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Response to Items 11 & 12 from Ming's preliminary comments conveyed 3/21/09

David Garrett & Associates
Engineering and Geology

March 23, 2009

Fac/Perm/Co ID #	Date	Doc ID#
mingchao	3/23/09	DIN 7077

MEMORANDUM

RECEIVED MAR 23 2009 SOLID WASTE SECTION

TO: Ed Mussler, PE – NC DENR Solid Waste Section

CC: Ming Chao, PE – NC DENR Solid Waste Section

RE: A-1 Sandrock CDLF Engineering Plan Update
Permit #41-17 (Guilford County, NC)

Based on preliminary verbal comments received from Ming Chao, PE, I revisited the stability analysis presented in Section 2.5.2.1 in the A-1 Sandrock CDLF Facility Plan Update, Permit #41-17 (Rev. 0, dated 2/13/09), and offer the following observations. The following is presented as a courtesy in advance of any formal comments that might arise from the technical review. Graphical results are attached. Specific computer printouts are available upon request. The printout for the original analysis discussed in the February 2009 report is attached per Ming's request.

Ming suggested we consider another soil layer representing the final cover. In response I modeled a 3-foot thick compacted soil layer on the surface of the 3H:1V slope and 5% cap, termed "Layer #6" in the analysis with phi = 25, c = 100 psf, and unit weight = 115 pcf. I did not distinguish two layers because the driving factor for slope stability is the weight of the soils, thus assuming a full depth of the heavier soils would be the conservative approach – the topsoil would be lighter than the compacted barrier layer.

Beginning with the block failure analysis (non-seismic) for deep-seated stability, which had yielded a factor of safety of 1.85 as discussed on Page 12 of the Engineering Plan, the addition of the final cap increased the factor of safety to 2.12 (see below). This can be attributed to a confining effect on the C&D wastes – hence a slight increase in strength along the theoretical failure surface – due to the weight of the cover. All the following results start with the original analysis with the final cap. Please note that this is not an appropriate method for modeling the stability of the cover itself – typically this is done with a veneer stability analysis, as was presented in the 2/13/09 submittal.

I further looked at two variable strength factors for a "sensitivity analysis" that considered different strengths in the foundation soils and within the waste itself. Inasmuch as the foundation of this landfill is weathered saprolite and bedrock, I do not believe any real issues exist with regard to foundation strength.

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The results for the foundation soil evaluation are tabulated below:

Phi * (deg)	C * (psf)	Safety Factor	Run #
35-45	40-5000	2.12	CDLF10A2 (original run w/ final cap)
35	40	2.12	CDLF10A3
25	0	2.12	CDLF10A4
25	0	1.02	CDLF10A5 (waste phi = 15, c = 0)

*range of values for saprolite and bedrock, respectively

The foregoing analysis indicates that the stability is not sensitive to the foundation strength. Ostensibly, the actual foundation strength likely is higher than the modeled conditions. Please also realize that, based on more than 25 years of performing stability analyses – and analyzing actual slope failures in landfills and other slopes – I have generally found that the block analysis is the critical failure mode; that is, lower factors of safety are typically yielded by a block analyses for a given geometry, compared to a circular analysis.

The search routine used by the STABL 5M numerical model (and other contemporary engineering models) determines the lowest factor of safety for a series of trial failure geometries – in this case 100 possible trial surfaces were analyzed. The failure surface is invariable located at the base of the weakest layer. For landfills I have generally found the failure surface extends through the base of the waste – typically we use conservative estimates of shear strength properties – or within the liner, if one is present.

In all our models, an anticipated water mound was assumed to exist within the waste – independent of the water table within the foundation – which reduces the available shear strength (i.e., the forces resisting a slide) and adds to the weight above the failure surface (i.e., the driving forces).

Overall stability is quite sensitive to the strength of the waste. Varying this property can move the factor of safety to less than unity – 1.5 is the minimum desired for non-seismic analyses. I found an on-line article (see reference) that suggests that a friction angle of 23 degrees and a cohesion of 100 psf is appropriate. Strength properties for C&D wastes do not seem to be a well published topic, but it should be realized that the wastes are similar to compacted earthen embankment (albeit with non-homogeneous properties).

