Bremo Bluff FFCP Management Facility, SWP 627 Part B Permit Application

ATTACHMENT VI – DESIGN REPORT

DESIGN REPORT

Bremo Bluff FFCP Management Facility Solid Waste Permit 627 Fluvanna County, Virginia

Prepared for:



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Prepared by: Schnabel Engineering 9800 Jeb Stuart Parkway, Suite 100 Glen Allen, Virginia 23059



Schnabel Reference No. 22130437.031

November 2024



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CERTIFICATION

This Design Report for the Bremo Bluff Fossil Fuel Combustion Products (FFCP) Management Facility (Facility) was prepared by Schnabel Engineering (Schnabel). The document and Certification/Statement of Professional Opinion are based on and limited to information that Schnabel has relied on from Dominion Energy and others, but not independently verified.

On the basis of and subject to the foregoing, it is my professional opinion as a Professional Engineer licensed in the Commonwealth of Virginia that this document has been prepared in accordance with good and accepted engineering practices as exercised by other engineers practicing in the same discipline(s), under similar circumstances, at the same time, and in the same locale. It is my professional opinion that the document was prepared consistent with the requirements in the United States Environmental Protection Agency's "Standards for the Disposal of Coal Combustion Residuals in Landfills and Surface Impoundments" (CCR Rule, 40 CFR §257 Subpart D) as well as the Virginia Department of Environmental Quality's Virginia Solid Waste Management Regulations (VSWMR, 9VAC20-81).

The use of the word "certification" and/or "certify" in this document shall be interpreted and construed as a Statement of Professional Opinion and is not and shall not be interpreted or construed as a guarantee, warranty, or legal opinion.

James R. DiFrancesco	Principal / Practice Leader Solid Waste
Name	Title
And b-	
	November 15, 2024
Signature	Date



1.0 INTRODUCTION

This Design Report (Report) has been prepared for the Bremo Bluff Fossil Fuel Combustion Products (FFCP) Management Facility (Facility) located in Bremo Bluff, Virginia. The Facility will accept coal combustion residuals (CCR) previously generated at the Bremo Station (Station) and operate as a new, captive industrial landfill (CCR Unit) under the Virginia Department of Environmental Quality (DEQ) Solid Waste Permit (SWP) 627. Schnabel Engineering (Schnabel) has prepared this Report on behalf of the Virginia Electric and Power Company d/b/a Dominion Energy Virginia (Dominion Energy).

The Facility is subject to the design requirements in the United States Environmental Protection Agency's "Standards for the Disposal of Coal Combustion Residuals in Landfills and Surface Impoundments" (CCR Rule, 40 CFR §257 Subpart D) as well as the DEQ's Virginia Solid Waste Management Regulations (VSWMR, 9VAC20-81).

1.1 Site Description

The Facility will be located along State Route 656 at 2134 Bremo Road in Bremo Bluff, Virginia on an approximately 214-acre parcel that is owned by Dominion Energy and adjacent to the Station property (Tax Parcel 62-A-7).

1.2 Permit Information

The Station, located at 1038 Bremo Road, includes an existing CCR surface impoundment, the North Ash Pond (NAP). In accordance with §10.1-1402.03 of the Virginia Waste Management Act, the NAP will complete closure by removing CCR and disposing of it at a permitted disposal facility.

This Facility is being proposed for the disposal of CCR generated during the operation of the Station, to include CCR currently in place in the NAP; materials generated during the closure of the NAP; coal fines and CCR debris related to other work at the Station; cleaning of sumps and wet wells; soils in contact with CCR; solids and filter bags from the proposed Dominion Energy-owned contact wastewater treatment activities; and inert NAP infrastructure demolition wastes, such as aggregate, concrete, geosynthetics, piping, etc. (CCR wastes).

1.3 General Facility Information

Operator: Virginia Electric and Power Company d/b/a Dominion Energy Virginia

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1.3.1 Site Acreage

Approximately 125 acres of the 214-acre property will be dedicated for Facility activities, i.e. the Facility Boundary (FB), with approximately 73 of those acres designated for waste management activities, i.e. the Waste Management Boundary (WMB), and 47 of those acres lined for disposal activities, i.e. the Disposal Unit Boundary (DUB).

1.3.2 CCR Unit Capacity and Life Expectancy

The CCR Unit will provide approximately 6.2 million cubic yards (cy) of net disposal capacity. Based on proposed operating conditions (i.e., a maximum daily intake rate of 15,000 tons per day) and the rate of the NAP closure activities, the life of the CCR Unit is estimated to be approximately 6 years.

1.4 Prior Approvals

The Facility received Part A Permit Application approval from the DEQ on January 27, 2023. Conditions of the DEQ Part A Permit Application approval for the Facility are listed in the section below.

1.4.1 DEQ Part A Permit Conditions

Included in this section are the conditions included in the DEQ Part A Application Conditional Approval letter, with each condition followed by discussion of how the condition is met by the design.

- 1. The facility boundary (125 acres) and the waste management boundary (73 acres) are limited to those areas identified as the "Facility Boundary" and "Waste Management Boundary" respectively, on the Facility Near Vicinity Map: Index Map and Maps A1-A3 & B1-B3, last revised May 30, 2024, as well as on Figure 1 Landfill Boundaries, dated February 18, 2024.
 - The FB, WMB, and metes and bounds for each are shown on Drawing 4 in Attachment III of the Part B Permit Application (Design Plans). The boundaries shown are the same as presented on the Facility Near Vicinity Map and Figure 1.
- 2. This Part A approval letter, the Near Vicinity Map(s), last revised May 30, 2024, and Figure 1 Landfill Boundaries dated February 18, 2024, shall be included with the Part B permit application as Attachment 1 to the Design Report. The Part B permit application must discuss how the conditions described in this Part A approval letter have been met.

The Part A Application Conditional Approval Letter, Near Vicinity Map(s), and Figure 1 are included as Attachment 1 to this Design Report.

- Prior to construction, any piezometers or monitoring wells located within the proposed waste management area shall be completely removed by removing the casing or overdrilling of the wellbore, followed by pressure grouting methods to the ground surface.
 - Note 5 on Drawing 3 of the Design Plans addresses this requirement.
- 4. All vehicle traffic to the landfill should be on roads internal to the facility. Should traffic access change to utilize public roads, a copy of the adequacy report required under 9VAC20-81-460.G that is submitted to the Virginia Department of Transportation (VDOT) and a VDOT approval letter shall be included in the Part B application.
 - All vehicle traffic involving the excavation, transportation, and disposal of CCR to be placed in the CCR Unit will occur on roads internal to the Facility.
- 5. The highest elevation of any point on the landfill is limited to 525 feet or less above mean sea level (AMSL). The Part B permit application cannot be submitted for a highest elevation of the top of the landfill beyond the elevation 525 feet AMSL.
 - As shown in the Design Plans, the highest elevation of any point on the landfill is below 525 feet (ft) AMSL.
- 6. The daily disposal limit for the Bremo Bluff FFCP Management Facility is 15,000 tons per day. This limit is subject to decreasing during the Part B permit application process depending on the planning and permitting for the equipment and other operational needs of the facility.
 - A daily disposal limit of 15,000 tons per day is requested with the Part B Permit Application.
- 7. During Part B design the disposal cells and the leachate storage system layout and location must be within the waste management boundary that is delineated in the Part A application. Also, the disposal capacity, considering the maximum build-out, must be equal to or less than 7,600,000 cubic yards. This is the capacity requested in the Part A application. The depth of the base grades for the disposal area are limited to a lowest elevation of 312 feet AMSL.
 - As illustrated in the Design Plans, the CCR Unit and leachate transfer system layout and location are within the WMB delineated in the Part A application. The disposal capacity at the proposed maximum build-out is 6,200,000 cubic yards, and the lowest base grade elevation is 312 ft AMSL.
- 8. All containment structures, including liners, leachate collection systems, and surface water control systems shall be designed to resist the maximum horizontal ground acceleration, with a 10% or greater probability of occurring in 250 years, for this site. The value was estimated to be 0.197g in the seismic analysis submitted with the Part A application. The Part B design analysis must be performed using the maximum horizontal acceleration of 0.197g or more.
 - A peak ground acceleration of 0.197g was used in the Part B design analysis.
- 9. The Part B design should address any requirements of the Wetland and Stream Impact permits issued and any approved variances.

The Facility has been designed in accordance with the Virginia Erosion and Sediment Control Handbook and the Virginia Solid Waste Management Regulations and meets the requirements of the Virginia Water Protection (VWP) Individual Permit Number 21-2305 and the approved variance to 9VAC20-81-120.C.1.b.

2.0 SITE FEATURES

2.1 Security

The permanent access to the Facility will be an entrance road off Bremo Road. This entrance will serve as the emergency access route into and out of the Facility. The entrance will be secured by a lockable security gate across the road. A Facility attendant will be stationed at the gatehouse located at the entrance road. The attendant's responsibilities are to monitor incoming vehicles and maintain records. Visitors are required to check-in with the Facility attendant upon arrival at the site. Unless an attendant is on duty, the gate is closed and locked during all non-operating hours to prevent entry and illegal disposal of wastes.

Access to the Facility for hauling operations will be a temporary haul road, constructed on Dominion Energy-owned property, from the Station property to the Facility. The existing security and perimeter controls at the Station will be extended to the temporary haul road accessing the Facility.

The Facility will be set back from Bremo Road and surrounded by natural vegetative and topographic barriers on all sides which limit access around the perimeter of the site. Fencing will be installed along the eastern and southern limits of the Facility Boundary and along Bremo Road to further prevent vehicular access except through the gate-controlled access road. Fencing, gates, and locks will be inspected and maintained.

Operators will be equipped with mobile radios or cellular phones to maintain contact with the gatehouse and office personnel.

2.2 Roads

Proposed all-weather access and perimeter roads within the Facility are shown on the Design Plans. The permanent access roads will be constructed of a 9-inch-thick base course layer of VDOT No. 3 stone placed overtop a woven geotextile and choked with 21A material to provide an all-weather travel surface and minimize dust generation from vehicles. Design criteria for access roads are generally a maximum sustained grade of 10 percent or less and a minimum width of 24 feet for two-way traffic. The roads will be crowned from the center of the road or sloped to one side to promote drainage from the road surface. The fill slope of perimeter access roads is a maximum of 2H:1V (horizontal to vertical).

CCR wastes will be transported by haul trucks from the Station property to the Facility via temporary haul roads constructed on Dominion Energy-owned property. The temporary haul roads will be hard-surfaced, making rutting and mud tracking unlikely to occur.

Ingress and egress into the CCR Unit is as shown on the Design Plans. Protections for the liner system under construction equipment shall be in accordance with Technical Specification Section 02599 in Attachment VII of the Part B Permit Application.

The working face of the CCR Unit will be accessed by temporary roads, which will be constructed by the

operator atop previously filled CCR. The roads will be maintained for all-weather access and have a maximum fill slope of 3H:1V.

Access roads will be maintained by site personnel through periodic maintenance that includes fugitive dust control, removal of mud deposited on the surface, surface regrading, surface re-compaction, placement of additional stone, and cleaning of ditches and other drainage structures along the road as needed to maintain drainage and ensure all-weather access to the active areas of the CCR Unit. Consideration for standard vehicles will be made when constructing and maintaining all internal roads.

2.3 Traffic Routing

CCR material will be transported by haul trucks from the Station property to the Facility via temporary haul roads constructed on Dominion Energy-owned property, i.e., no CCR hauling activities will occur on public roadways. Loads will be routed to the active working face in a manner that prevents congestion along the haul roads and working face. Roads will be constructed to have sufficient width to allow safe passage of users. All other vehicles will enter and exit the Facility through the Bremo Road entrance and be required to stop at the gatehouse.

2.4 Shelter

Shelter for site personnel will be provided in the form of construction trailers. Site personnel will have access to heating, air conditioning, lighting, sanitary facilities, and communication utilities (e.g., telephone, two-way, radio, and internet). The gatehouse, located near the Facility entrance, will be a construction trailer or similar structure. Portable sanitation facilities will be provided near the active portion of the CCR Unit.

2.5 Aesthetics

The Facility is located within a rural, undeveloped parcel along Bremo Road where natural screening surrounds the site, as shown on the Design Plans. Setbacks from the WMB were established during the re-zoning approval process with Fluvanna County. A fire break of at least 50 ft will be maintained between the tree line and the DUB. CCR Unit slopes will be seeded and maintained with adequate vegetation to minimize erosion and provide site aesthetics. Areas not used for Facility operations will remain undisturbed. Parcels surrounding the Facility are residential and wooded.

Noise at the Facility boundary should not be of concern as most Facility operations will take place at a distance of over 100 ft from the Facility Boundary. As can be seen in the table below, the average noise level for the anticipated types of construction equipment is below the 80 decibels (dBA) threshold at 100 ft. Proper maintenance of equipment, selective clearing, and the presence of a mixed tree buffer surrounding the site will act to further attenuate noise generated during Facility operations.

Equipment Type
Average A-Weighted Noise Level at 100 ft (dBA, Leq)

Water Truck
78

Bulldozer
79

Haul Truck
78

Table 1: Construction Noise Activity

Notes: Field-measured construction equipment noise data were found in Appendix N of the 2007 *Draft Environmental Impact Report* for the Port of Los Angeles Container Terminal Project (http://www.portoflosangeles.org/EIR/TraPac/DEIR/Appendix N Noise.pdf).

2.6 Site Benchmarks

There will be three site benchmarks, the proposed locations of which are shown on Drawing 4 of the Design Plans and below in Table 2. In the event that the benchmarks are damaged, destroyed, or removed for future development, new permanent benchmarks will be re-established, if necessary, to maintain at least two permanent benchmarks on site.

ID	Northing	Easting	Approximate Ground Elevation (ft AMSL)
BM-1	3780979.86	11547750.21	381.52
BM-2	3780578.26	11548781.88	332.15
BM-3	3781981.86	11550566.07	403.29

Table 2: Proposed Site Benchmarks

3.0 SITE DEVELOPMENT

The proposed FB area is currently undeveloped, wooded property with a former jurisdictional perennial stream feature, i.e. emergent groundwater, running through the center of the property. The site will be developed from south to north. An underdrain conduit pipe will be constructed to convey emergent groundwater flow from beneath the Facility, in accordance with the VWP Individual Permit Number 21-2305. Drainage will be diverted away from construction activities to the proposed sediment basins. A total of approximately 125 acres will be cleared and graded for operations, access, drainage, and construction of a 50-foot fire break from the disposal area.

Dominion Energy will be responsible for the baseline stake-out prior to construction activities for the project in accordance with the Design Plans. Dominion Energy will utilize subcontractors and subconsultants, as deemed appropriate, for specific functions related to the construction of the Facility.

Dominion Energy will employ a Professional Engineer licensed in the Commonwealth of Virginia to provide quality assurance services during construction. As-built drawings will be prepared during construction of newly constructed roads, site infrastructure, the disposal unit, and related utilities. Construction Quality Assurance (CQA) documentation and record drawings will verify that the site's facilities were constructed in substantial accordance with the plans and specifications upon which the permit was issued.

3.1 CCR Unit Development

Due to the anticipated rate of filling activities, the entire area enclosed by the Disposal Unit Boundary (47 acres) will be developed all at once and closed all at once.

The CCR Unit is to be developed from south to north to allow for flexibility in construction scheduling of the site with uninterrupted filling operations. The CCR Unit will be excavated and lined for disposal activities. Excavated soils will be used in the construction and operation of the Facility.

The capacity and estimated life of the CCR Unit are 6.2 million cy and approximately 6 years, respectively. For the purpose of determining the estimated life, the estimated maximum volume of CCR wastes, the assumed maximum daily intake rate of 15,000 tons per day (tpd), the properties of the CCR, and the rate of CCR removal activities were considered.

The proposed final grades were developed based on the estimated maximum volume of CCR wastes. The actual volume of CCR wastes is anticipated to be less, which will result in final grades that are lower than what is currently shown in the Design Plans. Once all CCR wastes from the Station are placed in the CCR Unit, the CCR Unit will be closed. Details of the construction sequence are included in the Design Plans.

3.2 Borrow and Stockpile Estimates

The Facility is expected to have a net surplus of soil through the closure timeframe. The anticipated volume of soil required over the life of the Facility is expected to come from readily available on-site soils from the proposed site development.

The volume of soil required through closure of the CCR Unit is estimated to be approximately 273,600 cy for intermediate and final cover, as daily cover soil is not required. Approximately 24,500 cy of soil are estimated to remain after the construction of the stormwater management structures and CCR Unit base grades. These soils will be stockpiled on-site for operational, site construction, and closure needs. Proposed stockpile locations are included in the Design Plans, but may vary during construction and operation of the Facility. Remaining soil volumes can be obtained from on-site borrow areas, as identified in the Design Plans. The proposed borrow areas are anticipated to provide up to 308,600 cy of soil, leaving a net excess of approximately 59,500 cy, which can be left in-place if these soils are not needed for other site uses.

Soil needs, stockpile, and borrow area calculations are included in Attachment 2.

4.0 CCR UNIT DESIGN

4.1 Liner Foundation

Construction of the liner foundation for the CCR Unit will require both cut of native, in-situ soils and fill of excess native soils to achieve the base grades. The CCR Unit area currently consists of wooded, uneven, and rocky terrain. Areas where bedrock is encountered during excavation will be removed by ripping, blasting, or other means until design grades are achieved, upon which the 12-inch controlled subgrade layer will be placed. Areas where existing soils have been subjected to standing water will be excavated and undercut as necessary to provide a suitable subgrade for placement of clean soil structural fill. The excavated subgrade in these areas shall be inspected in accordance with the CQA Plan prior to placing structural fill. Clean structural fill soil will be placed, compacted, and tested in accordance with Attachment VII of the Part B Permit Application (CQA Plan, Technical Specifications).

The Facility is designed to have a minimum 5-foot separation from the base of the CCR Unit to the upper limit of the uppermost aquifer; however, the Facility will be constructed atop existing low-volume and seasonal groundwater seeps, requiring that an underdrain system be constructed below the Facility to maintain drainage for the seeps. The underdrain pipe will be constructed along the flowline, with lateral extensions to collect tributary flows. Details of this system are shown in the Design Plans and discussed further in Section 6.0.

Additionally, this section presents the analyses and results to evaluate the settlement, bearing capacity, and stability for construction and operational loads. The following subsections present summary information and conclusions from the attached evaluations to determine the following:

- Slope and veneer stability of the proposed base and final grades;
- Bearing capacity of the CCR Unit foundation soils;
- Foundation settlement, including predicted strains in the liner system;
- Potential for bottom heave or blow-out, and;
- Liner performance under construction and operational loads.

4.1.1 Subsurface Exploration Data

A subsurface investigation of the Facility area was completed as part of the July 2022 Part A Permit Application (by others) to provide an adequate representation of the soil stratigraphy and properties. Representative samples of the subsurface materials were obtained and transported to a laboratory for testing. The subsurface information included in the Part A Permit Application was relied upon for the design of the CCR Unit and the calculations and analyses contained herein.

Additionally, the Facility area is not known to contain geologically unstable soils, sink holes, caverns, or underground mines.

4.1.2 Laboratory Data

Material properties' testing was performed on the samples of soil obtained from the Facility area during the subsurface investigation in support of the Part A Permit Application. The results of these tests were presented in the Part A Permit Application and were relied upon for the design of CCR Unit and the calculations and analyses contained herein.

4.1.2.1 Settlement Potential

A settlement analysis was completed to estimate the potential post-development settlement of the foundation soils below the proposed CCR Unit assuming maximum CCR elevations and final cover conditions. Potential settlement was calculated at two points along each proposed leachate collection header alignment, and the change in the leachate collection header slope, or liner floor grade slope, was calculated using the differential settlements between each point.

The settlements of the base grade at the points analyzed ranged from 0.14 ft to 2.25 ft. Based on these calculated settlements, the differential settlement would increase the base grade slopes overall, with the exception of one leachate header that changes from a 3.40% slope to a 3.37% slope. A leachate pipe capacity calculation is included in Attachment VIII of the Part B Permit Application (Leachate Management Plan) to demonstrate that the leachate collection pipes can convey the maximum expected leachate flows at the post-settlement leachate collection pipe slopes. The anticipated differential settlement will not adversely impact the performance of the leachate collection system.

The 60-mil high-density polyethylene (HDPE) geomembrane in the bottom liner system, discussed in Section 4.3, has an allowable yield elongation of 12%. The maximum tensile strain was calculated to be 0.0241%; therefore, tensile stain on the geomembrane is considered to be negligible and the differential settlement is not anticipated to have a negative impact on the liner.

This settlement is expected to occur over an extended period of time (the life of the CCR Unit) as loading to the area occurs with fill operations. The settlement analysis is included in Attachment 3.

4.1.2.2 Bearing Capacity and Stability

A bearing capacity analysis was completed to demonstrate that the bearing capacity of the underlying soils will not be exceeded by the expected loading by the CCR Unit. The ultimate bearing capacity of the subsurface soils is estimated to be 1,880,480 pounds per square foot (psf) and the loading of the CCR Unit is expected to be approximately 19,250 psf. These values yield a factor of safety (FS) against bearing capacity failure of 97.7. The calculations for bearing capacity are included in Attachment 3.

The global stability of the CCR Unit was also evaluated. Three cross-sections considered to be the most critical were selected and analyzed with the proposed design parameters. The critical sections were evaluated for circular, non-circular, and block slip surfaces. The calculated factors of safety for static conditions and seismic conditions meet the required minimum factors of safety and indicate that the FS against slope failure is satisfactory in a static and seismic case for the evaluated sections.

The permitted liner system must have a minimum peak interface friction angle between the controlled subgrade and the overlying geosynthetics, as well as any material interface of the bottom liner system, of at least 13.5 degrees, or equivalent shear strength as approved by the ENGINEER, as determined by ASTM D5321 at normal stresses of 2,000 pounds per square foot (psf), 5,000 psf, 10,000 psf, and 20,000 psf.

Additionally, the internal friction testing and interface friction testing of the GCL against the underlying soil subgrade surface and the overlying geomembrane shall be greater than or equal to 13.5 degrees, or equivalent shear strength as approved by the ENGINEER, as determined by ASTM D5321 and ASTM D6243 at normal stresses of 2,000 psf, 5,000 psf, 10,000 psf, and 20,000 psf.

The stability analysis is included in Attachment 3.

4.1.2.3 Bottom Heave or Blow-Out

Bottom heave is upward movement of the in-situ soils resulting in the rise of the ground surface. This movement is generally the result of unloading due to excavations, which allows an elastic rebound or an intake of water by the underlying soil. Excavations to establish base grade elevations at the Facility will generally be no greater than 20 feet below the existing grade. Elastic rebound resulting from removal of 20 feet of soil will be less than 1 inch and will likely have no effect on construction of the Facility.

Blow-out of the bottom or sides of an excavation can be caused by excessive hydrostatic pressure acting upward against a soil layer or particle. Blow-out will occur when the effective stress in the soil is equal to the neutral stress. When blow-out occurs, the hydraulic gradient must be approximately equal to 1.0. Bottom heave and/or blow out is not anticipated to occur within the CCR Unit, as hydrostatic conditions necessary for bottom heave and/or blow out are not present in the area. The water table will be sufficiently below the bottom liner system. The absence of a water table within the CCR Unit area eliminates the threat of damaging hydrostatic pressures; therefore, blow-out of the bottom of the excavation is not a concern.

Bottom heave or blow-out due to gas pressure is not anticipated to occur, as these pressures are not present at the Facility or within the site geology.

4.1.2.4 Construction and Operational Loading

The calculation titled *Base Grade Stress During Construction*, contained in Attachment 4, indicates that there will be adequate protection from installation and operation activities.

As demonstrated in the preceding section of this Report, the foundation of the CCR Unit adequately supports the anticipated ultimate load of the disposal unit. Construction and operational loads are considered to have a negligible effect on the foundation when compared to the ultimate load of the disposal unit; therefore, further analysis on the underlying foundation due to construction and operational loads is not warranted under the foundation section of this Report. Construction and operational loads are however evaluated for the liner system in Section 4.4 of this Report and for the leachate collection system in the Leachate Management Plan, where a discussion of the anticipated construction and operational loads is presented along with supporting calculations.

4.2 Limiting Site Characteristics

4.2.1 Presence of Springs, Seeps, or Other Groundwater Intrusion

Groundwater elevation data was collected and recorded as part of the site subsurface investigation presented in the July 2022 Part A Permit Application and springs, seeps, or other groundwater intrusions were identified. Groundwater elevation contours and the locations of the low-volume and seasonal groundwater seeps are provided in the Design Plans.

Due to the presence of springs, seeps, or other groundwater intrusion, an underdrain system will be installed to collect groundwater seepage beneath the Facility. Details of the underdrain design are discussed in Section 6.0 of this Report.

4.2.2 Presence of Gas, Water, Sewage, or Electrical or Other Utilities

No utilities under the Facility area have been identified in the Part A Permit Application, and none are known that would affect the Facility. Overhead electric utilities have been identified to the north, west, and south of the Facility and are indicated on the Design Plans. Utility locations for existing water, sewer, and additional electrical services will be performed prior to construction, as required by state law.

4.2.3 Prior Existence of Open Dump, Unpermitted Landfill, or Lagoons

No prior existence of open dumps, unpermitted landfills, or lagoons have been identified in the Part A Permit Application and none are known to exist in the area.

4.3 Liner System

4.3.1 CCR Unit

The proposed bottom liner system for the CCR Unit satisfies the requirements under 9VAC20-81-130.J.2.b, but is considered an alternative composite liner system under 40 CFR §257.70(c). In accordance with this section of the CCR Rule, an Alternate Liner Demonstration has been included as Attachment XIV of the Part B Permit Application. The CCR Unit will be constructed with a bottom liner and leachate collection system consisting of the following components (from top to bottom):

- 18-inch-thick aggregate leachate collection layer with a hydraulic conductivity greater than or equal to 1x10⁻³ centimeters per second (cm/s)
- 250-mil geocomposite, double-sided with 8-ounce per square yard (oz) non-woven geotextile

- 60-mil double-sided, textured HDPE geomembrane
- Geosynthetic clay liner (GCL) with a hydraulic conductivity less than or equal to 3.4x10-9 cm/s
- Minimum 12-inch-thick controlled subgrade

Details for the bottom liner system are shown in the Design Plans.

4.3.1.1 Leachate Collection Layer

In accordance with 9VAC20-81-130.J.2, the 18-inch-thick aggregate leachate collection layer is composed of a 12-inch-thick drainage layer for leachate removal and a 6-inch-thick protective layer placed above the drainage layer, both consisting of non-carbonate (less than or equal to 15%) aggregate with a minimum hydraulic conductivity of 1x10-3 cm/s.

Two options are being proposed for the granular leachate collection layer. Option 1 consists of a 12-inch-thick coarse aggregate drainage layer overlain by a 6-inch-thick fine aggregate protective layer, separated by a 10-oz non-woven filtration/separation geotextile. Option 2 consists of an 18-inch-thick layer of coarse aggregate overlain by a 10-oz non-woven filtration/separation geotextile (Option 2A) or an 18-inch-thick layer of fine aggregate (Option 2B). In the case of an Option 2B and the 6-inch-thick fine aggregate in Option 1, a 10-oz non-woven geotextile is not proposed between the placed CCR and fine aggregate layers because the fine aggregate acts as a filter layer to prevent the migration of the placed CCR. Calculations demonstrating the filter compatibility of the adjoining materials is included in Attachment 2 of the Leachate Management Plan.

A network of 6-inch perforated HDPE leachate collection laterals drain leachate to 8-inch perforated HDPE leachate collection mains, which drain by gravity into a leachate collection sump. Leachate collection headers and laterals will be enveloped in VDOT No. 57 stone. In the event that fine aggregate is used for the 18-inch-thick granular layer, i.e. Option 2B, the VDOT No. 57 stone will be wrapped with a 10-oz non-woven geotextile to provide separation and filtration capacity from the surrounding leachate drainage layer and prevent the fine aggregate from migrating into the stone and leachate collection piping.

4.3.1.2 250-mil Drainage Geocomposite

To provide additional drainage, as well as protection for the geomembrane, the aggregate drainage layer will be underlain with a 250-mil geocomposite consisting of a geonet core that is heat-laminated on both sides with an 8-oz non-woven geotextile fabric.

4.3.1.3 <u>60-mil HDPE Geomembrane</u>

The bottom liner geomembrane is constructed from double-sided textured HDPE material and shall conform to the standards contained in the Technical Specifications. Geomembrane installation shall conform to the practices outlined in the Technical Specifications and the CQA Plan.

4.3.1.4 Geosynthetic Clay Liner

The GCL consists of bentonite encapsulated between two stitched geosynthetic fabrics. The GCL will have a hydraulic conductivity less than or equal to 3.4x10⁻⁹ cm/s. Prior to placing the GCL, the liner subgrade must be certified by the installer and inspected by the Owner's Representative. Care shall be taken during installation of the GCL to prevent exposure to excessive moisture that may damage the

material.

4.3.1.5 Controlled Subgrade

The controlled subgrade layer will be a minimum of 12 inches, consist of soils classified as SC, SM, ML, CL, MH, or CH, and compacted to a minimum of 95% of the maximum dry density (Standard Proctor).

4.3.2 Geotextile Filtration

A calculation was performed to determine the appropriate maximum apparent opening size (AOS) of the 8-oz geocomposite geotextile and 10-oz filter/separation geotextile. The non-woven geocomposite geotextile shall have an AOS of 0.21 millimeters (mm) or smaller. The filter/separation geotextile shall have a maximum AOS size 0.15 mm. AOS sizing calculations for the geotextiles are included as Attachment 5.

4.3.3 Puncture Resistance

The geomembrane liner, geocomposite geotextile, filtration/separation geotextile were all evaluated for protection against puncture during initial construction and long-term final conditions. All geosynthetic components of the liner system are anticipated to have adequate factors of safety against puncture. Supporting calculations are provided in Attachment 6.

4.3.4 Contact Stormwater Pond

The proposed liner system for the Contact Stormwater Pond (CSWP), which is discussed in further detail in Section 5.0, consists of the following components (from top to bottom):

Pond Floor

- 6-inch-thick 3,000 pounds per square inch (psi) concrete slab with 6 by 6 W10 by W10 welded wire mesh
- 10-oz non-woven geotextile
- 60-mil double-sided, textured HDPE geomembrane
- Reinforced GCL with a hydraulic conductivity less than or equal to 3.4x10-9 cm/s
- 60-mil double-sided, textured HDPE geomembrane
- Minimum 12-inch-thick controlled subgrade

Pond Sideslopes

- 4-inch-thick fabric-formed concrete (filter point)
- 10-oz non-woven geotextile
- 60-mil double-sided, textured HDPE geomembrane
- Reinforced GCL with a hydraulic conductivity less than or equal to 3.4x10-9 cm/s
- 60-mil double-sided, textured HDPE geomembrane
- Minimum 12-inch-thick controlled subgrade

Details for the CSWP liner system are shown in the Design Plans.

4.4 Liner Slopes

The minimum base liner slope is 2.5%, post-settlement, and the maximum base liner slope is 28.6% (3.5H:1V). The liner subgrade shall conform to the requirements contained in the Technical

Specifications.

Based on the results of the settlement calculations, included in Attachment 3, the base liner slope is anticipated to effectively remain at the as-constructed slope and function as designed after settlement occurs.

Engineering analyses for the liner foundation and system include the following:

- Settlement Potential
- Bearing Capacity and Stability
- Bottom Heave or Blow-Out

These analyses are discussed in Section 4.1 and attached to this Report. In addition, calculations for veneer stability, liner self-weight, and base liner system run-out were performed to ensure an adequate FS for each. These calculations are discussed in the sections below.

4.4.1 Slope Stability

A sideslope veneer stability calculation was performed to analyze the bottom liner system slope stability. Veneer stability of the base liner system was evaluated for the 3.5H:1V sideslopes for the longest liner section, approximately 164 feet. The stability was evaluated as a series of interfaces where the liner system materials overlay one another. The permitted liner system must have a minimum peak interface friction angle between the controlled subgrade and the overlying geosynthetics, as well as any material interface of the bottom liner system, of at least 22.7 degrees, or equivalent shear strength as approved by the ENGINEER, as determined by ASTM D5321 at normal stresses of 500 psf, 1,000 psf, and 2,000 psf.

The veneer stability calculation is provided in Attachment 4.

4.4.2 Liner Stress Calculations

An evaluation was performed to determine the anticipated stresses on the geosynthetic components of the liner system and to compare these stresses to the tensile strengths of the materials. The calculation titled *Base Grade Liner Self Weight*, found in Attachment 4, indicates that the 60-mil HDPE geomembrane would not pull out of the anchor trench or be stressed beyond its yield strength.

4.4.3 Liner Anchor Trench

The base liner system geosynthetics will be installed with a perimeter anchor trench to secure the geosynthetics in place during construction. Due to the anticipated friction angle between the subgrade and the geosynthetic layer immediately above, an anchor trench or horizontal liner run-out is not required for stability since the geosynthetic materials are not in tension; however, one has been included for construction convenience. Supporting calculations are provided in Attachment 4.

4.5 Prevention of Exposure

During construction of the base liner system, the system will be protected from damage and degradation through careful construction sequencing and monitoring. Although protection techniques vary, some or all of the following techniques for liner protection can be employed.

For protection of the liner subgrade, the soil grade can be constructed approximately 0.2 feet higher, to serve as a wearing surface prior to geosynthetics deployment. Immediately prior to deployment of

geosynthetics, weather depending, the surface can be fine-graded and smooth drum rolled. The resulting subgrade will then be visually inspected in accordance with the CQA Plan.

The geomembrane component of the liner system will not be left exposed more than 30 days prior to placement of the geocomposite or leachate drainage layer. The geocomposite will not be left exposed more than 30 days prior to placement of the leachate drainage layer.

As detailed in the CQA Plan, the GCL will not be exposed to excessive moisture and it will be protected from premature hydration by covering it with geomembrane liner on the same day it is deployed, if possible.

After placement and survey of the leachate drainage layer, the drainage layer will be protected using a temporary rain cover, with the rain cover incrementally removed prior to the placement of CCR wastes. Maintenance of any exposed areas will include inspection of the surface after rainfall events and, should any damage be found (i.e., rills, washouts, slides, etc.), repairs will be made by placing additional drainage layer material in the damaged areas and re-grading those areas to achieve the minimum uniform thickness. Since the drainage material is relatively porous, it is anticipated that rainfall events of small intensity or volume will infiltrate directly into the drainage layer material and will not cause runoff or drainage layer material damage. If a large rain event causes drainage layer damage (i.e., rills, washouts, slides, etc.), additional drainage layer material will be placed, and the area re-graded to achieve the uniform minimum thickness.

5.0 RUN-ON AND RUN-OFF CONTROL SYSTEMS

The stormwater run-on and run-off management systems for the Facility were designed in accordance with the requirements of the CCR Rule and VSWMR. The design and analysis of the systems were prepared using the U.S. Army Corps of Engineers Hydrologic Engineering Center's Modeling System (HEC-HMS) model and calculation methodology from the Natural resource Conservation Services (NRCS) Technical Release 55 (TR-55).

Included in this Report are stormwater calculations that demonstrate the adequacy of the proposed stormwater management systems to effectively control post-development run-on and run-off at the Facility. Supporting calculations for this demonstration are included in Attachment 7.

5.1 Run-On Control System

The Facility is bounded by Bremo Road to the north, a CSX railroad right-of-way to the south, wooded property to the east, and the Station property to the west. Stormwater run-on from undisturbed, off-site areas will be controlled by natural drainage features or diversion berms. A small area to the north of the CCR Unit and the surrounding perimeter road, and areas disturbed from grading activities, will drain to the perimeter stormwater run-on drainage channel and conveyed to the proposed sediment basins at the southern edge of the Facility for attenuation and discharge through the outfalls.

5.1.1 Design and Performance

The proposed CCR Unit design incorporates the use of standard erosion control measures such as conveyance channels and diversion berms to direct surface run-on away from the active portions of the filling operations. Run-on stormwater controls are shown on the Design Plans.

5.1.2 Construction

All drainage structures and channels are to be constructed in accordance with current Virginia Erosion and Sediment Control Standards, Virginia Department of Transportation (VDOT) Drainage Manual, and the Design Plans. Designs for non-standard structures will follow current Federal Highway Administration (FHWA) or American Society for Testing and Measurement (ASTM) standards and the Design Plans.

5.2 Run-Off Control System

Stormwater run-off from the DUB is controlled by a series of drainage benches, tack-on berms, slope drains, and perimeter conveyance channels and pipes.

During filling operations, contact stormwater, i.e. stormwater that has come into contact with CCR wastes, will be managed separately from leachate and stormwater run-off. Contact stormwater from the face of the active area will be routed through dedicated slope drains into a perimeter contact stormwater pipe that discharges to a dedicated contact stormwater management structure, the CSWP. Contact stormwater collected in the CSWP will be pumped directly to a proposed Dominion Energy-owned, permitted wastewater treatment facility, which is further discussed in the Leachate Management Plan. Stormwater run-off that has not come into contact with open CCR wastes will be treated as non-contact stormwater. Non-contact stormwater run-off will be routed to the perimeter stormwater channel and conveyed to the proposed sediment basins, which discharge to an unnamed tributary of the James River that will convey the flows through an existing culvert beneath the CSX railroad right-of-way and to the James River.

