Closure Plan

Columbia Dry Ash Disposal Facility
Phase 1 Module 1
Phase 1 Module 2
Phase 1 Module 3
Phase 1 Module 4
Phase 1 Module 5
Phase 1 Module 6

Prepared for:

Wisconsin Power and Light Company
Columbia Energy Center
W8375 Murray Road
Pardeeville, Wisconsin 53954

SCS ENGINEERS

25221134.00 | December 9, 2021

2830 Dairy Drive
Madison, WI 53718-6751
608-224-2830

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PE CERTIFICATION

I, Phillip Gearing, hereby certify the following:

- This Closure Plan meets the requirements of 40 CFR 257.102(b)
- The final cover system described in this Closure Plan meets the design requirements in 40 CFR 257.102(d)(3)

The Closure Plan was prepared by me or under my direct supervision, and that I am a duly licensed Professional Engineer under the laws of the State of Wisconsin.

December 9, 2021

(signature) (date)

Phillip E. Gearing

(printed or typed name)

License number E-45115

My license renewal date is July 31, 2022.

Pages or sheets covered by this seal:

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1.0 INTRODUCTION AND PROJECT SUMMARY

On behalf of Wisconsin Power and Light Company (WPL), SCS Engineers (SCS) has prepared this Closure Plan for the Columbia (COL) Dry Ash Disposal Facility Phase 1, Modules 1 through 6 as required by 40 Code of Federal Regulations (CFR) 257.102(b), as stated below.

40 CFR 257.102(b). *"Written closure plan – (1) Content of the plan. The owner or operator of a CCR unit must prepare a written closure plan that describes the steps necessary to close the CCR unit at any point during the active life of the CCR unit consistent with recognized and generally accepted good engineering practices. The written closure plan must include, at a minimum, the information specified in paragraphs (b)(1)(i) through (vi) of this section."*

The COL facility includes an active coal combustion residue (CCR) landfill, which currently consists of the following modules, all located in Phase 1 of the facility.

- Phase 1 Module 1 – this module has received final cover over completed outer sideslope areas that will no longer receive additional CCR; intermediate cover has been placed over remaining areas. The final cover placed complies with the CCR Rule.
- Phase 1 Module 2 – this module has received intermediate cover over a majority of the in-place CCR.
- Phase 1 Module 3 – This module has received intermediate cover over a majority of the in-place CCR.
- Phase 1 Module 4 – This module is currently being filled.
- Phase 1 Module 5 - this module was constructed in 2021 and is approved by the Wisconsin Department of Natural Resources (WDNR) to receive CCR.
- Phase 1 Module 6 - this module was constructed in 2021 and is approved by the WDNR to receive CCR.

Modules 1-3 were previously described as separate existing CCR landfills although they are contiguous and are managed as a single landfill by the facility and by the WDNR. WPL has clarified in the operating record for the Columbia facility that Modules 1-3 are one existing CCR landfill as defined in 40 CFR 257.53 of the federal CCR Rule. Modules 4-6 are considered to be a new CCR landfill that initiated construction after October 19, 2015, and is therefore managed as a separate CCR unit under the CCR Rule even though they are contiguous to the existing CCR landfill (Modules 1-3).

Future landfill modules (Phase 2 Modules 7 through 13) are permitted with the WDNR, but have not been developed. As these modules are developed, they will be considered lateral expansions of the new CCR landfill currently comprised of Modules 4-6. Future lateral expansions are not addressed in this plan and are not discussed further herein.

Figure 1 shows the site location. **Figure 2** shows the closure areas. A detail of the final cover system is shown on **Figure 3**.

2.0 PROPOSED CLOSURE PLAN NARRATIVE

40 CFR 257.102(b)(1)(i). *"A narrative description of how the CCR unit will be closed in accordance with this section."*

When CCR placement is completed in the CCR unit, or if early closure is required, the unit will be closed by covering the CCR with the final cover system described in Section 3.0. Prior to final cover system construction, the CCR surfaces will be graded and compacted to establish a firm subgrade for final cover construction. The timing for completion of CCR placement in the units that are addressed with this closure plan will depend on CCR generation and disposal rates. Future CCR unit development will also impact the timing of closure. Each of the existing CCR units is designed to receive additional CCR once adjacent units are constructed and overlay airspace is available for filling. Based on the current CCR units alone, if early closure of all units were required, final cover will be placed in the active landfill areas shown on Figure 2. A closure schedule is discussed in Section 6.0 and presented in Appendix B.

The initiation of closure activities will commence no later than 30 days after the final receipt of CCR as required by 40 CFR 257.102(e)(1), or in accordance with 40 CFR 257.102(e)(2).

3.0 FINAL COVER SYSTEM AND PERFORMANCE

40 CFR 257.102(b)(1)(iii). *"If closure of the CCR unit will be accomplished by leaving CCR in place, a description of the final cover system, designed in accordance with paragraph (d) of this section, and the methods and procedures to be used to install the final cover. The closure plan must also discuss how the final cover system will achieve the performance standards specified in paragraph (d) of this section."*

"(d) Closure performance standard when leaving CCR in place."

