SCS ENGINEERS

Location Restriction Compliance Demonstrations Phase 1 Modules 1 through 4

Columbia Dry Ash Disposal Facility

Prepared for:

Wisconsin Power and Light Company

Columbia Energy Center
W8375 Murray Road
Pardeeville, Wisconsin 53954

Prepared by:

SCS ENGINEERS
2830 Dairy Drive
Madison, Wisconsin 53718-6751
(608) 224-2830

October 2018
File No. 25217156.01

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P.E. Certification

I, Eric J. Nelson, hereby certify that the unstable areas demonstration prepared for Phase 1 Modules 1 through 3 at the Columbia Energy Center dry ash disposal facility meets the requirements in 40 CFR 257.64(a). This certification is based on my review of the October 2018 Location Restriction Compliance Demonstrations for Phase 1 Modules 1 through 4 prepared by SCS Engineers. I am a duly licensed Professional Engineer under the laws of the State of Wisconsin.

10/12/2018

(signature) (date)

Eric J. Nelson

(printed or typed name)

License number E-37855-6

My license renewal date is July 31, 2020.

Pages or sheets covered by this seal:

Location Restriction Compliance Demonstrations, Ph 1 Mod 1-4

P.E. Certification

I, Eric J. Nelson, hereby certify that the location restriction demonstrations prepared for Phase 1 Module 4 at the Columbia Energy Center dry ash disposal facility meet the requirements in 40 CFR 257.60(a), 61(a), 62(a), 63(a), and 64(a). This certification is based on my review of the October 2018 Location Restriction Compliance Demonstrations for Phase 1 Modules 1 through 4 prepared by SCS Engineers. I am a duly licensed Professional Engineer under the laws of the State of Wisconsin.

10/12/2018

(signature) (date)

Eric J. Nelson

(printed or typed name)

License number E-37855-6

My license renewal date is July 31, 2020.

Pages or sheets covered by this seal:

Location Restriction Compliance Demonstrations, Ph 1 Mod 1-4

1.0 INTRODUCTION AND PROJECT SUMMARY

On behalf of Wisconsin Power and Light Company (WPL), SCS Engineers (SCS) has prepared the enclosed Location Restriction Compliance Demonstrations for the Columbia (COL) Dry Ash Disposal Facility Phase 1 Module 4 (new coal combustion residual [CCR] landfill) as required by 40 CFR 257.60-64. This document also includes the Location Restriction Compliance Demonstrations for Phase 1 Modules 1 through 3 (existing CCR landfills) as required by 40 CFR 257.64, as stated below.

The COL dry ash disposal facility consists of three existing CCR units (Modules 1 through 3) located in Phase 1 of the facility. Phase 1 Module 4 of the facility is a new unit recently constructed.

Future proposed CCR units (Phase 1 Modules 5 through 6 and Phase 2 Modules 7 through 13) are permitted with the Wisconsin Department of Natural Resources (WDNR), but have not been developed. When developed, the units will be new CCR landfills, as defined in 40 CFR 257.53. This document addresses Phase 1 Modules 1 through 4. Future CCR units beyond Phase 1 Module 4 are not addressed and are not discussed further herein.

Figure 1 shows the site location. **Figure 2** shows the Phase 1 Modules 1 through 4 locations.

2.0 LOCATION RESTRICTIONS

§257.60. ***"Placement above the uppermost aquifer."***

"(a) New CCR landfills, existing and new CCR surface impoundments, and all lateral expansions of CCR units must be constructed with a base that is located no less than 1.52 meters (five feet) above the upper limit of the uppermost aquifer, or must demonstrate that there will not be an intermittent, recurring, or sustained hydraulic connection between any portion of the base of the CCR unit and the uppermost aquifer due to normal fluctuations in groundwater elevations (including the seasonal high water table). The owner or operator must demonstrate by the dates specified in paragraph (c) of this section that the CCR unit meets the minimum requirements for placement above the uppermost aquifer."

The high water table within the uppermost aquifer below the Phase 1 Module 4 unit is approximately elevation 789 feet above mean sea level (amsl) based on a review of water table observation well water levels near Phase 1 Module 4, for the period from April 2008 to August 2018; refer to **Appendix A**. As shown on **Figure 3**, the lowest base elevation within Phase 1 Module 4 is approximately 803 feet amsl. Based on this information, the Phase 1 Module 4 unit is located at least 5 feet above the uppermost aquifer.

The requirements in 40 CFR 257.60 do not apply to existing CCR units, thus are not applicable to Phase 1 Modules 1 through 3.

§257.61 *"Wetlands."*

"(a) New CCR landfills, existing and new CCR surface impoundments, and all lateral expansions of CCR units must not be located in wetlands, as defined in §232.2 of this chapter, unless the owner or operator demonstrates by the dates specified in paragraph (c) of this section that the CCR unit meets the requirements of paragraphs (a)(1) through (5) of this section."

The Phase 1 Module 4 unit is not located in wetlands as defined by 40 CFR 232.2. The location of Phase 1 Module 4 is shown in **Figure 2**, and maps from a September 25, 2017 wetland delineation study conducted by Mach IV, are included in **Appendix B**.

The requirements in 40 CFR 257.61 do not apply to existing CCR units, thus are not applicable to Phase 1 Modules 1 through 3.

§257.62 *"Fault areas."*

"(a) New CCR landfills, existing and new CCR surface impoundments, and all lateral expansions of CCR units must not be located within 60 meters (200 feet) of the outermost damage zone of a fault that has had displacement in Holocene time unless the owner or operator demonstrates by the dates specified in paragraph (c) of this section that an alternative setback distance of less than 60 meters (200 feet) will prevent damage to the structural integrity of the CCR unit."

Based on a review of the U.S. Geological Survey (USGS) Quaternary faults database and map as shown in **Appendix C**, the Phase 1 Module 4 CCR unit is not located within 200 feet of the outermost damage zone of a fault that has had displacement in Holocene time. In 40 CFR 257.53, Holocene is defined as the most recent epoch of the Quaternary period extending from 11,700 years before present, to present. The USGS map shows that no faults are located in Wisconsin.

The requirements in 40 CFR 257.62 do not apply to existing CCR units, thus are not applicable to Phase 1 Modules 1 through 3.

§257.63 *"Seismic impact zones."*

"(a) New CCR landfills, existing and new CCR surface impoundments, and all lateral expansions of CCR units must not be located in seismic impact zones unless the owner or operator demonstrates by the dates specified in paragraph (c) of this section that all structural components including liners, leachate collection and removal systems, and surface water control systems, are designed to resist the maximum horizontal acceleration in lithified earth material for the site."

The Phase 1 Module 4 CCR unit is not located in seismic impact zones. In 40 CFR 257.53, a seismic impact zone is defined as an area having a 2 percent or greater probability that the maximum expected horizontal acceleration, expressed as a percentage of the earth's gravitational pull (g), will exceed 0.10 g in 50 years. Based on a review of the USGS 2014 Long-Term Model

National Seismic Hazard Map (see **Appendix D**), the maximum expected horizontal acceleration for the majority of Wisconsin, including all of Columbia County, is less than 0.04 g, below the threshold for a seismic impact zone.

The requirements in 40 CFR 257.64 do not apply to existing CCR units, thus are not applicable to Phase 1 Modules 1 through 3.

257.64 *"Unstable areas."*

"(a) An existing or new CCR landfill, existing or new CCR surface impoundment, or any lateral expansion of a CCR unit must not be located in an unstable area unless the owner or operator demonstrates by the dates specified in paragraph (d) of this section that recognized and generally accepted good engineering practices have been incorporated into the design of the CCR unit to ensure that the integrity of the structural components of the CCR unit will not be disrupted."

"(b) The owner or operator must consider all of the following factors, at a minimum, when determining whether an area is unstable:

"(1) On-site or local soil conditions that may result in significant differential settling;

As discussed in **Appendices E** and **F**, and as shown by the geologic cross sections from the June 1980 Supplementary Feasibility Study prepared by Warzyn Engineering Inc. (see **Appendix G**), the Phase 1 Modules 1 through 4 CCR units are not located in on-site or local soil conditions that may result in significant differential settling. The site soils consist primarily of sands of alluvial and glacial origin overlaying sandstone bedrock. Based on the Standard Penetration Test (SPT) blow counts on the geologic cross sections, the soils are typically medium dense to very dense and therefore not susceptible to appreciable differential settlement under the CCR landfill loads.

(2) On-site or local geologic or geomorphologic features; and

As discussed in **Appendices E**, **H**, and **I**, and shown by the geologic cross sections in **Appendix G**, the Phase 1 Modules 1 through 4 CCR units are not located in on-site or local geologic or geomorphologic features that are unstable. The cross sections show medium dense to very dense sands of alluvial and glacial origin overlaying sandstone bedrock. These geologic features provide a stable foundation for the CCR landfill. This assessment is confirmed by the slope stability analysis in **Appendix H** that indicates the slope stability safety factors are acceptable.

(3) On-site or local human-made features or events (both surface and subsurface)."

As shown by the geologic cross sections in **Appendix G**, the Phase 1 Modules 1 through 4 CCR units are not located in on-site or local human-made features or events (both surface and subsurface) that are unstable. The predominant native

sands are overlain by sand fill in some areas of the site. The sand fill was placed in the landfill area during excavation activities for construction of the generating station. Based on the SPT blow counts for the sand fill on the cross sections, the fill is typically medium dense to very dense and therefore provides a stable base material where present below the landfill.

As discussed in **Appendix I**, groundwater or surface water movement is unlikely to cause instability. The facility is designed with adequate run-on and run-off control systems, and is constructed above the water table.

3.0 REFERENCES

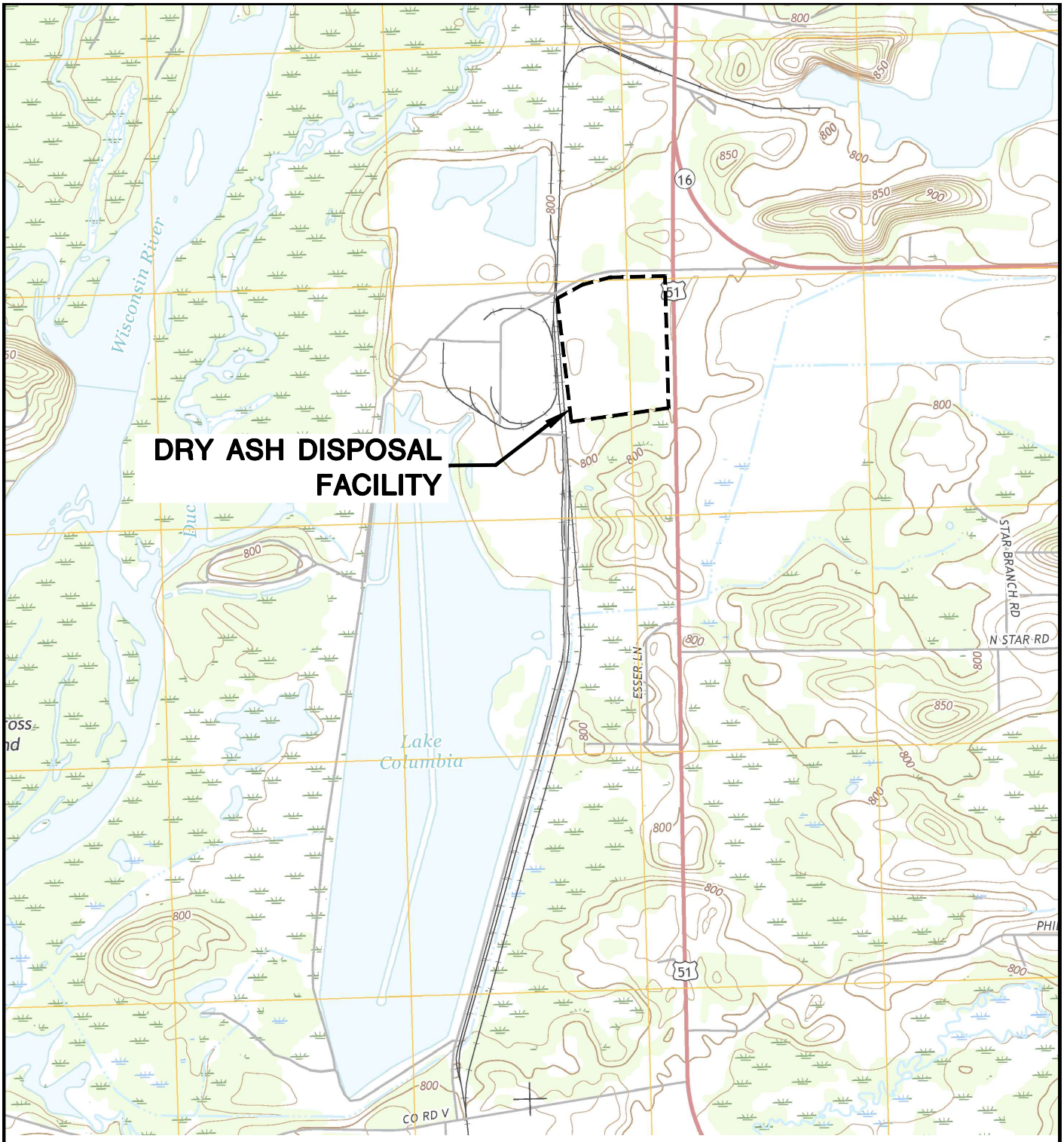
A. Mach IV, 2017, Assured Wetland Delineation Report, Alliant Columbia Energy, Town of Pacific, Columbia County, Wisconsin

B. USGS fault map website: http://usgs.maps.arcgis.com/apps/webappviewer/index.html?id=db287853794f4555b8e93e42290e9716

C. USGS seismic impact zones map website: https://earthquake.usgs.gov/static/lfs/nshm/conterminous/2014/2014pga2pct.pdf

D. Warzyn Engineering Inc., 1980, Supplementary Feasibility Study, Proposed Fly Ash and/or Scrubber Sludge Disposal Facility, Columbia Site – Wisconsin Power & Light Company, Town of Pacific, Columbia County, Wisconsin

FIGURES



N

POYNETTE QUADRANGLE
WISCONSIN–COLUMBIA CO.
7.5 MINUTE SERIES (TOPOGRAPHIC)
2016
SCALE: 1" = 2,000'

CLIENT	Wisconsin Power and Light Company	SITE	LOCATION RESTRICTION COMPLIANCE DEMONSTRATIONS COLUMBIA DRY ASH DISPOSAL FACILITY TOWN OF PACIFIC, WISCONSIN

SITE LOCATION MAP

PROJECT NO.	25217156.01	DRAWN BY:	BSS
DRAWN:	08/29/18	CHECKED BY:	PEG
REVISED:	08/29/18	APPROVED BY:	

ENGINEER

SCS ENGINEERS
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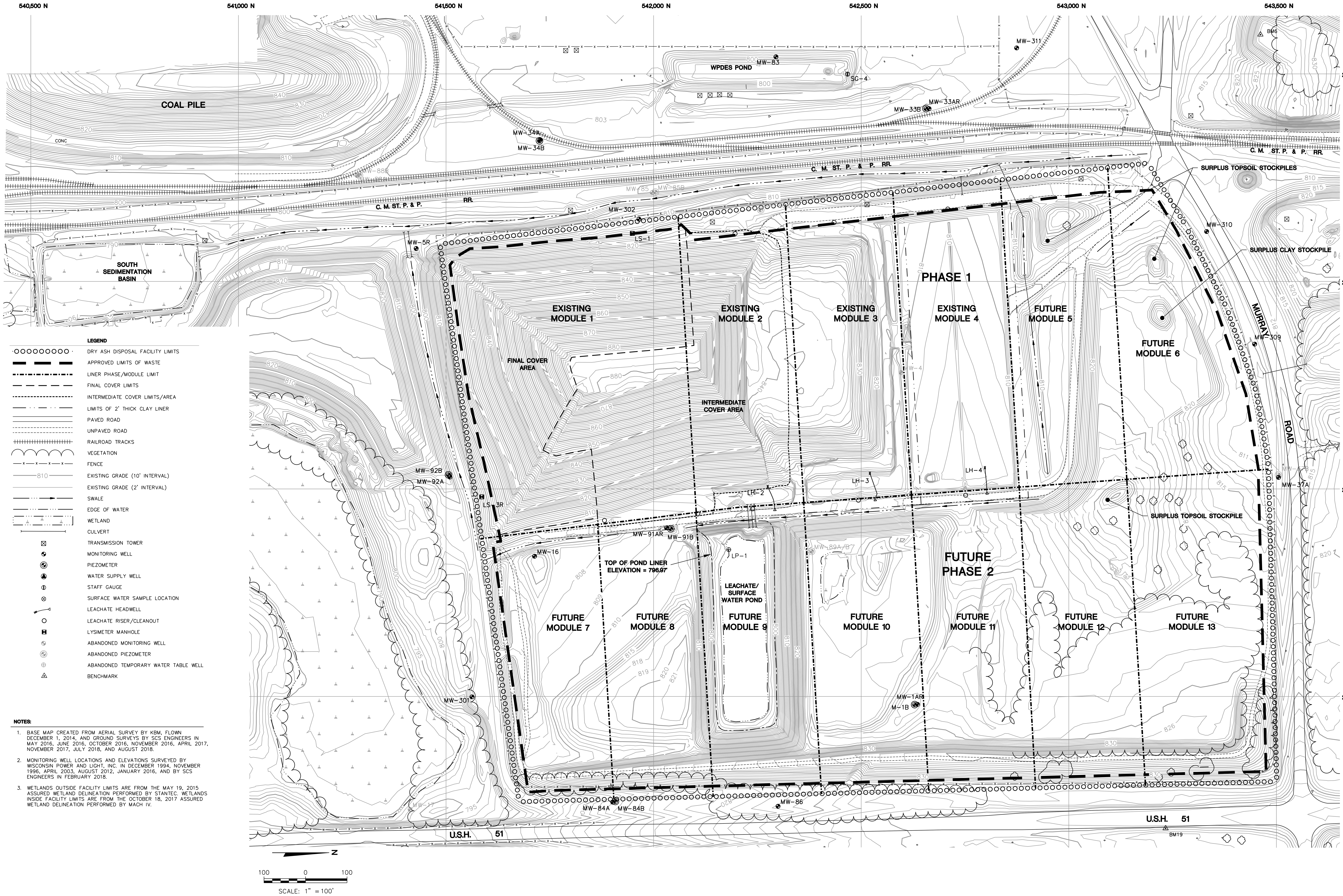
PHONE: (608) 224-2830

FIGURE 1

I:\25217156.00\Drawings\Location Restriction Compliance Report\Site Location Map.dwg, 10/3/2018 3:46:28 PM



LEGEND

Symbol	Description
○○○○○○○○○	DRY ASH DISPOSAL FACILITY LIMITS
— — —	APPROVED LIMITS OF WASTE
—·—·—	LINER PHASE/MODULE LIMIT
— — —	FINAL COVER LIMITS
········	INTERMEDIATE COVER LIMITS/AREA
—··—··—	LIMITS OF 2' THICK CLAY LINER
	PAVED ROAD
	UNPAVED ROAD
	RAILROAD TRACKS
	VEGETATION
—x—x—x—	FENCE
—810—	EXISTING GRADE (10' INTERVAL)
	EXISTING GRADE (2' INTERVAL)
	SWALE
	EDGE OF WATER
	WETLAND
	CULVERT
⊠	TRANSMISSION TOWER
	MONITORING WELL
	PIEZOMETER
	WATER SUPPLY WELL
	STAFF GAUGE
⊗	SURFACE WATER SAMPLE LOCATION
	LEACHATE HEADWELL
○	LEACHATE RISER/CLEANOUT
	LYSIMETER MANHOLE
	ABANDONED MONITORING WELL
	ABANDONED PIEZOMETER
⊕	ABANDONED TEMPORARY WATER TABLE WELL
△	BENCHMARK

NOTES:

1. BASE MAP CREATED FROM AERIAL SURVEY BY KBM, FLOWN DECEMBER 1, 2014, AND GROUND SURVEYS BY SCS ENGINEERS IN MAY 2016, JUNE 2016, OCTOBER 2016, NOVEMBER 2016, APRIL 2017, NOVEMBER 2017, JULY 2018, AND AUGUST 2018.
2. MONITORING WELL LOCATIONS AND ELEVATIONS SURVEYED BY WISCONSIN POWER AND LIGHT, INC. IN DECEMBER 1994, NOVEMBER 1996, APRIL 2003, AUGUST 2012, JANUARY 2016, AND BY SCS ENGINEERS IN FEBRUARY 2018.
3. WETLANDS OUTSIDE FACILITY LIMITS ARE FROM THE MAY 19, 2015 ASSURED WETLAND DELINEATION PERFORMED BY STANTEC. WETLANDS INSIDE FACILITY LIMITS ARE FROM THE OCTOBER 18, 2017 ASSURED WETLAND DELINEATION PERFORMED BY MACH IV.

DRAWN BY:	KP
CHECKED BY:	BSS
APPROVED BY:	
PROJECT NO.	25217156.01
DRAWN:	07/02/18
REVISED:	10/03/18

WISCONSIN POWER AND LIGHT
COLUMBIA ENERGY CENTER
W8375 MURRAY ROAD
PARDEEVILLE, WISCONSIN 53954

Wisconsin Power and Light Company

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ENGINEER

LOCATION RESTRICTION
COMPLIANCE DEMONSTRATIONS
COLUMBIA DRY ASH DISPOSAL FACILITY
TOWN OF PACIFIC, WISCONSIN

SITE

MODULE 1 THROUGH 4 LOCATION

SHEET
2 of 3

2,123,800 E | 2,123,900 E | 2,124,000 E | 2,124,100 E | 2,124,200 E | 2,124,300 E | 2,124,400 E | 2,124,500 E | 2,124,600 E

543,000 N

542,900 N

542,800 N

542,700 N

542,600 N

FUTURE MODULE 5

MODULE 4

EXISTING MODULE 3
(COMPOSITE LINER)

LEACHATE COLLECTION HEADER

EAST PERIMETER BERM

LEACHATE COLLECTION LINE

COMPOSITE LINER SYSTEM

LEGEND

- DRY ASH DISPOSAL FACILITY LIMITS
- APPROVED LIMITS OF WASTE
- PHASE/MODULE LIMIT
- AS-BUILT 2' THICK CLAY LINER LIMITS
- PERFORATED HDPE LEACHATE COLLECTION PIPE
- NON-PERFORATED HDPE LEACHATE PIPE
- LEACHATE COLLECTION SYSTEM CLEANOUT
- 806 — AS-BUILT MODULE 3 BASE GRADE (1' CONTOUR)
- 805 — AS-BUILT MODULE 3 BASE GRADE (5' CONTOUR)
- 806 — DESIGN MODULE 4 BASE GRADES (1' CONTOUR)
- 805 — DESIGN MODULE 4 BASE GRADES (5' CONTOUR)
- 806 — AS-BUILT MODULE 4 BASE GRADE (1' CONTOUR)
- 805 — AS-BUILT MODULE 4 BASE GRADE (5' CONTOUR)

NOTES

1. SEE SHEET 2 FOR BASE MAP NOTES.
2. DESIGN AND AS-BUILT CONTOURS WITHIN MODULE 4 LIMITS REPRESENT TOP OF 2' THICK CLAY LINER (BASE GRADES).
3. MODULE 3 BASE GRADES TAKEN FROM JULY 2016, MODULE 3 LINER CONSTRUCTION DOCUMENTATION REPORT PREPARED BY SCS ENGINEERS. BASE GRADES REPRESENT TOP OF 2' THICK CLAY LINER.

N

30 0 30

SCALE: 1" = 30'

DRAWN BY: KP
CHECKED BY: BSS
APPROVED BY:

PROJECT NO. 25217156.01
DRAWN: 01/02/18
REVISED: 10/03/18

WISCONSIN POWER AND LIGHT
COLUMBIA ASH DISPOSAL CENTER
W8375 MURRAY ROAD
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LOCATION RESTRICTION
COMPLIANCE DEMONSTRATIONS
COLUMBIA ASH DISPOSAL FACILITY
TOWN OF PACIFIC, WISCONSIN

