December 13, 2023 Project No. GL1239330907

Mr. Kevin O'Hara
Ohio Environmental Protection Agency
Division of Environmental Response & Revitalization
Southeast District Office
2195 E. Front Street
Logan, Ohio 43138

RE: RESPONSE TO COMMENTS ON IA WORK PLAN AMENDMENT 10, H&H DESIGN MEMO (90%), CQA PLAN (90%), SLAG TESTING MEMO (90%), DESIGN DRAWINGS (90%), AND DESIGN SPECIFICATIONS (90%)

Dear Kevin:

On behalf of Cyprus Amax Minerals Company, this letter provides responses to the above-referenced comments. We present your comments followed by our responses.

IA Work Plan Amendment 10

1) Section 2 of the work plan describes the removal basis and the proposed method for confirmation sampling in each of the 250-ft x 250-ft removal grids to ensure that each grid meets the 63 mg/Kg cleanup goal for hexavalent chromium. Cyprus Amax has proposed to analyze a composite sample from five randomly selected surface sampling locations in each grid. If a composite sample exceeds 63 mg/Kg for hexavalent chromium, then additional removal and verification sampling will continue until hexavalent chromium in the final composite sample from each grid is below 63 mg/Kg. With this method, there appears to be no means to narrow the limits of additional removal by identifying and isolating a hot spot (if one exists). The only option, then, appears to be the removal of additional soil from the entirety of each grid, before repeating the sampling process. In addition, Ohio EPA does not generally allow composite samples to be used for confirmation of areas subject to remediation, as mechanical dilution, and loss of spatial information results from the compositing process. Ohio EPA suggests an alternative approach. Each grid could be divided initially into four equal quadrants, with the collection of a discrete surface sample from the center of each quadrant. Samples would be analyzed individually, and an arithmetic mean for hexavalent chromium would be calculated using the four sample results. If the mean is less than or equal to 63 mg/Kg and there are no signs of remaining hot spots (e.g., individual discrete sample results significantly exceeding the cleanup level), then the removal in that grid would be considered complete. If the mean is greater than 63 mg/Kg, then the individual analytical results (which might identify a hot spot) could be used to direct additional, focused removal in one or more of the quadrants.

Response: We will revise the confirmation sampling approach in the IA Workplan in accordance with OEPA's proposed alternative approach. We need to discuss with OEPA a numeric criterion for "significantly exceeding the cleanup level" prior to finalizing the 100% design.

2) Section 2 of the work plan states: "Buried slag will be removed to the extent practicable. It is possible that some buried slag will not be found or will not be practicable to remove." Subsequent discussion indicates that these areas of slag would be covered with at least two feet of clean soil and revegetated. The term "practicable" seems to be subject to interpretation. Please provide a discussion of the scenarios for which Cyprus Amax might conclude that the removal of slag becomes "impracticable". If Cyprus Amax anticipates this scenario in specific areas of the site, please provide an additional drawing that identifies these areas. Additionally, provide an estimate of the total area and/or volume of slag that could be considered "impracticable" to remove. Also, please note that if various areas of the site outside of the footprint of the covered stockpile will continue to contain slag (albeit covered), these areas may require future use restrictions (e.g. prohibiting excavation) that would be recorded in an environmental covenant for the property.

Response: The only place where we know that we will be leaving slag is beneath the rail spur. It is possible (but not known with certainty) that we will encounter slag at the base of one of the slag piles that has "set up" like concrete and would be very difficult to break up and excavate. We may also encounter slag that is too deep to remove safely (such as behind the mill building foundation walls). We understand that future use restriction may be required for slag left in place.

Drawings

3) Drawing 562 illustrates the details for the energy dissipators that will be built at the bottoms of the surface water downchutes. Based on Ohio EPA's assessment of the 2017 spillway failure at the Oroville Dam in California, we offer the following recommendations: The drawing calls for the concrete reinforcement specifications "to be decided" (TBD). One of the factors that contributed to the Oroville failure was inadequate reinforcement in the concrete spillway. Ohio EPA will need to review a thorough analysis of the final reinforcement design to assure its adequacy. Another factor in the Oroville spillway failure was inadequate drainage and the resulting hydrostatic pressure buildup under the concrete spillway structure. The design shows a weephole for the drainage bed under the concrete dissipator, but Ohio EPA also recommends additional weepholes along the length of the downchutes to assure adequate drainage of the granular base, along with a maintenance plan to keep them flowing freely.

Response: See attached revised Drawing 562, as well as new Drawings 564 and 565 (Attachment A), that show the detailed reinforcement and weephole design. Also attached is the design memo describing the structural design of the energy dissipators, as well as the sizing and load calculations provided to the structural engineers (WSP) (Attachment C). Weepholes along the articulated concrete block (ACB) segments of the downchutes are not considered necessary because the blocks are open cells filled with gravel, which will provide discharge pathways from the underlying drainage layer. The ACB manufacturer and designer, Contech, provided the following evaluation of this question:

"I'd agree that one of the failure modes of the Oroville Dam Spillway was a buildup of hydrostatic pressure under the rigid concrete structure. However, the Armorflex Articulated Concrete Block System is a flexible erosion protection system with the ability to relieve the differential pore water pressures associated with high

velocity flows through the surface of the system itself. The proposed Armorflex Tapered Block System has a 20% open area which allows differential pore water pressure relief, unlike rigid concrete structures which require weepholes or drains to relieve pressure from underneath."

See example photo provided by Contech of the Armorflex Tapered Block System installed at one of their sites:

Lastly, we will add inspection and maintenance of the weepholes to the project Inspection and Maintenance Plan.

Hydrology and Hydraulics (H&H) Design Memorandum

4) Page 6 of the H&H Design Memorandum describes potential problems with surface water discharge and debris that could affect the rail line at the Gould Tunnel Eastern Portal. Cyprus Amax indicates that the "property owner to the north should be notified of these findings and potential concerns". Ohio EPA believes that simple notification is not sufficient, and that this issue requires further discussion to ensure that any potential risk to rail infrastructure or rail traffic is eliminated or mitigated.

Response: Cyprus Amax will contact the railroad, provide these findings, and provide access to the railroad via the Former Satralloy site if needed to perform any inspections or repairs.

Design Specifications

5) The Earthworks (02200) component of the specifications, Sections 3.4A and B, indicate that "*clean soil will be placed in 12-inch loose lifts and compacted to a firm and unyielding condition*". The term "firm and

unyielding" is vague and should be replaced with a more prescriptive requirement, such as a minimum number of passes with a roller. Also, Section 3.4C discusses moisture conditioning to achieve compaction requirements, but neither compaction density nor moisture content have been specified, so this statement may be unnecessary.

Response: Comments accepted. See attached revised specification Section 02200 (Attachment B). Article 3.4 has become Article 3.5 as a result of incorporating the addition of limestone amendment into this section. Paragraph 3.5 B has been modified so that "firm and unyielding" will be determined by the Construction Manager (which includes CQA personnel). The requirement to "Compact with a minimum of four passes of compaction equipment" has been moved to directly follow the list of acceptable compaction equipment. In paragraph 3.5 C, the word "requirements" has been replaced by "described in the previous paragraph". It is considered appropriate to warn the Contractor that moisture may be required even though the compaction is specified by method.

6) The Revegetation (02930) component of the specifications, Section 2.2D, indicates that "topsoil may be produced by mixing organic material such as chipped vegetation, manure, or other approved material into inorganic base soil that meets the requirements of this section." Ohio EPA believes that the amount of wood chips blended with other soil material should be limited, for reasons relating to both erosional stability and chemical nutrient levels. The presence of excessive green organic matter such as wood chips can significantly rob nitrogen from soil organisms and plant growth. Please revise this section to establish a limit for the percentage of chipped vegetation incorporated into manufactured topsoil.

Response: Comment accepted. See revised specification Section 02930, attached (Attachment B). The phrase "but not more than 15%" has been added to paragraph 2.2 D.

7) Revegetation (02930), Section 3.3A, specifies a minimum of 3 inches of topsoil on the slag cover soil and other areas to be revegetated. Ohio EPA typically requires a minimum of 6 inches of topsoil for landfill caps and other consolidation/cover projects. Please revise this specification accordingly, or provide rationale/justification that 3 inches is sufficient to support healthy vegetative growth.

Response: Comment accepted. See revised specification Section 02930, attached (Attachment B). The text in paragraph 3.3 A has been changed to clarify that "the thickness shall be at least 6 inches for the Consolidated Stockpile cover and 3 inches for clean soil fill areas". The minimum thickness in clean soil fill areas is based on previous work at the site, e.g., Wetlands K reclamation, where thick vegetation has become established even in areas of minimal topsoil. We wanted, however, to include at least a minimal thickness of topsoil in these areas. See also drawings 560 and 620 (not attached, since no changes) that show the minimum 6-inch thickness of the topsoil layer on the Consolidation Stockpile and old dump areas.

8) Revegetation (02930), Section 3.10, discusses the plans for an Enhanced Habitat Woodland, including tree planting density (600 per acre), with the timing and methods still to be determined. Please ensure that the final specifications include the appropriate protection of saplings from natural (e.g. wind) and other (e.g. deer scraping) forms of damage, to the maximum extent possible.

Response: Comment accepted. See revised specification Section 02930, attached (Attachment B). Paragraphs 3.10 A and 3.10 C have been modified to include reference to a Vegetation Restoration Plan, which will be developed at a future time, prior to replanting trees. This Plan will include protection of saplings and other necessary requirements.

We look forward to the resolution of your comments. If you wish to discuss these responses, please contact Barbara Nielsen at 480-313-2895.