Initially, the CCR Unit will be operated with a maximum active area of 0.5 acres to minimize leachate generation, with the remaining portion of the CCR Unit rain covered to allow stormwater run-on to be pumped to the on-site sediment basins and not collected as leachate. Once the average placed CCR waste mass height exceeds 10 feet, the CCR Unit will be operated with a maximum active area of 28 acres to not exceed the Facility's seven-day storage requirement, which is further discussed in the Leachate Management Plan. Until the average placed CCR waste mass height exceeds the perimeter berm elevation and allows for increasing areas of sideslope intermediate cover for stormwater run-off, the remaining portion of the CCR Unit shall be rain covered to allow stormwater run-on to be pumped to the on-site sediment basins and not collected as leachate.

5.2.1 Design and Performance

The proposed CCR Unit design incorporates the use of standard erosion control measures such as conveyance channels and piping, diversion berms, and slope drains to convey run-off to the proposed stormwater impoundments at the southern edge of the Facility. Stormwater run-off and contact stormwater run-off controls are shown on the Design Plans.

5.2.2 Design Rates

Run-off rates for the 2-, 25-, and 100-year, 24-hour storm events were determined using the Technical Release No. 55 (TR-55) methodology and were modeled in HEC-HMS.

5.2.3 Stormwater System Design

Run-off from the intermediate and final phases of the CCR Unit will be collected in a series of drainage benches or tack-on berms. The run-off from the benches and berms is collected in slope drainpipes that will safely convey the non-contact stormwater to the perimeter stormwater channel, which drains to the

proposed sediment basins for attenuation and discharge through their respective outfalls.

Drainage benches measure two feet in height and tack-on berms measure one and half feet in height. Both form a V-ditch channel with a minimum longitudinal slope of two percent. The drainage benches and tack-on berms divide the drainage area into subareas so that the run-off flow rates remain non-erosive during sheet and shallow concentrated flow conditions. The slope drainpipes receive stormwater from the drainage benches and tack-on berms and convey it down the sideslopes of the CCR Unit to the perimeter stormwater run-off channel. The slope drains will be buried within the final cover soil to facilitate mowing and to prevent water traveling along the axis of the pipe, causing erosion. Water will enter the pipes through engineered drop inlets at the low point of each drainage bench or tack-on berm.

The stormwater run-off perimeter channel is trapezoidal and concrete-lined to provide adequate erosion protection.

The proposed sediment basins are capable of receiving and attenuating the stormwater flows from the Facility development area, as well as provide trapping and storage for conveyed sediment during construction and Facility operations. The sediment basins are constructed partly by excavation and partly by compacted soil berms. The outlet structures and spillways will release run-off at non-erosive velocities.

5.2.4 Drainage Structure Maintenance

Maintenance of the Facility's drainage structures will include routine inspections as per the Operations Plan to identify areas of erosion, undercutting, or other maintenance needs. Additional inspections may be required after large storm events to check for damage. Specific items to be inspected include:

- Culvert inlets for accumulated sediment or debris;
- Diversion benches for erosion, sediment buildup, and establishment of vegetation;
- Slope drainpipes for proper anchorage, leaking joints, undercutting;
- Vegetation in other areas for proper establishment, need of mowing;
- Perimeter stormwater channels for signs of deterioration;
- Drop inlet structures for integrity and accumulated sediment; and,
- Other temporary controls (e.g., silt fence) for proper function and sediment control.

Activities to correct or repair identified deficiencies will be initiated by site operations as soon as practicable. Additional time may be required to correct larger deficiencies or if additional drainage structure construction is required. Sediment removed from the sediment basins during maintenance or repair activities will be dewatered and used as cover soil on the CCR Unit. The level of accumulated sediment will be monitored on a regular basis through visual inspection, and the removal of accumulated sediment can be performed as necessary.

6.0 EMERGENT GROUNDWATER UNDERDRAIN

The construction of the Facility requires an underdrain system for the collection and conveyance of emerging groundwater beneath the proposed CCR Unit. The underdrain system will be designed and constructed in accordance with the requirements of the VWP Individual Permit Number 21-2305.

The underdrain design consists of a 12-inch diameter SDR-11 header pipe along the low-volume flowline, with geotextile wrapped stone laterals extending into features to the east and west.

In the footprint of the proposed CCR Unit, as well as approximately 300 ft upstream and 75 ft downstream of the perimeter road, the underdrain header pipe will be perforated and enveloped in compacted VDOT No. 57 stone with a 10-oz non-woven geotextile wrap around the stone to allow for collection of the emerging groundwater and the retainage of soils to prevent them from migrating into the drain. The perforated portion of the pipe will be bedded per the detail included in the Design Plans. Emergent groundwater seeps from low points in the existing ground east and west of the low-volume flowline will be collected and conveyed to the underdrain header pipe via lateral extensions consisting of compacted VDOT No. 57 stone wrapped in a 10-oz non-woven geotextile. AOS sizing calculations for these geotextile wraps are included in Attachment 5.

The upstream and downstream ends of the underdrain header will be solid-wall pipe. Where the underdrain header transitions to solid pipe, the stone and geotextile wrap will terminate and the pipe will be enveloped in compacted fill soils, in accordance with the detail in the Design Plans. Four feet downstream of the transition from perforated to solid-wall pipe, an HDPE water stop will be embedded in a concrete anti-seep collar to prevent water from traveling along the pipe downstream of the perforations. A sand banket drain and drainpipe will be constructed in the downstream Facility embankment to relieve any emergent groundwater that has collected downstream of the perforation transition. A detail of the water stop, anti-seep collar, and sand blanket drain and pipe are included in the Design Plans.

The underdrain outfall (UD-01) will be located near the toe of the downstream Facility embankment slope, which will be protected with gabion armoring. Underdrain cleanout access points in the form of manholes are located upstream and downstream of the perforated pipe portions of the pipe. Underdrain inspection, maintenance, and sampling frequencies and procedures are outlined in the Underdrain Monitoring Plan, which has been included as an attachment to the Part B Permit Application.

6.1 Pipe Capacity

Emergent groundwater will flow through the underdrain pipe by gravity. Settlement is not anticipated to impact the underdrain pipe slope; therefore, the underdrain piping was evaluated at the minimum design slope, which is 1.5%.

Calculations in Attachment 8 demonstrate the ability of the proposed underdrain piping to convey the peak anticipated emergent groundwater flow, as determined through previous field investigations by others, from beneath the CCR Unit subgrade to the downstream outlet. Flow was calculated using Manning's equation for a partially full circular pipe. The pipe will have an estimated peak flow depth at approximately 42 percent of its nominal inner diameter and a peak flowrate at approximately 16 percent of its potential capacity. The computed velocity in the pipe is approximately 4.3 ft/s. The peak flow depth, flowrate, and velocity are summarized in Attachment 8.

The perforated portion of the underdrain pipe will have 4 rows of 3/8-inch diameter perforations spaced every 6 linear inches of pipe, as shown in the Design Plans, to allow for sufficient flow while preventing surrounding stone from entering or plugging the pipe. The perforation size and gravel gradation were checked to confirm the VDOT No. 57 stone does not migrate into the perforated piping. The d_{50} gradation point of VDOT No. 57 stone is approximately 0.5 inch. The U.S. Army Corps of Engineers Technical Letter ETL 1110-1-162 provides the following guidance on bedding stone size and perforation size for preventing infiltration of material into the perforated pipe:

$$\frac{50\%\ size\ of\ filter\ material}{hole\ diameter\ or\ slot\ width} \geq 1.0\ (holes)\ or\ \geq 1.2\ (slots)$$

The proposed pipe and stone results in a ratio of d_{50} to hole diameter of 1.3, which satisfies this criterion.

6.2 Pipe Strength

The underdrain collection piping was analyzed for compressive ring thrust, ring deflection, and wall buckling. Calculations presented in Attachment 8 demonstrate the piping is structurally stable under the full loading of the CCR Unit; therefore, the bedded underdrain pipe is protected against stresses and disturbances from overlying CCR, soil fill, and equipment operations.

ATTACHMENT 1

DEQ PART A PERMIT APPLICATION CONDITIONAL APPROVAL LETTER AND FIGURES



Commonwealth of Virginia

VIRGINIA DEPARTMENT OF ENVIRONMENTAL QUALITY

www.deq.virginia.gov

Travis A. Voyles Secretary of Natural and Historic Resources Michael S. Rolband, PE, PWD, PWS Emeritus
Director

December 19, 2024

VIA ELECTRONIC MAIL

Mr. Dennis Slade
Corporate Manager, Waste and Remediation
Dominion Energy Environmental Services
120 Tredegar Street
Richmond, VA 23219
dennis.a.slade@dominionenergy.com

Subject: Bremo Bluff FFCP Management Facility, Solid Waste Permit No. (SWP) 627

Part A Application Approval Bremo Bluff, Virginia

Dear Mr. Slade:

The Virginia Department of Environmental Quality (DEQ) Valley Regional Office is in receipt of the following documentation:

"Part A Permit Application: Bremo Bluff Fossil Fuel Combustion Products (FFCP) Management Facility," prepared by AECOM. The application was received by DEQ on July 6, 2021, with revisions received on October 1, 2021, April 7, 2022, July 8, 2022, August 24, 2022, March 6, 2024, and June 28, 2024.

VWP Individual Permit No. 21-2305 issued by DEQ and dated March 30, 2023.

Section 404 Permit NAO-2020-01000 (VRMC #21-V2305) issued by U.S. Army Corps of Engineers and dated January 12, 2024.

"Dominion Energy Bremo Bluff Fossil Fuel Combustion Products Management Facility, Solid Waste Permit #627; Variance Request to Part A Solid Waste Permit Siting Requirements," prepared by Dominion Energy Services, Inc., and dated June 28, 2024, which was approved by DEQ on November 12, 2024.

The application addressed the suitability of a new captive industrial CCR landfill with a waste management area of 73 acres located inside a 125-acre facility boundary.

Mr. Dennis Slade Bremo Bluff FFCP Management Facility, SWP627 Part A Application Approval December 19, 2024; Page 2 of 3

In accordance with § 9 VAC 20-81-450.A, B, and C, § 9 VAC 20-81-460, § 9 VAC 20-81-120, § 9 VAC 20-81-810.A.1 of the Virginia Solid Waste Management Regulations (VSWMR, 9 VAC 20-81-10, *et seq.*), the Part A Application has been reviewed for technical adequacy and regulatory compliance.

DEQ deems the application to be complete and technically adequate. Pursuant to § 9 VAC 20-81-450.C.3 of the VSWMR, the approval of the Part A Application is subject to the following conditions, which must be met in order to maintain the validity of this approval.

- 1. The facility boundary (125 acres) and the waste management boundary (73 acres) are limited to those areas identified as the "Facility Boundary" and "Waste Management Boundary" respectively, on the Facility Near Vicinity Map: Index Map and Maps A1-A3 & B1-B3, last revised May 30, 2024, as well as on Figure 1 Landfill Boundaries, dated February 18, 2024.
- 2. This Part A approval letter, the Near Vicinity Map(s), last revised May 30, 2024, and Figure 1 Landfill Boundaries dated February 18, 2024, shall be included with the Part B permit application as Attachment 1 to the Design Report. The Part B permit application must discuss how the conditions described in this Part A approval letter have been met.
- 3. Prior to construction, any piezometers or monitoring wells located within the proposed waste management area shall be completely removed by removing the casing or overdrilling of the wellbore, followed by pressure grouting methods to the ground surface.
- 4. All vehicle traffic to the landfill should be on roads internal to the facility. Should traffic access change to utilize public roads, a copy of the adequacy report required under 9VAC 20-81-460.G that is submitted to the Virginia Department of Transportation (VDOT) and a VDOT approval letter shall be included in the Part B application.
- 5. The highest elevation of any point on the landfill is limited to 525 feet or less above mean sea level (AMSL). The Part B permit application cannot be submitted for a highest elevation of the top of the landfill beyond the elevation 525 feet AMSL.
- 6. The daily disposal limit for the Bremo Bluff FFCP Management Facility is 15,000 tons per day. This limit is subject to decreasing during the Part B permit application process depending on the planning and permitting for the equipment and other operational needs of the facility.
- 7. During Part B design the disposal cells and the leachate storage system layout and location must be within the waste management boundary that is delineated in the Part A application. Also, the disposal capacity, considering the maximum build-out, must be equal to or less than 7,600,000 cubic yards. This is the capacity requested in the Part A application. The depth of the base grades for the disposal area are limited to a lowest elevation of 312 feet AMSL.

Mr. Dennis Slade Bremo Bluff FFCP Management Facility, SWP627 Part A Application Approval December 19, 2024; Page 3 of 3

- 8. All containment structures, including liners, leachate collection systems, and surface water control systems shall be designed to resist the maximum horizontal ground acceleration, with a 10% or greater probability of occurring in 250 years, for this site. The value was estimated to be 0.197g in the seismic analysis submitted with the Part A application. The Part B design analysis must be performed using the maximum horizontal acceleration of 0.197g or more.
- 9. The Part B design should address any requirements of the Wetland and Stream Impact permits issued and any approved variances.

If you should have questions regarding this matter, please contact JengHwa Lyang, Solid Waste Permit Writer, at 540-830-8837 or at jenghwa.lyang@deq.virginia.gov.

Sincerely,

Laura Stuart, P.G.

Land Protection Program Manager

Virginia Department of Environmental Quality

540-209-5605

laura.stuart@deq.virginia.gov

Lam Street

Valley Regional Office

4411 Early Road, P.O. Box 3000

540-574-7800

cc: (via email)

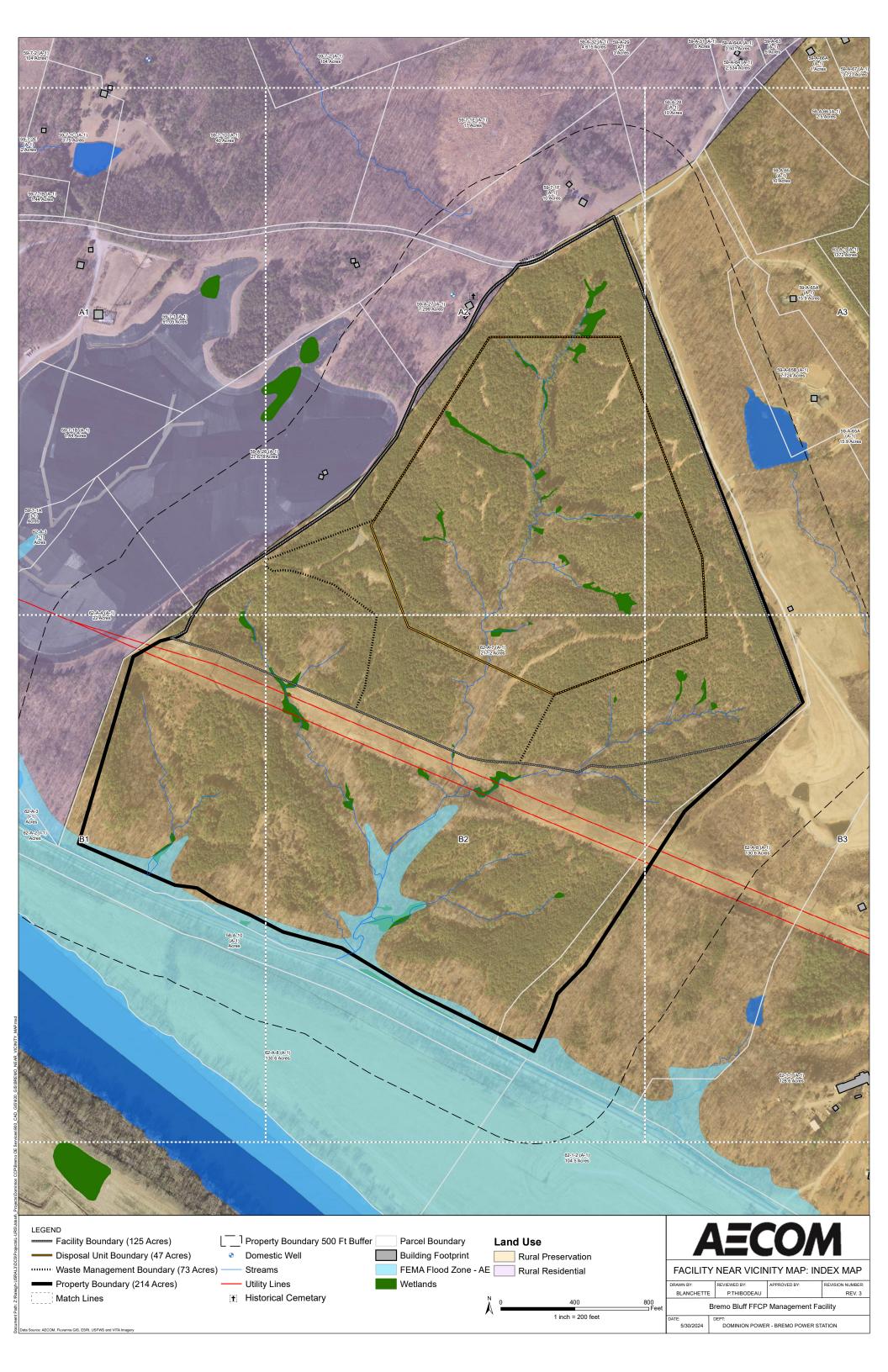
Jenny Poland, DEQ CO, Solid Waste Permit Coordinator, <u>jenny.poland@deq.virginia.gov</u> Geoff Christe, DEQ CO, Groundwater Coordinator, <u>geoff.christe@deq.virginia.gov</u>

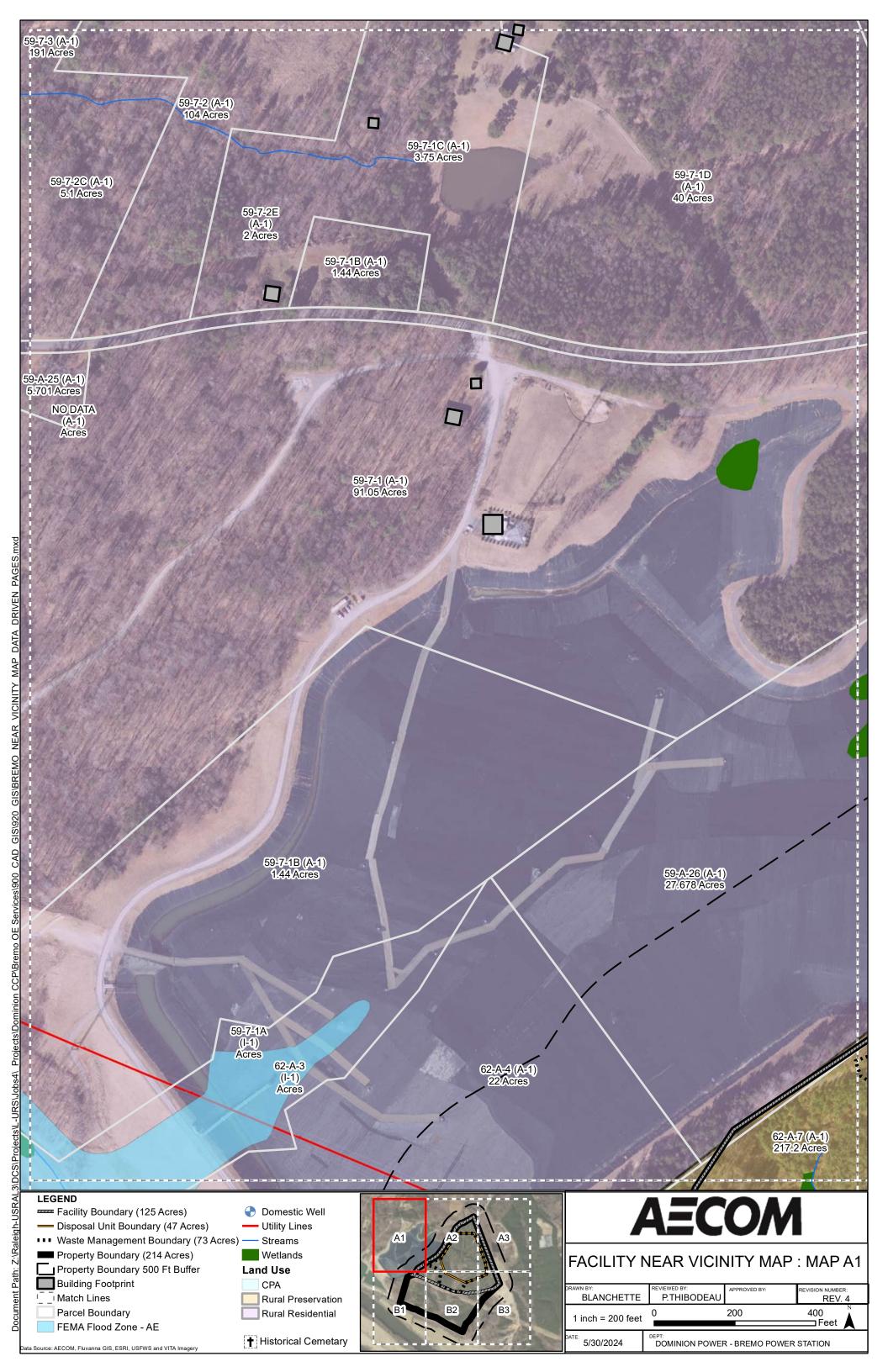
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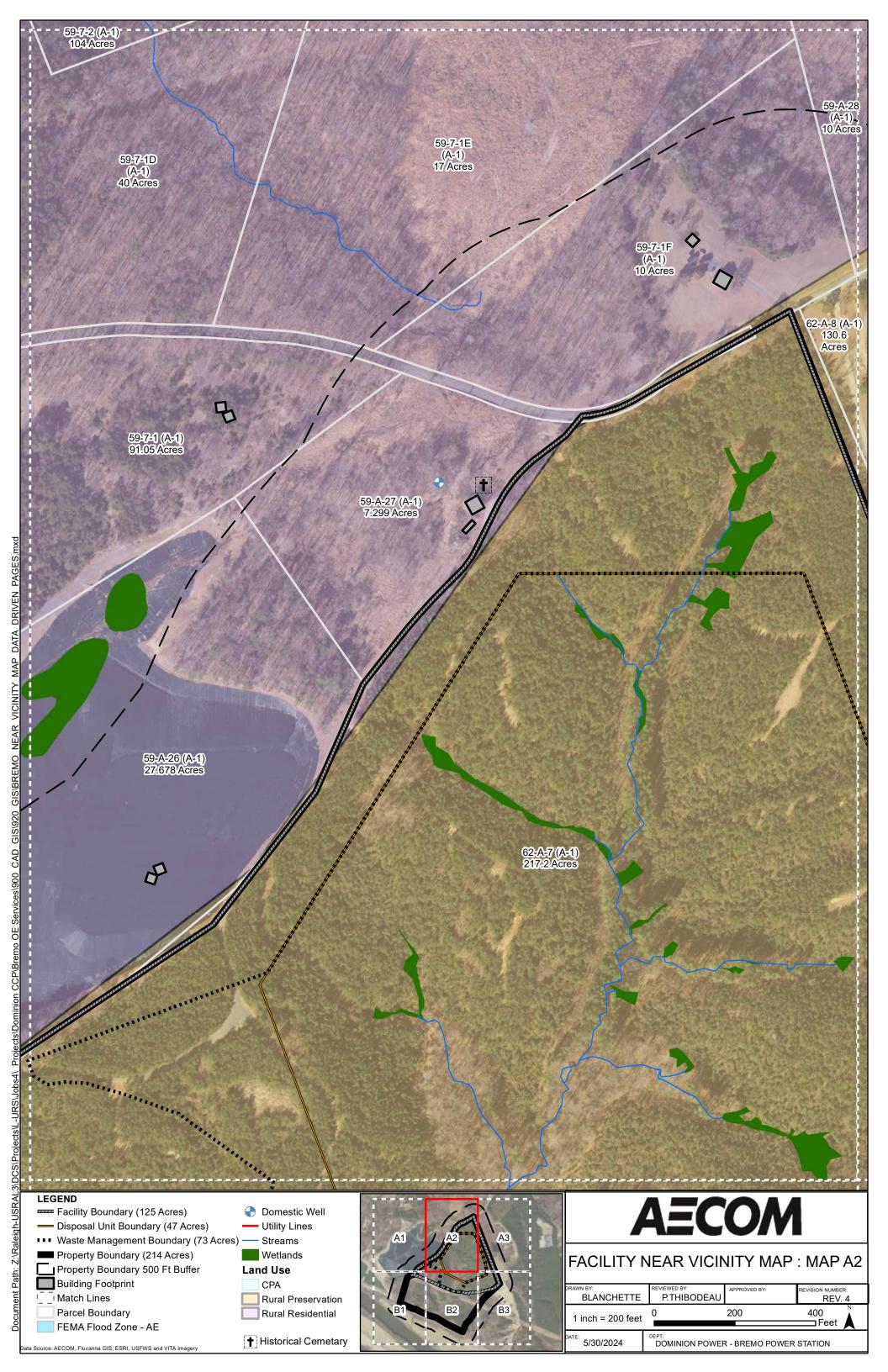
David Shaw, DEQ VRO, Solid Waste Compliance Inspector, <u>david.shaw@deq.virginia.gov</u> JengHwa Lyang, Ph.D., P.E., DEQ VRO, Solid Waste Permit Writer,

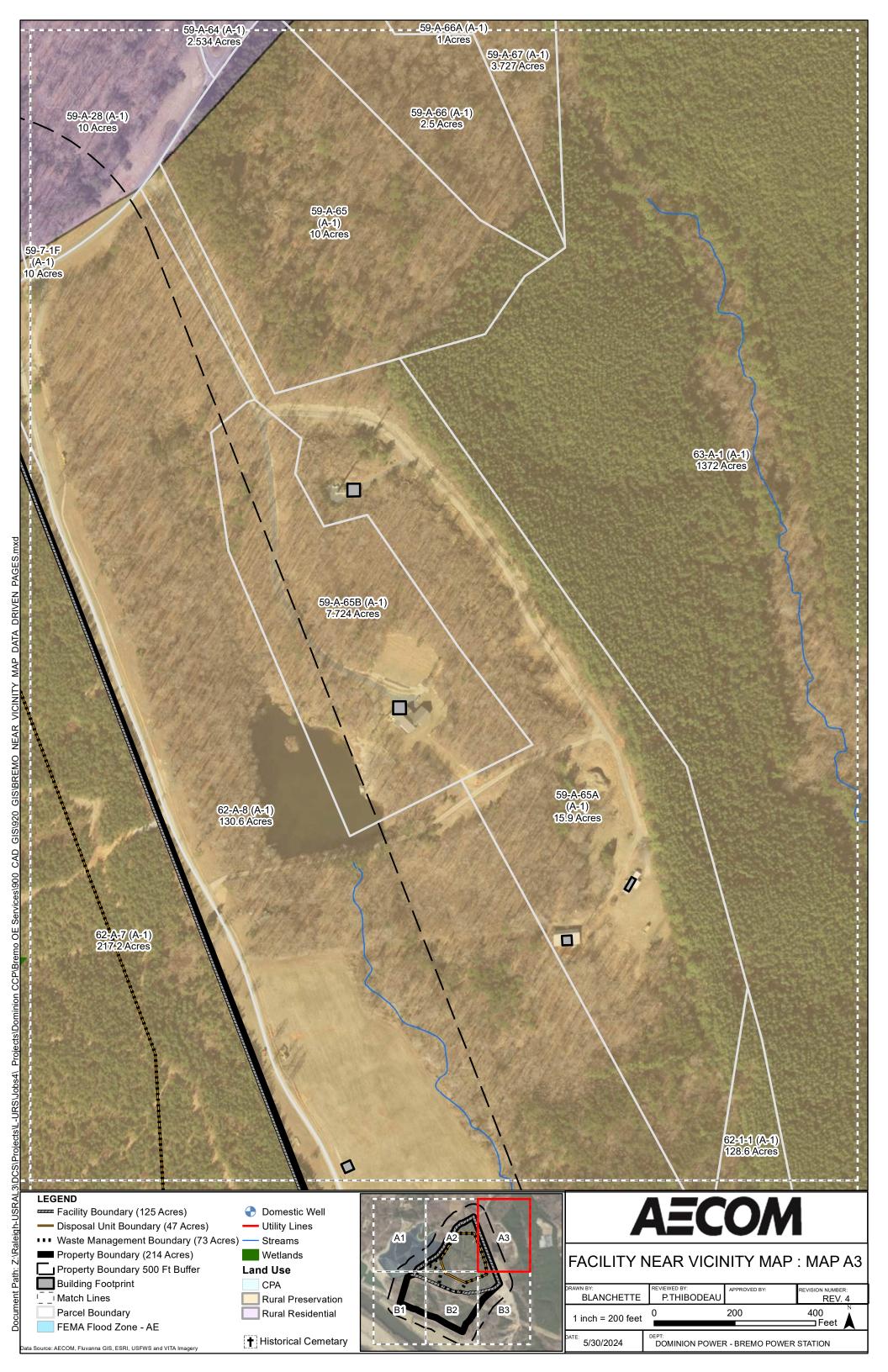
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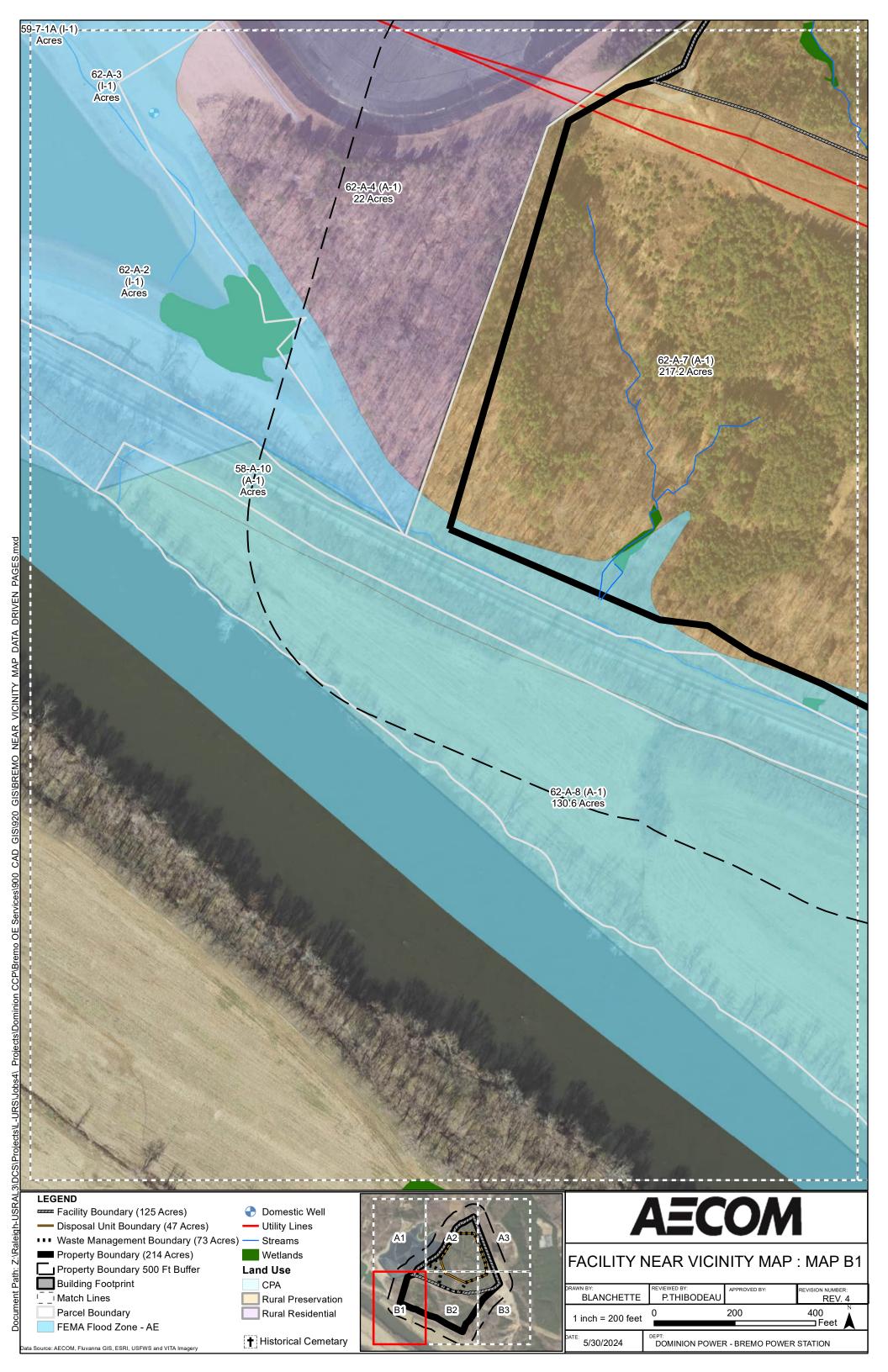
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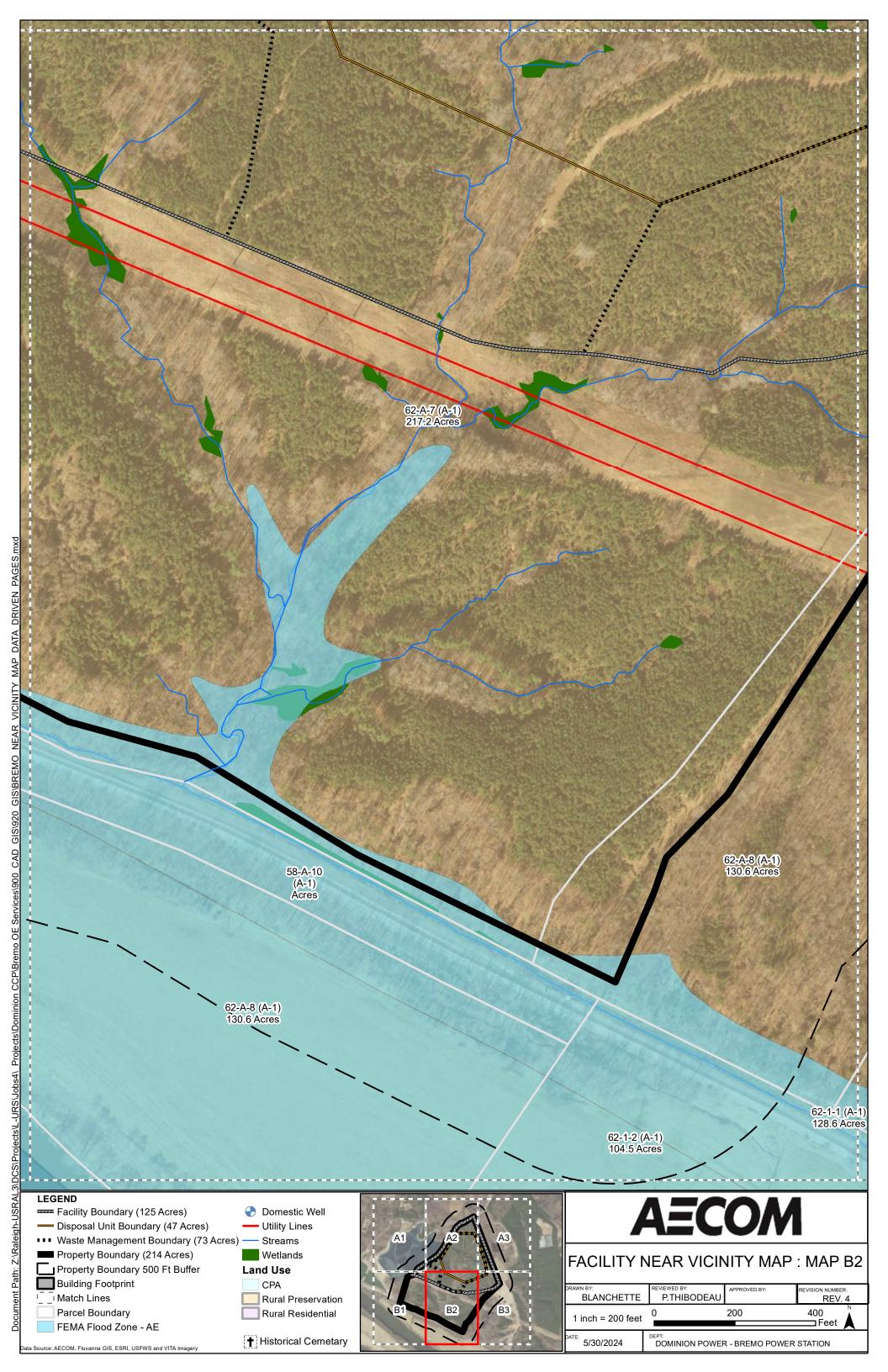