SITE

BASE GRADES AND LEACHATE COLLECTION SYSTEM

SHEET
3 of 3

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APPENDIX A

Water Levels

Table 1. Water Level Summary
Columbia Dry Ash Disposal Facility / SCS Engineers

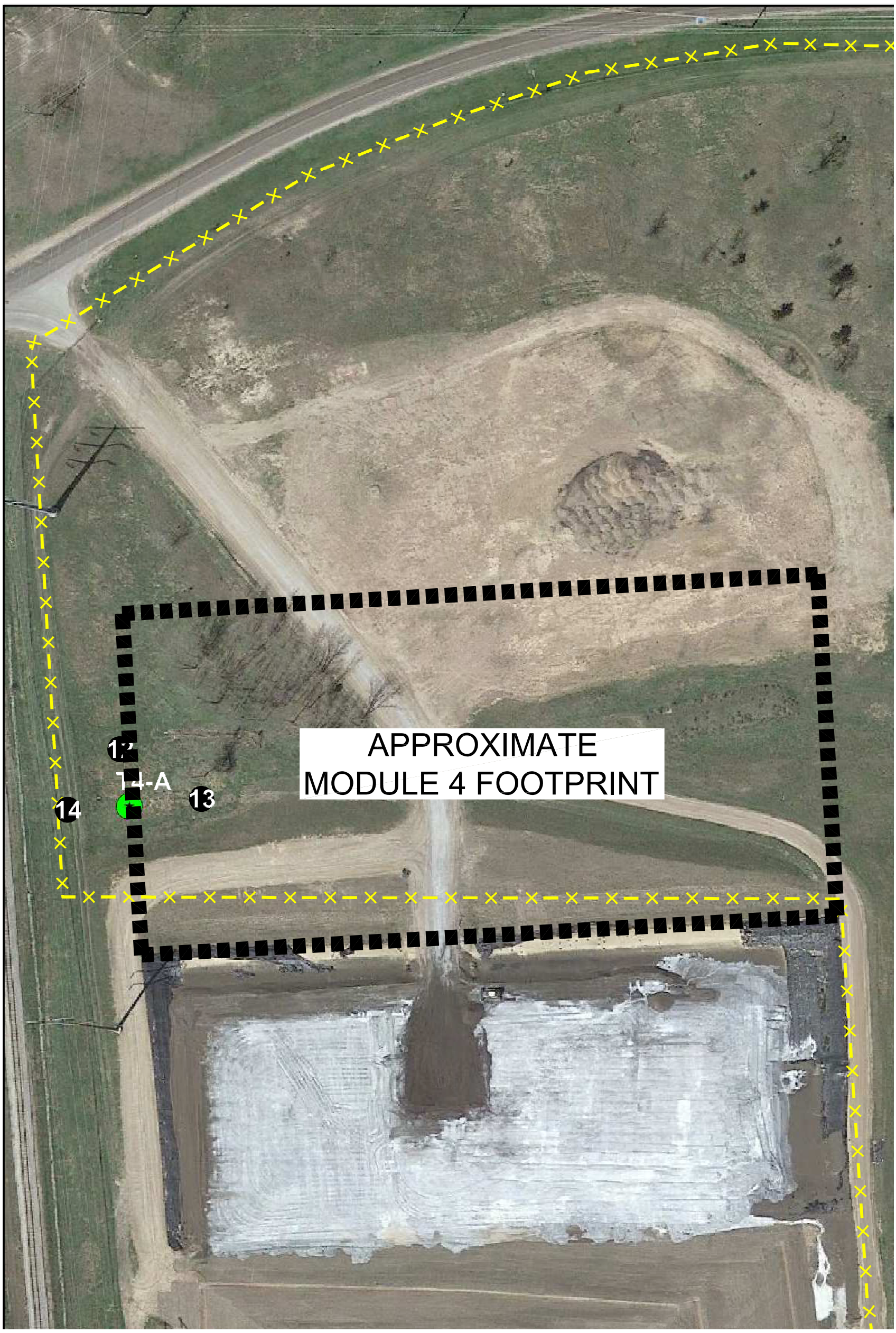
	Raw Data	MW-1AR	MW-4	MW-5R	MW-33AR	MW-33BR	MW-34A	MW-34B	MW-37A	MW-83	MW-84A	MW-84B	MW-86	MW-91AR	MW-91B	MW-92A	MW-92B
	Measurement Date																
	October 2, 2012	39.14	36.04	20.48	25.91	26.16	22.92	23.06	30.38	dry	30.44	30.32	40.98	24.94	24.55	23.98	24.35
	April 15, 2013	37.11	35.72	19.35	24.13	24.25	21.21	21.26	29.17	23.47	28.45	28.50	39.57	23.89	23.44	22.72	23.07
	October 8, 2013													23.37	23.03	22.5	22.89
	October 15, 2013	--	--	--	--	--	--	--	--	--	--	--	--	23.37	23.03	22.5	22.89
	April 14, 2014	37.60	35.65	19.81	24.55	24.48	21.32	21.35	29.59	24.23	28.70	28.74	39.83	23.99	23.49	22.48	22.87
	October 2-3, 2014	37.52	34.35	19.36	23.92	24.11	21.38	21.51	28.48	dry	29.04	29.08	39.60	23.56	23.17	22.72	23.08
	April 13-14, 2015	38.59	36.11	20.19	25.28	25.65	22.30	22.10	30.17	dry	29.85	29.75	40.62	24.55	24.08	23.40	23.75
	October 6-7, 2015	38.27	35.30	19.72	24.61	25.06	21.90	22.03	29.38	24.31	29.48	29.5	40.13	24.14	23.75	23.27	23.65
	April 4-6, 2016	36.73	aband	18.42	23.00	23.32	20.32	20.38	28.28	22.53	27.91	28.00	38.90	22.98	22.50	21.86	22.20
	October 11-13, 2016	35.91	aband	17.44	20.93	21.93	19.50	19.73	26.64	21.15	27.06	27.15	37.83	21.86	21.64	20.79	21.16
	April 10-13, 2017	35.59	aband	17.31	21.90	22.40	19.65	19.77	26.70	21.73	27.12	27.20	37.83	21.79	21.42	20.57	20.81
	October 3-5, 2017	37.07	aband	18.78	23.78	24.17	21.28	21.42	28.18	23.67	--	27.77	39.21	22.95	22.62	22.00	22.39
	October 9-10, 2017	--	aband	--	--	--	--	--	--	--	28.72 [6]	--	--	--	--	--	--
	February 21, 2018	38.58	aband	--	--	--	--	--	--	--	--	--	--	24.35	23.99	--	--
	April 23-25, 2018	38.56	aband	20.08	25.20	22.03	24.18	25.26	29.76	24.64	28.40	29.35	42.25	24.32	23.92	23.24	23.60
Dry Ash Facility (Facility ID #03025)	**Well Number**	**MW-1AR**	**MW-4**	**MW-5R**	**MW-33AR**	**MW-33BR**	**MW-34A**	**MW-34B**	**MW-37A**	**MW-83**	**MW-84A**	**MW-84B**	**MW-86**	**MW-91AR**	**MW-91B**	**MW-92A**	**MW-92B**
	Top of Casing Elevation (feet amsl)	822.55	819.74	805.44	808.29	808.39	805.95	806.05	813.04	807.96	814.28	814.26	824.79	809.03	808.45	808.47	808.41
	Screen Length (ft)																
	Total Depth (ft from top of casing)	44.40	39.58	25.97	31.08	57.50	35.43	56.95	31.80	25.42	40.21	52.02	45.43	32.90	52.38	28.94	51.75
	Top of Well Screen Elevation (ft)	778.15	780.16	779.47	777.21	750.89	770.52	749.10	781.24	782.54	774.07	762.24	779.36	776.13	756.07	779.53	756.66
	Measurement Date																
	October 2, 2012	783.41	783.70	784.96	782.38	782.23	783.03	782.99	782.66	dry	783.84	783.94	783.81	784.09	783.90	784.49	784.06
	April 15, 2013	785.44	784.02	786.09	784.16	784.14	784.74	784.79	783.87	784.49	785.83	785.76	785.22	785.14	785.01	785.75	785.34
	October 8, 2013													785.66	785.42	785.97	785.52
	October 15, 2013	--	--	--	--	--	--	--	--	--	--	--	--	785.66	785.42	785.97	785.52
	April 14, 2014	784.95	784.09	785.63	783.74	783.91	784.63	784.70	783.45	783.73	785.58	785.52	784.96	785.04	784.96	785.99	785.54
	October 2-3, 2014	785.03	785.39	786.08	784.37	784.28	784.57	784.54	784.56	dry	785.24	785.18	785.19	785.47	785.28	785.75	785.33
	April 13-14, 2015	783.96	783.63	785.25	783.01	782.74	783.65	783.95	782.87	dry	784.43	784.51	784.17	784.48	784.37	785.07	784.66
	October 6-7, 2015	784.28	784.44	785.72	783.68	783.33	784.05	784.02	783.66	dry	784.80	784.76	784.66	784.89	784.70	785.20	784.76
	April 4-6, 2016	785.82	aband	787.02	785.29	785.07	785.63	785.67	784.76	785.43	786.37	786.26	785.89	786.05	785.95	786.61	786.21
	October 11-13, 2016	786.64	aband	788.00	787.36	786.46	786.45	786.32	786.40	786.81	787.22	787.11	786.96	787.17	786.81	787.68	787.25
	April 10-13, 2017	786.96	aband	788.13	786.39	785.99	786.30	786.28	786.34	786.23	787.16	787.06	786.96	787.24	787.03	787.90	787.60
	October 3-5, 2017	785.48	aband	786.66	784.51	784.22	784.67	784.63	784.86	784.29	--	786.49	785.58	786.08	785.83	786.47	786.02
	October 9-10, 2017	--	aband	--	--	--	--	--	--	--	785.56 [6]	--	--	--	--	--	--
	February 21, 2018	783.97	aband	--	--	--	--	--	--	--	--	--	--	784.68	784.46	--	--
	April 23-25, 2018	783.99	aband	785.36	783.09	786.36	781.77	780.79	783.28	783.32	785.88	784.91	782.54	784.71	784.53	785.23	784.81
	Bottom of Well Elevation (ft)	778.15	780.16	779.47	777.21	750.89	770.52	749.10	781.24	782.54	774.07	762.24	779.36	776.13	756.07	779.53	756.66

Table 1. Water Level Summary
Columbia Dry Ash Disposal Facility / SCS Engineers

	Raw Data	MW-301	MW-302	MW-303	MW-304	MW-305	M-4R	MW-33AR	MW-34A	MW-84A	MW-306	MW-307	MW-308	MW-309	MW-310	MW-311
CCR Rule Wells	**Measurement Date**															
	December 21-22, 2015	21.33	28.22	27.41	19.29	17.36	18.52	24.52	22.45	28.97	--	--	--	--	--	--
	April 4-5, 2016	20.11	27.19	26.04	17.34	16.71	17.01	23.00	20.32	27.91	--	--	--	--	--	--
	July 7-8, 2016	20.58	26.72	26.92	18.06	17.06	18.67	23.10	20.90	28.39	--	--	--	--	--	--
	July 28, 2016	--	--	27.17	--	--	--	--	21.09	28.67	--	--	--	--	--	--
	October 11-13, 2016	19.25	25.24	25.34	17.24	16.54	18.22	20.93	19.50	27.06	--	--	--	--	--	--
	December 29, 2016	19.52	25.95	--	--	--	--	22.63	20.23	27.65	--	--	--	--	--	--
	January 25-26, 2017	19.62	26.11	26.24	16.08	16.96	16.46	22.41	19.97	27.58	22.13	21.53	21.17	--	--	--
	April 10 & 11, 2017	19.00	25.45	25.52	17.20	16.75	18.15	21.9	19.65	27.12	21.41	21.25	20.39	--	--	--
	June 6, 2017	18.64	24.63	25.03	16.84	16.53	18.27	21.02	19.29	26.65	20.78	20.82	20.44	--	--	--
	August 7-9, 2017	19.55	25.45	26.10	15.90	17.02	17.56	22.18	20.14	27.60	21.94	21.70	21.53	--	--	--
	October 23-24, 2017	21.00	27.06	27.60	16.45	18.18	18.10	24.16	21.45	28.96	23.66	22.10	22.73	--	--	--
	February 21, 2018	-	-	-	-	-	-	-	-	-	-	-	-	30.08	30.57	26.72
	March 23, 2018	-	-	-	-	-	-	-	-	-	-	-	-	30.17	30.52	26.74
	April 23-25, 2018	21.60	28.63	28.25	15.73	18.65	15.67	25.20	24.18	28.40	24.39	23.24	24.25	30.20	30.65	27.91
	May 24, 2018	-	-	-	-	-	-	-	-	-	21.84	21.80	-	27.82	27.65	23.63
	June 23, 2018	-	-	-	-	-	-	-	-	-	-	-	-	27.24	26.98	23.27
	July 23, 2018	-	-	-	-	-	-	-	-	-	-	-	-	27.00	27.27	23.19
	August 7, 2018	19.83	-	26.32	17.17	17.76	18.47	-	-	27.73	-	-	-	-	-	-
	August 22, 2018	-	-	-	-	-	-	-	-	-	-	-	-	27.73	28.22	24.28
	Well Number	**MW-301**	**MW-302**	**MW-303**	**MW-304**	**MW-305**	**M-4R**	**MW-33AR**	**MW-34A**	**MW-84A**	**MW-306**	**MW-307**	**MW-308**	**MW-309**	**MW-310**	**MW-311**
	Top of Casing Elevation (feet amsl)	806.89	813.00	811.52	805.42	806.32	806.10	808.29	805.95	814.28	807.63	806.89	806.9	813.27	813.62	809.74
	Screen Length (ft)	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
	Total Depth (ft from top of casing)	29.40	33.6	35.80	25.7	25.6	39.58	31.08	35.43	40.21	27	26.5	28	37.67	38.41	36.19
	Top of Well Screen Elevation (ft)	787.49	789.40	785.72	789.72	790.72	776.52	787.21	780.52	784.07	790.63	790.39	788.90	785.60	785.21	783.55
	Measurement Date													--	--	--
	December 21-22, 2015	--	784.78	784.11	786.13	788.96	787.58	783.77	783.50	785.31	--	--	--	--	--	--
	April 4-5, 2016	786.78	785.81	785.48	788.08	789.61	789.09	785.29	785.63	786.37	--	--	--	--	--	--
	July 7-8, 2016	786.31	786.28	784.60	787.36	789.26	787.43	785.19	785.05	785.89	--	--	--	--	--	--
	July 28, 2016	--	--	784.35	--	--	--	--	784.86	785.61	--	--	--	--	--	--
	October 11-13, 2016	787.64	787.76	786.18	788.18	789.78	787.88	787.36	786.45	787.22	--	--	--	--	--	--
	December 29, 2016	787.37	787.05	--	--	--	--	785.66	785.72	786.63	--	--	--	--	--	--
	January 25-26, 2017	787.27	786.89	785.28	789.34	789.36	789.64	785.88	785.98	786.70	785.50	785.36	785.73	--	--	--
	April 10 & 11, 2017	787.89	787.55	786.00	788.22	789.57	787.95	786.39	786.30	787.16	786.22	785.64	786.51	--	--	--
	June 6, 2017	788.25	788.37	786.49	788.58	789.79	787.83	787.27	786.66	787.63	786.85	786.07	786.46	--	--	--
	August 7-9, 2017	787.34	787.55	785.42	789.52	789.30	788.54	786.11	785.81	786.68	785.69	785.19	785.37	--	--	--
	October 23-24, 2017	785.89	785.94	783.92	788.97	788.14	788.00	784.13	784.50	785.32	783.97	784.79	784.17	--	--	--
	February 21, 2018	-	-	-	-	-	-	-	-	-	-	-	-	783.19	783.05	783.02
	March 23, 2018	-	-	-	-	-	-	-	-	-	-	-	-	783.10	783.10	783.00
	April 23-25, 2018	785.29	784.37	783.27	789.69	787.67	790.43	783.09	781.77	785.88	783.24	783.65	782.65	783.07	782.97	781.83
	May 24, 2018	-	-	-	-	-	-	-	-	-	785.79	785.09	-	785.45	785.97	786.11
	June 23, 2018	-	-	-	-	-	-	-	-	-	-	-	-	786.03	786.64	786.47
	July 23, 2018	-	-	-	-	-	-	-	-	-	-	-	-	786.27	786.35	786.55
	August 7, 2018	787.06	-	785.20	788.25	788.56	787.63	-	-	786.55	-	-	-	-	-	-
	August 22, 2018	-	-	-	-	-	-	-	-	-	-	-	-	785.54	785.40	785.46
	Bottom of Well Elevation (ft)	771.33	780.55	774.82	733.43	776.98	753.04	771.89	776.98	776.36	780.63	780.39	778.90	775.60	775.21	773.55

APPENDIX B

Wetland Delineation Maps



Wisconsin Power and Light
Tax Parcel ID No's: 373.A, 380, 380.A and 381
Town of Pacific, Columbia County
Wetland Delineation Map

Legend

- Wetland Delineation Limits
- Sample Point
- WDNR Protective Area
- Wetland Line
- Wetland Polygon
- Statewide Parcels 2016-9
- Possible Exempt Wetland

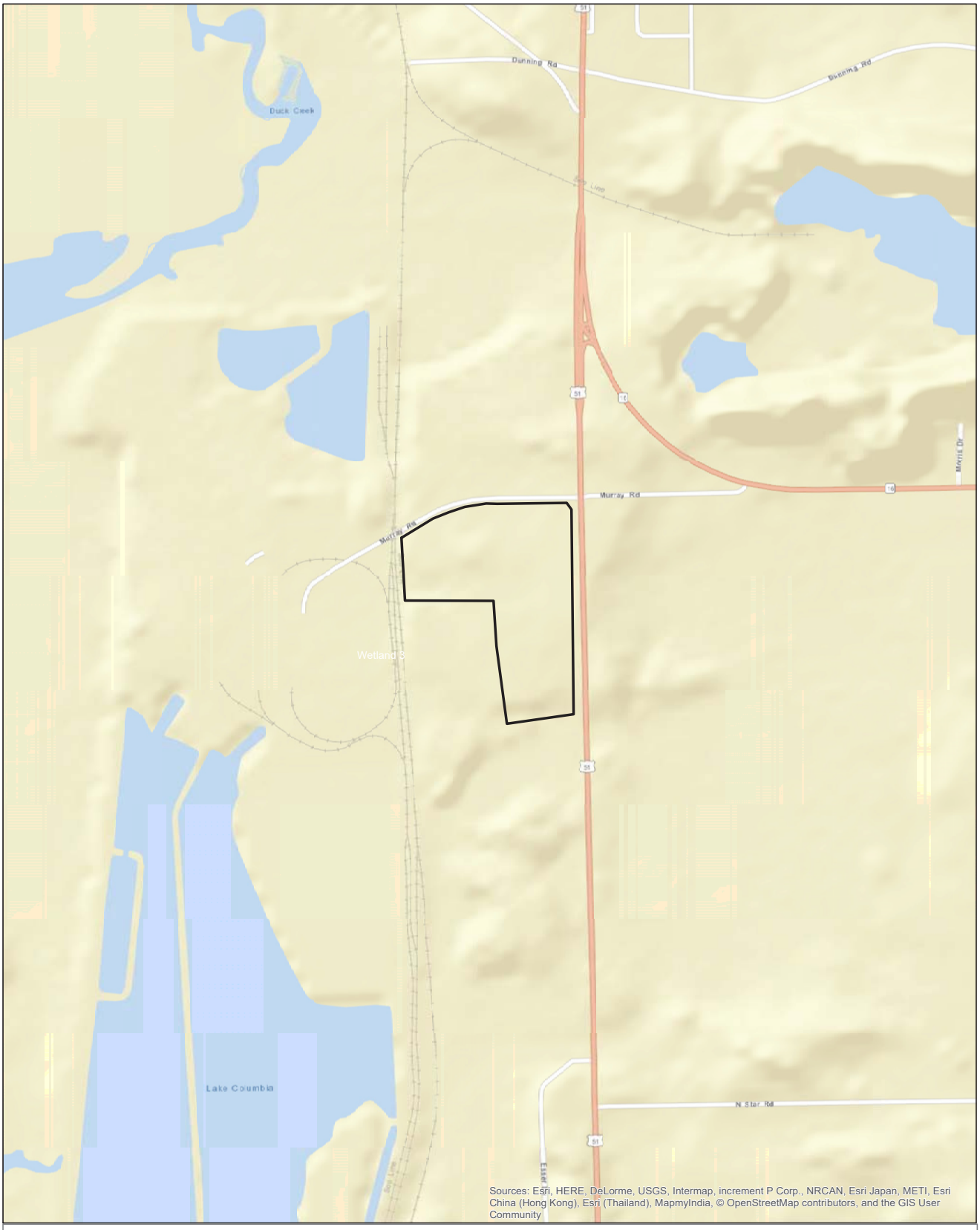
100 50 0 100
Feet

N
W E
S

Wetland Delineation was conducted by
Chad Fradette, EP, Chem,
WDNR Professionally Assured Wetland Delineator
with assistance from
Benjamin LaCount, PLS, Wetland Scientist and
Shyann Nieland, Environmental Specialist

Mach IV
Engineering Surveying Environmental
Phone: 920-569-5765 www.mach-iv.com

Proj.# 1444-01-17



Legend

Wetland Delineation Limits

800 400 0 800

Feet

Alliant Columbia Energy
Tax Parcel ID No's: 373.A, 380, 380.A and 381
Town of Pacific, Columbia County
Site Location Map

N
W E
S

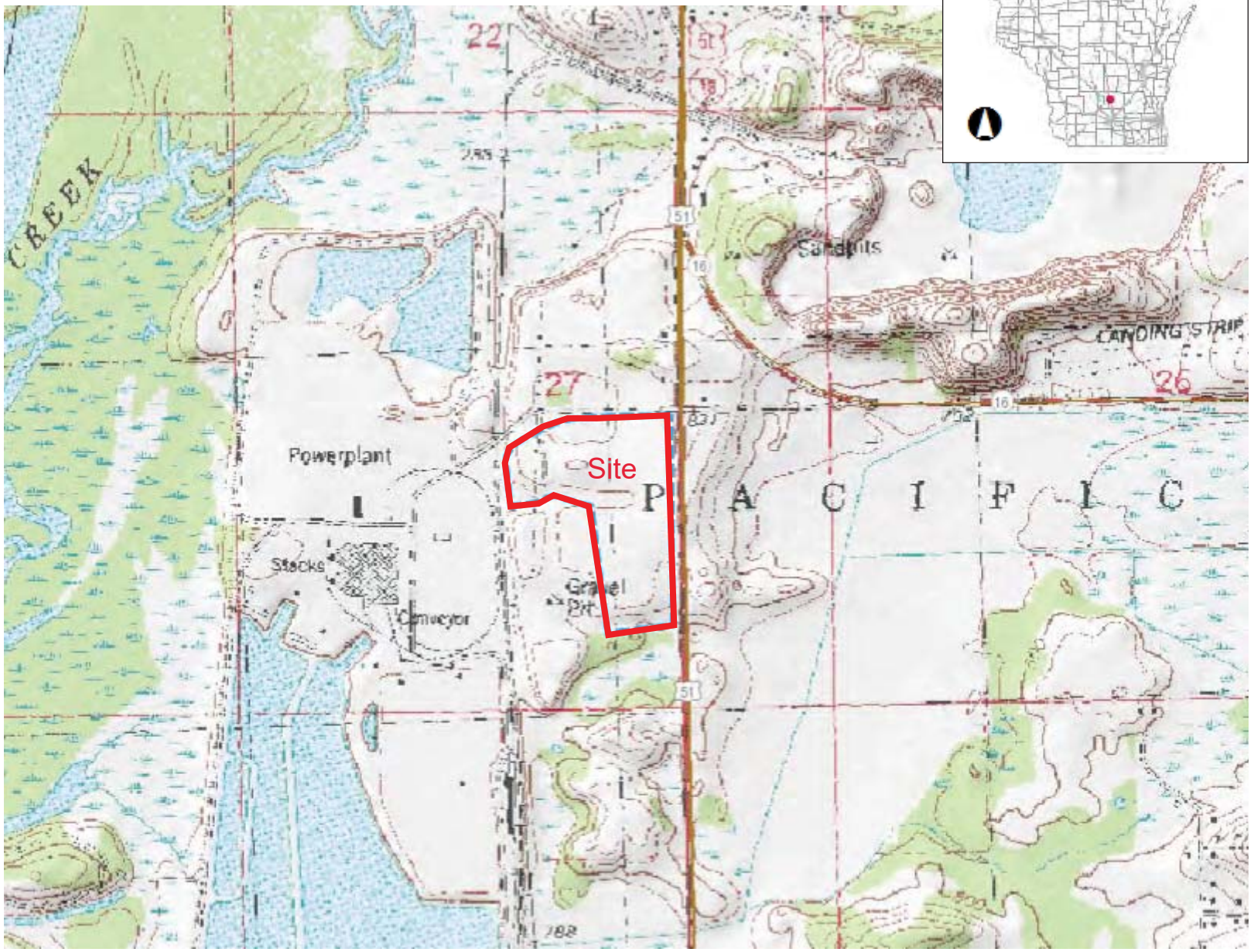
Mach IV

Engineering Surveying Environmental

Phone: 920-569-5765 www.mach-iv.com

Proj.# 1444-01-17

Quadrangle Map



Legend

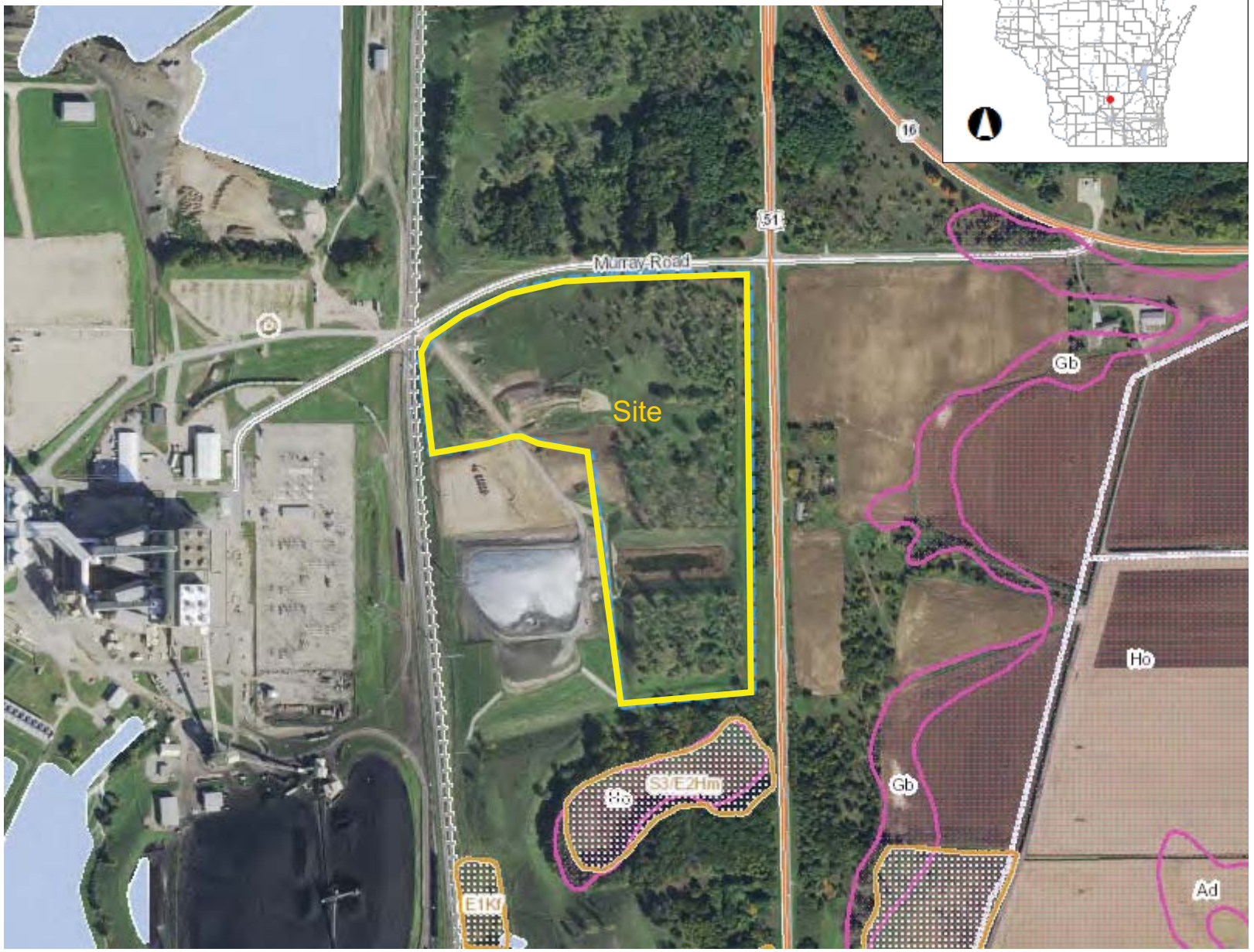
Notes

0.5 0 0.25 0.5 Miles

NAD_1983_HARN_Wisconsin_TM

1: 15,840

Surface Water Data Viewer Map



Legend

- Wetland Class Points
  - Dammed pond
  - Excavated pond
  - Filled excavated pond
  - Filled/drained wetland
  - Wetland too small to delineate
- Filled Points
- Wetland Class Areas
  - Wetland
  - Upland
- Filled Areas
- NRCS Wetspots
- Wetland Indicators
- Municipality
- State Boundaries
- County Boundaries
- Major Roads
  - Interstate Highway
  - State Highway
  - US Highway
- County and Local Roads
  - County HWY
  - Local Road
- Railroads
- Tribal Lands
- Rivers and Streams
- Intermittent Streams
- Lakes and Open water

Notes

0.3 0 0.13 0.3 Miles

NAD_1983_HARN_Wisconsin_TM

1: 7,920

U.S. Fish and Wildlife Service
National Wetlands Inventory

Wetlands

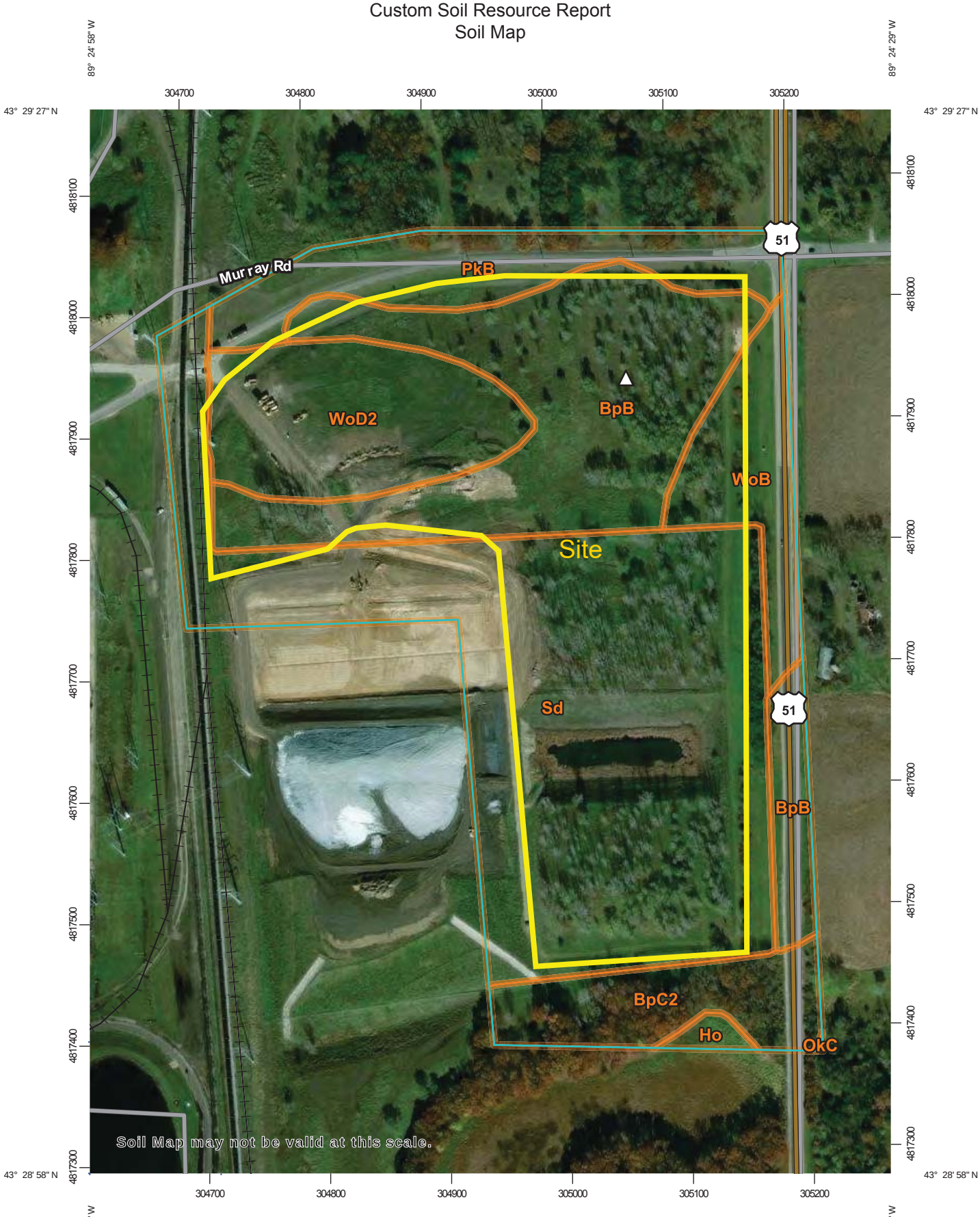
September 25, 2017

Wetlands

- Estuarine and Marine Deepwater
- Estuarine and Marine Wetland
- Freshwater Emergent Wetland
- Freshwater Forested/Shrub Wetland
- Freshwater Pond
- Lake
- Other
- Riverine

This map is for general reference only. The US Fish and Wildlife Service is not responsible for the accuracy or currentness of the base data shown on this map. All wetlands related data should be used in accordance with the layer metadata found on the Wetlands Mapper web site.

