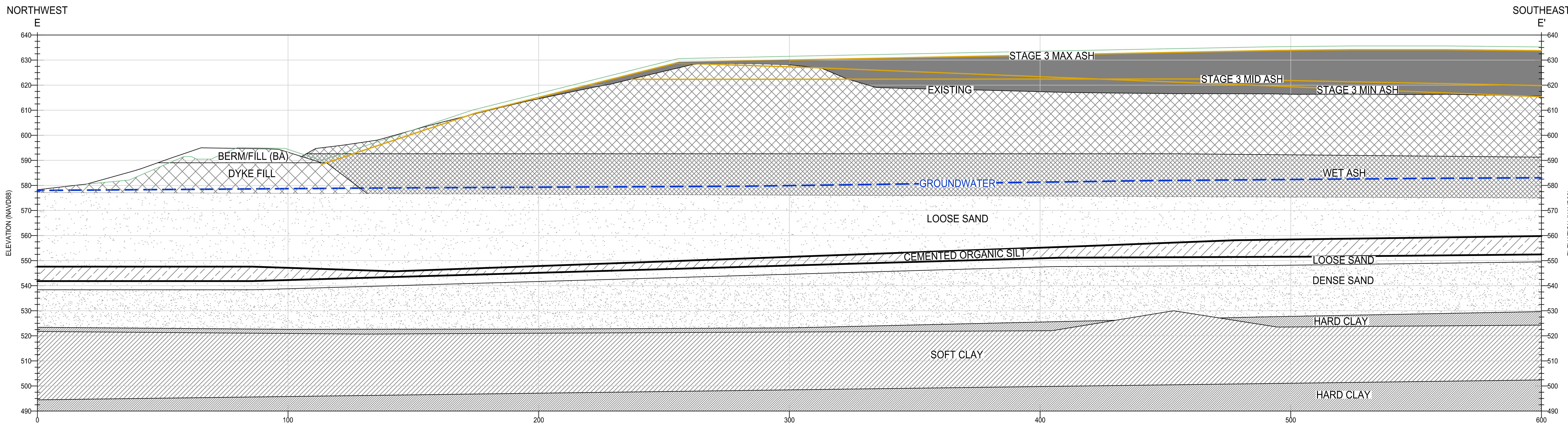
DESIGNED BY:	----
DRAWN BY:	DJS
CHECKED BY:	BAL
PROJECT NO:	094-13-001

SHEET TITLE

CROSS SECTION C-C'

FIGURE 3

C:\Civil 3D Projects\Vault\094-13-001\094-13-001 - BORE-A.dwg 11/8/2013 2:19 PM



CROSS SECTION E-E'
SCALE: 1" = 20'

LEGEND

EXISTING TOPO (EX) (ROWE APRIL 2013)	
PROPOSED COVER (MAX. SHOWN ONLY)	
PROPOSED SDA/ FLY ASH COMMINGLE	
DRY ASH (DA)	
COMPACT ASH (CA)	
WET ASH OR SLUICED FLY ASH (WA)	
GROUNDWATER (GW)	
LOOSE TO MEDIUM DENSE SAND (L)	
MEDIUM COMPACT TO COMPACT SAND (D)	
PEAT (PT)	
CEMENTED ORGANIC SILT (OH)	
HARD CLAY (H)	
SOFT TO STIFF CLAY (SC)	

Golder Associates
Great Lakes

Engineering & Environmental Solutions, LLC
400 136th Avenue, Building 100, Suite B, Holland, Michigan 49424
Phone/Fax: (616) 994-6541
www.goEESolutions.com

GEOTECHNICAL INVESTIGATION
D.E. KARN ASH LANDFILL
SECTIONS 1 & 2, T. 14 N., R. 5 E., HAMPTON TOWNSHIP, BAY COUNTY
CONSUMERS ENERGY COMPANY
2742 N. WEADOCK HWY, ESSEXVILLE, MI 48732

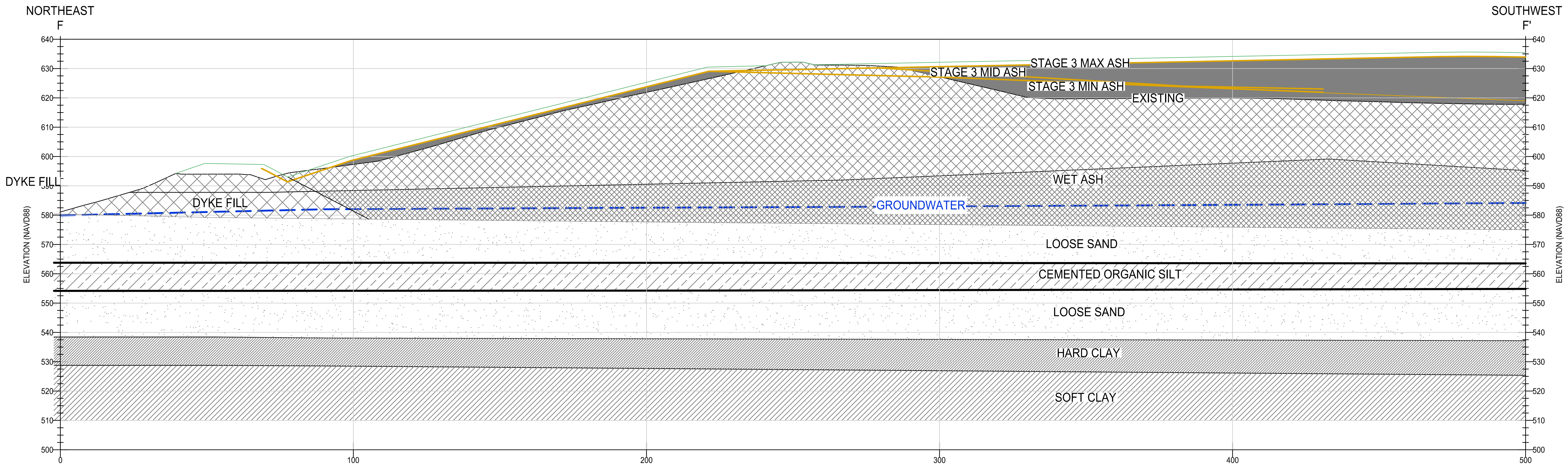
MARK	DATE	DESCRIPTION
	06-17-2013	ISSUED FOR 25% REPORT
	11-08-2013	ISSUED FOR 100% REPORT

DESIGNED BY: ---
DRAWN BY: DJS
CHECKED BY: BAL
PROJECT NO: 094-13-001
SHEET TITLE

CROSS SECTION E-E'

FIGURE 4

C:\Civil 3D Projects\Vault\094-13-001\094-13-001 - BORE-A.dwg 11/8/2013 2:19 PM



CROSS SECTION F-F'

SCALE: 1" = 20'

LEGEND

EXISTING TOPO (EX) (ROWE APRIL 2013)	
PROPOSED COVER (MAX. SHOWN ONLY)	
PROPOSED SDA/ FLY ASH COMMINGLE	
DRY ASH (DA)	
COMPACT ASH (CA)	
WET ASH OR SLUICED FLY ASH (WA)	
GROUNDWATER (GW)	
LOOSE TO MEDIUM DENSE SAND (L)	
MEDIUM COMPACT TO COMPACT SAND (D)	
PEAT (PT)	
CEMENTED ORGANIC SILT (OH)	
HARD CLAY (H)	
SOFT TO STIFF CLAY (SC)	

Golder Associates Great Lakes

Engineering & Environmental Solutions, LLC
400 136th Avenue, Building 100, Suite B, Holland, Michigan 49424
Phone/Fax: (616) 994-6541
www.goEESolutions.com

GEOTECHNICAL INVESTIGATION
D.E. KARN ASH LANDFILL
SECTIONS 1 & 2, T. 14 N., R. 5 E., HAMPTON TOWNSHIP, BAY COUNTY
CONSUMERS ENERGY COMPANY
2742 N. WEADOCK HWY, ESSEXVILLE, MI 48732

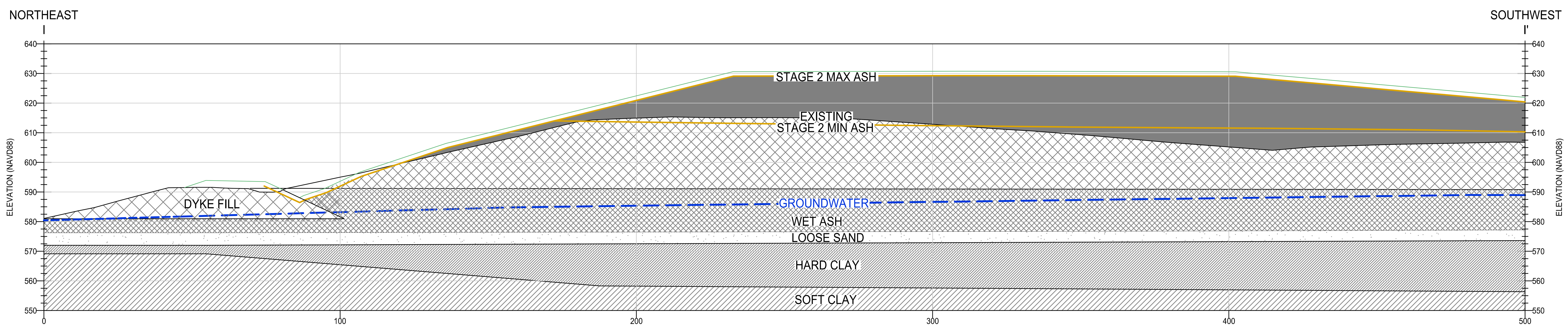
MARK	DATE	DESCRIPTION
	11-08-2013	ISSUED FOR 100% REPORT

DESIGNED BY: ----
DRAWN BY: DJS
CHECKED BY: BAL
PROJECT NO: 094-13-001
SHEET TITLE

CROSS SECTION F-F'

FIGURE 5

C:\Civil 3D Projects\Vault\094-13-001\094-13-001 - BORE-A.dwg 11/8/2013 2:19 PM



CROSS SECTION I-I'

SCALE: 1" = 20'

LEGEND

- EXISTING TOPO (EX) (ROWE APRIL 2013)
- PROPOSED COVER (MAX. SHOWN ONLY)
- PROPOSED SDA/ FLY ASH COMMINGLE
- DRY ASH (DA)
- COMPACT ASH (CA)
- WET ASH OR SLUICED FLY ASH (WA)
- GROUNDWATER (GW)
- LOOSE TO MEDIUM DENSE SAND (L)
- MEDIUM COMPACT TO COMPACT SAND (D)
- PEAT (PT)
- CEMENTED ORGANIC SILT (OH)
- HARD CLAY (H)
- SOFT TO STIFF CLAY (SC)

Golder Associates
Great Lakes

Engineering & Environmental Solutions, LLC
400 136th Avenue, Building 100, Suite B, Holland, Michigan 49424
Phone/Fax: (616) 994-6541
www.goEESolutions.com

GEOTECHNICAL INVESTIGATION
D.E. KARN ASH LANDFILL
SECTIONS 1 & 2, T. 14 N., R. 5 E., HAMPTON TOWNSHIP, BAY COUNTY
CONSUMERS ENERGY COMPANY
2742 N. WEADOCK HWY, ESSEXVILLE, MI 48732

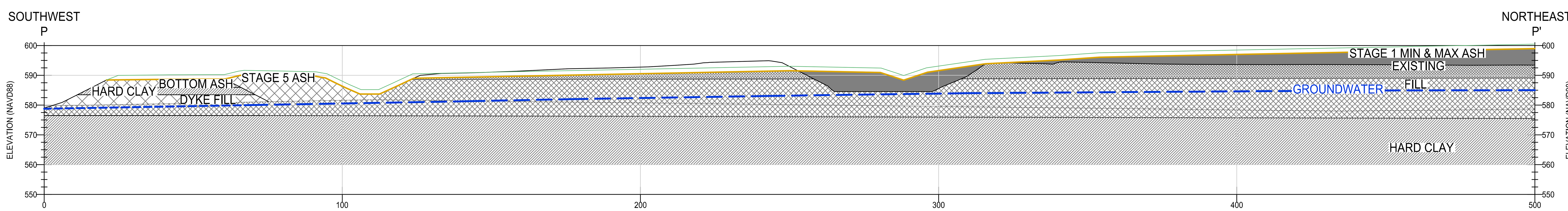
MARK	DATE	DESCRIPTION
	11-08-2013	ISSUED FOR 100% REPORT

DESIGNED BY:	---
DRAWN BY:	DJS
CHECKED BY:	BAL
PROJECT NO:	094-13-001
SHEET TITLE	

CROSS SECTION I-I'

FIGURE 6

C:\Civil 3D Projects\Vault\094-13-001\094-13-001 - BORE-A.dwg 11/8/2013 2:19 PM



CROSS SECTION P-P'
SCALE: 1" = 20'

LEGEND

- EXISTING TOPO (EX) (ROWE APRIL 2013)
- PROPOSED COVER (MAX. SHOWN ONLY)
- PROPOSED SDA/ FLY ASH COMMINGLE
- DRY ASH (DA)
- COMPACT ASH (CA)
- WET ASH OR SLUICED FLY ASH (WA)
- GROUNDWATER (GW)
- LOOSE TO MEDIUM DENSE SAND (L)
- MEDIUM COMPACT TO COMPACT SAND (D)
- PEAT (PT)
- CEMENTED ORGANIC SILT (OH)
- HARD CLAY (H)
- SOFT TO STIFF CLAY (SC)

Golder Associates
Great Lakes
Engineering & Environmental Solutions, LLC
400 136th Avenue, Building 100, Suite B, Holland, Michigan 49424
Phone/Fax: (616) 994-6541
www.goEESolutions.com

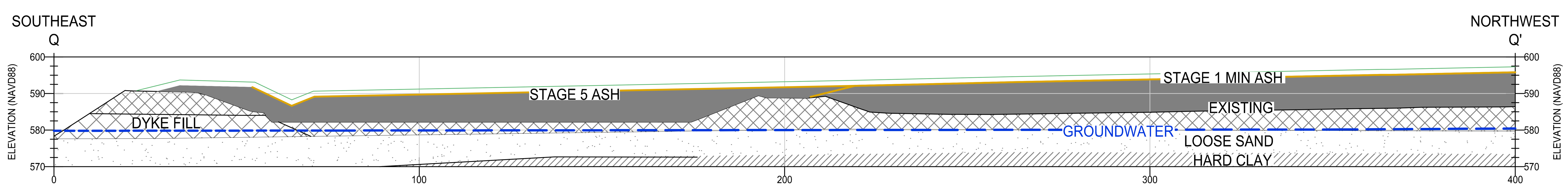
GEOTECHNICAL INVESTIGATION
D.E. KARN ASH LANDFILL
SECTIONS 1 & 2, T. 14 N., R. 5 E., HAMPTON TOWNSHIP, BAY COUNTY
CONSUMERS ENERGY COMPANY
2742 N. WEADOCK HWY, ESSEXVILLE, MI 48732

MARK	DATE	DESCRIPTION
	11-08-2013	ISSUED FOR 100% REPORT

DESIGNED BY: ---
DRAWN BY: DJS
CHECKED BY: BAL
PROJECT NO: 094-13-001
SHEET TITLE
CROSS SECTION P-P'

FIGURE 7

C:\Civil 3D Projects\Vault\094-13-001\094-13-001 - BORE-A.dwg 11/8/2013 2:19 PM



CROSS SECTION Q-Q'
SCALE: 1" = 20'

LEGEND

- EXISTING TOPO (EX) (ROWE APRIL 2013)
- PROPOSED COVER (MAX. SHOWN ONLY)
- PROPOSED SDA/ FLY ASH COMMINGLE
- DRY ASH (DA)
- COMPACT ASH (CA)
- WET ASH OR SLUICED FLY ASH (WA)
- GROUNDWATER (GW)
- LOOSE TO MEDIUM DENSE SAND (L)
- MEDIUM COMPACT TO COMPACT SAND (D)
- PEAT (PT)
- CEMENTED ORGANIC SILT (OH)
- HARD CLAY (H)
- SOFT TO STIFF CLAY (SC)

Golder Associates
Great Lakes

Engineering & Environmental Solutions, LLC
400 136th Avenue, Building 100, Suite B, Holland, Michigan 49424
Phone/Fax: (616) 994-6541
www.goEESolutions.com

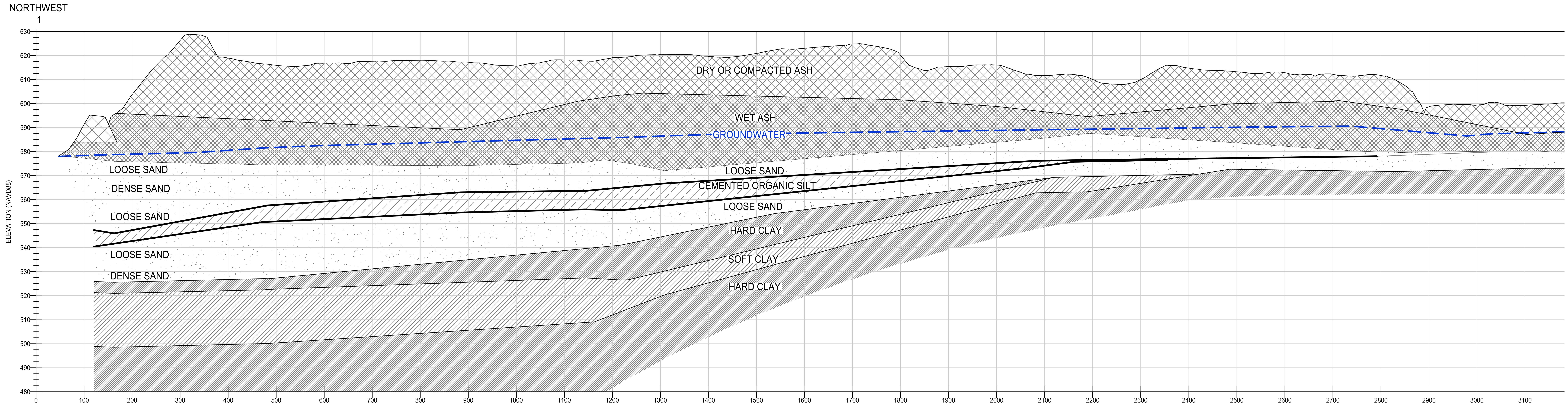
GEOTECHNICAL INVESTIGATION
D.E. KARN ASH LANDFILL
SECTIONS 1 & 2, T. 14 N., R. 5 E., HAMPTON TOWNSHIP, BAY COUNTY
CONSUMERS ENERGY COMPANY
2742 N. WEADOCK HWY, ESSEXVILLE, MI 48732