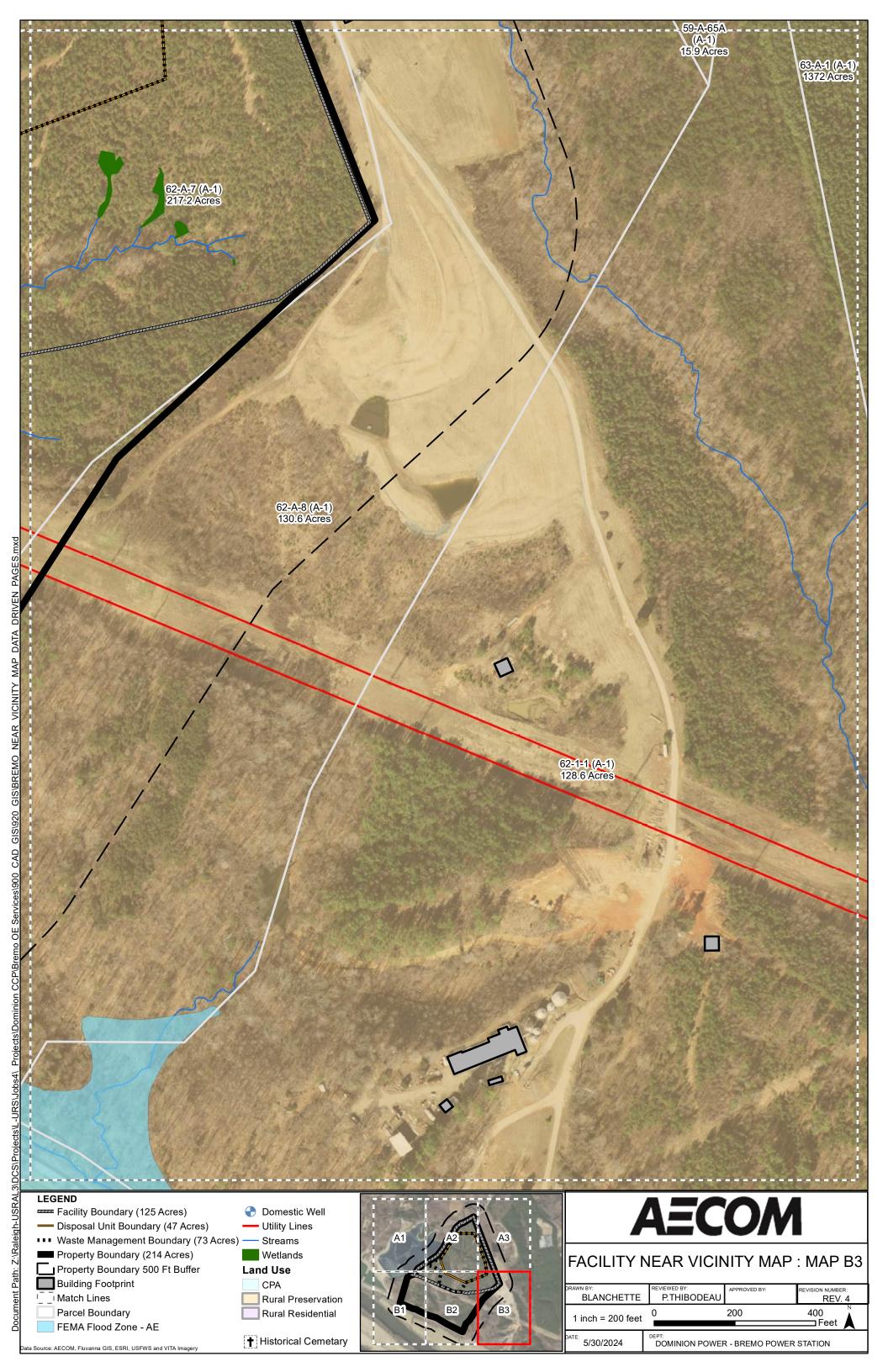


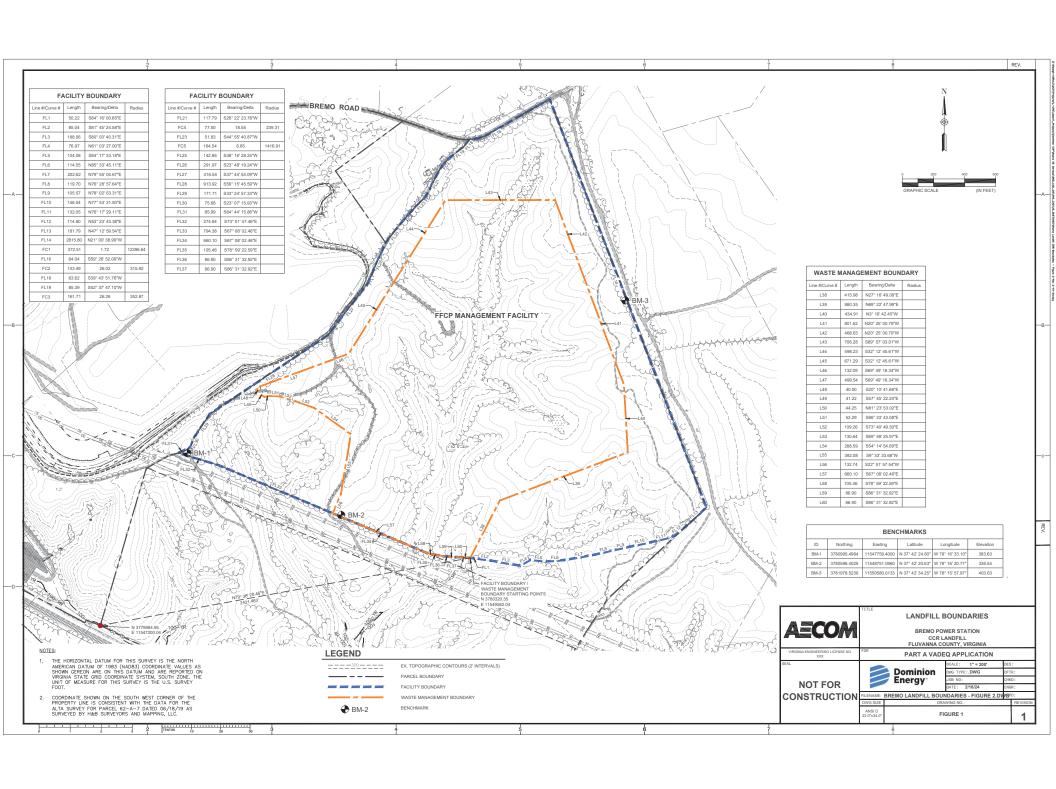












ATTACHMENT 2 BORROW AND STOCKPILE ESTIMATES

Bremo Bluff FFCP Management Facility Borrow and Stockpile Estimates

Total Earthworks	Volume (cy)
Cut	1,057,200
Fill	1,032,735
Net	24,465

Stockpile Areas	Available Volume (cy)
Stockpile 1	10,000
Stockpile 2	60,000
Total	70,000

Borrow Areas	Available Volume (cy)
Borrow Area 1	92,800
Borrow Area 2	13,000
Borrow Area 3	62,200
Borrow Area 4	61,500
Borrow Area 5	79,100
Total	308,600

Soil Needs	Volume (cy)
Intermediate Cover	76,000
Final Cover	152,000
Contingency (20%)	45,600
Total	273,600

FINAL EARTHWORKS (Soil Balance)	Volume (cy)
Total Available On-Site Soil	333,065
Total Soil Needs	273,600
Net Available Soil	59,465

ATTACHMENT 3

LINER FOUNDATION ANALYSES

Settlement Potential Analysis Bearing Capacity Analysis Stability Analysis





Calculations					
PROJECT: Bremo Bluff FFCP Management Facility	REFERENCE NO: 22130437.031				
SUBJECT: Settlement Analysis	DATE : 02/01/2024				

The objective of this analysis is to calculate the potential settlement of the foundation soil below the proposed Coal Combustion Residuals (CCR) Unit at the Bremo Bluff Fossil Fuel Combustion Products (FFCP) Management Facility (Facility) and estimate the impact of the differential settlement on the proposed bottom liner and leachate collection system.

2.0 METHODOLOGY

The modified Schmertmann method was used to estimate settlement of foundation soils, which was computed based on the proposed grades outlined in Attachment III of the Part B Permit Application (Design Plans) at locations along the leachate collection piping, as shown in Figure 1.

The changes in the floor grades are calculated using differential settlement between each point. The slopes of the leachate pipes were considered pre- and post-settlement to determine if the differential settlement will have any negative impacts on the proposed bottom liner and leachate flow.

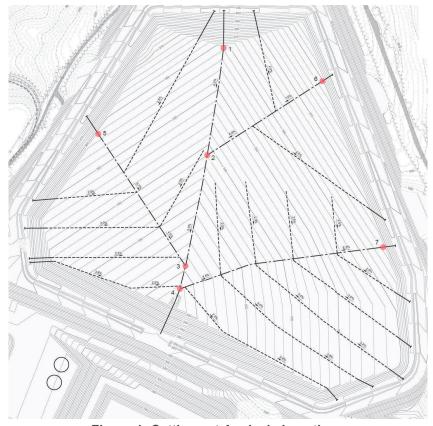


Figure 1: Settlement Analysis Locations

3.0 ASSUMPTIONS

Settlement calculations were based on the following assumptions and input parameters:

- Elastic settlement of granular foundation soils beneath the landfill footprint follows the model outlined by Schmertmann (Schmertmann, 1970) for shallow foundations of bridges.
- Thickness and unit weight of the bottom liner system and final cover system were not considered, as their impact is negligible compared to the height of CCR waste.
- Existing ground elevations were taken from the aerial survey completed by McKenzie Snyder, Inc. on March 24, 2019.
- Base grade and final grade elevations were based on the grading in the Design Plans.
- Subsurface data were based on previous subsurface investigations and test results (AECOM, 2022).
 - Subsurface materials consist primarily of silty sands or sand-silt mixtures (Unified Soil Classification System SM) and bedrock.
 - Soil excavated above the base grades, remaining below the base grades, and used as structural fill to establish base grades were assigned properties consistent with the SM material on-site; a unit weight of 112 pounds per cubic foot (pcf) based on the United States Department of Interior Bureau of Reclamation's Design of Small Dams Unified Soil Classification System (USBR, 1987) for SM material.
 - The bedrock is assumed to be incompressible.
 - The remaining materials were assumed to respond in a similar fashion to the SM soils.
 - The elastic modulus (Es) for the SM soils was assumed to be 300 kips per square foot (ksf).
- Groundwater elevations were based on measurements from January 2022, included in the Part A Application (by others).
- The influence factor outlined in the Schmertmann method is equal to 1 for large footprints overlying relatively shallow bedrock.
- A time period of 30 years was considered to represent a 30-year post-closure timeframe.
- CCR waste was assigned a unit weight of 110 pcf based on results presented in the Bremo Power Station CCR Surface Impoundments, Impounding Structure Design Report, DCR Inventory #06520 (Golder, 2017).

4.0 CALCULATIONS

4.1 Primary Consolidation

The immediate settlement of the CCR Unit due to the SM foundation soils is estimated by the modified Schmertmann method using the following equation:

$$S_i = C_1 C_2 \Delta p \sum_{i=1}^n \left(H_i \left(\frac{I_z}{E_{S_i}} \right) \right)$$

where:

$$C_1 = 1 - 0.5 \left(\frac{p_0}{\Delta p}\right) \ge 0.5$$
 $C_2 = 1 + 0.2 \log_{10} \left(\frac{t(yrs)}{0.1}\right)$

Design Report Settlement Analysis

and:

 S_i = Elastic settlement

 C_1 = Correction factor accounting for the embedment of a shallow foundation

 C_2 = Correction factor accounting for creep in settlement with time (t)

 p_0 = Vertical overburden stress at the midpoint of each subsurface layer

 Δp = Change in vertical overburden stress imparted by the landfill at the midpoint of each subsurface layer

 H_i = Thickness of each subsurface soil layer

 I_z = Influence factor based on the depth of each subsurface layer

 E_s = Modulus of elasticity for each layer

For this calculation, the C_1 correction factor is neglected (*i.e.*, assumed to be 1) because there is no strain relief in subsurface soils for typical foundation construction. Table 1 below outlines the input data for the calculations.

Table 1: Settlement Analysis Input Data

Parameters	Settlement Points						
Parameters	1	2	3	4	5	6	7
Bedrock [feet above mean sea level (ft AMSL)]	338.3	316.3	294.6	288.0	336.3	359.5	331.4
Existing Ground (ft AMSL)	345.4	320.4	297.8	284.3	373.7	396.9	389.4
Existing Groundwater (ft AMSL)	343.6	319.3	288.9	285.1	343.5	368.8	350.3
Proposed Base Grades (ft AMSL)	358.4	338.1	320.7	317.4	357.6	379.7	366.6
Proposed Final Grades (ft AMSL)	455.7	507.9	440.5	414.4	408.0	409.4	397.9
Embedment Depth Correction Factor, C ₁	1	1	1	1	1	1	1
Creep Correction Factor, C ₂	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Net Surcharge, Δp (psf)	12,156	20,666	15,737	14,377	3,737	1,340	894
Layer Thickness, H (ft)	20.0	21.9	26.0	29.4	21.3	20.3	35.2
Modulus of Elasticity, Es (ksf)	300	300	300	300	300	300	300

5.0 RESULTS

Calculations at the analyzed points under the proposed CCR Unit grades yield settlements ranging from 0.14 feet (ft) to 2.25 ft, as shown below in Table 2.

Table 2: Settlement Results

Pagulta	Settlement Points						
Results	1	2	3	4	5	6	7
Settlement (ft)	1.21	2.25	2.04	2.11	0.40	0.14	0.16
Final Base Grades (ft AMSL)	357.1	335.8	318.6	315.3	357.2	379.6	366.5

Due to the differential settlement of the base grades, the leachate piping slopes are expected to increase overall. The slope of the leachate header pipe from Points 2 to 4 decreases slightly (an initial slope of 3.40% to a final slope of 3.37%); however, the post-settlement slope is maintained above the minimum 2% slope for leachate

Design Report Settlement Analysis

drainage and promotes the positive flow of leachate through the system. The impacts of settlement on the leachate piping are summarized below in Table 3.

Table 3: Leachate Piping Results

Results	Points 1 to 2	Points 2 to 4	Points 1 to 4	Points 5 to 3	Points 6 to 2	Points 7 to 4
Initial, Pre-Settlement Slope (%)	4.19	3.40	3.75	5.25	6.81	5.30
Final, Post-Settlement Slope (%)	4.40	3.37	3.83	5.48	7.15	5.51

The allowable yield elongation for the 60-mil high-density polyethylene (HDPE) geomembrane in the bottom liner system is 12%, in accordance with the minimum value specified in Attachment VII of the Part B Permit Application (Technical Specifications) and manufacturer-reported data. The maximum calculated tensile strain is between Points 6 and 2 and is 0.0241%, thus yield elongation due to differential settlement is considered to be negligible.

Table 4: Bottom Liner Results

Results	Points 1 to 2	Points 2 to 4	Points 1 to 4	Points 5 to 3	Points 6 to 2	Points 7 to 4
Initial, Pre-Settlement Length (ft)	484.42	610.35	1,093.77	704.97	612.41	931.30
Final, Post-Settlement Length (ft)	484.47	610.35	1,093.80	705.06	612.56	931.41
Tensile Strain (%)	0.0092	-0.0008	0.0031	0.0125	0.0241	0.0113

Based on these calculations, it is not anticipated that differential settlement will have a negative impact on the performance of the bottom liner or leachate collection systems for the CCR Unit.

References:

- (1) AECOM (AECOM, 2022). Hydrogeologic and Geotechnical Report: Proposed Solid Waste Management Facility, Bremo Power Station, Rev. 1. August 19, 2022.
- (2) Golder Associates (Golder, 2017). Bremo Power Station CCR Surface Impoundments, Impounding Structure Design Report, DCR Inventory #06520. March 2015, Revised March 2017.
- (3) Schmertmann, J.H. (Schmertmann, 1970). "Static Cone to Compute Static Settlement Over Sand," Journal of Soil Mechanics & Foundations Division, 96(3), 1,011-1,043.
- (4) United States Department of Interiors Bureau of Reclamation (USBR, 1987). Design of Small Dams, Third Edition, 1987.





Calculations					
PROJECT: Bremo Bluff FFCP Management Facility	REFERENCE NO: 22130437.031				
SUBJECT: Bearing Capacity Analysis	DATE : 02/01/2024				

The objective of this analysis is to calculate the bearing capacity of the foundational soils below the proposed Coal Combustion Residuals (CCR) Unit at the Bremo Bluff Fossil Fuel Combustion Products (FFCP) Management Facility (Facility).

2.0 METHODOLOGY

The Terzaghi-Meyerhof method for calculating ultimate bearing capacity for a shallow continuous footing was used for this analysis. A factor of safety (FS) was calculated based on the anticipated maximum pressure exerted by the CCR Unit on the foundation soils.

3.0 ASSUMPTIONS

Bearing capacity calculations were based on the following assumptions and input parameters:

- Thickness and unit weight of the bottom liner system and final cover system were not considered, as their impact is negligible compared to the height of CCR waste.
- Existing ground elevations were taken from the aerial survey completed by McKenzie Snyder, Inc. on March 24, 2019.
- Base grade and final grade elevations were based on the grading in Attachment III of the Part B Permit Application (Design Plans).
- The maximum CCR waste thickness was estimated to be approximately 175 feet.
- CCR waste was assigned a unit weight of 110 pcf based on results presented in the Bremo Power Station CCR Surface Impoundments, Impounding Structure Design Report, DCR Inventory #06520 (Golder, 2017).
- Subsurface data were based on previous subsurface investigations and test results (AECOM, 2022).
 - Subsurface materials consist primarily of silty sands or sand-silt mixtures (Unified Soil Classification System Soil SM) and bedrock.
 - Soil excavated above the base grades, remaining below the base grades, and used as structural fill to establish base grades were assigned properties consistent with the SM material on-site; a unit weight of 112 pounds per cubic foot (pcf) and an estimated strength of 33.6 degrees based on the United States Department of Interior Bureau of Reclamation's Design of Small Dams Unified Soil Classification System (USBR, 1987) for SM material. The cohesion was conservatively assumed to be 0 psf.
- The base width of the foundation was estimated to be 1,150 feet.
- The footprint of the CCR Unit was assumed to behave as a continuous footing since the length in one dimension is larger than the perpendicular dimension.

4.0 CALCULATIONS

The following equation is used to compute the ultimate bearing capacity:

Design Report Bearing Capacity Analysis

$$q_{ult} = cN_c + \gamma DN_q + (\gamma B/2)N_{\gamma}$$

Because D, the depth of the footing, is equal to 0 feet and c, the cohesion of the SM soil, is equal to 0 psf, the equation reduces to:

$$q_{ult} = (\gamma B/2)N_{\gamma}$$

Where:

 N_{γ} = Meyerhof bearing capacity factor of γ for general shear $[\Theta = 33.6^{\circ}] = 29.2$

Therefore;

$$q_{ult} = 1,880,480 psf$$

The expected pressure from the CCR Unit does not include load dispersion with depth of soil layer, or dispersion of load throughout the mass of the CCR Unit; therefore, the calculation of the applied load (sum of upper layers) placed directly on the soil is considered conservative.

Based on the estimated maximum thickness and unit weight of CCR waste, the approximate pressure exerted by the CCR Unit is 19,250 psf.

5.0 RESULTS

These values yield an FS against bearing capacity failure of 97.7; therefore, the bearing capacity of the underlying soils will not be exceeded by the expected loading by the CCR Unit.

References:

- (1) AECOM (AECOM, 2022). Hydrogeologic and Geotechnical Report: Proposed Solid Waste Management Facility, Bremo Power Station, Rev. 1. August 19, 2022.
- (2) Golder Associates (Golder, 2017). Bremo Power Station CCR Surface Impoundments, Impounding Structure Design Report, DCR Inventory #06520. March 2015, Revised March 2017.
- (3) Professional Publications, Inc. Civil Engineering Reference Manual for the PE Exam, Eleventh Edition, 2008.
- (4) United States Department of Interiors Bureau of Reclamation (USBR, 1987). Design of Small Dams, Third Edition, 1987.





Calculations					
PROJECT: Bremo Bluff FFCP Management Facility	REFERENCE NO: 22130437.031				
SUBJECT: Stability Analysis	DATE : 02/01/2024				

The objective of this analysis is to calculate the global stability for the proposed Coal Combustion Residuals (CCR) Unit at the Bremo Bluff Fossil Fuel Combustion Products (FFCP) Management Facility (Facility) assuming maximum CCR waste elevations and final cover conditions.

2.0 METHODOLOGY

The computer program Slide2 Modeler Version 9.027 (Rocscience, 2023) was used to evaluate the stability of the proposed CCR Unit. The Morgenstern and Price generalized limit equilibrium (GLE) method (Morgenstern et al., 1965), which divides the resisting forces by the driving forces along the critical slip surface, and the Bishop Simplified method (Bishop, 1955), which assesses vertical force and moment equilibrium for each slice along the critical slip surface, were used to calculate the minimum factor of safety (FS). Circular, block, and non-circular slip surfaces were analyzed, and the lowest calculated FS from these surfaces and methods was used to identify the critical slip surface. The Slide2 Modeler focuses on slip surfaces causing global instability of the slope, so localized and surficial slip surfaces were excluded. Three cross-sections considered to be the most critical were identified for the CCR Unit, as shown in Figure 1, and analyzed with the proposed design parameters.

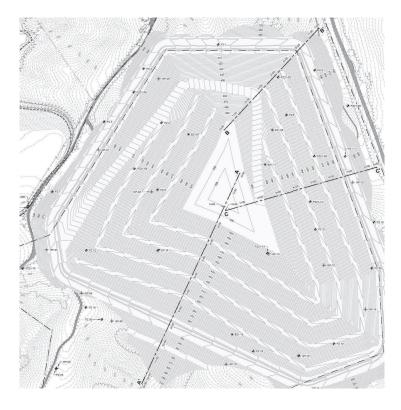


Figure 1: Stability Analysis Cross-Section Locations

Design Report Stability Analysis

Per the federal Environmental Protection Agency's (EPA's) Solid Waste Disposal Criteria Technical Manual (EPA, 1998), a pseudo-static slope stability analysis is required. According to the United States Geological Service Earthquake Hazard Program website (USGS, 2023), the peak ground acceleration (PGA) at this site for a 2,475-year return period earthquake event corresponding with a 2% probability of exceedance in 50 years is 0.1987g, which is above the 0.1g threshold.

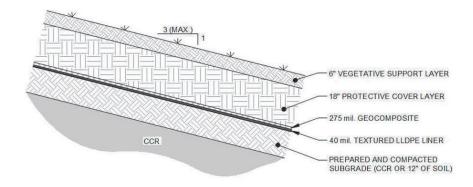
As recommended in the EPA's Resource Conservation and Recovery Act (RCRA) Subtitle D Seismic Design Guidance (Richardson et al., 1995), the screening method presented by Hynes-Griffin and Franklin (Hynes-Griffin et al., 1984) provides for the use of a seismic coefficient based on one-half the PGA (0.1g) and a 20% shear strength reduction in those materials impacted by the seismic loading.

3.0 ASSUMPTIONS

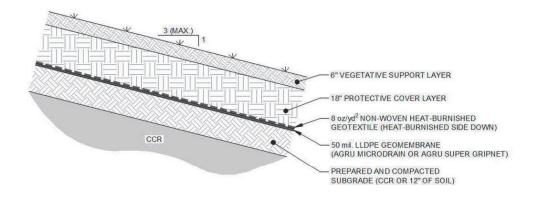
Stability calculations were based on the following assumptions and input parameters:

- Existing ground elevations were taken from the aerial survey completed by McKenzie Snyder, Inc. on March 24, 2019.
- Base grade and final grade elevations were based on the grading in Attachment III of the Part B Permit Application (Design Plans).
- Subsurface data were based on previous subsurface investigations and test results (AECOM, 2022).
- CCR waste was assigned a unit weight of 110 pounds per cubic foot (pcf), an estimated strength of 34 degrees, and a cohesion of 0 pounds per square foot (psf) based on results presented in the Bremo Power Station CCR Surface Impoundments, Impounding Structure Design Report, DCR Inventory #06520 (Golder, 2017).
- The final cover and bottom liner systems are shown below in Figures 2, 3, and 4.
 - The "Vegetative Support Layer" and "Protective Cover Layer" in the final cover system were
 assigned a unit weight 112 pcf and an estimated strength of 33.6 degrees, which is
 consistent with the United States Department of Interior Bureau of Reclamation's Design of
 Small Dams Unified Soil Classification System (USBR, 1987) for the silty sands or sand-silt
 mixtures (SM) on-site. The cohesion was conservatively assumed to be 0 psf.
 - The "Prepared and Compacted Subgrade" in the final cover system was conservatively
 assumed to be 12 inches of soil and assigned a unit weight 112 pcf and an estimated
 strength of 33.6 degrees, which is consistent with the United States Department of Interior
 Bureau of Reclamation's Design of Small Dams Unified Soil Classification System (USBR,
 1987) for the SM material on-site. The cohesion was conservatively assumed to be 0 psf.
 - The geosynthetic components in the final cover system and bottom liner system were modeled as 6-inch-thick layers and controlled by the weakest interface shear strength.
 - The internal geosynthetic clay liner (GCL) for the top deck of the final cover system
 was conservatively assigned an estimated strength of 13.5 degrees and a cohesion
 of 0 psf based on Schnabel's experience with direct shear strengths for
 soil-geosynthetic and geosynthetic-geosynthetic interface strengths for similar
 projects.
 - The textured geomembrane liner and geotextile for the sideslopes of the final cover system was assigned an estimated minimum strength of 25.9 degrees and a cohesion of 0 psf, as determined in the Veneer Stability calculation included in Attachment IV of the Part B Permit Application (Closure Plan).
 - The internal GCL for the bottom liner system was assigned an estimated peak strength of 13.5 degrees and a cohesion of 0 psf based on Schnabel's experience.

- Properties for aggregate in the bottom liner system were derived from the Field Engineer's Manual (Parmley, 1995).
- Soil remaining below the base grades was assigned properties consistent with the SM material on-site; a unit weight 112 pcf, an estimated strength of 33.6 degrees based on the United States Department of Interior Bureau of Reclamation's Design of Small Dams Unified Soil Classification System (USBR, 1987) for SM material. The cohesion was conservatively assumed to be 0 psf.
- Groundwater elevations were based on measurements from January 2022, included in the Part A Application (by others).

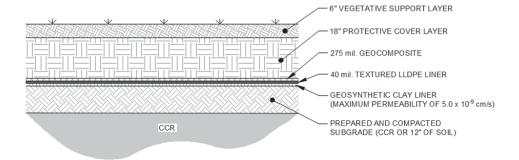


OPTION 1

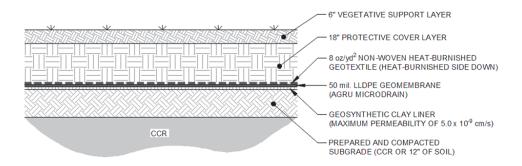


OPTION 2

Figure 2: Final Cover System Details for Sideslope Areas

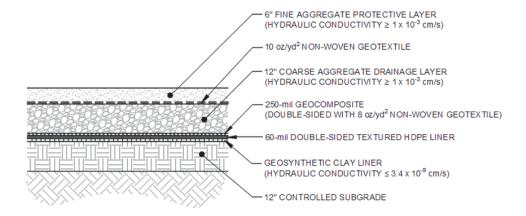


OPTION 1

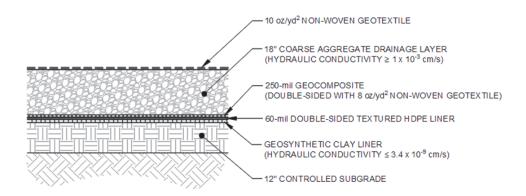


OPTION 2

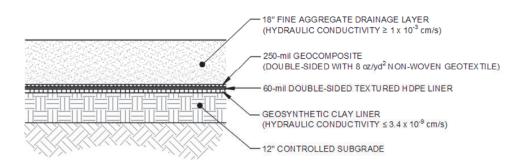
Figure 3: Final Cover System Details for Top Deck Areas



OPTION 1



OPTION 2A



OPTION 2B

Figure 3: Bottom Liner System Details

Material properties are summarized below in Table 1.

Table 1: Summary of Selected Material Properties

Material	Unit Weight	Peak Strength (Static)		Peak Strength (Seismic) ¹	
Material	(pcf)	Phi, φ' (deg)	Cohesion, c' (psf)	Phi, φ' (deg)	Cohesion, c' (psf)
Vegetative Cover Soil	112	33.6	0	28.0	0
Protective Cover Soil	112	33.6	0	28.0	0
Final Cover System Interface (Top Deck)	112	13.5	0	10.9	0
Final Cover System Interface (Sideslopes)	112	25.9	0	21.2	0
Controlled Subgrade	112	33.6	0	28.0	0
CCR ²	110	34.0	0	28.4	0
Granular Material	120	30.0	0	24.8	0
Bottom Liner Interface	120	13.5	0	10.9	0
Structural Fill	112	33.6	0	28.0	0
Native Soils	112	33.6	0	28.0	0
Weathered Rock	140	31.0	1000	25.7	800
Competent Rock	165	Infinite Strength			

Notes: ¹Used in seismic analyses for material(s) impacted by seismic loading.

4.0 ANALYSIS

With a maximum slope inclination of 3H:1V (horizontal to vertical), the FS was calculated along the critical failure surface, *i.e.* the failure surface yielding the lowest FS. A cross-section depicting the geometry of the CCR Unit and the critical slip surface is shown in Figure 5 below.

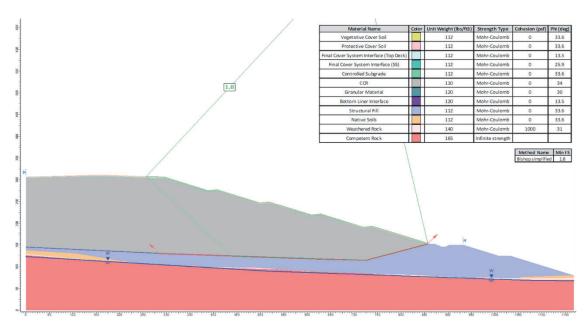


Figure 5: Global Slope Stability Cross-Section

²These strengths assume operational controls maintain a well-draining waste mass that does not include significant perched fluid pressures.

5.0 RESULTS

The minimum allowable FS for the global stability analyses was defined as 1.5 for long-term static conditions and 1.0 for seismic conditions. The calculated FS for static conditions and seismic conditions meet the required minimum FS and indicate that the FS against slope failure is satisfactory in a static and seismic case for the evaluated sections with the designed geometry. The results of the analyses are summarized below in Table 2 and further presented in the attached figures.

Analysis	Target Minimum FS	Cross-Section	Calculated Minimum FS	Attachment
		A-A'	1.8	A-1
Static	1.5	B-B'	2.1	B-1
		C-C'	1.9	C-1
		A-A'	1.1	A-2
Seismic	1.0	B-B'	1.2	B-2
		C-C'	1.2	C-2

Table 2: Results of Stability Analyses

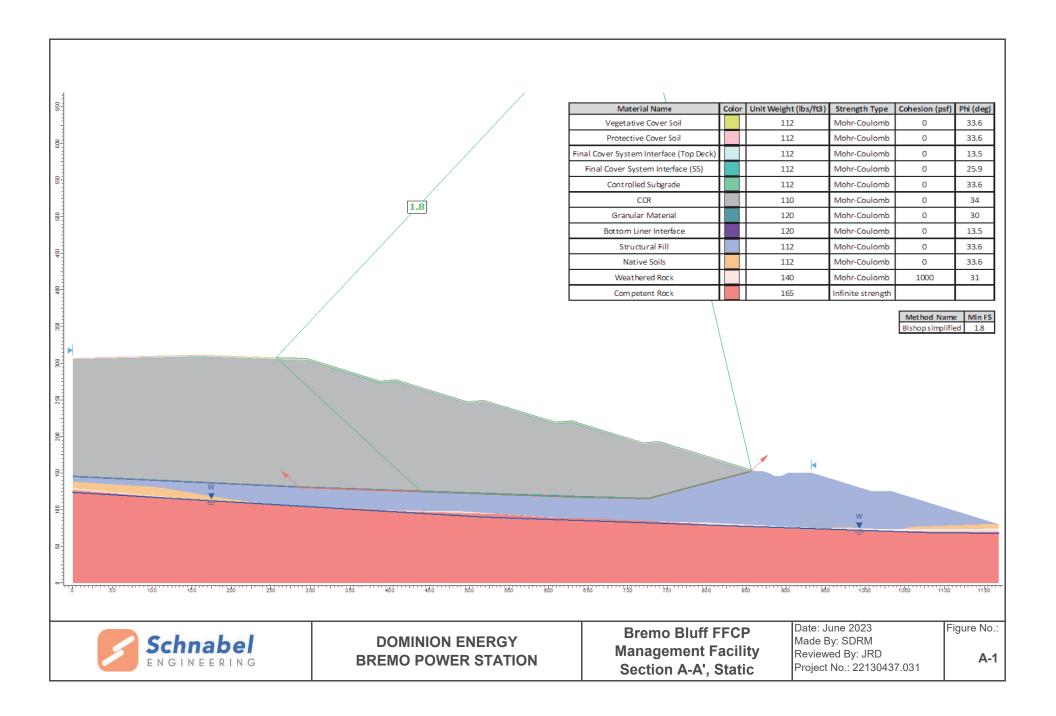
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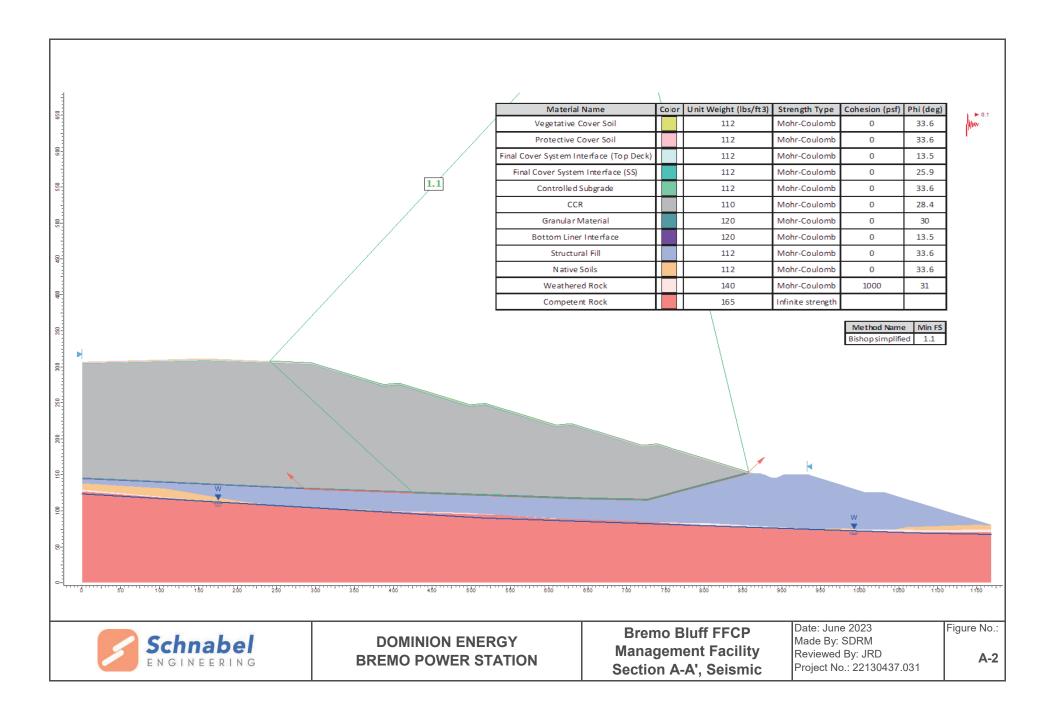
(1) Slide Output

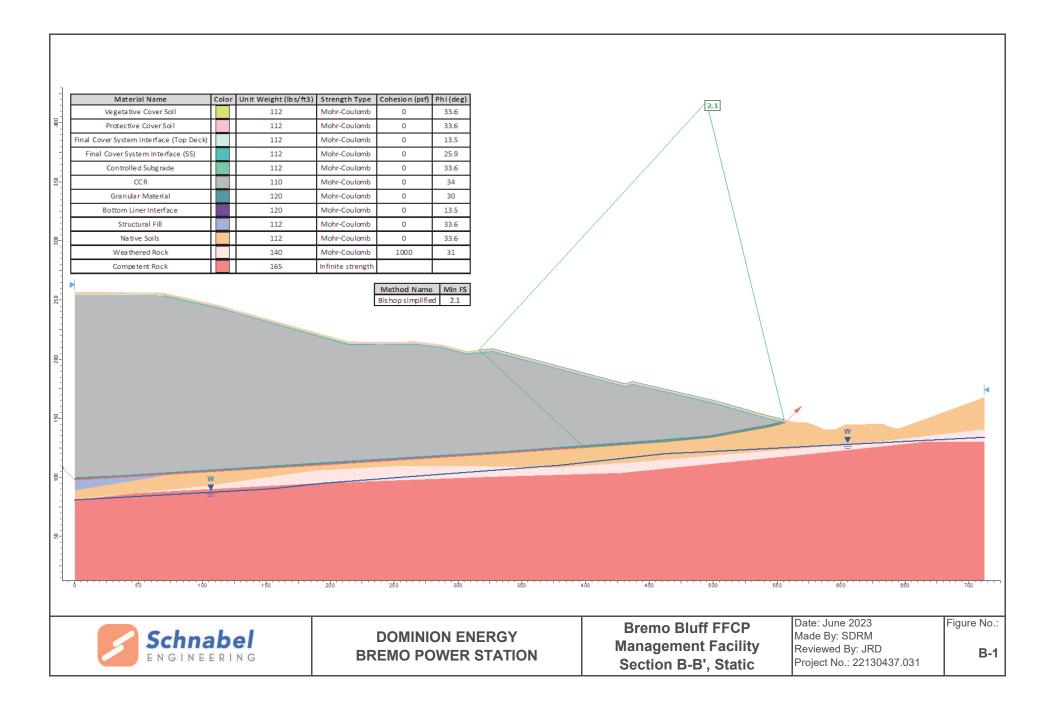
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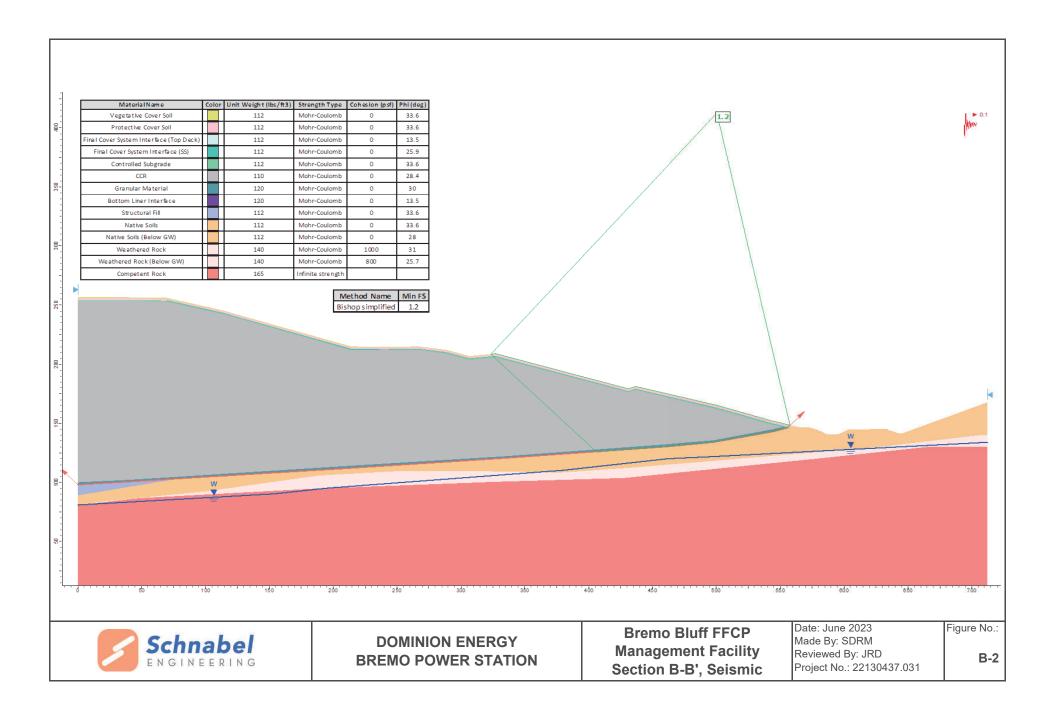
- (1) AECOM (AECOM, 2022). Hydrogeologic and Geotechnical Report: Proposed Solid Waste Management Facility, Bremo Power Station, Rev.1. August 19, 2022.
- (2) Bishop, A.W., (Bishop, 1955). "The use of the slip circle in the stability analysis of earth slopes." Geotechnique 1955, 5(1): 7–17.
- (3) Golder Associates (Golder, 2017). Bremo Power Station CCR Surface Impoundments, Impounding Structure Design Report, DCR Inventory #06520. March 2015, Revised March 2017.
- (4) Hynes-Griffin, Mary E. and Franklin, Arley G. (Hynes-Griffin et al., 1984). "Rationalizing the Seismic Coefficient Method," Miscellaneous Paper Prepared for the U.S. Army Corps of Engineers. July 1984.
- (5) Morgenstern, N.R. and Price, V.E. (Morgenstern et al., 1965). "The analysis of the stability of general slip surfaces" Geotechnique 1965, pp 11-26.
- (6) Parmley, Robert O. (Parmley, 1995). Field Engineer's Manual, Second Edition, 1995.
- (7) Richardson, Gregory N., Kavazanjian, Edward, Jr., and Matasovi, Neven (Richardson et al., 1995). "RCRA Subtitle D (258) Seismic Design Guidance for Municipal Solid Waste Landfill Facilities." April 1995.
- (8) RocScience (Rocscience, 2023). Slide2 Modeler Version 9.027. Build date: February 13, 2023.
- (9) United States Department of Interiors Bureau of Reclamation (USBR, 1987). Design of Small Dams, Third Edition, 1987.
- (10) United States Environmental Protection Agency (EPA, 1988). Solid Waste Disposal Facility Criteria: Technical Manual. November 1993, Revised April 13, 1988.
- (11) United States Geological Survey (USGS, 2023). PGA with 2% probability of exceedance in 50 years, USGS map, 2014 rev. Available online: http://earthquake.usgs.gov/hazards/products/conterminous/2014/2014pga2pct.pdf accessed June 9, 2023.