Custom Soil Resource Report
Soil Map



Map Scale: 1:4,270 if printed on A portrait (8.5" x 11") sheet.

N

Meters: 0 50 100 200 300

Feet: 0 200 400 800 1200

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 16N WGS84

Component Legend

This report presents general information about the map units and map unit components in the selected area. It shows map unit symbols and names and the components in each map unit. It also shows the percent of the components in the map units, the kind of component, and the slope range of each component.

Report—Component Legend

Component Legend–Columbia County, Wisconsin							
Map unit symbol and name	Map unit acres	Pct. of map unit	Component name	Component kind	Pct. slope		
					Low	RV	High
BpB—Boyer loamy sand, 2 to 6 percent slopes	7,715						
		90	Boyer	Series	2.0	4.0	6.0
BpC2—Boyer loamy sand, 6 to 12 percent slopes, eroded	3,268						
		93	Boyer, eroded	Series	6.0	9.0	12.0
Ho—Houghton muck, 0 to 2 percent slopes	21,084						
		90	Houghton, muck	Series	0.0	1.0	2.0
OkC—Okee loamy fine sand, 6 to 12 percent slopes	2,505						
		100	Okee	Series	6.0	9.0	12.0
PkB—Plainfield loamy fine sand, loamy substratum, 2 to 6 percent slopes	5,639						
		90	Plainfield, loamy substratum	Family	2.0	4.0	6.0
Sd—Sandy land	1,050						
		100	Sandy land	Miscellaneous area	0.0	1.0	2.0
WoB—Wyocena loamy sand, 2 to 6 percent slopes	3,924						
		100	Wyocena	Series	2.0	4.0	6.0
WoD2—Wyocena loamy sand, 12 to 20 percent slopes, eroded	2,235						
		100	Wyocena	Series	12.0	16.0	20.0

Data Source Information

Soil Survey Area: Columbia County, Wisconsin
Survey Area Data: Version 14, Oct 5, 2017

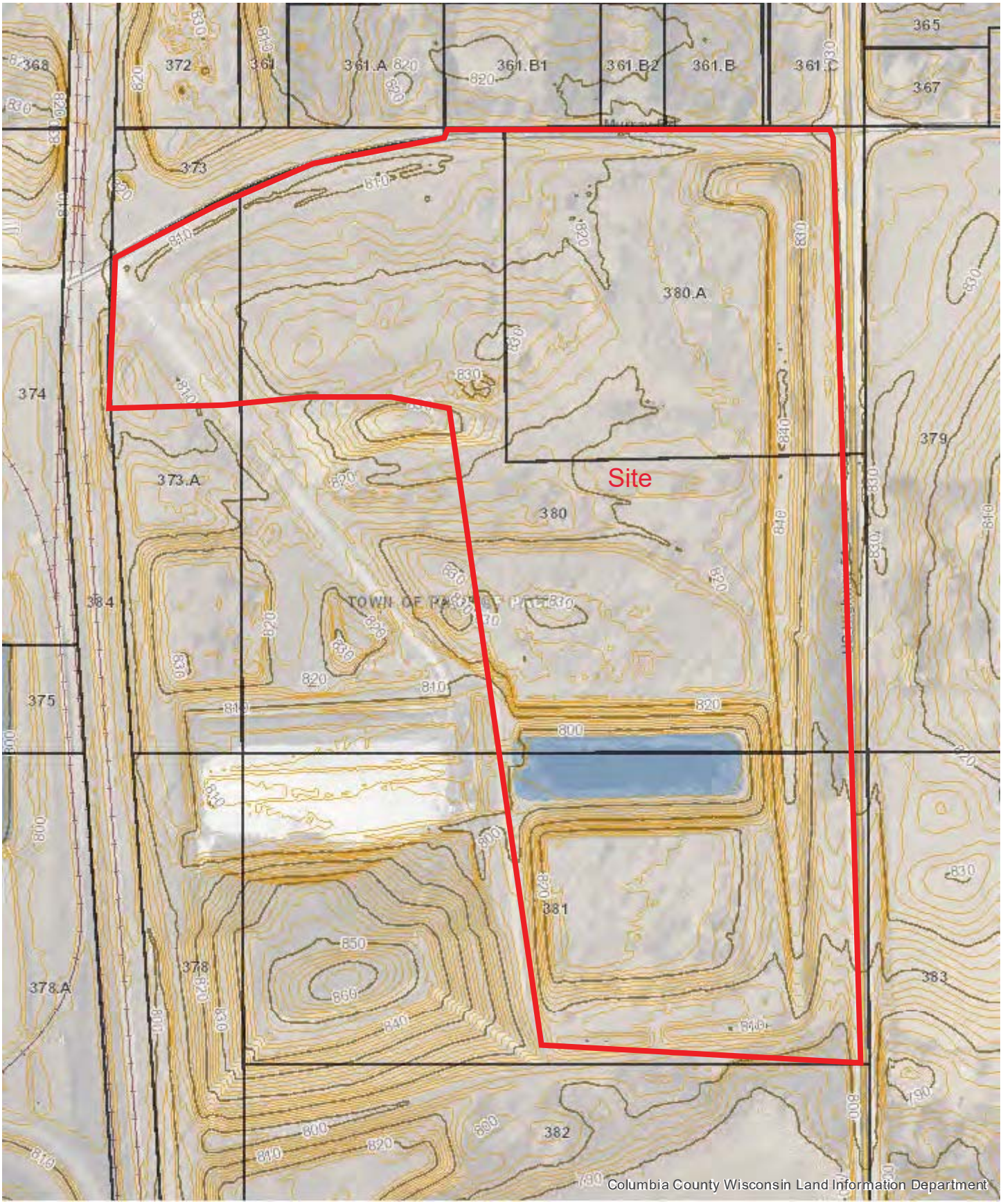
Columbia County, WI

Topographic Map

MAP SCALE 1:3,372

SOURCE Columbia County Land Information
www.co.columbia.wi.us/ColumbiaCounty/LandInformation

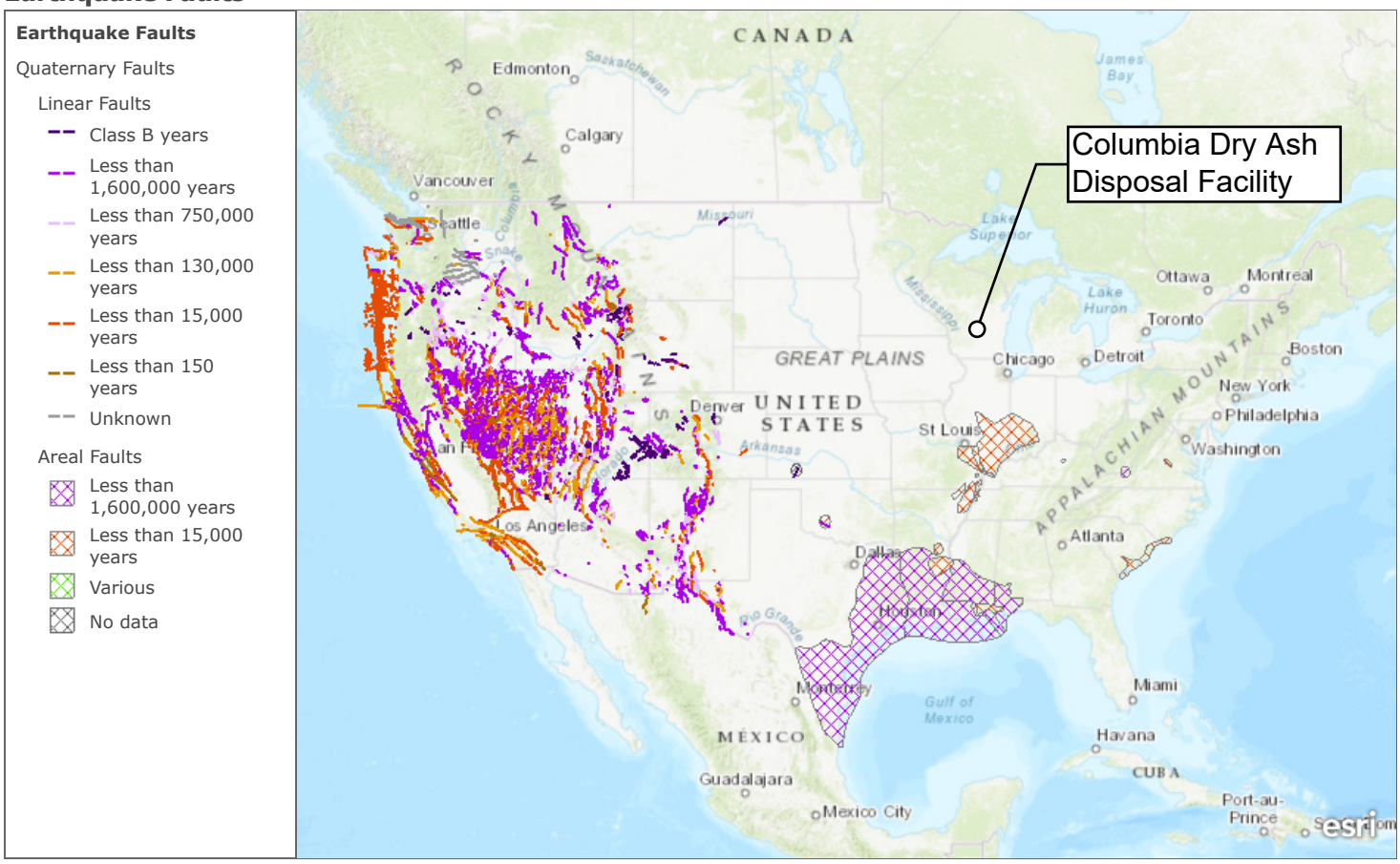
DATE September 25, 2017



APPENDIX C

Fault Location Map

Earthquake Faults

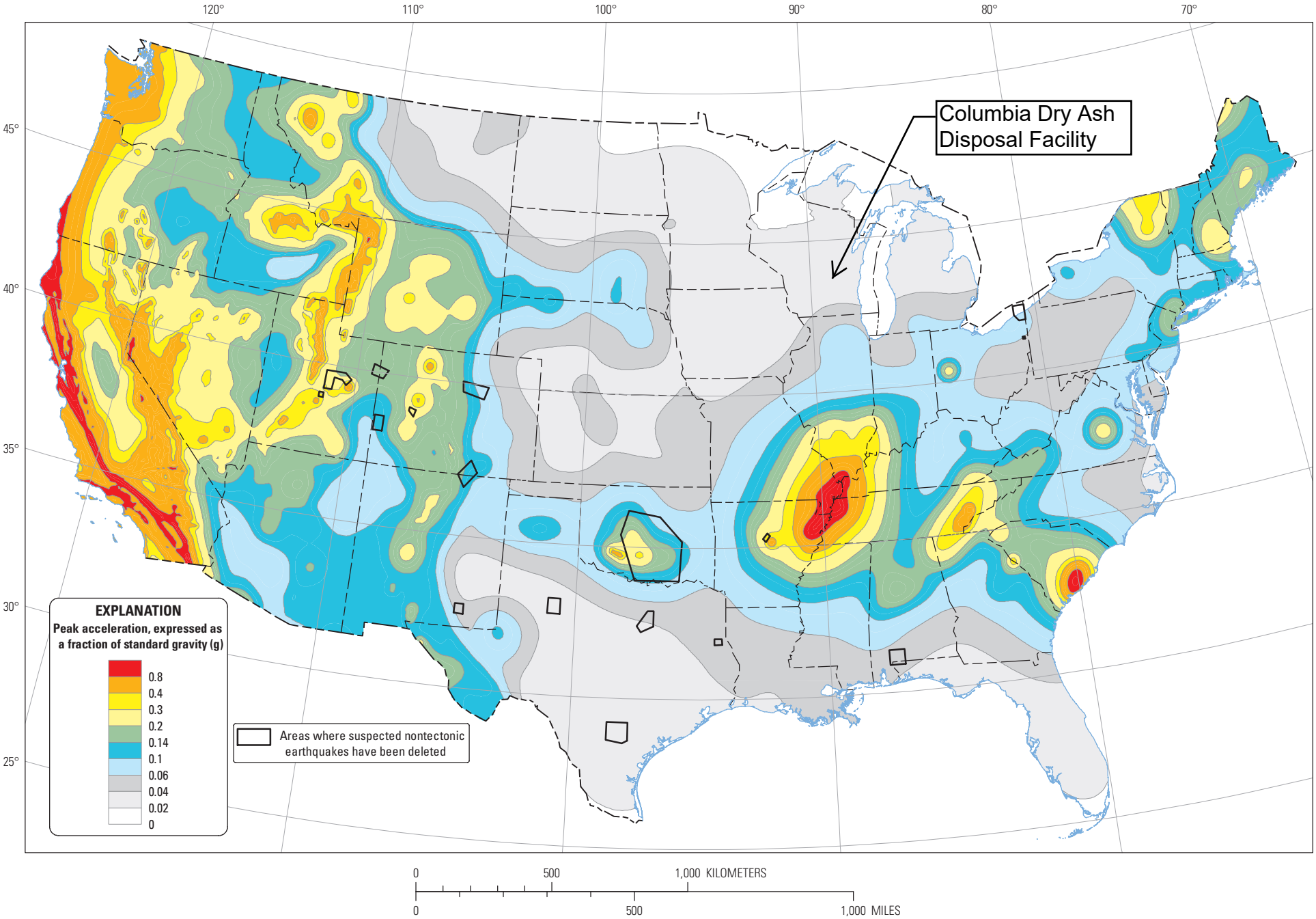


These map layers, utilizing data from the U.S. Geological Survey's (USGS) Earthquake Hazards Program (EHP), details known faults and folds in the U.S.

Esri, HERE, Garmin, FAO, NOAA, USGS, EPA | Acknowledgment of the Quaternary Faults and Fold Database, the U.S. Geological Survey, and (or) the National Atlas of the United States of America would be appreciated in products derived from these data.

APPENDIX D

Seismic Hazard Map



Two-percent probability of exceedance in 50 years map of peak ground acceleration

Source: USGS seismic impact zones map - https://earthquake.usgs.gov/static/lfs/nshm/conterminous/2014/2014pga2pct.pdf

APPENDIX E

Site Description and Geologic Summary

Site Description and Geologic Summary

Site Information

The COL dry ash disposal facility encompasses 62.5 acres, and is located in an industrial and agricultural area with scattered private residences. The site location is Section 27, T12N, R9E, in the town of Pacific, located in Columbia County, Wisconsin. The facility is bounded by U.S. Highway 51 to the east and railroad tracks to the west. Murray Road is located to the north and wetlands are located to the south of the facility.

Regional Geology

Columbia County glacial geology consists mostly of glacial drift. Glacial sediments from the Green Bay Lobe were deposit during the Wisconsin Glaciation (Har et. al, 1978). Underling the glacial drift is a mix of dolomite and sandstone from the Ordovician. The Ordovician units: Prairie du Chien Group (mostly dolomite), St. Peter Sandstone, as well as the Platteville and Decorah Formation, and the Galena Dolomite (Galena-Platteville unit) underlay the glacial sediments present in Columbia County (Har et. al, 1978). In many parts of the county, the Prairie du Chien Group was eroded away and the St. Peter Sandstone overlies Cambrian Sandstone. A bedrock geology map and stratigraphic column are provided in **Attachment E1** and **E2**.

A map of karst and shallow carbonate bedrock in Wisconsin, like the bedrock geology map from Har et. al, (1978), shows karst structures and shallow carbonate bedrock are found within Columbia County (Bradbury, 2009); however, the karst geology identified is not located at or near the COL dry ash disposal facility (**Attachment E3**).

The COL dry ash disposal facility is located within the area of the county where Ordovician St Peter sandstone bedrock underlies the glacial drift present at the surface (**Appendix G** and **H**). Karst features were not observed in boreholes at COL ADF, and the Wisconsin Geological and Natural History Survey (WGNH) did not identify the site as an area with potential karst structures.

Previous Geologic Investigations

The disposal facility area was investigated by Warzyn Engineering prior to construction by performing approximately 12 borings within and adjacent to the facility footprint. Eleven of the borings were instrumented with groundwater monitoring wells. The borings extended to depths of up to 100 feet. Split spoon samples were collected. Laboratory soil testing included grain size analysis, Atterberg limits, and organic content by loss on ignition. The boring locations and geologic cross sections are shown in **Appendix G**.

Based on the results of the subsurface investigations performed prior to disposal facility construction, the soils below the liner system within the facility footprint consist primarily of medium dense to very dense sands underlain by sandstone bedrock.

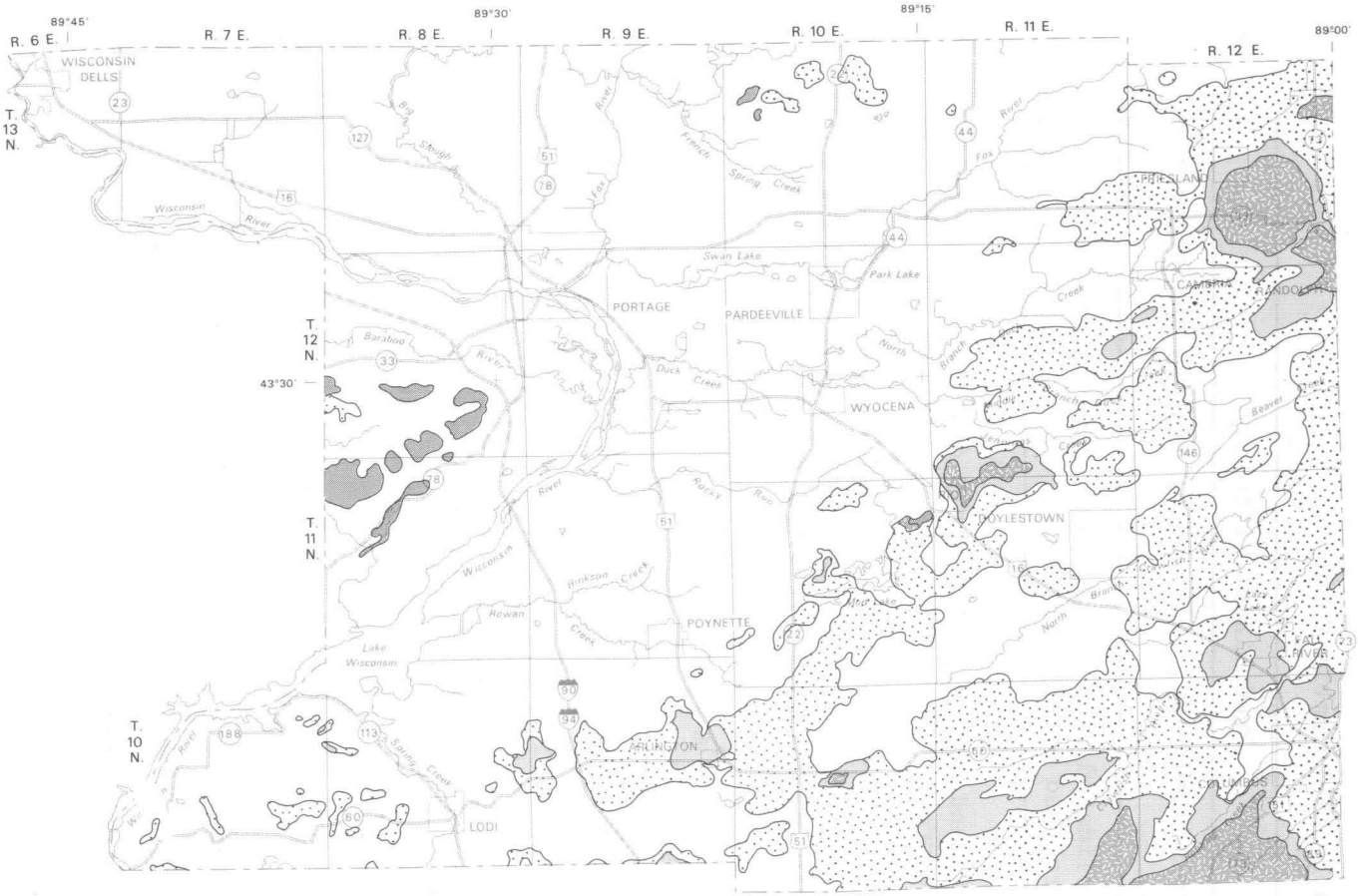
References

Harr, C.A., L.C. Trotta, and R.G. Borman, 1978, "Ground-Water Resources and Geology of Columbia County, Wisconsin," University of Wisconsin-Extension Geological and Natural History Survey Information Circular Number 37, 1978.

Bradbury, K. R., "Karst and Shallow Carbonate Bedrock in Wisconsin." University of Wisconsin-Extension Geological and Natural History Survey, Factsheet 02, 2009.

Warzyn Engineering, Inc., 1978, Feasibility Study, Proposed Fly Ash and/or Scrubber Sludge Disposal Facility – Columbia Site, Wisconsin Power and Light Company, Town of Pacific, Columbia County, WI, January 1978.

ATTACHMENT E1



Geology by L. C. Trotta (1976)

0 2 4 6 8 10 MILES

0 2 4 6 8 10 KILOMETERS

EXPLANATION

ORDOVICIAN

Galena Dolomite, Decorah, and Platteville Formations, undifferentiated
Mostly dolomite

St. Peter Sandstone
Mostly sandstone

Prairie du Chien Group
Mostly dolomite

CAMBRIAN

Trempleau Formation and Franconia, Galesville, Eau Claire, and Mount Simon Sandstones, undifferentiated
Mostly sandstone, some shale, siltstone and dolomite

PRECAMBRIAN

Crystalline Rock
Mostly quartzite and rhyolite

Figure 2. Bedrock geology.

ATTACHMENT E2

Table 1.--Stratigraphy of Columbia County

System	Rock unit	Predominant lithology
QUATERNARY	Holocene deposits	Unconsolidated clay, silt, sand, gravel, and organic matter.
	Pleistocene deposits	Unconsolidated clay, silt, sand, gravel, cobbles, boulders, and organic matter.
ORDOVICIAN	Galena Dolomite, Decorah Formation, and Platteville Formation, undifferentiated	Dolomite and some slightly shaly dolomite, light-gray to blue-gray.
	St. Peter Sandstone	Sandstone, dolomitic in some places, shaly at base in some places, white, light-gray, or pink, fine- to medium-grained.
	Prairie du Chien Group	Dolomite, tan, gray, or white; some sandstone and sandy dolomite.
CAMBRIAN	Trempealeau Formation	Sandstone, dolomitic, very fine- to medium-grained; dolomite interbedded with siltstone, light-gray.
	Franconia Sandstone	Sandstone, dolomitic, very fine- to medium-grained; siltstone, dolomitic.
	Galesville, Eau Claire, and Mount Simon Sandstones, undifferentiated	Sandstone, light-gray, fine- to coarse-grained, mostly medium grained.
PRECAMBRIAN	Precambrian rocks, undifferentiated	Crystalline rocks, mostly quartzite and rhyolite.

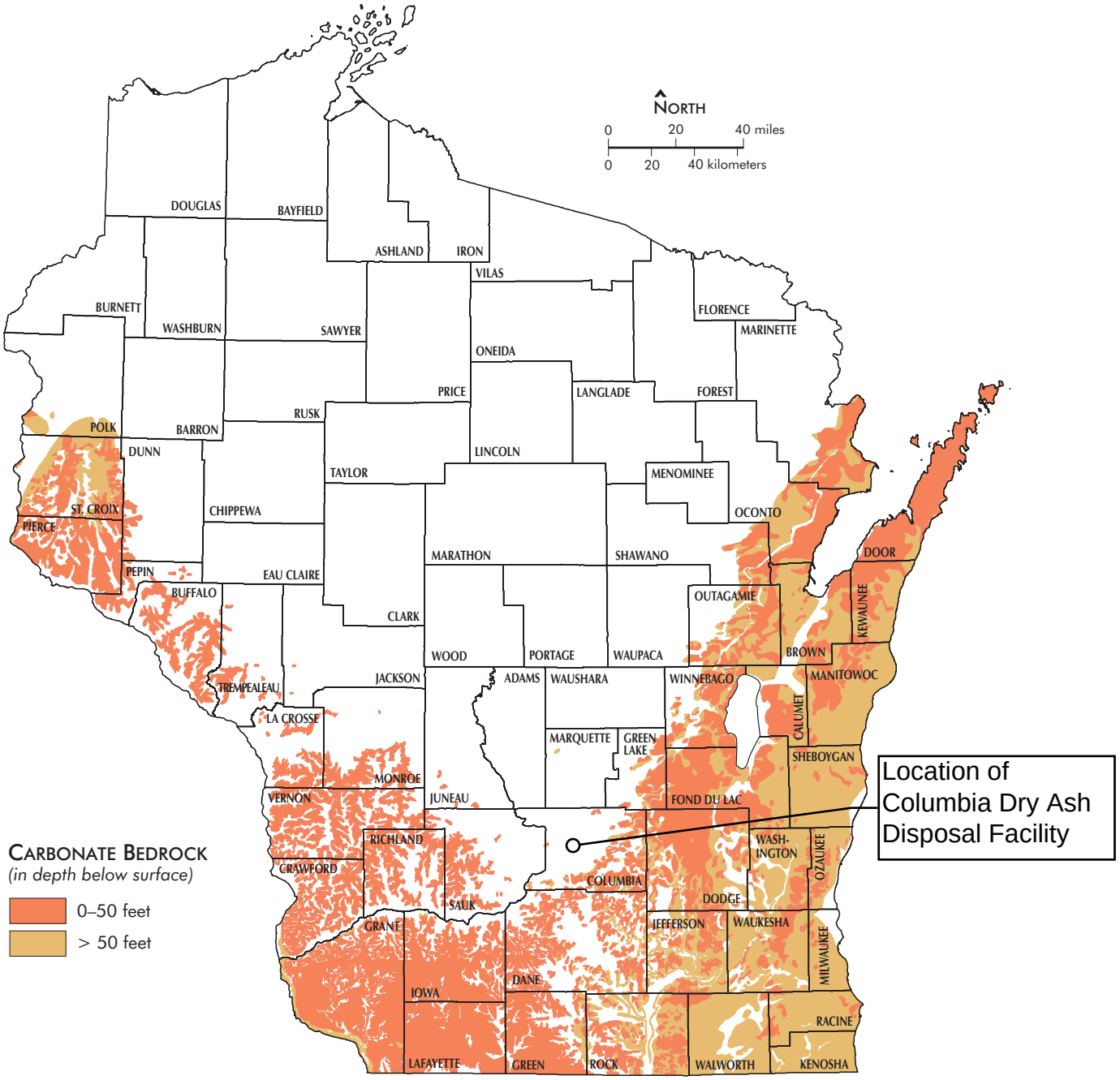
ATTACHMENT E3

Karst and shallow carbonate bedrock in Wisconsin

Wisconsin Geological and Natural History Survey

Factsheet 02 | 2009

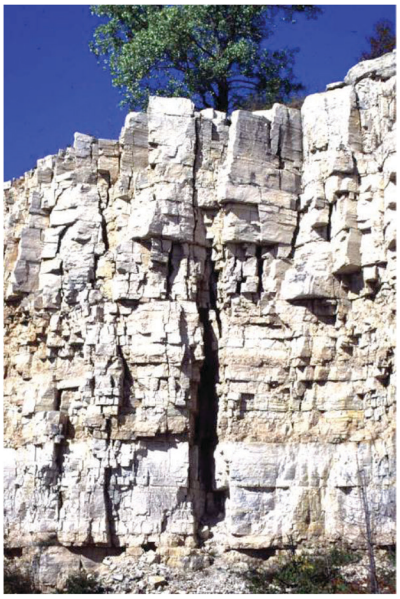
Areas with carbonate bedrock within 50 feet of the land surface are particularly vulnerable to groundwater contamination.