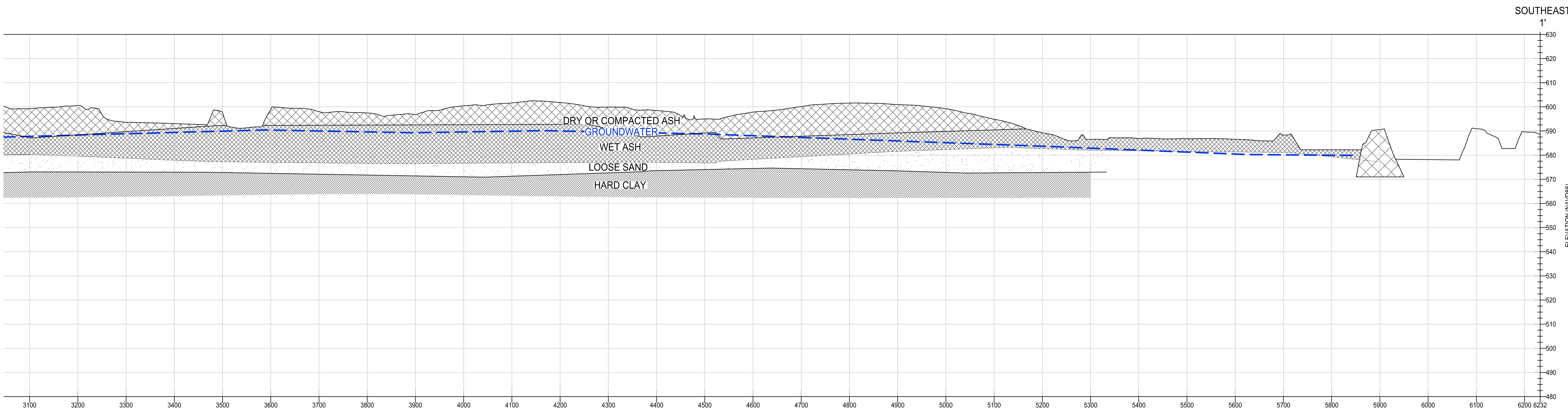
MARK	DATE	DESCRIPTION
	11-08-2013	ISSUED FOR 100% REPORT

DESIGNED BY: ---
DRAWN BY: DJS
CHECKED BY: BAL
PROJECT NO: 094-13-001
SHEET TITLE

CROSS SECTION Q-Q'

FIGURE 8





LEGEND

EXISTING TOPO (EX) (ROWE APRIL 2013)	
DRY ASH (DA)	
COMPACT ASH (CA)	
WET ASH OR SLUICED FLY ASH (WA)	
GROUNDWATER (GW)	
LOOSE TO MEDIUM DENSE SAND (L)	
MEDIUM COMPACT TO COMPACT SAND (D)	
PEAT (PT)	
CEMENTED ORGANIC SILT (OH)	
HARD CLAY (H)	
SOFT TO STIFF CLAY (SC)	

Golder Associates
Great Lakes
Engineering & Environmental Solutions, LLC
400 136th Avenue, Building 100, Suite B, Holland, Michigan 49424
Phone/Fax: (616) 994-6541
www.golEESolutions.com

GEOTECHNICAL INVESTIGATION

D.E. KARN ASH LANDFILL

SECTIONS 1 & 2, T. 14 N., R. 5 E., HAMPTON TOWNSHIP, BAY COUNTY

CONSUMERS ENERGY COMPANY

2742 N. WEADOCK HWY, ESSEXVILLE, MI 48732

MARK	DATE	DESCRIPTION
	11-08-2013	ISSUED FOR 100% REPORT
	06-17-2013	ISSUED FOR 25% REPORT

DESIGNED BY:	---
DRAWN BY:	DJS
CHECKED BY:	BAL
PROJECT NO:	094-13-001

SHEET TITLE

CROSS SECTION 1-1'

FIGURE 9

C:\Civil 3D Projects\Vault\094-13-001\094-13-001 - BORE-A.dwg 11/8/2013 2:19 PM

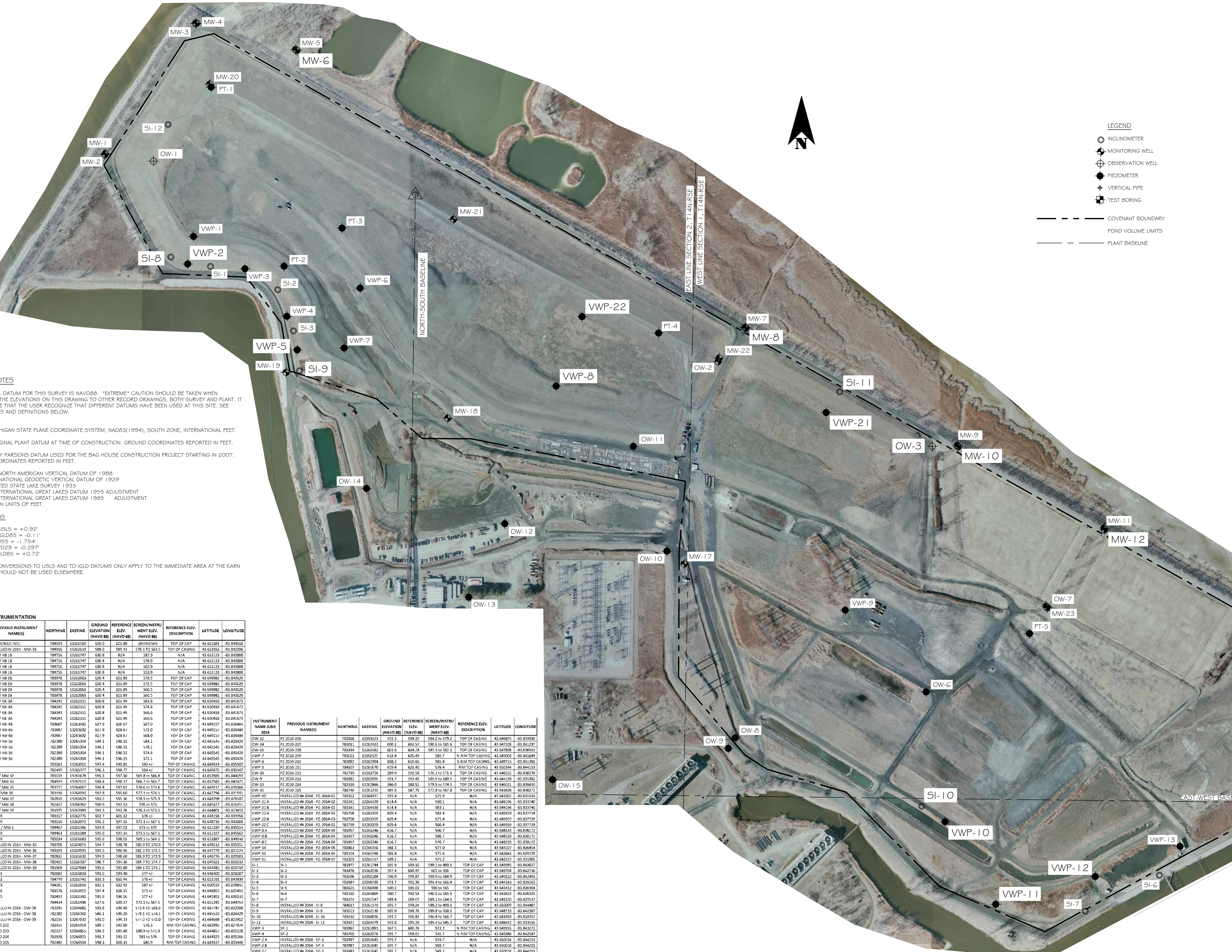
ATTACHMENT 2

Slug Test Data

FK Engineering Associates
Project: Karn Ash Landfill

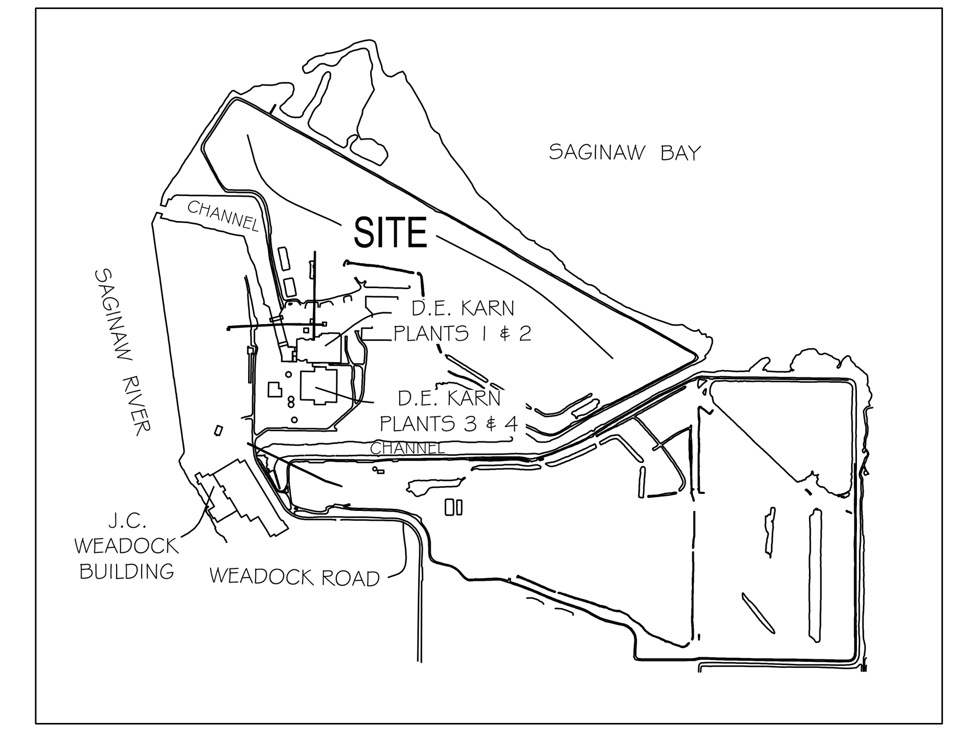
Well Number	Test Date	Test Number	K Value (cm/s)	Avg. K Value (cm/s)	Permeable Zone (ft.)
MW-33	6/10/2014	1	0.003388	0.003027	561.5 - 574.5
		2	0.002538		
		3	0.003155		
MW-35	6/10/2014	1	0.002959	0.002760333	570.7 - 576.2
		2	0.002586		
		3	0.002736		
MW-36	6/10/2014	1	0.007173	0.005634333	572 - 582
		2	0.004899		
		3	0.004831		
MW-37	6/10/2014	1	0.01047	0.010673333	573.4 - 584.4
		2	0.01047		
		3	0.01108		
MW-38	6/10/2014	1	0.0002023	0.002896433	573.7 - 581.7
		2	0.003794		
		3	0.004693		
MW-39	6/10/2014	1	0.006723	0.006344	573.6 - 586.6
		2	0.005809		
		3	0.0065		
MW-53A	6/10/2014	1	0.0003267	0.000445967	575.4 - 577.4
		2	0.0004843		
		3	0.0005269		
MW-54A	6/10/2014	1	0.0003109	0.000278867	576.3 - 578.8
		2	0.0002995		
		3	0.0002262		
OW-36	6/10/2014	1	0.0006168	0.000769133	567.6 - 569.1
		2	0.0009229		
		3	0.0007677		
OW-38	6/10/2014	1	0.0004807	0.0005104	573.1 - 578.6
		2	0.0005546		
		3	0.0004959		
OW-39	6/10/2014	1	0.005388	0.005742	572 - 578.5
		2	0.006035		
		3	0.005803		

ATTACHMENT 3



LEGEND

- INCLINOMETER
- MONITORING WELL
- OBSERVATION WELL
- PIEZOMETER
- VERTICAL PIPE
- TEST BORING
- COVENANT BOUNDARY
- POND VOLUME LIMITS
- PLANT BASELINE



LOCATION MAP

NOT TO SCALE

SECTION 1, 2
HAMPTON TOWNSHIP

T14N-R5E
BAY COUNTY

BASIS OF BEARING

MICHIGAN STATE PLANE COORDINATE SYSTEM, SOUTH ZONE
NORTH AMERICAN DATUM 1983,
1994 ADJUSTMENT - NAD83 (94) SITE
COMBINED SCALE FACTOR = 0.99996843

BASIS OF ELEVATION

NORTH AMERICAN VERTICAL DATUM OF 1988 - NAVD88

SEE DATUM NOTES

DATUM NOTES

THE VERTICAL DATUM FOR THIS SURVEY IS NAVD88. *EXTREME* CAUTION SHOULD BE TAKEN WHEN COMPARING THE ELEVATIONS ON THIS DRAWING TO OTHER RECORD DRAWINGS, BOTH SURVEY AND PLANT. IT IS IMPERATIVE THAT THE USER RECOGNIZE THAT DIFFERENT DATUMS HAVE BEEN USED AT THIS SITE. SEE CONVERSIONS AND DEFINITIONS BELOW.

MSPC = MICHIGAN STATE PLANE COORDINATE SYSTEM, NAD83(1994), SOUTH ZONE, INTERNATIONAL FEET.

PLANT = ORIGINAL PLANT DATUM AT TIME OF CONSTRUCTION. GROUND COORDINATES REPORTED IN FEET.

WP = WORLEY PARSONS DATUM USED FOR THE BAG HOUSE CONSTRUCTION PROJECT STARTING IN 2007. GROUND COORDINATES REPORTED IN FEET.

*NAVD88 = NORTH AMERICAN VERTICAL DATUM OF 1988
*NGVD29 = NATIONAL GEODETIC VERTICAL DATUM OF 1929
*USLS = UNITED STATE LAKE SURVEY 1935
*IGLD55 = INTERNATIONAL GREAT LAKES DATUM 1955 ADJUSTMENT
*IGLD85 = INTERNATIONAL GREAT LAKES DATUM 1985 ADJUSTMENT
* REPORTED IN UNITS OF FEET.

CONVERSIONS

NAVD88 TO USLS = +0.92'
NAVD88 TO IGLD85 = -0.11'
USLS TO IGLD55 = -1.754'
USLS TO NGVD29 = -0.297'
IGLD55 TO IGLD85 = +0.72'

NOTE: THE CONVERSIONS TO USLS AND TO IGLD DATUMS ONLY APPLY TO THE IMMEDIATE AREA AT THE KARN PLANT AND SHOULD NOT BE USED ELSEWHERE.