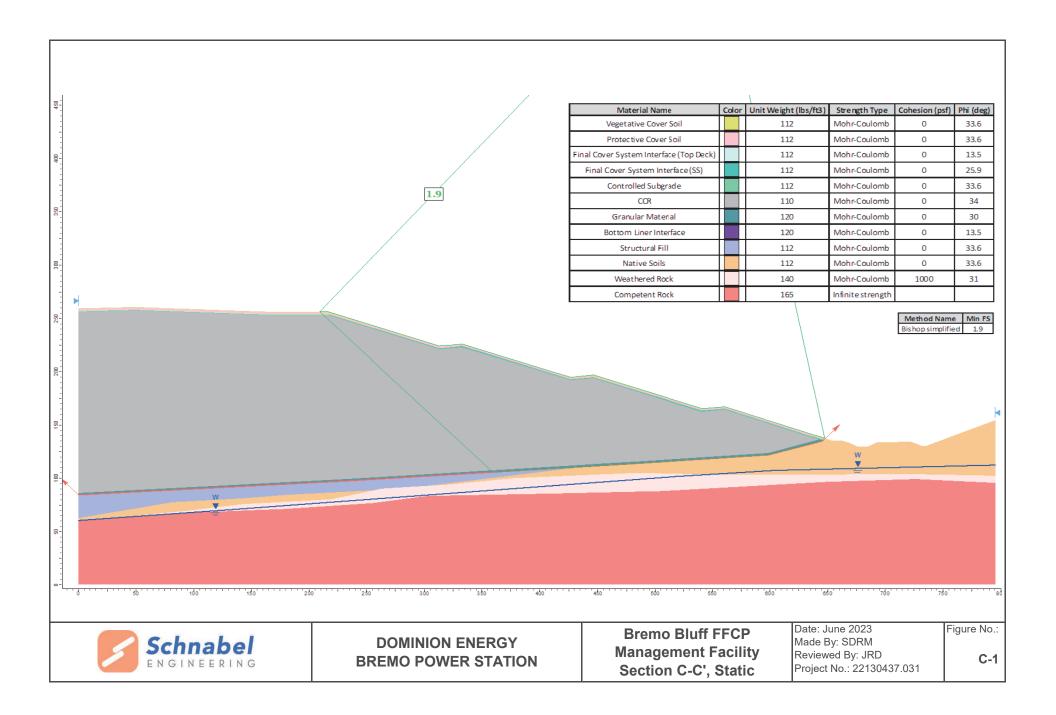
Stability Analysis Attachment 1
Slide Output

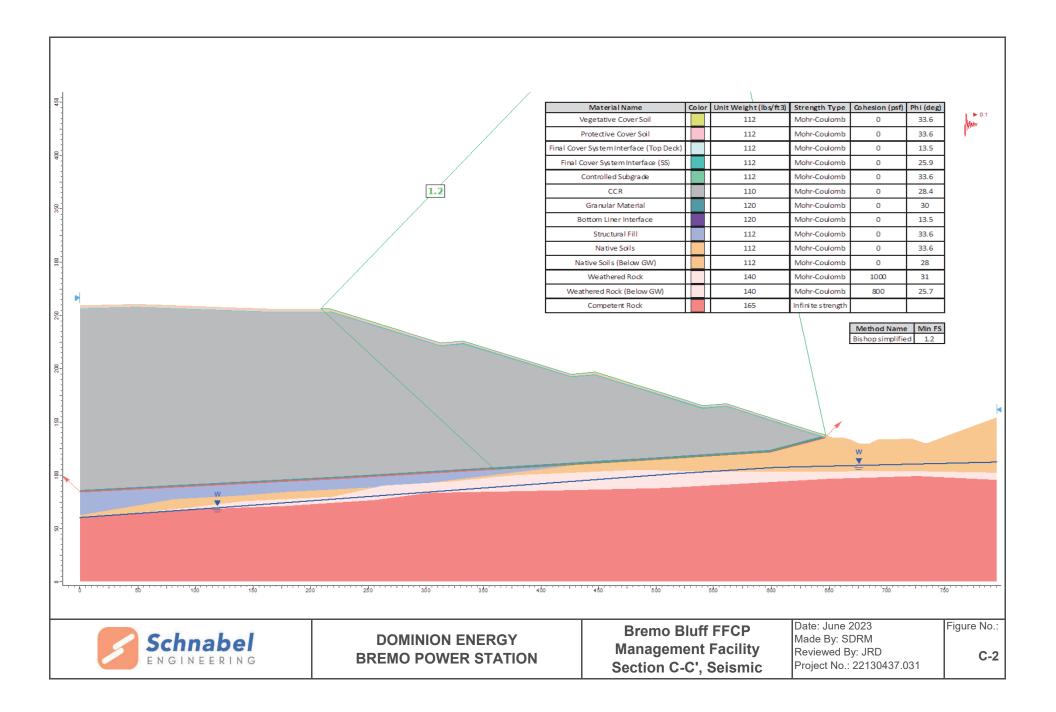












ATTACHMENT 4 LINER SLOPE ANALYSES

Base Grade Stress During Construction Veneer Stability Analysis Base Grade Liner Self Weight Anchor Trench Runout





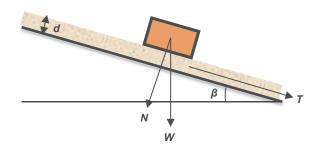
Calculations			
PROJECT: Bremo Bluff FFCP Management Facility	REFERENCE NO: 22130437.031		
SUBJECT: Stress on Liner During Construction – Base Grades	DATE: 02/01/2024		

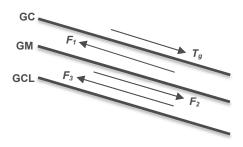
The objective of this analysis is to calculate the factor of safety (FS) against stress on the bottom liner during construction of the proposed Coal Combustion Residuals (CCR) Unit at the Bremo Bluff Fossil Fuel Combustion Products (FFCP) Management Facility (Facility).

2.0 METHODOLOGY

The bottom liner system will consist of a minimum 12-inch controlled subgrade overlain by a geosynthetic clay liner (GCL), a 60-mil textured, high-density polyethylene (HDPE) geomembrane liner (GM), a 250-mil geocomposite (GC), and an 18-inch-thick aggregate layer. The most critical portions of the CCR Unit for liner stress during construction are the sideslope areas; therefore, the sideslope angle of 3.5H:1V (horizontal to vertical), or 16 degrees, was used for these calculations.

The free-body diagrams were used to calculate the FS by balancing forces.





Equations:

$P_c = WnT_wT_l$	Where	P _c W T _w T _I	= Contact Pressure [pound per square inch (psi)] = Weight of Equipment [pound (lb)] = Track Width [feet (ft)] = Track Length (ft) = Number of Tracks	
$N = P_c cos \beta$	Where	N Pc B	= Normal Force (psi) = Contact Pressure (psi) = Slope Angle [degree (°)]	
$T = P_c sin\beta$	Where	Т	= Tension Force in GC (psi)	

Design Report

Stress on Liner During Construction - Base Grades

$N_g = N_g + \gamma_{soil} dcos \beta$	Where N_g γ_{soil} d	= Normal Force on GC (psi)= Unit Weight of Aggregate Layer [pound per cubic foot (pcf)]= Depth of Aggregate Layer (ft)
$T_g = T + \gamma_{soil} dsin\beta$	Where T _g	= Sliding Force on GC (psi)
$F_1 = N_g tan\delta_1$	Where F_1 δ_1	= Sliding Resistance on GC (psi) = GC/Aggregate Layer Interface Friction Angle (°)
$F_2 = T_g$	Where F ₂	= Sliding Resistance in GM/GC (psi)
$F_3 = N_g tan \delta_3$	Where F_3 δ_3	= Sliding Resistance on GM (psi) = GM/GCL Interface Friction Angle (°)
$FS = \frac{F_{1,2,3}}{T_g}$	Where FS	= Factor of Safety

3.0 ASSUMPTIONS

The calculations presented herein were based on the following assumptions and input parameters:

- A Caterpillar D6 low ground pressure (LGP) bulldozer with a ground pressure of 8 psi, or equipment of less than or equal weight, is considered in this calculation.
- The weights of the other bottom liner system components were considered negligible.
- The minimum interface friction angle of the geosynthetic-geosynthetic and geosynthetic-aggregate material is 22.7 degrees, as determined in the Veneer Stability calculation for the bottom liner system.

4.0 CALCULATIONS

Where;

	W	=	weight of equipment	=	48,788	lb
	T_w	=	track width	=	2	ft
	T_l	=	track length	=	10	ft
	n	=	number of tracks	=	2	
	β	=	slope angle	=	16	0
	d	=	depth of drainage layer	=	1.5	ft
	Ysoil	=	unit weight of drainage layer	=	120	pcf
	δ_1	=	interface friction angle, GC/Aggregate Layer	=	22.7	0
	δ_3	=	interface friction angle, GM/GCL	=	22.7	0
Then;						
	P_c	=	$W/(nT_wT_l)$	=	8.47	psi
	Ν	=	Pccosβ	=	8.14	psi
	Τ	=	Pcsinβ	=	2.33	psi
	N_g	=	N+γ _{soil} dcosβ	=	9.34	psi
	T_g	=	T+γ _{soil} dsinβ	=	2.68	psi
	F_1	=	$N_g tan \delta_1$	=	3.91	psi
	F_2	=	T_g	=	2.68	psi
	F ₃	=	$N_g tan \delta_3$	=	3.91	psi

Design Report

Stress on Liner During Construction - Base Grades

$$FS = F_1/T_g = 1.46$$

 $F_3/T_g = 1.46$

Since F_1 is greater than T_g , only the force equal to T_g will be transferred to the geomembrane liner. Therefore, F_2 is equal to T_g ($F_2 = T_g = 2.68$ psi). This stress is then transferred to the geomembrane and GCL interface, where F_3 is the resistive force, which results in an FS equal to 1.46 for the bottom liner system.

5.0 CONCLUSIONS

The FS value of 1.46 is greater than the minimum required FS value of 1.30 and, therefore, the bottom liner system design provides an adequate FS during construction. Additionally, the calculated FS value is conservative, as the load distribution along the depth of the aggregate layer is ignored and interface friction angle calculations conservatively ignore adhesion between the geomembrane and the GCL.

References:

(1) Koerner, Robert M. *Designing with Geosynthetics, Fifth Edition*. Upper Saddle River, New Jersey: Pearson Prentice Hall, 2005.





Calculations			
PROJECT: Bremo Bluff FFCP Management Facility	REFERENCE NO: 22130437.031		
SUBJECT: Veneer Stability Analysis – Bottom Liner	DATE : 02/01/2024		

The objective of this analysis is to evaluate the veneer stability of the bottom liner system for the proposed Coal Combustion Residuals (CCR) Unit at the Bremo Bluff Fossil Fuel Combustion Products (FFCP) Management Facility (Facility) and determine the factors of safety of the various analyzed conditions.

2.0 METHODOLOGY

The analysis was performed using spreadsheet analyses of the selected interfaces using the "finite slope model analysis" method outlined in Reference 1. The portions of the CCR Unit most sensitive to veneer failure are the sideslope areas; therefore, the sideslope angle of 3.5H:1V (horizontal to vertical), or 16 degrees, was used for these calculations.

The minimum allowable interface friction angle was determined by setting the factor of safety (FS) equal to the minimum required FS value for the Long-Term Veneer Stability condition, as shown in the table below. Using the minimum allowable interface friction angle, factors of safety for the bottom liner system in the Short-Term Veneer Stability, Parallel Seepage, and Seismic conditions were determined.

As outlined in Attachment VI of the Part B Permit Application (Design Report), the following options are being proposed for the 18-inch-thick aggregate layer of the bottom liner system; a 12-inch-thick coarse aggregate drainage layer overlain by a 6-inch-thick fine aggregate protective layer (Option 1) or an 18-inch-thick layer of coarse aggregate (Option 2A) or fine aggregate (Option 2B). As the internal friction angle of fine aggregate is lower than that of coarse aggregate, the 18-inch-thick aggregate layer was conservatively assumed to be a fine aggregate.

3.0 ASSUMPTIONS

Veneer stability calculations were based on the following assumptions and input parameters:

- The fine aggregate was assigned a unit weight of 120 pounds per cubic foot (pcf), a saturated unit weight of 135 pcf, and an estimated strength of 30 degrees based on typical values for sands.
- Based on the CCR Unit design grades, shown in Attachment III of the Part B Permit Application (Design Plans), the maximum slope length for the CCR Unit bottom liner is approximately 164 feet with a bottom liner thickness of approximately 1.5 feet.
- The open condition HELP models demonstrate the ability of the drainage layer to adequately transport leachate to the leachate collection layer, preventing saturation of the overlying CCR material. The depth of seepage was therefore assumed to be zero.

4.0 CALCULATIONS

Based on the spreadsheet calculations (Attachment 1), the minimum allowable friction angle for any interface in the bottom liner system was determined to be 22.7 degrees. The table below summarizes the required and

Design Report

Veneer Stability Analysis - Bottom Liner

calculated factors of safety for each of the conditions based on a calculated interface friction angle of 22.7 degrees.

Table 1: FS Results Summary

Condition	Minimum Required FS	Calculated FS
Long-Term Veneer Stability	1.5	1.50
Short-Term Veneer Stability (18" Lift)	1.3	1.49
Parallel Seepage	1.3	1.50
Seismic	1.0	1.09

5.0 CONCLUSION

The aggregate layer materials, combined with the proposed geosynthetics, will provide a bottom liner system that meets the required factors of safety given a minimum allowable interface friction angle of 22.7 degrees.

Attachments:

(1) Veneer Stability Calculations Spreadsheets

References:

- (1) Qian, Xuede; Keorner, Robert; Gray, Donald. "Geotechnical Aspects of Landfill Design and Construction". 2003
- (2) Das, Braja M. "Principles of Geotechnical Engineering, 3rd Edition".

Veneer Stability Analysis Attachment 1 Veneer Stability Calculations Spreadsheets



Project:Bremo Bluff FFCP Management FacilityMade by:ERRSubject:Veneer Slope Stability Analysis - Bottom Liner, Long-TermChecked by:SDRMReference No.:22130437.010Reviewed by:JRD

Date: 2/1/2024

Objective

Determine the long-term veneer slope stability by means of a factor of safety of the static condition for the 3.5:1 slope areas.

Method

Where:

 $a = (W_a - N_a \cos \beta)(\cos \beta)$

 $b = -\{(W_a - N_a cos β) sinβtanφ + (N_a tanβ+Ca) sinβtanβ + sinβ(C + W_p tanφ)\}$

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

 $FS = \frac{-b + (b^2 - 4ac)^{0.5}}{2a}$

Assumptions

β =	slope angle	=	16.0 ° (3.5:1)
1-	1 0		' '
φ =	internal friction angle drainage material	=	30.0 °
δ =	interface friction angle	=	22.7 °
c _a =	adhesion along interface	=	0.0 psf
c =	cohesion of cover soil	=	0.0 psf
L =	slope length	=	163.5 ft
h =	base liner thickness	=	1.5 ft
γ =	unit weight of cover soil	=	120 pcf

Calculations

$$W_a = \gamma h^2 (L/h - 1/\sin\beta - (\tan\beta/2))$$
 = 28411.74 lb/ft
 $N_a = W_a \cos\beta$ = 27311.12 lb/ft
 $C_a = c_a (L - h/\sin\beta)$ = 0.00 psf
 $W_p = \gamma h^2/\sin 2\beta$ = 509.51 lb/ft
 $C = ch/\sin\beta$ = 0.00 lb/ft

Static Conditions

$$a = (W_a - N_a \cos\beta)(\cos\beta) = 2074.99$$

$$b = -\{(W_a - N_a \cos\beta)\sin\beta\tan\phi + (N_a \tan\beta + Ca)\sin\beta\tan\beta + \sin\beta(C + W_p \tan\phi)\} = -3444.77$$

$$c = (N_a \tan\delta + C_a)\sin^2\beta\tan\phi = 500.00$$

$$FS = \frac{-b + (b^2 - 4ac)^{0.5}}{2a} = 1.50$$

References

- 1. Qian, Xuede; Keorner, Robert; Gray, Donald. "Geotechnical Aspects of Landfill Design and Construction". 2003
- 2. Das, Braja M. "Principles of Geotechnical Engineering, 3rd Edition".



Project:Bremo Bluff FFCP Management FacilityMade by:ERRSubject:Veneer Slope Stability Analysis - Bottom Liner, Short-TermChecked by:SDRMReference No.:22130437.010Reviewed by:JRD

Date: 2/1/2024

Objective

Determine the long-term veneer slope stability by means of a factor of safety of the static condition for the 3.5:1 slope areas.

Method

Where:

 $a = (W_{a+e} - N_{a+e} \cos\beta)(\cos\beta)$

b = $-\{(W_{a+e} - N_{a+e}\cos\beta)\sin\beta\tan\phi + (N_{a+e}\tan\beta + C_a)\sin\beta\tan\beta + \sin\beta(C + W_{p}\tan\phi)\}$

 $c = (N_{a+e} tan\delta + C_a) sin^2 \beta tan\phi$

 $FS = \frac{-b + (b^2 - 4ac)^{0.5}}{2a}$

Assumptions

β =	slope angle	=	16.0 ° (3.5:1)
φ =	internal friction angle drainage material	=	30.0 °
δ =	interface friction angle	=	22.7 °
c _a =	adhesion along interface	=	0.0 psf
C =	cohesion of cover soil	=	0.0 psf
L =	slope length	=	163.5 ft
h =	base liner thickness	=	1.5 ft
γ =	unit weight of cover soil	=	120 pcf

Calculations

$$W_{a} = \gamma h^{2}(L/h - 1/\sin\beta - (\tan\beta/2)) = 28,411.74 \text{ lb/ft}$$

$$Width of Dozer Track = 3.00 \text{ ft}$$

$$Contact Area = 64.26 \text{ sq.ft.}$$

$$Ground Pressure = 4.8 \text{ psi}$$

$$Influence factor (I) = 0.95 \text{ (obtained from Figure 13.7, page 493, ref. 1}$$

$$Ground Pressure at Geosynthetics = 652.4 \text{ psf}$$

$$Length of Dozer Track = 10.7 \text{ ft}$$

$$W_{e} = 6987 \text{ lb/ft}$$

$$W_{a+e} = 35399.15 \text{ lb/ft}$$

$$N_{a+e} = W_{a+e} \cos\beta = 34027.85 \text{ lb/ft}$$

$$C_{a} = c_{a}(L - h/\sin\beta) = 0.00 \text{ psf}$$

$$W_{p} = (\gamma h^{2})/\sin 2\beta = 509.51 \text{ lb/ft}$$

0.00 lb/ft

Static Conditions

References

- 1. Qian, Xuede; Keorner, Robert; Gray, Donald. "Geotechnical Aspects of Landfill Design and Construction". 2003
- 2. Das, Braja M. "Principles of Geotechnical Enginering, 3rd Edition".

 $C = ch/sin\beta$



Project:Bremo Bluff FFCP Management FacilityMade by:ERRSubject:Veneer Slope Stability Analysis - Bottom Liner, Parallel SeepageChecked by:SDRMReference No.:22130437.010Reviewed by:JRD

Date: 2/1/2024

Objective

Determine the long-term veneer slope stability by means of a factor of safety of the static condition for the 3.5:1 slope areas.

Method

Where:

 $a = W_A \sin\beta \cos\beta + U_H (1 - \cos^2\beta)$

 $b = -[W_P tan\phi + W_A (sin^2\beta tan\phi + cos^2\beta tan\delta) - U_{AN} cos\beta tan\delta - U_{PN} tan\phi + U_H sin\beta cos\beta (tan\phi - tan\delta)]$

c = $(W_A \cos \beta - U_{AN} + U_H \sin \beta) \sin \beta \tan \delta \tan \phi$

$$FS = \frac{-b + (b^2 - 4ac)^{0.5}}{2a}$$

Assumptions

β =	slope angle	=	16.0 ° (3.5:1)
φ =	internal friction angle drainage material	=	30.0 °
δ =	interface friction angle	=	22.7 °
c _a =	adhesion along interface	=	0.0 psf
c =	cohesion of cover soil	=	0.0 psf
L =	slope length between benches	=	163.5 ft
h =	base liner thickness	=	1.5 ft
γ =	unit weight of cover soil	=	120 pcf
$\gamma_w =$	Unit weight of water	=	62.4 pcf
γ_{sat} =	Saturated unit weight of cover soil	=	135 pcf
H =	Height of slope	=	45 ft
h _w =	Depth of seepage in soil	=	0.00 ft

Calculations

$$\begin{split} W_A = &0.5[\ \gamma(h-h_w)(2Hcos\beta-h-h_w) + \gamma_{sat}h_w(2Hcos\beta-h_w)]/(sin\beta cos\beta) &= 28,920.49 \\ U_{AN} = &\gamma_w h_w (H-0.5h_w cos\beta)/tan\beta &= 0.00 \\ U_H = &0.5\gamma_w h_w^2 &= 0.00 \\ W_p = &0.5[\gamma(h^2-h_w^2) + \gamma_{sat}h_w^2]/(sin\beta cos\beta) &= 509.51 \\ U_{PN} = &0.5\gamma_w h_w^2/tan\beta &= 0.00 \end{split}$$

Static Conditions

$$a = W_{A} sinβcosβ+U_{H}(1-cos^{2}β) = 7,662.76$$

$$b = -\{W_{P} tanφ+W_{A}(sin^{2}βtanφcos^{2}βtanδ)-U_{AN}cosβtanδ-U_{PN}tanφ+U_{H}sinβcosβ(tanφ-tanδ)\} = -12,741.32$$

$$c = (W_{A} cosβ-U_{AN}+U_{H} sinβ)sinβtanδtanφ = 1,850.64$$

$$FS = \frac{-b + (b^{2}-4ac)^{0.5}}{} = 1.50$$

References

- 1. Qian, Xuede; Keorner, Robert; Gray, Donald. "Geotechnical Aspects of Landfill Design and Construction". 2003
- 2. Das, Braja M. "Principles of Geotechnical Enginering, 3rd Edition".

2a



Project:Bremo Bluff FFCP Management FacilityMade by:ERRSubject:Veneer Slope Stability Analysis - Bottom Liner, SeismicChecked by:SDRMReference No.:22130437.010Reviewed by:JRD

Date: 2/1/2024

Objective

Determine the long-term veneer slope stability by means of a factor of safety of the static condition for the 3.5:1 slope areas.

Method

Where:

$$a = (C_sW_a + N_a \sin\beta) \cos\beta + C_sW_p \cos\beta$$

b =
$$-\{(C_sW_a + N_asinβ)sinβ tanφ + (N_atanδ + C_a) cos^2β + (C + W_ptanφ) cosβ\}$$

 $c = (N_a tanδ + C_a) cosβ sinβ tanφ$

$$FS = \frac{-b + (b^2 - 4ac)^{0.5}}{2a}$$

Assumptions

β =	slope angle	=	16.0 ° (3.5:1)
φ =	internal friction angle drainage material	=	30.0 °
δ =	interface friction angle	=	22.7 °
c _a =	adhesion along interface	=	0.0 psf
c =	cohesion of cover soil	=	0.0 psf
L =	slope length	=	163.5 ft
h =	base liner thickness	=	1.5 ft
γ =	unit weight of cover soil	=	120 pcf
C -	- dende	_	0.40 - (4/0

 C_s = seismic coefficient = 0.10 g (1/2 peak ground acceleration)

Calculations

$$\begin{split} W_a &= \gamma h^2 (L/h - 1/sin\beta - (tan\beta/2) &= 28411.74 \text{ lb/ft} \\ N_a &= W_a cos\beta &= 27311.12 \text{ lb/ft} \\ C_a &= c_a (L - h/sin\beta) &= 0.00 \text{ psf} \\ W_p &= \gamma h^2/sin2\beta &= 509.51 \text{ lb/ft} \\ C &= ch/sin\beta &= 0.00 \text{ lb/ft} \end{split}$$

Seismic Conditions

$$a = (C_sW_a + N_a sinβ) cosβ + C_sW_p cosβ = 10016.43$$

$$b = -\{(C_sW_a + N_a sinβ) sinβ tanφ + (N_a tanδ + C_a) cos²β + (C + W_p tanφ) cosβ\} = -12489.41$$

$$c = (N_a tanδ + C_a) cosβ sinβ tanφ = 1747.66$$

$$FS = \frac{-b + (b²-4ac)^{0.5}}{} = 1.09$$

References

- 1. Qian, Xuede; Keorner, Robert; Gray, Donald. "Geotechnical Aspects of Landfill Design and Construction". 2003
- 2. Das, Braja M. "Principles of Geotechnical Enginering, 3rd Edition".





Calculations				
PROJECT: Bremo Bluff FFCP Management Facility	REFERENCE NO: 22130437.031			
SUBJECT: Liner Self Weight – Base Grades	DATE : 02/01/2024			

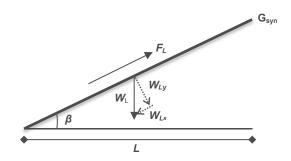
1.0 OBJECTIVE

The objective of this analysis is to calculate the factor of safety (FS) for the geosynthetics in the bottom liner system of the proposed Coal Combustion Residuals (CCR) Unit at the Bremo Bluff Fossil Fuel Combustion Products (FFCP) Management Facility (Facility) to support their own weight during construction.

2.0 METHODOLOGY

The geosynthetics in the bottom liner system (G_{syn}) will consist of a geosynthetic clay liner (GCL) overlain by a 60-mil textured, high-density polyethylene (HDPE) geomembrane liner (GM) and a 250-mil geocomposite (GC). The most critical portions of the CCR Unit for the liner to support its own weight are the sideslope areas; therefore, the sideslope angle of 3.5H:1V (horizontal to vertical), or 16 degrees, and the maximum length of 164 feet (ft) was used for these calculations.

The free-body diagram was used to calculate the FS by balancing forces.



Equations:

$W_L = \gamma_L t_L L cos \beta$	Where	WL YL tL L	 = Weight of the Liner [pound per foot (lb/ft)] = Unit Weight of Liner [pound per cubic foot (pcf)] = Thickness of Liner (ft) = Length of Slope Base (ft)
$W_{Lx} = W_L sin\beta$	Where	W_{Lx}	= Weight of Liner along Plane X (lb/ft)
$W_{Ly} = W_L cos \beta$	Where	W_{Ly}	= Weight of Liner along Plane Y (lb/ft)
$F_L = W_{Ly} tan \delta$	Where	F_L δ β	= Resistance force along Liner [pound (lb)] = Geomembrane to Subgrade Interface Friction Angle [degree (°)] = Angle of Slope (°)

Design Report

Line Self Weight - Base Grades

```
T = W_{LX} - F_L
                         Where T
                                          = Tension along liner (lb/ft)
```

$$FS = F_L/W_{LX}$$
 Where FS = Factor of Safety

3.0 **ASSUMPTIONS**

The calculations presented herein were based on the following assumptions and input parameters:

- The densities of the GM [0.94 grams per centimeter cubed (g/cm³)], GC (0.94 g/cm³), and GCL (0.565 g/cm³) were included in the unit weight of the liner.
- The minimum interface friction angle is 22.7 degrees, as determined in the Veneer Stability calculation for the bottom liner system.

4.0 **CALCULATIONS**

Where:

Then;

YL	=	unit weight of liner	=	47.67	pcf
t_{L}	=	thickness of liner	=	585	mil
			=	0.585	inches
δ	=	interface friction angle	=	22.7	0
β	=	side slope angle	=	16	0
L	=	length of slope base	=	157.17	ft
W_{L}	=	$\gamma_L t_L(L/cos\beta)$	=	380.01	lb/ft
W_{Lx}	=	W _L sinβ	=	104.75	lb/ft
W_{Ly}	=	W _L cosβ	=	365.29	lb/ft
F_L	=	W _{ly} tanδ	=	152.80	lb/ft
Т	=	W _{Lx} -F _L	=	-48.06	lb/ft

5.0 **CONCLUSIONS**

FS

 $= F_L/W_{Lx}$

Since the frictional resistance force (FL) is greater than the sliding force due to the weight of the geosynthetics in the x-plane (WLx), no sliding tension is present in the geosynthetics. The calculated FS for the geosynthetics to support their own weight is 1.46. Therefore, the geosynthetic components of the bottom liner system can sufficiently support their own weight during construction.

1.46

References:

Koerner, Robert M. Designing with Geosynthetics, Fifth Edition. Upper Saddle River, New Jersey: (1) Pearson Prentice Hall, 2005. Print.





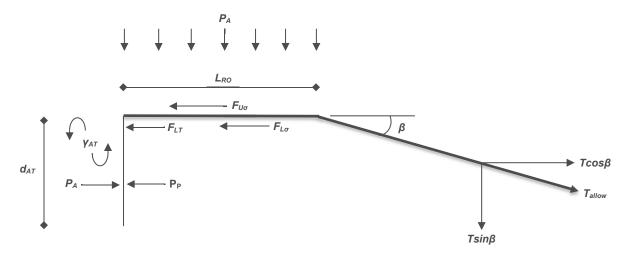
Calculations				
PROJECT: Bremo Bluff FFCP Management Facility	REFERENCE NO: 22130437.031			
SUBJECT: Anchor Trench Runout	DATE: 02/01/2024			

1.0 OBJECTIVE

The objective of this analysis is to calculate the required runout length for the bottom liner system anchor trench for the proposed Coal Combustion Residuals (CCR) Unit at the Bremo Bluff Fossil Fuel Combustion Products (FFCP) Management Facility (Facility).

2.0 METHODOLOGY

The free-body diagram was used to calculate the runout length by balancing forces.



Equations:

$$F_{U\sigma} = TAN\delta_{U}(L_{RO}) \qquad \text{Where} \quad F_{\cup\sigma} \qquad = \text{Shear force resulting from cover soil [pounds per foot (lb/ft)]} \\ \delta_{\cup} \qquad = \text{Shearing Resistance Above Liner [degrees (°)]} \\ L_{RO} \qquad = \text{Required Runout Length [feet (ft)]} \\ F_{L\sigma} = \sigma_{n}TAN\delta_{L}(L_{RO}) \qquad \text{Where} \quad F_{L\sigma} \qquad = \text{Shear force below geomembrane (GM) due to cover soil (lb/ft)} \\ \sigma_{n} \qquad = \text{Normal Force of Cover Material [pounds per square foot (psf)]} \\ \delta_{L} \qquad = \text{Soil/ Liner Interface Angle [degrees (°)]} \\ F_{LT} = T_{ALLOW}sin\beta \cdot TAN\delta_{L} \qquad \text{Where} \quad F_{LT} \qquad = \text{Shear force below GM from vertical component of T}_{ALLOW} (lb/ft) \\ T_{ALLOW} \qquad = \text{Allowable Stress in Liner, pound per foot (lb/ft)} \\ \beta \qquad = \text{Slope Angle (°)} \\ K_{A} = TAN^{2}(45 - \emptyset/2) \qquad \text{Where} \quad K_{A} \qquad = \text{Coefficient of active earth pressure} \\ \varnothing \qquad = \text{Shear Resistance Angle of Soil (°)} \\ P_{A} = (0.5\gamma_{AT}d_{AT} + \sigma_{n})K_{A}d_{AT} \text{Where} \quad P_{A} \qquad = \text{Active earth pressure against backfill side of anchor trench (lb/ft)} \\ \end{array}$$

Design Report Anchor Trench Runout

 γ_{AT} = Anchor Trench Density [pound per cubic foot (pcf)]

d_{AT} = Depth of Anchor Trench (ft)

 $K_P = TAN^2(45 + \emptyset/2)$ Where K_P = Coefficient of passive earth pressure

 $P_P = (0.5\gamma_{AT}d_{AT} + \sigma_n)K_Pd_{AT}$ Where P_P = Passive earth pressure against in-situ side of anchor trench (lb/ft)

 $T_{ALLOW}COS\beta = F_{U\sigma} + F_{L\sigma} + F_{LT} - P_A + P_P$

$$L_{RO} = \frac{(T_{ALLOW}COS\beta) - F_{LT} + P_A - P_P}{\sigma_n TAN\delta_L}$$

3.0 ASSUMPTIONS

The calculations presented herein were based on the following assumptions and input parameters:

- The allowable stress in the liner was assumed to be 1,512 lb/in, which is consistent with the yield strength for 60-mil high-density polyethylene (HDPE) geomembrane.
- The sideslope angle of 3.5H:1V (horizontal to vertical), or 16 degrees, was used for these calculations.
- A cover material depth of 1.5 ft was assumed.
- The cover and fill material were assigned a unit weight of 112 pcf and an estimated strength of 33.6 degrees, which is consistent with the United States Department of Interior Bureau of Reclamation's Design of Small Dams Unified Soil Classification System (USBR, 1987) for the silty sands or sand-silt mixtures (SM) on-site.
- The minimum interface friction angle is 22.7 degrees, as determined in the Veneer Stability calculation for the bottom liner system.
- The shearing resistance angle (δ_U) above the liner was assumed to be zero.