"(1) The owner or operator of a CCR unit must ensure that, at a minimum, the CCR unit is closed in a manner that will:

(i) Control, minimize or eliminate, to the maximum extent feasible, post-closure infiltration of liquids into the waste and releases of CCR, leachate, or contaminated run-off to the ground or surface waters or to the atmosphere;

The final cover system design will minimize or eliminate infiltration, as further described below.

(ii) Preclude the probability of future impoundment of water, sediment, or slurry;

The final cover system will meet these criteria, as further described below.

(iii) Include measures that provide for major slope stability to prevent the sloughing or movement of the final cover system during the closure and post-closure care period;

The final cover system is designed to provide slope stability and to prevent sloughing or movement during the closure and post-closure care period. Stability of the final cover system was assessed as part of the WDNR landfill permitting process and is further addressed below.

(iv) Minimize the need for further maintenance of the CCR unit; and

Maintenance of the final cover will be minimized by the establishment of vegetative cover and the erosion control systems, which are further described below.

(v) Be completed in the shortest amount of time consistent with recognized and generally accepted good engineering practices."

All closure activities for the CCR units will be completed within 6 months, as stated in **Section 7.0** below.

"(2) Drainage and stabilization of CCR surface impoundments."

This does not apply to the COL CCR landfill units.

"(3) Final cover system"

The final cover system (see **Figure 3** for details) in place on part of Module 1 will also be installed in the remaining areas of the CCR units. The final cover system is as follows from the bottom up:

- 3-inch grading layer
- Geosynthetic clay liner (GCL)
- 40-millimeters (mil) linear low-density polyethylene (LLDPE) geomembrane
- 12 inches of drainage material
- 12 inches of rooting zone
- 6 inches of topsoil

This final cover meets and exceeds the minimum requirements of 40 CFR 257.102(d)(3)(i)(A) through (D) as follows:

- Per 257.102(d)(3)(i)(A), the permeability of the final cover system is less than or equal to the permeability of the bottom liner system and is less than $1x10^{-5}$ centimeters per second (cm/sec) required by the rule. The COL cover system contains a GCL with a permeability of $1x10^{-9}$ cm/sec. The geomembrane above the GCL makes the cover system even less permeable.

The bottom liner system for the existing CCR landfill is as follows:

- Phase 1 Module 1 South:
  - GCL
  - 40-mil high density polyethylene (HDPE) geomembrane
  - The layers of the liner system are less than the cover system layers; therefore, infiltration will be more than the cover system

- Phase 1 Module 1 North:
  - 3 feet of compacted ash
  - The liner here does not include a geomembrane, and therefore the infiltration through the cover system will be less than this base liner

- Phase 1 Modules 2 and 3:
  - 2 feet of compacted clay
  - GCL
  - 60-mil HDPE geomembrane

The bottom liner system for the new CCR landfill is as follows:

- Phase 1 Modules 4, 5, and 6:
  - 2 feet of compacted clay
  - GCL
  - 60-mil HDPE geomembrane

Based on a comparison of the design slopes and drainage system components in the liner system and final cover system, the final cover system is less permeable than the liner system in Phase 1 Modules 1, 2, 3, 4, 5, and 6.

- Per 257.102(d)(3)(i)(B), the final cover system includes 2.5 feet of soil, which is greater than the 18 inches of earthen material required to minimize infiltration.

- Per 257.102(d)(3)(i)(C), erosion of the final cover system is minimized with a vegetative support layer consisting of 12 inches of uncompacted rooting zone material and 6 inches of topsoil. This provides more than the required 6-inch thickness for plant growth.

Also, this final cover system limits infiltration while promoting surface water run-off in a controlled manner to minimize erosion and promote stability. The surface layer of 18 inches of soil supports vegetation that assists with erosion control. Water that infiltrates will be collected by the 12-inch drainage layer and will be routed to the perimeter drainage system.

In addition, the surface has intermediate drainage swales to reduce the flow lengths down the final cover slope, also aiding in erosion control. Where needed, the intermediate drainage swales are connected to downslope channels to control storm water runoff and prevent erosion of the final cover.

- Per 257.102(d)(3)(i)(D), the design of the final cover system minimizes disruptions to the final cover system. Stability of the final cover system was assessed as part of the WDNR landfill permitting process. The stability calculations are included in **Appendix A**.

The design of the final cover system accommodates settling and subsidence of the CCR fill below the cover. The CCR at COL is placed dry and is compacted in place. CCR continues to consolidate and gain strength as filling progresses prior to final cover placement. The final cover system is designed with a maximum slope of 25 percent (4 horizontal to 1 vertical). Because the final cover has a relatively large positive slope and the CCR has been gaining strength over time, the final cover is expected to easily accommodate the remaining relatively minor settlement potential of the CCR fill when fill placement ends and the landfill is closed.

All final cover materials will be tested to confirm they meet specifications, and construction will be overseen and documented by a licensed engineer. Rooting zone and topsoil layers will be checked for thickness. All areas will be restored after final cover is placed. Vegetation will be monitored and maintained.