KARN PLANT INSTRUMENTATION

INSTRUMENT NAME JUNE 2014	PREVIOUS INSTRUMENT NAME(S)	NORTHING	EASTING	GROUND ELEVATION (NAVD 88)	REFERENCE ELEV. (NAVD 88)	SCREEN/INSTRUMENT ELEV. (NAVD 88)	REFERENCE ELEV. DESCRIPTION	LATITUDE	LONGITUDE
SI-12	ABANDONED INCL	784593	13261560	620.0	621.80	UNKNOWN	TOP OF CAP	43.651681	-83.844518
MW-6	INSTALLED IN 2014 - MW-33	784916	13262119	588.0	589.43	578.5 TO 563.5	TOP OF CASING	43.652555	-83.842396
PT-1 A	KB-1A / KB 1B	784756	13261747	630.8	N/A	587.9	N/A	43.652123	-83.843808
PT-1 B	KB-1A / KB 1B	784756	13261747	630.8	N/A	578.9	N/A	43.652123	-83.843808
PT-1 C	KB-1A / KB 1B	784756	13261747	630.8	N/A	565.9	N/A	43.652123	-83.843808
PT-1 D	KB-1A / KB 1B	784756	13261747	630.8	N/A	553.9	N/A	43.652123	-83.843808
PT-2 A	KB-2A / KB 2B	783978	13262063	620.4	621.89	578.5	TOP OF CAP	43.649982	-83.842629
PT-2 B	KB-2A / KB 2B	783978	13262063	620.4	621.89	572.5	TOP OF CAP	43.649982	-83.842629
PT-2 C	KB-2A / KB 2B	783978	13262063	620.4	621.89	566.5	TOP OF CAP	43.649982	-83.842629
PT-2 D	KB-2A / KB 2B	783978	13262063	620.4	621.89	560.5	TOP OF CAP	43.649982	-83.842629
PT-3 A	KB-3B / KB-3A	784143	13262315	620.8	621.49	583.6	TOP OF CAP	43.650433	-83.841673
PT-3 B	KB-3B / KB-3A	784143	13262315	620.8	621.49	574.6	TOP OF CAP	43.650433	-83.841673
PT-3 C	KB-3B / KB-3A	784143	13262315	620.8	621.49	566.6	TOP OF CAP	43.650433	-83.841673
PT 3 D	KB 3B / KB 3A	784143	13262315	620.8	621.49	560.6	TOP OF CAP	43.650433	83.841673
PT 4 A	KB 4A / KB 4B	783687	13263692	627.9	628.67	587.0	TOP OF CAP	43.649157	83.836484
PT-4 B	KB-4A / KB-4B	783687	13263692	627.9	628.67	572.0	TOP OF CAP	43.649157	-83.836484
PT-4 C	KB-4A / KB-4B	783687	13263692	627.9	628.67	568.0	TOP OF CAP	43.649157	-83.836484
PT-5 A	KB-5A / KB-5B	782380	13265304	594.1	596.11	584.1	TOP OF CAP	43.645545	-83.830424
PT-5 B	KB-5A / KB-5B	782380	13265304	594.1	596.11	578.1	TOP OF CAP	43.645545	-83.830424
PT-5 C	KB-5A / KB-5B	782380	13265304	594.1	596.11	574.6	TOP OF CAP	43.645545	-83.830424
PT-5 D	KB-5A / KB-5B	782380	13265304	594.1	596.11	571.1	TOP OF CAP	43.645545	-83.830424
OW-2	LH 101	783563	13263951	597.4	599.81	580 +/-	TOP OF CASING	43.648814	-83.835507
OW-7	LH 102	782499	13265377	596.3	598.77	584 +/-	TOP OF CASING	43.645870	-83.830147
MW-3	MW 2 / MW 32	785033	13261678	595.5	597.30	569.8 to 566.8	TOP OF CASING	43.652885	-83.844059
MW-5	MW 3 / MW 33	784919	13262113	588.4	590.17	566.7 to 563.7	TOP OF CASING	43.652565	-83.842421
MW-7	MW 5 / MW 35	783711	13264067	594.8	597.61	576.6 to 573.6	TOP OF CASING	43.649217	-83.835064
MW-9	MW 6 /MW 36	783199	13264990	592.8	595.60	577.1 to 574.1	TOP OF CASING	43.647796	-83.831591
MW-11	MW 7 / MW 37	782839	13265629	593.2	595.36	578.9 to 575.9	TOP OF CASING	43.646798	-83.829187
MW-13	MW 8 / MW 38	782417	13266382	590.9	592.53	576 to 573	TOP OF CASING	43.645627	-83.826351
MW-15	MW 9 / MW 39	781975	13267089	591.5	593.26	576.3 to 573.3	TOP OF CASING	43.644401	-83.823693
MW-18	MW 10R	783317	13262775	602.7	605.32	578 +/-	TOP OF CASING	43.648158	-83.839956
MW-19	MW 11R	783516	13262072	595.2	597.31	572.1 to 567.1	TOP OF CASING	43.648716	-83.842608
MW-1	MW 31 / MW 1	784467	13261286	594.9	597.02	573 to 570	TOP OF CASING	43.651339	-83.845554
MW-2	MW 31R	784463	13261284	595.0	597.34	572.5 to 567.5	TOP OF CASING	43.651327	-83.845562
MW-4	MW 32R	785034	13261683	595.6	598.01	569.5 to 564.5	TOP OF CASING	43.652887	-83.844040
MW-8	INSTALLED IN 2014 - MW-35	783709	13264071	594.7	598.78	580.9 TO 570.9	TOP OF CASING	43.649212	-83.835051
MW-10	INSTALLED IN 2014 - MW-36	783193	13264995	593.5	596.96	582.5 TO 572.5	TOP OF CASING	43.647779	-83.831574
MW-12	INSTALLED IN 2014 - MW-37	782831	13265630	594.9	598.60	583.9 TO 573.9	TOP OF CASING	43.646776	-83.829183
MW-14	INSTALLED IN 2014 - MW-38	782415	13266387	590.7	594.36	584.7 TO 574.7	TOP OF CASING	43.645621	-83.826332
MW-16	INSTALLED IN 2014 - MW-39	781969	13267084	591.6	595.80	584.1 TO 574.1	TOP OF CASING	43.644385	-83.823710
MW-17	MW 101	782683	13263803	591.0	593.40	577 +/-	TOP OF CASING	43.646400	-83.836087
MW-20	MW 102	784770	13261741	631.3	631.44	576 +/-	TOP OF CASING	43.652161	-83.843830
MW-21	MW 103	784181	13262800	632.1	632.92	587 +/-	TOP OF CASING	43.650529	-83.839841
MW-22	MW 104	783578	13263955	597.4	600.15	571 +/-	TOP OF CASING	43.648855	-83.835492
MW 23	MW 105	782493	13265381	595.9	598.06	577 +/-	TOP OF CASING	43.645851	83.830132
OW 1	OW 31	784434	13261496	627.6	630.17	572.5 to 567.5	TOP OF CASING	43.651245	83.844763
OW-3	INSTALLED IN 2014 - OW-36	783195	13264882	591.6	594.40	573.6 TO 568.6	TOP OF CASING	43.647787	-83.832000
OW-4	INSTALLED IN 2014 - OW-38	782382	13266362	586.1	590.20	579.1 TO 574.1	TOP OF CASING	43.645530	-83.826429
OW-5	INSTALLED IN 2014 - OW-39	782035	13267030	591.0	594.33	577.0 TO 572.0	TOP OF CASING	43.644568	-83.823912
VWP-13	PZ 2010-202	781455	13265959	589.7	592.60	576.3	RIM TOP CASING	43.642995	-83.827974
OW-6	PZ 2010-203	782127	13264855	594.2	595.40	580.9 to 575.9	TOP OF CASING	43.644857	-83.832128
OW-8	PZ 2010-204	781928	13264025	591.2	593.22	581 to 576	TOP OF CASING	43.644325	-83.835266
VWP-9	PZ 2010-205	782482	13264504	598.3	600.35	580.9	RIM TOP CASING	43.645837	-83.833446

COORDINATES SHOWN ARE:
MICHIGAN STATE PLANE COORDINATES, SOUTH ZONE, INTERNATIONAL FEET
VERTICAL DATUM IS: NAVD88

INSTRUMENT NAME JUNE 2014	PREVIOUS INSTRUMENT NAME(S)	NORTHING	EASTING	GROUND ELEVATION (NAVD 88)	REFERENCE ELEV. (NAVD 88)	SCREEN/INSTRUMENT ELEV. (NAVD 88)	REFERENCE ELEV. DESCRIPTION	LATITUDE	LONGITUDE
OW-12	PZ 2010-206	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	TOP OF CASING	[illegible]	[illegible]
OW-14	PZ 2010-207	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	TOP OF CASING	[illegible]	[illegible]
OW-11	PZ 2010-208	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	TOP OF CASING	[illegible]	[illegible]
VWP-7	PZ 2010-209	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	N.RIM TOP CASING	[illegible]	[illegible]
VWP-6	PZ 2010-210	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	S.RIM TOP CASING	[illegible]	[illegible]
VWP-1	PZ 2010-211	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	RIM TOP CASING	[illegible]	[illegible]
OW-10	PZ 2010-212	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	TOP OF CASING	[illegible]	[illegible]
OW-9	PZ 2010-213	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	TOP OF CASING	[illegible]	[illegible]
OW-13	PZ 2010-214	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	TOP OF CASING	[illegible]	[illegible]
OW-15	PZ 2010-215	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	TOP OF CASING	[illegible]	[illegible]
VWP-10	INSTALLED IN 2014 - PZ-2014-01	[illegible]	[illegible]	[illegible]	N/A	[illegible]	N/A	[illegible]	[illegible]
VWP-21 A	INSTALLED IN 2014 - PZ-2014-02	[illegible]	[illegible]	[illegible]	N/A	[illegible]	N/A	[illegible]	[illegible]
VWP-21 B	INSTALLED IN 2014 - PZ-2014-02	[illegible]	[illegible]	[illegible]	N/A	[illegible]	N/A	[illegible]	[illegible]
VWP-22 A	INSTALLED IN 2014 - PZ-2014-03	[illegible]	[illegible]	[illegible]	N/A	[illegible]	N/A	[illegible]	[illegible]
VWP-22 B	INSTALLED IN 2014 - PZ-2014-03	[illegible]	[illegible]	[illegible]	N/A	[illegible]	N/A	[illegible]	[illegible]
VWP-22 C	INSTALLED IN 2014 - PZ-2014-03	[illegible]	[illegible]	[illegible]	N/A	[illegible]	N/A	[illegible]	[illegible]
VWP-8 A	INSTALLED IN 2014 - PZ-2014-04	[illegible]	[illegible]	[illegible]	N/A	[illegible]	N/A	[illegible]	[illegible]
VWP-8 B	INSTALLED IN 2014 - PZ-2014-04	[illegible]	[illegible]	[illegible]	N/A	[illegible]	N/A	[illegible]	[illegible]
VWP-8 C	INSTALLED IN 2014 - PZ-2014-04	[illegible]	[illegible]	[illegible]	N/A	[illegible]	N/A	[illegible]	[illegible]
VWP-14	INSTALLED IN 2014 - PZ-2014-05	[illegible]	[illegible]	[illegible]	N/A	[illegible]	N/A	[illegible]	[illegible]
VWP-12	INSTALLED IN 2014 - PZ-2014-06	[illegible]	[illegible]	[illegible]	N/A	[illegible]	N/A	[illegible]	[illegible]
VWP-11	INSTALLED IN 2014 - PZ-2014-07	[illegible]	[illegible]	[illegible]	N/A	[illegible]	N/A	[illegible]	[illegible]
SI-1	SI-1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	TOP OF CAP	[illegible]	[illegible]
SI-2	SI-2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	TOP OF CAP	[illegible]	[illegible]
SI-3	SI-3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	TOP OF CAP	[illegible]	[illegible]
SI-4	SI-4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	TOP OF CAP	[illegible]	[illegible]
SI-5	SI-5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	TOP OF CAP	[illegible]	[illegible]
SI-6	SI-6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	TOP OF CAP	[illegible]	[illegible]
SI-7	SI-7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	TOP OF CAP	[illegible]	[illegible]
SI-8	INSTALLED IN 2014 - SI-8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	TOP OF CAP	[illegible]	[illegible]
SI-9	INSTALLED IN 2014 - SI-9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	TOP OF CAP	[illegible]	[illegible]
SI-10	INSTALLED IN 2014 - SI-10	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	TOP OF CAP	[illegible]	[illegible]
SI-11	INSTALLED IN 2014 - SI-11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	TOP OF CAP	[illegible]	[illegible]
VWP-3	SP-1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	N.RIM TOP CASING	[illegible]	[illegible]
VWP-4	SP-2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	N.RIM TOP CASING	[illegible]	[illegible]
VWP-2 A	INSTALLED IN 2014 - SP-3	[illegible]	[illegible]	[illegible]	N/A	[illegible]	N/A	[illegible]	[illegible]
VWP-2 B	INSTALLED IN 2014 - SP-3	[illegible]	[illegible]	[illegible]	N/A	[illegible]	N/A	[illegible]	[illegible]
VWP-2 C	INSTALLED IN 2014 - SP-3	[illegible]	[illegible]	[illegible]	N/A	[illegible]	N/A	[illegible]	[illegible]
VWP-5 A	INSTALLED IN 2014 - SP-4	[illegible]	[illegible]	[illegible]	N/A	[illegible]	N/A	[illegible]	[illegible]
VWP-5 B	INSTALLED IN 2014 - SP-4	[illegible]	[illegible]	[illegible]	N/A	[illegible]	N/A	[illegible]	[illegible]
VWP-5 C	INSTALLED IN 2014 - SP-4	[illegible]	[illegible]	[illegible]	N/A	[illegible]	N/A	[illegible]	[illegible]
VWP-18	P-1	[illegible]	[illegible]	[illegible]	N/A	UNKNOWN	N/A	[illegible]	[illegible]
VWP-17	P-2	[illegible]	[illegible]	[illegible]	N/A	UNKNOWN	N/A	[illegible]	[illegible]
VWP-19	P-3	[illegible]	[illegible]	[illegible]	N/A	UNKNOWN	N/A	[illegible]	[illegible]
VWP-16	P-4	[illegible]	[illegible]	[illegible]	N/A	UNKNOWN	N/A	[illegible]	[illegible]
VWP-15	P-5	[illegible]	[illegible]	[illegible]	N/A	UNKNOWN	N/A	[illegible]	[illegible]
VWP-20	P-6	[illegible]	[illegible]	[illegible]	N/A	UNKNOWN	N/A	[illegible]	[illegible]

COORDINATES SHOWN ARE:
MICHIGAN STATE PLANE COORDINATES, SOUTH ZONE, INTERNATIONAL FEET
VERTICAL DATUM IS: NAVD88

200 0 200

FKE PROJECT No.:	CAD FILE NAME:
14-013	14-013 LP.dwg
DESIGNED BY:	PLOT DATE:
NJB	30-Jul-14
DRAWN BY:	DRAWING SCALE:
NJB	1" =200'
CHECKED BY:	CREATED ON:
ZFC	24-Jul-14

FKE
Troy, MI
248.817.2946

REVISIONS

REV #	DATE	DESCRIPTION	BY
---	---	---	---
---	---	---	---
---	---	---	---
---	---	---	---
---	---	---	---
---	---	---	---
---	---	---	---
---	---	---	---
---	---	---	---

CONSUMERS ENERGY
KARN ASH LANDFILL
LOCATION PLAN

SHEET NO.
1

ATTACHMENT 4

Consumers J.C. Weadock Dry Ash Landfill
Cover Hydrologic Performance
HELP Model Inputs

1. Profile. Regulation Section

Model Settings

[HELP] Case Settings

Parameter	Value	Units
Runoff Method	Model calculated	(-)
Initial Moisture Settings	Model calculated	(-)

[HELP] Surface Water Settings

Parameter	Value	Units
Runoff Area	100	(%%)
Vegetation Class	Good stand of grass	(-)

Profile Structure

Layer	Top (ft)	Bottom (ft)	Thickness (ft)
Fine Sandy Loam	0.0000	-0.5000	0.5000
Silty Clay	-0.5000	-2.0000	1.5000

1.1. Layer. Fine Sandy Loam (topsoil)

Top Slope Length: 750.0000
Bottom Slope Length: 750.0000
Top Slope: 3.5000
Bottom Slope : 3.5000

[HELP] Vertical Perc. Layer Parameters

Parameter	Value	Units
total porosity	0.4730	(vol/vol)
field capacity	0.2220	(vol/vol)
wilting point	0.1040	(vol/vol)
sat.hydr.conductivity	1.0E-2	(cm/sec)
subsurface inflow	0.0000	(cm/day)

1.2. Layer. Silty Clay (infiltration layer)

Top Slope Length: 750.0000
Bottom Slope Length: 750.0000
Top Slope: 3.5000
Bottom Slope : 3.5000

[HELP] Barrier Soil Liner Parameters

Parameter	Value	Units
total porosity	0.479	(vol/vol)
field capacity	0.371	(vol/vol)
wilting point	0.251	(vol/vol)
sat.hydr.conductivity	1.0E-5	(cm/sec)
subsurface inflow	0	(mm/year)

2. Results.

2.1. Regulation Section

Total volumes (ft3) for 30 year model period

Description	Total Volume
Precipitation (ft3)	3.3174E+06
Runoff (ft3)	5.5102E+05
Evapotranspiration (ft3)	1.8387E+06
Soil water (ft3)	1.0983E+06
Snow water (ft3)	9.2814E+04
Percolation or leakance through Layer 2 (ft3)	9.3094E+05

Average annual volumes (ft3) for 30 year model period

Description	Average Annual Volume
Precipitation (ft3)	1.1058E+05
Runoff (ft3)	1.8367E+04
Evapotranspiration (ft3)	6.129E+04
Soil water (ft3)	3.661E+04
Snow water (ft3)	3.093E+03
Percolation or leakance through Layer 2 (ft3)	3.1031E+04

ATTACHMENT 5

DEFAULT SOIL, WASTE, AND GEOSYNTHETIC CHARACTERISTICS

Classification			Total Porosity	Field Capacity	Wilting Point	Saturated Hydraulic Conductivity
HELP	USDA	USCS	vol/vol	vol/vol	vol/vol	cm/sec
1	CoS	SP	0.417	0.045	0.018	$1.0x10^{-2}$
2	S	SW	0.437	0.062	0.024	$5.8x10^{-3}$
3	FS	SW	0.457	0.083	0.033	$3.1x10^{-3}$
4	LS	SM	0.437	0.105	0.047	$1.7x10^{-3}$
5	LFS	SM	0.457	0.131	0.058	$1.0x10^{-3}$
6	SL	SM	0.453	0.190	0.085	$7.2x10^{-4}$
7	FSL	SM	0.473	0.222	0.104	$5.2x10^{-4}$
8	L	ML	0.463	0.232	0.116	$3.7x10^{-4}$
9	SiL	ML	0.501	0.284	0.135	$1.9x10^{-4}$
10	SCL	SC	0.398	0.244	0.136	$1.2x10^{-4}$
11	CL	CL	0.464	0.310	0.187	$6.4x10^{-5}$
12	SiCL	CL	0.471	0.342	0.210	$4.2x10^{-5}$
13	SC	SC	0.430	0.321	0.221	$3.3x10^{-5}$
14	SiC	CH	0.479	0.371	0.251	$2.5x10^{-5}$
15	C	CH	0.475	0.378	0.265	$1.7x10^{-5}$
16	Barrier Soil		0.427	0.418	0.367	$1.0x10^{-7}$
17	Bentonite Mat (0.6 cm)		0.750	0.747	0.400	$3.0x10^{-9}$
18	Municipal Waste (900 lb/yd^3 or 312 kg/m^3)		0.671	0.292	0.077	$1.0x10^{-3}$
19	Municipal Waste (channeling and dead zones)		0.168	0.073	0.019	$1.0x10^{-3}$
20	Drainage Net (0.5 cm)		0.850	0.010	0.005	$1.0x10^{+1}$
21	Gravel		0.397	0.032	0.013	$3.0x10^{-1}$
22	L*	ML	0.419	0.307	0.180	$1.9x10^{-5}$
23	SiL*	ML	0.461	0.360	0.203	$9.0x10^{-6}$
24	SCL*	SC	0.365	0.305	0.202	$2.7x10^{-6}$
25	CL*	CL	0.437	0.373	0.266	$3.6x10^{-6}$
26	SiCL*	CL	0.445	0.393	0.277	$1.9x10^{-6}$
27	SC*	SC	0.400	0.366	0.288	$7.8x10^{-7}$
28	SiC*	CH	0.452	0.411	0.311	$1.2x10^{-6}$
29	C*	CH	0.451	0.419	0.332	$6.8x10^{-7}$
30	Coal-Burning Electric Plant Fly Ash*		0.541	0.187	0.047	$5.0x10^{-5}$
31	Coal-Burning Electric Plant Bottom Ash*		0.578	0.076	0.025	$4.1x10^{-3}$
32	Municipal Incinerator Fly Ash*		0.450	0.116	0.049	$1.0x10^{-2}$
33	Fine Copper Slag*		0.375	0.055	0.020	$4.1x10^{-2}$
34	Drainage Net (0.6 cm)		0.850	0.010	0.005	$3.3x10^{+1}$

* Moderately Compacted

(Continued)

DEFAULT SOIL, WASTE, AND GEOSYNTHETIC CHARACTERISTICS

Classification		Total Porosity	Field Capacity	Wilting Point	Saturated Hydraulic Conductivity
HELP	Geomembrane Material	vol/vol	vol/vol	vol/vol	cm/sec
35	High Density Polyethylene (HDPE)				$2.0x10^{-13}$
36	Low Density Polyethylene (LDPE)				$4.0x10^{-13}$
37	Polyvinyl Chloride (PVC)				$2.0x10^{-11}$
38	Butyl Rubber				$1.0x10^{-12}$
39	Chlorinated Polyethylene (CPE)				$4.0x10^{-12}$
40	Hypalon or Chlorosulfonated Polyethylene (CSPE)				$3.0x10^{-12}$
41	Ethylene-Propylene Diene Monomer (EPDM)				$2.0x10^{-12}$
42	Neoprene				$3.0x10^{-12}$

(Concluded)

ATTACHMENT 6

Date:	Revised October 29, 2018	**Made by:**	Brad Johnson
Project No.:	1773608	**Checked by:**	Bryan Weldon
Subject:	HELP Model Analysis	**Reviewed by:**	
Project Short Title:	**J.C. WEADOCK DRY ASH LANDFILL COVER HYDROLOGIC PERFORMANCE**		

1.0 INTRODUCTION

The HELP (Hydrologic Evaluation of Landfill Performance) model (Schroeder et al. 1994) was used to estimate water balance for the dry ash landfill cover system at the J.C. Weadock facility. The program models rainfall, runoff, infiltration, and other water components to estimate how much water builds up above each landfill liner, how much water is intercepted by lateral drainage layer(s), and how much water potentially leaks through “barrier layers” of the landfill.