4.0 CALCULATIONS

Where;

T_{allow}	=	allowable stress in liner	=	1,512	lb/ft
β	=	slope angle	=	16	0
σ_{n}	=	normal force of cover material	=	168	psf
δ_{L}	=	soil/liner interface angle	=	22.7	0
δυ	=	shearing resistance angle above liner	=	0	0
Υ ΑΤ	=	anchor trench density	=	112	pcf
$d_{AT} =$	=	anchor trench depth	=	2	ft
Ø	=	Shear resistance angle of soil	=	33.6	0

Then;

$$\begin{array}{llll} F_{u\sigma} & = & 0 & lb/ft \\ F_{L\sigma} & = & 101.9^*L_{RO} & lb/ft \\ F_{LT} & = & 174.3 & lb/ft \\ P_A & = & 161.0 & lb/ft \\ K_A & = & 0.29 \\ P_P & = & 1947.7 & lb/ft \\ K_P & = & 3.48 \\ L_{RO} & = & -7.22 & ft \\ \end{array}$$

Design Report Anchor Trench Runout

Since L_{RO} is less than 0, the forces pulling the liner out of the anchor trench are less than the resistive forces and the liner will not pull out of the trench.

5.0 CONCLUSIONS

The required runout length is less than zero and, therefore, the liner system anchor trench does not require a runout length based on the anchor trench depth assumed.

References:

- (1) Koerner, Robert M. *Designing with Geosynthetics, Fifth Edition*. Upper Saddle River, New Jersey: Pearson Prentice Hall, 2005. Print.
- (2) United States Department of Interiors Bureau of Reclamation (USBR, 1987). Design of Small Dams, Third Edition, 1987.

ATTACHMENT 5 GEOTEXTILE AOS CALCULATIONS



Calculations				
PROJECT: Bremo Bluff FFCP Management Facility	REFERENCE NO: 22130437.031			
SUBJECT: Geotextile AOS Calculations	DATE: 02/01/2024			

1.0 OBJECTIVE

The objective of this analysis is to determine the appropriate maximum apparent opening size (AOS) for the geotextile components of the bottom liner system, underdrain, and leachate collection system for the proposed Coal Combustion Residuals (CCR) Unit at the Bremo Bluff Fossil Fuel Combustion Products (FFCP) Management Facility (Facility).

2.0 METHODOLOGY

The selection of the geotextile AOS was made based on the Task Force 25 and Giroud methods. These methods are based on a sieve analysis and were used to determine the minimum AOS to prevent materials intended to be retained by the geotextile from passing through the geotextile.

The following options are proposed for the 18-inch-thick aggregate layer in the bottom liner system:

- Option 1 consists of a 12-inch-thick coarse aggregate layer overlain by a 6-inch-thick fine aggregate layer.
- Option 2 consists of an 18-inch-thick layer of coarse aggregate (Option 2A) or fine aggregate (Option 2B).

Where fine aggregate (i.e. sand) or CCR is placed atop coarse aggregate (i.e stone), a 10-ounce per square yard (oz) geotextile is proposed for filtration/separation to prevent the finer material from migrating into the coarser material. In Option 1, a 10-oz non-woven geotextile is proposed between the 6-inch-thick fine aggregate and 12-inch-thick coarse aggregate to prevent the fine aggregate from migrating into the coarse aggregate. In Option 2, a 10-oz non-woven geotextile is proposed above the 18-inch-thick coarse aggregate layer to prevent placed CCR from being deposited into the coarse aggregate. In the case of an 18-inch-thick layer of fine aggregate, a 10-oz non-woven geotextile is not necessary because the sand acts as a natural filter for the placed CCR. The aggregate layer will be underlain by a 250-mil geocomposite, double-sided with an 8-oz non-woven geotextile.

Leachate collection piping will be enveloped in Virginia Department of Transportation (VDOT) No. 57 stone. In the event that fine aggregate is used (Option 2B), the VDOT No. 57 stone shall be wrapped with a 10-oz non-woven geotextile to prevent the fine aggregate from migrating into the stone and leachate collection piping.

The underdrain piping will also be enveloped in VDOT No. 57 stone. Prior to being covered with structural fill, the VDOT No. 57 stone will be wrapped with a 10-oz non-woven geotextile to prevent soil from migrating into the stone and underdrain piping.

3.0 ASSUMPTIONS

Geotextile AOS calculations were based on the following assumptions and input parameters:

- The fine aggregate in the bottom liner system was assumed to be VDOT A-Sand. Example material index properties are included as Attachment 1.
- A CCR sample gradation that is coarser than approximately 50% of the site-specific sample data was

Design Report Geotextile AOS Calculations

- used and is included in Attachment 1. The sample is finer than bottom ash, which is anticipated to be placed in the CCR Unit first.
- The underdrain structural fill soil was assumed to be the on-site silty sands or sand-silt mixtures (Unified Soil Classification System SM). Sample data from the on-site SM soil was used and is included in Attachment 1.

4.0 CALCULATIONS

4.1 Task Force 25 Method

The Task Force 25 method examines the percentage of material passing the No. 200 sieve and selects an AOS based on the following recommendations.

- 1. Particles < 50% passing the No. 200 sieve, then AOS ≥ No. 30 sieve
- 2. Particles > 50% passing the No. 200 sieve, then AOS ≥ No. 50 sieve

For the sand, less than 50% of the material passes the No. 200 sieve. For the CCR, more than 50% of the material passes the No. 200 sieve. Per the Task Force 25 Method, the recommended maximum AOS for the 10-oz filter/separation geotextile is the No. 50 sieve (0.297 mm).

For the both the sand and the SM soils that could be in contact with the 10-oz pipe wrap geotextiles and the 8-oz geocomposite geotextile, less than 50% of the material passes the No. 200 sieve. Per the Task Force 25 Method, the recommended maximum AOS for these geotextiles is the No. 30 sieve (0.595 mm).

4.1 Giroud Method

The Giroud method uses a flowchart to determine the AOS for the geotextile. The paths taken through the flowchart are highlighted in Attachment 2.

For the fine aggregate, the following steps were followed:

- 1. The proposed material has less than 10% silt and more than 10% sand.
- 2. The drainage system design favors retention of material to prevent clogging.
- 3. C_c was calculated, based on the equation on the flowchart, as 0.77.
- 4. The material is considered unstable because C_c is less than 1.
- 5. C'u was calculated, based on the equation on the flowchart, as 7.64.
- 6. The material is considered widely graded because C'u is greater than 3.
- 7. The sand was considered "loose" to be conservative.

For the CCR, the following steps were followed:

- 1. The CCR has more than 10% silt and less than 20% clay.
- 2. The CCR is non-plastic.
- 3. The drainage system design favors retention of material to prevent clogging.
- 4. C_c was calculated, based on the equation on the flowchart, as 1.6.
- 5. The material is considered stable because C_c is between 1 and 3.
- 6. C'_u was calculated, based on the equation on the flowchart, as 4.77.
- 7. The material is considered widely graded because C'u is greater than 3.
- 8. The sand was considered "dense."

For the SM soil, the following steps were followed:

Design Report

Geotextile AOS Calculations

- 1. The SM soil has more than 10% silt and less than 20% clay.
- 2. The SM soil is non-plastic.
- 3. The drainage system design favors retention of material to prevent clogging.
- 4. C_c was calculated, based on the equation on the flowchart, as 3.33.
- 5. The material is considered unstable because C_c is greater than 3.
- 6. C'u was calculated, based on the equation on the flowchart, as 0.892.
- 7. The material is considered uniformly graded because C'u is less than 3.
- 8. The soil was considered "medium."

Based on the flowchart, the geotextile AOS for sand should be less than 1.1 mm or 0.04 inches, the geotextile AOS for CCR should be less than 0.15 mm or 0.0058 inches, and the geotextile AOS for SM soil should be less than 0.21 mm or 0.0084 inches.

6.0 CONCLUSION

Based on these calculations, the Giroud Method for CCR provides the more restrictive criteria for the 10-oz geotextile; therefore, the Giroud Method CCR AOS was used and the 10-oz filter/separation geotextile maximum AOS is 0.15 mm. The Giroud Method also provides the more restrictive criteria for sand and SM soil; therefore, the maximum AOS for the 10-oz geotextile for use in the leachate collection and underdrain pipe wrapping and the 8-oz geotextile portion of the geocomposite is 0.21 mm.

Attachments:

- (1) Material Index Properties
- (2) Giroud Method Flowchart

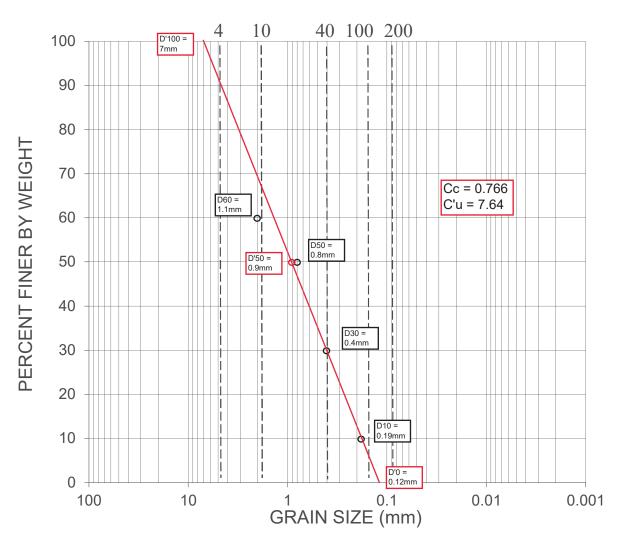
References:

- (1) Qia, Xuede, Koerner, and Gray. Geotextile Filter Design, Application, and Product Specification Guide. 2002.
- (2) Report on Task Force 25, Joint Committee Report of AASHTO-AGC-ARTBA, American Association of State Highway and Transportation Officials, Washington, DC, January, 1991.
- (3) Ten Cate Nicolon Corporation. Geotextile Filter Design, Application, and Product Selection Guide. 2002.
- (4) Virginia Department of Transportation. Road and Bridge Specifications. 2007.

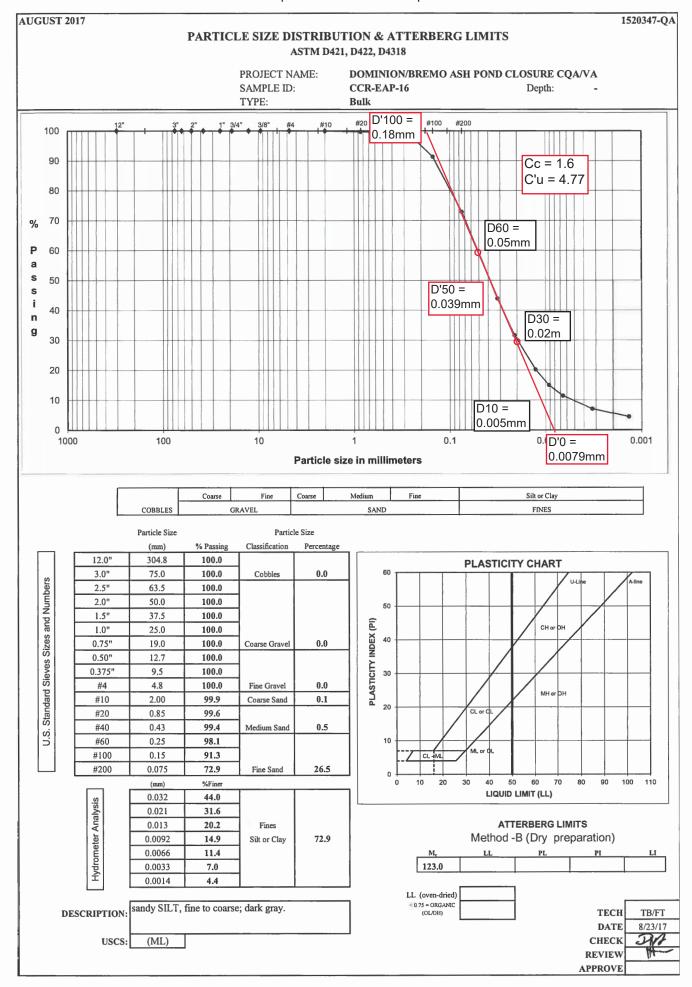
Geotextile AOS Calculations Attachment 1

Material Index Properties

U.S. Standard Sieve Nos.



Index Properties of a VDOT A-Sand





SIEVE AND HYDROMETER ANALYSIS

ASTM D 422-63 (2007)

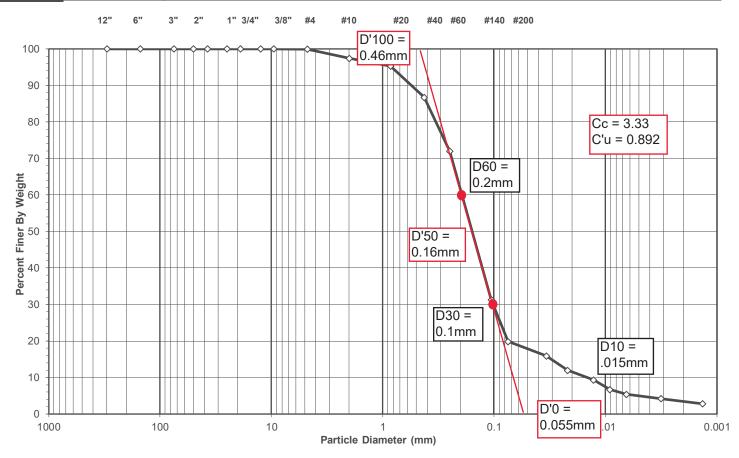
 Client
 AECOM
 Boring No.
 PZ-20

 Client Reference
 Dominion - Bremo
 Depth (ft)
 28-30

 Project No.
 R-2020-043-001
 Sample No.
 SS-9

 Lab ID
 R-2020-043-001-006
 Soil Color
 Brown

	SIEVE ANALYSIS				HYDROMETER	
USCS	cobbles	gravel sand			silt and clay fraction	
USDA	cobbles	gravel		sand	silt	clay



	USCS Summary		
Sieve Sizes (mm)		Percentage	
Greater Than #4	Gravel	0.10	
#4 To #200	Sand	80.05	
Finer Than #200	Silt & Clay	19.85	
#200 To .005mm	Silt	14.98	
Finer .005mm	Clay	4.87	

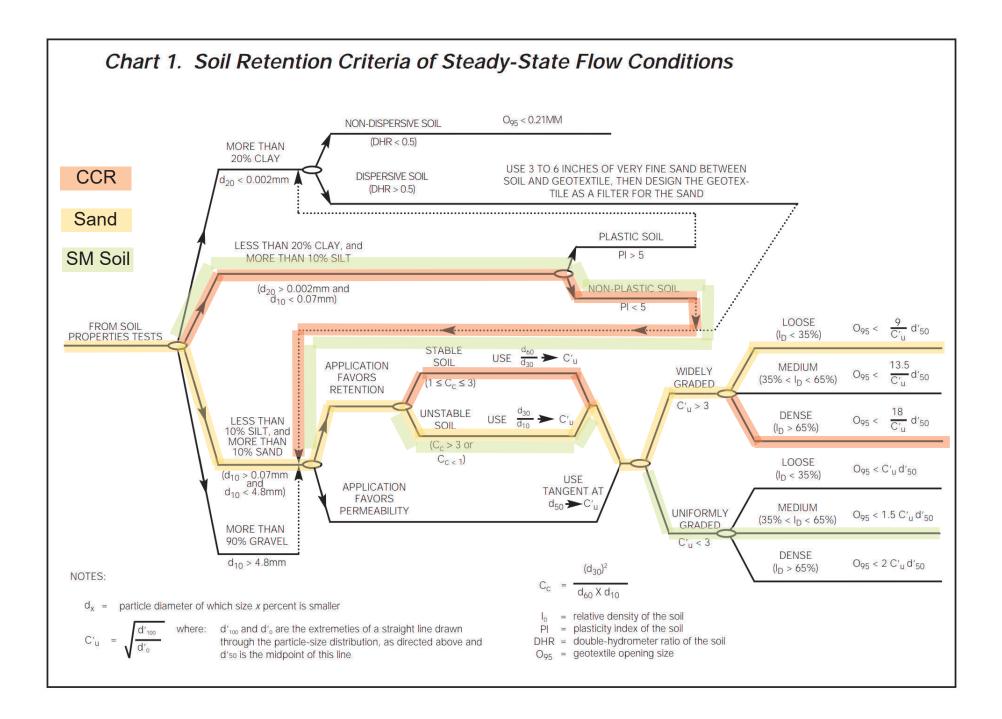
USCS Symbol SM, TESTED

(Non-Plastic Fines)

USCS Classification SILTY SAND

page 1 of 4

Geotextile AOS Calculations Attachment 2
Giroud Method Flowchart



Attachment 2 Giroud Method Flowchart

ATTACHMENT 6 PUNCTURE RESISTANCE



Calculations				
PROJECT: Bremo Bluff FFCP Management Facility	REFERENCE NO: 22130437.031			
SUBJECT: Puncture Resistance Calculations	DATE : 02/01/024			

1.0 OBJECTIVE

The objective of this analysis is to evaluate the puncture resistance strengths of the geotextile and geomembrane components of the bottom liner system for the proposed Coal Combustion Residuals (CCR) Unit at the Bremo Fossil Fuel Combustion Products (FFCP) Management Facility (Facility).

2.0 METHODOLOGY

The bottom liner system consists of a minimum 12-inch-thick controlled subgrade overlain by a geosynthetic clay liner (GCL), a 60-mil high-density polyethylene (HDPE) geomembrane liner, a 250-mil geocomposite, and an 18-inch-thick aggregate layer. The following options are being presented for the aggregate layer:

- Option 1 consists of a 12-inch-thick coarse aggregate drainage layer overlain by a 6-inch-thick fine aggregate protective layer, filtered/separated by a 10-ounce per square yard (oz) non-woven geotextile.
- Option 2 consists of an 18-inch-thick layer of coarse aggregate (Option 2A) or fine aggregate (Option 2B), with a 10-oz non-woven filter/separation geotextile placed directly atop the coarse aggregate in Option 2A.

The bottom liner system options are shown below in Figures 1 and 2.

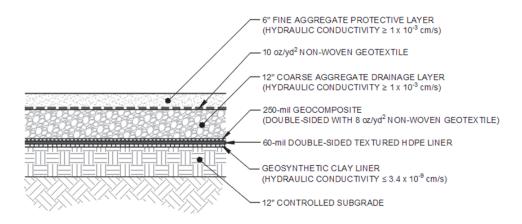
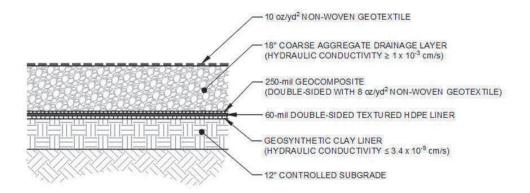
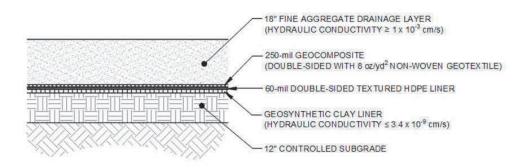


Figure 1: Bottom Liner System Option 1



OPTION 2A



OPTION 2B

Figure 2: Bottom Liner System Option 2

To ensure the integrity of the entire bottom liner system, puncture calculations were performed for the geomembrane, as protected by the geocomposite, the upper geotextile portion of the geocomposite, and the geotextile overlying the coarse aggregate. The methodology presented by Koerner (Koerner, 2012) was used to calculate the allowable pressure on the geomembrane and the puncture resistance of the geotextiles.

3.0 ASSUMPTIONS

Puncture resistance calculations were based on the following assumptions and input parameters:

- Base grade and final grade elevations were based on the grading in Attachment III of the Part B Permit Application (Design Plans).
- The coarse aggregate was assumed to be Virginia Department of Transportation (VDOT) No. 57 stone with a protrusion height of 0.5 inches, or 12 millimeters (mm), which is considered a typical d₅₀ for VDOT No. 57 stone.
- Fine aggregate was assumed to be sand.
- The VDOT No. 57 stone and sand were assigned a unit weight of 120 pounds per cubic foot (pcf).
- CCR waste was assigned a unit weight of 110 pcf based on results presented in the Bremo Power Station CCR Surface Impoundments, Impounding Structure Design Report, DCR Inventory #06520 (Golder, 2017).

- The final cover system soil was assigned a unit weight of 112 pcf, which is consistent with the United States Department of Interior Bureau of Reclamation's Design of Small Dams Unified Soil Classification System (USBR, 1987) for the silty sands or sand-silt mixtures (SM) on-site.
- The geocomposite, which consists of a geonet affixed between two 8-oz geotextiles, is represented as a 16-oz geotextile, conservatively neglecting any protection offered by the internal geonet.
- Bottom Liner System Option 1 with a VDOT No. 57 stone layer thickness of 12 inches and a sand layer thickness of 6 inches was used to analyze the filter/separation geotextile, geocomposite geotextile, and geomembrane.
- A maximum CCR waste height of 175 feet and a final cover system soil thickness of 2 feet were used.
- A Caterpillar D6 bulldozer with a ground pressure of 8 pounds per square inch (psi) was used to represent equipment operating above the liner. In evaluating the effects of construction equipment working above the liner, any load distribution provided by the drainage layer thickness was conservatively neglected.

4.0 CALCULATIONS

4.1 Geomembrane Puncture

The following equation is used to compute the allowable pressure on the geomembrane, as protected by the 16-oz geotextile portions of the geocomposite:

$$p_{allow} = \left(50 + 0.00045 \frac{M}{H^2}\right) \left[\frac{1}{MF_S \times MF_{PD} \times MF_A}\right] \left[\frac{1}{RF_{CR} \times RF_{CRD}}\right]$$

Where pallow = Allowable pressure on the geomembrane [kilopascal (kPa)]

50 = Representative puncture resistance of a 1.5 mm (60-mil) HDPE geomembrane

M = Geotextile mass per unit area [grams per square meter (g/m²)]

H = Protrusion height [meters (m)]

 MF_S = Modification factor for protrusion shape MF_{PD} = Modification factor for packing density MF_A = Modification factor for arching in soils RF_{CR} = Reduction factor for long-term creep

RF_{CBD} = Reduction factor for long-term chemical/biological degradation

Modification and reduction factors were selected based on either the expected conditions or the most conservative option and are presented in Table 1 below.

Table 1: Modification and Reduction Factors

Factor	Selected Value	Selection Reasoning
MFs	1	Angular (conservative)
MF _{PD}	0.5	Dense, 12 mm
MFA	1	Hydrostatic (conservative)
RF _{CR} ,16-oz	1.3	16-oz geotextile, ½-inch protrusion
RF _{CR} , 8/10-oz	1.6	8/10-oz geotextile, ½-inch protrusion
RFcbd	1.5	Harsh leachate (conservative)

To determine the factor of safety (FS) relating to the puncture resistance of the geotextile-protected geomembrane in the bottom liner system, the allowable pressure on the geomembrane was compared to the pressure exerted on the liner during placement of the drainage layer and CCR, as well as at final closure.

Design Report

Puncture Resistance Calculations

The pressure exerted on the geomembrane (p_{read}) was determined using the following equation:

$$p_{regd} = (\gamma H) + q_{eqp}$$

Where p_{reqd} = Required pressure to be resisted (psf)

 γ = Unit weight of overlying material (pcf)

H = Height of overlying material (ft)

q_{eqp} = Ground pressure of any equipment (psf)

$$FS = \frac{p_{allow}}{p_{reqd}}$$

4.2 Geotextile Puncture

To determine the FS relating to the puncture resistance of geotextiles in the bottom liner system design, the minimum puncture resistances outlined in Attachment VII of the Part B Permit Application (Technical Specifications) were compared to the vertical force exerted on the geotextiles during placement of the drainage layer and CCR, as well as at final closure.

$$F_{read} = p'd_a^2 S_1 S_2 S_3$$

Where F_{regd} = Required vertical puncturing force to be resisted (lbs)

d_a = Average diameter of the puncturing aggregate (ft)

p' = Pressure exerted on the geotextile (psf) S₁ = Protrusion factor of the puncturing object

S₂ = Scale factor to adjust ASTM D4833 puncture test value from probe to puncturing object

S₃ = Shape factor to adjust the ASTM D4833 flat puncture probe to shape of the puncturing object

The following table presents the selected S factors.

Table 2: S Factors

Factor	Selected Value	Selection Reasoning
S ₁	0.9	Angular, large (conservative)
S ₂	0.8	Angular, large (conservative)
S ₃	0.9	Angular, large (conservative)

$$FS = \frac{F_{allow}}{F_{reqd}} = \frac{F_{ult}/(MF \times RF)}{F_{reqd}}$$

Where F_{ult} = Ultimate force the geotextile can resist (lbs)

MF = Cumulative modification factor (MF_S x MF_{PD} x MF_A)

RF = Cumulative reduction factor ($RF_{CR} \times RF_{CBD}$)

This method of determining the necessary puncture resistance relates to puncture resistance as determined by pin puncture testing (ASTM 4833). As California Bearing Ratio (CBR) puncture resistance (ASTM D6241) has become the preferred method of measuring and reporting geotextile puncture resistance, CBR puncture resistance was related to pin puncture resistance through an empirical relationship developed by Elhajjar et al. (Elhajjar et al., 2017).

Design Report

Puncture Resistance Calculations

As the correlation was developed with limited data, the more conservative relationship for non-woven geotextiles was used, as follows:

CBR Puncture Strength = $5.91 \times Pin$ Puncture Strength

In support of the assumption that the two 8-oz geotextiles of the geocomposite perform as a single 16-oz geotextile in protecting the geomembrane, this analysis evaluates the upper 8-oz portion of the geocomposite to demonstrate that it does not puncture and would join with the lower geotextile before doing so. Ultimate CBR puncture strengths of 320 and 700 pounds, obtained from minimum values in the Technical Specifications as well as manufacturer-reported data, were used for the 8- and 10-oz geotextiles to translate to ultimate pin puncture strengths of 54 and 118 pounds, respectively.

5.0 RESULTS

5.1 Geomembrane

Using the equations, assumptions, and design values discussed above, the allowable pressure on the geomembrane was calculated to be 232.6 psi. After calculating the allowable pressure, the actual pressure exerted on the geomembrane was evaluated for two conditions.

The first condition considers the construction of the drainage layer or placement of initial lifts of CCR, where pressure is applied to the liner by the weight of the drainage layer as well as equipment operating on the stone, sand, or CCR, without enough thickness to significantly dissipate the weight of the equipment. For this condition, the pressure exerted on the geomembrane, 9.3 psi, was the sum of the pressure from the Caterpillar D6 bulldozer and 18-inch-thick drainage layer.

The second condition evaluated was the final closure of the landfill, where pressure is exerted on the liner by the weight of the drainage layer, the maximum height of CCR, and the final cover soils. The pressure exerted on the liner in this condition was calculated to be 136.6 psi. Both conditions and the resulting factors of safety are summarized below in Table 3.

	Calculated Pressures						
Condition	(psi)						
Condition	Drainage Layer	Operating Equipment	CCR	Final Cover Soils	Total	Allowable	FS
1 - Construction	1.3	8.0	N/A	N/A	9.3	232.6	25.0
2 - Final Closure	1.3	N/A	133.7	1.6	136.6	232.6	1.7

Table 3: Pressures Exerted on Geomembrane

5.2 Geocomposite Geotextile

Using the equations, assumptions, and design values discussed above, the allowable puncture force on the upper geotextile portion of the geocomposite was calculated to be 45.2 pounds (lbs). After calculating the allowable force, the actual force exerted on the geotextile was evaluated for the two conditions discussed in Section 5.1. For the first and second conditions, the forces exerted on the geomembrane were calculated to be 1.5 and 22.1 lbs, respectively. These conditions and the resulting factors of safety are summarized below in Table 4.

Table 4: Pressures Exerted on Upper Geotextile of Geocomposite

Calculated Pressure (psi)					Applied Force (lbs)		
Condition	Drainage Layer	Operating Equipment	CCR	Final Cover Soils	Total	Allowable	FS
1 - Construction	1.3	8.0	N/A	N/A	1.5	45.2	30.1
2 - Final Closure	1.3	N/A	133.7	1.6	22.1	45.2	2.0

5.3 Filter/Separation Geotextile

Using the equations, assumptions, and design values discussed above, the allowable puncture force on the filter/separation geotextile was calculated to be 98.2 lbs. After calculating the allowable force, the actual force exerted on the geotextile was evaluated for the two conditions discussed in Section 5.1. Pressures exerted on the geotextile were applied to the protrusion area to obtain an exerted puncture force. For the first and second conditions, the forces exerted on the geomembrane were calculated to be 1.4 and 22.0 lbs, respectively. These conditions and the resulting factors of safety are summarized below in Table 5.

Table 5: Pressures Exerted on the Filter/Separation Geotextile

		Calculated	Applie				
Condition	Protective Layer Sand	Operating Equipment	CCR	Final Cover Soils	(lbs) Total Allowable		FS
1 - Construction	0.4	8.0	N/A	N/A	1.4	98.2	70.1
2 - Final Closure	0.4	N/A	133.68	1.6	22.0	98.2	4.5

5.0 CONCLUSION

This puncture resistance evaluation demonstrates that the geotextile and geomembrane components of the bottom liner system will not puncture during the heaviest loading scenarios, i.e., equipment operating above the liner with minimal buffer and the final closure conditions of the CCR Unit. The factors of safety for all evaluated conditions are summarized below in Table 6.

Table 6: Factors of Safety Against Puncture of Geosynthetics

Condition	Geomembrane	Geocomposite Geotextile, 8-oz	Filter/Separation Geotextile, 10-oz
1 - Construction	25.0	30.1	70.1
2 - Final Closure	1.7	2.0	4.5

Based on this analysis, equipment with an 8-psi ground pressure or lower can safely operate above the bottom liner with minimal buffer, though steps outlined in the Technical Specifications to protect underlying geosynthetics during placement of the drainage layer and initial lifts of CCR should be followed to ensure liner integrity is maintained. Additionally, the load from the maximum height of the CCR Unit will not exceed the puncture resistance capacity of the filter/separation geotextile, geocomposite geotextile, or the geomembrane given the cushion and protection of the geocomposite.

References:

(1) Elhajjar, R., Erfanian, H., Titi, H. H., Van Dyke, S. (Elhajjar et al., 2017). Correlation of ASTM D4833 and

Design Report

Puncture Resistance Calculations

- D6241 Geotextile Puncture Test Methods and Results for Use on WisDOT Projects. Wisconsin Department of Transportation.
- (2) Golder Associates (Golder, 2017). Bremo Power Station CCR Surface Impoundments, Impounding Structure Design Report, DCR Inventory #06520. March 2015, Revised March 2017.
- (3) Koerner, R. M. (Koerner, 2012). Designing with Geosynthetics, Sixth Edition, Volumes 1 and 2, 2012.
- (4) United States Department of Interiors Bureau of Reclamation (USBR, 1987). Design of Small Dams, Third Edition, 1987.

ATTACHMENT 7 STORMWATER ANALYSIS





Calculations						
PROJECT: Bremo Bluff FFCP Management Facility	REFERENCE NO: 22130437.031					
SUBJECT: Stormwater Analysis	DATE: 02/01/2024					

1.0 OBJECTIVE

The objective of this analysis is to demonstrate the adequacy of the proposed stormwater management systems to convey flow from the 25-year, 24-hour storm event in accordance with the Virginia Solid Waste Management Regulations (VSWMR) for the Bremo Bluff Fossil Fuel Combustion Products (FFCP) Management Facility (Facility).

2.0 BACKGROUND

During filling operations, contact stormwater, i.e., stormwater that contacts CCR, will be managed separately from leachate and stormwater run-off. Contact stormwater run-off from the face of the active area of the proposed Coal Combustion Residuals (CCR) Unit will be routed through dedicated temporary slope drains into collection piping around the perimeter of the CCR Unit and conveyed to a dedicated stormwater management structure, the Contact Stormwater Pond (CSWP). Contact stormwater collected in the CSWP will be pumped directly to a proposed Dominion Energy-owned, permitted wastewater treatment facility, which is further discussed in Attachment VIII of the Part B Permit Application (Leachate Management Plan).

Stormwater run-on to the Facility will be collected in outer perimeter run-on control channels, which will drain to the stormwater ponds at the southern edge of the Facility for attenuation prior to release.

After closure of the CCR Unit, stormwater run-off from the final cover system will be collected in a series of drainage benches and permanent slope drains, which convey flow to the perimeter stormwater channels that will drain to the stormwater ponds at the southern edge of the Facility for attenuation prior to release.

3.0 METHODOLOGY

The site was modeled in the U.S. Army Corps of Engineers Hydrologic Engineering Center's Hydrologic Modeling System (HEC-HMS) using calculation methodology from the Natural Resources Conservation Service's (NRCS) Technical Release 55 (TR-55). The HEC-HMS model was used to determine flow rates and volumes to the various stormwater structures, which were analyzed to demonstrate compliance with the VSWMR; Title 9 Virginia Administration Code (VAC) Agency 20, Chapter 81, Section 130, Subsection H (9VAC20-81-130.H). Additionally, channel capacities and velocities were analyzed to demonstrate compliance with Virginia Erosion and Sediment Control Regulations Minimum Standard No. 19 (9VAC25-840-40).

Existing topography was based on the aerial survey completed by McKenzie Snyder, Inc. on March 24, 2019, and existing landcover conditions were determined from ESRI's Geographic Information System (GIS) aerial imagery for the Bremo Bluff area, data October 3rd, 2022.

Meteorological data was obtained from the National Ocean and Atmospheric Administration (NOAA) Atlas 14 Precipitation Frequency Data Server and was used to model the design frequency storms. The Facility is located in Bremo Bluff, Virginia and detailed precipitation data is provided in Attachment 1.

Information on site soil types and corresponding hydrologic soil groups (HSG) was obtained from the NRCS' Web

Soil Survey. Existing soils within the proposed Facility footprint are predominantly HSG Type A soils. For modeling, all disturbed areas were assumed to be HSG Type B soils in the post-development condition. Web Soil Survey data is included in Attachment 2.

Each drainage area was assigned an area-weighted runoff curve number (CN) based on the existing and proposed land covers and HSGs found within the delineated areas.

3.1 HEC-HMS Model

The site was divided into drainage areas, reaches, and ponds for modeling in HEC-HMS. Drainage areas were delineated by hand based on the existing topography, proposed grading, and proposed stormwater conveyance structures and are shown on the Drainage Area Map included in Attachment 3. Travel times and lag times for each drainage area were calculated using the methodology described in TR-55. HEC-HMS Model inputs and outputs are included in Attachments 4 and 5, respectively.

3.2 Stormwater Conveyance

3.2.1 Benches and Channels

In accordance with 9VAC25-840-40 MS-19, stormwater conveyance benches and channels shall be non-erosive during the 2-year, 24-hour storm event and contain the 10-year, 24-hour storm event. Per the VSWMR, stormwater controls systems are to be designed to contain the flow from the 25-year, 24-hour storm event, which exceed the 10-year, 24-hour capacity requirements from MS-19. The benches and channels were designed to contain flows up to the 100-year, 24-hour storm event, exceeding the design requirements of the VSWMR. Per NOAA Atlas 14, the 25-year, 24-hour storm event and the 100-year, 24-hour storm event at the Facility results in 5.93 inches and 7.91 inches of precipitation, respectively.