4.0 MAXIMUM INVENTORY OF CCR

40 CFR 257.102(b)(1)(iv). *"An estimate of the maximum inventory of CCR ever on-site over the active life of the CCR unit."*

The following table reflects the estimated maximum volumes of CCR in the CCR landfill units at the COL facility.

Area	Capacity (cy)
Phase 1 Module 1-3	1,912,800
Phase 1 Module 4-6	1,274,800
Total Maximum CCR Quantity	**3,187,600**

The estimated maximum inventory of CCR ever on site over the active life of the CCR landfill units is based on the design capacity of each unit. The design capacity of each unit is defined in the WDNR approved 2010 Plan of Operation Update.

5.0 LARGEST AREA OF CCR UNIT REQUIRING FINAL COVER

40 CFR 257.102(b)(1)(v). *"An estimate of the largest area of the CCR unit ever requiring a final cover as required by paragraph (d) of this section at any time during the CCR unit's active life."*

The largest area of each CCR unit requiring final cover is the open area shown on **Figure 2**, with areas as follows:

Areas Requiring Final Cover (acres)	
Phase 1 Module 1- 3	12.9
Phase 1 Module 4-6	12.0
Total	**24.9**

6.0 SCHEDULE OF SEQUENTIAL CLOSURE ACTIVITIES

40 CFR 257.102(b)(1)(vi). *"A schedule for completing all activities necessary to satisfy the closure criteria in this section, including an estimate of the year in which all closure activities for the CCR unit will be completed."*

Alliant Energy's plans to eliminate coal as a fuel source by 2040. WPL has also announced plans to retire Columbia Unit 1 by the end of 2023 and Unit 2 by the end of 2024. The dates below reflect the latest dates when CCR placement is estimated to be complete in each of the CCR units:

CCR Unit	Filling Completed
Phase 1 Module 1-3	December 2040
Phase 1 Module 4-6	December 2040

Based on the design capacity of each CCR unit and the currently anticipated disposal rates, the facility is expected to have sufficient capacity through the end of 2024. During the life of the facility, there will be periods of time when the sideslopes will not receive CCR or non-CCR waste. These periods are a part of normal plant operations, as described in the Plan of Operations approved by WDNR. Finally, the dates assume that the adjacent future CCR units that are currently permitted with WDNR will be constructed allowing for the overlay of additional CCR onto the existing units. The preliminary schedule for closure of the CCR units is provided in **Appendix B**.

7.0 COMPLETION OF CLOSURE ACTIVITIES

40 CFR257.102((f)(1). *"Except as provided for in paragraph (f)(2) of this section, the owner or operator must complete closure of the CCR unit:*

(i) For existing and new CCR landfills and any lateral expansion of a CCR landfill, within six months of commencing closure activities."

As shown on the enclosed schedule, closure of each CCR unit will be completed within 6 months of commencing closure activities.

40 CFR 257.102(f)(3). *"Upon completion, the owner or operator of the CCR unit must obtain a certification from a qualified professional engineer verifying that closure has been completed in accordance with the closure plan specified in paragraph (b) of this section and the requirements of this section."*

A qualified licensed engineer will oversee the final cover construction. The engineer will verify final cover materials and methods and oversee material testing. At the end of construction, the engineer will provide a report summarizing and documenting construction and will certify compliance with the requirements.

8.0 CERTIFICATION

40 CFR 257.102(b)(4). "*The owner or operator of the CCR unit must obtain a written certification from a qualified professional engineer that the initial and any amendment of the written closure plan meets the requirement of this section."*

Phillip Gearing, PE, a licensed professional engineer in the State of Wisconsin has overseen the preparation of this Closure Plan. A certification statement is provided on **page iii** of this plan.

40 CFR 257.102(d)(2)(iii). *"The owner or operator of the CCR unit must obtain a written certification from a qualified professional engineer that the design of the final cover system meets the requirement of this section."*

Phillip Gearing, PE, a licensed professional engineer in the State of Wisconsin has overseen the design of the final cover system and certifies that the design meets the requirements of 40 CFR 257.102(d). The certification statement is provided on **page iii** of this plan.

9.0 RECORDKEEPING AND REPORTING

40 CFR 257.102(b)(vi)(2)(iii). "*The owner or operator has completed the written closure plan when the plan including the certification required by paragraph (b)(4) of this section, has been placed in the facility's operating record as required by Section 257.105(i)(4).*"

The Closure Plan will be placed in the facility's operating record and on Alliant Energy's CCR Rule Compliance Data and Information website.