The results for the waste strength evaluation are tabulated below:

Phi (deg)	C (psf)	Safety Factor	Run #
15	0	1.02	CDLF10A6 (soil phi = 25, c = 50 psf)

15	20	1.07	CDLF10A7
15	40	1.12	CDLF10A8
20	20	1.40	CDLF10A12
20	30	1.43	CDLF10A14
20	40	1.45	CDLF10A10
23	20	1.61	CDLF10A11 (meets minimum Fs)
23	30	1.63	CDLF10A13
23	40	1.66	CDLF10A9

The foregoing suggests that with a minimum friction angle of 23 degrees in the C&D wastes and a moderate cohesion of at least 20 psf, the safety factor will meet or exceed the minimum requirement. I had used 25 degrees and 100 psf in the 2/13/09 submittal. Ostensibly, the friction and cohesion values entered into the stability analysis must be construed to represent macroscopic properties of the waste, not localized properties, which can vary considerably within the non-homogeneous waste.

I believe that the strength parameters used in the analysis producing safety factors higher than 1.5 are representative of the macroscopic properties of the waste. Also, the water mound assumed in the analysis likely will not exist, because the waste is free draining and the Operations Plan dictates waste placement practices that will minimize water buildup within the waste. I do not believe that stability will be a problem for the landfill with slopes constructed at 3H:1V.

If stability remains a concern for the SWS, the Operations Plan could be modified to include select waste placement practices within a predetermined setback from exterior slopes, i.e., wastes should be placed in horizontal lifts with no stratification of plastic-laden materials allowed within 30 feet of an exterior slope. These practices will avoid weaker materials being placed behind the slope and/or a potentially weak layer sloping toward the exterior slope. However, such provisions are not commonly mandated – certainly these are not required by the Solid Waste Rules – and it should be pointed out that deep-seated stability issues are not characteristically known at C&D landfills.

Reference: "Report of Geotechnical Investigation, Gentilly Landfill Slope Stability Analyses, New Orleans (Orleans Parish), Louisiana, for LA Department of Environmental Quality, Baton Rouge, Louisiana," Soil Testing Engineers, Inc., Jefferson, Louisiana, July 25, 2006, viewed on-line.

Please contact me if I can provide any additional data.

Sincerely,

G. David Garrett, P.G., P.E.
Consulting Engineer

** PCSTABL5M **

by
Purdue University

1

--Slope Stability Analysis--
Simplified Janbu, Simplified Bishop
or Spencer`s Method of Slices

Run Date: 03-22-09
Time of Run: 12:09am
Run By: DAVID GARRETT
Input Data Filename: C:CDLF10A2
Output Filename: C:CDLF10A2.OUT
Plotted Output Filename: C:CDLF10A2.PLT

PROBLEM DESCRIPTION A1 CDLF GLOBAL STABILITY, BLOCK ANALYSIS
W/FINAL COVER, WATER MOUNDING, NO EQUAKE

BOUNDARY COORDINATES

6 Top Boundaries
18 Total Boundaries

Boundary No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Soil Type Below Bnd
1	.00	60.00	68.00	77.00	5
2	68.00	77.00	121.00	90.00	4
3	121.00	90.00	126.00	92.00	3
4	126.00	92.00	142.00	98.00	2
5	142.00	98.00	325.00	153.00	6
6	325.00	153.00	666.00	183.00	6
7	142.00	98.00	168.00	98.00	2
8	168.00	98.00	325.00	150.00	1
9	325.00	150.00	666.00	180.00	1
10	168.00	98.00	192.00	98.00	2
11	192.00	98.00	666.00	140.00	2
12	126.00	92.00	192.00	98.00	3
13	192.00	98.00	666.00	132.00	3
14	121.00	90.00	192.00	98.00	3
15	121.00	90.00	192.00	93.00	4
16	192.00	93.00	666.00	126.00	4
17	68.00	77.00	192.00	86.00	5
18	192.00	86.00	666.00	86.00	5