Very truly yours,

WSP

Vanessa M. Nancarrow, PE
Lead Consultant, Civil/Water Engineer

R. Stephen Anderson
Mid-Atlantic District Leader, E & E, Vice President

VMN/RSA/mtd

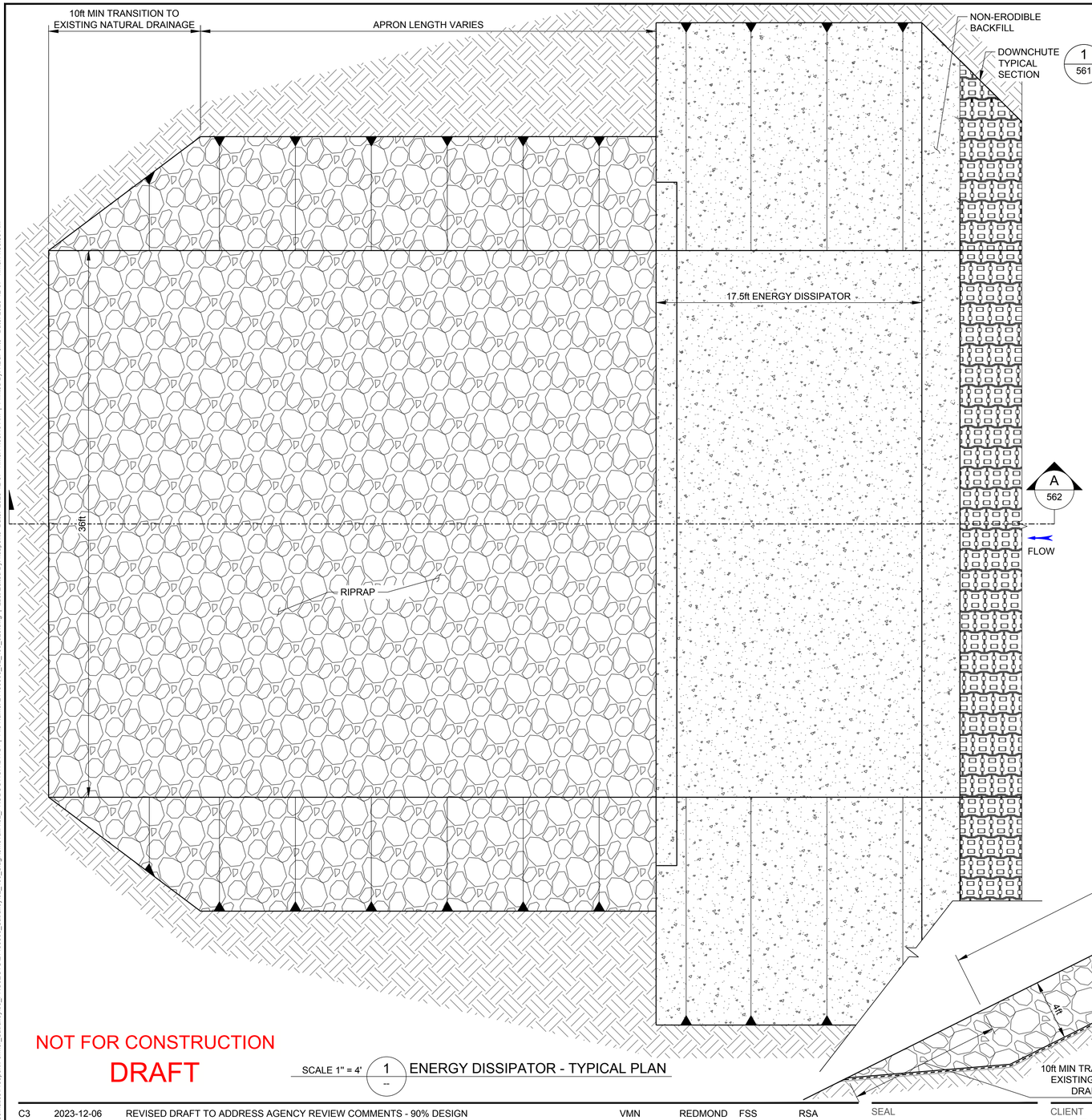
CC: Barbara Nielsen, Cyprus Amax Minerals Company

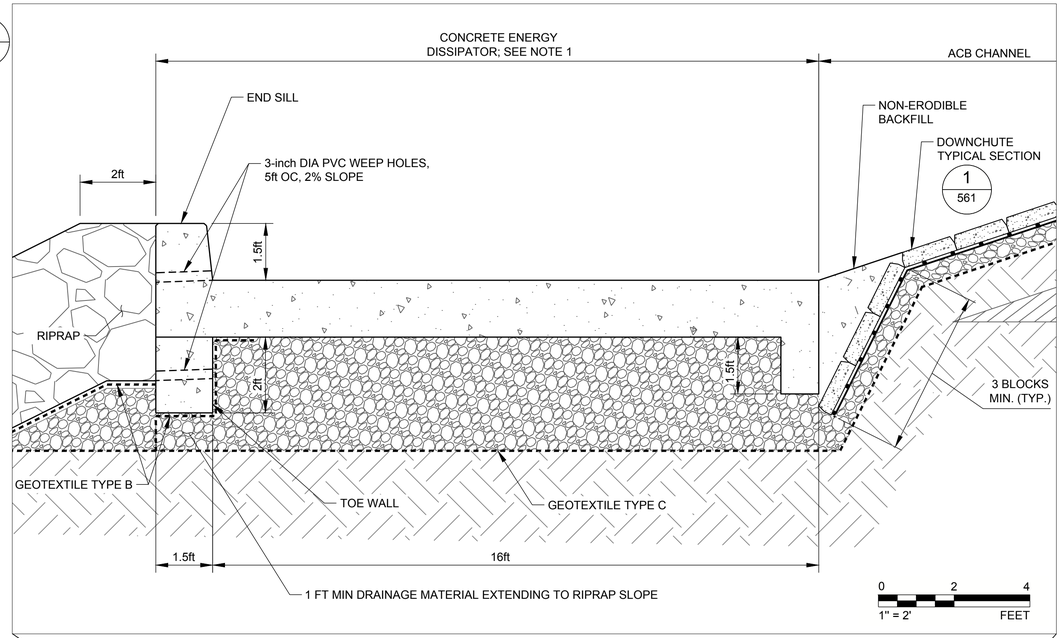
Attachments: Attachment A – Revised 90% Design Drawings
Attachment B – Revised 90% Design Specifications
Attachment C – Concrete Energy Dissipator Structural Memo and Supporting Design Calculations

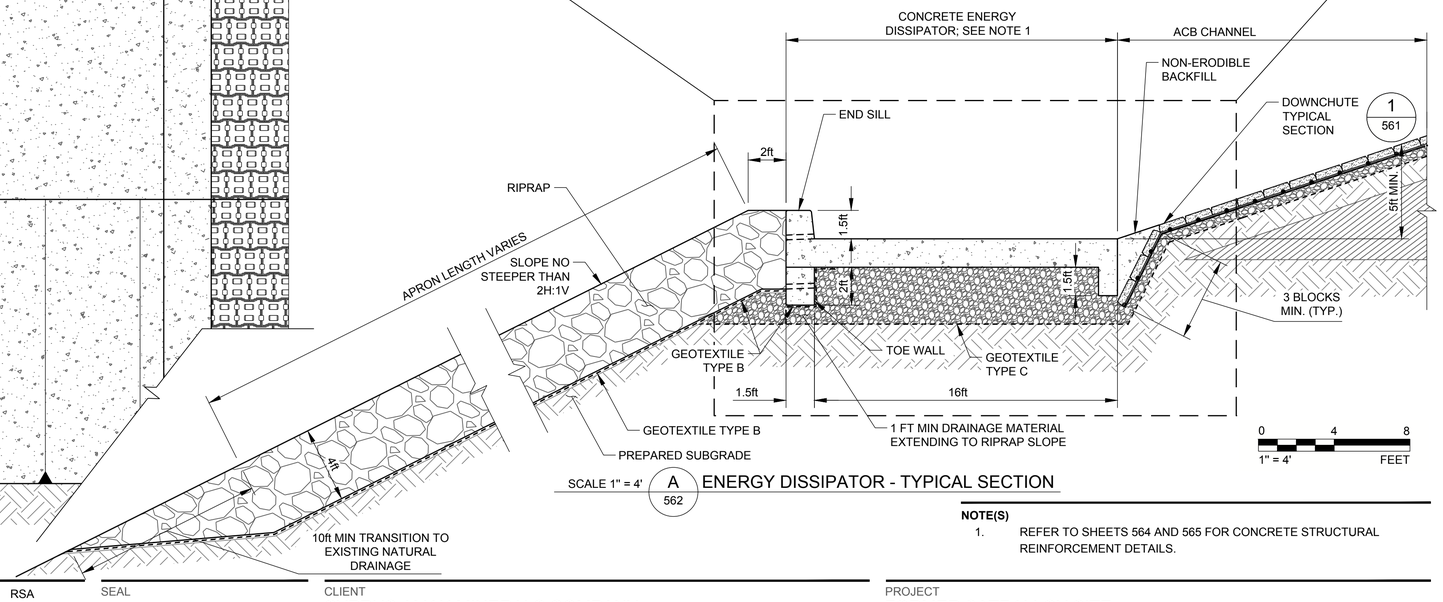
https://golderassociates.sharepoint.com/sites/151150/project files/5 technical work/slag removal ia design/ia work plan - amendment 10/2023-12-13_response to oepa comments/satralloy_iawp_amendment10_commentresponses_2023-12-13.docx

ATTACHMENT A

Revised 90% Design Drawings







SCALE 1" = 4' 1 -- ENERGY DISSIPATOR - TYPICAL PLAN

SCALE 1" = 4' A 562 ENERGY DISSIPATOR - TYPICAL SECTION

NOTE(S)

1. REFER TO SHEETS 564 AND 565 FOR CONCRETE STRUCTURAL REINFORCEMENT DETAILS.

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REV.	YYYY-MM-DD	DESCRIPTION	DESIGNED	PREPARED	REVIEWED	APPROVED
C3	2023-12-06	REVISED DRAFT TO ADDRESS AGENCY REVIEW COMMENTS - 90% DESIGN	VMN	REDMOND	FSS	RSA
C2	2023-08-28	REVISED DRAFT FOR AGENCY REVIEW - 90% DESIGN	VMN	REDMOND	FSS	RSA
C1	2023-05-12	DRAFT FOR AGENCY REVIEW - 90% DESIGN	VMN	REDMOND	FSS	RSA
C	2023-01-26	DRAFT FOR CLIENT REVIEW - 90% DESIGN	VMN	REDMOND	FSS	RSA
B1	2022-04-20	DRAFT FOR AGENCY REVIEW - 60% DESIGN	VMN	REDMOND	FSS	JW
B	2022-03-25	DRAFT FOR CLIENT REVIEW - 60% DESIGN	VMN	REDMOND	FSS	JW
A	2022-01-21	DRAFT FOR CLIENT REVIEW - 30% DESIGN	VMN	REDMOND	FSS	JW

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PROJECT
FORMER SATRALLOY SITE
SLAG REMOVAL INTERIM ACTION
JEFFERSON COUNTY, OHIO

TITLE
MINE AREA STOCKPILE - DETAILS (3 OF 4)