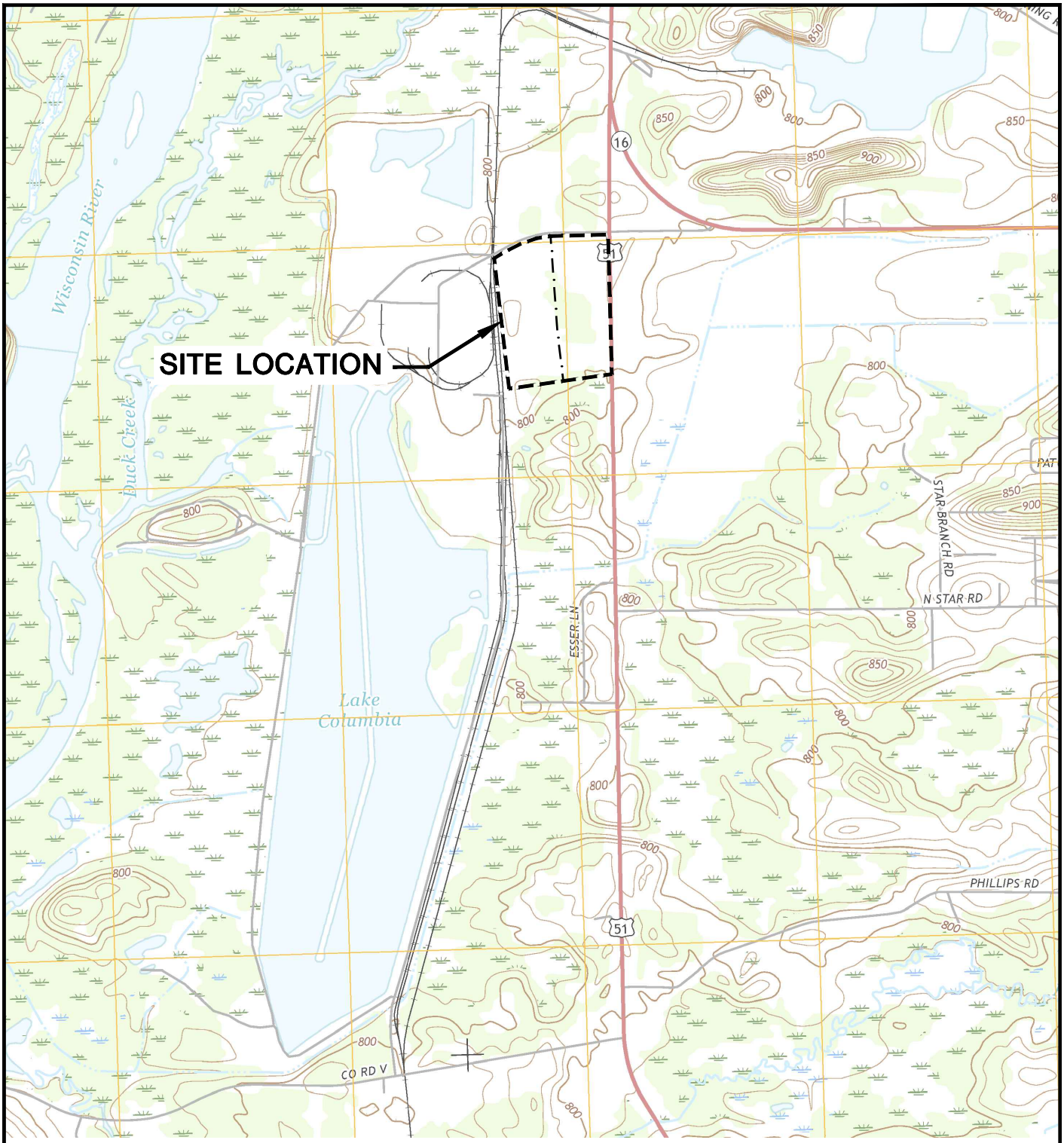
Amendments to the written Closure Plan will be done when a new module is constructed, when there is a change in the operation of the CCR unit that affects the plan, or when unanticipated events warrant revision to the written Closure Plan as required by 40 CFR 257.102(b)(3).

WPL will provide notification as follows:

- Intent to initiate closure
- Closure completion
- Availability of the written Closure Plan and any amendments

All notifications will be placed in the facility's operating record and on the website per 40 CFR 257.105(i), 257.106(i), 257.107(i).

Figures



N

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

CLIENT	WISCONSIN POWER AND LIGHT COLUMBIA ENERGY CENTER W8375 MURRAY ROAD PARDEEVILLE, WISCONSIN 53954	SITE	CLOSURE PLAN COLUMBIA DRY ASH DISPOSAL FACILITY TOWN OF PACIFIC, WISCONSIN

SITE LOCATION MAP

PROJECT NO.	25221134.00	DRAWN BY:	AHB
DRAWN:	08/09/2016	CHECKED BY:	RJG
REVISED:	11/30/2021	APPROVED BY:	PEG 12/09/21

ENGINEER

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

FIGURE 1

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LEGEND

- ASH DISPOSAL FACILITY LIMITS
- APPROVED LIMITS OF ASH FILL
- PHASE/MODULE LIMIT
- 810 EXISTING GRADE (5' CONTOUR)
- EXISTING GRADE (1' CONTOUR)
- PAVED ROAD
- UNPAVED ROAD
- RAILROAD TRACKS
- VEGETATION
- FENCE
- SWALE
- EDGE OF WATER
- APPROXIMATE LIMITS OF EXISTING LEACHATE/SURFACE WATER POND LINER
- FINAL COVER LIMITS
- CULVERT
- TRANSMISSION TOWER
- WATER SUPPLY WELL
- STAFF GAUGE
- WATER TABLE WELL
- PIEZOMETER
- SURFACE WATER SAMPLE LOCATION
- LYSIMETER
- ABANDONED WATER TABLE WELL
- ABANDONED PIEZOMETER
- BENCHMARK
- PROPOSED FINAL GRADE (2' CONTOUR)
- 820 PROPOSED FINAL GRADE (10' CONTOUR)
- ACTIVE LANDFILL AREA
- PROPOSED DIVERSION BERM
- PROPOSED DOWNSLOPE CHANNEL
- CLOSED AREA
- AREA TO BE CLOSED

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, AUGUST 2018, AND NOVEMBER 2021.
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.