1

ISOTROPIC SOIL PARAMETERS

6 Type(s) of Soil

Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	64.0	110.0	100.0	25.0	.00	.0	2
2	125.0	135.0	300.0	34.0	.00	.0	2
3	120.0	130.0	40.0	35.0	.00	.0	1
4	125.0	135.0	200.0	36.0	.00	.0	1
5	145.0	155.0	5000.0	45.0	.00	.0	1
6	115.0	115.0	100.0	35.0	.00	.0	2

1

2 PIEZOMETRIC SURFACE(S) HAVE BEEN SPECIFIED

Unit Weight of Water = 62.40

Piezometric Surface No. 1 Specified by 3 Coordinate Points

Point No.	X-Water (ft)	Y-Water (ft)
1	68.00	77.00
2	192.00	94.00
3	666.00	124.00

Piezometric Surface No. 2 Specified by 2 Coordinate Points

Point No.	X-Water (ft)	Y-Water (ft)
1	198.00	108.00
2	666.00	160.00

1

A Critical Failure Surface Searching Method, Using A Random Technique For Generating Sliding Block Surfaces, Has Been Specified.

10 Trial Surfaces Have Been Generated.

2 Boxes Specified For Generation Of Central Block Base

Length Of Line Segments For Active And Passive Portions Of Sliding Block Is 30.0

Box No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Height (ft)
1	180.00	92.00	200.00	95.00	10.00
2	250.00	100.00	350.00	120.00	10.00

1

Following Are Displayed The Ten Most Critical Of The Trial Failure Surfaces Examined. They Are Ordered - Most Critical First.

* * Safety Factors Are Calculated By The Modified Janbu Method * *

Failure Surface Specified By 6 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	174.79	107.85
2	193.20	98.37
3	328.66	110.78
4	348.90	132.92
5	370.10	154.14
6	371.70	157.11

*** 2.117 ***

Individual data on the 11 slices

Slice No.	Width Ft(m)	Weight Lbs(kg)	Water Force Top Lbs(kg)	Water Force Bot Lbs(kg)	Tie Force Norm Lbs(kg)	Tie Force Tan Lbs(kg)	Earthquake Force Hor Lbs(kg)	Earthquake Force Ver Lbs(kg)	Surcharge Load Lbs(kg)
1	9.0	3787.5	.0	240.1	.0	.0	.0	.0	.0
2	9.4	11928.9	.0	4068.3	.0	.0	.0	.0	.0
3	4.8	8360.0	.0	2750.0	.0	.0	.0	.0	.0
4	.3	521.0	.0	166.8	.0	.0	.0	.0	.0
5	126.7	330538.6	.0	82845.5	.0	.0	.0	.0	.0
6	3.7	12484.2	.0	2681.4	.0	.0	.0	.0	.0
7	12.0	32998.1	.0	6486.5	.0	.0	.0	.0	.0
8	8.3	15261.5	.0	.0	.0	.0	.0	.0	.0

9	21.0	20147.5	.0	.0	.0	.0	.0	.0	.0
10	.2	63.9	.0	.0	.0	.0	.0	.0	.0
11	1.6	259.6	.0	.0	.0	.0	.0	.0	.0

Failure Surface Specified By 5 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	175.45	108.05
2	186.29	97.50
3	335.71	114.56
4	354.10	138.27
5	364.04	156.43

*** 2.227 ***

1

Failure Surface Specified By 5 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	178.36	108.93
2	191.60	97.09
3	312.84	111.42
4	329.91	136.09
5	345.53	154.81

*** 2.298 ***

Failure Surface Specified By 5 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	169.13	106.16
2	184.59	91.51
3	281.12	110.49
4	301.93	132.10
5	305.88	147.25

*** 2.791 ***

1

Failure Surface Specified By 5 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	163.73	104.53
2	181.67	91.63
3	341.91	122.46
4	348.68	151.69
5	349.17	155.13

*** 2.864 ***

Failure Surface Specified By 5 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	180.90	109.69
2	197.90	96.01
3	313.47	110.65
4	322.42	139.29
5	336.25	153.99

*** 2.949 ***

1

Failure Surface Specified By 5 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	182.13	110.06
2	195.72	97.93
3	288.91	106.47
4	307.85	129.73
5	314.48	149.84