PROJECT NO.	PHASE	REV.	of	SHEET
1239330907	900	C3		562

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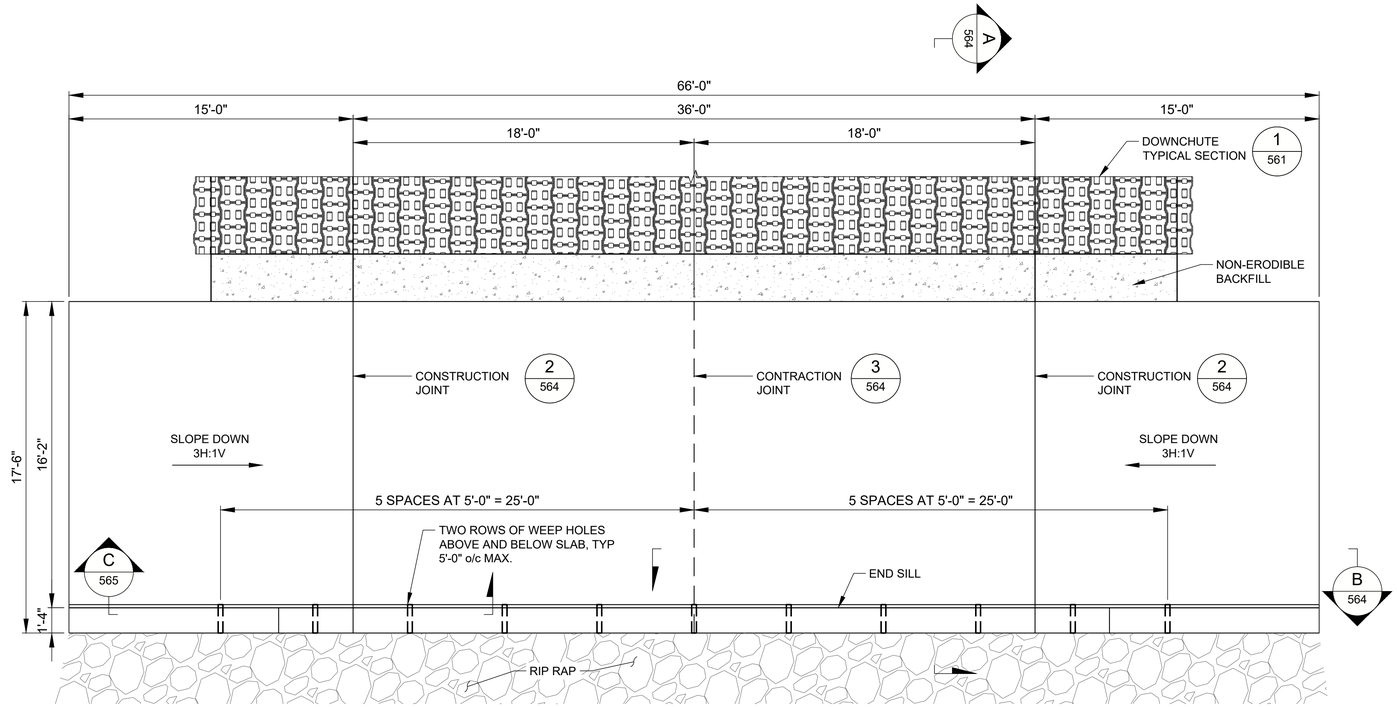
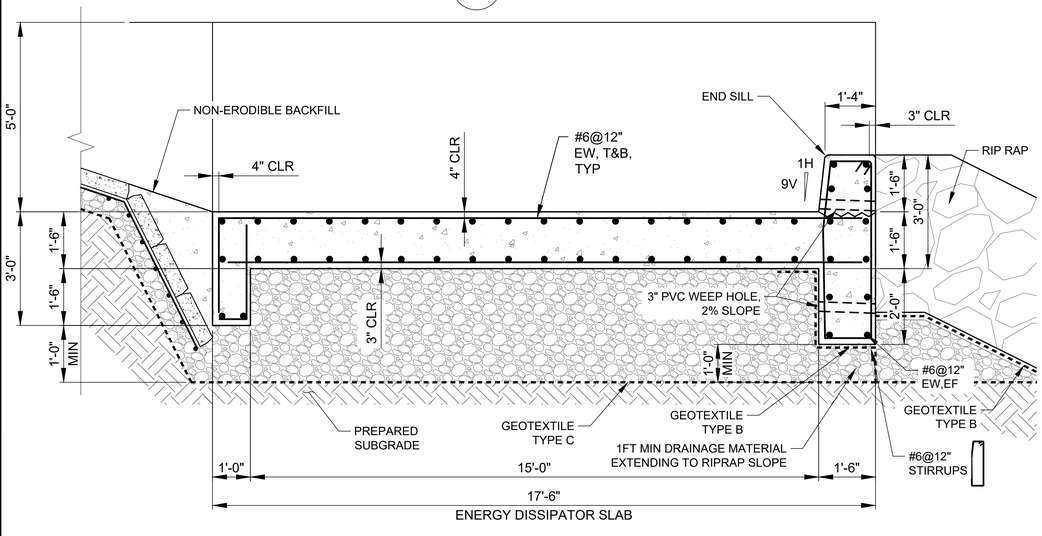
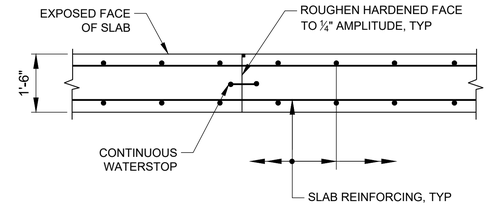


SCALE 1/4" = 1'-0" 1 - ENERGY DISSIPATOR SLAB - PLAN



SCALE 1/2" = 1'-0" A 564 ENERGY DISSIPATOR - TYPICAL SECTION



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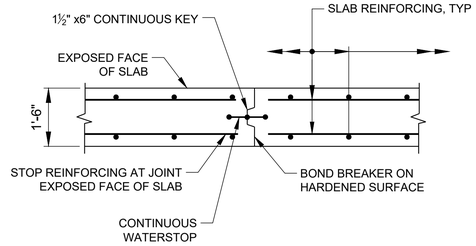

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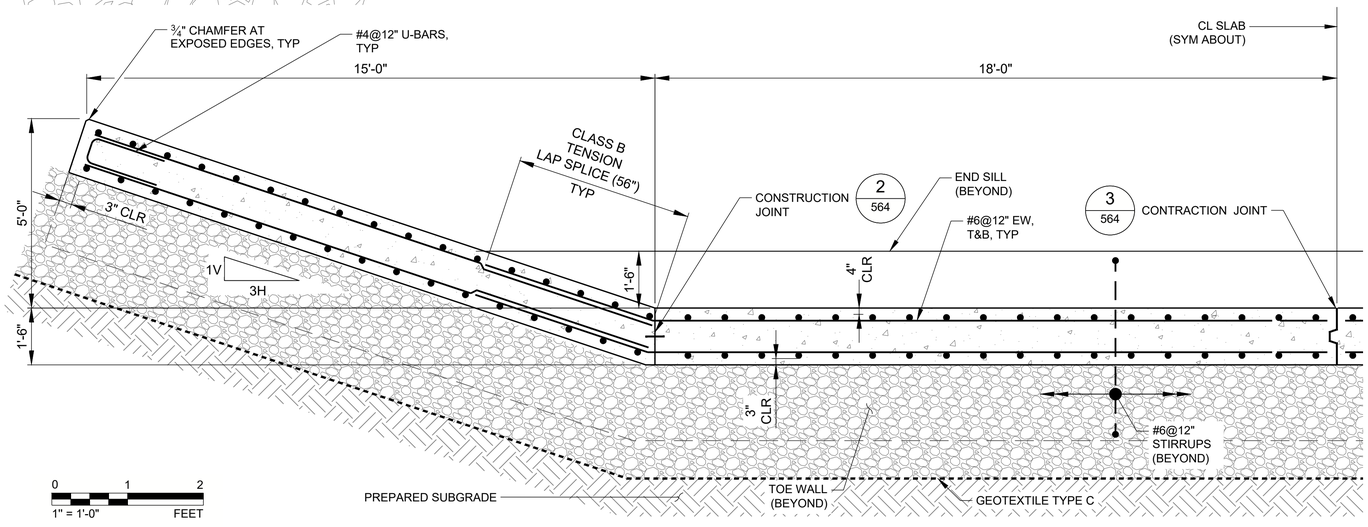

SCALE 1/2" = 1'-0" B 564 ENERGY DISSIPATOR - TYPICAL SECTION

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1" = 1'-0" FEET

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1/2" = 1'-0" FEET

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1/4" = 1'-0" FEET

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REV.	YYYY-MM-DD	DESCRIPTION	DESIGNED	PREPARED	REVIEWED	APPROVED
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B	2022-03-25	DRAFT FOR CLIENT REVIEW - 60% DESIGN	VMN	REDMOND	FSS	JW
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PROJECT
FORMER SATRALLOY SITE
SLAG REMOVAL INTERIM ACTION
JEFFERSON COUNTY, OHIO

TITLE
MINE AREA STOCKPILE - STRUCTURAL DETAILS (1 OF 2)