N

200 0 200

SCALE: 1" = 200'

COAL PILE
WPDES POND
CLOSED LANDFILL
ACTIVE LANDFILL
C. M. ST. P. & P. RR.
PLANT ENTRANCE ROAD
MODULE 1
MODULE 2
MODULE 3
MODULE 4
MODULE 5
MODULE 6
PHASE 1
FUTURE MODULE 7
FUTURE MODULE 8
FUTURE MODULE 9
FUTURE MODULE 10
FUTURE MODULE 11
FUTURE MODULE 12
FUTURE MODULE 13
FUTURE PHASE 2
LEACHATE/ SURFACE WATER POND
LP-1
MW-83
MW-311
SG-4
MW-33B
MW-33AR
MW-34A
MW-34B
MW-88B
MW-88A
MW-85B
MW-85A
MW-302
MW-5R
MW-310
MW-309
MW-37A
MW-92B
MW-92A
LS-3R
MW-91B
MW-16
MW-89A/B7
MW-1AR
M-1B
MW-301
MW-84A
MW-84B
MW-86
U.S.H. 51
BM19

CLOSURE PLAN

CLOSURE PLAN
COLUMBIA DRY ASH DISPOSAL FACILITY
TOWN OF PACIFIC, WISCONSIN

SITE

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

CLIENT

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

FIGURE 2

ENGINEER

DRAWN BY:	KP
CHECKED BY:	BSS
APPROVED BY:	PEG 12/09/21
PROJECT NO.	25221134.00
DRAWN:	11/30/2021
REVISED:	11/30/2021

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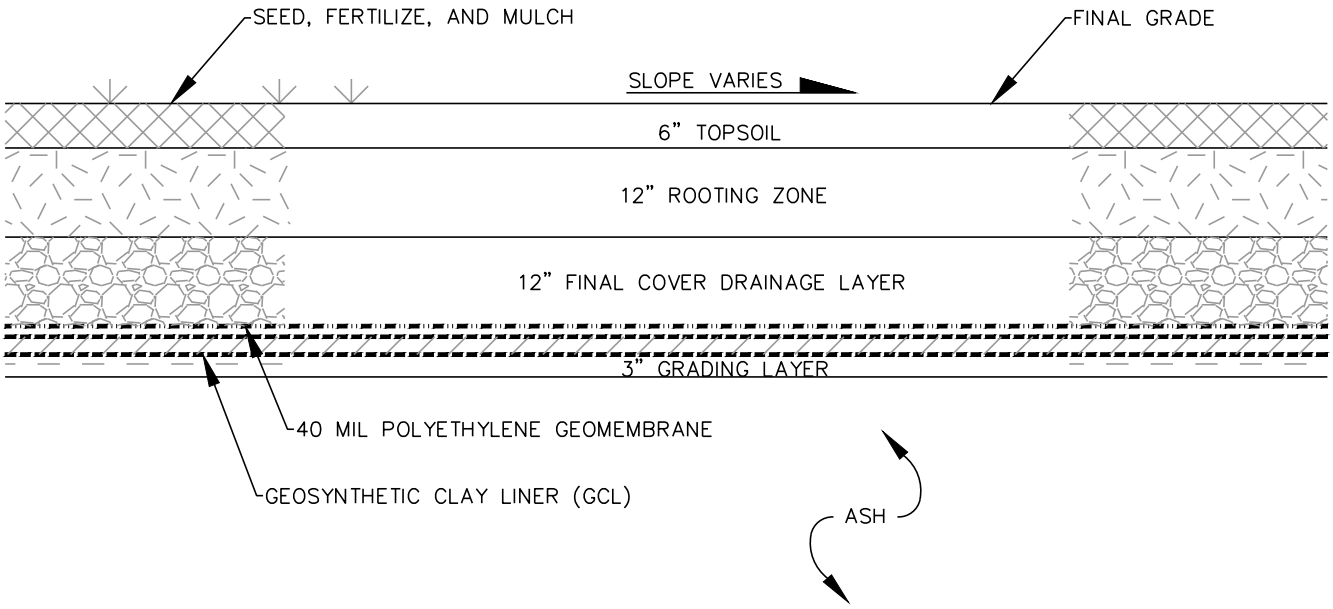

FINAL COVER SYSTEM

SCALE: 1" = 5'