*** 2.961 ***

Failure Surface Specified By 6 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	160.50	103.56
2	161.78	102.32
3	190.45	93.49
4	295.36	111.76
5	301.18	141.19
6	307.66	147.79

*** 2.981 ***

1

Failure Surface Specified By 6 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	151.03	100.71
2	156.86	97.90
3	185.44	88.77
4	346.48	120.79
5	354.57	149.68
6	359.99	156.08

*** 3.027 ***

Failure Surface Specified By 6 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	157.07	102.53
2	181.73	89.72
3	273.24	101.55
4	293.70	123.49
5	312.70	146.71
6	314.77	149.93

*** 3.182 ***

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1
                 Y            A     X     I     S           F     T

             .00      83.25     166.50    249.75    333.00    416.25
X        .00 +------*--+---------+---------+---------+---------+
             -
             -
             -
             -
             -        *
       83.25 +
             -
             -
             -          *
             -           *
             -           9
A     166.50 +           *4
             -          421
             -         ***W
             -
             -
             -
X     249.75 +
             -
             -           04
             -            7 0
             -               484
             -            3   6*
I     333.00 +            12 3 6
             -              51 53
             -                292
             -                  1
             -
             -
S     416.25 +
             -
             -
             -
             -
             -
      499.50 +
             -
             -
             -
             -
             -
F     582.75 +
             -
             -
             -
             -
             -
T     666.00 +         *    *** W  *
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** PCSTABL5M **

by
Purdue University

1

--Slope Stability Analysis--
Simplified Janbu, Simplified Bishop
or Spencer`s Method of Slices

Run Date:	02-15-09
Time of Run:	10:42pm
Run By:	DAVID GARRETT
Input Data Filename:	C:CDLF10A1
Output Filename:	C:CDLF10A1.OUT
Plotted Output Filename:	C:CDLF10A1.PLT

PROBLEM DESCRIPTION A1 CDLF GLOBAL STABILITY, BLOCK ANALYSIS
WATER MOUNDING IN WASTE, NO EQUAKE

BOUNDARY COORDINATES

7 Top Boundaries
16 Total Boundaries

Boundary No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Soil Type Below Bnd
1	.00	60.00	68.00	77.00	5
2	68.00	77.00	121.00	90.00	4
3	121.00	90.00	126.00	92.00	3
4	126.00	92.00	142.00	98.00	2
5	142.00	98.00	168.00	98.00	2
6	168.00	98.00	325.00	150.00	1
7	325.00	150.00	666.00	180.00	1
8	168.00	98.00	192.00	98.00	2
9	192.00	98.00	666.00	140.00	2
10	126.00	92.00	192.00	98.00	3
11	192.00	98.00	666.00	132.00	3
12	121.00	90.00	192.00	98.00	3
13	121.00	90.00	192.00	93.00	4
14	192.00	93.00	666.00	126.00	4
15	68.00	77.00	192.00	86.00	5
16	192.00	86.00	666.00	86.00	5

1

ISOTROPIC SOIL PARAMETERS

5 Type(s) of Soil

Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	64.0	110.0	100.0	25.0	.00	.0	2
2	125.0	135.0	300.0	34.0	.00	.0	2
3	120.0	130.0	40.0	35.0	.00	.0	1
4	125.0	135.0	200.0	36.0	.00	.0	1
5	145.0	155.0	5000.0	45.0	.00	.0	1

1

2 PIEZOMETRIC SURFACE(S) HAVE BEEN SPECIFIED

Unit Weight of Water = 62.40

Piezometric Surface No. 1 Specified by 3 Coordinate Points

Point No.	X-Water (ft)	Y-Water (ft)
1	68.00	77.00
2	192.00	94.00
3	666.00	124.00

Piezometric Surface No. 2 Specified by 2 Coordinate Points

Point No.	X-Water (ft)	Y-Water (ft)
1	198.00	108.00
2	666.00	160.00

1

A Critical Failure Surface Searching Method, Using A Random Technique For Generating Sliding Block Surfaces, Has Been Specified.