UW Extension
University of Wisconsin-Extension

Wisconsin Geological and Natural History Survey 3817 Mineral Point Road • Madison, Wisconsin 53705-5100
Tel 608.263.7389 • Fax 608.262.8086 • WisconsinGeologicalSurvey.org

Director and State Geologist: James M. Robertson



Fracturing and bedding in an exposure of carbonate bedrock near Sturgeon Bay in Door County.

Karst and shallow carbonate bedrock in Wisconsin

Wisconsin Geological and Natural History Survey

Factsheet 02 | 2009

Carbonate bedrock, rock formations composed primarily of limestone or dolomite, underlie the southern third of Wisconsin in a V-shaped belt (see map on other side). These rocks are commonly fractured, with the fractures providing primary pathways for groundwater movement.

Carbonate rocks are soluble, and percolating surface water can enlarge fractures to form conduits, caves, and sinkholes that are the hallmarks of a **karst** system and its related karst landscape.

In Wisconsin, karst landscapes are direct evidence of underlying shallow, fractured carbonate bedrock. But the lack of classic karst features in a landscape does not mean that shallow fractured carbonate bedrock is absent, or that the groundwater is potentially any less vulnerable to contamination.

Carbonate bedrock and groundwater contamination

Carbonate formations are important aquifers in Wisconsin. These aquifers supply water for homes, farms, cities, industries, and other human uses as well as maintaining water levels in lakes and wetlands and flows in streams and springs.

Carbonate aquifers are exceptionally vulnerable to contamination for two reasons:

- Groundwater flow in fractured rocks and karst systems can be extremely rapid—tens to hundreds of feet per day.
- Carbonate rocks are poor at filtering or otherwise removing contaminants.

Some site-specific questions to ask about carbonate aquifers

Carbonate aquifers are particularly vulnerable where overlying soils are thin or absent. There are numerous examples of groundwater contamination of carbonate aquifers in such settings in Wisconsin. Consequently, land-use activities in areas of carbonate rock must be carefully managed to avoid the release of contaminants to groundwater.

Types of questions to ask:

- Is carbonate bedrock present in the subsurface?
- How deeply is it buried? In other words, what is the thickness of the overlying material?
- What is the nature of the overlying material? For example, what is its origin, composition, grain size, etc?

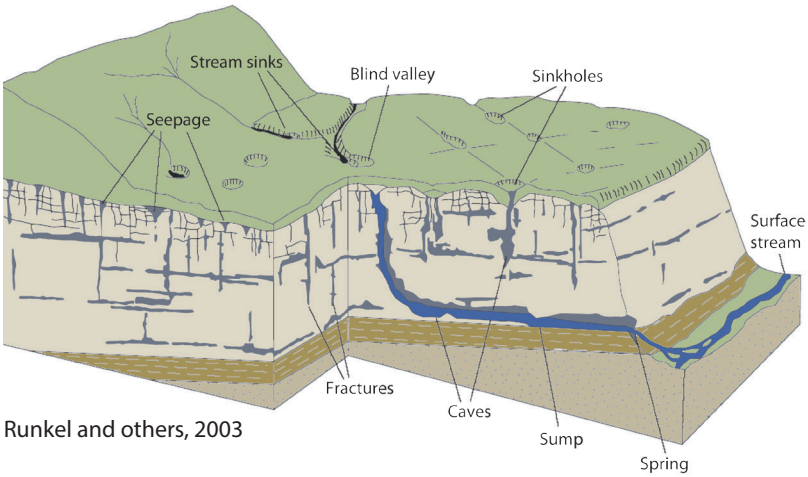
Water- and land-use management plans in areas with carbonate bedrock should always address these sorts of questions as they seek to protect groundwater quantity and quality.

For more information, contact

Kenneth R. Bradbury, Ph.D.
Wisconsin Geological and Natural History Survey
608.263.7921, krbradbu@wisc.edu

UW Extension
University of Wisconsin-Extension

Typical features of a karst sytem and landscape: Seepages, sinkholes, caves, fractures, springs, and stream sinks.



Runkel and others, 2003

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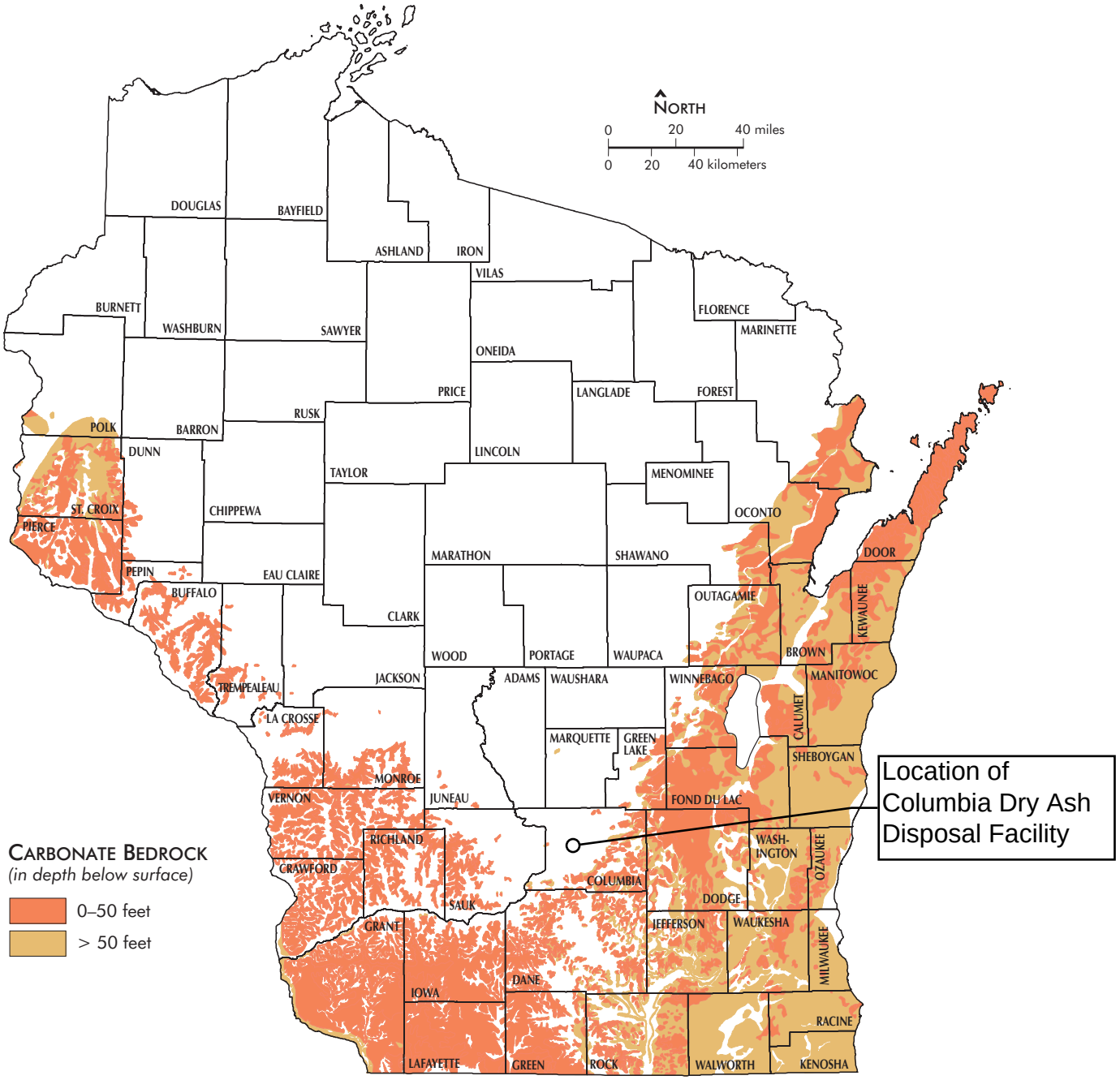
PRECAMBRIAN	Precambrian rocks, undifferentiated	Crystalline rocks, mostly quartzite and rhyolite.

Karst and shallow carbonate bedrock in Wisconsin

Wisconsin Geological and Natural History Survey

Factsheet 02 | 2009

Areas with carbonate bedrock within 50 feet of the land surface are particularly vulnerable to groundwater contamination.



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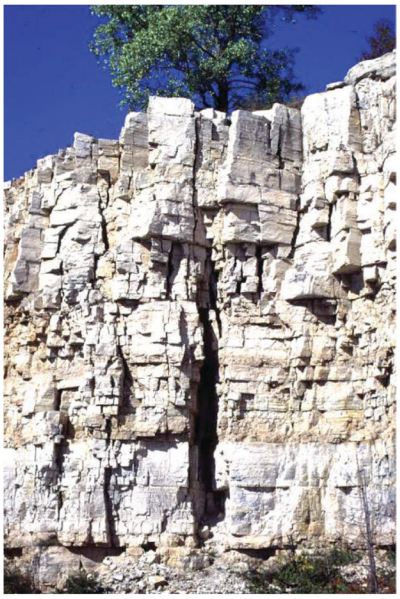
Tel 608.263.7389 • Fax 608.262.8086 • WisconsinGeologicalSurvey.org

Director and State Geologist: James M. Robertson



Fracturing and bedding in an exposure of carbonate bedrock near Sturgeon Bay in Door County.

Karst and shallow carbonate bedrock in Wisconsin

Wisconsin Geological and Natural History Survey

Factsheet 02 | 2009

Carbonate bedrock, rock formations composed primarily of limestone or dolomite, underlie the southern third of Wisconsin in a V-shaped belt (see map on other side). These rocks are commonly fractured, with the fractures providing primary pathways for groundwater movement.

Carbonate rocks are soluble, and percolating surface water can enlarge fractures to form conduits, caves, and sinkholes that are the hallmarks of a **karst** system and its related karst landscape.

In Wisconsin, karst landscapes are direct evidence of underlying shallow, fractured carbonate bedrock. But the lack of classic karst features in a landscape does not mean that shallow fractured carbonate bedrock is absent, or that the groundwater is potentially any less vulnerable to contamination.

Carbonate bedrock and groundwater contamination

Carbonate formations are important aquifers in Wisconsin. These aquifers supply water for homes, farms, cities, industries, and other human uses as well as maintaining water levels in lakes and wetlands and flows in streams and springs.

Carbonate aquifers are exceptionally vulnerable to contamination for two reasons:

- Groundwater flow in fractured rocks and karst systems can be extremely rapid—tens to hundreds of feet per day.
- Carbonate rocks are poor at filtering or otherwise removing contaminants.

Some site-specific questions to ask about carbonate aquifers

Carbonate aquifers are particularly vulnerable where overlying soils are thin or absent. There are numerous examples of groundwater contamination of carbonate aquifers in such settings in Wisconsin. Consequently, land-use activities in areas of carbonate rock must be carefully managed to avoid the release of contaminants to groundwater.

Types of questions to ask:

- Is carbonate bedrock present in the subsurface?
- How deeply is it buried? In other words, what is the thickness of the overlying material?
- What is the nature of the overlying material? For example, what is its origin, composition, grain size, etc?

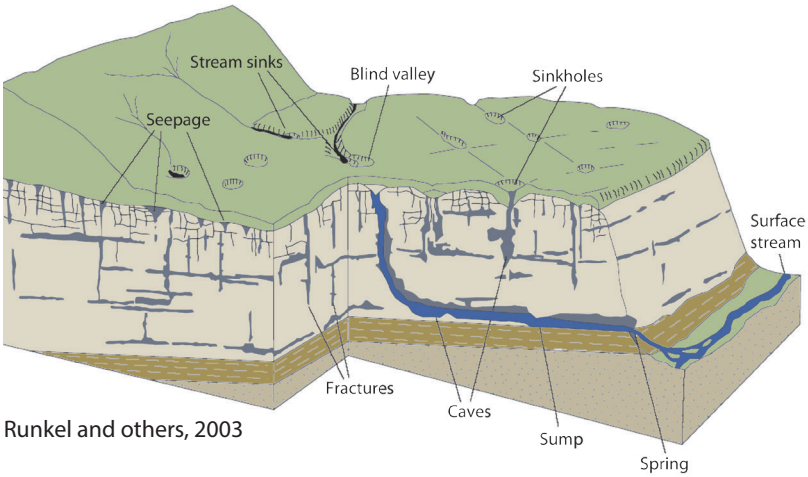
Water- and land-use management plans in areas with carbonate bedrock should always address these sorts of questions as they seek to protect groundwater quantity and quality.

For more information, contact

Kenneth R. Bradbury, Ph.D.
Wisconsin Geological and Natural History Survey
608.263.7921, krbradbu@wisc.edu

UW Extension
University of Wisconsin-Extension

Typical features of a karst sytem and landscape: Seepages, sinkholes, caves, fractures, springs, and stream sinks.



Runkel and others, 2003

APPENDIX F

Liquefaction and Settlement Potential Evaluation

Liquefaction and Settlement Potential Evaluation

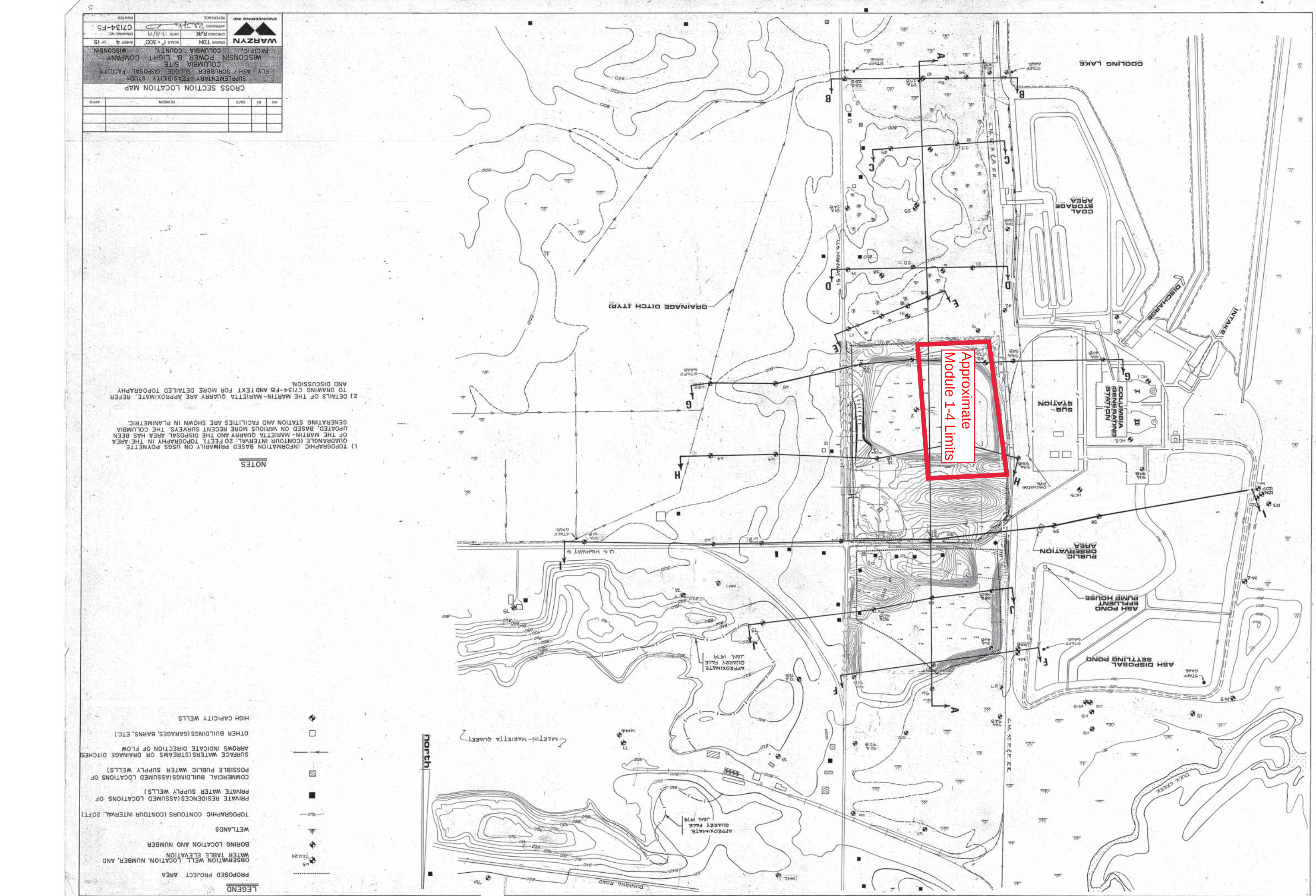
Based on the results of the site investigation borings and laboratory soil test results, the disposal facility soils are not subject to liquefaction or settlement concerns for the performance of the disposal facility.

Liquefaction is the process by which a saturated, loose, cohesionless soil influenced by external forces can suddenly loses its shear strength and behave as a fluid. The external forces result from ground motion from an earthquake. The disposal facility site soils consist primarily of sand. Borings show that the sands are medium dense to very dense rather than loose so liquefaction is not a concern given the low magnitude of maximum ground accelerations expected in the area; see **Appendix D**.

Settlement below a disposal facility can be a concern if the facility is underlain by extensive soft, fine-grained soils. Soft soils are subject to consolidation settlement depending on the load over the soft soils. The disposal facility soils consist of medium dense to very dense sands that are not subject to consolidation settlement so settlement is not a concern at the disposal facility.

APPENDIX G

Geologic Cross Sections



NOTES

1) TOPOGRAPHIC INFORMATION BASED PRIMARILY ON USGS POYNETTE QUADRANGLE (CONTOUR INTERVAL: 20 FEET). TOPOGRAPHY IN THE AREA OF THE MARTIN-MARIETTA QUARRY AND THE DISPOSAL AREA HAS BEEN UPDATED, BASED ON VARIOUS MORE RECENT SURVEYS. THE COLUMBIA GENERATING STATION AND FACILITIES ARE SHOWN IN PLANIMETRIC.

2) DETAILS OF THE MARTIN-MARIETTA QUARRY ARE APPROXIMATE. REFER TO DRAWING C7134-F6 AND TEXT FOR MORE DETAILED TOPOGRAPHY AND DISCUSSION.

LEGEND

- PROPOSED PROJECT AREA
- OBSERVATION WELL LOCATION, NUMBER, AND WATER TABLE ELEVATION
- BORING LOCATION AND NUMBER
- WETLANDS
- TOPOGRAPHIC CONTOURS (CONTOUR INTERVAL: 20FT)
- PRIVATE RESIDENCES (ASSUMED LOCATIONS OF PRIVATE WATER SUPPLY WELLS)
- COMMERCIAL BUILDINGS (ASSUMED LOCATIONS OF POSSIBLE PUBLIC WATER SUPPLY WELLS)
- SURFACE WATERS (STREAMS OR DRAINAGE DITCHES; ARROWS INDICATE DIRECTION OF FLOW
- OTHER BUILDINGS (GARAGES, BARNS, ETC.)
- HIGH CAPICITY WELLS

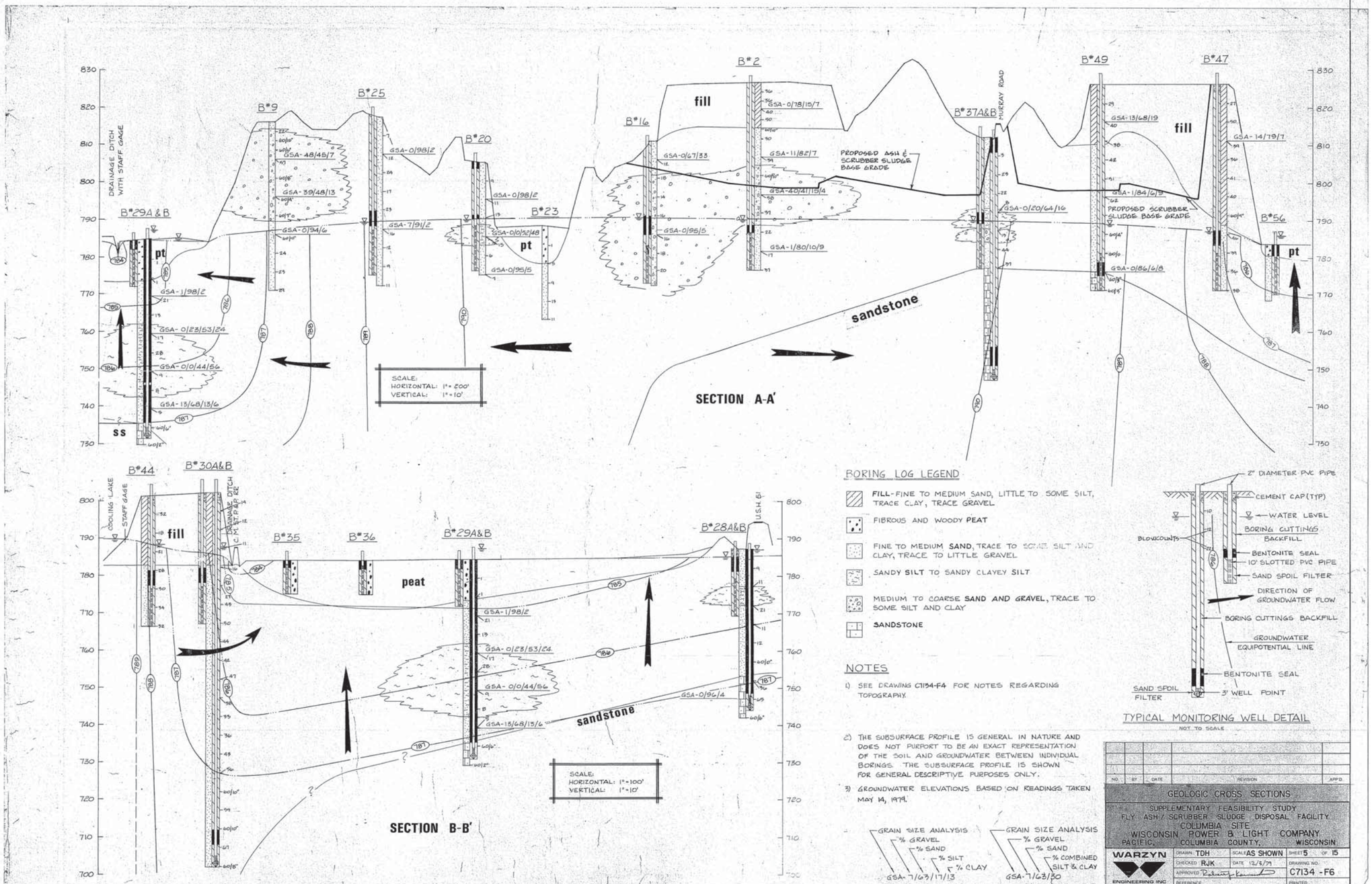
CROSS SECTION LOCATION MAP

SUPPLEMENTARY FEASIBILITY STUDY
FLY ASH / SCRUBBER SLUDGE DISPOSAL FACILITY
COLUMBIA SITE
WISCONSIN POWER & LIGHT COMPANY
PACIFIC, COLUMBIA COUNTY, WISCONSIN

NO.	BY	DATE	REVISION	APP'D

ENGINEERING INC
WARZYN

DRAWN TDH	SCALE 1" = 300'	SHEET 4 OF 15
CHECKED RJK	DATE 12/3/79	DRAWING NO. C7134-F5
APPROVED	REFERENCE	PRINTED



BORING LOG LEGEND

- **FILL** - FINE TO MEDIUM SAND, LITTLE TO SOME SILT, TRACE CLAY, TRACE GRAVEL
- FIBROUS AND WOODY **PEAT**
- FINE TO MEDIUM **SAND**, TRACE TO SOME SILT AND CLAY, TRACE TO LITTLE GRAVEL
- SANDY **SILT** TO SANDY CLAYEY **SILT**
- MEDIUM TO COARSE **SAND AND GRAVEL**, TRACE TO SOME SILT AND CLAY
- **SANDSTONE**

NOTES

1) SEE DRAWING C7134-F4 FOR NOTES REGARDING TOPOGRAPHY.

2) THE SUBSURFACE PROFILE IS GENERAL IN NATURE AND DOES NOT PURPORT TO BE AN EXACT REPRESENTATION OF THE SOIL AND GROUNDWATER BETWEEN INDIVIDUAL BORINGS. THE SUBSURFACE PROFILE IS SHOWN FOR GENERAL DESCRIPTIVE PURPOSES ONLY.

3) GROUNDWATER ELEVATIONS BASED ON READINGS TAKEN MAY 14, 1979.

GRAIN SIZE ANALYSIS
% GRAVEL
% SAND
% SILT
% CLAY
GSA-7/63/17/13

GRAIN SIZE ANALYSIS
% GRAVEL
% SAND
% COMBINED SILT & CLAY
GSA-7/63/30

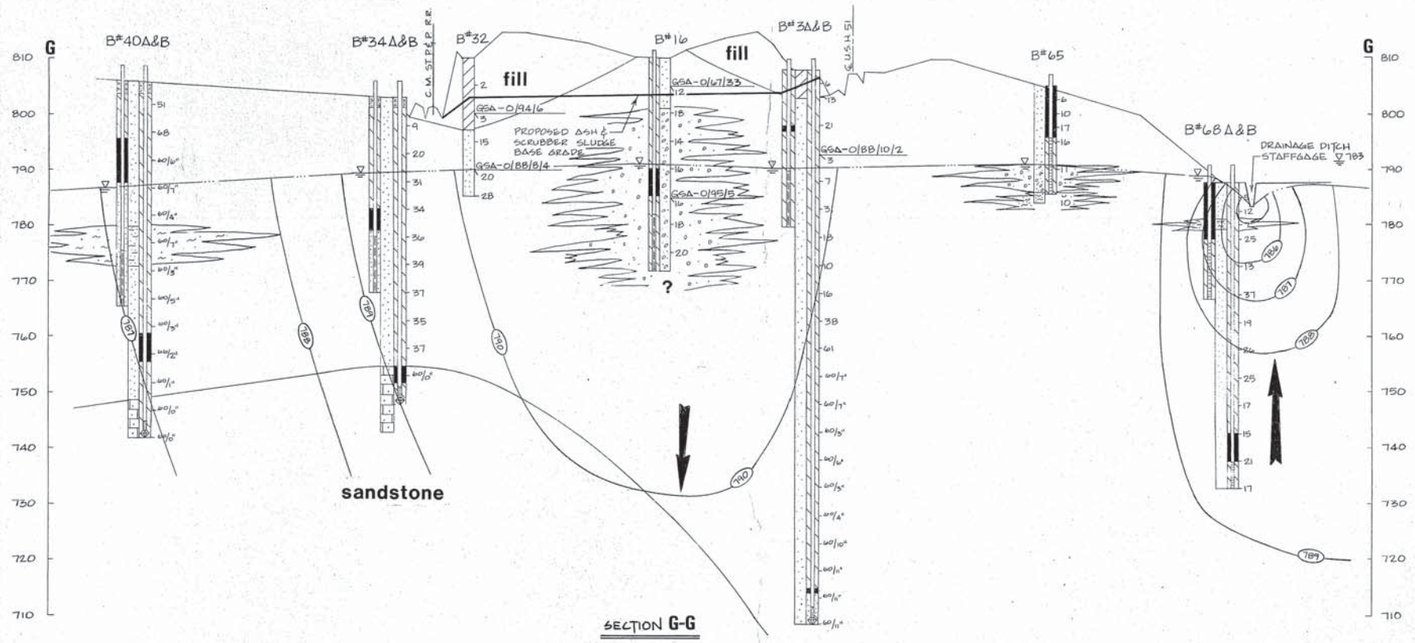
TYPICAL MONITORING WELL DETAIL
NOT TO SCALE

NO.	BY	DATE	REVISION	APP'D

GEOLOGIC CROSS SECTIONS
SUPPLEMENTARY FEASIBILITY STUDY
FLY ASH / SCRUBBER SLUDGE DISPOSAL FACILITY
COLUMBIA SITE
WISCONSIN POWER & LIGHT COMPANY
PACIFIC, COLUMBIA COUNTY, WISCONSIN

WARZYN ENGINEERING INC.