CLIENT	WISCONSIN POWER AND LIGHT COLUMBIA ENERGY CENTER W8375 MURRAY ROAD PARDEEVILLE, WISCONSIN 53954	SITE	CLOSURE PLAN COLUMBIA DRY ASH DISPOSAL FACILITY TOWN OF PACIFIC, WISCONSIN	FINAL COVER SYSTEM	
PROJECT NO.	25221134.00	DRAWN BY:	KP	ENGINEER	SCS ENGINEERS 2830 DAIRY DRIVE MADISON, WI 53718-6751 PHONE: (608) 224-2830
DRAWN:	08/17/2016	CHECKED BY:	RJG		FIGURE 3
REVISED:	11/24/2021	APPROVED BY:	PEG 12/09/21		

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Appendix A

Stability Calculations

E-3 Liner Slope Stability

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CIVIL & ENVIRONMENTAL ENGINEERING

Sheet No. 1			
Calc. No.			
Rev. No.			
Job No. 4071	Job: Columbia Ash Generation Landfill	By: PEG	Date 9/23/10
Client: Alliant	Subject: Liner Side Slope Drainage Layer Stability	Chk'd: DLN	Date 9/24/10

EVALUATION:

Evaluate the Phase 1 landfill liner side slope drainage layer for static veneer slope stability.

The side slope on the modules base runs at a 3:1 slope for an approximate maximum of 80 feet.

The following calculations evaluate the static veneer slope stability of the 3:1 slope.

REFERENCES:

1.) Koerner, Robert M. & Te-Yang Soong, Analysis and Design of Veneer Cover Soils, Geosynthetic Research Institute.

2.) U.S. Department of Transportation - Federal Highway Administration Recycled Materials, Coal Bottom Ash User's Guide

EQUATIONS:

$FS = (-b+(b^2-4*a*c)^{1/2})/(2*a)$

$a = (W_A-N_A*\cos\beta)*\cos\beta$

$b = -((W_A-N_A*\cos\beta)*\sin\beta*\tan\phi+(N_A*\tan\delta+C_a)*\sin\beta*\cos\beta+(C+W_P*\tan\phi)*\sin\beta)$

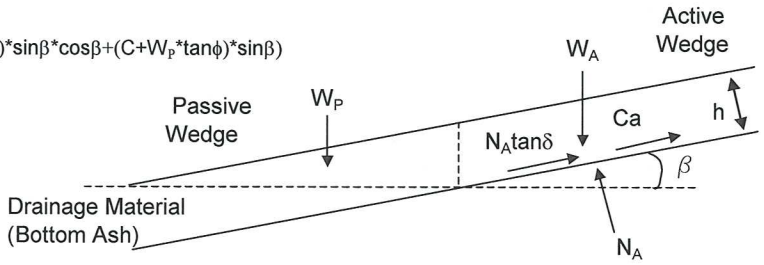
$c = (N_A*\tan\delta+C_a)*(\sin\beta)^2*\tan\phi$

$N_A = W_A*\cos\beta$

$W_A = \gamma*h^2*(L/h-1/\sin\beta-\tan\beta/2)$

$W_P = (\gamma*h^2)/\sin 2\beta)$

$C_a = c_a(L-h/\sin\beta)$



DEFINITIONS OF VARIABLES:

FS = Factor of Safety

a, b, & c = intermediate variables (= calculated variable)

N_A = Effective force normal to the failure plane of the active wedge (= calculated variable)

W_A = Total weight of active wedge (= calculated variable)

W_P = Total weight of passive wedge (= calculated variable)

β = Soil slope angle beneath the geomembrane (= 18.42 degrees or 0.322 radians based on liner slope of 3 to 1)

ϕ = Friction angle of the drainage layer material (= 35 degrees 0.611 radians based on Ref #2)

δ = Interface friction angle for liner system geosynthetics (to be determined)

c_a = Adhesion for liner system geosynthetics at active wedge (to be determined) , Variable

γ = Unit weight of the drainage layer material (= 135 pcf based on conservative wet density of bottom ash).

C = Cohesive force along the failure plane of the passive wedge (assumed 0 for drainage layer material)

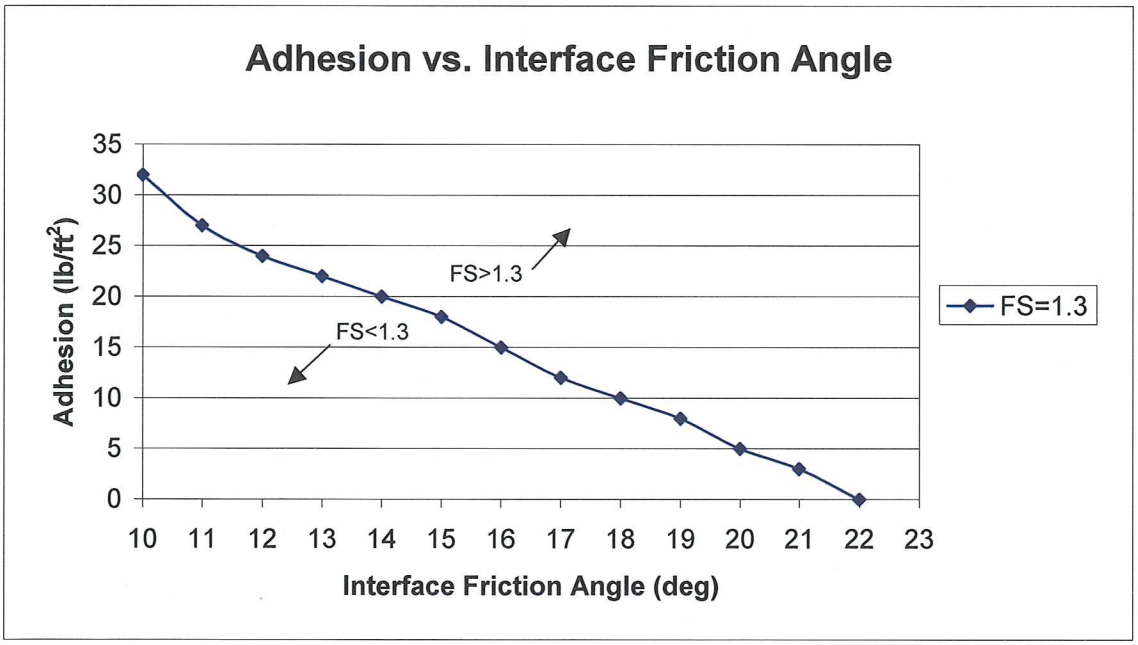
C_a = Adhesive force of the active wedge for the liner system geosynthetics