10 Trial Surfaces Have Been Generated.

2 Boxes Specified For Generation Of Central Block Base

Length Of Line Segments For Active And Passive Portions Of Sliding Block Is 30.0

Box No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Height (ft)
1	180.00	92.00	200.00	95.00	10.00
2	250.00	100.00	350.00	120.00	10.00

1

Following Are Displayed The Ten Most Critical Of The Trial Failure Surfaces Examined. They Are Ordered - Most Critical First.

* * Safety Factors Are Calculated By The Modified Janbu Method * *

Failure Surface Specified By 5 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	183.77	103.22
2	193.20	98.37
3	328.66	110.78
4	348.90	132.92
5	369.91	153.95

*** 1.848 ***

Individual data on the 7 slices

Slice No.	Width Ft(m)	Weight Lbs(kg)	Water Force Top Lbs(kg)	Water Force Bot Lbs(kg)	Tie Force Norm Lbs(kg)	Tie Force Tan Lbs(kg)	Earthquake Force Hor Lbs(kg)	Earthquake Force Ver Lbs(kg)	Surcharge Load Lbs(kg)
1	9.4	4138.0	1336.9	4068.3	.0	.0	.0	.0	.0
2	4.8	4515.3	186.6	2750.0	.0	.0	.0	.0	.0
3	127.0	258806.9	.0	83012.2	.0	.0	.0	.0	.0
4	3.7	11222.8	.0	2681.4	.0	.0	.0	.0	.0
5	12.0	28875.4	.0	6486.5	.0	.0	.0	.0	.0
6	8.3	12399.8	.0	.0	.0	.0	.0	.0	.0
7	21.0	12899.2	.0	.0	.0	.0	.0	.0	.0

Failure Surface Specified By 5 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	182.03	102.65
2	192.18	94.63
3	333.51	117.99
4	353.51	140.35
5	362.47	153.30

*** 2.264 ***

1

Failure Surface Specified By 5 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	178.66	101.53
2	196.15	92.67
3	339.50	119.22
4	359.20	141.85
5	368.87	153.86

*** 2.474 ***

Failure Surface Specified By 5 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	182.09	102.67
2	197.33	90.68
3	328.61	119.30
4	347.44	142.65
5	356.46	152.77

*** 2.572 ***

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Failure Surface Specified By 5 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	175.22	100.39
2	184.59	91.51
3	281.12	110.49
4	301.93	132.10
5	304.86	143.33

*** 2.628 ***

Failure Surface Specified By 6 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	165.80	98.00
2	166.33	97.52
3	195.68	91.31
4	281.46	110.85
5	302.39	132.34
6	313.01	146.03

*** 2.650 ***

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Failure Surface Specified By 5 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	174.06	100.01
2	192.04	94.03
3	299.24	109.38
4	308.07	138.05
5	317.06	147.37

*** 2.816 ***

Failure Surface Specified By 5 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	150.09	98.00
2	157.05	92.99
3	186.77	88.85
4	293.74	112.94
5	300.44	141.87

*** 3.372 ***

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Failure Surface Specified By 5 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	184.49	103.46
2	198.13	90.58
3	274.58	102.24
4	288.41	128.86
5	300.59	141.92

*** 3.539 ***

Failure Surface Specified By 6 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	150.85	98.00
2	157.17	94.92
3	187.13	93.29
4	277.19	101.39
5	286.32	129.97
6	290.47	138.56

*** 3.933 ***

1

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           Y            A     X     I     S            F     T

            .00     83.25    166.50    249.75    333.00    416.25

X       .00 +------*--+---------+---------+---------+---------+
            -
            -
            -
            -
            -        *
      83.25 +
            -
            -
            -          *
            -           *
            -          88
A    166.50 +           *
            -          51
            -         ***W
            -
            -
            -
X    249.75 +
            -
            -           95
            -             8900
            -            7  55
            -                 *
I    333.00 +            12
            -               12
            -                32
            -                 1
            -
            -
S    416.25 +
            -
            -
            -
            -
            -
     499.50 +
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            -
            -
            -
            -
F    582.75 +
            -
            -
            -
            -
            -
T    666.00 +         *    *** W  *
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