Bench and channel flow depth was calculated using Manning's Equation for open channel flow:

$$Q = \frac{1.49}{n} A R^{\frac{2}{3}} S^{\frac{1}{2}}$$

Where:

Q = Flowrate [cubic feet per second (cfs)]

n = Manning's roughness coefficient

A = Cross Sectional Flow Area [square feet (sf)]

R = Hydraulic Radius (ft)

S = Longitudinal Slope [feet per foot (ft/ft)]

The shear stress in each bench and channel was calculated using the following equation:

$$T_o = \gamma dS$$

Where:

 T_o = Mean Boundary Shear Stress [pounds per square foot (psf)]

 γ = Unit Weight of Water, 62.4 [pounds per cubic foot (pcf)]

d = Maximum Depth of Channel Flow (ft)

Grass lining erodibility was evaluated based on the guidance in the Virginia Erosion and Sediment Control Handbook (VESCH) (Chapter 3.17 and Table 5-14). None of the disturbed soils were identified as having a high

erosive tendency, i.e., a k factor greater than 0.35; therefore, no correction was required for the VESCH-supplied permissible velocities. The grass seed blend is assumed to be a grass-legume mixture.

Riprap lining erodibility was evaluated using guidance from the Federal Highway Administration's (FHWA) Hydraulic Engineering Circular No. 15 (HEC-15) Design of Roadside Channels with Flexible Linings. Calculated depths, velocities, and additional details are included in Section 4.1, Table 1.

HydroTurf erodibility was evaluated using manufacturer's data, which states it can handle flows up to 40 feet per second with no instability or damage.

In accordance with the FHWA HEC-15, rigid linings such as concrete are considered non-erodible. Calculated depths, velocities, and additional details are included in Section 4.1, Table 1.

3.2.2 Slope Drains

Non-contact stormwater run-off from the CCR Unit will be collected in a series of drainage benches and conveyed through final cover slope drains to the perimeter stormwater conveyance channel. The slope drains will be constructed in the final cover system and are proposed to be 24-inch diameter Advanced Drainage System (ADS) N-12 piping with a 24-inch diameter drop inlet tee collecting flow from each drainage bench. Flows from the largest contributing drainage area to a drain, as determined from HEC-HMS, were used to verify pipe capacity is not exceeded. The slope drain inlets were evaluated using the weir and orifice equations, shown in Section 3.2.5, and the flow rate from the drainage bench with the largest contributing area.

The hydraulic grade line (HGL) was calculated to verify that the HGL will not exceed the overtopping elevation (i.e., drop inlet rim elevations plus 2-feet) at any point in the final cover slope drain. The HGL was calculated using Autodesk Storm and Sanitary Analysis for the longest proposed slope drain with the largest contributing flow.

Inlet capacity and HGL calculations are included in Attachment 6.

3.2.3 Culverts

The stormwater run-off collected from the perimeter drainage channels is conveyed to the stormwater ponds via concrete culverts and the storm sewer system described in the section below. The culverts were designed to convey the anticipated flows from the 100-year, 24-hour storm event without creating an overtopping headwater condition. Each culvert was analyzed using the FHWA's HY-8 culvert analysis program. Culvert calculations comparing the maximum available flow capacity with the design flows resulting from the 25-year and 100-year, 24-hour storm events are included in Attachment 7.

3.2.4 Storm Sewer System

Stormwater from the western portion of the Facility is conveyed through a storm sewer system comprised of a series of drop inlets, concrete pipes, and concrete manholes. This system is shown in Attachment III of the Part B Permit Application (Design Plans) as Storm Sewer Profiles A and B.

The HGL of the storm sewer system was calculated using Autodesk Storm and Sanitary Analysis to verify that the HGL will not exceed the drop inlet or manhole rim elevations. These calculations are included in Attachment 8.

3.2.5 Stormwater Ponds

The stormwater ponds were evaluated using discharge structure rating tables with flowrates and water levels calculated through HEC-HMS. Each pond's discharge structure consists of a combination of orifices and weirs that control the discharge rate based on the impounded water elevation. Discharge from orifices, such as the

dewatering devices, were calculated using the orifice equation, shown below, assuming an orifice discharge coefficient of 0.61.

$$Q = C_d A_o \sqrt{2gh}$$

Discharge from weirs, such as the flow over the principal riser structure at low heads, were calculated using the rectangular weir equation, shown below, with a weir coefficient of 3.33 for a sharp-crested weir.

$$Q = C_w L h^{1.5}$$

Where:

C_d = Orifice Discharge Coefficient

*C*_w = Weir Discharge Coefficient

 A_o = Orifice Area (sf)

g = Gravitational Constant [feet per square second (ft/s²)]

h = head (ft)

L = Weir Crest Length (ft)

Depending on the head on the structure, the principal spillway may function as either an orifice or a weir. This effect was included in the riser structure calculations by limiting flow through the structure to the lesser of the calculated discharges. Flows from the riser structure outlet pipe were calculated using a culvert hydraulic spreadsheet developed by the Urban Drainage and Flood Control District in Denver, Colorado. (UD Culvert). The stage-storage, discharge rating curves, and details for the stormwater ponds are included in Attachment 9.

3.2.6 Cap Drainage Layer

The final cover system for the closed CCR Unit will include a drainage layer to manage stormwater infiltrating through the cover soil. The drainage layer consists of a 250-mil geocomposite which outlets to a network of cap drainpipes and returns the infiltrated stormwater to the main stormwater conveyance systems. To demonstrate this additional flow quantity is adequately managed, the drainage layer discharge is included as an additional flow quantity in the stormwater calculations. Infiltration into the landfill cover system was modeled as baseflow and routed through the stormwater conveyance systems using the linear reservoir method in HEC-HMS. This method accounts for nearly 100 percent of infiltration volume and simulates the recession of flow through the drainage layer after a storm event. Hydrographs from the final cover area subbasins in HEC-HMS resulting from the 25-year storm event are included in Attachment 12.

3.3 Contact Stormwater Conveyance

3.3.1 Contact Stormwater Pipes

Contact stormwater from the active area of the CCR Unit will be routed through dedicated temporary slope drains to the perimeter contact water pipes. The slope drains will be constructed down the side slopes of the CCR Unit and are proposed to be 24-inch diameter SDR-17 high-density polyethylene (HDPE) piping with a 24-inch by 36-inch tee conveying flow to the perimeter 36-inch diameter SDR-11 HDPE contact stormwater piping.

The contact stormwater slope drains and perimeter pipes were modeled using Manning's equation, shown in Section 3.2.1, with a Manning's coefficient of 0.013 to determine capacity at the minimum slopes. Flows from the largest contributing active area were used to verify pipe capacity is not exceeded. Pipe capacity calculations for the contact stormwater slope drains and perimeter pipes are included as Attachment 10.

3.3.2 Contact Stormwater Pond

The contact stormwater pipes discharge to the proposed CSWP, which is lined with geosynthetics and concrete

armoring. The CSWP is pumped directly to a proposed Dominion Energy-owned, permitted wastewater treatment facility. The HEC-HMS model results and stage-storage of the CSWP are included in Attachment 5 and Attachment 9, respectively. Post capping, the CSWP will be converted to a permanent stormwater management pond (Basin 3).

4.0 CALCULATIONS

4.1 Stormwater Conveyance

4.1.1 Benches and Channels

Using the flows determined from HEC-HMS (Attachment 4), the various proposed sideslope drainage benches and perimeter drainage channels were sized and modeled in AutoCAD's Hydraflow Express. The drainage bench flows were determined from the drainage bench with the largest contributing drainage area. Calculated values for each channel are summarized in the table below.

Table 1: Summary of Calculated Channel Values

				Eroc	libility		Capacity			
Channel ID	Slope (%)	Channel Lining	2-Year, 24-Hour Flow Rate (cfs ¹)	Flow Depth (ft²)	Velocity (ft/s³)	Shear Stress (psf ⁴)	100-Year, 24-Hour Flow Rate (cfs)	Flow Depth (ft)	Channel Depth (ft)	Freeboard (ft)
C.AR1	6.0%	Hydro Turf	6.27	0.55	8.29	2.06	21.38	0.86	2	1.14
C.E1	1.5%	Concrete	4.06	0.14	3.50	0.13	14.21	0.29	4	3.71
C.E2	1.5%	Concrete	9.32	0.23	4.79	0.22	36.80	0.51	4	3.49
C.E3	1.5%	Concrete	2.21	0.10	2.70	0.09	5.46	0.17	4	3.83
C.PE1	1.5%	Grass	2.01	0.24	1.82	0.22	23.58	0.95	3.6	2.65
C.PW1	2.5%	Grass	087	0.13	1.55	0.20	11.49	0.56	3.6	3.04
C.W1	2.5%	Concrete	4.80	0.13	4.47	0.20	18.57	0.29	4	3.71
C.W2	8.0%	Concrete	0.31	0.03	1.28	0.05	0.95	0.05	4	3.95
C.W3	1.5%	Concrete	6.47	0.18	4.30	0.17	22.19	0.38	4	3.62
C.W4	1.5%	Concrete	2.74	0.11	3.03	0.10	9.10	0.23	4	3.77
C.W5	1.5%	Concrete	3.25	0.12	3.29	0.11	10.64	0.25	4	3.75
C.RR1	13.5%	Grouted RR ⁵ /Gabion	13.35	0.28	7.12	2.36	73.68	0.75	2	1.25
C.RR2	12.5%	Riprap	4.42	0.26	3.66	2.03	24.14	0.66	2	1.34
C.RR3	7.0%	Grouted RR/Gabion	17.70	0.40	6.32	1.75	97.15	1.04	2	0.96
C.RR4	8.0%	Riprap	6.52	0.29	3.34	1.45	39.45	0.81	2	1.19
Drainage Bench (maximum)	2.0%	Grass	1.38	0.35	1.73	0.44	10.38	0.73	2	1.27

Notes:

- ¹ Cubic feet per second (cfs).
- ² Feet (ft).
- ³ Feet per second (ft/s).
- ⁴ Pounds per square foot (psf).

The maximum permissible flow velocities for a grass-lined channel with a grass and legume seed mixture are presented in the VESCH (Chapter 3.17 and Table 5-14) and are 4.00 feet per second (ft/s) for slopes less than 5 percent and 3.00 ft/s for slopes between 5 and 10 percent. The 100-year, 24-hour storm event was analyzed to determine the maximum flow depth in each channel, exceeding the VSWMR 25-year, 24-hour storm event requirement.

⁵ Riprap (RR).

As shown in Table 2.3 of the FHWA's HEC-15, the permissible shear stress for rock riprap with a d_{50} of 1.0 ft (approximately Class I) is 4.8 psf.

Based on the values shown in the table above, the drainage benches and receiving perimeter channels will not exceed the permissible criteria for flow depth or erodibility during the 2-year, 24-hour storm event and 100-year, 24-hour storm event, respectively.

4.1.2 Slope Drains

The most critical slope drain collects flow from approximately 12.9 acres and results in a maximum inflow rate of 36.14 cfs during the 100-year, 24-hour storm event. The slope drain was analyzed using Autodesk Storm and Sanitary Analysis to demonstrate capacity of the system to safely convey the design flows. Calculation results are included in Attachment 8,

As shown in Section 4.1.1, during the 100-year, 24-hour storm, the most critical drainage bench has an inflow rate of 10.07 cfs and a peak flow depth of 0.72 ft. The 24-inch diameter slope drain inlet tee with 0.72 ft of head has an inflow capacity of approximately 10.49 cfs, thus exceeding the inflow received from the channel.

To determine the HGL of the slope drain flowing at its maximum inflow rate, the slope drain was divided into different stations for each drop inlet. The slope drain is designed so that the water levels will not overtop the drop inlets drainage berm (rim elevation plus 2-foot channel depth). A table summarizing the station inverts, overtopping elevations, and 100-year, 24-hour storm HGL is shown below.

Table 2: Summary of Slope Drain Capacity

Station Location	Invert (ft-amsl ¹)	Overtopping Elevation (ft-amsl)	HGL from the 100-year, 24-hour Storm Event (ft-amsl)
Inlet S.1.5	375.35	381.35	379.92
Inlet S.1.4	404.79	411.29	409.30
Inlet S.1.3	434.87	441.37	436.70
Inlet S.1.2	464.96	471.46	466.17
Inlet S.1.1	501.60	508.1	501.90

Notes: ¹ Feet above mean sea level (ft-amsl).

4.1.3 Culverts

Using the flows determined from HEC-HMS (Attachment 4), the various proposed culverts were sized and modeled using the FHWA's HY-8 culvert analysis program, based on the maximum flow capacity without overtopping the associated channel section during the 100-year, 24-hour storm event. Calculated values for each culvert are summarized in the table below.

Table 3: Summary of Culvert Capacity

Culvert Name/No.	Diameter (in ¹)	Туре	Maximum Capacity (cfs)	100-year, 24-hour Design Flow (cfs)
C1A	36	2x Class IV RCP, with Headwall and Endwall	100.7	22.2
C2A	18	1x Class III RCP, with Headwall	15.4	3.2
C2B	36	1x Class III RCP, with Headwall	53.1	39.5
C2C	36	2x Class III RCP, with Headwall	169.2	97.2
C2D	36	2x Class III RCP, with Headwall and Endwall	103.2	97.2
C2E	36	2x Class III RCP, with Headwall and Endwall	102.0	73.7

C2F	24	1x Class III RCP, Drop Inlet	40.0	24.1
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Notes: 1 Inch (in).

Based on the values shown in the table above, the proposed culverts convey flow up to the 100-year, 24-hour storm event, exceeding the VSWMR 25-year, 24-hour storm event requirement.

4.1.4 Stormwater Ponds

Using HEC-HMS, inflows to the stormwater ponds under proposed conditions were modeled. The calculated values for the stormwater ponds are summarized in the table below.

Table 4: Summary of Stormwater Pond Values

Pond ID	Drainage Area (ac)	100-Year, 24-Hour Inflow Rate (cfs)	Maximum Pool Elevation (ft-amsl)	Freeboard to Emergency Spillway (ft)	Peak Discharge (cfs)
Basin 1	45.74	160.75	328.23	1.77	49.90
Basin 2	59.66	136.65	303.73	2.27	50.13
Basin 3	12.13	45.79	285.64	4.36	0.69

Based on the values shown in the table above, the proposed ponds convey flows up to the 100-year, 24-hour storm event, exceeding the VSWMR 25-year, 24-hour storm event requirement.

4.2 Contact Stormwater Conveyance

4.2.1 Contact Stormwater Pipes

The maximum active area draining to the contact stormwater system will be 28 acres and results in a peak discharge of approximately 145 cfs during the 100-year, 24-hour storm event. The discharge from the active area will be divided between the western and eastern contact stormwater systems located along the perimeter of the CCR Unit. A table summarizing the systems' maximum capacities is shown below.

Table 5: Summary of Contact Stormwater Pipes

System Control	Typical Slope (%)	Maximum Capacity (cfs)
24-in HDPE Slope Drain	33.3	130.96
24-in HDPE Slope Drain	5.0	50.72
Eastern 36-in HDPE Contact Stormwater Pipe	1.5	81.91
Western 36-in HDPE Contact Stormwater Pipe	1.5	81.91

Based on the values shown in the table above, the active CCR area is to be divided between the two contact stormwater pipes.

4.2.2 Contact Stormwater Pond

Using HEC-HMS, inflows to the CSWP under proposed conditions were modeled. The calculated values for the CSWP are summarized in the table below.

Table 6: Summary of CSWP Values

Pond ID	Drainage Area (ac)	100-Year, 24-Hour Inflow Rate (cfs)	Maximum Pool Elevation (ft-amsl)	Freeboard to Emergency Spillway (ft)	Peak Discharge (cfs)
CSWP	40.13	205.36	293.97	4.03	3.34 ¹

Notes: ¹ CSWP will have pumped discharge of 1500 gallons per minute (3.34 cfs)

Based on the values shown in the table above, the proposed pond conveys flow up to the 100-year, 24-hour storm event, exceeding the VSWMR 25-year, 24-hour storm event requirement.

5.0 Conclusion

The proposed stormwater management systems for the Facility are adequately sized and designed for anticipated conditions. The systems satisfy the minimum requirements set forth by MS-19 and the VSWMR.

Attachments:

- (1) NOAA Atlas 14 Precipitation Data
- (2) Web Soil Survey
- (3) Post-Development Drainage Area Map (SWM-1)
- (4) HEC-HMS Model and Inputs
- (5) HEC-HMS Results
- (6) Slope Drains
- (7) Culvert Calculations
- (8) Storm Sewer System Profiles
- (9) Pond Stage-Storage and Rating Curve
- (10) Contact Stormwater Pipes
- (11) Basin Hydrographs
- (12) Final Cover Area Subbasin Hydrographs

Stormwater Analysis Attachment 1 NOAA Atlas 14 Precipitation Data





NOAA Atlas 14, Volume 2, Version 3 Location name: Bremo Bluff, Virginia, USA* Latitude: 37.7113°, Longitude: -78.284°

Elevation: 291 ft**

* source: ESRI Maps

** source: USGS



POINT PRECIPITATION FREQUENCY ESTIMATES

G.M. Bonnin, D. Martin, B. Lin, T. Parzybok, M.Yekta, and D. Riley NOAA, National Weather Service, Silver Spring, Maryland

PF tabular | PF graphical | Maps & aerials

PF tabular

PDS-based point precipitation frequency estimates with 90% confidence intervals (in inches) ¹								hes) ¹		
Duration	Average recurrence interval (years)									
Duration	1	2	5	10	25	50	100	200	500	1000
5-min	0.341 (0.306-0.380)	0.389 (0.350-0.432)	0.435 (0.391-0.483	0.512 (0.459-0.568)	0.574 (0.515-0.635)	0.633 (0.564-0.699)	0.681 (0.605-0.752)	0.724 (0.639-0.799)	0.767 (0.673-0.848)	0.813 (0.707-0.899)
10-min	0.545 (0.490-0.607)	0.621 (0.560-0.691)	0. 696 (0.627-0.774)	0.818 (0.735-0.908)	0.914 (0.820-1.01)	1.01 (0.899-1.11)	1.08 (0.961-1.20)	1.15 (1.01-1.27)	1.21 (1.06-1.34)	1.28 (1.11-1.42)
15-min	0.682 (0.612-0.758)	0.781 (0.704-0.869)	0.881 (0.793-0.979)	1.04 (0.929-1.15)	1.16 (1.04-1.28)	1.28 (1.14-1.41)	1.37 (1.21-1.51)	1.45 (1.28-1.60)	1.53 (1.34-1.69)	1.61 (1.40-1.78)
30-min	0.934 (0.839-1.04)	1.08 (0.972-1.20)	1.25 (1.13-1.39)	1.50 (1.35-1.66)	1.72 (1.54-1.90)	1.92 (1.71-2.12)	2.10 (1.86-2.31)	2.26 (1.99-2.49)	2.43 (2.13-2.69)	2.60 (2.26-2.88)
60-min	1.16 (1.05-1.30)	1.35 (1.22-1.51)	1.60 (1.44-1.78)	1.95 (1.75-2.17)	2.28 (2.05-2.53)	2.60 (2.32-2.88)	2.88 (2.56-3.19)	3.16 (2.79-3.49)	3.48 (3.06-3.86)	3.80 (3.31-4.20)
2-hr	1.39 (1.24-1.56)	1.61 (1.44-1.81)	1.91 (1.71-2.15)	2.35 (2.10-2.63)	2.78 (2.47-3.11)	3.21 (2.83-3.59)	3.60 (3.15-4.01)	3.99 (3.48-4.44)	4.48 (3.86-4.98)	4.94 (4.23-5.51)
3-hr	1.50 (1.33-1.69)	1.74 (1.55-1.96)	2.06 (1.84-2.33)	2.53 (2.25-2.85)	2.99 (2.65-3.37)	3.45 (3.03-3.87)	3.86 (3.38-4.34)	4.29 (3.73-4.81)	4.80 (4.13-5.38)	5.30 (4.52-5.94)
6-hr	1.84 (1.63-2.11)	2.14 (1.90-2.44)	2.53 (2.24-2.89)	3.10 (2.74-3.54)	3.70 (3.24-4.21)	4.31 (3.76-4.89)	4.88 (4.22-5.54)	5.49 (4.70-6.22)	6.25 (5.29-7.08)	7.03 (5.87-7.95)
12-hr	2.25 (2.00-2.58)	2.61 (2.32-2.99)	3.09 (2.74-3.54)	3.81 (3.36-4.36)	4.60 (4.02-5.24)	5.42 (4.70-6.15)	6.22 (5.34-7.04)	7.09 (6.00-7.98)	8.22 (6.86-9.25)	9.40 (7.72-10.6)
24-hr	2.64 (2.41-2.92)	3.19 (2.92-3.54)	4.08 (3.72-4.52)	4.82 (4.38-5.34)	5.93 (5.35-6.54)	6.87 (6.16-7.57)	7.91 (7.03-8.69)	9.05 (7.97-9.91)	10.7 (9.31-11.7)	12.1 (10.4-13.3)
2-day	3.09 (2.81-3.41)	3.74 (3.40-4.13)	4.74 (4.31-5.23)	5.58 (5.06-6.14)	6.78 (6.12-7.45)	7.79 (6.99-8.54)	8.87 (7.91-9.71)	10.0 (8.89-11.0)	11.7 (10.3-12.9)	13.1 (11.4-14.4)
3-day	3.27 (2.99-3.60)	3.95 (3.61-4.35)	5.02 (4.58-5.52)	5.90 (5.37-6.47)	7.17 (6.50-7.85)	8.23 (7.42-9.00)	9.37 (8.39-10.2)	10.6 (9.42-11.6)	12.4 (10.9-13.5)	13.8 (12.0-15.2)
4-day	3.45 (3.16-3.78)	4.17 (3.82-4.58)	5.30 (4.85-5.80)	6.22 (5.68-6.80)	7.56 (6.88-8.25)	8.67 (7.85-9.46)	9.86 (8.86-10.8)	11.2 (9.95-12.2)	13.0 (11.5-14.2)	14.5 (12.7-15.9)
7-day	3.95 (3.65-4.29)	4.75 (4.39-5.17)	5.94 (5.47-6.45)	6.91 (6.35-7.50)	8.30 (7.60-8.99)	9.45 (8.61-10.2)	10.7 (9.66-11.6)	12.0 (10.8-13.0)	13.9 (12.3-15.0)	15.4 (13.5-16.7)
10-day	4.46 (4.14-4.82)	5.35 (4.96-5.79)	6.60 (6.12-7.13)	7.62 (7.04-8.22)	9.05 (8.33-9.76)	10.2 (9.37-11.0)	11.4 (10.4-12.3)	12.7 (11.6-13.7)	14.5 (13.1-15.7)	16.0 (14.2-17.3)
20-day	6.01 (5.62-6.43)	7.17 (6.71-7.67)	8.66 (8.09-9.26)	9.83 (9.18-10.5)	11.4 (10.6-12.2)	12.7 (11.8-13.5)	13.9 (12.9-14.9)	15.2 (14.0-16.3)	17.0 (15.5-18.2)	18.3 (16.6-19.6)
30-day	7.41 (6.97-7.88)	8.78 (8.27-9.34)	10.4 (9.77-11.0)	11.6 (10.9-12.3)	13.2 (12.4-14.0)	14.4 (13.5-15.3)	15.6 (14.5-16.5)	16.7 (15.5-17.7)	18.2 (16.8-19.3)	19.3 (17.7-20.5)
45-day	9.32 (8.79-9.87)	11.0 (10.4-11.6)	12.9 (12.1-13.6)	14.2 (13.4-15.1)	16.0 (15.1-16.9)	17.3 (16.3-18.3)	18.6 (17.4-19.7)	19.8 (18.5-20.9)	21.3 (19.9-22.6)	22.4 (20.8-23.8)
60-day	11.1 (10.4-11.7)	13.0 (12.3-13.7)	15.0 (14.2-15.8)	16.5 (15.6-17.4)	18.4 (17.4-19.4)	19.8 (18.6-20.9)	21.1 (19.9-22.3)	22.4 (21.0-23.6)	24.0 (22.4-25.3)	25.1 (23.3-26.6)

¹ Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS).

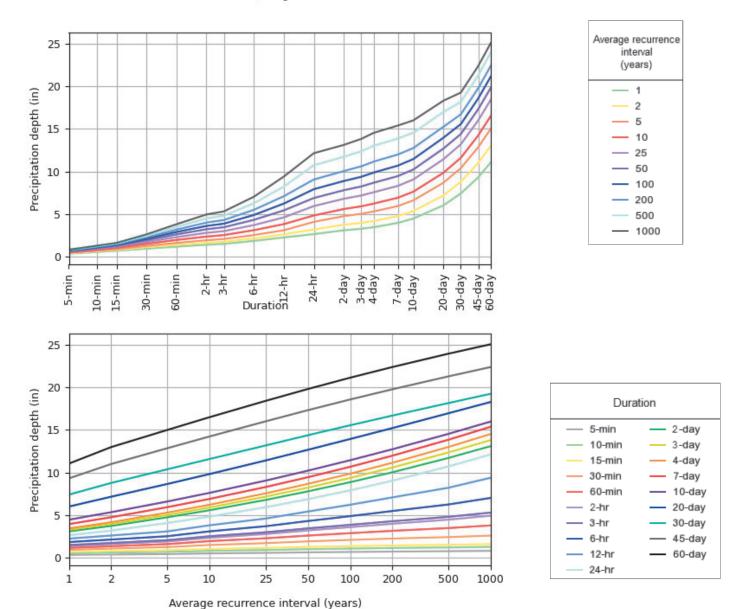
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Please refer to NOAA Atlas 14 document for more information.

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PF graphical

PDS-based depth-duration-frequency (DDF) curves Latitude: 37.7113°, Longitude: -78.2840°



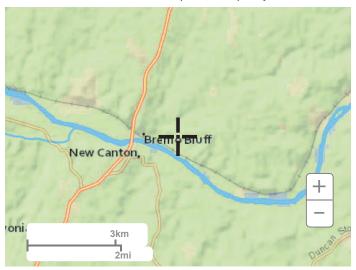
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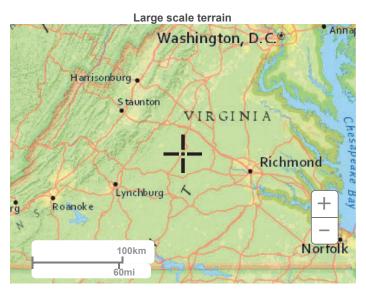
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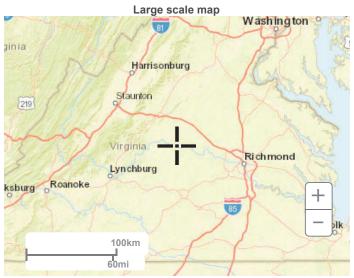
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Maps & aerials

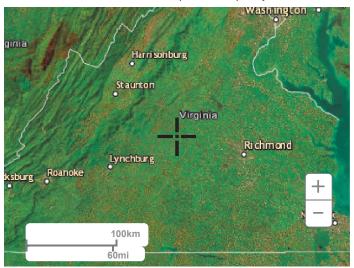
Small scale terrain







Large scale aerial



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US Department of Commerce

National Oceanic and Atmospheric Administration

National Weather Service National Water Center 1325 East West Highway Silver Spring, MD 20910 Questions?: <u>HDSC.Questions@noaa.gov</u>

<u>Disclaimer</u>

Stormwater Analysis Attachment 2 Web Soil Survey





Natural Resources Conservation

Service

A product of the National Cooperative Soil Survey, a joint effort of the United States Department of Agriculture and other Federal agencies, State agencies including the Agricultural Experiment Stations, and local participants Custom Soil Resource
Report for
Buckingham County,
Virginia, and Fluvanna
County, Virginia



Preface

Soil surveys contain information that affects land use planning in survey areas. They highlight soil limitations that affect various land uses and provide information about the properties of the soils in the survey areas. Soil surveys are designed for many different users, including farmers, ranchers, foresters, agronomists, urban planners, community officials, engineers, developers, builders, and home buyers. Also, conservationists, teachers, students, and specialists in recreation, waste disposal, and pollution control can use the surveys to help them understand, protect, or enhance the environment.

Various land use regulations of Federal, State, and local governments may impose special restrictions on land use or land treatment. Soil surveys identify soil properties that are used in making various land use or land treatment decisions. The information is intended to help the land users identify and reduce the effects of soil limitations on various land uses. The landowner or user is responsible for identifying and complying with existing laws and regulations.

Although soil survey information can be used for general farm, local, and wider area planning, onsite investigation is needed to supplement this information in some cases. Examples include soil quality assessments (http://www.nrcs.usda.gov/wps/portal/nrcs/main/soils/health/) and certain conservation and engineering applications. For more detailed information, contact your local USDA Service Center (https://offices.sc.egov.usda.gov/locator/app?agency=nrcs) or your NRCS State Soil Scientist (http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/contactus/?cid=nrcs142p2 053951).

Great differences in soil properties can occur within short distances. Some soils are seasonally wet or subject to flooding. Some are too unstable to be used as a foundation for buildings or roads. Clayey or wet soils are poorly suited to use as septic tank absorption fields. A high water table makes a soil poorly suited to basements or underground installations.

The National Cooperative Soil Survey is a joint effort of the United States Department of Agriculture and other Federal agencies, State agencies including the Agricultural Experiment Stations, and local agencies. The Natural Resources Conservation Service (NRCS) has leadership for the Federal part of the National Cooperative Soil Survey.

Information about soils is updated periodically. Updated information is available through the NRCS Web Soil Survey, the site for official soil survey information.

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How Soil Surveys Are Made

Soil surveys are made to provide information about the soils and miscellaneous areas in a specific area. They include a description of the soils and miscellaneous areas and their location on the landscape and tables that show soil properties and limitations affecting various uses. Soil scientists observed the steepness, length, and shape of the slopes; the general pattern of drainage; the kinds of crops and native plants; and the kinds of bedrock. They observed and described many soil profiles. A soil profile is the sequence of natural layers, or horizons, in a soil. The profile extends from the surface down into the unconsolidated material in which the soil formed or from the surface down to bedrock. The unconsolidated material is devoid of roots and other living organisms and has not been changed by other biological activity.

Currently, soils are mapped according to the boundaries of major land resource areas (MLRAs). MLRAs are geographically associated land resource units that share common characteristics related to physiography, geology, climate, water resources, soils, biological resources, and land uses (USDA, 2006). Soil survey areas typically consist of parts of one or more MLRA.

The soils and miscellaneous areas in a survey area occur in an orderly pattern that is related to the geology, landforms, relief, climate, and natural vegetation of the area. Each kind of soil and miscellaneous area is associated with a particular kind of landform or with a segment of the landform. By observing the soils and miscellaneous areas in the survey area and relating their position to specific segments of the landform, a soil scientist develops a concept, or model, of how they were formed. Thus, during mapping, this model enables the soil scientist to predict with a considerable degree of accuracy the kind of soil or miscellaneous area at a specific location on the landscape.

Commonly, individual soils on the landscape merge into one another as their characteristics gradually change. To construct an accurate soil map, however, soil scientists must determine the boundaries between the soils. They can observe only a limited number of soil profiles. Nevertheless, these observations, supplemented by an understanding of the soil-vegetation-landscape relationship, are sufficient to verify predictions of the kinds of soil in an area and to determine the boundaries.

Soil scientists recorded the characteristics of the soil profiles that they studied. They noted soil color, texture, size and shape of soil aggregates, kind and amount of rock fragments, distribution of plant roots, reaction, and other features that enable them to identify soils. After describing the soils in the survey area and determining their properties, the soil scientists assigned the soils to taxonomic classes (units). Taxonomic classes are concepts. Each taxonomic class has a set of soil characteristics with precisely defined limits. The classes are used as a basis for comparison to classify soils systematically. Soil taxonomy, the system of taxonomic classification used in the United States, is based mainly on the kind and character of soil properties and the arrangement of horizons within the profile. After the soil

scientists classified and named the soils in the survey area, they compared the individual soils with similar soils in the same taxonomic class in other areas so that they could confirm data and assemble additional data based on experience and research.

The objective of soil mapping is not to delineate pure map unit components; the objective is to separate the landscape into landforms or landform segments that have similar use and management requirements. Each map unit is defined by a unique combination of soil components and/or miscellaneous areas in predictable proportions. Some components may be highly contrasting to the other components of the map unit. The presence of minor components in a map unit in no way diminishes the usefulness or accuracy of the data. The delineation of such landforms and landform segments on the map provides sufficient information for the development of resource plans. If intensive use of small areas is planned, onsite investigation is needed to define and locate the soils and miscellaneous areas.

Soil scientists make many field observations in the process of producing a soil map. The frequency of observation is dependent upon several factors, including scale of mapping, intensity of mapping, design of map units, complexity of the landscape, and experience of the soil scientist. Observations are made to test and refine the soil-landscape model and predictions and to verify the classification of the soils at specific locations. Once the soil-landscape model is refined, a significantly smaller number of measurements of individual soil properties are made and recorded. These measurements may include field measurements, such as those for color, depth to bedrock, and texture, and laboratory measurements, such as those for content of sand, silt, clay, salt, and other components. Properties of each soil typically vary from one point to another across the landscape.

Observations for map unit components are aggregated to develop ranges of characteristics for the components. The aggregated values are presented. Direct measurements do not exist for every property presented for every map unit component. Values for some properties are estimated from combinations of other properties.

While a soil survey is in progress, samples of some of the soils in the area generally are collected for laboratory analyses and for engineering tests. Soil scientists interpret the data from these analyses and tests as well as the field-observed characteristics and the soil properties to determine the expected behavior of the soils under different uses. Interpretations for all of the soils are field tested through observation of the soils in different uses and under different levels of management. Some interpretations are modified to fit local conditions, and some new interpretations are developed to meet local needs. Data are assembled from other sources, such as research information, production records, and field experience of specialists. For example, data on crop yields under defined levels of management are assembled from farm records and from field or plot experiments on the same kinds of soil.

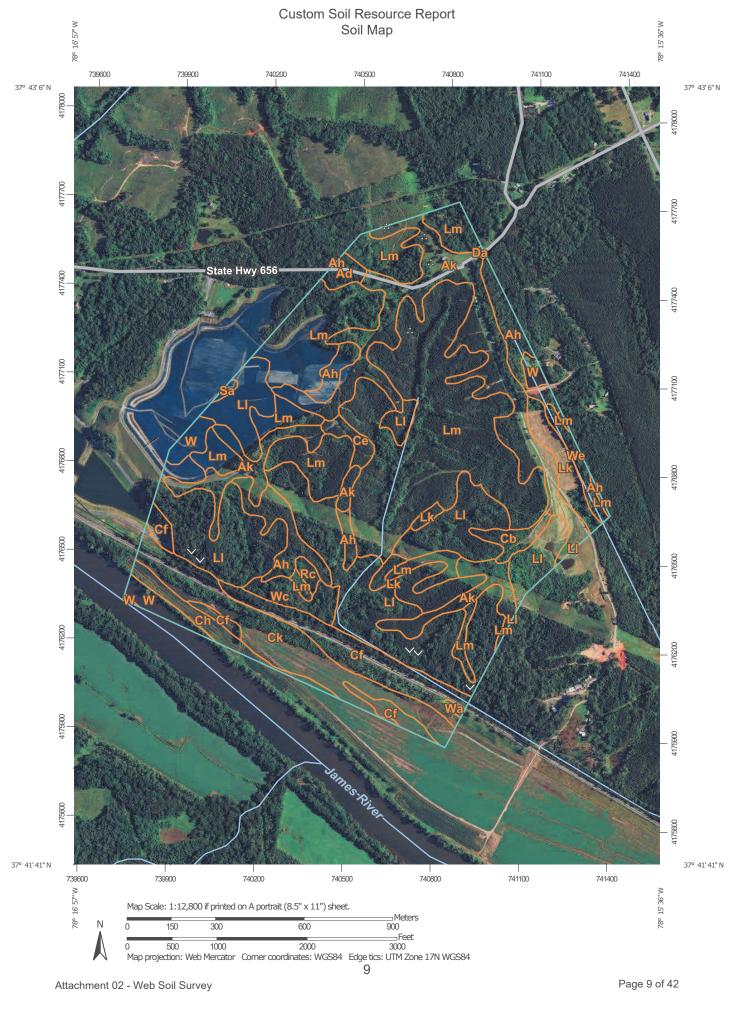
Predictions about soil behavior are based not only on soil properties but also on such variables as climate and biological activity. Soil conditions are predictable over long periods of time, but they are not predictable from year to year. For example, soil scientists can predict with a fairly high degree of accuracy that a given soil will have a high water table within certain depths in most years, but they cannot predict that a high water table will always be at a specific level in the soil on a specific date.

After soil scientists located and identified the significant natural bodies of soil in the survey area, they drew the boundaries of these bodies on aerial photographs and

identified each as a specific map unit. Aerial photographs show trees, buildings, fields, roads, and rivers, all of which help in locating boundaries accurately.

Soil Map

The soil map section includes the soil map for the defined area of interest, a list of soil map units on the map and extent of each map unit, and cartographic symbols displayed on the map. Also presented are various metadata about data used to produce the map, and a description of each soil map unit.