h = Thickness of the drainage layer material(= 1.0 foot based on base design)

L = Length of slope measured along the geomembrane (= 80 feet based on base design)

CALCULATIONS:

δ		c_a	W_A	W_P	N_A	C_a	a	b	c	FS
(deg)	(rad)	(lb/ft^2)	(lb/ft)	(lb/ft)	(lb/ft)	(lb/ft)	(lb/ft)	(lb/ft)	(lb/ft)	
10	0.175	32	10,350	225	9,820	2,459	981	-1,535	293	**1.3**
11	0.192	27	10,350	225	9,820	2,075	981	-1,473	279	**1.3**
12	0.209	24	10,350	225	9,820	1,844	981	-1,457	275	**1.3**
13	0.227	22	10,350	225	9,820	1,690	981	-1,465	277	**1.3**
14	0.244	20	10,350	225	9,820	1,537	981	-1,473	279	**1.3**
15	0.262	18	10,350	225	9,820	1,383	981	-1,482	281	**1.3**
16	0.279	15	10,350	225	9,820	1,153	981	-1,468	277	**1.3**
17	0.297	12	10,350	225	9,820	922	981	-1,455	274	**1.3**
18	0.314	10	10,350	225	9,820	768	981	-1,465	277	**1.3**
19	0.332	8	10,350	225	9,820	615	981	-1,477	279	**1.3**
20	0.349	5	10,350	225	9,820	384	981	-1,465	277	**1.3**
21	0.367	3	10,350	225	9,820	231	981	-1,478	280	**1.3**
22	0.384	0	10,350	225	9,820	0	981	-1,468	277	**1.3**



CONCLUSION:

The landfill liner side slope drainage layer was evaluated for static veneer slope stability along its longest slope. Calculations were performed to determine the minimum adhesion necessary for a range of interface friction angles to reach a FS of 1.3 or greater. Each interface friction angle and the coinciding adhesion was graphed in order to easily determine if a material interface is acceptable along the side slope.

BT SQUARED

Sheet No.	1 of 1		
Calc. No.			
Rev. No.			
Job No. 4071	Job: Columbia Ash Generation Landfill	By PEG	Date 9/27/10
Client: Alliant	Subject: GCL Internal Shear for Liner System	Chk'd DLN	Date 9/29/10

Purpose: Determine the maximum shear stress acting on a Geosynthetic Clay Liner (GCL) and the GCL internal shear strength required to provide a minimum slope stability safety factor (FS) of 1.5 for the liner system.

Approach: Use maximum shear stress formula and assumed values.

References: **Design of GCL Barrier for Final Cover Side Slope Applications**
Gregory N. Richardson, Ph.D., P.E. Geosynthetics '97 - 541

Calculation: The maximum shear stress acting on the GCL can be calculated as follows:

$$\tau_{act} = W_T \sin \beta$$

$$\beta = 18.4^{\circ}$$

$$W_T = \gamma * h$$

Where,

γ = Ash Unit Weight = 135 pcf

h = drainage layer thickness = 1 ft

$$W_T = 135 \text{ psf}$$

$$\tau_{act} = 42.6 \text{ psf}$$

$$FS = \frac{\tau_{resist}}{\tau_{act}} = 1.5$$

$$\tau_{resist} = FS * \tau_{act} = 1.5 * 42.6 = 64 \text{ psf}$$

Assumptions: 1. Slope angle, β=18.4° (3:1 horizontal/vertical liner side slope).
2. Ash unit weight, γ = 135 pcf