PROJECT NO.	PHASE	REV.	of	SHEET
1239330907	900	C3		564

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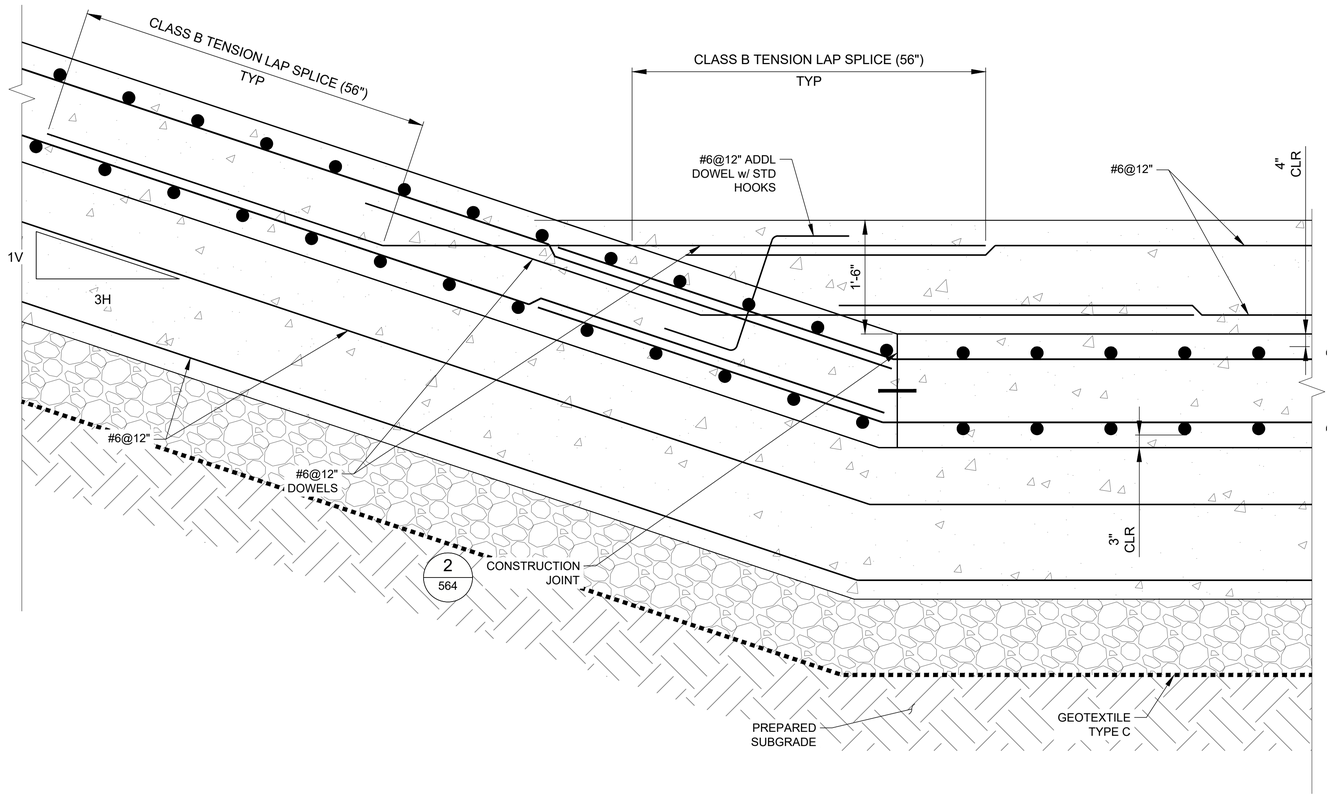

SCALE 1" = 1'-0" C 564 SILL WALL DOWEL PLACEMENT

CONCRETE AND REINFORCEMENT NOTES

1. ENERGY DISSIPATOR SLABS SHALL BEAR ON DRAINAGE MATERIAL. IF FIELD CONDITIONS REQUIRE FORMING THE SLAB ON NATURAL SUBGRADE, A SEAL SLAB MAY BE USED, IF REQUIRED, TO PROTECT THE PREPARED NATURAL SUBGRADE PRIOR TO SLAB PLACEMENT. SEAL SLABS SHALL NOT BE USED ABOVE DRAINAGE MATERIAL.
2. NO CONCRETE SHALL BE PLACED IN WATER OR ON FROZEN GROUND. ALL CAST-IN-PLACE CONCRETE SHALL BE PROTECTED AGAINST FROST UNTIL THE CONCRETE HAS SET IN ACCORDANCE WITH ACI RECOMMENDATIONS AND IN NO CASE LESS THAN 28 DAYS AFTER POURING.
3. CHAMFER ALL EXPOSED CORNERS 3/4" UNLESS OTHERWISE NOTED OR SHOWN.
4. BACKFILL UNDER ANY PORTION OF THE DISSIPATOR SLAB SHALL BE PLACED IN MAXIMUM 6" LOOSE LIFTS AND COMPACTED USING A HEAVY PLATE COMPACTOR, WALK-BEHIND ROLLER, TAMPING RAMMER (JUMPING JACK), OR OTHER METHOD AS APPROVED BY THE CONSTRUCTION MANAGER. COMPACT USING A SUFFICIENT NUMBER OF PASSES THAT NO FURTHER COMPACTION IS OBSERVED ON SUBSEQUENT PASSES.
5. ALL CONCRETE WORK SHALL CONFORM TO "BUILDING CODE REQUIREMENTS FOR REINFORCED CONCRETE" (ACI 318-14) AND "SPECIFICATIONS FOR STRUCTURAL CONCRETE FOR BUILDINGS" (ACI 301-LATEST EDITION), INCLUDING HOT AND COLD WEATHER CONCRETING.
6. CONCRETE SHALL HAVE A MINIMUM COMPRESSIVE STRENGTH OF 5,000 P.S.I. AT 28 DAYS.
7. CONCRETE SHALL HAVE A SLUMP OF NO MORE THAN 5" AND AIR ENTRAINMENT OF 4-6%. THE USE OF CALCIUM CHLORIDE IS NOT PERMITTED. MAINTAIN PROPER CURING PROCEDURES IN ACCORDANCE WITH ALL ACI REQUIREMENTS.
8. CONCRETE SHALL REACH 75% OF SPECIFIED STRENGTH BEFORE CONSTRUCTION LOADS ARE APPLIED, UNLESS SPECIFICALLY APPROVED BY THE STRUCTURAL ENGINEER-OF-RECORD. CONCRETE STRENGTH SHALL BE VERIFIED WITH 7-DAY CYLINDER BREAKS.
9. STEEL REINFORCEMENT SHALL BE EPOXY COATED AND SHALL CONFORM TO ASTM A775 OR A934, GRADE 60.
10. ALL REINFORCING BARS SHALL BE COLD BENT IN ACCORDANCE WITH THE PROPER RADII ESTABLISHED BY THE ACI. UNDER NO CIRCUMSTANCES SHALL HEAT BE APPLIED TO THE BARS TO OBTAIN BENDS.
11. WHERE CONTINUOUS BARS ARE CALLED FOR, THEY SHALL BE RUN CONTINUOUSLY AROUND CORNERS AND LAPPED AT NECESSARY SPLICES OR HOOKED AT DISCONTINUOUS ENDS. LAPS SHALL BE 74 BAR DIAMETERS, UNLESS OTHERWISE SHOWN. ALL BARS SHALL BE PROPERLY DEVELOPED ACCORDING TO ACI 318.
12. ALL REINFORCING BAR COVER SHALL BE ASSUMED TO BE 3" UNLESS OTHERWISE NOTED OR SHOWN.
13. WATERSTOP SHALL BE GREENSTREAK PVC, #696.

SILL WALL DOWEL NOTES:
1. INSTALL DOWELS AT BOTH ENDS OF SILL WALL
2. SEE OTHER SECTIONS AND DETAILS ON THIS SHEET AND RELATED SHEETS FOR INFORMATION NOT CALLED OUT

NOT FOR CONSTRUCTION

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1" = 1'-0" FEET

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TITLE
MINE AREA STOCKPILE - STRUCTURAL DETAILS (2 OF 2)

PROJECT NO.	PHASE	REV.	of	SHEET
1239330907	900	C3		565

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ATTACHMENT B

Revised 90% Design Specifications

SECTION 02200
EARTHWORKS

PART 1 - GENERAL

1.1 SUMMARY

A. This section describes requirements for excavating slag and clean soil, stockpiling materials, placing slag in the consolidated stockpile, and placing clean soil fill in slag removal areas and the consolidated slag stockpile cover.

B. This section also establishes requirements for constructing the closure cover over the consolidated stockpile and restoring borrow areas.

C. Clean soil from the borrow areas in the former Mine Area shall be amended with limestone to minimize the potential for acid generation. This section describes materials and requirements for this process.

D. Requirements for maintaining and upgrading on-site access roads are specified in Section 02505.

E. Requirements for earth materials associated with surface water drainage are specified in Section 02720.

F. Requirements for topsoil to be used for revegetation of disturbed areas are specified in Section 02930.

1.2 PERMITS

CONTRACTOR shall obtain and pay for any and all necessary permits for excavation, grading, or other activities included in this section, unless the permit has already been obtained by the OWNER.

1.3 SUBMITTALS

A. Copies of all permits required for activities described in this section.

B. Earthworks Plan. Submit with Bid a detailed description of the equipment, material sources, and construction sequence for all earthwork activities involved in the Work. The Earthworks Plan shall include at a minimum the following information:

1. Limits of ground disturbance for all activities.

2. Sequence and location of slag removal. Note that the preferred sequence of removal is the North Lowlands, South Lowlands, and Uplands areas in that order. However, the CONTRACTOR may propose for approval an alternative sequence that better satisfies the cost and schedule objectives of this project.

3. Sequence and location of clearing and slag placement in the former Mine Area.

4. Development of clean soil borrow areas, including locations and assumed volumes. Discuss excavating borrow and fill areas so that they drain adequately to minimize working in wet conditions.

5. Sequence of placing clean soil fill in former slag areas.

6. How the proposed Earthworks Plan satisfies the requirements of the Stormwater Pollution Protection Plan (SW3P) for this Site.

7. Discussions shall include the construction sequence and design for temporary and permanent stockpiles of materials addressed in this section.

The Earthworks Plan shall include plan view drawings showing the proposed areas for the various activities described above. AutoCAD drawing files will be made available to the BIDDERS for this purpose.

The Earthworks Plan shall be updated after award of contract and before any ground-disturbing activities begin to provide additional information as requested by the CONSTRUCTION MANAGER and to include a detailed critical path schedule of earthwork activities over the duration of the project.

PART 2 - PRODUCTS

2.1 BORROW SOURCES

A. Clean soil fill shall be obtained only from the areas shown on the Drawings or approved in advance of the Work by the CONSTRUCTION MANAGER in writing.

B. Use only existing roads to access borrow areas unless indicated otherwise on the Drawings. Improve and upgrade such roads as necessary subject to prior approval by the CONSTRUCTION MANAGER.

C. Prior to any ground-disturbing activities in borrow areas, install silt fence, straw bales, and other erosion control measures indicated on the Drawings, described in Section 02375, or required by the Construction Stormwater Pollution Prevention Plan (SWP3).

D. Develop the clean soil borrow area(s) only to the minimum extent needed. Develop the borrow areas in the sequence indicated in the approved Earthworks Plan.

E. The CONTRACTOR shall ensure that there is sufficient drainage in the excavation and fill areas so that rain water does not drain into or pond in the area.

F. If unexpected subsurface conditions are encountered during soil excavation, notify the CONSTRUCTION MANAGER immediately and discontinue the work until approved to resume or modify the borrow source location.

2.2 MATERIALS

A. Clean Soil Fill

1. Clean soil fill materials shall be clean and free from debris, roots, wood, scrap material, vegetation, refuse, soft unsound particles, ice, frozen soil, and any other deleterious or objectionable materials.

2. Clean soil fill shall not contain any slag.

3. Clean soil fill shall be well-graded and shall not contain any rock fragments greater than 6-inches in largest dimension that cannot be readily broken down by tracked excavators or bulldozer, or as approved in advance by the CONSTRUCTION MANAGER.

B. Limestone Amendment

1. Limestone shall consist of calcium carbonate ($CaCO_3$). Dolomite ($CaMg(CO_3)_2$) or other rock types will not be acceptable.