DRAWN: TDH	SCALE: AS SHOWN	SHEET 5	OF 15
CHECKED: RJK	DATE: 12/5/79	DRAWING NO.	C7134 -F6
APPROVED:			
REFERENCE		PRINTED	



SCALE:
VERTICAL: 1"=10'
HORIZONTAL: 1"=200'

NOTES

1) REFER TO DRAWING C7134-F5 FOR NOTES AND LEGEND

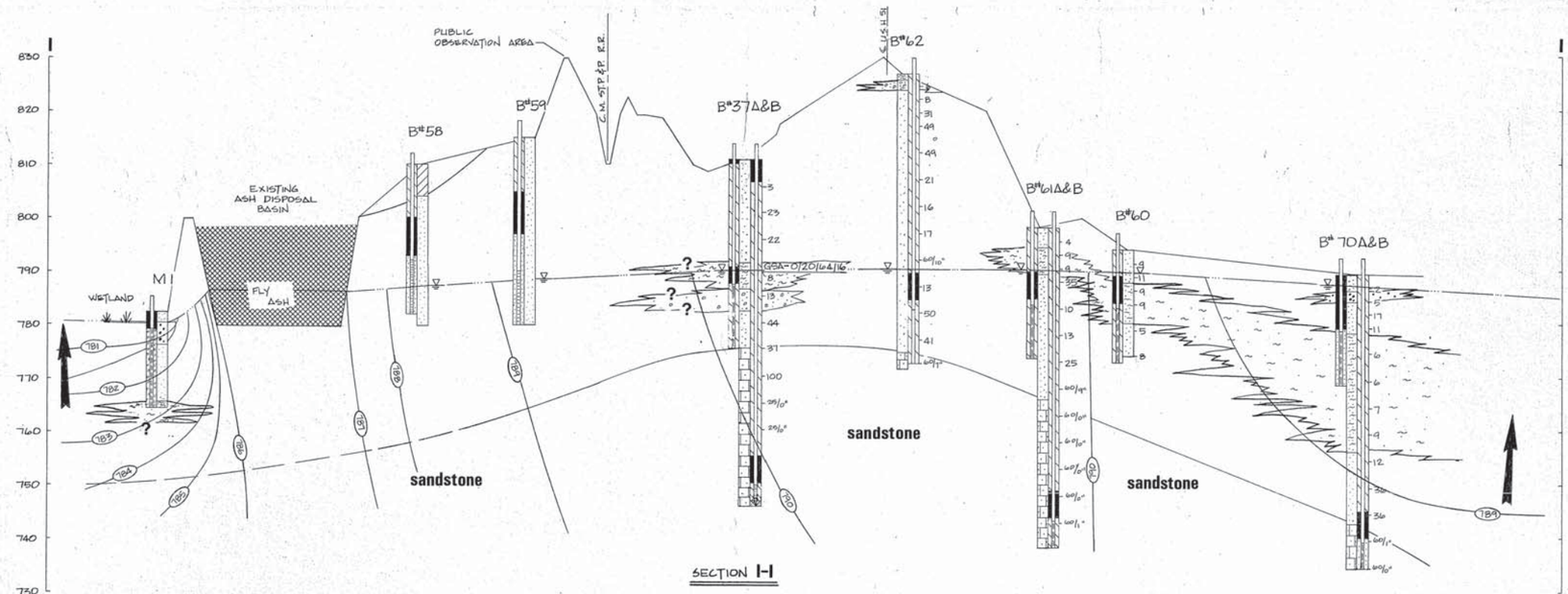
NO.	BY	DATE	REVISION	APP'D

GEOLOGIC CROSS SECTIONS

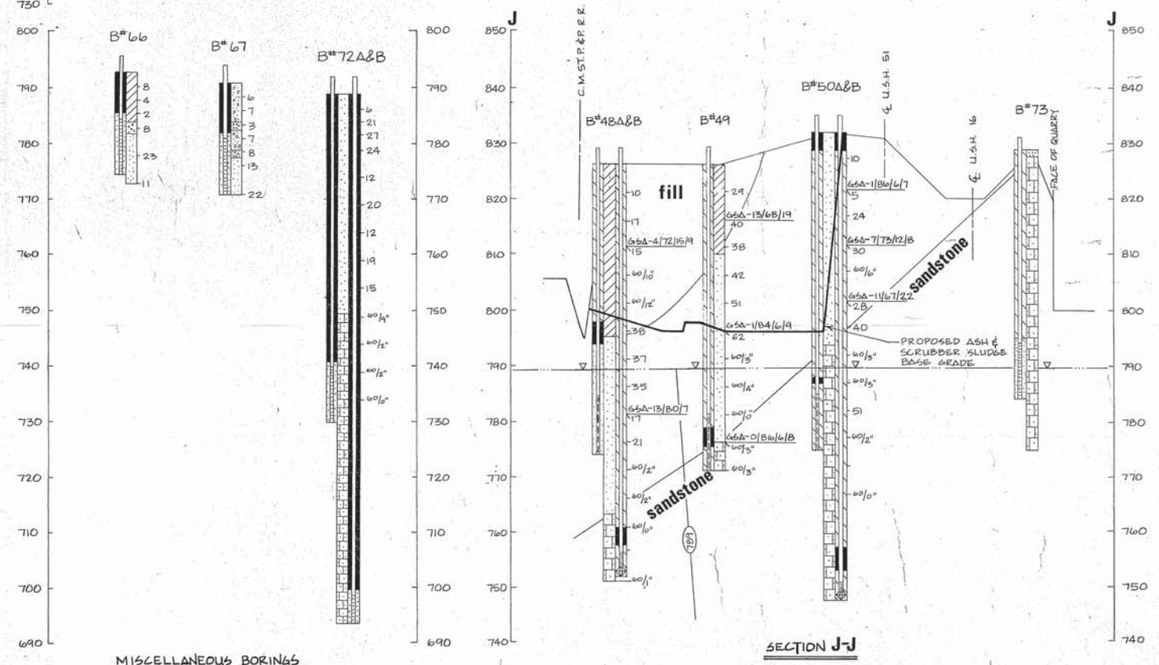
SUPPLEMENTARY FEASIBILITY STUDY
FLY ASH / SCRUBBER SLUDGE DISPOSAL FACILITY
COLUMBIA SITE
WISCONSIN POWER & LIGHT COMPANY
PACIFIC, COLUMBIA COUNTY, WISCONSIN

WARZYN ENGINEERING INC.

DRAWN TDH	SCALE AS SHOWN	SHEET 7	OF 15
CHECKED RJK	DATE 12/3/79	DRAWING NO.	C7134 -F8
APPROVED			
REFERENCE		PRINTED	



SECTION I-I



MISCELLANEOUS BORINGS

SECTION J-J

NOTES

1) REFER TO DRAWING C7134-F5 FOR NOTES AND LEGEND.

NO.	BY	DATE	REVISION	APP'D

GEOLOGIC CROSS SECTIONS

SUPPLEMENTARY FEASIBILITY STUDY
FLY ASH / SCRUBBER SLUDGE DISPOSAL FACILITY
COLUMBIA SITE
WISCONSIN POWER & LIGHT COMPANY
PACIFIC, COLUMBIA COUNTY, WISCONSIN

WARZYN ENGINEERING INC

DRAWN TDH	SCALE AS SHOWN	SHEET 8 OF 15	
CHECKED RJK	DATE 12/3/79	DRAWING NO.	
APPROVED Robert J. Kuss		C7134-F9	
REFERENCE		PRINTED	

APPENDIX H

Slope Stability Analysis

Environmental Consultants
and Contractors

2830 Dairy Drive
Madison, WI 53718-6751

608 224-2830
FAX 608 224-2839
www.scsengineers.com

SCS ENGINEERS

August 31, 2018
File No. 25217156.01

DRAFT

TECHNICAL MEMORANDUM

ANALYSIS BY: Brandon Suchomel

REVIEWED BY: Deb Nelson
Phil Gearing

SUBJECT: Interim Waste Slope Stability Analyses
Location Restriction Compliance Demonstration Report
Columbia Dry Ash Disposal Facility

PURPOSE

The purposes of the slope stability analyses were to evaluate:

- The interim 3H:1V north waste slope in Module 3 at the highest waste grade (Module 4 pre-filling stage)
- The interim 4H:1V east waste slope in Phase 1, Module 4 at the highest waste grade (Phase 1, Module 6 construction stage)

CONCLUSION

The attached results confirm that the Module 3 and Module 4 interim waste slopes will be stable during the construction and operation of the disposal facility modules.

APPROACH

SCS Engineers (SCS) evaluated the waste mass slope stability of the interim slope of Module 3 during Module 4 pre-filling and the waste mass slope stability of the interim slope of Module 4 during Module 6 construction stage at the most critical/highest waste grade cross-sections. The Module 3 interim 3H:1V waste slope analyzed is at the northern filling face with a maximum waste fill height of approximately 83 feet corresponding to a peak elevation of approximately 886 feet above mean sea level. The Module 4 interim 4H:1V waste slope analyzed is at the eastern filling face with a maximum waste fill height of approximately 83 feet corresponding to a peak elevation of approximately 890 feet above mean sea level. The interim waste slopes were evaluated for block failure and circular failure.

RESULTS

The calculated safety factors for each slope section and failure type are shown in the attached summary table. The calculated safety factors range from 1.58 to 1.98.

SCS recommends a minimum safety factor of 1.3 for the interim waste slopes. The results indicate that the 3H:1V waste slope for Module 3 and 4H:1V waste slope for Module 4 have acceptable minimum safety factor of approximately 1.66 and 1.58 respectively.

REFERENCES

1. SCS Engineers, Columbia Dry Ash Disposal Facility, Phase Analysis, 2013, module design interim waste grades.
2. SCS Engineers, Columbia Dry Ash Disposal Facility, Phase 1, Module 2 Liner Construction, 2012, existing composite liner grades.
3. SCS Engineers, Columbia Dry Ash Disposal Facility, Module 3 Liner Construction, 2016, existing composite liner grades and material properties for geosynthetics.
4. SCS Engineers, Columbia Dry Ash Disposal Facility, 2018 Module 4 Liner Construction, 2018, existing composite liner grades and material properties for subbase, clay, and drainage layer.
5. TRI/Environmental, Interface Friction Test Results, 2016, for 2016 Module 3 Liner Construction.
6. TRI/Environmental, Consolidated-Undrained Triaxial Compression Test Results for FGD Material, 2015, material properties for CCR.
7. U.S. Department of Transportation, Federal Highway Administration, Recycled Materials, Coal Ash User's Guide.
8. Stabilization of FGD By-Products by Using Fly Ash, Cement, and Sialite, 2009 WOCA Conference.
9. Geo-Slope International, Ltd., GeoStudio 2016, Version 8.16.2.14053, Slope/W slope stability software.

ASSUMPTIONS

- Bottom Ash drainage layer in Module 2/Module 3 and Sand drainage layer in Module 4 have the same properties.
- Geosynthetics installed for each of the module composite liners have the same properties.
- Clay material for each of the module composite liners have the same properties.
- CCR waste material will be the same in each of the existing and future modules.

- Circular and sliding block failure stability analyses are appropriate to evaluate the waste interim slope stability.

- Material properties are as shown in the table below, based on the indicated references and assumed values based on experience. Friction angles for soils are conservative assumed values based on soil type, published typical values, and SCS experience. The CCR friction angle is a conservative assumed value based on published values and 2015 triaxial compression test results by TRI/Environmental for CCR.

Material	Unit Weight (pcf)	Friction Angle (degrees)	Cohesion (psf)	Reference
Subbase Soil (Sand)	120	30	0	4
Clay Liner	125	28	0	4
Geosynthetics	58	24.3	0	5
Drainage Layer (Sand or Bottom Ash)	115	30	0	4
CCR	86	20	0	6, 7, 8

Attachments: Calculations organized as follows:

- Factor of Safety Summary Table
- Cross Section Location Figures
- Slope/W Outputs

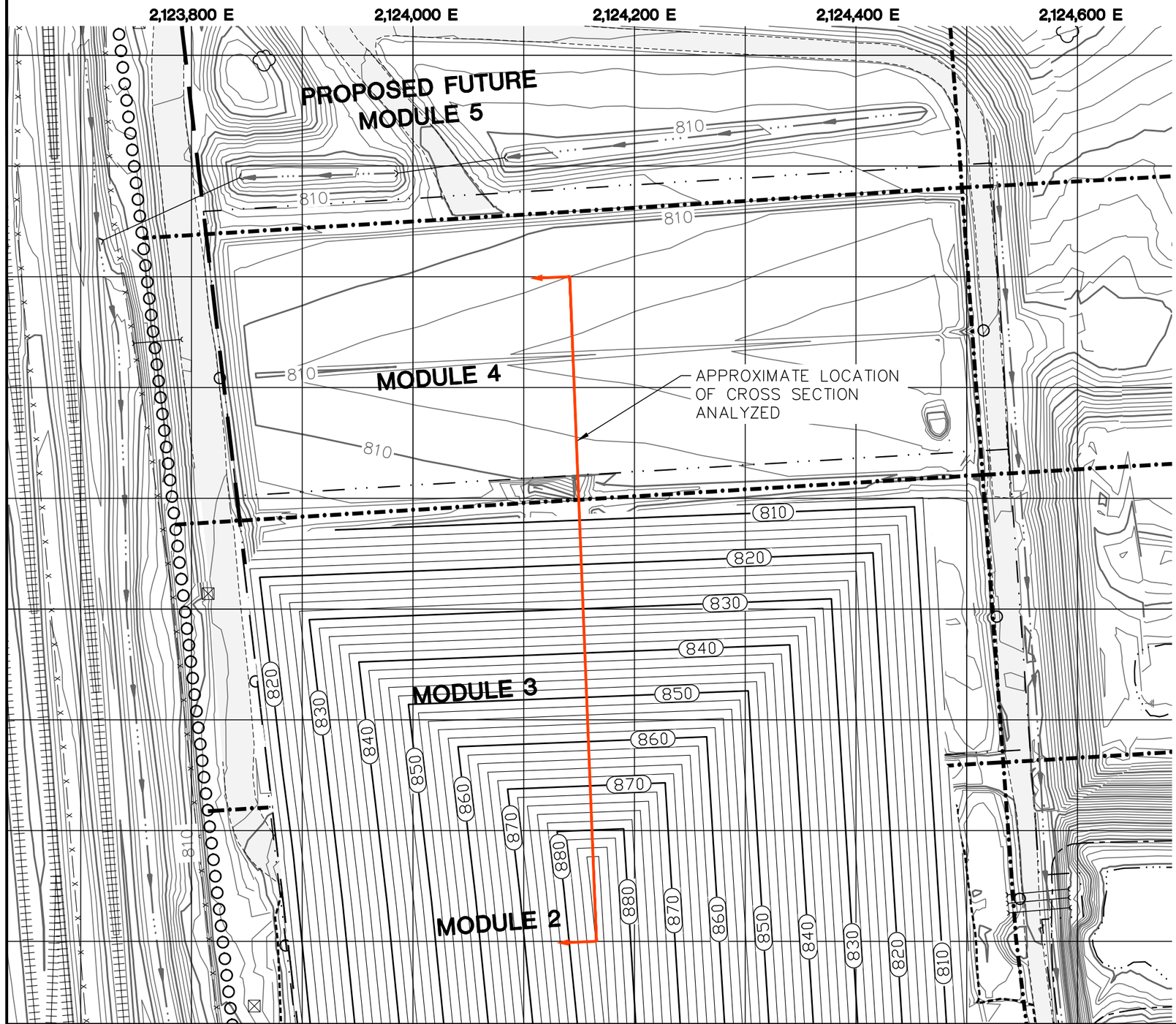
BSS/AJR/DLN/PEG
Coordinates checked by BJM

Slope Stability Analyses
Factors of Safety Results Summary
Columbia Dry Ash Disposal Facility - Location Restriction Compliance Demonstration

Module 3 Northern Interim Waste Slope Into Module 4		
Failure Type	**Calculated Safety Factor**	**Recommended Min. Safety Factor**
Block	1.98	1.3
Circular	1.66	1.3

Module 4 Eastern Interim Waste Slope		
Failure Type	**Calculated Safety Factor**	**Recommended Min. Safety Factor**
Block	1.98	1.3
Circular	1.58	1.3

Created by: BSS, 8/22/18
Last Revision by: BSS, 8/27/18
Checked by: DLN, 8/27/18



LEGEND

- 810 — EXISTING GRADE (10' INTERVAL)
- EXISTING GRADE (2' INTERVAL)
- 880 — PROPOSED WASTE GRADE (10' INTERVAL)
- PROPOSED WASTE GRADE (2' INTERVAL)

NOTES:

1. BASE MAP CREATED FROM AERIAL SURVEY BY KBM, FLOWN DECEMBER 1, 2014, AND GROUND SURVEYS BY SCS ENGINEERS IN MAY 2016, JUNE 2016, OCTOBER 2016, NOVEMBER 2016, APRIL 2017, NOVEMBER 2017, JULY 2018, AND AUGUST 2018.
2. PROPOSED GRADES REPRESENT MODULE 3 INTERIM WASTE GRADES AT THE MODULE 4 PRE-FILLING STAGE.

N

100 0 100

SCALE: 1" = 100'

PROJECT NO.	25217156.01	DRAWN BY:	BSS
DRAWN:	08/17/18	CHECKED BY:	PEG
REVISED:	08/22/18	APPROVED BY:	

ENGINEER: SCS ENGINEERS, 2830 DAIRY DRIVE MADISON, WI 53718-6751, PHONE: (608) 224-2830

CLIENT: Wisconsin Power and Light Company

SITE: WISCONSIN POWER AND LIGHT COLUMBIA ENERGY CENTER W8375 MURRAY ROAD PARDEEVILLE, WISCONSIN 53954

LOCATION RESTRICTION
COMPLIANCE DEMONSTRATION REPORT
COLUMBIA DRY ASH DISPOSAL FACILITY
TOWN OF PACIFIC, WISCONSIN

SLOPE STABILITY ANALYSIS
CROSS SECTION LOCATION
– MODULE 3 INTERIM WASTE SLOPE –

FIGURE
1 OF 2

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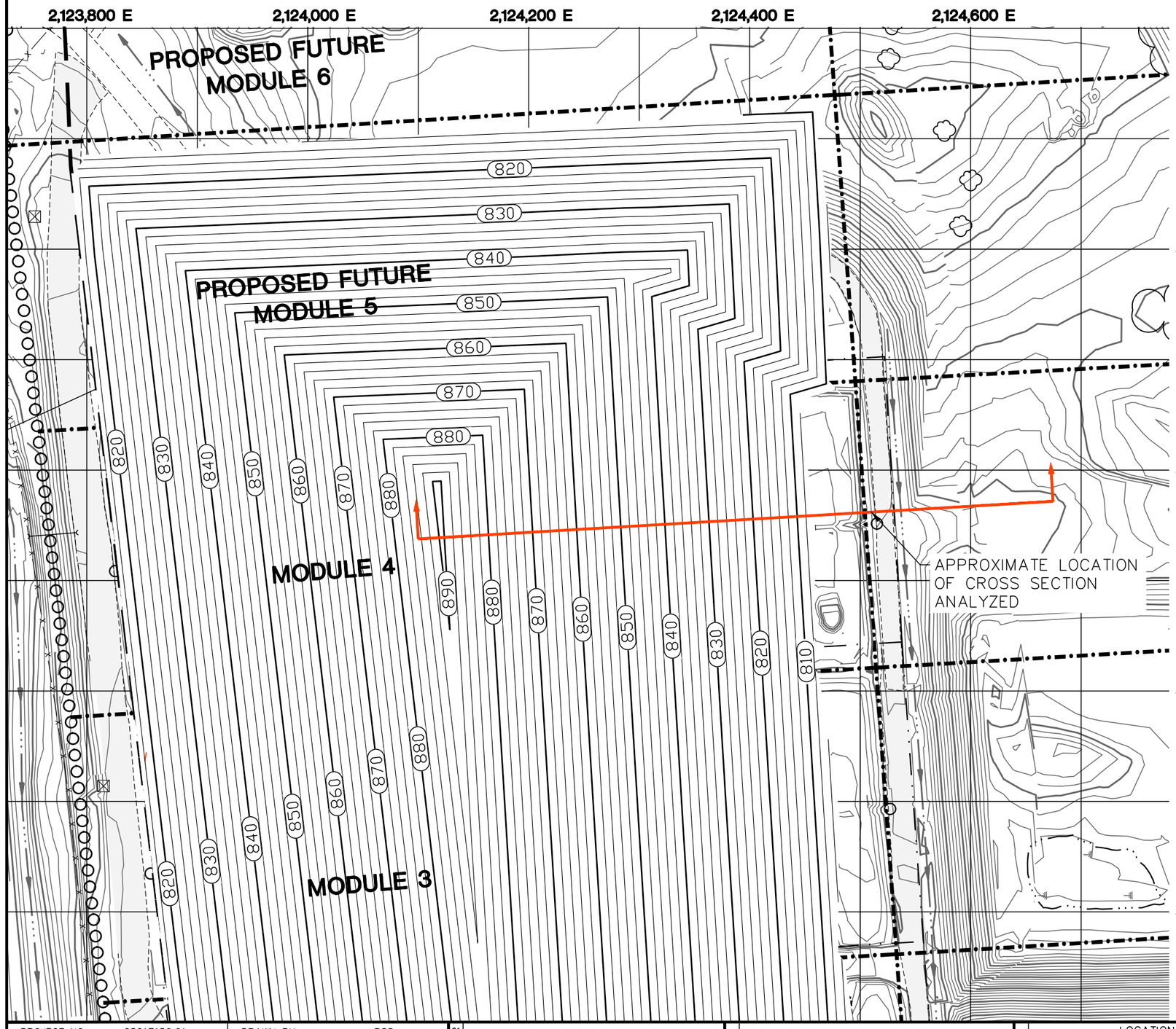


LEGEND

- 810 — EXISTING GRADE (10' INTERVAL)
- EXISTING GRADE (2' INTERVAL)
- 880 — PROPOSED WASTE GRADE (10' INTERVAL)
- PROPOSED WASTE GRADE (2' INTERVAL)

NOTES:

1. BASE MAP CREATED FROM AERIAL SURVEY BY KBM, FLOWN DECEMBER 1, 2014, AND GROUND SURVEYS BY SCS ENGINEERS IN MAY 2016, JUNE 2016, OCTOBER 2016, NOVEMBER 2016, APRIL 2017, NOVEMBER 2017, JULY 2018, AND AUGUST 2018.
2. PROPOSED GRADES REPRESENT MODULE 5 INTERIM WASTE GRADES AT THE MODULE 6 CONSTRUCTION STAGE.

N

100 0 100

SCALE: 1" = 100'

PROJECT NO.	25217156.01	DRAWN BY:	BSS
DRAWN:	08/17/18	CHECKED BY:	PEG
REVISED:	08/24/18	APPROVED BY:	

ENGINEER: SCS ENGINEERS, 2830 DAIRY DRIVE MADISON, WI 53718-6751, PHONE: (608) 224-2830

CLIENT: Wisconsin Power and Light Company, WISCONSIN POWER AND LIGHT COLUMBIA ENERGY CENTER W8375 MURRAY ROAD PARDEEVILLE, WISCONSIN 53954

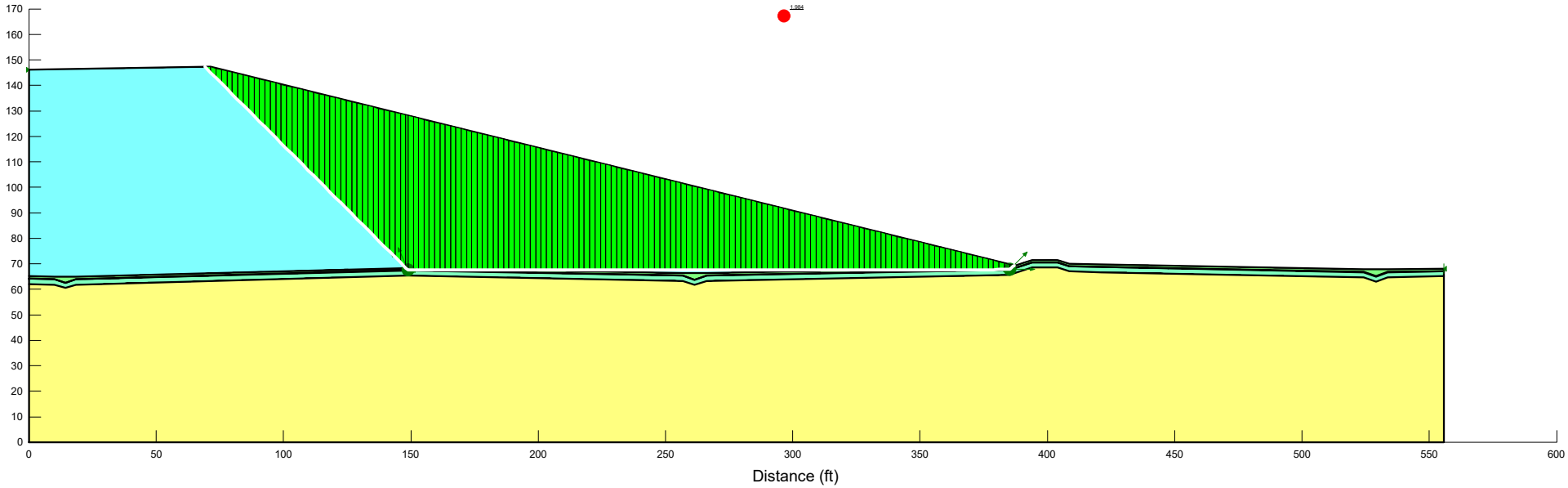
SITE: LOCATION RESTRICTION COMPLIANCE DEMONSTRATION REPORT COLUMBIA DRY ASH DISPOSAL FACILITY TOWN OF PACIFIC, WISCONSIN

SLOPE STABILITY ANALYSIS
CROSS SECTION LOCATION
– MODULE 4 INTERIM WASTE SLOPE –

FIGURE 2 OF 2

I:\25217156.00\Drawings\Location Restriction Compliance Report\Sections for Slope Stability.dwg, 8/24/2018 5:22:58 PM

Columbia Unstable Areas Analysis 2018 - Mod 3 Northern Slope into Mod 4
Analysis: Block
F of S: 1.984



Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	CCR	Mohr-Coulomb	86	0	20
	Clay	Mohr-Coulomb	125	0	28
	Drainage Layer	Mohr-Coulomb	115	0	30
	Geosynthetics	Mohr-Coulomb	58	0	24.3
	Subbase	Mohr-Coulomb	120	0	30

Block

File Information

File Version: 8.16
Title: Columbia Unstable Areas Analysis 2018 - Mod 3 Northern Slope into Mod 4
Comments: Running slope stability analysis on the north interim waste slope of Module 3, Phase 1 leading into Module 4, Phase 1 of the Columbia Dry Ash Disposal Facility. Location of analysis was selected based on longest and steepest slope at the time of peak waste placement within Module 3. Assumptions: Bottom Ash drainage layer in Mod 2/3 and Sand drainage layer in Mod 4 have the same properties. Drainage Layer is 'level' accross the leachate collection trenches. Geosynthetics for Mod 2-Mod 4 have the same properties. Clay for Mod 2-Mod 4 have the same properties. CCR waste in Mod 2-Mod 4 will have the same properties. References: Mod 2 Base Grades (top of clay): SCS Engineers, Civil 3D as-built surface "CLAY BASE (kp)", January 2012 Mod 3 Base Grades (top of clay): SCS Engineers, Civil 3D as-built surface "Ph1Mod3_Base_As-built 160623", June 2016 Mod 4 Base Grades (top of clay): SCS Engineers, Civil 3D as-built surface "As-built Mod 4 Base Grades", August 2018 Mod 2 Subbase Grades: Mod 2 Base Grades (top of clay) minus 2 ft Mod 3 Subbase Grades: Mod 3 Base Grades (top of clay) minus 2 ft Mod 4 Subbase Grades: Mod 4 Base Grades (top of clay) minus 2 ft Mod 2 Drainage Layer Grades: Mod 2 Base Grades (top of clay) plus 1 ft Mod 3 Drainage Layer Grades: Mod 3 Base Grades (top of clay) plus 1 ft Mod 4 Drainage Layer Grades: SCS Engineers, Civil 3D as-built surface "As-built Leachate Drainage Layer and Perimeter", August 2018 Mod 3 Waste Grades: SCS Engineers, Civil 3D design surface "MOD3INTERIM", December 2013 Geosynthetic Material Properties: SCS Engineers, Mod 3 and Mod 4 Interface Friction Testing, Completed by TRI/Environmental, March/April 2016 and April 2018 CCR Material Properties: SCS Engineers, Ottumwa - FGD Material Testing, July 2015
Created By: Suchomel, Brandon
Last Edited By: Suchomel, Brandon
Revision Number: 42
Date: 8/27/2018
Time: 9:37:46 AM
Tool Version: 8.16.3.14580
File Name: Mod 3 Northern Slope.gsz
Directory: I:\25217156.00\Data and Calculations\Slope Stability\
Last Solved Date: 8/27/2018
Last Solved Time: 9:38:07 AM