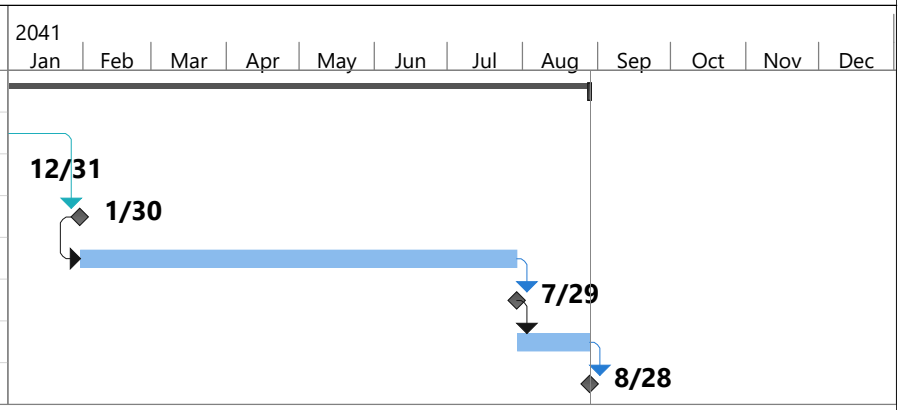
Conclusions: For a total weight of the leachate drainage layer of 135 psf and a slope angle of 3:1, the maximum shear stress will be 42.6 psf. A minimum GCL internal shear strength of 64 psf is required to provide a slope stability safety factor of 1.5.

Appendix B

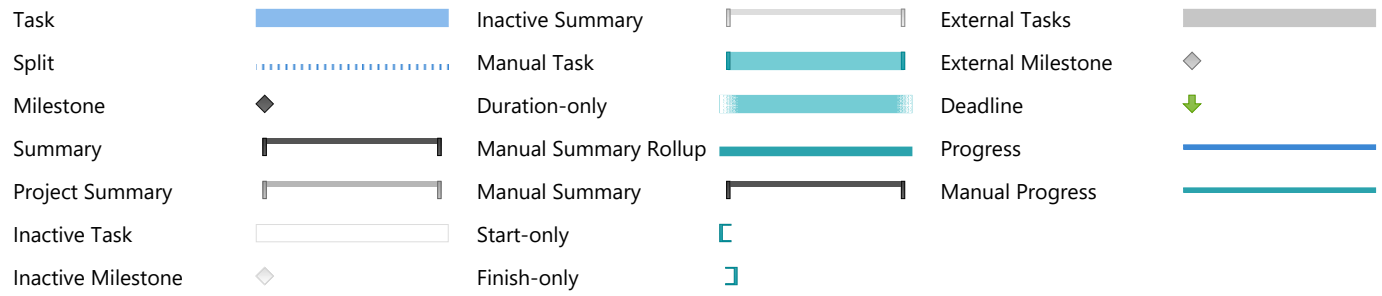
Schedule

Closure Plan Phase 1 Modules 1-3 - Columbia Ash Disposal Facility

ID	Task Name	Duration	Start
1	**Phase 1 Modules 1-3 Closure**	**241 days**	**Mon 12/31/40**
2	Ash Filling Ceases	1 day	Mon 12/31/40
3	Other Regulatory Permits - None	0 days	Mon 12/31/40
4	Notification of Intent to Close	0 days	Wed 1/30/41
5	Construction Activities	180 days	Thu 1/31/41
6	Notification of Closure Completion	0 days	Mon 7/29/41
7	Documentation of Closure	30 days	Tue 7/30/41
8	State Submittal of Documentation Report	0 days	Wed 8/28/41

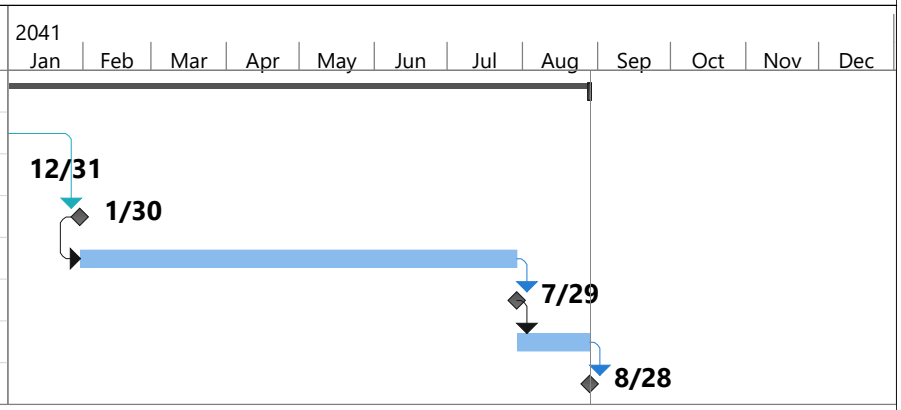


Date: Tue 11/30/21



Closure Plan Phase 1 Modules 4-6 - Columbia Ash Disposal Facility

ID	Task Name	Duration	Start
1	**Phase 1 Modules 4-6 Closure**	**241 days**	**Mon 12/31/40**
2	Ash Filling Ceases	1 day	Mon 12/31/40
3	Other Regulatory Permits - None	0 days	Mon 12/31/40
4	Notification of Intent to Close	0 days	Wed 1/30/41
5	Construction Activities	180 days	Thu 1/31/41
6	Notification of Closure Completion	0 days	Mon 7/29/41
7	Documentation of Closure	30 days	Tue 7/30/41
8	State Submittal of Documentation Report	0 days	Wed 8/28/41



Date: Tue 11/30/21