2. Limestone shall be free of heavy metals and other contaminants in excess of project cleanup standards. Submit 50-lb sample of proposed material for testing by the CQA MANAGER at least one month prior to anticipated use.

3. Limestone amendment shall be angular to sub-angular crushed stone having 100% finer than 1.5 inches and no more than 5% by dry weight passing the US #4 sieve.

4. Limestone amendment shall conform to the physical requirements of the Ohio Department of Transportation 2019 *Construction and Material Specifications* section 703.04 B. unless specified or approved otherwise.

C. Materials for erosion and sediment control shall be as shown on the Drawings, as specified in Section 02375, and as described in the SWP3.

D. Materials for restoration of borrow areas shall conform to the requirements of Section 02930.

PART 3 - EXECUTION

3.1 GENERAL OPERATIONS

A. Furnish all labor, materials, equipment, and related items required to excavate, haul, and place slag, clean soil fill, and other earth materials.

B. During all excavation, hauling, and placement activities, CONTRACTOR shall implement appropriate dust control measures as described in other sections of these Specifications. Note that the OWNER has a zero-dust goal for all earthwork activities.

C. Confine temporary stockpiles to disturbed areas or to other locations shown on the Drawings, unless approved in advance of the work by the CONSTRUCTION MANAGER.

D. Manage clean soil fill and topsoil stockpiles to prevent release of sediment. As necessary, install silt fence, straw bales, and other erosion control measures indicated on the Drawings or required by the Stormwater Pollution Prevention Plan (SWP3) for this project.

E. Protect all silt fences, security fences, guard rails, signage, and other existing environmental controls and security features during fill excavation, hauling, placement, and other associated activities. Immediately repair any damage to the satisfaction of the CONSTRUCTION MANAGER. Such repairs shall be at the CONTRACTOR'S expense with no additional cost to the OWNER.

F. The CONSTRUCTION MANAGER may modify the placement requirements in this section at any time to address actual field conditions. Such changes will be documented in writing in daily field reports or other appropriate project records.

3.2 SLAG EXCAVATION

A. Excavate slag until all visible slag has been removed, or as directed by the CONSTRUCTION MANAGER.

B. Notify the CONSTRUCTION MANAGER when slag removal has been completed in the subject area.

C. Remove impacted native subgrade soil as directed by the CONSTRUCTION MANAGER base on field screening and \ or analytical data. Impacted soil shall be placed in the consolidated stockpile in the same way as slag.

D. Debris

1. Slag to be excavated is known to contain decommissioned monitoring wells, steel cables, timbers, concrete fragments, and other types of debris. The CONTRACTOR'S equipment and methods shall be capable of handling such debris.

2. Unless directed or approved otherwise by the CONSTRUCTION MANAGER, place all debris in a single lift in the consolidated stockpile, laterally spaced to allow the next lift of slag to fully surround the debris without forming voids.

3.3 SLAG PLACEMENT

A. Place slag in maximum 18-inch-thick loose lifts.

B. Compact each lift of slag with a minimum of four passes of a smooth drum vibrating roller with a nominal static weight of 25,000 lb or greater, such as a CAT CS54, IR SD-105, or similar approved equivalent to achieve a firm and unyielding surface.

C. Do not add moisture to slag except the minimum as necessary for dust control.

3.4 CLEAN SOIL FILL AMENDMENT

A. Clean soil shall be amended before the associated lift is compacted.

B. All clean soil fill shall be amended with a minimum of 5% limestone by dry weight. No more than 15% limestone by dry weight shall be used.

C. Amending methods shall ensure that the limestone is uniformly mixed throughout the lift, both vertically and laterally, to achieve a uniform, homogeneous material free of any pockets of limestone or zones without limestone.

D Potentially acceptable mixing methods include pug mill blending, scarifying limestone placed on the lift surface into the lift, or other types of methods. The CONTRACTOR shall demonstrate satisfactory mixing methods prior to use. The CONSTRUCTION MANAGER may require changes to mixing methods at any time when CQA observations indicate that mixing requirements are not being achieved.

3.5 CLEAN SOIL FILL PLACEMENT

A. Place clean soil fill in maximum 12-inch-thick loose lifts.

B. Compact the surface of each lift to a firm and unyielding condition, as determined by the CONSTRUCTION MANAGER. In large areas, use a smooth drum vibrating roller a nominal static weight of 15,000 lb or greater, such as a CAT CS44, IR SD-70, or approved equal. Compact with a minimum of four passes of compaction equipment. In confined areas where a roller is not practical, use a plate compactor, jumping jack, hoe-pack, or similar piece of equipment. ~~Compact with a minimum of four passes of compaction equipment.~~ Compaction activities shall not damage underlying culverts or adjacent structures.

C. Moisture condition clean soil fill as necessary to achieve compaction ~~requirements~~described in the previous paragraph. This may include drying or wetting and mixing of fill soil.

D. Final compacted fill surface shall tie in smoothly to the surrounding grades and shall be free of mounds or depressions.

F. Fill in wetlands areas shall be elevated in the center of the fill area by approximately 6 to 12 inches and graded to provide positive drainage at all locations.

G. Where fill is to be placed over the inlet to underground stormwater piping, first install a tight-fitting precast concrete cap over the inlet to prevent soil from entering the pipe. The cap shall conform to the requirements for precast concrete described in Section 02720.

3.6 BORROW AREA RESTORATION

A. After borrow material removal has been completed, regrade the borrow area as indicated on the Drawings and to provide positive drainage at all locations. Leave no abrupt ledges that may pose a physical safety hazard for workers or equipment that would frequent the area.

B. Seed, mulch, and fertilize, or install erosion control mat, in disturbed borrow areas, not including access roads, in accordance with the requirements of Section 02930 of these Specifications.

3.7 TOPSOIL PLACEMENT

Place topsoil in accordance with the requirements of Section 02930.

PART 4 – MEASUREMENT AND PAYMENT

Measurement and payment for earth materials is described in Section 01020.

END OF SECTION

SECTION 02930
REVEGETATION

PART 1 - GENERAL

1.1 SUMMARY

A. This section describes the materials, procedures, and requirements for revegetation of disturbed areas, including but not limited to the consolidated slag stockpile cover, clean soil fill areas, and borrow areas.

B. This section also includes requirements for revegetation of constructed wetlands.

C. This section describes general requirements for reforestation of selected disturbed areas, as shown on the Drawings. Complete requirements for reforestation are described in the *Reforestation Plan* for this project. If the requirements of the *Reforestation Plan* conflict with the requirements of this section, the *Reforestation Plan* shall prevail.

1.2 REFERENCES

A. Ohio Department of Natural Resources 2006 *Rainwater and Land Development Manual* (*RDLM*).

B. Ohio Department of Transportation (ODOT) 2019 *Construction and Material Specifications.*

1.3 SUBMITTALS

A. Qualifications of topsoil testing laboratory.

B. Proposed topsoil source and test data.

C. Certifications that seed mix and mulch are free of noxious weeds.

D. Tags or labels from seed and fertilizer bags.

E. Manufacturer's data such as descriptive literature, specification sheets, QA test results, certifications, and the like to demonstrate that manufactured materials conform to the requirements of this section and the construction Drawings.

F. Supplier, species name, and other pertinent information for enhanced habitat woodland trees and associated materials and products.

PART 2 - PRODUCTS

2.1 EROSION CONTROL MAT

Erosion control mat shall conform to the requirements of ODOT 2019 *Construction and Material Specifications*, item 712.11, Type B or C.

2.2 TOPSOIL

A. Topsoil shall be free of contaminants of concern above allowable limits and shall be free of trash, debris, concrete, ice, rocks greater than 6 inches in maximum dimension, branches, wood fragments greater than 3 inches in maximum dimension, and other deleterious materials. Acceptability of topsoil shall be determined by the CONSTRUCTION MANAGER.

B. Topsoil may be obtained from stockpiled topsoil material previously removed as part of other activities, provided that it meets the requirements of this section.

C. Natural topsoils shall have a minimum organic materials content of 5% by dry weight as determined by ASTM D2974.

D. Alternatively, topsoil may be produced by mixing organic material such as chipped vegetation, manure, or other approved material into inorganic base soil that meets the requirements of this section. Manufactured topsoil shall have a minimum organic materials content of 10% but not more than 15% by dry weight as determined by ASTM D2974.

E. CONTRACTOR shall retain a qualified commercial laboratory to perform testing of topsoil for organic material content of manufactured topsoil.

2.3 SEED

A. Seed shall be free of noxious weeds and shall conform to the pertinent requirements of Sections 659.07 and 659.09 of the ODOT *2019 Specifications*. In addition, seed shall be free of the following invasive species:

Spotted knapweed (*Centaurea stoebe*)

Canada thistle (*Cirsium arvens*e)

Common dandelion (*Taraxacum officinale*)

White sweetclover (*Melilotus albus*)

Johnson grass (*Sorghum halepe*nse)

B. Grass seed mix for various areas shall be per Table 659.09-1 in the ODOT 2019 *Construction and Material Specifications*:

1. Consolidated stockpile cover: Class 4A, Native Grass Mixture

2. Clean soil fill areas (former slag areas except constructed wetlands): Class 5B, Native Wildflower and Grass Mixture

3. Borrow areas and other disturbed areas: Class 6, Wildlife Mixture

C. Monarch butterfly habitat areas shall include one or more of the following milkweed species in addition to the base seed mix specified in the previous article:

Butterfly-weed (*Asclepias tuberosa*)

Common milkweed (*Asclepias syriaca*)

Purple milkweed (*Asclepias purpurascens*)

Sullivant's milkweed (*Asclepias sullivantii*)

Swamp milkweed (*Asclepias incarnata*)

D. Grass seed mix for constructed wetlands areas:

1. Wetlands seed mix shall be used in areas specifically designated as wetlands on the Drawings or as directed by the CONSTRUCTION MANAGER.

2. Wetlands seed mix shall have the following composition, or approved equal:

Slough Sedge (Carex obnupta)	35%
Small Fruited Bulrush (Scirpus microcarpus)	25%
Saw Beaked Sedge (Carex stipata)	20%
Slender Rush (Juncus tenius)	10%
Creeping Spike Rush (Eleocharis palustris)	10%

2.4 FERTILIZER

A. Fertilizer shall be low-phosphorous formulation, with percentages of other compounds as recommended by the seed supplier.