Model inputs included daily weather data (precipitation, temperature and solar radiation), soil properties (porosity, field capacity, wilting point and saturated hydraulic conductivity for each soil layer), and evapotranspiration (ET) parameters (e.g., leaf area index and evaporative zone depth). The following sections describe the model inputs.

2.0 LANDFILL LAYERS

The model was used to simulate the landfill condition depicted on the cross section in Attachment A. In the HELP model, the layers are “typed” by the hydraulic function that they perform. Four types are of layers are available: vertical percolation layers, lateral drainage layers, barrier soil liners and geomembrane liners. As shown on the landfill cross section in Attachment A, the cover system consists of a 6-inch topsoil layer, a 12-inch thick rooting zone, and a geocomposite drainage layer above a 40-mil LLDPE geomembrane (a HDPE has similar hydraulic conductivity). Approximately 60-feet of CCR fly ash lies beneath the cover; the thickness of the underlying CCR fly ash has no bearing on performance of the cover system. Table 1 shows the soil and design data input to mimic the cover and waste within the landfill; the soil and design data are also included in Attachment A in a format familiar to Visual HELP users. The engineering documentation for the HELP model (Schroeder et al., 1994) provides default soil properties (porosity, field capacity, wilting point, and saturated hydraulic conductivity) for a wide variety of soil texture classes and materials used in landfill construction. Table 4 (Default Soil, Waste, and Geosynthetic Characteristics) from the HELP Unser Guide for Version 3 is included in Attachment A.

As noted in a footnote at the bottom of Table 1, there are three model parameters for a geomembrane liner that do not apply to other layers in the model. For layer No. 4 (LLDPE or HDPE geomembrane), pinhole density of 1/acre, defects 1/acre, and placement quality "good" were used as model inputs.

3.0 WEATHER DATA

The HELP model requires general climate data for computing potential landfill water balance. The required general climate data include average annual wind speed, average quarterly relative humidity, normal mean monthly temperatures, and latitude. Daily weather data required in the HELP model are classified into four groups: (1) evapotranspiration, (2) precipitation, (3) temperature, and (4) solar radiation data. Daily weather data may be input by the user, generated stochastically (i.e., synthetic weather data), or taken from the model's historical data base. For this analysis, it was deemed desirable generate synthetic weather data for multiple years with the same statistical characteristics as the actual weather at the site (or in the general vicinity of the site) to capture the effects of varying annual precipitation and the timing of precipitation during the year on landfill water balance. The HELP model incorporates a routine, WGEN, for generating daily values of precipitation, mean temperature, and solar radiation for an n-year period (up to 100 years).

Model Inputs

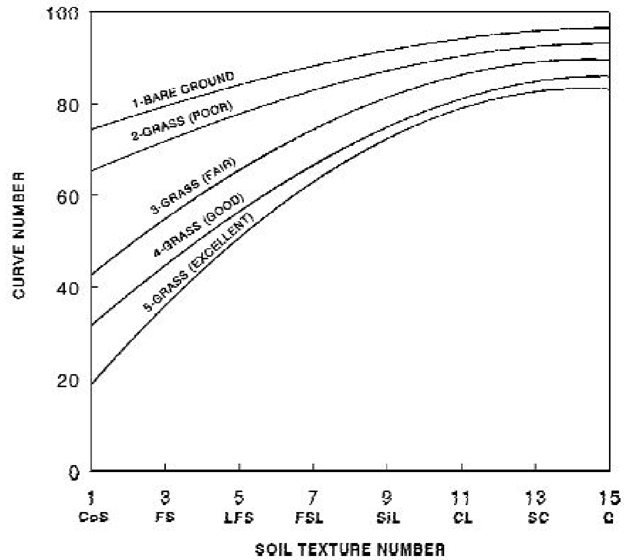
As indicated above, there are four groups of daily weather data that must be input or generated by the model. The WGEN module of HELP was used to generate the daily inputs. Screen shots from the HELP model documenting these inputs are included in Attachment B.

1) The nearest Michigan weather station with available ET parameters (growing season start, growing season end, average wind speed, and quarterly relative humidity) is located in East Lansing, Michigan (Screen 1). Two of the parameters on this screen were input for the Weadock dry ash landfill: evaporative zone depth of 18 inches (topsoil + rooting zone thicknesses) and maximum leaf area index of 3 (for a good cover of vegetation).
2) Detroit, Michigan was selected as the nearest representative meteorological station for daily precipitation. The model includes a feature that provides for the correction of the generated precipitation and temperatures based on actual mean monthly values. The 1981 to 2010 precipitation Normals[1] for Essexville, Michigan were input into the model in the column "USER" (Screen 2) to facilitate generation of monthly and annual precipitation totals that are representative of the site.
3) East Lansing, Michigan was selected as the nearest representative meteorological station for daily temperatures. The 1981 to 2010 temperature Normals for Essexville, Michigan were input into the model in the column "USER" (Screen 3) to facilitate generation of monthly and annual temperature averages that are representative of the site.
4) East Lansing, Michigan was selected as the nearest representative meteorological station for daily solar radiation data (Screen 4). On this screen, the station latitude was replaced with the latitude of the Weadock dry ash landfill (approximately 43.64 degrees) to more accurately simulate global radiation at the site.

Note that 30 years of synthetic weather data were generated.

[1] Climate Normals are three-decade averages of climatological variables including temperature and precipitation. The climate normal are produced once every 10 years. The 1981–2010 U.S. Climate Normals dataset is the latest release of National Centers for Environmental Information (NCEI's) Climate Normals.

4.0 RUNOFF



The rainfall-runoff processes are modeled using the SCS "curve-number" (CN) method, which is widely accepted and allows the user to adjust the runoff calculation to a variety of soil types and land management practices. The maximum value of CN, which is 100, occurs when there is no infiltration. The smaller CN is, the more rainwater will infiltrate into the uppermost layer. The engineering documentation for the HELP model (Schroeder et al., 1994) includes the figure shown at the right which shows the relation between CN and soil texture for various levels of vegetation. Three methods are available in the HELP model to define a SCS runoff curve number: (1) user-specified curve number without modification by the model, (2) user-specified curve number modified for surface slope and slope length, and (3) curve number computed by HELP based on surface slope, slope length, default soil texture, and the quality of vegetation cover. The third method was used for the final cover scenario. The calculated curve number for material texture 10 (i.e., layer 1) with a slope of 3.0%, a slope length of 650 feet, and a good stand of grass was 85.3.

5.0 RESULTS

The model output is included in Attachment C; Average annual totals for the 30-year simulation are summarized on Table 2. The principal water balance components (precipitation, runoff and ET) are presented along with lateral drainage from the lateral drainage layer (the geocomposite which was simulated using the drainage net, number 34) and average head on the top of the LLDPE (or HDPE) geomembrane liner. In summary:

- Average annual precipitation was 31.78 inches, slightly less than the Normal for Essexville, Michigan (32.39 inches).
- Average annual runoff was 4.74 inches due to the relatively flat cover system (3% slope) and good vegetation cover.
- Average annual ET was 20.28 inches. This water balance component is sensitive to the input evaporative zone depth (18 inches). It is anticipated that the soils used to construct the cover system will allow the plant roots to explore the full 18 inches of soil (topsoil plus rooting zone) above the geocomposite/geomembrane liner.
- Average annual lateral drainage from layer 3 is approximately 6.79 inches, which is approximately equal to the difference: Precipitation – runoff – ET.
- Percolation/drainage through layer 4 (0.00021 inches/year) is negligible with the proposed cover system and the climate of Essexville, Michigan.

TABLES

Consumers J.C. Weadock Dry Ash Landfill Cover Hydrologic Performance
HELP3 Model Analysis (30-Year Simulation)

TABLE 1: Soil and Design Data

Layer No.	Layer Description	HELP Layer Type	Material Texture No.	Thickness	Porosity	Field Capacity	Wilting Point	Initial Wtr Content	Ksat
				inches	vol/vol	vol/vol	vol/vol	vol/vol	cm/sec
1	6 inch topsoil (SC)	Vertical percolation	10	6	0.398	0.244	0.136	0.3468	1.2E-04
2	12-in thick Rooting Zone (SM)	Vertical percolation	5	12	0.457	0.131	0.058	0.2429	1.0E-03
3	Geocomposite w/ 200 mil geonet core [1]	Lateral drainage	34	0.2	0.85	0.01	0.005	0.01	33
4	40-mil LLDPE (or HDPE) geomembrane [2]	Geomembrane	36	0.04	0.000	0.000	0.000	0.000	4.0E-13
5	60 feet of CCR	Vertical percolation	30	720	0.541	0.187	0.047	0.187	5.0E-05

Notes:

[1] For layer No. 3 (laterial drainage), slope length of 650 ft and slope of 3.0% were used

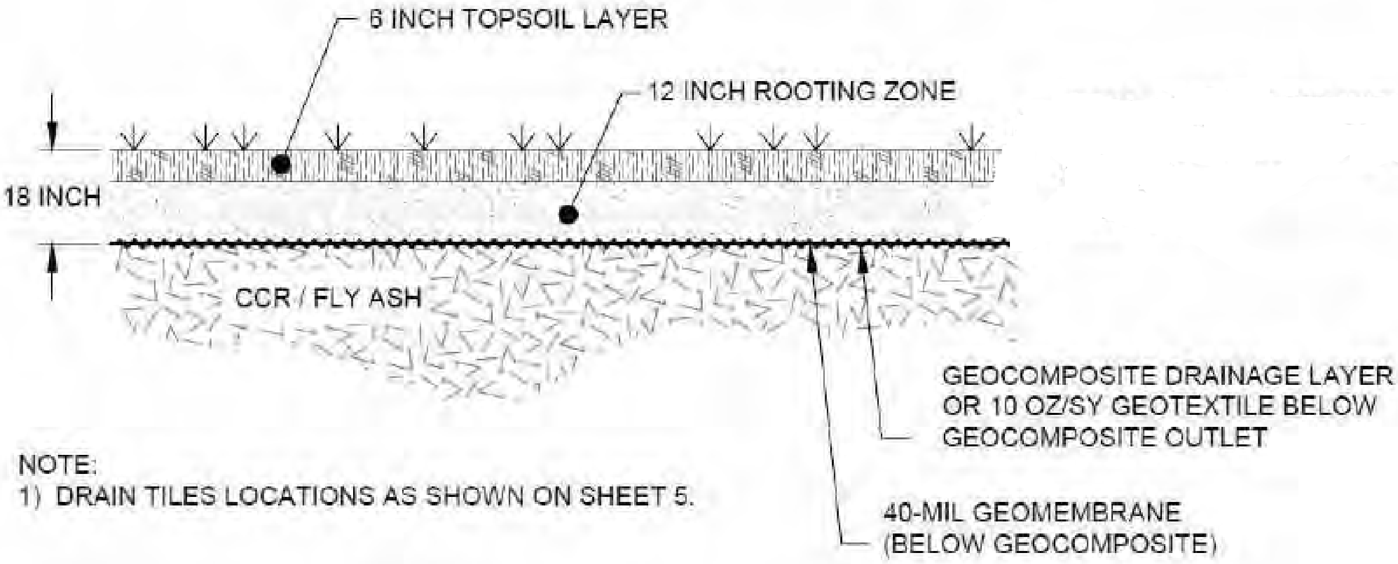
[2] For layer No. 4 (LLDPE geomembrane), pinhole density of 1/acre, defects 1/acre, and placement quality "good" were used

TABLE 2: Results - Average annual totals for years 1 through 30

	inches	CU feet/Acre
Precipitation	31.78	115,361
Runoff	4.74	17,206
Evapotranspiration	20.284	73,631
Later drainage from layer 3	6.791	24,650
Perc/leakage through layer 4	0.00021	0.762
Average head on top of layer 4	0.005	
Perc/leakage through layer 5	0.00021	0.000

Golder Associates

ATTACHMENT A



NOTE:
1) DRAIN TILES LOCATIONS AS SHOWN ON SHEET 5.

2	COVER SYSTEM WITH 6" TOPSOIL LAYER, 12" ROOTING ZONE, GEOCOMPOSITE, AND GEOMEMBRANE DETAIL
16	NOT TO SCALE

Consumers J.C. Weadock Dry Ash Landfill
Cover Hydrologic Performance
HELP3 Model Inputs

1. Profile Structure

Layer	Top (inches)	Bottom (inches)	Thickness (inches)
Silty clay loam topsoil (SC)	0	-6	6
Loamy fine sand Rooting Zone (SM)	-6	-18	12
Geocomposite w/ 200 mil geonet core	-18	-18.2	0.2
40-mil LLDPE geomembrane	-18.2	-18.24	0.04
60 feet of CCR	-18.24	-738.24	720

1.1 Layer - Silty clay loam (topsoil)

Slope length 750 feet
Slope 3.5%
Vertical percolation layer parameters:

Parameter	Value	Units
Total porosity	0.398	vol/vol
Field capacity	0.244	vol/vol
Wilting point	0.136	vol/vol
Saturaged hydraulic conductivity	1.2E-04	cm/sec
Subsurface inflow	0.000	cm/day

1.2 Layer - Loamy fine sand (rooting zone)

Vertical percolation layer parameters:

Parameter	Value	Units
Total porosity	0.457	vol/vol
Field capacity	0.131	vol/vol
Wilting point	0.058	vol/vol
Saturaged hydraulic conductivity	1.0E-03	cm/sec
Subsurface inflow	0.000	cm/day

1.3 Layer - Geocomposite w/ 200 mil geonet core

Slope length 750 feet
Slope 3.5%
Lateral drainage layer parameters:

Parameter	Value	Units
Total porosity	0.85	vol/vol
Field capacity	0.01	vol/vol
Wilting point	0.005	vol/vol
Saturaged hydraulic conductivity	33	cm/sec
Subsurface inflow	0.000	cm/day

1.4 Layer - 40-mil LLDPE (or HDPE) geomembrane

Barrier geomembrane properties:

Parameter	Value	Units
Total porosity	0.000	vol/vol
Field capacity	0.000	vol/vol
Wilting point	0.000	vol/vol
Saturaged hydraulic conductivity	4.0E-13	cm/sec
Subsurface inflow	0.000	cm/day

Note: LLDPE and HDPE exhibit same order of magnitude saturated hydraulic conductivity.