MAP LEGEND

Special Line Features Streams and Canals Interstate Highways Aerial Photography Very Stony Spot Major Roads Local Roads Stony Spot **US Routes** Spoil Area Wet Spot Other Nater Features ransportation **3ackground** W ŧ Soil Map Unit Polygons Area of Interest (AOI) Miscellaneous Water Soil Map Unit Points Soil Map Unit Lines Closed Depression Marsh or swamp Mine or Quarry Special Point Features **Gravelly Spot Borrow Pit** Lava Flow Clay Spot Area of Interest (AOI) **Gravel Pit** Blowout 9 Soils

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at scales ranging from 1:15,800 to 1:24,000.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Buckingham County, Virginia Survey Area Data: Version 8, Aug 24, 2022

Soil Survey Area: Fluvanna County, Virginia Survey Area Data: Version 17, Aug 26, 2022

Your area of interest (AOI) includes more than one soil survey area. These survey areas may have been mapped at different scales, with a different land use in mind, at different times, or at different levels of detail. This may result in map unit symbols, soil properties, and interpretations that do not completely agree across soil survey area boundaries.

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Severely Eroded Spot

Slide or Slip

Sinkhole

Sodic Spot

Perennial Water

Rock Outcrop

Saline Spot

Sandy Spot

Date(s) aerial images were photographed: May 19, 2022—Jul 1, 2022

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background

MAP LEGEND

MAP INFORMATION

imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Map Unit Legend

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI			
W	Water	0.2	0.0%			
Subtotals for Soil Survey Area		0.2	0.0%			
Totals for Area of Interest		435.3	100.0%			

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI	
Ad	Appling fine sandy loam, undulating phase	2.7	0.6%	
Ah			4.9%	
Ak	Appling sandy loam, undulating phase	65.3	15.0%	
Cb	Cecil clay loam, eroded undulating phase	4.0	0.9%	
Се	Cecil sandy loam, undulating phase	3.1	0.7%	
Cf	Chewacla silt loam	24.4	5.6%	
Ch	Congaree fine sandy loam	6.6	1.5%	
Ck	Congaree silt loam	29.2	6.7%	
Da	Durham fine sandy loam, undulating phase	0.2	0.1%	
Lk	Louisburg sandy loam, eroded rolling and hilly phases	16.6	3.8%	
LI	Louisburg sandy loam, eroded steep phase	101.2	23.2%	
Lm	Louisburg sandy loam, rolling and hilly phases	139.2	32.0%	
Rc	Rough gullied land	1.4	0.3%	
Sa	Seneca fine sandy loam	0.6	0.1%	
W	Water	8.8	2.0%	
Wa	Wehadkee silt loam	0.4	0.1%	
Wc	Wilkes sandy loam, hilly and steep phases	6.3	1.5%	
We	Worsham sandy loam	3.9	0.9%	
Subtotals for Soil Survey A	rea	435.1	100.0%	
Totals for Area of Interest		435.3	100.0%	

Map Unit Descriptions

The map units delineated on the detailed soil maps in a soil survey represent the soils or miscellaneous areas in the survey area. The map unit descriptions, along with the maps, can be used to determine the composition and properties of a unit.

A map unit delineation on a soil map represents an area dominated by one or more major kinds of soil or miscellaneous areas. A map unit is identified and named according to the taxonomic classification of the dominant soils. Within a taxonomic class there are precisely defined limits for the properties of the soils. On the landscape, however, the soils are natural phenomena, and they have the characteristic variability of all natural phenomena. Thus, the range of some observed properties may extend beyond the limits defined for a taxonomic class. Areas of soils of a single taxonomic class rarely, if ever, can be mapped without including areas of other taxonomic classes. Consequently, every map unit is made up of the soils or miscellaneous areas for which it is named and some minor components that belong to taxonomic classes other than those of the major soils.

Most minor soils have properties similar to those of the dominant soil or soils in the map unit, and thus they do not affect use and management. These are called noncontrasting, or similar, components. They may or may not be mentioned in a particular map unit description. Other minor components, however, have properties and behavioral characteristics divergent enough to affect use or to require different management. These are called contrasting, or dissimilar, components. They generally are in small areas and could not be mapped separately because of the scale used. Some small areas of strongly contrasting soils or miscellaneous areas are identified by a special symbol on the maps. If included in the database for a given area, the contrasting minor components are identified in the map unit descriptions along with some characteristics of each. A few areas of minor components may not have been observed, and consequently they are not mentioned in the descriptions, especially where the pattern was so complex that it was impractical to make enough observations to identify all the soils and miscellaneous areas on the landscape.

The presence of minor components in a map unit in no way diminishes the usefulness or accuracy of the data. The objective of mapping is not to delineate pure taxonomic classes but rather to separate the landscape into landforms or landform segments that have similar use and management requirements. The delineation of such segments on the map provides sufficient information for the development of resource plans. If intensive use of small areas is planned, however, onsite investigation is needed to define and locate the soils and miscellaneous areas.

An identifying symbol precedes the map unit name in the map unit descriptions. Each description includes general facts about the unit and gives important soil properties and qualities.

Soils that have profiles that are almost alike make up a *soil series*. Except for differences in texture of the surface layer, all the soils of a series have major horizons that are similar in composition, thickness, and arrangement.

Soils of one series can differ in texture of the surface layer, slope, stoniness, salinity, degree of erosion, and other characteristics that affect their use. On the basis of such differences, a soil series is divided into *soil phases*. Most of the areas

shown on the detailed soil maps are phases of soil series. The name of a soil phase commonly indicates a feature that affects use or management. For example, Alpha silt loam, 0 to 2 percent slopes, is a phase of the Alpha series.

Some map units are made up of two or more major soils or miscellaneous areas. These map units are complexes, associations, or undifferentiated groups.

A *complex* consists of two or more soils or miscellaneous areas in such an intricate pattern or in such small areas that they cannot be shown separately on the maps. The pattern and proportion of the soils or miscellaneous areas are somewhat similar in all areas. Alpha-Beta complex, 0 to 6 percent slopes, is an example.

An association is made up of two or more geographically associated soils or miscellaneous areas that are shown as one unit on the maps. Because of present or anticipated uses of the map units in the survey area, it was not considered practical or necessary to map the soils or miscellaneous areas separately. The pattern and relative proportion of the soils or miscellaneous areas are somewhat similar. Alpha-Beta association, 0 to 2 percent slopes, is an example.

An *undifferentiated group* is made up of two or more soils or miscellaneous areas that could be mapped individually but are mapped as one unit because similar interpretations can be made for use and management. The pattern and proportion of the soils or miscellaneous areas in a mapped area are not uniform. An area can be made up of only one of the major soils or miscellaneous areas, or it can be made up of all of them. Alpha and Beta soils, 0 to 2 percent slopes, is an example.

Some surveys include *miscellaneous areas*. Such areas have little or no soil material and support little or no vegetation. Rock outcrop is an example.

Buckingham County, Virginia

W-Water

Map Unit Composition

Water: 100 percent

Estimates are based on observations, descriptions, and transects of the mapunit.

Fluvanna County, Virginia

Ad—Appling fine sandy loam, undulating phase

Map Unit Setting

National map unit symbol: 42pp Elevation: 250 to 510 feet

Mean annual precipitation: 24 to 58 inches Mean annual air temperature: 55 to 58 degrees F

Frost-free period: 153 to 205 days

Farmland classification: All areas are prime farmland

Map Unit Composition

Appling and similar soils: 85 percent

Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Appling

Setting

Landform: Hillslopes

Landform position (two-dimensional): Summit Landform position (three-dimensional): Interfluve

Down-slope shape: Convex Across-slope shape: Convex

Parent material: Residuum weathered from granite and gneiss

Typical profile

H1 - 0 to 12 inches: fine sandy loam

H2 - 12 to 46 inches: clay

H3 - 46 to 65 inches: sandy clay loam

Properties and qualities

Slope: 2 to 8 percent

Depth to restrictive feature: More than 80 inches

Drainage class: Well drained

Runoff class: Low

Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high

(0.57 to 1.98 in/hr)

Depth to water table: More than 80 inches

Frequency of flooding: None Frequency of ponding: None

Available water supply, 0 to 60 inches: Moderate (about 7.6 inches)

Interpretive groups

Land capability classification (irrigated): None specified

Land capability classification (nonirrigated): 2e

Hydrologic Soil Group: B

Ecological site: F136XY320VA - Northern inner piedmont acidic upland forest,

moist

Ah—Appling sandy loam, rolling phase

Map Unit Setting

National map unit symbol: 42pt Elevation: 210 to 440 feet

Mean annual precipitation: 24 to 58 inches Mean annual air temperature: 55 to 58 degrees F

Frost-free period: 153 to 205 days

Farmland classification: Farmland of statewide importance

Map Unit Composition

Appling and similar soils: 85 percent

Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Appling

Setting

Landform: Hillslopes

Landform position (two-dimensional): Shoulder Landform position (three-dimensional): Interfluve

Down-slope shape: Convex Across-slope shape: Convex

Parent material: Residuum weathered from granite and gneiss

Typical profile

H1 - 0 to 9 inches: sandy loam H2 - 9 to 47 inches: clay

H3 - 47 to 79 inches: sandy loam

Properties and qualities

Slope: 8 to 15 percent

Depth to restrictive feature: More than 80 inches

Drainage class: Well drained

Runoff class: Low

Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high

(0.57 to 1.98 in/hr)

Depth to water table: More than 80 inches

Frequency of flooding: None Frequency of ponding: None

Available water supply, 0 to 60 inches: High (about 9.2 inches)

Interpretive groups

Land capability classification (irrigated): None specified

Land capability classification (nonirrigated): 4e

Hydrologic Soil Group: B

Ecological site: F136XY320VA - Northern inner piedmont acidic upland forest,

moist

Ak—Appling sandy loam, undulating phase

Map Unit Setting

National map unit symbol: 42pv Elevation: 200 to 480 feet

Mean annual precipitation: 24 to 58 inches Mean annual air temperature: 55 to 58 degrees F

Frost-free period: 153 to 205 days

Farmland classification: All areas are prime farmland

Map Unit Composition

Appling and similar soils: 85 percent

Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Appling

Setting

Landform: Hillslopes

Landform position (two-dimensional): Summit Landform position (three-dimensional): Interfluve

Down-slope shape: Convex Across-slope shape: Convex

Parent material: Residuum weathered from granite and gneiss

Typical profile

H1 - 0 to 9 inches: sandy loam H2 - 9 to 47 inches: clay

H3 - 47 to 79 inches: sandy loam

Properties and qualities

Slope: 2 to 8 percent

Depth to restrictive feature: More than 80 inches

Drainage class: Well drained

Runoff class: Low

Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high

(0.57 to 1.98 in/hr)

Depth to water table: More than 80 inches

Frequency of flooding: None Frequency of ponding: None

Available water supply, 0 to 60 inches: High (about 9.2 inches)

Interpretive groups

Land capability classification (irrigated): None specified

Land capability classification (nonirrigated): 2e

Hydrologic Soil Group: B

Ecological site: F136XY320VA - Northern inner piedmont acidic upland forest,

moist

Cb—Cecil clay loam, eroded undulating phase

Map Unit Setting

National map unit symbol: 42q2 Elevation: 200 to 1,400 feet

Mean annual precipitation: 24 to 58 inches Mean annual air temperature: 55 to 58 degrees F

Frost-free period: 153 to 205 days

Farmland classification: Not prime farmland

Map Unit Composition

Cecil and similar soils: 85 percent

Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Cecil

Setting

Landform: Hillslopes

Landform position (two-dimensional): Summit Landform position (three-dimensional): Interfluve

Down-slope shape: Convex Across-slope shape: Convex

Parent material: Residuum weathered from granite and gneiss

Typical profile

H1 - 0 to 9 inches: clay loam H2 - 9 to 60 inches: clay

H3 - 60 to 79 inches: sandy clay loam

Properties and qualities

Slope: 2 to 8 percent

Depth to restrictive feature: More than 80 inches

Drainage class: Well drained

Runoff class: Low

Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high

(0.57 to 1.98 in/hr)

Depth to water table: More than 80 inches

Frequency of flooding: None Frequency of ponding: None

Available water supply, 0 to 60 inches: Moderate (about 8.3 inches)

Interpretive groups

Land capability classification (irrigated): None specified

Land capability classification (nonirrigated): 3e

Hydrologic Soil Group: B

Ecological site: F136XY320VA - Northern inner piedmont acidic upland forest,

moist

Ce—Cecil sandy loam, undulating phase

Map Unit Setting

National map unit symbol: 42q5 Elevation: 200 to 1,400 feet

Mean annual precipitation: 24 to 58 inches Mean annual air temperature: 55 to 58 degrees F

Frost-free period: 153 to 205 days

Farmland classification: All areas are prime farmland

Map Unit Composition

Cecil and similar soils: 85 percent

Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Cecil

Setting

Landform: Hillslopes

Landform position (two-dimensional): Summit Landform position (three-dimensional): Interfluve

Down-slope shape: Convex Across-slope shape: Convex

Parent material: Residuum weathered from granite and gneiss

Typical profile

H1 - 0 to 8 inches: sandy loam H2 - 8 to 56 inches: clay H3 - 56 to 72 inches: loam

Properties and qualities

Slope: 2 to 8 percent

Depth to restrictive feature: More than 80 inches

Drainage class: Well drained

Runoff class: Low

Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high

(0.57 to 1.98 in/hr)

Depth to water table: More than 80 inches

Frequency of flooding: None Frequency of ponding: None

Available water supply, 0 to 60 inches: Moderate (about 8.3 inches)

Interpretive groups

Land capability classification (irrigated): None specified

Land capability classification (nonirrigated): 2e

Hydrologic Soil Group: B

Ecological site: F136XY320VA - Northern inner piedmont acidic upland forest,

moist

Cf—Chewacla silt loam

Map Unit Setting

National map unit symbol: 42q6 Elevation: 200 to 430 feet

Mean annual precipitation: 24 to 58 inches Mean annual air temperature: 55 to 58 degrees F

Frost-free period: 153 to 205 days

Farmland classification: Not prime farmland

Map Unit Composition

Chewacla and similar soils: 85 percent

Minor components: 7 percent

Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Chewacla

Setting

Landform: Flood plains

Landform position (three-dimensional): Tread

Down-slope shape: Linear Across-slope shape: Linear Parent material: Alluvium

Typical profile

H1 - 0 to 10 inches: silt loam H2 - 10 to 44 inches: silt loam H3 - 44 to 79 inches: loam

Properties and qualities

Slope: 0 to 2 percent

Depth to restrictive feature: More than 80 inches Drainage class: Somewhat poorly drained

Runoff class: Low

Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high

(0.57 to 1.98 in/hr)

Depth to water table: About 6 to 18 inches Frequency of flooding: NoneFrequent

Frequency of ponding: None

Available water supply, 0 to 60 inches: High (about 11.3 inches)

Interpretive groups

Land capability classification (irrigated): None specified

Land capability classification (nonirrigated): 4w

Hydrologic Soil Group: B/D

Ecological site: F136XY110VA - Northern inner piedmont flood plain forest, wet

Hydric soil rating: No

Minor Components

Wehadkee

Percent of map unit: 7 percent

Landform: Flood plains

Landform position (three-dimensional): Tread

Down-slope shape: Linear Across-slope shape: Linear Hydric soil rating: Yes

Ch—Congaree fine sandy loam

Map Unit Setting

National map unit symbol: 42q8 Elevation: 100 to 500 feet

Mean annual precipitation: 24 to 58 inches
Mean annual air temperature: 55 to 58 degrees F

Frost-free period: 153 to 205 days

Farmland classification: All areas are prime farmland

Map Unit Composition

Congaree and similar soils: 85 percent

Minor components: 7 percent

Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Congaree

Setting

Landform: Flood plains

Landform position (three-dimensional): Tread

Down-slope shape: Linear Across-slope shape: Linear Parent material: Alluvium

Typical profile

H1 - 0 to 8 inches: fine sandy loam H2 - 8 to 30 inches: sandy clay loam H3 - 30 to 60 inches: fine sandy loam

Properties and qualities

Slope: 0 to 2 percent

Depth to restrictive feature: More than 80 inches

Drainage class: Well drained

Runoff class: Low

Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high

(0.57 to 1.98 in/hr)

Depth to water table: About 30 to 48 inches Frequency of flooding: NoneOccasional

Frequency of ponding: None

Available water supply, 0 to 60 inches: Moderate (about 8.2 inches)

Interpretive groups

Land capability classification (irrigated): None specified

Land capability classification (nonirrigated): 2w

Hydrologic Soil Group: C

Ecological site: F136XY120VA - Northern inner piedmont flood plain forest, moist

Hydric soil rating: No

Minor Components

Wehadkee

Percent of map unit: 7 percent

Landform: Flood plains

Landform position (three-dimensional): Tread

Down-slope shape: Linear Across-slope shape: Linear Hydric soil rating: Yes

Ck—Congaree silt loam

Map Unit Setting

National map unit symbol: 42q9

Elevation: 100 to 500 feet

Mean annual precipitation: 24 to 58 inches
Mean annual air temperature: 55 to 58 degrees F

Frost-free period: 153 to 205 days

Farmland classification: All areas are prime farmland

Map Unit Composition

Congaree and similar soils: 85 percent

Minor components: 7 percent

Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Congaree

Setting

Landform: Flood plains

Landform position (three-dimensional): Tread

Down-slope shape: Linear Across-slope shape: Linear Parent material: Alluvium

Typical profile

H1 - 0 to 10 inches: silt loam
H2 - 10 to 62 inches: silty clay loam

Properties and qualities

Slope: 0 to 2 percent

Depth to restrictive feature: More than 80 inches

Drainage class: Well drained

Runoff class: Low

Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high

(0.57 to 1.98 in/hr)

Depth to water table: About 30 to 48 inches Frequency of flooding: NoneOccasional

Frequency of ponding: None

Available water supply, 0 to 60 inches: High (about 9.6 inches)

Interpretive groups

Land capability classification (irrigated): None specified

Land capability classification (nonirrigated): 2w

Hydrologic Soil Group: C

Ecological site: F136XY120VA - Northern inner piedmont flood plain forest, moist

Hydric soil rating: No

Minor Components

Wehadkee

Percent of map unit: 7 percent

Landform: Flood plains

Landform position (three-dimensional): Tread

Down-slope shape: Linear Across-slope shape: Linear Hydric soil rating: Yes

Da—Durham fine sandy loam, undulating phase

Map Unit Setting

National map unit symbol: 42qb Elevation: 280 to 460 feet

Mean annual precipitation: 24 to 58 inches

Mean annual air temperature: 55 to 58 degrees F

Frost-free period: 153 to 205 days

Farmland classification: All areas are prime farmland

Map Unit Composition

Durham and similar soils: 85 percent

Minor components: 3 percent

Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Durham

Setting

Landform: Hillslopes

Landform position (two-dimensional): Summit Landform position (three-dimensional): Interfluve

Down-slope shape: Convex Across-slope shape: Convex

Parent material: Residuum weathered from granite and gneiss

Typical profile

H1 - 0 to 19 inches: fine sandy loam
H2 - 19 to 23 inches: sandy clay loam
H3 - 23 to 27 inches: sandy clay loam
H4 - 27 to 46 inches: silty clay loam
H5 - 46 to 52 inches: fine sandy loam

Properties and qualities

Slope: 2 to 8 percent

Depth to restrictive feature: More than 80 inches

Drainage class: Well drained

Runoff class: Low

Capacity of the most limiting layer to transmit water (Ksat): Moderately high (0.20

to 0.57 in/hr)

Depth to water table: More than 80 inches

Frequency of flooding: None Frequency of ponding: None

Available water supply, 0 to 60 inches: Moderate (about 8.0 inches)

Interpretive groups

Land capability classification (irrigated): None specified

Land capability classification (nonirrigated): 2e

Hydrologic Soil Group: C

Ecological site: F136XY320VA - Northern inner piedmont acidic upland forest,

moist

Hydric soil rating: No

Minor Components

Worsham

Percent of map unit: 3 percent Landform: Depressions, hillslopes

Landform position (two-dimensional): Shoulder Landform position (three-dimensional): Interfluve

Down-slope shape: Convex Across-slope shape: Convex Hydric soil rating: Yes

Lk—Louisburg sandy loam, eroded rolling and hilly phases

Map Unit Setting

National map unit symbol: 42r5 Elevation: 500 to 800 feet

Mean annual precipitation: 24 to 58 inches Mean annual air temperature: 55 to 58 degrees F

Frost-free period: 153 to 205 days

Farmland classification: Not prime farmland

Map Unit Composition

Louisburg and similar soils: 85 percent

Minor components: 5 percent

Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Louisburg

Setting

Landform: Hillslopes

Landform position (two-dimensional): Shoulder, backslope

Landform position (three-dimensional): Interfluve

Down-slope shape: Convex Across-slope shape: Convex

Parent material: Residuum weathered from granite and gneiss

Typical profile

H1 - 0 to 7 inches: sandy loam H2 - 7 to 24 inches: sandy loam H3 - 24 to 79 inches: bedrock

Properties and qualities

Slope: 8 to 25 percent

Depth to restrictive feature: 20 to 40 inches to lithic bedrock

Drainage class: Well drained Runoff class: Very low

Capacity of the most limiting layer to transmit water (Ksat): Very low to moderately

low (0.00 to 0.06 in/hr)

Depth to water table: More than 80 inches

Frequency of flooding: None Frequency of ponding: None

Available water supply, 0 to 60 inches: Very low (about 2.6 inches)

Interpretive groups

Land capability classification (irrigated): None specified

Land capability classification (nonirrigated): 7e

Hydrologic Soil Group: A

Ecological site: F136XY370VA - Northern inner piedmont acidic woodlands and

glades, dry *Hydric soil rating:* No

Minor Components

Worsham

Percent of map unit: 5 percent Landform: Depressions, hillslopes

Landform position (two-dimensional): Shoulder Landform position (three-dimensional): Interfluve

Down-slope shape: Convex Across-slope shape: Convex Hydric soil rating: Yes

LI—Louisburg sandy loam, eroded steep phase

Map Unit Setting

National map unit symbol: 42r6 Elevation: 500 to 800 feet

Mean annual precipitation: 24 to 58 inches
Mean annual air temperature: 55 to 58 degrees F

Frost-free period: 153 to 205 days

Farmland classification: Not prime farmland

Map Unit Composition

Louisburg and similar soils: 85 percent

Minor components: 5 percent

Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Louisburg

Setting

Landform: Hillslopes

Landform position (two-dimensional): Backslope Landform position (three-dimensional): Side slope

Down-slope shape: Linear Across-slope shape: Convex

Parent material: Residuum weathered from granite and gneiss

Typical profile

H1 - 0 to 7 inches: sandy loam H2 - 7 to 24 inches: sandy loam H3 - 24 to 79 inches: bedrock

Properties and qualities

Slope: 25 to 40 percent

Depth to restrictive feature: 20 to 40 inches to lithic bedrock

Drainage class: Well drained

Runoff class: Low

Capacity of the most limiting layer to transmit water (Ksat): Very low to moderately

low (0.00 to 0.06 in/hr)

Depth to water table: More than 80 inches

Frequency of flooding: None Frequency of ponding: None

Available water supply, 0 to 60 inches: Very low (about 2.6 inches)

Interpretive groups

Land capability classification (irrigated): None specified

Land capability classification (nonirrigated): 7e

Hydrologic Soil Group: A

Ecological site: F136XY370VA - Northern inner piedmont acidic woodlands and

glades, dry *Hydric soil rating:* No

Minor Components

Worsham

Percent of map unit: 5 percent Landform: Depressions, hillslopes

Landform position (two-dimensional): Shoulder Landform position (three-dimensional): Interfluve

Down-slope shape: Convex Across-slope shape: Convex Hydric soil rating: Yes

Lm—Louisburg sandy loam, rolling and hilly phases

Map Unit Setting

National map unit symbol: 42r7 Elevation: 500 to 800 feet

Mean annual precipitation: 24 to 58 inches Mean annual air temperature: 55 to 58 degrees F

Frost-free period: 153 to 205 days

Farmland classification: Not prime farmland

Map Unit Composition

Louisburg and similar soils: 85 percent

Minor components: 3 percent

Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Louisburg

Setting

Landform: Hillslopes

Landform position (two-dimensional): Shoulder, backslope

Landform position (three-dimensional): Interfluve

Down-slope shape: Convex Across-slope shape: Convex

Parent material: Residuum weathered from granite and gneiss

Typical profile

H1 - 0 to 7 inches: sandy loam H2 - 7 to 24 inches: sandy loam H3 - 24 to 79 inches: bedrock

Properties and qualities

Slope: 8 to 25 percent

Depth to restrictive feature: 20 to 40 inches to lithic bedrock

Drainage class: Well drained Runoff class: Very low

Capacity of the most limiting layer to transmit water (Ksat): Very low to moderately

low (0.00 to 0.06 in/hr)

Depth to water table: More than 80 inches

Frequency of flooding: None Frequency of ponding: None

Available water supply, 0 to 60 inches: Very low (about 2.6 inches)

Interpretive groups

Land capability classification (irrigated): None specified

Land capability classification (nonirrigated): 7e

Hydrologic Soil Group: A

Ecological site: F136XY370VA - Northern inner piedmont acidic woodlands and

glades, dry *Hydric soil rating:* No

Minor Components

Worsham

Percent of map unit: 3 percent Landform: Depressions, hillslopes

Landform position (two-dimensional): Shoulder Landform position (three-dimensional): Interfluve

Down-slope shape: Convex Across-slope shape: Convex Hydric soil rating: Yes

Rc—Rough gullied land

Map Unit Setting

National map unit symbol: 42s1

Mean annual precipitation: 24 to 58 inches
Mean annual air temperature: 55 to 58 degrees F

Frost-free period: 153 to 205 days

Farmland classification: Not prime farmland

Map Unit Composition

Rough gullied land: 100 percent

Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Rough Gullied Land

Interpretive groups

Land capability classification (irrigated): None specified

Land capability classification (nonirrigated): 8e

Hydric soil rating: Unranked

Sa—Seneca fine sandy loam

Map Unit Setting

National map unit symbol: 42s2 Elevation: 200 to 480 feet

Mean annual precipitation: 24 to 58 inches Mean annual air temperature: 55 to 58 degrees F

Frost-free period: 153 to 205 days

Farmland classification: All areas are prime farmland

Map Unit Composition

Seneca and similar soils: 85 percent

Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Seneca

Setting

Landform: Stream terraces

Landform position (three-dimensional): Tread

Down-slope shape: Linear Across-slope shape: Linear Parent material: Alluvium

Typical profile

H1 - 0 to 8 inches: fine sandy loam H2 - 8 to 23 inches: clay loam H3 - 23 to 30 inches: silty clay loam

Properties and qualities

Slope: 2 to 8 percent

Depth to restrictive feature: More than 80 inches

Drainage class: Moderately well drained

Runoff class: Medium

Capacity of the most limiting layer to transmit water (Ksat): Moderately low to high

(0.06 to 1.98 in/hr)

Depth to water table: About 24 to 42 inches

Frequency of flooding: None Frequency of ponding: None

Available water supply, 0 to 60 inches: Low (about 4.3 inches)

Interpretive groups

Land capability classification (irrigated): None specified

Land capability classification (nonirrigated): 2e

Hydrologic Soil Group: C

Ecological site: F136XY160VA - Northern inner piedmont high-bottomland forest,

moist

Hydric soil rating: No

W-Water

Map Unit Composition

Water: 100 percent

Estimates are based on observations, descriptions, and transects of the mapunit.

Wa-Wehadkee silt loam

Map Unit Setting

National map unit symbol: 42sf Elevation: 180 to 430 feet

Mean annual precipitation: 24 to 58 inches Mean annual air temperature: 55 to 58 degrees F

Frost-free period: 153 to 205 days

Farmland classification: Not prime farmland

Map Unit Composition

Wehadkee and similar soils: 85 percent

Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Wehadkee

Settina

Landform: Flood plains

Landform position (three-dimensional): Tread

Down-slope shape: Linear Across-slope shape: Linear Parent material: Alluvium

Typical profile

H1 - 0 to 42 inches: silt loam H2 - 42 to 54 inches: silt loam H3 - 54 to 62 inches: clay loam

Properties and qualities

Slope: 0 to 2 percent

Depth to restrictive feature: More than 80 inches

Drainage class: Poorly drained

Runoff class: Low

Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high

(0.57 to 1.98 in/hr)

Depth to water table: About 0 to 12 inches Frequency of flooding: NoneFrequent

Frequency of ponding: None

Available water supply, 0 to 60 inches: High (about 11.1 inches)

Interpretive groups

Land capability classification (irrigated): None specified

Land capability classification (nonirrigated): 6w

Hydrologic Soil Group: B/D

Ecological site: F136XY100VA - Northern inner piedmont flood plain swamp

forest, hydric soils Hydric soil rating: Yes

Wc-Wilkes sandy loam, hilly and steep phases

Map Unit Setting

National map unit symbol: 42sh Elevation: 180 to 390 feet

Mean annual precipitation: 24 to 58 inches
Mean annual air temperature: 55 to 58 degrees F

Frost-free period: 153 to 205 days

Farmland classification: Not prime farmland

Map Unit Composition

Wilkes and similar soils: 85 percent

Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Wilkes

Setting

Landform: Hillslopes

Landform position (two-dimensional): Backslope Landform position (three-dimensional): Side slope

Down-slope shape: Linear Across-slope shape: Convex

Parent material: Mixed mafic residuum

Typical profile

H1 - 0 to 8 inches: sandy loam H2 - 8 to 17 inches: sandy clay loam H3 - 17 to 27 inches: bedrock

Properties and qualities

Slope: 15 to 40 percent

Depth to restrictive feature: 10 to 20 inches to lithic bedrock

Drainage class: Well drained Runoff class: Medium

Capacity of the most limiting layer to transmit water (Ksat): Very low to moderately

low (0.00 to 0.06 in/hr)

Depth to water table: More than 80 inches

Frequency of flooding: None Frequency of ponding: None

Available water supply, 0 to 60 inches: Very low (about 2.7 inches)

Interpretive groups

Land capability classification (irrigated): None specified

Land capability classification (nonirrigated): 7e

Hydrologic Soil Group: D

Ecological site: F136XY230VA - Northern inner piedmont basic upland forest, dry

Hydric soil rating: No

We—Worsham sandy loam

Map Unit Setting

National map unit symbol: 42sk Elevation: 200 to 480 feet

Mean annual precipitation: 24 to 58 inches
Mean annual air temperature: 55 to 58 degrees F

Frost-free period: 153 to 205 days

Farmland classification: Not prime farmland

Map Unit Composition

Worsham and similar soils: 85 percent

Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Worsham

Setting

Landform: Depressions, hillslopes

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Landform position (two-dimensional): Shoulder Landform position (three-dimensional): Interfluve

Down-slope shape: Convex Across-slope shape: Convex

Parent material: Residuum weathered from granite and gneiss

Typical profile

H1 - 0 to 18 inches: sandy loam H2 - 18 to 28 inches: clay H3 - 28 to 36 inches: sandy loam

Properties and qualities

Slope: 0 to 8 percent

Depth to restrictive feature: More than 80 inches

Drainage class: Poorly drained

Runoff class: Low

Capacity of the most limiting layer to transmit water (Ksat): Very low to moderately

low (0.00 to 0.06 in/hr)

Depth to water table: About 0 to 12 inches

Frequency of flooding: None Frequency of ponding: None

Available water supply, 0 to 60 inches: Low (about 4.7 inches)

Interpretive groups

Land capability classification (irrigated): None specified

Land capability classification (nonirrigated): 4w

Hydrologic Soil Group: D

Ecological site: F136XY300VA - Northern inner piedmont acidic upland

depression swamp forest, hydric soils

Hydric soil rating: Yes

Soil Information for All Uses

Soil Properties and Qualities

The Soil Properties and Qualities section includes various soil properties and qualities displayed as thematic maps with a summary table for the soil map units in the selected area of interest. A single value or rating for each map unit is generated by aggregating the interpretive ratings of individual map unit components. This aggregation process is defined for each property or quality.

Soil Qualities and Features

Soil qualities are behavior and performance attributes that are not directly measured, but are inferred from observations of dynamic conditions and from soil properties. Example soil qualities include natural drainage, and frost action. Soil features are attributes that are not directly part of the soil. Example soil features include slope and depth to restrictive layer. These features can greatly impact the use and management of the soil.

Hydrologic Soil Group

Hydrologic soil groups are based on estimates of runoff potential. Soils are assigned to one of four groups according to the rate of water infiltration when the soils are not protected by vegetation, are thoroughly wet, and receive precipitation from long-duration storms.

The soils in the United States are assigned to four groups (A, B, C, and D) and three dual classes (A/D, B/D, and C/D). The groups are defined as follows:

Group A. Soils having a high infiltration rate (low runoff potential) when thoroughly wet. These consist mainly of deep, well drained to excessively drained sands or gravelly sands. These soils have a high rate of water transmission.

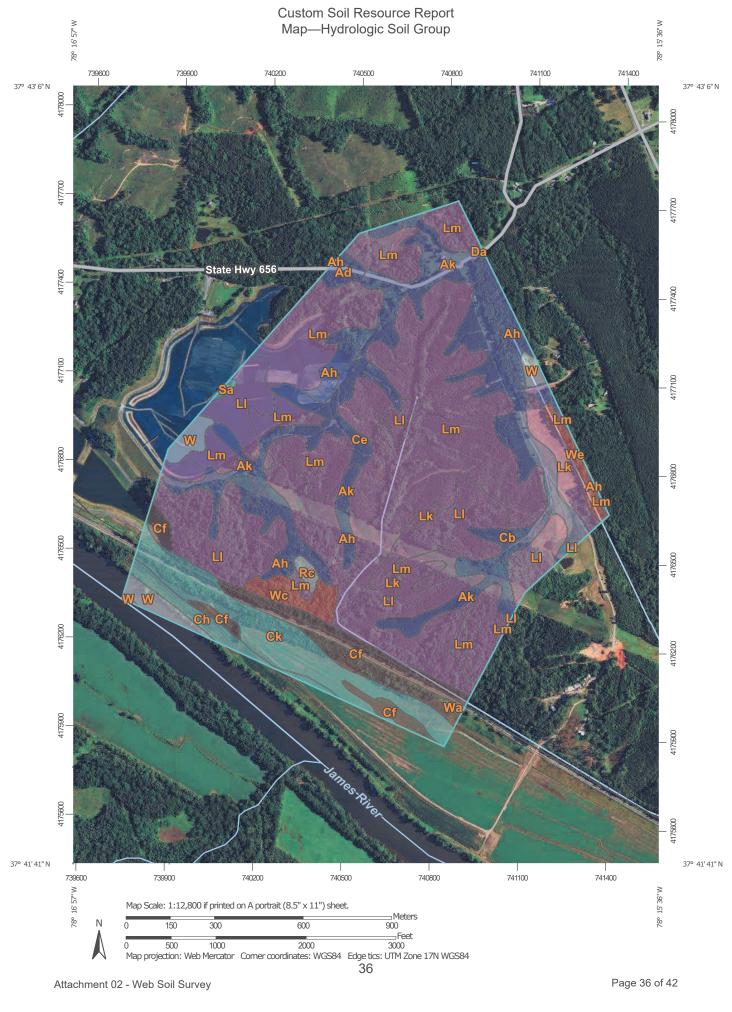
Group B. Soils having a moderate infiltration rate when thoroughly wet. These consist chiefly of moderately deep or deep, moderately well drained or well drained soils that have moderately fine texture to moderately coarse texture. These soils have a moderate rate of water transmission.

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Group C. Soils having a slow infiltration rate when thoroughly wet. These consist chiefly of soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture. These soils have a slow rate of water transmission.

Group D. Soils having a very slow infiltration rate (high runoff potential) when thoroughly wet. These consist chiefly of clays that have a high shrink-swell potential, soils that have a high water table, soils that have a claypan or clay layer at or near the surface, and soils that are shallow over nearly impervious material. These soils have a very slow rate of water transmission.

If a soil is assigned to a dual hydrologic group (A/D, B/D, or C/D), the first letter is for drained areas and the second is for undrained areas. Only the soils that in their natural condition are in group D are assigned to dual classes.



MAP LEGEND

Not rated or not available Streams and Canals Interstate Highways Major Roads Local Roads **US Routes** Rails C/D Nater Features **Transportation 3ackground** ŧ Not rated or not available Area of Interest (AOI) Soil Rating Polygons Area of Interest (AOI) Soil Rating Lines A/D B/D C/D Δ O Soils

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at scales ranging from 1:15,800 to 1:24,000.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Buckingham County, Virginia Survey Area Data: Version 8, Aug 24, 2022

Aerial Photography

A/D

Ш

B/D

C/D

O

Soil Survey Area: Fluvanna County, Virginia Survey Area Data: Version 17, Aug 26, 2022

Your area of interest (AOI) includes more than one soil survey area. These survey areas may have been mapped at different scales, with a different land use in mind, at different times, or at different levels of detail. This may result in map unit symbols, soil properties, and interpretations that do not completely agree across soil survey area boundaries.