B. Fertilizer shall not be used with the wetlands seed mix.

2.5 MULCH

A. Straw mulch free of any seed that could germinate, or

B. Clean wood fiber mulch, manufactured expressly for the purpose. Wood for fiber mulch shall not contain lead paint, varnish, printing ink, and petroleum-based compounds. Do not use wood fiber mulch manufactured from recycled materials of unknown origin such as sawdust, paper, cardboard, or residue from chlorine-bleached pulp and paper mills.

2.6 TACKIFIER

A. For hydroseeding, provide a commercial quality tackifier containing no agent toxic to plant or aquatic life. Furnish tackifier of either a liquid stabilizing emulsion or a dry powder tackifier meeting the requirements of this section.

B. Liquid Stabilizer Emulsion - Tackifier with a base material of liquid polyvinyl acetate polymers, using emulsion resins and containing not less than 55% total solids by weight. Liquid tackifiers shall not contain polyacrylates or polyvinyl acrylics. The emulsion shall, when diluted with water and upon drying, allow exchange of air and moisture to the seeds and shall have an effective life of at least one year.

C. Dry Powder Tackifier - Tackifier base consisting of one or more active hydrocolloids from natural plant sources, which hydrates in water and blends with other hydroseed slurry materials, and upon application and drying tacks the slurry particles to the soil surface and exhibits no growth or germination inhibiting factors. Dry powder tackifiers shall consist of a processed organic adhesive derivative of one of the following:

- Gumbinder derived from guar (Cyamopsis tetragonoloba)
- Gumbinder derived from plantain (Plantago insularis)

2.7 HYDROSEEDING EQUIPMENT

A. Hydroseeder shall utilize water as the carrying agent and shall maintain continuous agitation of seed mix.

B. Hydroseeder shall have sufficient operating capacity to agitate, suspend, and mix specified products into a homogenous slurry.

C. Distribution and discharge lines shall be large enough to prevent clogging.

D. Spray nozzles shall provide a uniform distribution of slurry.

2.8 OTHER SEEDING EQUIPMENT

Other types of seeding equipment, such as seed drills and broadcast (cyclone) seeders, shall be capable of uniformly applying dry seed at the specified rate.

2.9 SLOPE AND OTHER ARMOR ROCK

Conform to the requirements for armor rock in Section 02720.

2.10 ENHANCED HABITAT WOODLAND

A. Trees for enhanced habitat woodland shall consist of a mixture of the following species:

Common Name	Scientific Name
American elm	*Ulmus americana*
American sycamore	*Platanus occidentalis*
Black locust	*Robinia pseudoacacia*
Eastern cottonwood	*Populus deltoides*
Eastern hemlock	*Tsuga canadensis*
Green ash	*Fraxinus pennsylvanica*
Ohio buckeye	*Aesculus glabra*
Shagbark hickory	*Carya ovata*
Silver maple	*Acer saccharinum*
Sugar maple	*Acer saccharum*
White oak	*Quercus alba*

B. Provide a mixture of species suitable for the exposure and other local conditions in the particular woodland area, as recommended by the supplier or qualified arborist.

C. [Other required materials and products TBD].

2.11 UNDERSTORY VEGETATION

Provide the following understory shrubs in reforestation areas:

Common elderberry (Sambucus nigra)

Black raspberry (R*ubus occidentalis*)

Multiflora rose (*Rosa multiflora*)

2.12 WETLANDS PERIMETER VEGETATION

Provide the following species around the perimeter of constructed or expanded wetlands:

American elm (*Ulmus americana*)

American sycamore (*Platanus occidentalis*)

Narrowleaf willow (*Salix interior*)

Narrowleaf cattail (*Typha angustifolia*)

PART 3 - EXECUTION

3.1 CLEANUP VERIFICATION

Do not begin regrading or clean soil fill placement in slag removal areas until directed by the CONSTRUCTION MANAGER, based on field screening and\or analytical results.

3.2 GRADES

Prior to beginning revegetation work in a given area, regrade and place clean soil fill to the lines and grades shown on the Drawings, as required by the Stormwater Pollution Prevention Plan for this project, or as directed by the CONSTRUCTION MANAGER in the field based on actual conditions. The CONSTRUCTION MANAGER shall inspect and approve all regraded areas before the CONTRACTOR proceeds with subsequent revegetation activities.

3.3 TOPSOIL

A. Where topsoil is required, the thickness shall be at least ~~3~~ 6 inches for the Consolidated Stockpile cover and 3 inches for clean soil fill areas, unless indicated otherwise on the Drawings or approved \ directed otherwise by the CONSTRUCTION MANAGER.

B. If organic material is mixed into existing in-place soil subgrade to form the topsoil layer, the depth of mixing shall be at least 6 inches.

C. Place topsoil in a single lift using a dozer with cleated tracks that will produce an indented surface to retain soil. Run dozer up and down (not across) slopes. Minimize the number of passes and resulting compaction of the topsoil layer.

3.4 APPLICATION RATES

Apply seed and associated materials at the following minimum rates:

- Seed Mix (non-wetland areas): per Table 659.09-1 of ODOT 2019 *Construction and Material Specifications*
- Seed Mix (milkweed areas): 0.2 lbs/acre milkweed, in addition to base seed mix
- Seed Mix (wetland areas): 10 lbs/acre pure live seed.
- Fertilizer (non-wetland areas): 400 lbs/acre
- Straw Mulch: 4,000 lbs/acre (dry fiber basis)
- Wood Fiber Mulch: 2,000 lbs/acre (dry fiber basis)
- Tackifier for Hydroseeding 30 gal/acre (liquid diluted 30:1)
  60 lbs/acre (dry powder)

3.5 SEEDING METHODS

A. Seed shall be placed using hydroseeding methods, unless access limitations or other conditions prevent their use. Use of seeding methods other than hydroseeding shall be approved in advance by the CONSTRUCTION MANAGER.

B. When hydroseeding is used, comply with the following:

1. No more than 30 minutes shall elapse between placing the mix components in the hydroseeder tank and beginning the hydroseed application.

2. Apply mixture with uniform, continuous, and complete coverage.

3. Prevent drift and displacement of hydroseed mixture. Use protective covering on structures and objects where coverage and stains would be objectionable. Protect vehicles and personnel from drifting spray.

C. After seed has been placed by methods other than hydroseeding, cultipackers may be used in lieu of raking or mulching, if approved by the CONSTRUCTION MANAGER.

D. For items not specifically defined in this section, use methods and application rates in accordance with seed supplier's recommendations. For activities where the supplier does not make recommendations, execute the work in accordance with the applicable provisions of Section 659 of the ODOT *2019 Specifications* or Chapter 7 of the *RDLM*.

3.6 TIME OF SEEDING

A. Perform seeding during the time periods recommended in the *RDLM* to the extent practicable, to allow natural precipitation to support germination and growth until a self-sustaining stand of vegetation has become established.

B. Notwithstanding the previous requirement, perform seeding within two weeks of completion of grading in the subject area to reduce the potential for soil erosion.

3.7 COVERAGE STANDARD

A. Acceptable cover is defined as a uniform vegetative perennial cover with a density of at least 70% healthy ground cover at 12 months after seeding. The CONSTRUCTION MANAGER may at his discretion modify this standard to account for site specific factors or weather conditions.

B. Areas that do not meet the coverage standard shall be re-seeded in accordance with this section until adequate coverage is achieved.

3.8 EROSION CONTROL MAT

A. Place erosion control mat in areas indicated on the Drawings and in other areas with slopes that are potentially susceptible to erosion and as directed by the CONSTRUCTION MANAGER.

B. Handle, place, and secure erosion control mats as shown on the Drawings and in accordance with the supplier's recommendations, whichever are more stringent.

3.9 SLOPE ARMOR ROCK

A. Place slope armor rock using methods that prevent disturbance of the underlying subgrade and, if present, geotextiles.

B. Place slope armor rock using methods that produce a compact rock mass with a relatively smooth, even surface.

C. Place slope armor rock to the lines and grades shown on the Drawings and taper into the adjacent ground surface.

3.10 ENHANCED HABITAT WOODLAND

A. Plant trees in accordance with the ~~following~~ procedures described in the Vegetation Restoration Plan~~:~~. [To Be Developed at a future date].

B. Plant at a density of 600 trees per acre.

C. Plant following completion of reseeding in subject area and only during ~~[TBD]~~ the allowable time periods described in the Vegetation Restoration Plan.

3.11 PROTECTION

CONTRACTOR shall not drive equipment on or allow other damage to areas where revegetation has been completed.

PART 4 – MEASUREMENT AND PAYMENT

Measurement and payment for revegetation is described in Section 01020.

END OF SECTION

ATTACHMENT C

Concrete Energy Dissipator Structural Design Memo and Supporting Design Calculations

Our ref.: GL1239330907

May 10, 2023

Vanessa Nancarrow
Lead Consultant, Civil/Water Engineer WSP
18300 NE Union Hill Road, Suite 200
Redmond, WA 98052

Subject: Satralloy Project – Design of reinforced concrete energy dissipator

Dear Vanessa,

WSP USA is pleased to provide you with this memo regarding the structural design of the reinforced concrete for the energy dissipator at the Satralloy site in Ohio. WSP understands that a reinforced concrete energy dissipator was requested by the client. Your team provided the shape and footprint of the concrete dissipator and the impulse load and sliding check for the energy dissipator. This letter report contains a summary of the structural design of the reinforced concrete structure.

Concrete energy dissipator design consideration

This design was limited to the energy dissipator bottom concrete slab and end sill design. To evaluate the dissipator bottom slab and end sill, reinforced concrete design spreadsheets were prepared in accordance with ACI 318. Based on the dimension provided by your team, the energy dissipator was 17.5 ft long and 66 ft overall width. The width includes a 36 ft wide bottom slab with a 15 ft wide wing slab sloped at 3H:1V. The end sill was 36 ft long and 1.5 ft tall.

The bottom slab of the dissipator was designed as a simply supported beam. The end sill wall was designed as a cantilever beam. The self-weight of concrete and the weight of the water for a 1.5 ft depth was considered for the slab design. The impulse load of 0.3 kip/ft was used for the design of the end sill. The impulse load was used from the energy dissipator force calculations sheet prepared by your team on 04/06/2023.

The concrete compressive strength was taken as 5,000 psi and the rebar of yield strength of 60,000 psi was chosen, which is the industry standard. An effective concrete cover of 4 inches was provided on the top exposed concrete surface after considering the potential for concrete erosion from flowing water and to prevent corrosion of the reinforcement from exposure due to erosion.