1.5 Layer - Coal combustion residuals

Vertical percolation layer parameters:

Parameter	Value	Units
Total porosity	0.541	vol/vol
Field capacity	0.187	vol/vol
Wilting point	0.047	vol/vol
Saturaged hydraulic conductivity	5.0E-05	cm/sec
Subsurface inflow	0.000	cm/day

TABLE 4. DEFAULT SOIL, WASTE, AND GEOSYNTHETIC CHARACTERISTICS

Classification			Total Porosity	Field Capacity	Wilting Point	Saturated Hydraulic Conductivity
HELP	USDA	USCS	vol/vol	vol/vol	vol/vol	cm/sec
1	CoS	SP	0.417	0.045	0.018	$1.0x10^{-2}$
2	S	SW	0.437	0.062	0.024	$5.8x10^{-3}$
3	FS	SW	0.457	0.083	0.033	$3.1x10^{-3}$
4	LS	SM	0.437	0.105	0.047	$1.7x10^{-3}$
5	LFS	SM	0.457	0.131	0.058	$1.0x10^{-3}$
6	SL	SM	0.453	0.190	0.085	$7.2x10^{-4}$
7	FSL	SM	0.473	0.222	0.104	$5.2x10^{-4}$
8	L	ML	0.463	0.232	0.116	$3.7x10^{-4}$
9	SiL	ML	0.501	0.284	0.135	$1.9x10^{-4}$
10	SCL	SC	0.398	0.244	0.136	$1.2x10^{-4}$
11	CL	CL	0.464	0.310	0.187	$6.4x10^{-5}$
12	SiCL	CL	0.471	0.342	0.210	$4.2x10^{-5}$
13	SC	SC	0.430	0.321	0.221	$3.3x10^{-5}$
14	SiC	CH	0.479	0.371	0.251	$2.5x10^{-5}$
15	C	CH	0.475	0.378	0.265	$1.7x10^{-5}$
16	Barrier Soil		0.427	0.418	0.367	$1.0x10^{-7}$
17	Bentonite Mat (0.6 cm)		0.750	0.747	0.400	$3.0x10^{-9}$
18	Municipal Waste (900 lb/yd^3 or 312 kg/m^3)		0.671	0.292	0.077	$1.0x10^{-3}$
19	Municipal Waste (channeling and dead zones)		0.168	0.073	0.019	$1.0x10^{-3}$
20	Drainage Net (0.5 cm)		0.850	0.010	0.005	$1.0x10^{+1}$
21	Gravel		0.397	0.032	0.013	$3.0x10^{-1}$
22	L*	ML	0.419	0.307	0.180	$1.9x10^{-5}$
23	SiL*	ML	0.461	0.360	0.203	$9.0x10^{-6}$
24	SCL*	SC	0.365	0.305	0.202	$2.7x10^{-6}$
25	CL*	CL	0.437	0.373	0.266	$3.6x10^{-6}$
26	SiCL*	CL	0.445	0.393	0.277	$1.9x10^{-6}$
27	SC*	SC	0.400	0.366	0.288	$7.8x10^{-7}$
28	SiC*	CH	0.452	0.411	0.311	$1.2x10^{-6}$
29	C*	CH	0.451	0.419	0.332	$6.8x10^{-7}$
30	Coal-Burning Electric Plant Fly Ash*		0.541	0.187	0.047	$5.0x10^{-5}$
31	Coal-Burning Electric Plant Bottom Ash*		0.578	0.076	0.025	$4.1x10^{-3}$
32	Municipal Incinerator Fly Ash*		0.450	0.116	0.049	$1.0x10^{-2}$
33	Fine Copper Slag*		0.375	0.055	0.020	$4.1x10^{-2}$
34	Drainage Net (0.6 cm)		0.850	0.010	0.005	$3.3x10^{+1}$

* Moderately Compacted

(Continued)

TABLE 4 (continued). DEFAULT SOIL, WASTE, AND GEOSYNTHETIC CHARACTERISTICS

Classification		Total Porosity	Field Capacity	Wilting Point	Saturated Hydraulic Conductivity
HELP	Geomembrane Material	vol/vol	vol/vol	vol/vol	cm/sec
35	High Density Polyethylene (HDPE)				2.0×10^{-13}
36	Low Density Polyethylene (LDPE)				4.0×10^{-13}
37	Polyvinyl Chloride (PVC)				2.0×10^{-11}
38	Butyl Rubber				1.0×10^{-12}
39	Chlorinated Polyethylene (CPE)				4.0×10^{-12}
40	Hypalon or Chlorosulfonated Polyethylene (CSPE)				3.0×10^{-12}
41	Ethylene-Propylene Diene Monomer (EPDM)				2.0×10^{-12}
42	Neoprene				3.0×10^{-12}

(concluded)

user-defined soil option accepts non-default soil characteristics for layers assigned soil type numbers greater than 42. This is especially convenient for specifying characteristics of waste layers. User-specified soil characteristics can be assigned any soil type number greater than 42.

When a default soil type is used to describe the top soil layer, the program adjusts the saturated hydraulic conductivities of the soils in the top half of the evaporative zone for the effects of root channels. The saturated hydraulic conductivity value is multiplied by an empirical factor that is computed as a function of the user-specified maximum leaf area index. Example values of this factor are 1.0 for a maximum LAI of 0 (bare ground), 1.8 for a maximum LAI of 1 (poor stand of grass), 3.0 for a maximum LAI of 2 (fair stand of grass), 4.2 for a maximum LAI of 3.3 (good stand of grass) and 5.0 for a maximum LAI of 5 (excellent stand of grass).

The manual option requires values for porosity, field capacity, wilting point, and saturated hydraulic conductivity. These and related soil properties are defined below.

Soil Water Storage (Volumetric Content): the ratio of the volume of water in a soil to the total volume occupied by the soil, water and voids.

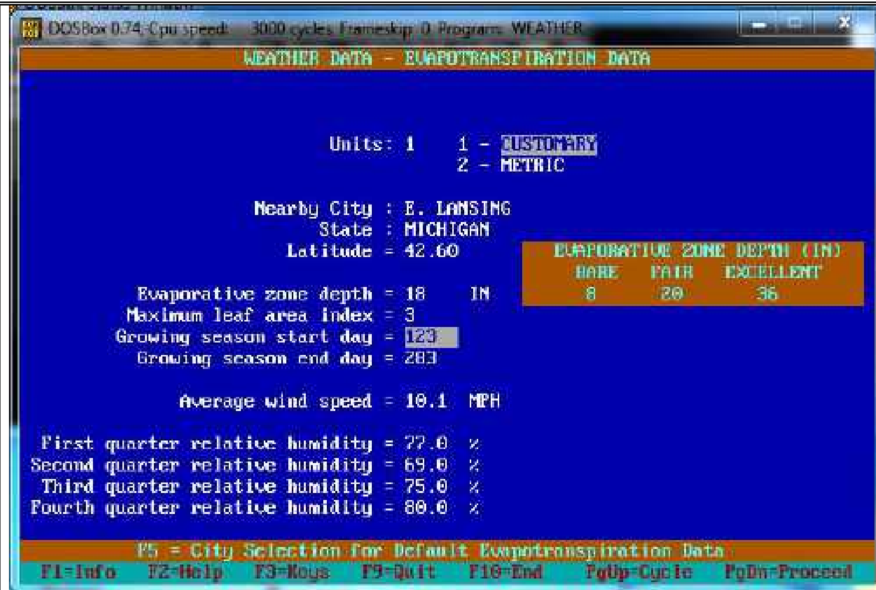
Total Porosity: the soil water storage/volumetric content at saturation (fraction of total volume).

ATTCHMENT B

Project Title: Consumers J.C. Weadock Dry Ash Landfill Cover Hydrologic Performance

SCREEN 1

Evapotranspiration Inputs



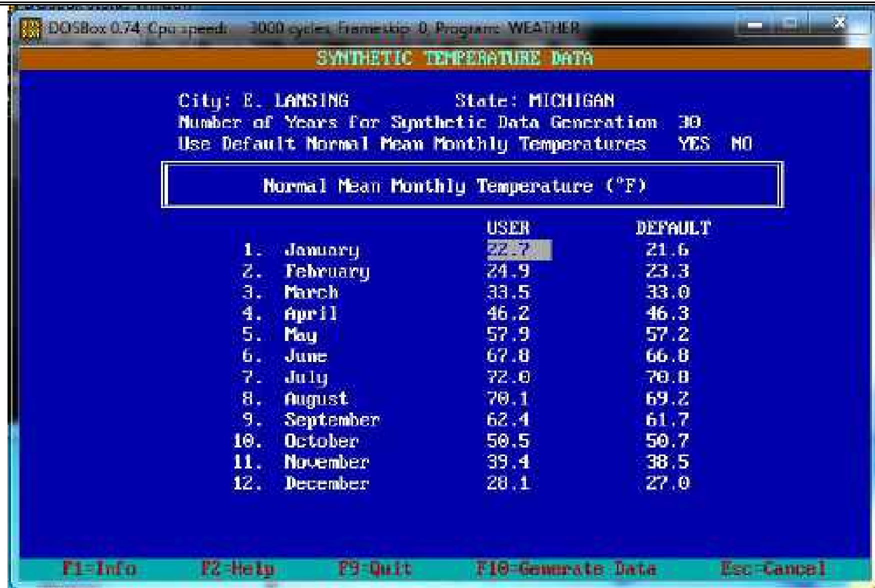
SCREEN 2

Precipitation Inputs (including the 30-year Normals for Essexville, MI)

Project Title: Consumers J.C. Weadock Dry Ash Landfill Cover Hydrologic Performance

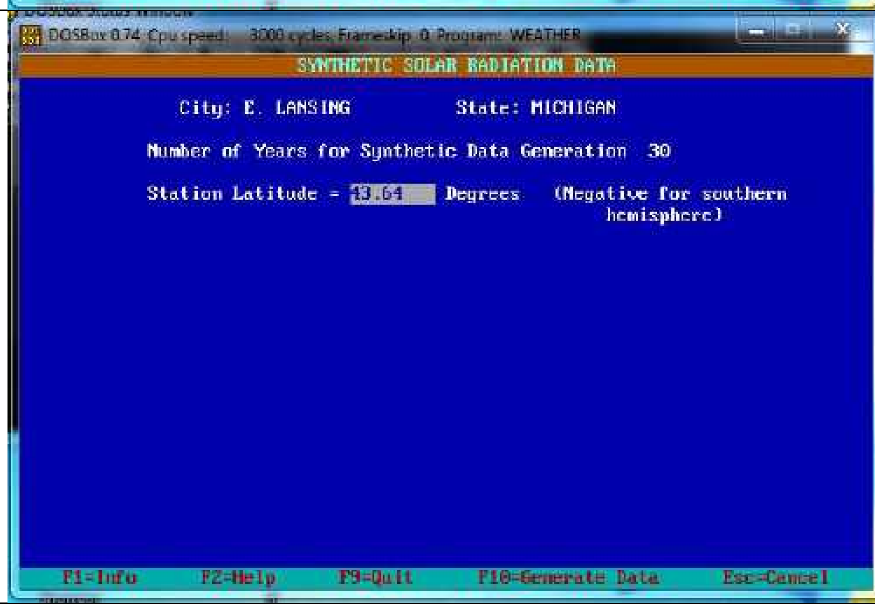
SCREEN 3

Temperature Inputs (including the 30-year Normals for Essexville, MI)



SCREEN 4

Solar Radiation Data (replaced station latitude with site latitude of 43.64)



ATTCHMENT C

```
♀
******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)                **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************


PRECIPITATION DATA FILE:    C:\input\weadck\DATA4.D4
TEMPERATURE DATA FILE:      C:\input\weadck\DATA7.D7
SOLAR RADIATION DATA FILE:  C:\input\weadck\DATA13.D13
EVAPOTRANSPIRATION DATA:    C:\input\weadck\DATA11.D11
SOIL AND DESIGN DATA FILE:  C:\input\weadck\DATA10A.D10
OUTPUT DATA FILE:           C:\output\WEAD6.OUT


TIME:  10:11     DATE:  10/29/2018


******************************************************************************

     TITLE:  Weadock Closure Cover Hydrologic Analysis

******************************************************************************


     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
              COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                   LAYER  1
                                   --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER  10
           THICKNESS                 =      6.00   INCHES
           POROSITY                  =      0.3980 VOL/VOL
           FIELD CAPACITY            =      0.2440 VOL/VOL
           WILTING POINT             =      0.1360 VOL/VOL
           INITIAL SOIL WATER CONTENT  =    0.3467 VOL/VOL
           EFFECTIVE SAT. HYD. COND.   =  0.119999997000E-03 CM/SEC
         NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  4.20
                  FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.


                                   LAYER  2
                                   --------
```

```
          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER   5
THICKNESS                    =     12.00   INCHES
POROSITY                     =      0.4570 VOL/VOL
FIELD CAPACITY               =      0.1310 VOL/VOL
WILTING POINT                =      0.0580 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.2426 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.100000005000E-02 CM/SEC


                          LAYER  3
                          --------

            TYPE 2 - LATERAL DRAINAGE LAYER
              MATERIAL TEXTURE NUMBER  34
THICKNESS                    =      0.20   INCHES
POROSITY                     =      0.8500 VOL/VOL
FIELD CAPACITY               =      0.0100 VOL/VOL
WILTING POINT                =      0.0050 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0100 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =   33.0000000000     CM/SEC
SLOPE                        =      3.00   PERCENT
DRAINAGE LENGTH              =    650.0    FEET


                          LAYER  4
                          --------

            TYPE 4 - FLEXIBLE MEMBRANE LINER
              MATERIAL TEXTURE NUMBER  36
THICKNESS                    =      0.04   INCHES
POROSITY                     =      0.0000 VOL/VOL
FIELD CAPACITY               =      0.0000 VOL/VOL
WILTING POINT                =      0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.399999993000E-12 CM/SEC
FML PINHOLE DENSITY          =      1.00   HOLES/ACRE
FML INSTALLATION DEFECTS     =      1.00   HOLES/ACRE
FML PLACEMENT QUALITY        =  3 - GOOD


                          LAYER  5
                          --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER  30
THICKNESS                    =    720.00   INCHES
POROSITY                     =      0.5410 VOL/VOL
FIELD CAPACITY               =      0.1870 VOL/VOL
WILTING POINT                =      0.0470 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.1870 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.499999987000E-04 CM/SEC
```

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE #10 WITH A FAIR STAND OF GRASS, A SURFACE SLOPE OF 3.% AND A SLOPE LENGTH OF 650. FEET.

SCS RUNOFF CURVE NUMBER	=	85.30	
FRACTION OF AREA ALLOWING RUNOFF	=	100.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1.000	ACRES
EVAPORATIVE ZONE DEPTH	=	18.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	4.991	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	7.872	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	1.512	INCHES
INITIAL SNOW WATER	=	0.000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	139.633	INCHES
TOTAL INITIAL WATER	=	139.633	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM E. LANSING MICHIGAN

STATION LATITUDE	=	43.64	DEGREES
MAXIMUM LEAF AREA INDEX	=	3.00	
START OF GROWING SEASON (JULIAN DATE)	=	123	
END OF GROWING SEASON (JULIAN DATE)	=	283	
EVAPORATIVE ZONE DEPTH	=	18.0	INCHES
AVERAGE ANNUAL WIND SPEED	=	10.10	MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	77.00	%
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	69.00	%
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	75.00	%
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	80.00	%

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR DETROIT MICHIGAN

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
1.57	1.46	1.84	3.17	3.31	3.48
2.52	3.44	4.20	2.83	2.77	1.80

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR E. LANSING MICHIGAN

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
22.70	24.90	33.50	46.20	57.90	67.80

72.00	70.10	62.40	50.50	39.40	28.10

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR E. LANSING MICHIGAN
AND STATION LATITUDE = 43.64 DEGREES

****

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 30

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	1.52	1.53	1.72	3.35	3.54	3.41
	2.39	3.17	4.23	2.22	2.81	1.89
STD. DEVIATIONS	0.55	0.68	0.78	1.31	1.34	1.44
	1.02	1.74	2.46	1.42	1.19	0.75
RUNOFF						
TOTALS	0.449	0.971	1.429	1.052	0.097	0.060
	0.018	0.165	0.231	0.055	0.066	0.147
STD. DEVIATIONS	0.426	0.814	1.229	1.465	0.175	0.124
	0.056	0.305	0.362	0.204	0.118	0.300
EVAPOTRANSPIRATION						
TOTALS	0.381	0.340	0.440	2.389	3.585	3.982
	2.284	2.324	2.160	1.224	0.742	0.434
STD. DEVIATIONS	0.078	0.070	0.217	0.987	1.056	1.255
	0.952	0.978	0.837	0.317	0.159	0.113
LATERAL DRAINAGE COLLECTED FROM LAYER 3						
TOTALS	0.0160	0.0000	0.3017	1.7224	0.5578	0.2574
	0.2743	0.3392	0.6890	0.8507	1.1599	0.6223
STD. DEVIATIONS	0.0631	0.0000	0.6400	0.8411	0.5655	0.1019
	0.1397	0.3353	0.7241	1.0045	1.0524	0.5663
PERCOLATION/LEAKAGE THROUGH LAYER 4						
TOTALS	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
PERCOLATION/LEAKAGE THROUGH LAYER 5						
TOTALS	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000

	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0001	0.0002	0.0001	0.0000
	0.0000	0.0001	0.0001	0.0001	0.0001	0.0001

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 4

AVERAGES	0.0001	0.0000	0.0057	0.0364	0.0044	0.0010
	0.0010	0.0014	0.0034	0.0035	0.0065	0.0023
STD. DEVIATIONS	0.0002	0.0000	0.0132	0.0326	0.0142	0.0004
	0.0005	0.0019	0.0053	0.0046	0.0094	0.0021

****

****

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 30

	INCHES		CU. FEET	PERCENT
PRECIPITATION	31.78	(4.336)	115372.3	100.00
RUNOFF	4.740	(1.6158)	17204.65	14.912
EVAPOTRANSPIRATION	20.284	(2.4852)	73630.09	63.820
LATERAL DRAINAGE COLLECTED FROM LAYER 3	6.79073	(2.45348)	24650.363	21.36593
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.00021	(0.00009)	0.777	0.00067
AVERAGE HEAD ON TOP OF LAYER 4	0.005	(0.003)		
PERCOLATION/LEAKAGE THROUGH LAYER 5	0.00021	(0.00025)	0.759	0.00066
CHANGE IN WATER STORAGE	-0.031	(1.0064)	-113.58	-0.098

****

♀
****

PEAK DAILY VALUES FOR YEARS 1 THROUGH 30

	(INCHES)	(CU. FT.)
PRECIPITATION	3.13	11361.900
RUNOFF	2.161	7844.8032

DRAINAGE COLLECTED FROM LAYER 3	1.30367	4732.33350
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.000295	1.06937
AVERAGE HEAD ON TOP OF LAYER 4	3.606	
MAXIMUM HEAD ON TOP OF LAYER 4	5.089	
LOCATION OF MAXIMUM HEAD IN LAYER 3 (DISTANCE FROM DRAIN)	42.7 FEET	
PERCOLATION/LEAKAGE THROUGH LAYER 5	0.000584	2.11854
SNOW WATER	6.42	23311.9043

MAXIMUM VEG. SOIL WATER (VOL/VOL) 0.3519

MINIMUM VEG. SOIL WATER (VOL/VOL) 0.0840

*** Maximum heads are computed using McEnroe's equations. ***

Reference: Maximum Saturated Depth over Landfill Liner
by Bruce M. McEnroe, University of Kansas
ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

****

♀
****

FINAL WATER STORAGE AT END OF YEAR 30

LAYER	(INCHES)	(VOL/VOL)
1	1.4162	0.2360
2	2.4196	0.2016
3	0.0044	0.0221
4	0.0000	0.0000
5	134.6399	0.1870
SNOW WATER	0.214	

****
****

APPENDIX E-2
PUNCTURE RESISTANCE CALCULATION

TECHNICAL MEMORANDUM

DATE March 16, 2018 **Project No.** 1773608

TO JR Register, P.E., Consumers Energy

CC

FROM Golder Associates Inc.