Project Settings

Length(L) Units: Feet
Time(t) Units: Seconds
Force(F) Units: Pounds
Pressure(p) Units: psf
Strength Units: psf
Unit Weight of Water: 62.4 pcf
View: 2D
Element Thickness: 1

Analysis Settings

Block

Kind: SLOPE/W
Method: Janbu
Settings
    PWP Conditions Source: (none)
Slip Surface
    Direction of movement: Left to Right
    Use Passive Mode: No
    Slip Surface Option: Block
    Critical slip surfaces saved: 10
    Resisting Side Maximum Convex Angle: 1 °
    Driving Side Maximum Convex Angle: 5 °
    Restrict Block Crossing: No
    Optimize Critical Slip Surface Location: No
    Tension Crack
        Tension Crack Option: (none)
F of S Distribution
    F of S Calculation Option: Constant
Advanced

Number of Slices: 150
F of S Tolerance: 0.001
Minimum Slip Surface Depth: 0.1 ft

Materials

Subbase

Model: Mohr-Coulomb
Unit Weight: 120 pcf
Cohesion': 0 psf
Phi': 30 °
Phi-B: 0 °

Geosynthetics

Model: Mohr-Coulomb
Unit Weight: 58 pcf
Cohesion': 0 psf
Phi': 24.3 °
Phi-B: 0 °

Drainage Layer

Model: Mohr-Coulomb
Unit Weight: 115 pcf
Cohesion': 0 psf
Phi': 30 °
Phi-B: 0 °

Clay

Model: Mohr-Coulomb
Unit Weight: 125 pcf
Cohesion': 0 psf
Phi': 28 °
Phi-B: 0 °

CCR

Model: Mohr-Coulomb
Unit Weight: 86 pcf
Cohesion': 0 psf
Phi': 20 °
Phi-B: 0 °

Slip Surface Limits

Left Coordinate: (0, 146.14) ft
Right Coordinate: (555.72, 68.16) ft

Slip Surface Block

Left Grid
- Upper Left: (148.89, 67.54) ft
- Lower Left: (148.89, 67.44) ft
- Lower Right: (151.15, 67.4) ft
- X Increments: 10
- Y Increments: 4
- Starting Angle: 115 °
- Ending Angle: 135 °
- Angle Increments: 2

Right Grid
- Upper Left: (383.64, 67.7) ft
- Lower Left: (383.64, 67.6) ft
- Lower Right: (385.18, 67.63) ft
- X Increments: 10
- Y Increments: 4
- Starting Angle: 0 °
- Ending Angle: 45 °

Angle Increments: 2

Points

	X (ft)	Y (ft)
Point 1	0	64.09
Point 2	10.01	63.86
Point 3	14.26	62.52
Point 4	18.51	63.86
Point 5	148.9	67.44
Point 6	256.7	65.31
Point 7	261.48	63.72
Point 8	266.26	65.33
Point 9	385.18	67.63
Point 10	387.27	68.32
Point 11	393.96	70.53
Point 12	403.95	70.5
Point 13	408.59	69
Point 14	421.1	68.74
Point 15	524.2	66.68
Point 16	528.99	64.96
Point 17	533.77	66.7
Point 18	555.72	67.1
Point 19	0	0
Point 20	555.72	0
Point 21	0	146.14
Point 22	71.39	147.29
Point 23	0	62.09
Point 24	10.01	61.86
Point 25	14.26	60.52
Point 26	18.51	61.86
Point 27	148.9	65.44
Point 28	256.7	63.31
Point 29	261.48	61.72
Point 30	266.26	63.33
Point 31	385.18	65.63
Point 32	387.27	66.32
Point 33	393.96	68.53
Point 34	403.95	68.5
Point 35	408.59	67
Point 36	421.1	66.74
Point 37	524.2	64.68
Point 38	528.99	62.96
Point 39	533.77	64.7
Point 40	555.72	65.1
Point 41	0	64.19
Point 42	10.01	63.96
Point 43	14.26	62.63
Point 44	18.51	63.96
Point 45	148.9	67.54
Point 46	256.7	65.41
Point 47	261.48	63.82
Point 48	266.26	65.43
Point 49	385.18	67.73
Point 50	387.27	68.42
Point 51	393.96	70.63
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Point 55	524.2	66.78
Point 56	528.99	65.06
Point 57	533.77	66.8
Point 58	555.72	67.2
Point 59	0	65.09
Point 60	10.01	64.86
Point 61	18.51	64.86
Point 62	148.9	68.44
Point 63	256.7	66.31
Point 64	266.26	66.33
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Point 67	393.96	71.53
Point 68	403.95	71.5
Point 69	408.59	70
Point 70	421.1	69.79
Point 71	524.2	67.73
Point 72	533.77	67.76
Point 73	555.72	68.16

Regions

	Material	Points	Area (ft²)
Region 1	Subbase	19,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,20	35,879
Region 2	Clay	23,1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,40,39,38,37,36,35,34,33,32,31,30,29,28,27,26,25,24	1,111.4
Region 3	Drainage Layer	41,59,60,61,62,63,64,65,66,67,68,69,70,71,72,73,58,57,56,55,54,53,52,51,50,49,48,47,46,45,44,43,42	529.04
Region 4	CCR	59,21,22,66,65,64,63,62,61,60	18,727
Region 5	Geosynthetics	41,1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,58,57,56,55,54,53,52,51,50,49,48,47,46,45,44,43,42	55.615

Current Slip Surface

Slip Surface: 22,275
F of S: 1.984
Volume: 9,851.2815 ft³
Weight: 848,444.07 lbs
Resisting Force: 349,577.58 lbs
Activating Force: 176,179.78 lbs
F of S Rank (Analysis): 1 of 27,225 slip surfaces
F of S Rank (Query): 1 of 27,225 slip surfaces

Exit: (386.86898, 69.418984) ft
Entry: (69.17567, 147.25433) ft
Radius: 149.53805 ft
Center: (242.32466, 166.71317) ft

Slip Slices

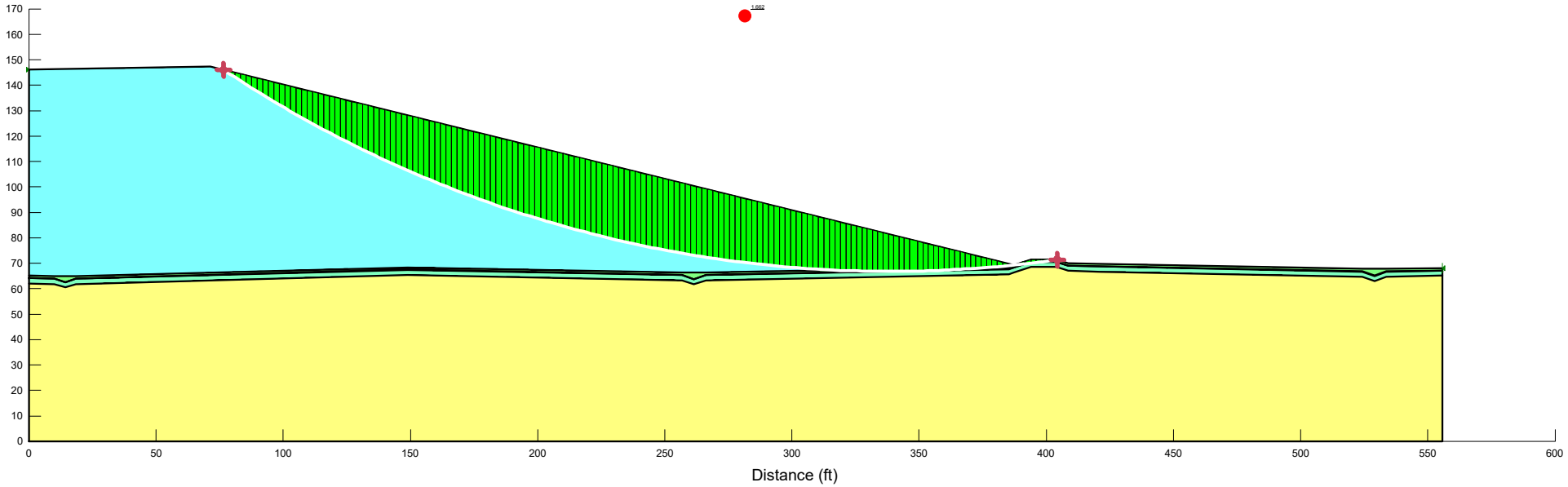
	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
Slice 1	70.282835	146.14717	0	81.759591	29.758057	0
Slice 2	72.454227	143.97577	0	221.77119	80.718111	0
Slice 3	74.58268	141.84732	0	338.2752	123.1221	0
Slice 4	76.711133	139.71887	0	454.7792	165.52609	0
Slice 5	78.839586	137.59041	0	571.28321	207.93009	0
Slice 6	80.96804	135.46196	0	687.78722	250.33408	0
Slice 7	83.096493	133.33351	0	804.29123	292.73807	0
Slice 8	85.224946	131.20505	0	920.79524	335.14206	0
Slice 9	87.353399	129.0766	0	1,037.2993	377.54605	0
Slice 10	89.481853	126.94815	0	1,153.8033	419.95004	0
Slice 11	91.610306	124.81969	0	1,270.3073	462.35403	0
Slice 12	93.738759	122.69124	0	1,386.8113	504.75803	0
Slice 13	95.867212	120.56279	0	1,503.3153	547.16202	0
Slice 14	97.995666	118.43433	0	1,619.8193	589.56601	0
Slice 15	100.12412	116.30588	0	1,736.3233	631.97	0
Slice 16	102.25257	114.17743	0	1,852.8273	674.37399	0
Slice 17	104.38103	112.04897	0	1,969.3313	716.77798	0
Slice 18	106.50948	109.92052	0	2,085.8353	759.18198	0
Slice 19	108.63793	107.79207	0	2,202.3393	801.58597	0
Slice 20	110.76639	105.66361	0	2,318.8434	843.98996	0
Slice 21	112.89484	103.53516	0	2,435.3474	886.39395	0
Slice 22	115.02329	101.40671	0	2,551.8514	928.79794	0
Slice 23	117.15175	99.278255	0	2,668.3554	971.20193	0
Slice 24	119.2802	97.149802	0	2,784.8594	1,013.6059	0
Slice 25	121.40865	95.021348	0	2,901.3634	1,056.0099	0
Slice 26	123.5371	92.892895	0	3,017.8674	1,098.4139	0
Slice 27	125.66556	90.764442	0	3,134.3714	1,140.8179	0
Slice 28	127.79401	88.635989	0	3,250.8754	1,183.2219	0
Slice 29	129.92246	86.507535	0	3,367.3794	1,225.6259	0
Slice 30	132.05092	84.379082	0	3,483.8834	1,268.0299	0
Slice 31	134.17937	82.250629	0	3,600.3875	1,310.4339	0
Slice 32	136.30782	80.122176	0	3,716.8915	1,352.8379	0
Slice 33	138.43628	77.993722	0	3,833.3955	1,395.2418	0
Slice 34	140.56473	75.865269	0	3,949.8995	1,437.6458	0
Slice 35	142.69318	73.736816	0	4,066.4035	1,480.0498	0
Slice 36	144.82164	71.608363	0	4,182.9075	1,522.4538	0
Slice 37	146.95009	69.479909	0	4,299.4115	1,564.8578	0
Slice 38	148.45716	67.977845	0	4,037.0708	2,330.8039	0
Slice 39	149.94209	67.540846	0	5,217.6421	3,012.4071	0
Slice 40	152.02627	67.542522	0	5,172.0021	2,986.0568	0
Slice 41	154.11044	67.544198	0	5,126.362	2,959.7065	0
Slice 42	156.19462	67.545874	0	5,080.722	2,933.3562	0
Slice 43	158.2788	67.54755	0	5,035.0819	2,907.0059	0
Slice 44	160.36298	67.549225	0	4,989.4419	2,880.6556	0
Slice 45	162.44716	67.550901	0	4,943.8019	2,854.3053	0
Slice 46	164.53133	67.552577	0	4,898.1618	2,827.955	0
Slice 47	166.61551	67.554253	0	4,852.5218	2,801.6048	0
Slice 48	168.69969	67.555929	0	4,806.8817	2,775.2545	0
Slice 49	170.78387	67.557605	0	4,761.2417	2,748.9042	0
Slice 50	172.86805	67.559281	0	4,715.6017	2,722.5539	0
Slice 51	174.95222	67.560957	0	4,669.9616	2,696.2036	0
Slice 52	177.0364	67.562632	0	4,624.3216	2,669.8533	0

Slice 53	179.12058	67.564308	0	4,578.6815	2,643.503	0
Slice 54	181.20476	67.565984	0	4,533.0415	2,617.1527	0
Slice 55	183.28893	67.56766	0	4,487.4015	2,590.8024	0
Slice 56	185.37311	67.569336	0	4,441.7614	2,564.4521	0
Slice 57	187.45729	67.571012	0	4,396.1214	2,538.1019	0
Slice 58	189.54147	67.572688	0	4,350.4813	2,511.7516	0
Slice 59	191.62565	67.574364	0	4,304.8413	2,485.4013	0
Slice 60	193.72626	67.576053	0	4,259.1044	1,550.1872	0
Slice 61	195.84332	67.577755	0	4,214.0111	1,533.7746	0
Slice 62	197.96037	67.579457	0	4,168.9177	1,517.362	0
Slice 63	200.07743	67.58116	0	4,123.8244	1,500.9493	0
Slice 64	202.19448	67.582862	0	4,078.731	1,484.5367	0
Slice 65	204.31154	67.584564	0	4,033.6376	1,468.124	0
Slice 66	206.42859	67.586267	0	3,988.5443	1,451.7114	0
Slice 67	208.54565	67.587969	0	3,943.4509	1,435.2988	0
Slice 68	210.66271	67.589671	0	3,898.3576	1,418.8861	0
Slice 69	212.77976	67.591374	0	3,853.2642	1,402.4735	0
Slice 70	214.89682	67.593076	0	3,808.1708	1,386.0608	0
Slice 71	217.01387	67.594778	0	3,763.0775	1,369.6482	0
Slice 72	219.13093	67.59648	0	3,717.9841	1,353.2356	0
Slice 73	221.24798	67.598183	0	3,672.8908	1,336.8229	0
Slice 74	223.36504	67.599885	0	3,627.7974	1,320.4103	0
Slice 75	225.48209	67.601587	0	3,582.704	1,303.9976	0
Slice 76	227.59915	67.60329	0	3,537.6107	1,287.585	0
Slice 77	229.7162	67.604992	0	3,492.5173	1,271.1724	0
Slice 78	231.83326	67.606694	0	3,447.424	1,254.7597	0
Slice 79	233.95032	67.608397	0	3,402.3306	1,238.3471	0
Slice 80	236.06737	67.610099	0	3,357.2373	1,221.9344	0
Slice 81	238.18443	67.611801	0	3,312.1439	1,205.5218	0
Slice 82	240.30148	67.613504	0	3,267.0505	1,189.1091	0
Slice 83	242.41854	67.615206	0	3,221.9572	1,172.6965	0
Slice 84	244.53559	67.616908	0	3,176.8638	1,156.2839	0
Slice 85	246.65265	67.618611	0	3,131.7705	1,139.8712	0
Slice 86	248.7697	67.620313	0	3,086.6771	1,123.4586	0
Slice 87	250.88676	67.622015	0	3,041.5837	1,107.0459	0
Slice 88	253.00381	67.623718	0	2,996.4904	1,090.6333	0
Slice 89	255.12087	67.62542	0	2,951.397	1,074.2207	0
Slice 90	257.23792	67.627122	0	2,906.3037	1,057.808	0
Slice 91	259.35498	67.628825	0	2,861.2103	1,041.3954	0
Slice 92	261.47204	67.630527	0	2,816.1169	1,024.9827	0
Slice 93	263.58909	67.632229	0	2,771.0236	1,008.5701	0
Slice 94	265.70615	67.633931	0	2,725.9302	992.15746	0
Slice 95	267.8232	67.635634	0	2,680.8369	975.74482	0
Slice 96	269.94026	67.637336	0	2,635.7435	959.33218	0
Slice 97	272.05731	67.639038	0	2,590.6501	942.91954	0
Slice 98	274.17437	67.640741	0	2,545.5568	926.5069	0
Slice 99	276.29142	67.642443	0	2,500.4634	910.09426	0
Slice 100	278.40848	67.644145	0	2,455.3701	893.68162	0
Slice 101	280.52553	67.645848	0	2,410.2767	877.26898	0
Slice 102	282.64259	67.64755	0	2,365.1834	860.85634	0
Slice 103	284.75965	67.649252	0	2,320.09	844.4437	0
Slice 104	286.8767	67.650955	0	2,274.9966	828.03106	0
Slice 105	288.99376	67.652657	0	2,229.9033	811.61842	0
	291.11081	67.654359	0	2,184.8099	795.20578	0

Slice 106						
Slice 107	293.22787	67.656062	0	2,139.7166	778.79314	0
Slice 108	295.34492	67.657764	0	2,094.6232	762.3805	0
Slice 109	297.46198	67.659466	0	2,049.5298	745.96786	0
Slice 110	299.57903	67.661169	0	2,004.4365	729.55521	0
Slice 111	301.69609	67.662871	0	1,959.3431	713.14257	0
Slice 112	303.81314	67.664573	0	1,914.2498	696.72993	0
Slice 113	305.9302	67.666275	0	1,869.1564	680.31729	0
Slice 114	308.04725	67.667978	0	1,824.063	663.90465	0
Slice 115	310.16431	67.66968	0	1,778.9697	647.49201	0
Slice 116	312.28137	67.671382	0	1,733.8763	631.07937	0
Slice 117	314.39842	67.673085	0	1,688.783	614.66673	0
Slice 118	316.51548	67.674787	0	1,643.6896	598.25409	0
Slice 119	318.63253	67.676489	0	1,598.5962	581.84145	0
Slice 120	320.74959	67.678192	0	1,553.5029	565.42881	0
Slice 121	322.86664	67.679894	0	1,508.4095	549.01617	0
Slice 122	324.9837	67.681596	0	1,463.3162	532.60353	0
Slice 123	327.10075	67.683299	0	1,418.2228	516.19089	0
Slice 124	329.21781	67.685001	0	1,373.1295	499.77825	0
Slice 125	331.33486	67.686703	0	1,328.0361	483.36561	0
Slice 126	333.45192	67.688406	0	1,282.9427	466.95297	0
Slice 127	335.56897	67.690108	0	1,237.8494	450.54033	0
Slice 128	337.68299	67.691808	0	1,193.4914	689.06257	0
Slice 129	339.79397	67.693505	0	1,149.6586	663.75572	0
Slice 130	341.90495	67.695203	0	1,105.8259	638.44887	0
Slice 131	344.01593	67.6969	0	1,061.9931	613.14202	0
Slice 132	346.1269	67.698598	0	1,018.1604	587.83517	0
Slice 133	348.23788	67.700295	0	974.32762	562.52831	0
Slice 134	350.34886	67.701992	0	930.49487	537.22146	0
Slice 135	352.45984	67.70369	0	886.66212	511.91461	0
Slice 136	354.57082	67.705387	0	842.82936	486.60776	0
Slice 137	356.6818	67.707085	0	798.99661	461.30091	0

Slice 138	358.79277	67.708782	0	755.16386	435.99406	0
Slice 139	360.90375	67.71048	0	711.33111	410.68721	0
Slice 140	363.01473	67.712177	0	667.49835	385.38035	0
Slice 141	365.12571	67.713874	0	623.6656	360.0735	0
Slice 142	367.23669	67.715572	0	579.83285	334.76665	0
Slice 143	369.34766	67.717269	0	536.0001	309.4598	0
Slice 144	371.45864	67.718967	0	492.16735	284.15295	0
Slice 145	373.56962	67.720664	0	448.33459	258.8461	0
Slice 146	375.6806	67.722362	0	404.50184	233.53925	0
Slice 147	377.79158	67.724059	0	360.66909	208.2324	0
Slice 148	379.90255	67.725756	0	316.83634	182.92554	0
Slice 149	382.01353	67.727454	0	273.00358	157.61869	0
Slice 150	384.12451	67.729151	0	229.17083	132.31184	0
Slice 151	385.85179	68.401786	0	172.20549	99.422886	0
Slice 152	386.69628	69.246278	0	22.676627	8.2536173	0

Columbia Unstable Areas Analysis 2018 - Mod 3 Northern Slope into Mod 4
Analysis: Circular
F of S: 1.662



Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	CCR	Mohr-Coulomb	86	0	20
	Clay	Mohr-Coulomb	125	0	28
	Drainage Layer	Mohr-Coulomb	115	0	30
	Geosynthetics	Mohr-Coulomb	58	0	24.3
	Subbase	Mohr-Coulomb	120	0	30

Circular

File Information

File Version: 8.16
Title: Columbia Unstable Areas Analysis 2018 - Mod 3 Northern Slope into Mod 4
Comments: Running slope stability analysis on the north interim waste slope of Module 3, Phase 1 leading into Module 4, Phase 1 of the Columbia Dry Ash Disposal Facility. Location of analysis was selected based on longest and steepest slope at the time of peak waste placement within Module 3. Assumptions: Bottom Ash drainage layer in Mod 2/3 and Sand drainage layer in Mod 4 have the same properties. Drainage Layer is 'level' accross the leachate collection trenches. Geosynthetics for Mod 2-Mod 4 have the same properties. Clay for Mod 2-Mod 4 have the same properties. CCR waste in Mod 2-Mod 4 will have the same properties. References: Mod 2 Base Grades (top of clay): SCS Engineers, Civil 3D as-built surface "CLAY BASE (kp)", January 2012 Mod 3 Base Grades (top of clay): SCS Engineers, Civil 3D as-built surface "Ph1Mod3_Base_As-built 160623", June 2016 Mod 4 Base Grades (top of clay): SCS Engineers, Civil 3D as-built surface "As-built Mod 4 Base Grades", August 2018 Mod 2 Subbase Grades: Mod 2 Base Grades (top of clay) minus 2 ft Mod 3 Subbase Grades: Mod 3 Base Grades (top of clay) minus 2 ft Mod 4 Subbase Grades: Mod 4 Base Grades (top of clay) minus 2 ft Mod 2 Drainage Layer Grades: Mod 2 Base Grades (top of clay) plus 1 ft Mod 3 Drainage Layer Grades: Mod 3 Base Grades (top of clay) plus 1 ft Mod 4 Drainage Layer Grades: SCS Engineers, Civil 3D as-built surface "As-built Leachate Drainage Layer and Perimeter", August 2018 Mod 3 Waste Grades: SCS Engineers, Civil 3D design surface "MOD3INTERIM", December 2013 Geosynthetic Material Properties: SCS Engineers, Mod 3 and Mod 4 Interface Friction Testing, Completed by TRI/Environmental, March/April 2016 and April 2018 CCR Material Properties: SCS Engineers, Ottumwa - FGD Material Testing, July 2015
Created By: Suchomel, Brandon
Last Edited By: Suchomel, Brandon
Revision Number: 55
Date: 8/27/2018
Time: 10:25:07 AM
Tool Version: 8.16.3.14580
File Name: Mod 3 Northern Slope.gsz
Directory: I:\25217156.00\Data and Calculations\Slope Stability\
Last Solved Date: 8/27/2018
Last Solved Time: 10:25:29 AM

Project Settings

Length(L) Units: Feet
Time(t) Units: Seconds
Force(F) Units: Pounds
Pressure(p) Units: psf
Strength Units: psf
Unit Weight of Water: 62.4 pcf
View: 2D
Element Thickness: 1

Analysis Settings

Circular

Kind: SLOPE/W
Method: Bishop
Settings
    PWP Conditions Source: (none)
Slip Surface
    Direction of movement: Left to Right
    Use Passive Mode: No
    Slip Surface Option: Entry and Exit
    Critical slip surfaces saved: 10
    Resisting Side Maximum Convex Angle: 1 °
    Driving Side Maximum Convex Angle: 5 °
    Optimize Critical Slip Surface Location: No
    Tension Crack
        Tension Crack Option: (none)
F of S Distribution
    F of S Calculation Option: Constant
Advanced
    Number of Slices: 150

F of S Tolerance: 0.001
Minimum Slip Surface Depth: 0.1 ft

Materials

Subbase

Model: Mohr-Coulomb
Unit Weight: 120 pcf
Cohesion': 0 psf
Phi': 30 °
Phi-B: 0 °

Geosynthetics

Model: Mohr-Coulomb
Unit Weight: 58 pcf
Cohesion': 0 psf
Phi': 24.3 °
Phi-B: 0 °

Drainage Layer

Model: Mohr-Coulomb
Unit Weight: 115 pcf
Cohesion': 0 psf
Phi': 30 °
Phi-B: 0 °

Clay

Model: Mohr-Coulomb
Unit Weight: 125 pcf
Cohesion': 0 psf
Phi': 28 °
Phi-B: 0 °

CCR

Model: Mohr-Coulomb
Unit Weight: 86 pcf
Cohesion': 0 psf
Phi': 20 °
Phi-B: 0 °

Slip Surface Entry and Exit

Left Projection: Range
Left-Zone Left Coordinate: (76.45, 146.04102) ft
Left-Zone Right Coordinate: (76.72, 145.97437) ft
Left-Zone Increment: 30
Right Projection: Range
Right-Zone Left Coordinate: (404.13, 71.44181) ft
Right-Zone Right Coordinate: (404.46, 71.33513) ft
Right-Zone Increment: 30
Radius Increments: 20

Slip Surface Limits

Left Coordinate: (0, 146.14) ft
Right Coordinate: (555.72, 68.16) ft

Points

	X (ft)	Y (ft)
Point 1	0	64.09
Point 2	10.01	63.86
Point 3	14.26	62.52
Point 4	18.51	63.86

Point 5	148.9	67.44
Point 6	256.7	65.31
Point 7	261.48	63.72
Point 8	266.26	65.33
Point 9	385.18	67.63
Point 10	387.27	68.32
Point 11	393.96	70.53
Point 12	403.95	70.5
Point 13	408.59	69
Point 14	421.1	68.74
Point 15	524.2	66.68
Point 16	528.99	64.96
Point 17	533.77	66.7
Point 18	555.72	67.1
Point 19	0	0
Point 20	555.72	0
Point 21	0	146.14
Point 22	71.39	147.29
Point 23	0	62.09
Point 24	10.01	61.86
Point 25	14.26	60.52
Point 26	18.51	61.86
Point 27	148.9	65.44
Point 28	256.7	63.31
Point 29	261.48	61.72
Point 30	266.26	63.33
Point 31	385.18	65.63
Point 32	387.27	66.32
Point 33	393.96	68.53
Point 34	403.95	68.5
Point 35	408.59	67
Point 36	421.1	66.74

Point 37	524.2	64.68
Point 38	528.99	62.96
Point 39	533.77	64.7
Point 40	555.72	65.1
Point 41	0	64.19
Point 42	10.01	63.96
Point 43	14.26	62.63
Point 44	18.51	63.96
Point 45	148.9	67.54
Point 46	256.7	65.41
Point 47	261.48	63.82
Point 48	266.26	65.43
Point 49	385.18	67.73
Point 50	387.27	68.42
Point 51	393.96	70.63
Point 52	403.95	70.6
Point 53	408.59	69.1
Point 54	421.1	68.84
Point 55	524.2	66.78
Point 56	528.99	65.06
Point 57	533.77	66.8
Point 58	555.72	67.2
Point 59	0	65.09
Point 60	10.01	64.86
Point 61	18.51	64.86
Point 62	148.9	68.44
Point 63	256.7	66.31
Point 64	266.26	66.33
Point 65	385.18	68.63
Point 66	387.27	69.32
Point 67	393.96	71.53
Point 68	403.95	71.5