Result:

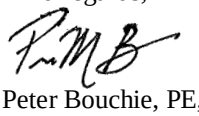
Considering all the criteria from ACI 318, the concrete slab of 18 in depth is required with No. 6 (3/4 inch) reinforcement bars spaced at 12 inches on center at the top and bottom of the energy dissipator slab. The wing slabs thickness and reinforcement match the bottom slab of the energy dissipator. The end sill also requires an 18 inch thickness with No. 6 reinforcement bars spaced at 12 inches on center. The dowel reinforcement bars and construction/contraction joints are provided per ACI 318 and USACE recommendations, and details are shown in the structural drawings. The calculation is attached in the appendix.

Conclusion

The slab and end sill thickness and reinforcing bars were designed to sustain the provided load at the energy dissipator. The design was done to meet all the requirements of ACI 318 for the slab and beam design.

Should you have any questions, please feel free to contact me at (617) 960-4810.

Kind regards,



Peter Bouchie, PE, PMP
Assistant Vice President, Structural Engineer

APPENDIX A

COMPUTATION SHEET

Page:	
Made by:	G. Acharya
Date:	4/11/2023
Checked by:	M. Samaha
Date:	4/13/2023
Calc. No.:	TBD

Subject: Satralloy Dissipator - Uplift Check

Input
Calculated

Geometry

Length of the slab (L)	17.5	ft
Width of slab (W)	36.0	ft
Thickness of the slab (T)	1.5	ft
Area of the slab (A)	630.0	ft^2
Unit wt. of concrete (γ_c)	150.0	pcf
Unit wt. of water (γ_w)	62.4	pcf
Depth of water (h_w)	1.5	ft
Weight of the slab (W_c)	141.8	kips
Velocity of water (V)	17.4	ft/sec
acc. Gravity constant (V)	32.2	ft/s^2

Uplift check on slab

Downward load (Dt)= Slab wt + Water wt	200.7	**kips**
Uplift force (water depth) U= γw*h*A	59.0	**kips**
Dt > U =	**OK**	

COMPUTATION SHEET

Page:	
Made by:	G. Acharya
Date:	4/11/2023
Checked by:	M. Samaha
Date:	4/13/2023
Calc. No.:	TBD

Subject: Satralloy Dissipator - Spillway Slab Rebar

Input
Calculated

Geometry

Length of the slab (L)	17.5	ft
Width of slab (W)	1.0	ft
Thickness of the slab (T)	1.5	ft

Loading:

Unit Weight of concrete =	0.15	kcf
Load from water weight (F) =	0.09	klf
Self weight of concrete	0.23	klf
Slab Load =	0.45	klf

Load comb = 1.4 DL+ 1.4F

$P_u = P$ =	0.0	kips
$V_u = V$ =	3.9	kips
$M_u = M$ =	17.1	k-ft

Smiply supported condition

Minimum Slab reinforcement

Min steel requirement, $A_{s,min}$ =	0.39	in^2	Clause 7.6.1.1
Min steel requirement, Ast = $3*\sqrt{(f'_c)}*b_w*d/F_y$ =	0.62	in^2	Clause 9.6.1.2
Min steel requirement, Ast = $200*b_w*d/fy$	0.59	in^2	Clause 9.6.1.2
Min steel required for flexure, $As_{min.flex}$	0.30	in^2	
Min steel requirement, Ast = (4/3)* $As_{min.flex}$	0.41	in^2	Clause 9.6.1.3
Ast, Min	0.41		
Provided number of bars =	1.0		
Provided bar size =	6	#	
Diameter of the bar, d_b =	0.75	in	
Area of the bar = $\pi\, d_b^2/4$ =	0.44	in^2	
As, provided = $\pi\, d_b^2/4$ =	0.44	in^2	

Reinforcement type	f_y, psi	$A_{s,min}$	
Deformed bars	< 60,000	$0.0020A_g$	
Deformed bars or welded wire reinforcement	≥ 60,000	Greater of	$\frac{0.0018\times 60{,}000}{f_y}A_g$
			$0.0014A_g$

(a) $\frac{3\sqrt{f'_c}}{f_y}b_w d$

(b) $\frac{200}{f_y}b_w d$

spacing (s)= 12 in

Ast, provided > Ast, Min = **OK**

Minimum shear reinforcement

Concrete strength, f'_c =	5000	psi	
Reinforcement rebar yield strength, F_y =	60000	psi	
clear cover, c =	3	in	
effective depth, d	14.63	in	
max bar spacing, $s = d_{ef}/2$ =	7.31	in	
Provided bar =	0	#	
Diameter of the bar, d_b =	0.00	in	
Provided bar spacing, s =	12.0	in	
$A_{v,min}$ =	0.00	in^2	10.6.2.2 (a)
or			
$A_{v,min}$ =	0.00	in^2	10.6.2.2 (b)
Av =	0.00	in^2	

(a) $0.75\sqrt{f'_c}\frac{b_w s}{f_{yt}}$

(b) $50\frac{b_w s}{f_{yt}}$

COMPUTATION SHEET

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Date:	4/11/2023
Checked by:	M. Samaha
Date:	4/13/2023
Calc. No.:	TBD

Subject: Satralloy Dissipator - Spillway Slab Rebar

Input
Calculated

Check for Shear, øVn > Vu

λ =	1.0				
Shear reduction factor, ø =	0.75				
Vc =	24,819	lbs	24.8	kips	$V_c = 2\left(1+\frac{N_u}{2000A_g}\right)\lambda\sqrt{f_c'}b_w d$ (22.5.6.1)
Shear d =	14.6	in			
Vs =	0	lbs	0.0	kips	$V_s = \frac{A_v f_{yt} d}{s}$ (22.5.10.5.3)
Shear bw = D =	12.0	in			
So, Vn = Vc + Vs =	24,819	lbs	24.8	kips	
$øV_n$ =	18,614.59	lbs	18.6	kips	
V_u =	3.90	kips			
$øV_n > V_u$	**OK**				

Check for Bending, øMn > Mu

Bending adjustment factor, ø =	0.90			
clear cover, c =	3	in		
reinforcement, d_b =	0.75	in		
effective depth d=	14.63	in		
width b =	12.00			
a = A_s*F_y/ (0.85*f'_c*b) =	0.52	in		
A_s =	0.44	in^2		
$øM_n = øA_s f_y (d-a/2)$ =	342,701	lb-in	29	k-ft
M_u =	17.1	k-ft		
$øM_n > M_u$	**OK**			

COMPUTATION SHEET

Page:	
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Checked by:	M. Samaha
Date:	4/13/2023
Calc. No.:	TBD

Subject: Satralloy Dissipator - Spillway Slab Rebar

Input
Calculated

Geometry

Length (L)	1.5	ft
Width (W)	1.0	ft
Thickness (T)	1.5	ft

Loading:

Unit Weight of concrete =	0.15	kcf
Load from water weight (H) =	0.30	klf
Slab Load =	0.48	klf

Load comb = 1.6H

$P_u = P$ =	0.0	kips
$V_u = V$ =	0.36	kips
$M_u = M$ =	0.54	k-ft

Cantilever Condition

Minimum Slab reinforcement

Min steel requirement, $A_{s,min}$ =	0.39	in^2	Clause 7.6.1.1
Min steel requirement, Ast = $3*\sqrt{(f'_c)}*b_w*d/F_y$ =	0.58	in^2	Clause 9.6.1.2
Min steel requirement, Ast = $200*b_w*d/fy$	0.55	in^2	Clause 9.6.1.2
Min steel required for flexure, $As_{min.flex}$	0.01		
Min steel requirement, Ast = (4/3)* $As_{min.flex}$	0.01	in^2	Clause 9.6.1.3
Ast, Min	0.39		
Provided number of bars =	1.0		
Provided bar size =	6	#	
Diameter of the bar, d_b =	0.75	in	
Area of the bar = $\pi d_b^2/4$ =	0.44	in^2	
As, provided = $\pi d_b^2/4$ =	0.44	in^2	

Reinforcement type	f_y, psi	$A_{s,min}$		
Deformed bars	< 60,000	$0.0020A_g$		
Deformed bars or welded wire reinforcement	≥ 60,000	Greater of:	$\frac{0.0018 \times 60,000}{f_y} A_g$	$0.0014A_g$

(a) $\frac{3\sqrt{f'_c}}{f_y} b_w d$

(b) $\frac{200}{f_y} b_w d$

spacing (s)= 12 in

Ast, provided > Ast, Min = **OK**

Minimum shear reinforcement

Concrete strength, f'_c =	5000	psi	
Reinforcement rebar yield strength, F_y =	60000	psi	
clear cover, c =	3	in	
effective depth, d	14.63	in	
max bar spacing, $s = d_{ef}/2$ =	7.31	in	
Provided bar =	0	#	
Diameter of the bar, d_b =	0.00	in	
Provided bar spacing, s =	12.0	in	
$A_{v,min}$ =	0.00	in^2	(a) $0.75\sqrt{f'_c}\frac{b_w s}{f_{yt}}$ 10.6.2.2 (a)
or			
$A_{v,min}$ =	0.00	in^2	(b) $50\frac{b_w s}{f_{yt}}$ 10.6.2.2 (b)
Av =	0.00	in^2	

COMPUTATION SHEET

Page:	
Made by:	G. Acharya
Date:	4/11/2023
Checked by:	M. Samaha
Date:	4/13/2023
Calc. No.:	TBD

Subject: Satralloy Dissipator - Spillway Slab Rebar

Input
Calculated

Check for Shear, øVn > Vu

λ =	1.0				
Shear reduction factor, ø =	0.75				
Vc =	24,819	lbs	24.8	kips	$V_c = 2\left(1+\frac{N_u}{2000A_g}\right)\lambda\sqrt{f'_c}b_w d$ (22.5.6.1)
Shear d =	14.6	in			
Vs =	0	lbs	0.0	kips	$V_s = \frac{A_v f_{yt} d}{s}$ (22.5.10.5.3)
Shear bw = D =	12.0	in			
So, Vn = Vc + Vs =	24,819	lbs	24.8	kips	
$øV_n$ =	18,614.59	lbs	18.6	kips	
V_u =	0.36	kips			
$øV_n > V_u$	**OK**				

Check for Bending, øMn > Mu

Bending adjustment factor, ø =	0.90			
clear cover, c =	4	in		
reinforcement, d_b =	0.75	in		
effective depth d=	13.63	in		
width b =	12.00			
a = A_s*F_y/ (0.85*f'_c*b) =	0.52	in		
A_s =	0.44	in^2		
$øM_n = øA_s f_y$ (d-a/2) =	318,845	lb-in	27	k-ft
M_u =	0.5	k-ft		
$øM_n > M_u$	**OK**			

Energy Dissipator Sizing Calculations
FMI / Satralloy / Slag Removal IA Design
Project #: 21480300
Prepared by: VMN 03/17/2023
Reviewed by: SJS 4/11/2023

Objective

Hydraulic calculations were performed to design concrete energy dissipators for the Probable Maximum Flood (PMF) design flow at the ACB downchute terminations.