RE: J.C. WEADOCK DRY ASH LANDFILL – FINAL CLOSURE DESIGN AND CONSTRUCTION USING GEOSYNTHETICS – PUNCTURE RESISTANCE

Golder Associates Inc. (Golder) has prepared this Technical Memorandum (TM) to demonstrate the adequacy of the current closure cover design at the J.C. Weadock Dry Ash Landfill (Landfill) to resist puncture. The Landfill is currently permitted at as Type III Low Hazard Industrial Waste Landfill, Operating License Number 9440, and is subject to Part 115, Solid Waste Management (Part 115), of the Natural Resources and Environmental Protection Act (NREPA), Public Act 451 of 1994, as amended, and any regulations promulgated pursuant to this act.

The current closure cover design includes (from top to bottom):

- 6 inch thick topsoil layer
- 12 inch thick rooting layer
- A geocomposite drainage layer (10 ounce per square yard (oz/sy) non-woven (NW), needle-punched (NP) geotextiles heat bonded to either side of a 200-mil thick geonet core).
- 40 mil thick linear low density polyethylene (LLDPE) smooth OR textured geomembrane
- Prepared subgrade

The closure cover exceeds the Part 115 rules requirements with the addition of the geocomposite drainage layer. This layer adds extra environmental protection using the highly transmissive properties of the geocomposite to route storm water away from the top of the landfill quickly to perimeter ditches. Thus, rarely allowing head to build-up on the geomembrane.

The prepared subgrade for the closure cover consists of either a bottom ash material or a cemented (or granular) fly ash material, depending on the location in the landfill. The bottom ash material is a coarse grained material with a typical largest particle size of ¾-inch up to 2 inches or greater in diameter. The fly ash is a finer grained material; generally, a mixture of flue gas desulfurization (FGD) byproducts and powder river basin (PRB) coal fly ash along with varying amounts of eastern coal fly ash. This material can cement or behave cohesionless (granular in nature) based on the blend of FGD/PRB/eastern coal and water content, etc. Typical LLDPE geomembrane puncture and tearing concerns with these types of materials include the angularity and size of the bottom ash particles and the possible cracking and localized subsidence within the cemented fly ash material.

Calculations were performed to demonstrate that the closure cover design, in its entirety, is environmentally protective and resistant to puncture and tearing.

1.0 CALCULATIONS

Four separate calculations were performed to demonstrate the adequacy of the current closure cover design to resist against puncture and tearing.

1) Cap Geomembrane Strain Calculation using methods from Peggs et. al. (2005), and Qian et. Al (2002)

2) Cap Geomembrane Puncture with Top Cushion Calculation using methods from Koerner et. al. (2005).

3) Cap Geomembrane Puncture with Bottom Cushion Calculation using methods from Koerner et. al. (2005).

4) Cap Geomembrane Puncture – No Cushion Calculation using methods from Giroud et. al. (1995) and ASTM D 4833.

1.1 Cap Geomembrane Strain

Calculation 1), Cap Geomembrane Strain, analyzes the allowable multi-axial tensile strength (1,200 pounds per square inch (psi)) and strain (maximum 8 percent (%) for textured and 10% for smooth) of the LLDPE geomembrane against the required strain resulting from either a total settlement of the landfill waste mass or a localized subsidence (crack) in the cemented fly ash waste mass. The material properties for 40-mil thick LLDPE geomembrane were provided by GSE (2012). The factor of safety (FS) against tearing is found by dividing the allowable strength or strain for LLDPE geomembrane materials by the actual strength or strain from the estimated settlement or localized subsidence. Based on the calculations and methods used (see Attachment 1), the FS against unacceptable strain due to newly placed ash waste settlement is much greater than 3.0 for LLDPE. The high FS is due to the very low strain (0.01%) resulting from less than 1-inch of expected total settlement. Tearing due to localized subsidence has a FS of 3.0 for both textured and smooth LLDPE. Therefore, it can be concluded that the LLDPE's internal tensile strength is adequate to resist strain and tearing without the use of a cushion geotextile under the geomembrane for the J.C. Weadock closure cover.

1.2 Cap Geomembrane Puncture with Top Cushion

Calculation 2), Cap Geomembrane Puncture with Top Cushion, analyzes the allowable puncture resistance pressure of the geomembrane and geotextile cushion against the pressure applied by normal loading (equipment, soil, snow) and a nominal ¾-inch diameter angular particle (assume larger 2 inch particles will be removed prior to geomembrane placement). The current design includes a geocomposite drainage layer (10 oz/sy NW NP geotextiles heat bonded to either side of a 200-mil thick geonet core) placed on top of the geomembrane, however, the calculation will only consider the cushion benefit from the bottom layer of 10 oz/sy NW NP geotextile. The FS is again found by dividing the allowable pressure of the cushion geotextile by the actual normal pressures applied (equipment, snow, soil). Based on the calculations and methods used (see Attachment 3), the FS against puncture using a cushion geotextile on top of the LLDPE geomembrane is 6.7. Therefore, it can be concluded that a geotextile cushion on top of the LLDPE geomembrane has adequate internal puncture resistance for the Landfill closure cover. This does not take into account the added cushion and protection benefit from the other components of the geocomposite (200-mil thick geonet core and top geotextile).

For reference, the calculation for the geocomposite on top of the geomembrane includes an analysis of a 2-inch particle protrusion, should some of these particles not be removed prior to installation of the geomembrane, with the resulting FS = 1.9, which is acceptable.

Note that the calculation method used in Attachment 2 is a metric calculation; therefore, the parameters were converted from SI-units to metric for the purposes of the calculation.

1.3 Cap Geomembrane Puncture with Bottom Cushion

Calculation 3), Cap Geomembrane Puncture with Bottom Cushion, analyzes the allowable puncture resistance pressure of the geomembrane and geotextile cushion against the pressure applied by normal loading (equipment, soil, snow) and a typical ¾-inch diameter angular particle (assume larger 2-inch particles will be removed prior to geomembrane placement). This calculation assumes a 10 oz/sy NW NP geotextile under the liner and bases the allowable strength on Figure 5.8 in Koerner et. al. (2005). In general, "...the placement of a geotextile below and/or above a nonreinforced geomembrane greatly increases the puncture resistance of the geomembrane and essentially takes all the load before the geomembrane absorbs any of it." (Koerner et. al. 2005, page 450). Figure 5.8 (Koerner et. al. 2005) notes that the puncture resistance of a geotextile in front (on top) of a geomembrane is greater that the puncture resistance of a geotextile behind (below) a geomembrane. This difference is approximately 10 percent (%). The FS is again found by dividing the allowable pressure of the cushion geotextile by the actual normal pressures applied (equipment, snow, soil). Based on the calculations and methods used (see Attachment 3), the FS against puncture using a cushion geotextile under the LLDPE geomembrane is 6.1. Therefore, a geotextile cushion on top of the LLDPE geomembrane is more protective than a geotextile underneath the LLDPE geomembrane.

Note that the calculation method used in Attachment 2 is a metric calculation; therefore, the parameters were converted from SI-units to metric for the purposes of the calculation.

1.4 Cap Geomembrane Puncture – No Cushion

Calculation 4), Cap Geomembrane Puncture – No Cushion, analyzes the allowable puncture resistance of the geomembrane (tensile strength at break is 44 pounds force (lbf) for textured LLDPE and 56 lbf for smooth LLDPE) against the force applied by an 8 millimeter (8mm) diameter probe, as per ASTM D4833. Geomembrane manufacturers test/certify products for various properties including puncture resistance, using ASTM D4833. This test evaluates the resistance of an 8 millimeter (mm) probe pushing through a geomembrane fastened over a 1.8-inch diameter void. Consider the planned loading over an equivalent area for the Landfill closure cover, geomembrane only, and directly evaluate the results. The FS is then found by dividing the allowable force of the LLDPE geomembrane by the actual force applied by the probe, over a 1.8-inch diameter void, assuming there are equipment, soil, and snow normal loads applied. Based on the calculations and methods used (see Attachment 4), the FS of textured LLDPE against puncture is 1.9. The FS of smooth LLDPE against puncture is 2.4. So, it can be concluded that the smooth and textured LLDPE geomembrane has adequate internal puncture resistance without the use of a cushion geotextile under the liner, for the Landfill closure cover, specifically for the bottom ash sections.

It is good practice, however, to place a geotextile cushion above a geomembrane liner, to prevent damage during cover soil placement. The calculation that determines the FS against puncture for this case is described in Section 1.2.

1.5 Summary and Analysis

Table 1 – Summary of Results

Analysis	Factor of Safety		Acceptable?	
	Smooth LLDPE	Textured LLDPE	Smooth LLDPE	Textured LLDPE
Strain Due to Total Settlement	>>3	>>3	YES	YES
Tension Due to Localized Subsidence	3.0	3.0	YES	YES
Puncture Resistance with Top Cushion	6.7	6.7	YES	YES
Puncture Resistance with Bottom Cushion	6.1	6.1	YES	YES
Puncture Resistance with No Cushion	2.4	1.9	YES	YES

Based on the analysis, and in support of Koerner et. al. (2005) who notes that a cushion greatly increases puncture resistance, each condition, was found to have adequate resistance to puncture and tearing. However, as supported by the analysis, a geocomposite on top of the geomembrane is the most protective case. Therefore, the currently designed closure cover system is adequate to protect against strain, tearing, and puncture and adds an extra level of environmental protection using the geocomposite drainage layer to quickly route storm water away from the geomembrane and reduce head build-up.

2.0 CONSTRUCTION METHODS

Formal construction methods and construction quality assurance (CQA) is included with the Final Closure Plan Specifications and Drawings, but general guidance is included in Section 2.0. In addition to the engineering controls designed into the closure cover system, described in Section 1.0, proper construction methods are also recommended to ensure a proper installation.

2.1 Subgrade Preparation

Subgrade condition should be accepted by the Owner or the Owner's Representative, the CQA Officer or his/her representative and the Geosynthetics Contractor to verify that the subgrade is suitable for the installation of the overlying geosynthetics components.

Earthworks Contractor: The Earthworks Contractor shall perform all of the following during the preparation of subgrade for geosynthetics installation:

- Prepare the soil to a smooth surface, using a smooth drum roller or other suitable equipment, with grades which meet the construction drawings and grade tolerances.
- Remove debris, organic materials, roots, and angular or sharp rocks (3/4 inch or larger) or other material which may damage the geosynthetic components.
- Make any other repairs as deemed necessary by the CQA Officer or his/her representative.

CQA Officer or his/her representative: During the preparation of subgrade for geosynthetics installation, the CQA Officer or his/her representative shall verify that:

- The subgrade is properly prepared for the installation of geosynthetic materials and is in compliance with the project specifications.
- The underlying soil has been rolled, adequately compacted or hand-worked to be free of irregularities, protrusions, standing water, organic matter and abrupt changes in grade that may damage or adversely affect the performance of the geosynthetics.
- Elevations of the subgrade are verified before geosynthetics installation and are within the tolerance specified.
- Areas that do not meet the requirements of the project specifications are properly repaired and documented.

Geosynthetics Contractor: The Geosynthetics Contractor shall perform all of the following during the preparation of the subgrade for geosynthetics installation:

- Inspect the subgrade surface.
- Accept, with the Geosynthetics Contractor's signature on a Subgrade Acceptance Certification, that the soil surface is acceptable for geosynthetics installation prior to deployment of the geosynthetic material.

Once the subgrade is accepted, the Geosynthetics Contractor shall maintain and repair any defects resulting from the deployment and installation process.

Typical Photos of a Properly Prepared Subgrade:

Rock picking and smooth drum rolling.

Rock Picking

Completed, smoothed subgrade.

2.2 Prevention of Geomembrane Damage

The Geosynthetics Contractor shall be responsible to assure that:

- No wheeled vehicles shall traverse on the geosynthetics, other methods must be used to deploy the geocomposite over the geomembrane.
- Installation personnel do not use equipment or tools that may damage the geomembrane.
- No installation personnel shall smoke, wear damaging shoes, or engage in other activities that could damage the geomembrane.
- The method used to unroll the panels shall not cause scratches or crimps in the geomembrane and shall not damage the supporting soil.
- The method used to deploy the geomembrane shall minimize wrinkles.
- Bridging of grade changes by the geomembrane shall be removed as directed by, and at the discretion of the CQA Officer or his/her representative.

- Adequate loading (i.e. sandbags or similar items that shall not damage the geomembrane) shall be placed on the geomembrane to prevent uplift and relocation of panels by wind.
- Direct contact with the geomembrane shall be minimized (i.e. the geomembrane in traffic areas is to be protected by geotextiles, additional geomembrane layer, or other materials approved by the CQA Officer or his/her representative).

The CQA Officer or his/her representative shall perform the following activities regarding geomembrane placement:

- Verify that each panel is clearly identified, and its location noted.
- Verify and document that the panel deployment proceeds according to the panel layout drawing and that pertinent information including panel overlap is recorded.
- Visually observe the geomembrane for uniformity, damage and imperfections, including any of the following: holes, cracks, thin spots, tears, punctures, blisters or foreign material. Any problem identified in the geomembrane shall be repaired by the Geosynthetics Contractor such that the properties of the repaired areas meet the project specifications.

Typical Photo of Geocomposite Deployment:

Deploying geocomposite by hand, up or down slope.

2.1 Construction Methods / Placement

The Earthworks Contractor shall install the rooting layer and top soils in accordance with the following:

- Low ground-pressure tire or track equipment shall be utilized for work on the cover soil materials whenever the thickness of the cover soil material is less than 36 inches. The granular soil beneath roadways for transporting material over the closure cover side slopes shall be at least 36 inches thick at all times. Excessive rutting shall be prevented. No portion of any earthmoving equipment shall be allowed to contact the underlying geomembrane material at any time.
- Cover soils shall be placed to minimize stresses on the underlying geomembrane. Placement of granular soil shall generally proceed by pushing the granular soil up the side slope. No granular soil shall be allowed to fall or slide into place down the side slope.

The CQA Officer or his/her representative shall perform the following:

- Observe the placement of the granular soil and document soil material uniformity and the presence or absence of foreign materials.
- Observe for potential and actual damage to the geomembrane during cover soil placement. When damage is suspected, the geomembrane surface shall be exposed to verify its condition. Actual damage to the geomembrane shall be documented and repaired in accordance with procedures outlined in the specifications.
- Observe and document that the cover soil material meets the material specifications, placement procedures and thickness requirements of the project specifications.

Typical Photos of Soil Placement on Top of Geosynthetics:

Low ground pressure equipment with minimum 36-inch soil base.

Low ground pressure equipment pushing cover soils up the slope with adequate soil base.

<u>Low ground pressure equipment pushing cover soils up the slope with adequate soil base.</u>

3.0 REFERENCES

1) Giroud, J.P., et. Al., Theoretical Analysis of Geomembrane Puncture, Geosynthetics International, 1995, Vol. 2, No. 6.

2) GSE Manufacturer Data Sheet for Nonwoven Geotextile, 2014.

3) Polyflex Inc,. Geomembrane REFERENCE MANUAL, March 2014 update.

4) Koerner, R.M. (2005), Designing with Geosynthetics, Prentice Hall Publishing Co., Englewood Cliffs, NJ, 5th edition.

5) Peggs, Ian D, et al., Assessment of Maximum Allowable Strains in Polyethylene and Polypropylene Geomembranes, Geosynthetica, 2005.

6) GSE, Linear Low Density Polyethylene Textured Geomembrane Product Data Sheet, Updated February, 2012.

7) GSE, Linear Low Density Polyethylene Smooth Geomembrane Product Data Sheet, Updated March, 2012.

8) Qian, Xuede, Robert M. Koerner and Donald H. Gray, Geotechnical Aspects of Landfill Design and Construction, Prentice Hall, 2002.

9) ASTM D4833 Standard Test Method for Index Puncture Resistance of Geomembranes and Related Products.

4.0 ATTACHMENTS

1) Cap Geomembrane Strain and Strength Calculation

2) Cap Geomembrane Puncture with Top Cushion Calculation

3) Cap Geomembrane Puncture with Bottom Cushion Calculation

4) Cap Geomembrane Puncture – No Cushion Calculation

ATTACHMENT A

Cap Geomembrane Strain and Strength Calculation

ATTACHMENT 1 **CALCULATIONS**

Date:	22-Mar-18	**Made by:**	ACB
Project No.:	1773608	**Checked by:**	TDJ
Subject:	Cap Geomembrane Strain and Strength	**Reviewed by:**	DML
Project Short Title:	J.C. Weadock Dry Ash Landfill Closure Project		

1.0 OBJECTIVE

Determine whether the final cover geomembrane, 40-mil thick linear low density density polyethylene (LLDPE), has the allowable strain and strength to handle the normal stresses created from total waste mass settlement and localized subsidence.