Point 69	408.59	70
Point 70	421.1	69.79
Point 71	524.2	67.73
Point 72	533.77	67.76
Point 73	555.72	68.16

Regions

	Material	Points	Area (ft²)
Region 1	Subbase	19,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,20	35,879
Region 2	Clay	23,1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,40,39,38,37,36,35,34,33,32,31,30,29,28,27,26,25,24	1,111.4
Region 3	Drainage Layer	41,59,60,61,62,63,64,65,66,67,68,69,70,71,72,73,58,57,56,55,54,53,52,51,50,49,48,47,46,45,44,43,42	529.04
Region 4	CCR	59,21,22,66,65,64,63,62,61,60	18,727
Region 5	Geosynthetics	41,1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,58,57,56,55,54,53,52,51,50,49,48,47,46,45,44,43,42	55.615

Current Slip Surface

Slip Surface: 6,830
F of S: 1.662
Volume: 5,996.1971 ft³
Weight: 517,152.71 lbs
Resisting Moment: 93,438,482 lbs-ft
Activating Moment: 56,209,635 lbs-ft
F of S Rank (Analysis): 1 of 20,181 slip surfaces
F of S Rank (Query): 1 of 20,181 slip surfaces
Exit: (404.295, 71.38847) ft
Entry: (76.54, 146.0188) ft
Radius: 473.34483 ft
Center: (338.66098, 540.16081) ft

Slip Slices

	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
Slice 1	77.633035	145.29625	0	34.015108	12.380487	0
Slice 2	79.819106	143.85978	0	101.54923	36.960898	0
Slice 3	82.005177	142.44051	0	167.98918	61.143062	0
Slice 4	84.191248	141.03827	0	233.34071	84.929074	0
Slice 5	86.377319	139.65286	0	297.60947	108.32099	0
Slice 6	88.56339	138.28413	0	360.801	131.32082	0
Slice 7	90.74946	136.93189	0	422.9207	153.93055	0
Slice 8	92.935531	135.59598	0	483.97391	176.1521	0
Slice 9	95.121602	134.27625	0	543.96582	197.98737	0
Slice 10	97.307673	132.97253	0	602.90154	219.43821	0
Slice 11	99.493744	131.68467	0	660.78606	240.50646	0
Slice 12	101.67981	130.41252	0	717.62427	261.19387	0
Slice 13	103.86589	129.15593	0	773.42097	281.50221	0
Slice 14	106.05196	127.91477	0	828.18084	301.43318	0
Slice 15	108.23803	126.68889	0	881.90848	320.98844	0
Slice 16	110.4241	125.47816	0	934.60837	340.16963	0
Slice 17	112.61017	124.28245	0	986.28492	358.97835	0
Slice 18	114.79624	123.10162	0	1,036.9424	377.41617	0
Slice 19	116.98231	121.93555	0	1,086.5851	395.48462	0

Slice 20	119.16838	120.78412	0	1,135.217	413.18519	0
Slice 21	121.35445	119.64721	0	1,182.8422	430.51935	0
Slice 22	123.54052	118.5247	0	1,229.4646	447.48852	0
Slice 23	125.72659	117.41647	0	1,275.0881	464.09411	0
Slice 24	127.91266	116.32241	0	1,319.7164	480.33747	0
Slice 25	130.09874	115.24242	0	1,363.3531	496.21995	0
Slice 26	132.28481	114.17639	0	1,406.0019	511.74285	0
Slice 27	134.47088	113.1242	0	1,447.6662	526.90742	0
Slice 28	136.65695	112.08577	0	1,488.3495	541.71493	0
Slice 29	138.84302	111.06099	0	1,528.0551	556.16657	0
Slice 30	141.02909	110.04976	0	1,566.7862	570.26353	0
Slice 31	143.21516	109.05198	0	1,604.5459	584.00695	0
Slice 32	145.40123	108.06757	0	1,641.3374	597.39796	0
Slice 33	147.5873	107.09644	0	1,677.1637	610.43766	0
Slice 34	149.77337	106.13848	0	1,712.0276	623.12709	0
Slice 35	151.95944	105.19363	0	1,745.9321	635.46731	0
Slice 36	154.14551	104.26178	0	1,778.8799	647.45932	0
Slice 37	156.33159	103.34286	0	1,810.8736	659.1041	0
Slice 38	158.51766	102.43679	0	1,841.916	670.40261	0
Slice 39	160.70373	101.54349	0	1,872.0096	681.35576	0
Slice 40	162.8898	100.66287	0	1,901.1567	691.96446	0
Slice 41	165.07587	99.794873	0	1,929.3599	702.22958	0
Slice 42	167.26194	98.93941	0	1,956.6215	712.15197	0
Slice 43	169.44801	98.096413	0	1,982.9436	721.73245	0
Slice 44	171.63408	97.265811	0	2,008.3286	730.97182	0
Slice 45	173.82015	96.447533	0	2,032.7784	739.87084	0
Slice 46	176.00622	95.641513	0	2,056.2952	748.43026	0
Slice 47	178.19229	94.847683	0	2,078.881	756.6508	0
Slice 48	180.37836	94.065979	0	2,100.5376	764.53315	0
Slice 49	182.56444	93.296336	0	2,121.2668	772.07798	0
Slice 50	184.75051	92.538692	0	2,141.0705	779.28595	0
Slice 51	186.93658	91.792988	0	2,159.9504	786.15767	0
Slice 52	189.12265	91.059162	0	2,177.9081	792.69373	0
Slice 53	191.30872	90.337158	0	2,194.9452	798.89472	0
Slice 54	193.49479	89.626917	0	2,211.0632	804.76119	0
Slice 55	195.68086	88.928386	0	2,226.2635	810.29365	0
Slice 56	197.86693	88.241508	0	2,240.5476	815.49262	0
Slice 57	200.053	87.566232	0	2,253.9167	820.35857	0
Slice 58	202.23907	86.902506	0	2,266.3721	824.89197	0
Slice 59	204.42514	86.250278	0	2,277.9149	829.09324	0
Slice 60	206.61121	85.609499	0	2,288.5465	832.96279	0
Slice 61	208.79728	84.980122	0	2,298.2677	836.50103	0
Slice 62	210.98336	84.362098	0	2,307.0796	839.70831	0
Slice 63	213.16943	83.755381	0	2,314.9832	842.58497	0
Slice 64	215.3555	83.159927	0	2,321.9793	845.13134	0
Slice 65	217.54157	82.575692	0	2,328.0687	847.34772	0
Slice 66	219.72764	82.002632	0	2,333.2523	849.23439	0
Slice 67	221.91371	81.440707	0	2,337.5307	850.7916	0
Slice 68	224.09978	80.889874	0	2,340.9046	852.01958	0
Slice 69	226.28585	80.350094	0	2,343.3745	852.91855	0
Slice 70	228.47192	79.821328	0	2,344.9409	853.48869	0
Slice 71	230.65799	79.303538	0	2,345.6044	853.73018	0
Slice 72	232.84406	78.796688	0	2,345.3653	853.64315	0
Slice 73	235.03013	78.300741	0	2,344.224	853.22774	0
Slice 74	237.21621	77.815662	0	2,342.1807	852.48405	0
Slice 75	239.40228	77.341417	0	2,339.2356	851.41215	0
Slice 76	241.58835	76.877973	0	2,335.3891	850.0121	0
Slice 77	243.77442	76.425297	0	2,330.641	848.28395	0
Slice 78	245.96049	75.983358	0	2,324.9915	846.22771	0

Slice 79	248.14656	75.552125	0	2,318.4406	843.84338	0
Slice 80	250.33263	75.131568	0	2,310.9882	841.13092	0
Slice 81	252.5187	74.721659	0	2,302.6341	838.09028	0
Slice 82	254.70477	74.32237	0	2,293.3782	834.72141	0
Slice 83	256.89084	73.933672	0	2,283.2202	831.0242	0
Slice 84	259.07691	73.55554	0	2,272.1598	826.99855	0
Slice 85	261.26298	73.187948	0	2,260.1967	822.64431	0
Slice 86	263.44906	72.830871	0	2,247.3303	817.96133	0
Slice 87	265.63513	72.484285	0	2,233.5602	812.94943	0
Slice 88	267.8212	72.148167	0	2,218.8859	807.60841	0
Slice 89	270.00727	71.822494	0	2,203.3067	801.93804	0
Slice 90	272.19334	71.507244	0	2,186.8219	795.93809	0
Slice 91	274.37941	71.202397	0	2,169.4309	789.60828	0
Slice 92	276.56548	70.907931	0	2,151.1329	782.94833	0
Slice 93	278.75155	70.623828	0	2,131.9269	775.95792	0
Slice 94	280.93762	70.350069	0	2,111.812	768.63672	0
Slice 95	283.12369	70.086636	0	2,090.7874	760.98437	0
Slice 96	285.30976	69.833511	0	2,068.8519	753.0005	0
Slice 97	287.49583	69.590677	0	2,046.0044	744.6847	0
Slice 98	289.68191	69.358119	0	2,022.2438	736.03655	0
Slice 99	291.86798	69.135822	0	1,997.5689	727.0556	0
Slice 100	294.05405	68.923771	0	1,971.9783	717.74139	0
Slice 101	296.24012	68.721952	0	1,945.4706	708.0934	0
Slice 102	298.42619	68.530352	0	1,918.0446	698.11114	0
Slice 103	300.61226	68.348958	0	1,889.6986	687.79406	0
Slice 104	302.79833	68.17776	0	1,860.4312	677.14159	0
Slice 105	304.9844	68.016745	0	1,830.2407	666.15314	0
Slice 106	307.17047	67.865903	0	1,799.1255	654.82811	0
Slice 107	309.35654	67.725225	0	1,767.0837	643.16586	0
Slice 108	311.54261	67.594702	0	1,734.1135	631.16571	0
Slice 109	313.72868	67.474324	0	1,700.2132	618.827	0
Slice 110	315.91476	67.364085	0	1,665.3807	606.149	0
Slice 111	318.05484	67.265875	0	1,623.2855	937.20431	0
Slice 112	320.14893	67.17927	0	1,592.88	919.6497	0
Slice 113	322.24303	67.101951	0	1,561.3256	901.43177	0
Slice 114	324.33712	67.033913	0	1,528.6178	882.54789	0
Slice 115	326.43121	66.975152	0	1,494.7519	862.99541	0
Slice 116	328.52531	66.925665	0	1,459.7232	842.77159	0
Slice 117	330.6194	66.885449	0	1,423.527	821.87367	0
Slice 118	332.7135	66.854501	0	1,386.1582	800.2988	0
Slice 119	334.80759	66.83282	0	1,347.6119	778.04408	0
	336.90168	66.820404	0	1,307.8829	755.10656	0

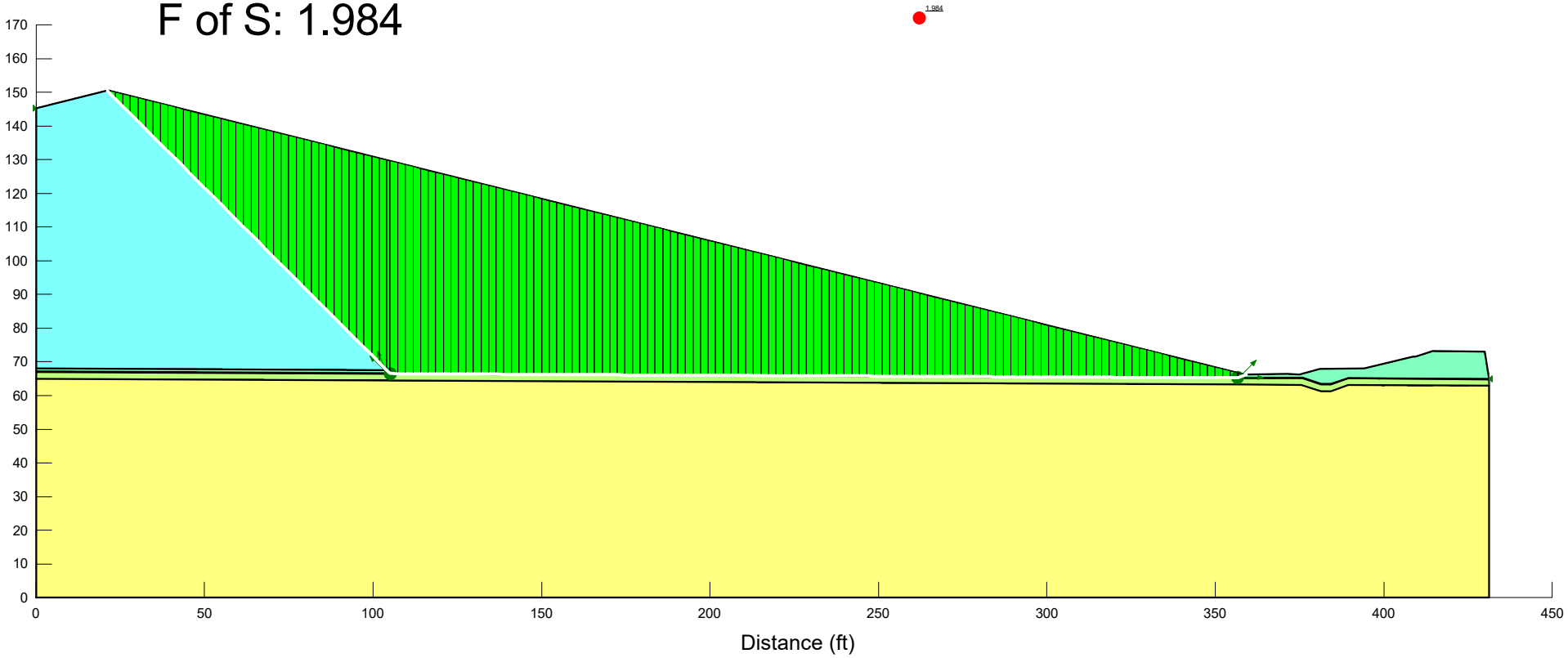
Slice 120						
Slice 121	338.97722	66.8172	0	1,266.1796	571.70203	0
Slice 122	341.0342	66.823043	0	1,222.4965	551.97835	0
Slice 123	343.09117	66.837827	0	1,178.1903	531.97334	0
Slice 124	345.14815	66.86155	0	1,133.2589	511.68601	0
Slice 125	347.81405	66.907315	0	1,073.9924	484.92618	0
Slice 126	350.47947	66.964659	0	1,013.878	457.78347	0
Slice 127	352.53548	67.02048	0	966.70409	436.48363	0
Slice 128	354.59149	67.085243	0	918.89472	414.89688	0
Slice 129	356.6475	67.158952	0	870.44741	393.02208	0
Slice 130	358.72081	67.242382	0	822.2208	474.7094	0
Slice 131	360.81143	67.33569	0	768.67768	443.79627	0
Slice 132	362.90204	67.438263	0	713.88286	412.16046	0
Slice 133	364.99266	67.550105	0	657.82963	379.79812	0
Slice 134	367.08327	67.671225	0	600.51118	346.70529	0
Slice 135	369.17388	67.801628	0	541.92051	312.87795	0
Slice 136	371.2645	67.941323	0	482.05052	278.312	0
Slice 137	373.35511	68.090317	0	420.89394	243.00323	0
Slice 138	375.44573	68.248621	0	358.44338	206.94738	0
Slice 139	377.53634	68.416242	0	294.69128	170.14009	0
Slice 140	379.66686	68.59675	0	227.93593	82.961895	0
Slice 141	381.83728	68.790519	0	164.15125	59.746168	0
Slice 142	384.0077	68.994366	0	99.348997	36.160078	0
Slice 143	386.18145	69.208648	0	33.421913	12.164582	0
Slice 144	388.2783	69.424764	0	27.254447	15.735362	0
Slice 145	390.29489	69.641691	0	81.006622	46.769195	0
Slice 146	391.53261	69.778126	0	109.74995	49.554001	0
Slice 147	392.86101	69.930586	0	144.16008	76.651273	0
Slice 148	394.90756	70.170659	0	159.98475	85.065403	0
Slice 149	396.80269	70.401339	0	129.43876	68.823811	0
Slice 150	398.1359	70.56746	0	110.18979	49.752599	0
Slice 151	399.87865	70.793305	0	86.59789	49.997315	0

Slice 152	402.59288	71.155301	0	42.101835	24.307506	0
Slice 153	404.1225	71.364382	0	9.6509921	5.5720029	0

Columbia Unstable Areas Analysis 2018 - Mod 4 Eastern Slope

Analysis: Block

F of S: 1.984



Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	CCR	Mohr-Coulomb	86	0	20
	Clay	Mohr-Coulomb	125	0	28
	Drainage Layer	Mohr-Coulomb	115	0	30
	Geosynthetics	Mohr-Coulomb	58	0	24.3
	Subbase	Mohr-Coulomb	120	0	30

Block

File Information

File Version: 8.16
Title: Columbia Unstable Areas Analysis 2018 - Mod 4 Eastern Slope
Comments: Running slope stability analysis on the eastern interim waste slope of Module 4, Phase 1 of the Columbia Dry Ash Disposal Facility. Location of analysis was selected based on longest and steepest slope at the time of peak waste placement within Module 4. References: Mod 4 Base Grades (top of clay): SCS Engineers, Civil 3D as-built surface "As-built Mod 4 Base Grades", August 2018 Mod 4 Subbase Grades: Mod 4 Base Grades (top of clay) minus 2 ft Mod 4 Drainage Layer Grades: SCS Engineers, Civil 3D as-built surface "As-built Leachate Drainage Layer and Perimeter", August 2018 Mod 4 Waste Grades: Based on SCS Engineers, Civil 3D design surface "MOD4INTERIM" and "MOD5INTERIM", December 2013 --> Design surface has waste at 4H:1V but analysis ran at 3H:1V slope Geosynthetic Material Properties: SCS Engineers, Mod 3 and Mod 4 Interface Friction Testing, Completed by TRI/Environmental, March/April 2016 and April 2018 CCR Material Properties: SCS Engineers, Ottumwa - FGD Material Testing, July 2015
Created By: Suchomel, Brandon
Last Edited By: Suchomel, Brandon
Revision Number: 84
Date: 8/27/2018
Time: 9:18:34 AM
Tool Version: 8.16.3.14580
File Name: Mod 4 Eastern Slope_4-1.gsz
Directory: I:\25217156.00\Data and Calculations\Slope Stability\
Last Solved Date: 8/27/2018
Last Solved Time: 9:19:03 AM

Project Settings

Length(L) Units: Feet
Time(t) Units: Seconds
Force(F) Units: Pounds
Pressure(p) Units: psf
Strength Units: psf
Unit Weight of Water: 62.4 pcf
View: 2D
Element Thickness: 1

Analysis Settings

Block

Kind: SLOPE/W
Method: Janbu
Settings

PWP Conditions Source: (none)

Slip Surface

Direction of movement: Left to Right
Use Passive Mode: No
Slip Surface Option: Block
Critical slip surfaces saved: 10
Resisting Side Maximum Convex Angle: 1 °
Driving Side Maximum Convex Angle: 5 °
Restrict Block Crossing: No
Optimize Critical Slip Surface Location: No

Tension Crack

Tension Crack Option: (none)

F of S Distribution

F of S Calculation Option: Constant

Advanced

Number of Slices: 150
F of S Tolerance: 0.001
Minimum Slip Surface Depth: 0.1 ft

Materials

Subbase

Model: Mohr-Coulomb
Unit Weight: 120 pcf
Cohesion': 0 psf
Phi': 30 °
Phi-B: 0 °

Clay

Model: Mohr-Coulomb
Unit Weight: 125 pcf
Cohesion': 0 psf
Phi': 28 °
Phi-B: 0 °

Geosynthetics

Model: Mohr-Coulomb
Unit Weight: 58 pcf
Cohesion': 0 psf
Phi': 24.3 °
Phi-B: 0 °

Drainage Layer

Model: Mohr-Coulomb
Unit Weight: 115 pcf
Cohesion': 0 psf
Phi': 30 °
Phi-B: 0 °

CCR

Model: Mohr-Coulomb
Unit Weight: 86 pcf
Cohesion': 0 psf
Phi': 20 °
Phi-B: 0 °

Slip Surface Limits

Left Coordinate: (0, 145.27) ft
Right Coordinate: (431.15, 64.96) ft

Slip Surface Block

Left Grid
- Upper Left: (104.3, 66.6) ft
- Lower Left: (104.3, 66.5) ft
- Lower Right: (105.95, 66.49) ft
- X Increments: 10
- Y Increments: 4
- Starting Angle: 115 °
- Ending Angle: 135 °
- Angle Increments: 2

Right Grid
- Upper Left: (355.76, 65.33) ft
- Lower Left: (355.76, 65.23) ft
- Lower Right: (356.97, 65.23) ft
- X Increments: 10
- Y Increments: 4
- Starting Angle: 0 °
- Ending Angle: 45 °
- Angle Increments: 2

Points

	X (ft)	Y (ft)
Point 1	0	0
Point 2	431.15	0
Point 3	0	67.02
Point 4	358.54	65.22
Point 5	375.87	65.14
Point 6	381.27	63.33
Point 7	384.26	63.37
Point 8	389.46	65.08
Point 9	431.15	64.86
Point 10	0	65.02
Point 11	358.54	63.22

Point 12	375.57	63.14
Point 13	381.27	61.33
Point 14	384.26	61.37
Point 15	389.46	63.08
Point 16	431.15	62.86
Point 17	0	67.12
Point 18	358.54	65.32
Point 19	375.87	65.24
Point 20	381.27	63.43
Point 21	384.26	63.47
Point 22	389.46	65.18
Point 23	431.15	64.96
Point 24	0	68.07
Point 25	358.54	66.29
Point 26	371.51	66.35
Point 27	374.87	66.21
Point 28	380.99	67.86
Point 29	394.11	68.01
Point 30	408.74	71.54
Point 31	409.5	71.59
Point 32	414.56	73.12
Point 33	429.91	72.97
Point 34	21.3	150.59
Point 35	0	145.27

Regions

	Material	Points	Area (ft²)
Region 1	Subbase	1,2,16,15,14,13,12,11,10	27,553
Region 2	Clay	10,3,4,5,6,7,8,9,16,15,14,13,12,11	862.58
Region 3	Geosynthetics	3,17,18,19,20,21,22,23,9,8,7,6,5,4	43.115
Region 4	Drainage Layer	17,24,25,26,27,28,29,30,31,32,33,23,22,21,20,19,18	661.02
Region 5	CCR	24,35,34,25	15,634

Current Slip Surface

Slip Surface: 2,828
F of S: 1.984
Volume: 10,792.952 ft³
Weight: 934,580.66 lbs
Resisting Force: 389,494 lbs
Activating Force: 196,325 lbs
F of S Rank (Analysis): 1 of 27,225 slip surfaces
F of S Rank (Query): 1 of 27,225 slip surfaces
Exit: (359.17314, 66.292929) ft
Entry: (21.083959, 150.53604) ft
Radius: 159.5553 ft
Center: (205.87196, 171.59682) ft

Slip Slices

	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
Slice 1	21.19198	150.42802	0	9.8109345	3.5708881	0
Slice 2	22.418468	149.20153	0	80.586603	29.331125	0
Slice 3	24.655405	146.9646	0	202.51607	73.709822	0
Slice 4	26.892341	144.72766	0	324.44554	118.08852	0
Slice 5	29.129277	142.49072	0	446.37501	162.46722	0
Slice 6	31.366214	140.25379	0	568.30448	206.84591	0
Slice 7	33.60315	138.01685	0	690.23395	251.22461	0
Slice 8	35.840087	135.77991	0	812.16341	295.60331	0
Slice 9	38.077023	133.54298	0	934.09288	339.98201	0
Slice 10	40.313959	131.30604	0	1,056.0224	384.3607	0
Slice 11	42.550896	129.0691	0	1,177.9518	428.7394	0
Slice 12	44.787832	126.83217	0	1,299.8813	473.1181	0
Slice 13	47.024769	124.59523	0	1,421.8108	517.49679	0
Slice 14	49.261705	122.35829	0	1,543.7402	561.87549	0
	51.498641	120.12136	0	1,665.6697	606.25419	0

Slice 15						
Slice 16	53.735578	117.88442	0	1,787.5992	650.63289	0
Slice 17	55.972514	115.64749	0	1,909.5286	695.01158	0
Slice 18	58.209451	113.41055	0	2,031.4581	739.39028	0
Slice 19	60.446387	111.17361	0	2,153.3876	783.76898	0
Slice 20	62.683324	108.93668	0	2,275.317	828.14767	0
Slice 21	64.92026	106.69974	0	2,397.2465	872.52637	0
Slice 22	67.157196	104.4628	0	2,519.176	916.90507	0
Slice 23	69.394133	102.22587	0	2,641.1054	961.28377	0
Slice 24	71.631069	99.988931	0	2,763.0349	1,005.6625	0
Slice 25	73.868006	97.751994	0	2,884.9644	1,050.0412	0
Slice 26	76.104942	95.515058	0	3,006.8938	1,094.4199	0
Slice 27	78.341878	93.278122	0	3,128.8233	1,138.7986	0
Slice 28	80.578815	91.041185	0	3,250.7528	1,183.1773	0
Slice 29	82.815751	88.804249	0	3,372.6823	1,227.5559	0
Slice 30	85.052688	86.567312	0	3,494.6117	1,271.9346	0
Slice 31	87.289624	84.330376	0	3,616.5412	1,316.3133	0
Slice 32	89.52656	82.09344	0	3,738.4707	1,360.692	0
Slice 33	91.763497	79.856503	0	3,860.4001	1,405.0707	0
Slice 34	94.000433	77.619567	0	3,982.3296	1,449.4494	0
Slice 35	96.23737	75.38263	0	4,104.2591	1,493.8281	0
Slice 36	98.474306	73.145694	0	4,226.1885	1,538.2068	0
Slice 37	100.71124	70.908758	0	4,348.118	1,582.5855	0
Slice 38	102.94818	68.671821	0	4,470.0475	1,626.9642	0

Slice 39	104.54696	67.073039	0	4,188.4077	2,418.1783	0
Slice 40	106.19882	66.538215	0	5,372.831	2,425.9262	0
Slice 41	108.49306	66.478058	0	5,378.0466	2,428.2811	0
Slice 42	110.73844	66.466763	0	5,330.8052	2,406.9508	0
Slice 43	112.98381	66.455469	0	5,283.5637	2,385.6205	0
Slice 44	115.22919	66.444174	0	5,236.3223	2,364.2902	0
Slice 45	117.47456	66.432879	0	5,189.0809	2,342.9599	0
Slice 46	119.71994	66.421585	0	5,141.8395	2,321.6295	0
Slice 47	121.96531	66.41029	0	5,094.598	2,300.2992	0
Slice 48	124.21069	66.398996	0	5,047.3566	2,278.9689	0
Slice 49	126.45606	66.387701	0	5,000.1152	2,257.6386	0
Slice 50	128.70144	66.376406	0	4,952.8738	2,236.3083	0
Slice 51	130.94681	66.365112	0	4,905.6323	2,214.9779	0
Slice 52	133.19219	66.353817	0	4,858.3909	2,193.6476	0
Slice 53	135.43756	66.342522	0	4,811.1495	2,172.3173	0
Slice 54	137.68294	66.331228	0	4,763.9081	2,150.987	0
Slice 55	139.92831	66.319933	0	4,716.6666	2,129.6566	0
Slice 56	142.17369	66.308638	0	4,669.4252	2,108.3263	0
Slice 57	144.41906	66.297344	0	4,622.1838	2,086.996	0
Slice 58	146.66444	66.286049	0	4,574.9424	2,065.6657	0
Slice 59	148.90981	66.274754	0	4,527.7009	2,044.3354	0
Slice 60	151.15519	66.26346	0	4,480.4595	2,023.005	0
Slice 61	153.40056	66.252165	0	4,433.2181	2,001.6747	0
Slice 62	155.64594	66.240871	0	4,385.9767	1,980.3444	0