Downchutes	North	East	South	West
Discharge (cfs)	280	280	280	280
Base Width (ft)	36	36	36	36
Slope (ft/ft)	0.33	0.4	0.33	0.35
Side Slope (xH:1V)	3	3	3	3
Manning's n-value	0.030	0.030	0.030	0.030
d_1, Normal Depth, calc'd using Watertools (ft)	0.46	0.43	0.46	0.45
Area, calc'd using Watertools (ft^2)	17.1	16.1	17.1	16.7
Velocity, V = Q/A (ft/s)	16.4	17.4	16.4	16.7
Velocity Head, V^2/2g (ft)	4.19	4.72	4.19	4.34
Froude No., calc'd using Watertools	4.36	4.76	4.36	4.48
Freeboard, FB = 2 + 0.025*V(d)^(1/3) (ft)	2.32	2.33	2.32	2.32
Total Depth (ft)	2.77	2.76	2.77	2.77

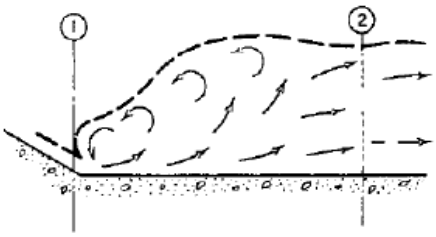
Conjugate Depth

$$\frac{d_2}{d_1} = \frac{\sqrt{1+8F^2}-1}{2}$$

Where: d_2 is the conjugate depth or depth at the downstream end of the hydraulic jump (ft).

d_2, Conjugate Depth (ft)	2.60	2.69	2.60	2.63

Free Hydraulic Jump Energy Dissipator Basin (4.5 < Fr < 20)



Type I – Hydraulic jump, horizontal apron

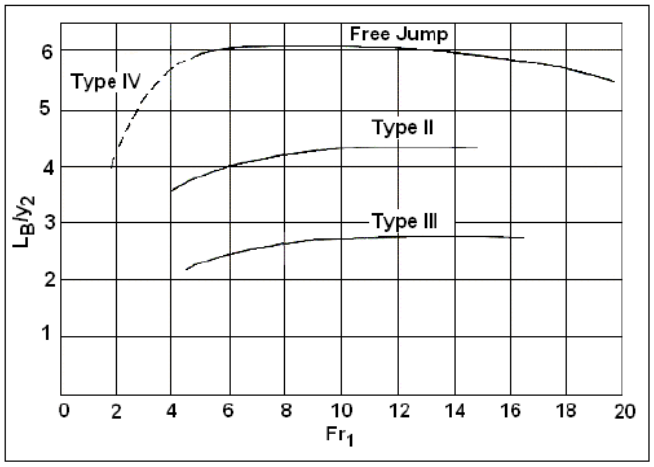


Figure 8.2. Length of Hydraulic Jump on a Horizontal Floor

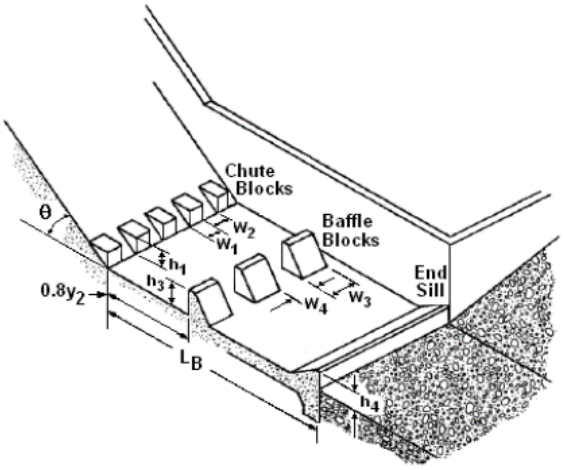
Downchutes	North	East	South	West
C, Ratio of Tailwater to Conjugate Depth	1	1	1	1
Water Depth in Energy Dissipator, $y_2 = d_2$ x C (ft)	2.60	2.69	2.60	2.63
LB/y_2, Ratio from Figure 8.2	6	6	6	6
LB, Length of Basin Floor (ft)	16	16	16	16

$FB_T = 0.1(V_1 + d_2)$ (terminal structure wall freeboard equation) [3]

Where: FB_T is the minimum freeboard above the water surface (ft).
V_1 is the average velocity entering the stilling basin (ft/s).
d_2 is the conjugate depth or depth at the downstream end of the hydraulic jump (ft).

FB_T, Freeboard (ft)	1.90	2.01	1.90	1.93
Total Height of Dissipator Wall (ft)	4.50	4.70	4.50	4.56
y_c, Critical Depth, calc'd using Watertools, Assumed Depth of Water Discharge Over End Sill (ft)	1.19	1.19	1.19	1.19
End Sill Height, Depth of Basin, $y_2 - y_c$ (ft)	1.40	1.50	1.40	1.43

USBR Type III Energy Dissipator Basin (4.5 < Fr < 17)



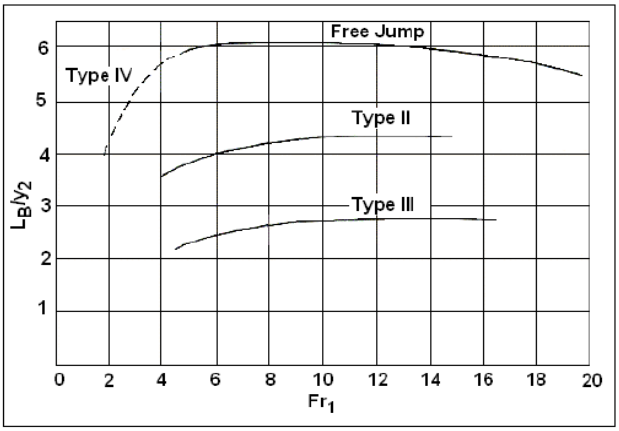


Figure 8.2. Length of Hydraulic Jump on a Horizontal Floor

Downchutes	North	East	South	West
C, Ratio of Tailwater to Conjugate Depth	1	1	1	1
Water Depth in Energy Dissipator, $y_2 = d_2$ x C (ft)	2.60	2.69	2.60	2.63
LB/y_2, Ratio from Figure 8.2	2	2	2	2
LB, Length of Basin Floor (ft)	5	5	5	5
FB_T, Freeboard (ft)	1.90	2.01	1.90	1.93
Total Height of Dissipator Wall (ft)	4.50	4.70	4.50	4.56
y_c, Critical Depth, calc'd using Watertools,	1.19	1.19	1.19	1.19
End Sill Height, Depth of Basin, $y_2 - y_c$ (ft)	1.40	1.50	1.40	1.43
h_1, height of chute block, = y_1 or 8 in min (in)	8	8	8	8

$$N_c = \frac{W_B}{2y_1}$$

N_c, number of chute blocks	39	42	39	40

$$W_1 = W_2 = \frac{W_B}{2N_c}$$

W_1, W_2, chute block width and block spacing (in)	5	5	5	5

$$h_3 = y_1(0.168Fr_1 + 0.58)$$

h_3, height of baffle block (in)	7	7	7	7

$$N_B = \frac{W_B}{1.5h_3}$$

N_B, number of baffle blocks	40	40	40	40

$$W_3 = W_4 = \frac{W_B}{2N_B}$$

W_3, W_4, baffle block width and spacing (in)	5	5	5	5

Results

Since the East Downchute results in the most conservative design requirements, the East Downchute results were used for design of all the downchute energy dissipators:

Length of Basin Floor = 16 ft
Height of Dissipator Wall = 5 ft
End Sill Height = 1.5 ft

Alternatively, with the addition of baffle blocks, a shorter basin (5 ft) could be used, but the longer basin (16 ft) fits within the project topography and will be easier to construct.

References

Federal Highway Administration (FHWA). 2006. Hydraulic Engineering Circular No. 14, Third Edition, Hydraulic Design of Energy Dissipators for Culverts and Channels.

United States Bureau of Reclamation (USBR). 2014. Design Standards No. 14, Appurtenant Structures for Dams (Spillways and Outlet Works) Design Standard.

USBR. 1984. Hydraulic Design of Stilling Basins and Energy Dissipators.

Energy Dissipator Force Calculations
FMI / Satralloy / Slag Removal IA Design
Project #: 21480300
Prepared by: VMN 04/06/2023
Reviewed by: FSS 04/07/2023

Objective

Force calculations and an analysis of the factor of safety against sliding were performed for concrete energy dissipator structural reinforcement design.

Impulse Force on End Sill

Use Equation for Force Exerted by a Jet on a Vertical Flat Plate (Equation 17.177b, Lindeburg 2006):

F_x (lbf) = $(\rho a V^2)/g_c$

Density of Water, ρ (lbm/ft^3)	62.4
Gravitational Conversion Constant, g_c (lbm-ft/lbf-sec^2)	32.2
Discharge (cfs)	280
Base Width (ft)	36
Slope (ft/ft)	0.4
Side Slope (xH:1V)	3
Manning's n-value	0.030
d_1, Normal Depth, calc'd using Watertools (ft)	**0.43**
Cross-Sectional Area of Jet, calc'd using Watertools (ft^2)	**16.1**
Velocity, V = Q/A (ft/s)	**17.4**
Total Force (lbf)	**9,457**
Force per Unit Width (lbf/ft)	**263**

Frictional Resistance Force

F_f (lbf) = $\mu_s W$ (Equation 15.34, Lindeburg 2006)

μ_s = tan(ϕ) (Equation 73.22, Lindeburg 2006)

Internal Angle of Friction, ϕ (degrees)	35	for gravel
Internal Angle of Friction, ϕ (radians)	**0.61**	
Coefficient of Friction, μ_s	**0.70**	
Dissipator Length (ft)	16	
Dissipator Base Width (ft)	36	
Thickness of Concrete (ft)	0.67	
Depth of Water Above Concrete (ft)	1.5	
Density of Concrete (lb/ft^3)	150	
Density of Water (lb/ft^3)	62.4	
Weight (lb)	**111,514**	

Total Force (lbf)	78,083
Force per Unit Width (lbf/ft)	2,169

Factor of Safety Against Sliding ($FS_{sliding}$) = sliding resistance force/sliding force

$FS_{sliding}$	8.26

Results

The factor of safety against sliding is greater than 8, even using conservative assumptions for subgrade soil strength. This is considered acceptable for this structure.

References

Michael R. Lindeburg. 2006. Civil Engineering Reference Manual, Tenth Edition.