2.0 GIVENS/ASSUMPTIONS

1) The maximum expected settlement is 1 inch (.08 feet). No settlement analysis for Weadock was performed.
2) GSE (Manufacturer) product information for 40-mil textured LLDPE geomembrane. (Ref. 1).
3) GSE (Manufacturer) product information for 40-mil smooth LLDPE geomembrane. (Ref. 2).
4) The longest slope length is 1,200 feet (measured in Auto CAD).
5) The maximum allowable strain (MAS) for the final cover geomembrane (LLDPE) varies depending on reference, per Reference 3, a textured LLDPE allowable strain is 8%. A high density (0.94 grams per cubic centimeter (g/cm^3)), smooth LLDPE has a allowable strain of 10%.
6) The allowable multiaxial tensile strength of the geomembrane is 1,200 pounds per square inch (psi) (Table 4.4, Ref. 4)
7) The proposed Final Cover system consists of (from top to bottom):

   6-inch (in) topsoil layer
   12-in rooting zone
   10 ounce per square yard (oz/sy) double sided geocomposite (GC) with 200 mil thick geonet core
   40-mil thick Linear Low Density Polyethylene (LLDPE) textured OR smooth geomembrane (TGM)
   6-in thick grading/cushion layer of fly ash

7) In place unit weight of the rooting zone and topsoil is assumed to be 125 pounds per cubic foot (pcf).
8) A localized subsidence of 1-foot is assumed as a worst case possibility for the Weadock site.

Date:	22-Mar-18	**Made by:**	ACB
Project No.:	1773608	**Checked by:**	TDJ
Subject:	Cap Geomembrane Strain and Strength	**Reviewed by:**	DML
Project Short Title:	J.C. Weadock Dry Ash Landfill Closure Project		

3.0 METHODS

A) GEOMEMBRANE STRAIN DUE TO TOTAL SETTLEMENT (REF. 4)

The factor of safety (FS) is calculated by:

$$FS = \frac{\varepsilon_{ALLOWABLE}}{\varepsilon_{ACTUAL}}$$

Where, ε = Strain

The following equation is used to calculate strain:

$$\text{Strain } (\varepsilon) = \frac{L_1 - L_0}{L_o}$$

Where, L_1 = new length of geomembrane after settlement (ft)
L_o = original length of geomembrane (ft)

Assume that the new length of the geomembrane is L_0 + the settlement.
Slope length is 1,200 feet = L_0.

Date:	22-Mar-18	**Made by:**	ACB
Project No.:	1773608	**Checked by:**	TDJ
Subject:	Cap Geomembrane Strain and Strength	**Reviewed by:**	DML
Project Short Title:	J.C. Weadock Dry Ash Landfill Closure Project		

3.0 METHODS cont.

B) GEOMEMBRANE TENSION (STRENGTH) DUE TO LOCALIZED SUBSIDENCE (REF. 4)

The factor of safety (FS) is calculated by:

$$FS = \frac{\sigma_{ALLOWABLE}}{\sigma_{REQUIRED}}$$

A FS >3 is considered acceptable.

Where, $\sigma_{ALLOWABLE}$ = allowable tensile strength of the geomembrane
$\sigma_{REQUIRED}$ = required tensile strength of geomembrane caused by subsidence

Multiaxial tensile strength (Mts) = 1,200 psi (from manufacturer, Ref. 4)

$$\sigma_{REQUIRED} = \gamma s \times Hcs \times L$$

$$\sigma_{ALLOWABLE} = Mts \times t$$

Where,

L = distance between symmetric axis and top edge of subsidence (ft)
γs = unit weight of cover soils (pcf)
Hcs = thickness of cover soils (ft)
t = thickness of geomembrane (in)
Mts = multiaxial tensile strength (psi)

Date:	22-Mar-18	**Made by:**	ACB
Project No.:	1773608	**Checked by:**	TDJ
Subject:	Cap Geomembrane Strain and Strength	**Reviewed by:**	DML
Project Short Title:	J.C. Weadock Dry Ash Landfill Closure Project		

4.0 CALCULATIONS

A) GEOMEMBRANE STRAIN DUE TO TOTAL SETTLEMENT (REF. 4)

Calculate the final thickness of waste mass = Original Height - Total Settlement =

Total Settlement = 0.08 ft
Slope length of Geomembrane (original length) = 1200 ft

Calculate the initial and final lengths of the geomembrane after settlement:

L_o = 1,200.0 ft
L_1 = 1,200.1 ft

Calculate the change in length of the geomembrane:

ΔL = 0.1 ft

Calculate the strain:

Strain (ε) = 0.01 % < 8% ok for textured LLDPE
< 10% ok for smooth LLDPE

Calculate the Factor of Safety for textured LLDPE:

FS = 8% / calculated strain

FS = 1,200 OK >> 3

Calculate the Factor of Safety for smooth LLDPE:

FS = 10% / calculated strain

FS = 1,500 OK >> 3

Date:	22-Mar-18	**Made by:**	ACB
Project No.:	1773608	**Checked by:**	TDJ
Subject:	Cap Geomembrane Strain and Strength	**Reviewed by:**	DML

Project Short Title: J.C. Weadock Dry Ash Landfill Closure Project

4.0 CALCULATIONS cont.

B) GEOMEMBRANE TENSION DUE TO LOCALIZED SUBSIDENCE (REF. 4)

Mts = 1,200 psi (from manufacturer, Ref. 4)

$\sigma_{REQUIRED} = \gamma s \times Hcs \times L$

$\sigma_{ALLOWABLE} =$ Mts x t = 48 ppi

L = 1 ft
γs = 125 pcf
Hcs = 1.5 ft
t = 0.04 in

$\sigma_{required} =$ 188 ppf
16 ppi

$$FS = \frac{\sigma_{ALLOWABLE}}{\sigma_{REQUIRED}}$$

FS = 3.1 OK >3

5.0 CONCLUSIONS

The strain on the final cover geomembrane due to the stresses imposed by the waste settlement predicted was calculated to be 0.01%. Textured LLDPE has an allowable strain of 8% with a factor of safety of >3. The smooth LLDPE has an allowable strain of 10% with a factor of safety of >3. These high factor of safety values are due to the small amount of total settlement which is resulting in a very small amount of strain put upon the geomembrane. Additionally, the tension in the geomembrane due to localized subsidence had a calculated factor of safety of 3. Therefore the final cover LLDPE geomembrane has the required tensile strength to withstand the normal stresses imposed by the waste stabilization process.

6.0 REFERENCES

1) GSE, Linear Low Density Polyethylene Textured Geomembrane Product Data Sheet.

2) GSE, Linear Low Density Polyethylene Smooth Geomembrane Product Data Sheet.

3) Peggs, Ian D, et al., *Assessment of Maximum Allowable Strains in Polyethylene and Polypropylene*

4) Qian, Xuede, Robert M. Koerner and Donald H. Gray, *Geotechnical Aspects of Landfill Design and Construction*, Prentice Hall, 2002.

ATTACHMENT B

Cap Geomembrane Puncture with Top Cushion Calculation

Golder Associates

ATTACHMENT 2 **CALCULATIONS**

Date:	22-Mar-18	**Made by:**	ACB
Project No.:	1773608	**Checked by:**	TDJ
Subject:	Cap Geomembrane Puncture with Top Cushion	**Reviewed by:**	DML
Project Short Title:	J.C. Weadock Dry Ash Landfill Closure Project		

1.0 OBJECTIVE

To evaluate the puncture resistance of 40 mil thick LLDPE geomembrane when overlain by a double sided geocomposite using soil, snow, and equipment loading.

2.0 GIVENS/ASSUMPTIONS

1) GSE (Manufacturer) product information for 40-mil textured LLDPE geomembrane. (Ref. 1).
2) GSE (Manufacturer) product information for 40-mil smooth LLDPE geomembrane. (Ref. 2).
3) The proposed Final Cover system consists of (from top to bottom):

   6-inch (in) topsoil layer
   12-in rooting zone
   10 ounce per square yard (oz/sy) double sided geocomposite (GC) with 200 mil thick geonet core
   40-mil thick Linear Low Density Polyethylene (LLDPE) textured OR smooth geomembrane (TGM).
   6-in thick grading/cushion layer of fly ash

4) In place unit weight of the rooting zone and topsoil is assumed to be 125 pounds per cubic foot (pcf).
5) The average diameter particle size that could damage the geomembrane is 3/4-inch diameter angular particle and up to 2-inch in diameter.
6) The normal pressure exerted by the cover soils is 125 pcf x 1.5 ft thickness = 188 pounds per square foot (psf).
7) The normal pressure exerted by typical low ground pressure installation equipment is 5 pounds per square inch (psi) or 720 pounds per square foot (psf) at the liner
8) Typical snow loading is 40 psf.
9) Total normal loading pressures are soils + equipment + snow = 188 psf + 720 psf + 40 psf = 948 psf
10) The Modification Factors and Reduction Factors for LLDPE geomembrane are comparable to those of HDPE geomembrane

Date:	22-Mar-18	**Made by:**	ACB
Project No.:	1773608	**Checked by:**	TDJ
Subject:	Cap Geomembrane Puncture with Top Cushion	**Reviewed by:**	DML
Project Short Title:	J.C. Weadock Dry Ash Landfill Closure Project		

3.0 METHODS

The method presented herein (Koerner, 2005) focuses on the protection of 40 mil (1.0 mm) thick HDPE textured geomembrane. The method uses the design by function approach.

$$FS = P_{allow} / P_{actual}$$

where:
FS = factor of safety against geomembrane puncture.
P_{actual} = actual pressure due to the cover soils and equipment loads.
P_{allow} = allowable pressure using different types of geotextiles and site specific conditions.

The allowable pressure, P_{allow} is determined by the following equation:

$$P_{allow} = [50 + 0.00045^* (M/H^2)] * [1/(MFs^* MF_{PD} * MF_{A})] * [1/(RF_{CR} * RF_{CBD})]$$

where:
P_{allow} = allowable pressure (kPa)
M = geotextile mass per unit area (g/m^2)
H = protrusion height (m)
MFs = modification factor for protrusion shape
MF_{PD} = modification factor for packing density
MF_{A} = modification factor for arching in solids
RF_{CR} = reduction factor for long-term creep
RF_{CBD} = reduction factor for long-term chemical/biological degradation

Golder Associates

ATTACHMENT 2 **CALCULATIONS**

Date:	22-Mar-18	**Made by:**	ACB
Project No.:	1773608	**Checked by:**	TDJ
Subject:	Cap Geomembrane Puncture with Top Cushion	**Reviewed by:**	DML
Project			
Short Title:	J.C. Weadock Dry Ash Landfill Closure Project		

4.0 CALCULATIONS

Evaluate the factor of safety against geomembrane puncture when an 10 oz/sy nonwoven geotextile on a double sided geocomposite overlies the geomembrane.

Table 1 - Modification Factors and Reduction Factors for Geomembrane Protection Design (reference 1).

MF_s		MF_{PD}		MF_A	
Angular:	1	Isolated	1	Hydrostatic	1
Subrounded:	0.5	Dense, 38 mm	0.83	Geostatic, shallow	0.75
Rounded:	0.25	Dense, 25 mm	0.67	Geostatic, mod.	0.5
		Dense, 12mm	0.5	Geostatic, deep	0.25

RF_{CBD}	
Mild leachate	1.1
Moderate leachate	1.3
Harsh leachate	1.5

RF_{CR}			
Mass per unit area (g/m^2)	Protrusion (mm)		
	38	25	12
Geomembrane alone	N/R	N/R	N/R
270	N/R	N/R	>1.5
550	N/R	1.5	1.3
1100	1.3	1.2	1.1
>1100	1.2	1.1	1

- Geotextile mass per unit area, M = 339 g/m^2 (10 oz/sy).
- Depth of material on top of geomembrane, d = 0.46 m (Max. Cover)
- Unit weight of material on top of geomembrane, γ = 19.6 kN/m^3 (125 pcf)
- Pressure from equipment loading = 34.4 kPa
- Pressure from snow loading = 1.9 kPa

- Protrusion height, H = 0.01905 m (0.75 inches average)
- Modification and Reduction Factors:

MF_S = 1 assume angular particles

MF_{PD} = 1

MF_A = 1

RF_{CR} = 1.5

RF_{CBD} = 1.1 storm water

For a 3/4-inch particle size:

$$P_{allow} = [50 + 0.00045 * (M/H^2)] * [1/(MFs * MF_{PD} * MF_A)] * [1/(RF_{CR} * RF_{CBD})]$$

P_{allow} = 305 kPa

P_{actual} = $d * \gamma$ + Pequip + Psnow = 45.3 kPa

***FS* =** $\frac{305}{45}$ = 6.7 **OK for 3/4-inch particle**

ATTACHMENT 2 **CALCULATIONS**

Date:	22-Mar-18	**Made by:**	ACB
Project No.:	1773608	**Checked by:**	TDJ
Subject:	Cap Geomembrane Puncture with Top Cushion	**Reviewed by:**	DML
Project Short Title:	J.C. Weadock Dry Ash Landfill Closure Project		

4.0 CALCULATIONS cont.

For a 2-inch particle size: • Protrusion height, H = 0.0508 m (2 inches)

$$P_{allow} = [50 + 0.00045 * (M/H^2)] * [1/(MFs * MF_{PD} * MF_A)] * [1/(RF_{CR} * RF_{CBD})]$$

P_{allow} = 86 kPa

P_{actual} = $d * \gamma +$ Pequip + Psnow = 45.3 kPa

$$\textbf{\textit{FS}} = \frac{86}{45} = 1.9$$ **OK for 2-inch particle**

5.0 CONCLUSION

The results show a factor of safety against geomembrane puncture of 6.7, when the geomembrane is overlain by a 10 oz/sy non-woven, needle punched geotextile on a double sided geocomposite. This calculation does not take into account the added protection from the 300-mil thick geonet core or additional 10 oz/sy non-woven geotextile components of the geocomposite.

6.0 REFERENCES

1) GSE, Linear Low Density Polyethylene Textured Geomembrane Product Data Sheet.

2) GSE, Linear Low Density Polyethylene Smooth Geomembrane Product Data Sheet.

3) Koerner, R.M. (2005), *Designing with Geosynthetics*, Prentice Hall Publishing Co., Englewood Cliffs, NJ, 5th edition.

4) GSE manufacturer data sheet for nonwoven geotextile, 2018.

ATTACHMENT C

Cap Geomembrane Puncture with Bottom Cushion Calculation

ATTACHMENT 3 | CALCULATIONS

Date:	22-Mar-18	**Made by:**	ACB
Project No.:	1773608	**Checked by:**	TDJ
Subject:	Cap Geomembrane Puncture with Bottom Cushion	**Reviewed by:**	DML
Project Short Title:	J.C. Weadock Dry Ash Landfill Closure Project		

1.0 OBJECTIVE

To evaluate the puncture resistance of 40 mil thick LLDPE geomembrane when underlain by a geotextile only - using soil, snow, and equipment loading.

2.0 GIVENS/ASSUMPTIONS

1) GSE (Manufacturer) product information for 40-mil textured LLDPE geomembrane. (Ref. 1).
2) GSE (Manufacturer) product information for 40-mil smooth LLDPE geomembrane. (Ref. 2).
3) The proposed Final Cover system consists of (from top to bottom):

   6-inch (in) topsoil layer
   12-in rooting zone
   40-mil thick Linear Low Density Polyethylene (LLDPE) textured OR smooth geomembrane (TGM).
   10 ounce per square yard (oz/sy) geotextile
   6-in thick grading/cushion layer of fly ash

4) In place unit weight of the rooting zone and topsoil is assumed to be 125 pounds per cubic foot (pcf).
5) The average diameter particle size that could damage the geomembrane is 3/4-inch diameter angular particle.
6) The normal pressure exerted by the cover soils is 125 pcf x 1.5 ft thickness = 188 pounds per square foot (psf).
7) The normal pressure exerted by typical low ground pressure installation equipment is 5 pounds per square inch (psi) or 720 pounds per square foot (psf) at the liner
8) Typical snow loading is 40 psf.
9) Total normal loading pressures are soils + equipment + snow = 188 psf + 720 psf + 40 psf = 948 psf
10) The reduction in puncture resistance of the geomembrane, found in Figure 5.8 of reference 1, is the same for LLDPE as it is for HDPE.
11) The Modification Factors and Reduction Factors for LLDPE geomembrane are comparable to those of HDPE geomembrane

Date:	22-Mar-18	**Made by:**	ACB
Project No.:	1773608	**Checked by:**	TDJ
Subject:	Cap Geomembrane Puncture with Bottom Cushion	**Reviewed by:**	DML
Project Short Title:	J.C. Weadock Dry Ash Landfill Closure Project		

3.0 METHODS

The method presented herein (Koerner, 2005) focuses on the protection of 60 mil (1.5 mm) thick HDPE textured geomembrane. The method uses the design by function approach.

$$FS = P_{allow} / P_{actual}$$

where:

FS = factor of safety against geomembrane puncture.

P_{actual} = actual pressure due to the cover soils and equipment loads.

P_{allow} = allowable pressure using different types of geotextiles and site specific conditions.

The allowable pressure, P_{allow} is determined by the following equation:

$$P_{allow} = [50 + 0.00045^* (M/H^2)] * [1/(MFs^* MF_{PD} * MF_A)] * [1/(RF_{CR} * RF_{CBD})]$$

where:
P_{allow} = allowable pressure (kPa)
M = geotextile mass per unit area (g/m^2)
H = protrusion height (m)
MFs = modification factor for protrusion shape
MF_{PD} = modification factor for packing density
MF_A = modification factor for arching in solids
RF_{CR} = reduction factor for long-term creep
RF_{CBD} = reduction factor for long-term chemical/biological degradation

As noted with Figure 5.8 (Reference 3), '...the placement of a geotextile below and/or above a nonreinforced geomembrane greatly increases the puncture resistance of the geomembrane and essentially takes all the load before the geomembrane absorbs any of it." (Reference 3, page 450).

Figure 5.8 notes that the puncture resistance of a geotextile in front (on top) of a geomembrane is greater that the puncture resistance of a geotextile behind (below) a geomembrane. This difference is approximately 10 percent (%).