Slice 63	157.89131	66.229576	0	4,338.7352	1,959.0141	0
Slice 64	160.13669	66.218281	0	4,291.4938	1,937.6838	0
Slice 65	162.38206	66.206987	0	4,244.2524	1,916.3534	0
Slice 66	164.62744	66.195692	0	4,197.011	1,895.0231	0
Slice 67	166.87281	66.184397	0	4,149.7695	1,873.6928	0
Slice 68	169.11819	66.173103	0	4,102.5281	1,852.3625	0
Slice 69	171.36356	66.161808	0	4,055.2867	1,831.0321	0
Slice 70	173.60894	66.150513	0	4,008.0452	1,809.7018	0
Slice 71	175.85431	66.139219	0	3,960.8038	1,788.3715	0
Slice 72	178.09969	66.127924	0	3,913.5624	1,767.0412	0
Slice 73	180.34506	66.116629	0	3,866.321	1,745.7109	0
Slice 74	182.59044	66.105335	0	3,819.0795	1,724.3805	0
Slice 75	184.83581	66.09404	0	3,771.8381	1,703.0502	0
Slice 76	187.08119	66.082746	0	3,724.5967	1,681.7199	0
Slice 77	189.32656	66.071451	0	3,677.3553	1,660.3896	0
Slice 78	191.57194	66.060156	0	3,630.1138	1,639.0593	0
Slice 79	193.81731	66.048862	0	3,582.8724	1,617.7289	0
Slice 80	196.06269	66.037567	0	3,535.631	1,596.3986	0
Slice 81	198.30806	66.026272	0	3,488.3896	1,575.0683	0
Slice 82	200.55344	66.014978	0	3,441.1481	1,553.738	0
Slice 83	202.79881	66.003683	0	3,393.9067	1,532.4076	0
Slice 84	205.04419	65.992388	0	3,346.6653	1,511.0773	0
Slice 85	207.28956	65.981094	0	3,299.4239	1,489.747	0
Slice 86	209.53494	65.969799	0	3,252.1824	1,468.4167	0

Slice 87	211.78031	65.958504	0	3,204.941	1,447.0864	0
Slice 88	214.02569	65.94721	0	3,157.6996	1,425.756	0
Slice 89	216.27106	65.935915	0	3,110.4582	1,404.4257	0
Slice 90	218.51644	65.924621	0	3,063.2167	1,383.0954	0
Slice 91	220.76181	65.913326	0	3,015.9753	1,361.7651	0
Slice 92	223.00719	65.902031	0	2,968.7339	1,340.4347	0
Slice 93	225.25256	65.890737	0	2,921.4925	1,319.1044	0
Slice 94	227.49794	65.879442	0	2,874.251	1,297.7741	0
Slice 95	229.74331	65.868147	0	2,827.0096	1,276.4438	0
Slice 96	231.98869	65.856853	0	2,779.7682	1,255.1135	0
Slice 97	234.23406	65.845558	0	2,732.5268	1,233.7831	0
Slice 98	236.47944	65.834263	0	2,685.2853	1,212.4528	0
Slice 99	238.72481	65.822969	0	2,638.0439	1,191.1225	0
Slice 100	240.97019	65.811674	0	2,590.8025	1,169.7922	0
Slice 101	243.21556	65.800379	0	2,543.5611	1,148.4619	0
Slice 102	245.46094	65.789085	0	2,496.3196	1,127.1315	0
Slice 103	247.70631	65.77779	0	2,449.0782	1,105.8012	0
Slice 104	249.95169	65.766496	0	2,401.8368	1,084.4709	0
Slice 105	252.19706	65.755201	0	2,354.5954	1,063.1406	0
Slice 106	254.44244	65.743906	0	2,307.3539	1,041.8102	0
Slice 107	256.68781	65.732612	0	2,260.1125	1,020.4799	0
Slice 108	258.93319	65.721317	0	2,212.8711	999.14961	0
Slice 109	261.17856	65.710022	0	2,165.6297	977.81928	0
Slice 110	263.42394	65.698728	0	2,118.3882	956.48896	0

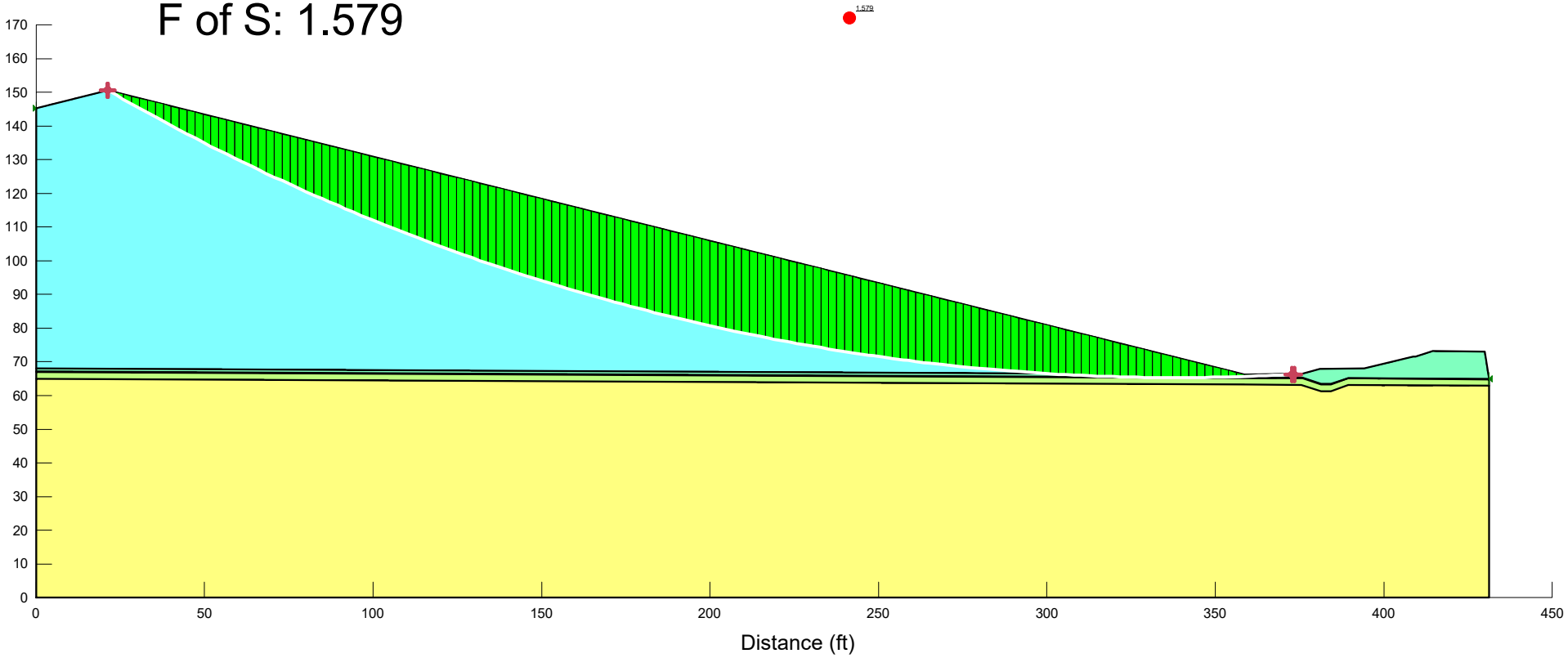
Slice 111	265.66931	65.687433	0	2,071.1468	935.15864	0
Slice 112	267.91469	65.676138	0	2,023.9054	913.82832	0
Slice 113	270.16006	65.664844	0	1,976.664	892.498	0
Slice 114	272.40544	65.653549	0	1,929.4225	871.16768	0
Slice 115	274.65081	65.642254	0	1,882.1811	849.83736	0
Slice 116	276.89619	65.63096	0	1,834.9397	828.50703	0
Slice 117	279.14156	65.619665	0	1,787.6983	807.17671	0
Slice 118	281.38694	65.608371	0	1,740.4568	785.84639	0
Slice 119	283.63231	65.597076	0	1,693.2154	764.51607	0
Slice 120	285.87769	65.585781	0	1,645.974	743.18575	0
Slice 121	288.12306	65.574487	0	1,598.7326	721.85543	0
Slice 122	290.36844	65.563192	0	1,551.4911	700.5251	0
Slice 123	292.61381	65.551897	0	1,504.2497	679.19478	0
Slice 124	294.85919	65.540603	0	1,457.0083	657.86446	0
Slice 125	297.10456	65.529308	0	1,409.7669	636.53414	0
Slice 126	299.34994	65.518013	0	1,362.5254	615.20382	0
Slice 127	301.59531	65.506719	0	1,315.284	593.8735	0
Slice 128	303.84069	65.495424	0	1,268.0426	572.54318	0
Slice 129	306.08606	65.484129	0	1,220.8011	551.21285	0
Slice 130	308.33144	65.472835	0	1,173.5597	529.88253	0
Slice 131	310.57681	65.46154	0	1,126.3183	508.55221	0
Slice 132	312.82219	65.450246	0	1,079.0769	487.22189	0
Slice 133	315.06756	65.438951	0	1,031.8354	465.89157	0
Slice 134	317.31294	65.427656	0	984.59402	444.56125	0

Slice 135	319.55831	65.416362	0	937.3526	423.23093	0
Slice 136	321.80369	65.405067	0	890.11117	401.9006	0
Slice 137	324.04906	65.393772	0	842.86975	380.57028	0
Slice 138	326.29444	65.382478	0	795.62832	359.23996	0
Slice 139	328.53981	65.371183	0	748.38689	337.90964	0
Slice 140	330.78519	65.359888	0	701.14547	316.57932	0
Slice 141	333.03056	65.348594	0	653.90404	295.249	0
Slice 142	335.27594	65.337299	0	606.66262	273.91868	0
Slice 143	337.52131	65.326004	0	559.42119	252.58835	0
Slice 144	339.76669	65.31471	0	512.17977	231.25803	0
Slice 145	342.01206	65.303415	0	464.93834	209.92771	0
Slice 146	344.25744	65.292121	0	417.69692	188.59739	0
Slice 147	346.50281	65.280826	0	370.45549	167.26707	0
Slice 148	348.74819	65.269531	0	323.21407	145.93675	0
Slice 149	350.99356	65.258237	0	275.97264	124.60643	0
Slice 150	353.23894	65.246942	0	228.73121	103.2761	0
Slice 151	355.48431	65.235647	0	181.48979	81.945782	0
Slice 152	356.72591	65.279255	0	168.53372	76.095893	0
Slice 153	357.69241	65.679593	0	100.66899	58.12127	0
Slice 154	358.85657	66.161802	0	16.953895	9.7883357	0

Columbia Unstable Areas Analysis 2018 - Mod 4 Eastern Slope

Analysis: Circular

F of S: 1.579



Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	CCR	Mohr-Coulomb	86	0	20
	Clay	Mohr-Coulomb	125	0	28
	Drainage Layer	Mohr-Coulomb	115	0	30
	Geosynthetics	Mohr-Coulomb	58	0	24.3
	Subbase	Mohr-Coulomb	120	0	30

Circular

File Information

File Version: 8.16
Title: Columbia Unstable Areas Analysis 2018 - Mod 4 Eastern Slope
Comments: Running slope stability analysis on the eastern interim waste slope of Module 4, Phase 1 of the Columbia Dry Ash Disposal Facility. Location of analysis was selected based on longest and steepest slope at the time of peak waste placement within Module 4. References: Mod 4 Base Grades (top of clay): SCS Engineers, Civil 3D as-built surface "As-built Mod 4 Base Grades", August 2018 Mod 4 Subbase Grades: Mod 4 Base Grades (top of clay) minus 2 ft Mod 4 Drainage Layer Grades: SCS Engineers, Civil 3D as-built surface "As-built Leachate Drainage Layer and Perimeter", August 2018 Mod 4 Waste Grades: Based on SCS Engineers, Civil 3D design surface "MOD5INTERIM", December 2013 Geosynthetic Material Properties: SCS Engineers, Mod 3 and Mod 4 Interface Friction Testing, Completed by TRI/Environmental, March/April 2016 and April 2018 CCR Material Properties: SCS Engineers, Ottumwa - FGD Material Testing, July 2015 / U.S. Department of Transportation, Federal Highway Administration, Recycled Materials, Coal Ash User's Guide / Stabilization of FGD By-Products by Using Fly Ash, Cement, and Sialite, 2009 WOCA Conference.
Created By: Suchomel, Brandon
Last Edited By: Suchomel, Brandon
Revision Number: 101
Date: 8/27/2018
Time: 10:46:39 AM
Tool Version: 8.16.3.14580
File Name: Mod 4 Eastern Slope_4-1.gsz
Directory: I:\25217156.00\Data and Calculations\Slope Stability\
Last Solved Date: 8/27/2018
Last Solved Time: 10:47:02 AM

Project Settings

Length(L) Units: Feet
Time(t) Units: Seconds
Force(F) Units: Pounds
Pressure(p) Units: psf
Strength Units: psf
Unit Weight of Water: 62.4 pcf
View: 2D
Element Thickness: 1

Analysis Settings

Circular

Kind: SLOPE/W
Method: Bishop

Settings
PWP Conditions Source: (none)
Slip Surface
Direction of movement: Left to Right
Use Passive Mode: No
Slip Surface Option: Entry and Exit
Critical slip surfaces saved: 10
Resisting Side Maximum Convex Angle: 1 °
Driving Side Maximum Convex Angle: 5 °
Optimize Critical Slip Surface Location: No
Tension Crack
Tension Crack Option: (none)
F of S Distribution
F of S Calculation Option: Constant
Advanced
Number of Slices: 150
F of S Tolerance: 0.001
Minimum Slip Surface Depth: 0.1 ft

Materials

Subbase

Model: Mohr-Coulomb
Unit Weight: 120 pcf
Cohesion': 0 psf
Phi': 30 °
Phi-B: 0 °

Clay

Model: Mohr-Coulomb
Unit Weight: 125 pcf
Cohesion': 0 psf
Phi': 28 °
Phi-B: 0 °

Geosynthetics

Model: Mohr-Coulomb
Unit Weight: 58 pcf
Cohesion': 0 psf
Phi': 24.3 °
Phi-B: 0 °

Drainage Layer

Model: Mohr-Coulomb
Unit Weight: 115 pcf
Cohesion': 0 psf
Phi': 30 °
Phi-B: 0 °

CCR

Model: Mohr-Coulomb
Unit Weight: 86 pcf
Cohesion': 0 psf
Phi': 20 °
Phi-B: 0 °

Slip Surface Entry and Exit

Left Projection: Range
Left-Zone Left Coordinate: (21.17, 150.55753) ft
Left-Zone Right Coordinate: (21.42, 150.56) ft
Left-Zone Increment: 30
Right Projection: Range
Right-Zone Left Coordinate: (372.68, 66.30125) ft
Right-Zone Right Coordinate: (373.48, 66.26792) ft
Right-Zone Increment: 30
Radius Increments: 20

Slip Surface Limits

Left Coordinate: (0, 145.27) ft
Right Coordinate: (431.15, 64.96) ft

Points

	X (ft)	Y (ft)
Point 1	0	0
Point 2	431.15	0
Point 3	0	67.02
Point 4	358.54	65.22
Point 5	375.87	65.14
Point 6	381.27	63.33
Point 7	384.26	63.37
Point 8	389.46	65.08
Point 9	431.15	64.86
Point 10	0	65.02
Point 11	358.54	63.22
Point 12	375.57	63.14
Point 13	381.27	61.33
Point 14	384.26	61.37
Point 15	389.46	63.08
Point 16	431.15	62.86
Point 17	0	67.12
Point 18	358.54	65.32
Point 19	375.87	65.24

Point 20	381.27	63.43
Point 21	384.26	63.47
Point 22	389.46	65.18
Point 23	431.15	64.96
Point 24	0	68.07
Point 25	358.54	66.29
Point 26	371.51	66.35
Point 27	374.87	66.21
Point 28	380.99	67.86
Point 29	394.11	68.01
Point 30	408.74	71.54
Point 31	409.5	71.59
Point 32	414.56	73.12
Point 33	429.91	72.97
Point 34	21.3	150.59
Point 35	0	145.27

Regions

	Material	Points	Area (ft²)
Region 1	Subbase	1,2,16,15,14,13,12,11,10	27,553
Region 2	Clay	10,3,4,5,6,7,8,9,16,15,14,13,12,11	862.58
Region 3	Geosynthetics	3,17,18,19,20,21,22,23,9,8,7,6,5,4	43.115
Region 4	Drainage Layer	17,24,25,26,27,28,29,30,31,32,33,23,22,21,20,19,18	661.02
Region 5	CCR	24,35,34,25	15,634

Current Slip Surface

Slip Surface: 10,945
F of S: 1.579
Volume: 5,780.1438 ft³

Weight: 498,555.89 lbs
Resisting Moment: 1.176349e+008 lbs-ft
Activating Moment: 74,500,499 lbs-ft
F of S Rank (Analysis): 1 of 20,181 slip surfaces
F of S Rank (Query): 1 of 20,181 slip surfaces
Exit: (373.34667, 66.273472) ft
Entry: (21.303337, 150.58917) ft
Radius: 633.39188 ft
Center: (338.70065, 698.71709) ft

Slip Slices

	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
Slice 1	22.478926	149.91179	0	29.116028	10.597367	0
Slice 2	24.830105	148.56373	0	86.941203	31.64401	0
Slice 3	27.181283	147.22898	0	143.88572	52.370118	0
Slice 4	29.532462	145.90745	0	199.95246	72.776743	0
Slice 5	31.88364	144.59906	0	255.14428	92.864922	0
Slice 6	34.234819	143.3037	0	309.46396	112.63567	0
Slice 7	36.585998	142.02128	0	362.91427	132.08999	0
Slice 8	38.937176	140.75172	0	415.49789	151.22886	0
Slice 9	41.288355	139.49493	0	467.21747	170.05325	0
Slice 10	43.639533	138.25081	0	518.07562	188.56411	0
Slice 11	45.990712	137.0193	0	568.0749	206.76235	0
Slice 12	48.341891	135.8003	0	617.21781	224.64891	0
Slice 13	50.693069	134.59373	0	665.50681	242.22467	0
Slice 14	53.044248	133.39951	0	712.94434	259.49052	0
Slice 15	55.395427	132.21758	0	759.53274	276.44731	0
Slice 16	57.746605	131.04784	0	805.27436	293.0959	0
Slice 17	60.097784	129.89022	0	850.17148	309.43711	0
Slice 18	62.448962	128.74466	0	894.22632	325.47176	0
Slice 19	64.800141	127.61107	0	937.4411	341.20066	0
Slice 20	67.15132	126.48939	0	979.81795	356.62457	0
Slice 21	69.502498	125.37954	0	1,021.359	371.74427	0
	71.853677	124.28146	0	1,062.0663	386.56051	0

Slice 22						
Slice 23	74.204855	123.19509	0	1,101.9418	401.07403	0
Slice 24	76.556034	122.12034	0	1,140.9876	415.28554	0
Slice 25	78.907213	121.05717	0	1,179.2056	429.19575	0
Slice 26	81.258391	120.0055	0	1,216.5977	442.80536	0
Slice 27	83.60957	118.96528	0	1,253.1657	456.11503	0
Slice 28	85.960748	117.93643	0	1,288.9115	469.12543	0
Slice 29	88.311927	116.91891	0	1,323.8368	481.83721	0
Slice 30	90.663106	115.91265	0	1,357.9434	494.25098	0
Slice 31	93.014284	114.91759	0	1,391.2329	506.36738	0
Slice 32	95.365463	113.93368	0	1,423.7071	518.187	0
Slice 33	97.716641	112.96085	0	1,455.3675	529.71044	0
Slice 34	100.06782	111.99907	0	1,486.2156	540.93826	0
Slice 35	102.419	111.04826	0	1,516.2532	551.87102	0
Slice 36	104.77018	110.10838	0	1,545.4815	562.50927	0
Slice 37	107.12136	109.17938	0	1,573.9022	572.85355	0
Slice 38	109.47253	108.2612	0	1,601.5166	582.90436	0
Slice 39	111.82371	107.3538	0	1,628.3261	592.66222	0
Slice 40	114.17489	106.45711	0	1,654.332	602.12762	0
Slice 41	116.52607	105.57111	0	1,679.5357	611.30102	0
Slice 42	118.87725	104.69573	0	1,703.9385	620.1829	0
Slice 43	121.22843	103.83093	0	1,727.5416	628.7737	0
Slice 44	123.57961	102.97667	0	1,750.3461	637.07387	0
Slice 45	125.93078	102.13289	0	1,772.3532	645.08382	0

Slice 46	128.28196	101.29957	0	1,793.5642	652.80397	0
Slice 47	130.63314	100.47664	0	1,813.98	660.23471	0
Slice 48	132.98432	99.664068	0	1,833.6017	667.37643	0
Slice 49	135.3355	98.861815	0	1,852.4303	674.2295	0
Slice 50	137.68668	98.069837	0	1,870.4669	680.79427	0
Slice 51	140.03786	97.288094	0	1,887.7123	687.0711	0
Slice 52	142.38904	96.516545	0	1,904.1676	693.06032	0
Slice 53	144.74021	95.755151	0	1,919.8335	698.76224	0
Slice 54	147.09139	95.003874	0	1,934.7109	704.17718	0
Slice 55	149.44257	94.262677	0	1,948.8006	709.30543	0
Slice 56	151.79375	93.531521	0	1,962.1035	714.14727	0
Slice 57	154.14493	92.810372	0	1,974.6202	718.70297	0
Slice 58	156.49611	92.099193	0	1,986.3514	722.97279	0
Slice 59	158.84729	91.397948	0	1,997.2979	726.95698	0
Slice 60	161.19846	90.706605	0	2,007.4602	730.65576	0
Slice 61	163.54964	90.025129	0	2,016.839	734.06937	0
Slice 62	165.90082	89.353486	0	2,025.4349	737.198	0
Slice 63	168.252	88.691645	0	2,033.2483	740.04186	0
Slice 64	170.60318	88.039574	0	2,040.2798	742.60112	0
Slice 65	172.95436	87.39724	0	2,046.5299	744.87596	0
Slice 66	175.30554	86.764615	0	2,051.999	746.86654	0
Slice 67	177.65671	86.141667	0	2,056.6874	748.57301	0
Slice 68	180.00789	85.528367	0	2,060.5957	749.9955	0
Slice 69	182.35907	84.924686	0	2,063.7241	751.13414	0

Slice 70	184.71025	84.330596	0	2,066.0729	751.98903	0
Slice 71	187.06143	83.746069	0	2,067.6424	752.56028	0
Slice 72	189.41261	83.171078	0	2,068.4328	752.84797	0
Slice 73	191.76379	82.605596	0	2,068.4444	752.85218	0
Slice 74	194.11496	82.049597	0	2,067.6772	752.57297	0
Slice 75	196.46614	81.503055	0	2,066.1316	752.0104	0
Slice 76	198.81732	80.965945	0	2,063.8075	751.1645	0
Slice 77	201.1685	80.438243	0	2,060.705	750.03529	0
Slice 78	203.51968	79.919924	0	2,056.8243	748.62281	0
Slice 79	205.87086	79.410965	0	2,052.1652	746.92704	0
Slice 80	208.22204	78.911343	0	2,046.7278	744.94799	0
Slice 81	210.57321	78.421036	0	2,040.512	742.68563	0
Slice 82	212.92439	77.94002	0	2,033.5177	740.13992	0
Slice 83	215.27557	77.468276	0	2,025.7449	737.31083	0
Slice 84	217.62675	77.005781	0	2,017.1932	734.1983	0
Slice 85	219.97793	76.552514	0	2,007.8627	730.80225	0
Slice 86	222.32911	76.108457	0	1,997.753	727.12262	0
Slice 87	224.68029	75.673589	0	1,986.8639	723.1593	0
Slice 88	227.03147	75.247891	0	1,975.195	718.9122	0
Slice 89	229.38264	74.831343	0	1,962.7462	714.38119	0
Slice 90	231.73382	74.423929	0	1,949.517	709.56614	0
Slice 91	234.085	74.025629	0	1,935.507	704.46693	0
Slice 92	236.43618	73.636427	0	1,920.7158	699.08338	0
Slice 93	238.78736	73.256306	0	1,905.143	693.41535	0

Slice 94	241.13854	72.885248	0	1,888.7881	687.46265	0
Slice 95	243.48972	72.523238	0	1,871.6505	681.22508	0
Slice 96	245.84089	72.170261	0	1,853.7298	674.70246	0
Slice 97	248.19207	71.8263	0	1,835.0252	667.89457	0
Slice 98	250.54325	71.491341	0	1,815.5363	660.80117	0
Slice 99	252.89443	71.16537	0	1,795.2623	653.42203	0
Slice 100	255.24561	70.848373	0	1,774.2025	645.7569	0
Slice 101	257.59679	70.540336	0	1,752.3562	637.80551	0
Slice 102	259.94797	70.241246	0	1,729.7227	629.56759	0
Slice 103	262.29914	69.951089	0	1,706.3012	621.04285	0
Slice 104	264.65032	69.669855	0	1,682.0908	612.23099	0
Slice 105	267.0015	69.39753	0	1,657.0907	603.13168	0
Slice 106	269.35268	69.134104	0	1,631.2999	593.74461	0
Slice 107	271.70386	68.879565	0	1,604.7176	584.06944	0
Slice 108	274.05504	68.633902	0	1,577.3427	574.1058	0
Slice 109	276.40622	68.397105	0	1,549.1743	563.85333	0
Slice 110	278.75739	68.169164	0	1,520.2113	553.31166	0
Slice 111	281.10857	67.950069	0	1,490.4526	542.48038	0
Slice 112	283.45975	67.739811	0	1,459.8971	531.3591	0
Slice 113	285.81093	67.538382	0	1,428.5437	519.9474	0
Slice 114	288.16211	67.345772	0	1,396.3912	508.24483	0
Slice 115	290.51329	67.161974	0	1,363.4383	496.25096	0
Slice 116	292.86447	66.986981	0	1,329.6838	483.96533	0
Slice 117	295.21564	66.820784	0	1,295.1264	471.38745	0

Slice 118	297.56682	66.663377	0	1,259.7647	458.51685	0
Slice 119	299.89658	66.516028	0	1,215.8543	701.97383	0
Slice 120	302.20491	66.378573	0	1,184.0064	683.58641	0
Slice 121	304.51324	66.249573	0	1,151.1204	664.59968	0
Slice 122	306.82156	66.129022	0	1,117.193	645.01168	0
Slice 123	309.12989	66.016915	0	1,082.2208	624.82045	0
Slice 124	311.43822	65.913249	0	1,046.2002	604.02396	0
Slice 125	313.74655	65.818018	0	1,009.1277	582.62017	0
Slice 126	316.05488	65.73122	0	970.99982	560.60701	0
Slice 127	318.36321	65.652851	0	931.81274	537.98234	0
Slice 128	320.67154	65.582907	0	891.56278	514.74401	0
Slice 129	322.97987	65.521386	0	850.24615	490.88984	0
Slice 130	325.34059	65.467275	0	807.12225	364.42967	0
Slice 131	327.75371	65.420963	0	759.39091	342.87814	0
Slice 132	330.16683	65.383849	0	711.02436	321.03981	0
Slice 133	332.57995	65.355931	0	662.02069	298.9138	0
Slice 134	335.52085	65.335564	0	601.36424	271.52637	0
Slice 135	338.46187	65.326403	0	539.89425	243.7716	0
Slice 136	340.87524	65.330091	0	488.67998	220.64747	0
Slice 137	343.28861	65.342974	0	436.81946	197.23155	0
Slice 138	345.70198	65.365054	0	384.31055	173.52287	0
Slice 139	348.0718	65.395604	0	331.1936	191.21471	0
Slice 140	350.39807	65.434299	0	276.47533	159.6231	0
Slice 141	352.72433	65.481542	0	220.61787	127.37379	0

Slice 142	355.0506	65.537336	0	163.61634	94.463941	0
Slice 143	357.37687	65.601681	0	105.46577	60.890688	0
Slice 144	359.62083	65.67171	0	72.554752	41.889506	0
Slice 145	361.7825	65.746842	0	65.055311	37.559701	0
Slice 146	363.94417	65.829366	0	56.674193	32.720861	0
Slice 147	366.10583	65.919285	0	47.40769	27.370843	0
Slice 148	368.2675	66.016603	0	37.252042	21.507476	0
Slice 149	370.42917	66.121322	0	26.20343	15.128558	0
Slice 150	372.42833	66.224502	0	10.231347	5.9070707	0

APPENDIX I

Seepage Potential and Karst Condition Assessment

Seepage Potential and Karst Condition Assessment

The disposal facility is designed and constructed to include storm water run-on and run-off management and leachate collection systems. The liner system is designed and constructed to be above the high groundwater level. There are currently no concerns that storm water, leachate, or groundwater movement will impact the stability of the landfill.

As noted in **Appendix E**, karst features were not observed in the borings within and adjacent to the disposal facility. The borings encountered sandstone bedrock that is not subject to karst conditions. The Wisconsin map of karst and shallow carbonate bedrock in **Appendix E** indicates that karst structures are not located in or near the disposal facility.