ATTACHMENT 3 **CALCULATIONS**

Date:	22-Mar-18	**Made by:**	ACB
Project No.:	1773608	**Checked by:**	TDJ
Subject:	Cap Geomembrane Puncture with Bottom Cushion	**Reviewed by:**	DML
Project Short Title:	J.C. Weadock Dry Ash Landfill Closure Project		

3.0 METHODS cont.

Figure 5.8 from Reference 1 is below:

2000 N for reinforced geomembranes. Here again the influence of the scrim reinforcement is seen. Note that the placement of a geotextile below and/or above a nonreinforced geomembrane greatly increases the puncture resistance of the geomembrane and essentially takes all the load before the geomembrane absorbs any of it. The results of the test for varying thicknesses of HDPE geomembrane are shown in Figure 5.8. As

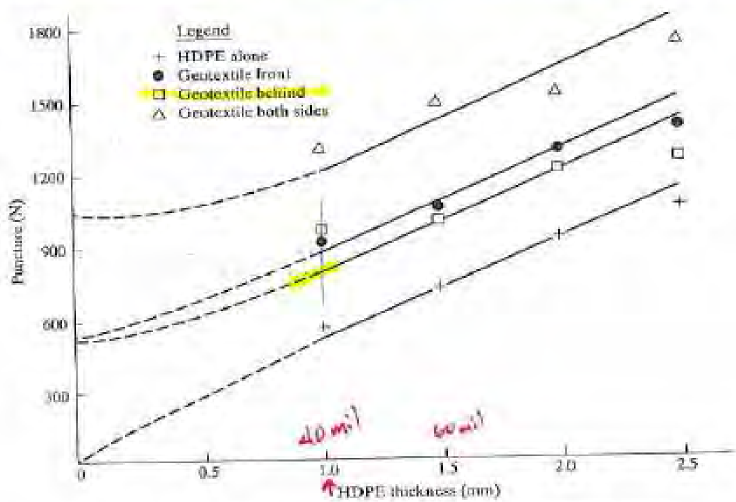


Figure 5.8 Beveled flat-tip puncture test results on varying thicknesses of HDPE geomembranes and different combinations of geomembranes with 400 g/m² nonwoven needle-punched geotextiles. (After Koerner et al. [14])

Golder Associates

ATTACHMENT 3 **CALCULATIONS**

Date:	22-Mar-18	**Made by:**	ACB
Project No.:	1773608	**Checked by:**	TDJ
Subject:	Cap Geomembrane Puncture with Bottom Cushion	**Reviewed by:**	DML
Project Short Title:	J.C. Weadock Dry Ash Landfill Closure Project		

4.0 CALCULATIONS

Evaluate the factor of safety against geomembrane puncture when an 10 oz/sy nonwoven geotextile is placed under the geomembrane, using an approximate reduction in puncture reistance of 10%.

Table 1 - Modification Factors and Reduction Factors for Geomembrane Protection Design (reference 3).

MF_S		MF_{PD}		MF_A	
Angular:	1	Isolated	1	Hydrostatic	1
Subrounded:	0.5	Dense, 38 mm	0.83	Geostatic, shallow	0.75
Rounded:	0.25	Dense, 25 mm	0.67	Geostatic, mod.	0.5
		Dense, 12mm	0.5	Geostatic, deep	0.25

RF_{CBD}		RF_{CR}			
		Mass per unit area (g/m^2)	Protrusion (mm)		
			38	25	12
Mild leachate	1.1	Geomembrane alone	N/R	N/R	N/R
Moderate leachate	1.3	270	N/R	N/R	>1.5
Harsh leachate	1.5	550	N/R	1.5	1.3
		1100	1.3	1.2	1.1
		>1100	1.2	1.1	1

- Geotextile mass per unit area, M = 339 g/m^2 (10 oz/sy).
- Depth of material on top of geomembrane, d = 0.46 m (Max. Cover)
- Unit weight of material on top of geomembrane, γ = 19.6 kN/m^3 (125 pcf)
- Pressure from equipment loading = 34.4 kPa
- Pressure from snow loading = 1.9 kPa

- Protrusion height, H = 0.01905 m (0.75 inches max.)
- Modification and Reduction Factors:

MF_S = 1 assume angular particles

MF_{PD} = 1

MF_A = 1

RF_{CR} = 1.5

RF_{CBD} = 1.1 storm water

$$P_{allow} = [50 + 0.00045*(M/H^2)] * [1/(MFs* MF_{PD} * MF_A)] * [1/(RF_{CR} * RF_{CBD})]$$

P_{allow} -10% = 274 kPa

P_{actual} = d * γ + Pequip + Psnow = 45.3 kPa

$$\textbf{\textit{FS}} = \frac{274}{45} = 6.1$$ **OK**

ATTACHMENT 3 **CALCULATIONS**

Date:	22-Mar-18	**Made by:**	ACB
Project No.:	1773608	**Checked by:**	TDJ
Subject:	Cap Geomembrane Puncture with Bottom Cushion	**Reviewed by:**	DML
Project Short Title:	J.C. Weadock Dry Ash Landfill Closure Project		

5.0 CONCLUSION

The results show a factor of safety against geomembrane puncture of 6.1 for a geotextile under the liner which is less than the FS of a geotextile over the geomembrane (6.7) as noted in Attachment 2.

6.0 REFERENCES

1) GSE, Linear Low Density Polyethylene Textured Geomembrane Product Data Sheet.

2) GSE, Linear Low Density Polyethylene Smooth Geomembrane Product Data Sheet.

3) Koerner, R.M. (2005), *Designing with Geosynthetics* , Prentice Hall Publishing Co., Englewood Cliffs, NJ, 5th edition.

4) GSE manufacturer data sheet for nonwoven geotextile, 2018.

ATTACHMENT D

Cap Geomembrane Puncture – No Cushion Calculation

ATTACHMENT 4 CALCULATIONS

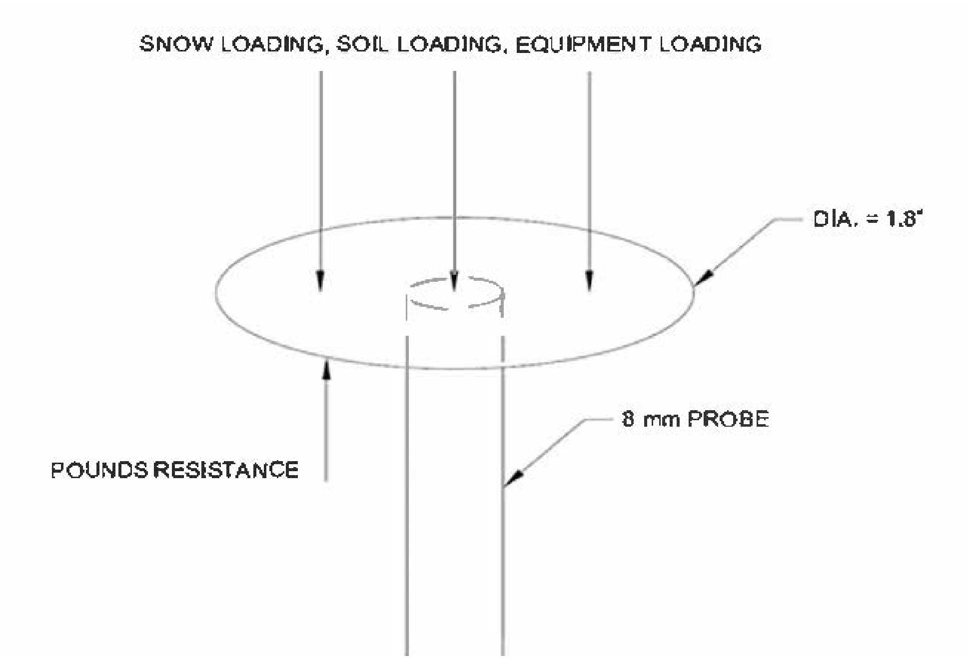
Date:	22-Mar-18	**Made by:**	ACB
Project No.:	1773608	**Checked by:**	TDJ
Subject:	Cap Geomembrane Puncture - No Cushion	**Reviewed by:**	DML
Project			
Short Title:	J.C. Weadock Dry Ash Landfill Closure Project		

1.0 OBJECTIVE

Consideration of the puncture resisance of both textured and smooth 40-mil LLDPE geomembrane liner without consideration of geotextile cushion.

2.0 APPROACH

Geomembrane manufacturers test/certify products for various properties including puncture resistance, using ASTM D4833. This test evaluates the resistance of an 8 millimeter (mm) probe pushing through a geomembrane fastened over a 1.8 inch diameter void. Consider the planned loading over an equivalent area for the JC Weadock Closure Cover, geomembrane only, and directly evaluate the results.



Date:	22-Mar-18	**Made by:**	ACB
Project No.:	1773608	**Checked by:**	TDJ
Subject:	Cap Geomembrane Puncture - No Cushion	**Reviewed by:**	DML
Project Short Title:	J.C. Weadock Dry Ash Landfill Closure Project		

3.0 GIVENS/ASSUMPTIONS

1) GSE (Manufacturer) product information for 40-mil textured LLDPE geomembrane. (Ref. 1).
2) GSE (Manufacturer) product information for 40-mil smooth LLDPE geomembrane. (Ref. 2).
3) The proposed Final Cover system consists of (from top to bottom):

   6-inch (in) topsoil layer
   12-in rooting zone
   40-mil thick Linear Low Density Polyethylene (LLDPE) textured OR smooth geomembrane (TGM).
   6-in thick grading/cushion layer of fly ash

4) In place unit weight of the rooting zone and topsoil is assumed to be 125 pounds per cubic foot (pcf).
5) The normal pressure exerted by the cover soils is 125 pcf x 1.5 ft thickness = 188 pounds per square foot (psf).
6) The normal pressure exerted by typical low ground pressure installation equipment is 5 pounds per square inch (psi) or 720 pounds per square foot (psf) at the liner
7) Typical snow loading is 40 psf.
8) Total normal loading pressures are soils + equipment + snow = 188 psf + 720 psf + 40 psf = 948 psf

Date: 22-Mar-18
Project No.: 1773608
Subject: Cap Geomembrane Puncture - No Cushion
Project Short Title: J.C. Weadock Dry Ash Landfill Closure Project

Made by: ACB
Checked by: TDJ
Reviewed by: DML

4.0 METHODS/CALCULATIONS

A) SMOOTH GEOMEMBRANE PUNCTURE FROM ANGULAR PARTICLES (REF. 3)

The factor of safety (FS) is calculated by:

$$FS = \frac{F_{ALLOWABLE}}{F_{ACTUAL}}$$

Where, F = force in pound-force (lbf) or newtons (N)

The following equation, developed by J.P. Giroud, et. Al. in 1995, is used to calculate the point force exerted by a particle on the geomembrane with a given normal pressure (see eqn. 38 in Reference 3):

$F_{ALLOWABLE}$ = 56 pounds force (lbf)

$$F_{ACTUAL} \quad \frac{(\pi/4)\, d_s^2\, p_p}{t_{GM}} \times Dm$$

Where, d_s = diameter of angular particle (ft)
p_p = normal pressure from overlying cover soils and equipment loads (psf)
t_{GM} = thick of geomembrane (ft)
Dm = diameter of void (geomembrane)

d_s = 0.31 in (8 mm pole)
d_s = 0.03 ft
p_p = 948 psf
t_{GM} = 40 mil
t_{GM} = 0.0033 ft
Dm = 0.1500 ft (1.8 inches)

$$F_{ACTUAL} = \frac{(\pi/4)\, d_s^2\, p_p}{t_{GM}} \times Dm = \quad 23 \text{ lbf}$$

$$\mathbf{FS} = \frac{F_{ALLOWABLE}}{F_{ACTUAL}} = \mathbf{2.4}$$ **OK**

Date:	22-Mar-18	**Made by:**	ACB
Project No.:	1773608	**Checked by:**	TDJ
Subject:	Cap Geomembrane Puncture - No Cushion	**Reviewed by:**	DML
Project Short Title:	J.C. Weadock Dry Ash Landfill Closure Project		

B) TEXTURED GEOMEMBRANE PUNCTURE FROM ANGULAR PARTICLES (REF. 3)

The factor of safety (FS) is calculated by:

$$FS = \frac{F_{ALLOWABLE}}{F_{ACTUAL}}$$

Where, F = force in pound-force (lbf) or newtons (N)

The following equation, developed by J.P. Giroud, et. Al. in 1995, is used to calculate the point force exerted by a particle on the geomembrane with a given normal pressure (see eqn. 38 in Reference 3):

$F_{ALLOWABLE}$ = 44 pounds force (lbf)

$$F_{ACTUAL} \quad \frac{(\pi/4)\, d_s^2\, p_p}{t_{GM}} \times Dm$$

Where, d_s = diameter of angular particle (ft)
p_p = normal pressure from overlying cover soils and equipment loads (psf)
t_{GM} = thick of geomembrane (ft)
Dm = diameter of void (geomembrane)

d_s =	0.31	in (8 mm pole)
d_s =	0.03	ft
p_p =	948	psf
t_{GM} =	40	mil
t_{GM} =	0.0033	ft
Dm =	0.1500	ft (1.8 inches)

$$F_{ACTUAL} = \frac{(\pi/4)\, d_s^2\, p_p}{t_{GM}} \times Dm = \quad 23 \quad \text{lbf}$$

$$\mathbf{FS} = \frac{F_{ALLOWABLE}}{F_{ACTUAL}} = \mathbf{1.9} \quad \textbf{OK}$$

Date:	22-Mar-18	**Made by:**	ACB
Project No.:	1773608	**Checked by:**	TDJ
Subject:	Cap Geomembrane Puncture - No Cushion	**Reviewed by:**	DML
Project Short Title:	J.C. Weadock Dry Ash Landfill Closure Project		

4.0 CONCLUSIONS

The smooth geomembrane alone is resistant to puncture, per the methods noted. The textured geomembrane alone was less resistant to puncture, per the noted methods, but still acceptable.

5.0 REFERENCES

1) GSE, Linear Low Density Polyethylene Textured Geomembrane Product Data Sheet.

2) GSE, Linear Low Density Polyethylene Smooth Geomembrane Product Data Sheet.

3) Giroud, J.P., et. Al., *Theoretical Analysis of Geomembrane Puncture* , Geosynthetics International, 1995, Vol. 2, No. 6.

4) ASTM D4833 Standard Test Method for Index Puncture Resistance of Geomembranes and Related Products.

APPENDIX F
AIRSPACE CALCULATION

CALCULATION SHEET

Client CEC	**Subject** Airspace Calculation		
Project J.C. Weadock Dry Ash Landfill		**Prepared By** JSH	**Date** 11/13/18
		Reviewed By JDP	**Date** 11/13/18
		Approved By DML	**Date** 11/13/18

AIRSPACE CALCULATION

Objective

Determine the difference in airspace from the 2011 Revised Closure Plan top of ash grades versus the 2018 Revised Closure Plan – Rev-01 top of ash grades. This will demonstrate a reduction in airspace from the 2011 Revised Closure Plan. Also determine the remaining airspace by comparing the most recent survey data with the proposed 2018 top of ash grades. This will report the remaining airspace to be filled to reach the proposed closure grades.

Calculations

Computer generated surfaces by AutoCAD Civil 3D (CAD) was used to calculate the volumes summarized in the Objective above and the CAD output is provided in Attachment 1. Table 1 below provides a summary of the results and Attachment 1 provides the CAD output.

TABLE 1- AIRSPACE SUMMARY

Surface Evaluation	Cut Volume (CY)	Fill Volume (CY)	Net Volume (CY)
2011 Top of Ash versus 2018 Top of Ash	8,810,357	415,627	8,394,730 (Cut)
Existing Topography versus 2018 Top of Ash	558,326	2,952,435	2,394,109 (Fill)

Conclusions

The airspace currently permitted (2011) will be reduced by approximately 8,394,730 CY and will provide CEC with approximately 2,394,109 CY of remaining airspace to close at the proposed (2018) grades.

ATTACHMENT 1

Cut/Fill Report

Generated:	2018-11-13 12:06:39
By user:	STAnderson
Drawing:	P:\0 projects\Consumers Energy\1773608 JC Weadock Dry Ash Landfill Closure Plan\CAD\VOLUMES\P:\0 projects\Consumers Energy\1773608 JC Weadock Dry Ash Landfill Closure Plan\CAD\VOLUMES\1773608_JCW_DAL_CP_Prop-Grading_MODELS_VOLUMES.dwg

Volume Summary

Name	Type	Cut Factor	Fill Factor	2d Area (Sq. Ft.)	Cut (Cu. Yd.)	Fill (Cu. Yd.)	Net (Cu. Yd.)
VOLUME1_JCW-DAL-EXGR_04-13_08-16_08-17B_DikeFC-vs-JCW-DAL-PROP-TOP-OF-ASH	full	1.000	1.000	11846987.59	558326.36	2952435.08	2394108.72<Fill>

Totals

	2d Area (Sq. Ft.)	Cut (Cu. Yd.)	Fill (Cu. Yd.)	Net (Cu. Yd.)
Total	11846987.59	558326.36	2952435.08	2394108.72<Fill>

* Value adjusted by cut or fill factor other than 1.0

Cut/Fill Report

Generated:	2018-11-13 12:08:06
By user:	STAnderson
Drawing:	P:\0 projects\Consumers Energy\1773608 JC Weadock Dry Ash Landfill Closure Plan\CAD\VOLUMES\P:\0 projects\Consumers Energy\1773608 JC Weadock Dry Ash Landfill Closure Plan\CAD\VOLUMES\1773608_JCW_DAL_CP_Prop-Grading_MODELS_VOLUMES.dwg

Volume Summary

Name	**Type**	**Cut Factor**	**Fill Factor**	**2d Area** (Sq. Ft.)	**Cut** (Cu. Yd.)	**Fill** (Cu. Yd.)	**Net** (Cu. Yd.)
VOLUME2_JCW-DAL-PROP-AECOM-FINAL-ASH-Dec2011-vs-JCW-DAL-PROP-TOP-OF-ASH	full	1.000	1.000	11577826.32	8810357.09	415627.32	8394729.77<Cut>

Totals

	2d Area (Sq. Ft.)	**Cut** (Cu. Yd.)	**Fill** (Cu. Yd.)	**Net** (Cu. Yd.)
Total	11577826.32	8810357.09	415627.32	8394729.77<Cut>

* Value adjusted by cut or fill factor other than 1.0