Not rated or not available

Soil Rating Points

A/D

B/D

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: May 19, 2022—Jul 1, 2022

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background

MAP LEGEND

MAP INFORMATION

imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Table—Hydrologic Soil Group

Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
W	Water		0.2	0.0%
Subtotals for Soil Survey	y Area	0.2	0.0%	
Totals for Area of Interes	st	435.3	100.0%	

Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI		
Ad	Appling fine sandy loam, undulating phase	В	2.7	0.6%		
Ah	Appling sandy loam, rolling phase	Appling sandy loam, rolling phase				
Ak	Appling sandy loam, undulating phase	В	65.3	15.0%		
Cb	Cecil clay loam, eroded undulating phase	В	4.0	0.9%		
Се	Cecil sandy loam, undulating phase	В	3.1	0.7%		
Cf	Chewacla silt loam	B/D	24.4	5.6%		
Ch	Congaree fine sandy loam	С	6.6	1.5%		
Ck	Congaree silt loam	С	29.2	6.7%		
Da	Durham fine sandy loam, undulating phase	С	0.2	0.1%		
Lk	Louisburg sandy loam, eroded rolling and hilly phases	A	16.6	3.8%		
LI	Louisburg sandy loam, eroded steep phase	А	101.2	23.2%		
Lm	Louisburg sandy loam, rolling and hilly phases	А	139.2	32.0%		
Rc	Rough gullied land		1.4	0.3%		
Sa	Seneca fine sandy loam	С	0.6	0.1%		
W	Water		8.8	2.0%		
Wa	Wehadkee silt loam	B/D	0.4	0.1%		
Wc	Wilkes sandy loam, hilly and steep phases	D	6.3	1.5%		
We	Worsham sandy loam	D	3.9	0.9%		
Subtotals for Soil Surv	ey Area		435.1	100.0%		
Totals for Area of Inter	est		435.3	100.0%		

Rating Options—Hydrologic Soil Group

Aggregation Method: Dominant Condition

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Component Percent Cutoff: None Specified

Tie-break Rule: Higher

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Custom Soil Resource Report

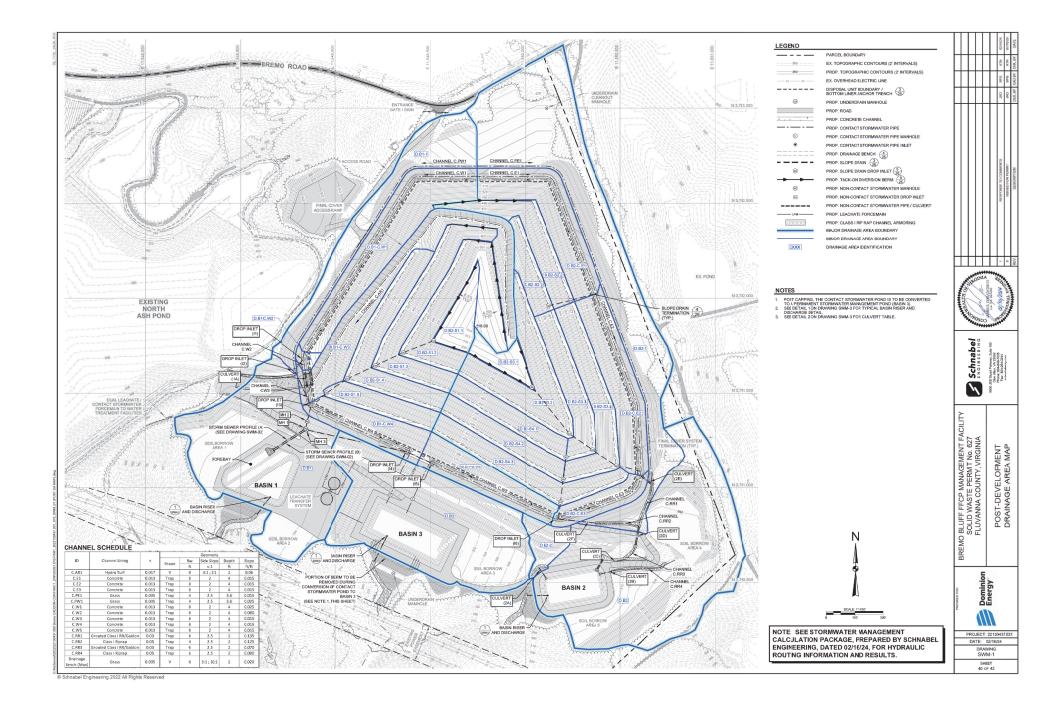
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Stormwater Analysis Attachment 3
Post-Development Drainage Area Map

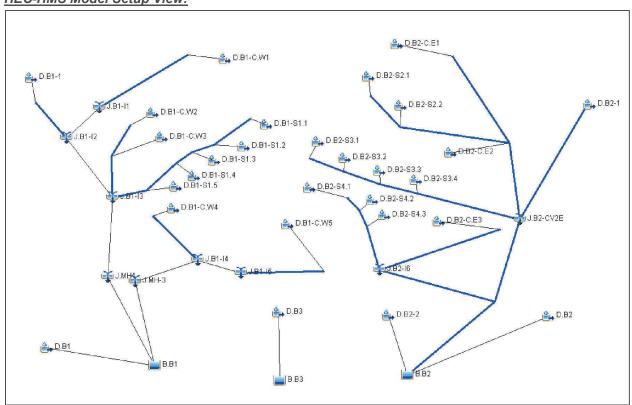




Stormwater Analysis Attachment 4
HEC-HMS Model and Inputs



HEC-HMS Model Setup View:



NOAA Precipitation Data https://hdsc.nws.noaa.gov/hdsc/pfds/										
Design Storm	Rainfall (in)									
1-yr, 24-hr	2.64									
2-yr, 24-hr	3.19									
10-yr, 24-hr	4.83									
25-yr, 24-hr	5.93									
100-yr, 24-hr	7.91									

													HEC-HMS	Model Inpu	its														
Dest Develo	oment Conditions						DA B	Basin-1													DA Basin-2								DA Basin-3
Post Develo	pinent conditions	D.B1	D.B1-1	D.B1-C.W1	D.B1-C.W2	D.B1-C.W3	D.B1-C.W4	D.B1-C.W5	D.B1-S1.1	D.B1-S1.2	D.B1-S1.3	D.B1-S1.4	D.B1-S1.5	D.B2	D.B2-1	D.B2-2	D.B2-C.E1	D.B2-C.E2	D.B2-C.E3	D.B2-S2.1	D.B2-S2.2	D.B2-S3.1	D.B2-S3.2	D.B2-S3.3	D.B2-S3.4	D.B2-S4.1	D.B2-S4.2	D.B2-S4.3	D.B3
Total Dra	inage Area (ac)	12.57	4.74	5.16	0.22	5.07	2.33	2.71	1.36	3.73	3.28	3.10	1.47	16.46	14.19	1.05	3.76	3.53	1.17	1.18	2.15	1.02	3.63	2.16	2.89	1.74	1.85	2.86	12.13
	Is (Good), HSG A, CN = 30	0.13	0.48											1.97	2.69														0.03
ල Open Spac	e (Good), HSG A, CN = 39	0.00												0.22	0.12														
	Is (Good), HSG B, CN = 55	0.06	1.35											3.66	3.39	0.00													0.07
Open Space	e (Good), HSG B, CN = 61	5.51	2.79	3.52	0.11	2.37	1.37	1.57	1.36	3.73	3.28	3.10	1.47	7.52	7.21	1.02	2.32	2.02	0.31	1.18	2.15	1.02	3.63	2.16	2.89	1.74	1.85	2.84	7.91
2	Gravel, HSG B, CN = 85	4.83	0.00	0.99	0.06	2.59	0.46	0.54						1.20	0.06	0.03	0.73	0.70	0.42	0.01	0.00		0.00						1.78
Composite CN		72	56	66	70	74	67	67	61	61	61	61	61	57	53	62	67	67	75	61	61	61	61	61	61	61	61	61	65
0	Impervious Area:	2.05	0.13	0.65	0.05	0.11	0.49	0.60						1.91	0.72		0.71	0.81	0.44									0.02	2.35
	* Percent Impervious (%):	16%	3%	13%	22%	2%	21%	22%	0%	0%	0%	0%	0%	12%	5%	0%	19%	23%	38%	0%	0%	0%	0%	0%	0%	0%	0%	1%	19%
	Length (ft) [max. 100 ft] =	85	100	100	85	65	100	100	100	100	100	100	100	100	100	100	100	100	62	100	92	100	90	90	90	93	87	87	100
Sheet Flow	Slope (ft/ft) =	0.33	0.22	0.33	0.14	0.33	0.33	0.33	0.07	0.33	0.33	0.33	0.33	0.13	0.03	0.32	0.33	0.33	0.25	0.33	0.33	0.07	0.33	0.33	0.33	0.33	0.33	0.33	0.27
	Manning's (n) = T, (hr) =	0.24											0.24		0.24					0.24									0.24
	1; (111) -	0.07	0.09	0.08	0.10	0.05	0.08	0.08	0.15	0.08	0.08	0.08	0.08	0.23	0.20	0.08	0.08	0.08	0.06	0.08	0.07	0.15	0.07	0.07	0.07	0.07	0.07	0.07	0.08
	Land Cover Type	Pasture/Open		Pasture/Open			Pasture/Open	Pasture/Open		Pasture/Open				Pasture/Open	Forested	Pasture/Open						Pasture/Open							Pasture/Open
		Space	Space	Space			Space	Space	Space	Space				Space		Space	Space	Space				Space							Space
Shallow Concentrated	Length (ft) [max. 1000 ft] =	238	175	73			42	25	115	30				535	535	112	25	25				28							340
Flow	Slope (ft/ft) =	0.03	0.06	0.29			0.22	0.30	0.07	0.07				0.10	0.08	0.25	0.30	0.30				0.30							0.10
TE STATE OF THE ST	Velocity (ft/s) =	1.10	1.66	3.75			3.28	3.81	1.77	1.77				2.23	0.69	3.48	3.81	3.81				3.81							2.17
2	T _t (hr) =	0.06	0.03	0.01			0.00	0.00	0.02	0.00				0.067	0.22	0.01	0.00	0.00				0.00							0.04
9	Length (ft) =					1520	1			425	830	715	578	4						268	491		643	753	872	692	722	743	-
Ē	Slope (ft/ft) =					0.07	ł			0.02	0.02	0.02	0.02	1						0.02	0.02	-	0.02	0.02	0.02	0.02	0.02	0.02	-
86	Cross Section, a (ft ²) =					1.96	1			0.94	1.04	1.04	0.67	4						0.55	0.75		1.09	0.84	0.94	0.71	0.71	0.94	-
Channel Flow Section 1	Wetted Perim, p _w (ft) =		Modeled	in HEC-HMS		5.53	N.	todeled in HEC-HI	MS	3.54	5.28	5.28	4.23	1		Modeled i	n HEC-HMS			3.83	4.49	Modeled in	5.42	4.76	5.02	4.36	4.36	5.02	Modeled in
to to	Hydr Radius, r =					0.35	1			0.27	0.20	0.20	0.16	1						0.14	0.17	HEC-HMS	0.20	0.18	0.19	0.16	0.16	0.19	HEC-HMS
tr a	Manning's Channel (n) =					0.03	1			0.04	0.04	0.04	0.04	4						0.04	0.04		0.04	0.04	0.04	0.04	0.04	0.04	-
ë	Velocity (ft/s) =					5.77	1			2.49	2.04	2.04	1.76	4						1.64	1.83		2.07	1.90	1.97	1.79	1.79	1.97	-
8	T _t (hr) =					0.07				0.05	0.11	0.10	0.09							0.05	0.07		0.09	0.11	0.12	0.11	0.11	0.10	-
70	Length (ft) =									665	1																		
ž .	Slope (ft/ft) =									0.02	1																		
-	Cross Section, a (ft ²) =									1.15	1																		
Channel Flow Section 2	Wetted Perim, p _w (ft) =				Modeled	in HEC-HMS				5.55	M	lodeled in HEC-H	MS							M	odeled in HEC-H	MS							Modeled in HEC-HMS
	Hydr Radius, r =									0.21	1																		HEC-HMS
	Manning's Channel (n) =									0.04	+																		
	Velocity (ft/s) = T, (hr) =									2.10	+			I															1
Time of Concentration.		0.13	0.12	0.08	0.10	0.13	0.08	0.08	0.17	0.09	0.19	0.18	0.17	0.30	0.42	0.09	0.08	0.08	0.06	0.12	0.15	0.15	0.16	0.18	0.19	0.18	0.18	0.17	0.13
Lag Time (min) (min. 6 min		0.13	0.12	0.08	0.10	0.13	0.08	6	6	0.22	0.19	0.18	0.17	11	15	0.09	0.08	0.08	0.06	0.12	0.15	0.15	0.16	7	0.19	0.18	7	6	0.13
	hown above is an input parameter						- 6		- 6	8	7	ь	- 6	- 11	15	6	6	ь	6	6		6	6	/	/	0	7	- 6	ь

Attachment 04 - HEC-HMS
Model and Inputs

Stormwater Analysis Attachment 5
HEC-HMS Model Results



Prop	osed Conditions	- 1-Year, 24-Hour I	Event
Hydrologic	Drainage Area	Peak Discharge	
Element	(mi2)	(ft3/s)	Volume (ac-ft)
B.B1	0.07147	0.54	3.67
B.B2	0.09322	0.49	3.26
B.B3	0.01896	0.18	0.76
C.E1	0.00588	2.95	0.78
C.E2	0.01661	6.41	2.18
C.E3	0.00182	1.75	0.25
C.PE1	0.02217	1.40	0.25
C.PW1	0.0074	0.35	0.08
C.RR1	0.05395	8.34	4.39
C.RR2	0.01189	2.71	1.55
C.RR3 C.W1	0.06585 0.00807	10.96 3.30	5.94 1.06
C.W2	0.00035	0.23	0.05
C.W2	0.00033	4.40	1.09
C.W4	0.00363	1.96	0.48
C.W5	0.00303	2.34	0.56
D.B1	0.01964	12.39	0.96
D.B1-C.W1	0.00807	3.50	1.06
D.B1-C.W2	0.00035	0.24	0.05
D.B1-C.W2	0.00792	4.27	1.04
D.B1-C.W4	0.00732	2.12	0.48
D.B1-C.W5	0.00424	2.56	0.56
D.B1-S1.1	0.00424	0.24	0.27
D.B1-S1.2	0.00582	0.62	0.75
D.B1-S1.3	0.00513	0.56	0.66
D.B1-S1.4	0.00484	0.54	0.63
D.B1-S1.5	0.0023	0.26	0.30
D.B1-1	0.0074	0.38	0.08
D.B2	0.02573	4.36	0.58
D.B2-C.E1	0.00588	3.20	0.78
D.B2-C.E2	0.00552	3.4	0.73
D.B2-C.E3	0.00182	1.86	0.25
D.B2-S2.1	0.00185	0.22	0.24
D.B2-S2.2	0.00336	0.38	0.43
D.B2-S3.1	0.0016	0.18	0.21
D.B2-S3.2	0.00568	0.64	0.73
D.B2-S3.3	0.00338	0.38	0.44
D.B2-S3.4	0.00451	0.49	0.58
D.B2-S4.1	0.00272	0.3	0.35
D.B2-S4.2	0.00288	0.32	0.37
D.B2-S4.3	0.00447	0.53	0.58
D.B2-1	0.02217	1.41	0.25
D.B2-2	0.00165	0.17	0.02
D.B3	0.01896	9.25	0.81
J.B1-l1	0.00807	3.3	1.06
J.B1-I2	0.01547	3.51	1.14
J.B1-I3	0.04396	9.42	4.84
J.B1-I4	0.00787	4.29	1.04
J.B1-I5	0.00424	2.34	0.56
J.B2-CV2E	0.03178	8.08	4.14
J.B2-I6	0.01189	2.71	1.55
J.MH1	0.04396	9.42	4.84
J.MH3	0.00787	4.29	1.04
S.1.1	0.00212	0.24	0.27
S.1.2 S.1.3	0.00794 0.01307	0.85 1.4	1.03 1.69
S.1.3	0.01307	1.93	2.31
S.1.4 S.1.5	0.01791	2.18	2.61
S.2.1	0.02021	0.21	0.24
S.2.1	0.00183	0.59	0.67
S.3.1	0.00321	0.18	0.07
S.3.2	0.00728	0.82	0.94
S.3.3	0.01066	1.19	1.38
S.3.4	0.01517	1.67	1.96
S.4.1	0.00272	0.3	0.35
S.4.2	0.00561	0.62	0.72
S.4.3	0.01007	1.15	1.3
0.7.0	0.01001	1.10	1.0

Hydrologic Element Drainage Area (mi2) Peak Discharge (ft3/s) Volume (ac-ft (ft3/s)) B.B1 0.07147 0.83 4.38 B.B2 0.09322 0.55 3.72 B.B3 0.01896 0.22 1.02 C.E1 0.00588 4.04 0.94 C.E2 0.01661 9.25 2.65 C.E3 0.00182 2.20 0.30 C.PE1 0.02217 1.98 0.42 C.PW1 0.0074 0.85 0.14 C.RR1 0.05395 13.23 5.44 C.RR2 0.01189 4.37 1.88 C.RR3 0.06585 17.53 7.32 C.W1 0.00807 4.77 1.28 C.W2 0.00035 0.31 0.06 C.W3 0.00827 6.45 1.32 C.W4 0.00363 2.73 0.58 C.W5 0.00424 3.23 0.68 D.B1 0.01964 17.06 1.34 <
Element (mi2) (ft3/s) Volume (ac-n B.B1 0.07147 0.83 4.38 B.B2 0.09322 0.55 3.72 B.B3 0.01896 0.22 1.02 C.E1 0.00588 4.04 0.94 C.E2 0.01661 9.25 2.65 C.E3 0.00182 2.20 0.30 C.PE1 0.02217 1.98 0.42 C.PW1 0.0074 0.85 0.14 C.RR1 0.05395 13.23 5.44 C.RR2 0.01189 4.37 1.88 C.RR3 0.06585 17.53 7.32 C.W1 0.00807 4.77 1.28 C.W2 0.00035 0.31 0.06 C.W3 0.00827 6.45 1.32 C.W4 0.00363 2.73 0.58 C.W5 0.00424 3.23 0.68 D.B1-C.W1 0.00807 5.19 1.29 D.B1-C.W2
B.B1 0.07147 0.83 4.38 B.B2 0.09322 0.55 3.72 B.B3 0.01896 0.22 1.02 C.E1 0.00588 4.04 0.94 C.E2 0.01661 9.25 2.65 C.E3 0.00182 2.20 0.30 C.PE1 0.02217 1.98 0.42 C.PW1 0.0074 0.85 0.14 C.RR1 0.05395 13.23 5.44 C.RR2 0.01189 4.37 1.88 C.RR3 0.06585 17.53 7.32 C.W1 0.00807 4.77 1.28 C.W2 0.00035 0.31 0.06 C.W3 0.00827 6.45 1.32 C.W4 0.00363 2.73 0.58 C.W5 0.00424 3.23 0.68 D.B1 0.01964 17.06 1.34 D.B1-C.W2 0.00035 0.32 0.06 D.B1-C.W3 0.00
B.B2 0.09322 0.55 3.72 B.B3 0.01896 0.22 1.02 C.E1 0.00588 4.04 0.94 C.E2 0.01661 9.25 2.65 C.E3 0.00182 2.20 0.30 C.PE1 0.02217 1.98 0.42 C.PW1 0.0074 0.85 0.14 C.RR1 0.05395 13.23 5.44 C.RR2 0.01189 4.37 1.88 C.RR3 0.06585 17.53 7.32 C.W1 0.00807 4.77 1.28 C.W2 0.00035 0.31 0.06 C.W3 0.00827 6.45 1.32 C.W4 0.00363 2.73 0.58 C.W5 0.00424 3.23 0.68 D.B1 0.01964 17.06 1.34 D.B1-C.W1 0.00807 5.19 1.29 D.B1-C.W2 0.00035 0.32 0.06 D.B1-C.W3 <td< td=""></td<>
B.B3 0.01896 0.22 1.02 C.E1 0.00588 4.04 0.94 C.E2 0.01661 9.25 2.65 C.E3 0.00182 2.20 0.30 C.PE1 0.02217 1.98 0.42 C.PW1 0.0074 0.85 0.14 C.RR1 0.05395 13.23 5.44 C.RR2 0.01189 4.37 1.88 C.RR3 0.06585 17.53 7.32 C.W1 0.00807 4.77 1.28 C.W2 0.00035 0.31 0.06 C.W3 0.00827 6.45 1.32 C.W4 0.00363 2.73 0.58 C.W5 0.00424 3.23 0.68 D.B1 0.01964 17.06 1.34 D.B1-C.W1 0.00807 5.19 1.29 D.B1-C.W2 0.00035 0.32 0.06 D.B1-C.W3 0.00792 6.25 1.27 D.B1-C.W4
C.E1 0.00588 4.04 0.94 C.E2 0.01661 9.25 2.65 C.E3 0.00182 2.20 0.30 C.PE1 0.02217 1.98 0.42 C.PW1 0.0074 0.85 0.14 C.RR1 0.05395 13.23 5.44 C.RR2 0.01189 4.37 1.88 C.RR3 0.06585 17.53 7.32 C.W1 0.00807 4.77 1.28 C.W2 0.00035 0.31 0.06 C.W3 0.00827 6.45 1.32 C.W4 0.00363 2.73 0.58 C.W5 0.00424 3.23 0.68 D.B1 0.01964 17.06 1.34 D.B1-C.W1 0.00807 5.19 1.29 D.B1-C.W2 0.00035 0.32 0.06 D.B1-C.W3 0.00792 6.25 1.27 D.B1-C.W4 0.00363 2.91 0.58 D.B1-C.W5
C.E3 0.00182 2.20 0.30 C.PE1 0.02217 1.98 0.42 C.PW1 0.0074 0.85 0.14 C.RR1 0.05395 13.23 5.44 C.RR2 0.01189 4.37 1.88 C.RR3 0.06585 17.53 7.32 C.W1 0.00807 4.77 1.28 C.W2 0.00035 0.31 0.06 C.W3 0.00827 6.45 1.32 C.W4 0.00363 2.73 0.58 C.W5 0.00424 3.23 0.68 D.B1 0.01964 17.06 1.34 D.B1-C.W1 0.00807 5.19 1.29 D.B1-C.W2 0.00035 0.32 0.06 D.B1-C.W3 0.00792 6.25 1.27 D.B1-C.W4 0.00363 2.91 0.58 D.B1-C.W5 0.00424 3.48 0.68 D.B1-S1.1 0.00212 0.52 0.33
C.PE1 0.02217 1.98 0.42 C.PW1 0.0074 0.85 0.14 C.RR1 0.05395 13.23 5.44 C.RR2 0.01189 4.37 1.88 C.RR3 0.06585 17.53 7.32 C.W1 0.00807 4.77 1.28 C.W2 0.00035 0.31 0.06 C.W3 0.00827 6.45 1.32 C.W4 0.00363 2.73 0.58 C.W5 0.00424 3.23 0.68 D.B1 0.01964 17.06 1.34 D.B1-C.W1 0.00807 5.19 1.29 D.B1-C.W2 0.00035 0.32 0.06 D.B1-C.W3 0.00792 6.25 1.27 D.B1-C.W4 0.00363 2.91 0.58 D.B1-C.W5 0.00424 3.48 0.68 D.B1-S1.1 0.00212 0.52 0.33
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C.RR1 0.05395 13.23 5.44 C.RR2 0.01189 4.37 1.88 C.RR3 0.06585 17.53 7.32 C.W1 0.00807 4.77 1.28 C.W2 0.00035 0.31 0.06 C.W3 0.00827 6.45 1.32 C.W4 0.00363 2.73 0.58 C.W5 0.00424 3.23 0.68 D.B1 0.01964 17.06 1.34 D.B1-C.W1 0.00807 5.19 1.29 D.B1-C.W2 0.00035 0.32 0.06 D.B1-C.W3 0.00792 6.25 1.27 D.B1-C.W4 0.00363 2.91 0.58 D.B1-C.W5 0.00424 3.48 0.68 D.B1-S1.1 0.00212 0.52 0.33
C.RR2 0.01189 4.37 1.88 C.RR3 0.06585 17.53 7.32 C.W1 0.00807 4.77 1.28 C.W2 0.00035 0.31 0.06 C.W3 0.00827 6.45 1.32 C.W4 0.00363 2.73 0.58 C.W5 0.00424 3.23 0.68 D.B1 0.01964 17.06 1.34 D.B1-C.W1 0.00807 5.19 1.29 D.B1-C.W2 0.00035 0.32 0.06 D.B1-C.W3 0.00792 6.25 1.27 D.B1-C.W4 0.00363 2.91 0.58 D.B1-C.W5 0.00424 3.48 0.68 D.B1-S1.1 0.00212 0.52 0.33
C.RR3 0.06585 17.53 7.32 C.W1 0.00807 4.77 1.28 C.W2 0.00035 0.31 0.06 C.W3 0.00827 6.45 1.32 C.W4 0.00363 2.73 0.58 C.W5 0.00424 3.23 0.68 D.B1 0.01964 17.06 1.34 D.B1-C.W1 0.00807 5.19 1.29 D.B1-C.W2 0.00035 0.32 0.06 D.B1-C.W3 0.00792 6.25 1.27 D.B1-C.W4 0.00363 2.91 0.58 D.B1-C.W5 0.00424 3.48 0.68 D.B1-S1.1 0.00212 0.52 0.33
C.W1 0.00807 4.77 1.28 C.W2 0.00035 0.31 0.06 C.W3 0.00827 6.45 1.32 C.W4 0.00363 2.73 0.58 C.W5 0.00424 3.23 0.68 D.B1 0.01964 17.06 1.34 D.B1-C.W1 0.00807 5.19 1.29 D.B1-C.W2 0.00035 0.32 0.06 D.B1-C.W3 0.00792 6.25 1.27 D.B1-C.W4 0.00363 2.91 0.58 D.B1-C.W5 0.00424 3.48 0.68 D.B1-S1.1 0.00212 0.52 0.33
C.W2 0.00035 0.31 0.06 C.W3 0.00827 6.45 1.32 C.W4 0.00363 2.73 0.58 C.W5 0.00424 3.23 0.68 D.B1 0.01964 17.06 1.34 D.B1-C.W1 0.00807 5.19 1.29 D.B1-C.W2 0.00035 0.32 0.06 D.B1-C.W3 0.00792 6.25 1.27 D.B1-C.W4 0.00363 2.91 0.58 D.B1-C.W5 0.00424 3.48 0.68 D.B1-S1.1 0.00212 0.52 0.33
C.W3 0.00827 6.45 1.32 C.W4 0.00363 2.73 0.58 C.W5 0.00424 3.23 0.68 D.B1 0.01964 17.06 1.34 D.B1-C.W1 0.00807 5.19 1.29 D.B1-C.W2 0.00035 0.32 0.06 D.B1-C.W3 0.00792 6.25 1.27 D.B1-C.W4 0.00363 2.91 0.58 D.B1-C.W5 0.00424 3.48 0.68 D.B1-S1.1 0.00212 0.52 0.33
C.W4 0.00363 2.73 0.58 C.W5 0.00424 3.23 0.68 D.B1 0.01964 17.06 1.34 D.B1-C.W1 0.00807 5.19 1.29 D.B1-C.W2 0.00035 0.32 0.06 D.B1-C.W3 0.00792 6.25 1.27 D.B1-C.W4 0.00363 2.91 0.58 D.B1-C.W5 0.00424 3.48 0.68 D.B1-S1.1 0.00212 0.52 0.33
C.W5 0.00424 3.23 0.68 D.B1 0.01964 17.06 1.34 D.B1-C.W1 0.00807 5.19 1.29 D.B1-C.W2 0.00035 0.32 0.06 D.B1-C.W3 0.00792 6.25 1.27 D.B1-C.W4 0.00363 2.91 0.58 D.B1-C.W5 0.00424 3.48 0.68 D.B1-S1.1 0.00212 0.52 0.33
D.B1 0.01964 17.06 1.34 D.B1-C.W1 0.00807 5.19 1.29 D.B1-C.W2 0.00035 0.32 0.06 D.B1-C.W3 0.00792 6.25 1.27 D.B1-C.W4 0.00363 2.91 0.58 D.B1-C.W5 0.00424 3.48 0.68 D.B1-S1.1 0.00212 0.52 0.33
D.B1-C.W1 0.00807 5.19 1.29 D.B1-C.W2 0.00035 0.32 0.06 D.B1-C.W3 0.00792 6.25 1.27 D.B1-C.W4 0.00363 2.91 0.58 D.B1-C.W5 0.00424 3.48 0.68 D.B1-S1.1 0.00212 0.52 0.33
D.B1-C.W2 0.00035 0.32 0.06 D.B1-C.W3 0.00792 6.25 1.27 D.B1-C.W4 0.00363 2.91 0.58 D.B1-C.W5 0.00424 3.48 0.68 D.B1-S1.1 0.00212 0.52 0.33
D.B1-C.W3 0.00792 6.25 1.27 D.B1-C.W4 0.00363 2.91 0.58 D.B1-C.W5 0.00424 3.48 0.68 D.B1-S1.1 0.00212 0.52 0.33
D.B1-C.W4 0.00363 2.91 0.58 D.B1-C.W5 0.00424 3.48 0.68 D.B1-S1.1 0.00212 0.52 0.33
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D.B1-S1.1 0.00212 0.52 0.33
ו ש.וכ-ום.ע ו ע.טטטע ו 1.36 ו -1.0.ע ו 1.91
D.B1-S1.3 0.00513 1.21 0.81 D.B1-S1.4 0.00484 1.15 0.76
D.B1-S1.5 0.0023 0.56 0.36
D.B1-1 0.0074 0.89 0.14 D.B2 0.02573 6.45 0.86
D.B2-C.E1 0.00588 4.47 0.94 D.B2-C.E2 0.00552 4.62 0.89
D.B2-C.E2 0.00552 4.62 0.89 D.B2-C.E3 0.00182 2.32 0.3
D.B2-C.E3 0.00162 2.32 0.3 D.B2-S2.1 0.00185 0.46 0.29
D.B2-S2.2 0.00336 0.82 0.53
D.B2-S2.2 0.00330 0.02 0.33
D.B2-S3.2 0.00568 1.39 0.89
D.B2-S3.3 0.00338 0.79 0.53
D.B2-S3.4 0.00451 1.06 0.71
D.B2-S4.1 0.00272 0.64 0.43
D.B2-S4.2 0.00288 0.68 0.45
D.B2-S4.3 0.00447 1.12 0.7
D.B2-1 0.02217 2.03 0.42
D.B2-2 0.00165 0.41 0.04
D.B3 0.01896 13.09 1.12
J.B1-I1 0.00807 4.77 1.28
J.B1-I2 0.01547 5.2 1.42
J.B1-I3 0.04396 15.49 5.92
J.B1-l4 0.00787 5.96 1.27
J.B1-l5 0.00424 3.23 0.68
J.B2-CV2E 0.03178 12.81 5.03
J.B2-l6 0.01189 4.6 1.88
J.MH1 0.04396 15.49 5.92
J.MH3 0.00787 5.96 1.27
S.1.1 0.00212 0.51 0.33
S.1.2 0.00794 1.85 1.25
S.1.3 0.01307 3.05 2.05
S.1.4 0.01791 4.18 2.81
S.1.5 0.02021 4.71 3.17
S.2.1 0.00185 0.46 0.29
S.2.2 0.00521 1.27 0.82
S.3.1 0.0016 0.38 0.25
S.3.2 0.00728 1.74 1.14
S.3.3 0.01066 2.5 1.67
S.3.4 0.01517 3.56 2.38
S.4.1 0.00272 0.64 0.43
S.4.2 0.00561 1.31 0.88
S.4.3 0.01007 2.4 1.58

Prop	osed Conditions	· 10-Year, 24-Hour	Event
Hydrologic	Drainage Area	Peak Discharge	Volume (ac-ft)
Element	(mi2)	(ft3/s)	` ′
B.B1	0.07147	4.63	9.43
B.B2	0.09322	4.66	8.95
B.B3	0.01896	0.32	1.74
C.E1 C.E2	0.00588 0.01661	7.82 18.90	1.44 4.05
C.E3	0.00182	3.53	0.45
C.PE1	0.00102	7.93	1.18
C.PW1	0.0074	4.07	0.42
C.RR1	0.05395	31.59	8.87
C.RR2	0.01189	11.40	2.88
C.RR3	0.06585	42.02	11.75
C.W1	0.00807	9.71	1.97
C.W2	0.00035	0.56	0.09
C.W3	0.00827	12.63	2.03
C.W4 C.W5	0.00363 0.00424	5.15 6.05	0.89
D.B1	0.00424	31.19	1.04 2.60
D.B1-C.W1	0.00807	10.58	1.97
D.B1-C.W1	0.00035	0.57	0.09
D.B1-C.W3	0.00792	12.20	1.94
D.B1-C.W4	0.00363	5.38	0.89
D.B1-C.W5	0.00424	6.36	1.04
D.B1-S1.1	0.00212	1.75	0.51
D.B1-S1.2	0.00582	4.32	1.40
D.B1-S1.3	0.00513	4.06	1.23
D.B1-S1.4	0.00484	3.96	1.16
D.B1-S1.5	0.0023	1.90	0.55
D.B1-1 D.B2	0.0074	4.34	0.42
D.B2-C.E1	0.02573 0.00588	17.32 8.44	1.98 1.44
D.B2-C.E1	0.00552	8.37	1.36
D.B2-C.E3	0.00332	3.67	0.45
D.B2-S2.1	0.00185	1.55	0.44
D.B2-S2.2	0.00336	2.79	0.81
D.B2-S3.1	0.0016	1.32	0.38
D.B2-S3.2	0.00568	4.7	1.36
D.B2-S3.3	0.00338	2.73	0.81
D.B2-S3.4	0.00451	3.55	1.08
D.B2-S4.1	0.00272	2.2	0.65
D.B2-S4.2	0.00288 0.00447	2.33	0.69
D.B2-S4.3 D.B2-1	0.00447	3.71 8.01	1.07 1.18
D.B2-1	0.02217	1.37	0.12
D.B3	0.01896	25.41	2.21
J.B1-I1	0.00807	9.71	1.97
J.B1-I2	0.01547	13.54	2.38
J.B1-l3	0.04396	40.37	9.27
J.B1-I4	0.00787	11.2	1.93
J.B1-I5	0.00424	6.05	1.04
J.B2-CV2E	0.03178	31.04	7.69
J.B2-I6	0.01189	11.71	2.88
J.MH1 J.MH3	0.04396 0.00787	40.37 11.2	9.27 1.93
S.1.1	0.00787	1.74	0.51
S.1.2	0.00212	6.02	1.91
S.1.3	0.01307	10.02	3.14
S.1.4	0.01791	13.91	4.3
S.1.5	0.02021	15.77	4.86
S.2.1	0.00185	1.54	0.44
S.2.2	0.00521	4.31	1.25
S.3.1	0.0016	1.3	0.38
S.3.2	0.00728	5.97	1.75
S.3.3	0.01066	8.65	2.56
S.3.4 S.4.1	0.01517 0.00272	12.14	3.64
S.4.1 S.4.2	0.00272	2.19 4.5	0.65 1.35
S.4.2 S.4.3	0.00561	8.19	2.42
0.7.0	0.01007	0.10	۷.٦٢

Prop	osed Conditions	- 25-Year, 24-Hour	Event
Hydrologic	Drainage Area	Peak Discharge	
Element	(mi2)	(ft3/s)	Volume (ac-ft)
B.B1	0.07147	8.54	13.11
B.B2	0.09322	8.39	13.06
B.B3	0.01896	0.37	2.17
C.E1	0.00588	10.17	1.78
C.E2	0.01661	25.43	5.01
C.E3	0.00182	4.25	0.56
C.PE1	0.02217	13.08	1.86
C.PW1	0.0074	6.86	0.66
C.RR1	0.05395	45.93	11.39
C.RR2	0.01189	16.01	3.56
C.RR3	0.06585	60.94 12.95	14.95
C.W1 C.W2	0.00807 0.00035	0.70	2.43 0.11
C.W2	0.00035	16.19	2.51
C.W4	0.00363	6.60	1.10
C.W5	0.00303	7.74	1.29
D.B1	0.01964	39.30	3.55
D.B1-C.W1	0.00807	13.85	2.44
D.B1-C.W2	0.00035	0.71	0.11
D.B1-C.W3	0.00033	15.63	2.40
D.B1-C.W4	0.00363	6.83	1.10
D.B1-C.W5	0.00424	8.05	1.29
D.B1-S1.1	0.00212	2.58	0.63
D.B1-S1.2	0.00582	6.50	1.73
D.B1-S1.3	0.00513	6.04	1.53
D.B1-S1.4	0.00484	5.84	1.44
D.B1-S1.5	0.0023	2.79	0.68
D.B1-1	0.0074	6.95	0.66
D.B2	0.02573	25.14	2.91
D.B2-C.E1	0.00588	10.80	1.78
D.B2-C.E2	0.00552	10.57	1.68
D.B2-C.E3	0.00182	4.39	0.56
D.B2-S2.1	0.00185	2.27	0.55
D.B2-S2.2	0.00336	4.1	1
D.B2-S3.1	0.0016	1.95	0.48
D.B2-S3.2	0.00568	6.92	1.69
D.B2-S3.3	0.00338	4.04	1
D.B2-S3.4	0.00451	5.28	1.34
D.B2-S4.1	0.00272	3.26	0.81
D.B2-S4.2	0.00288	3.45	0.86
D.B2-S4.3	0.00447	5.45	1.33
D.B2-1	0.02217	13.44	1.86
D.B2-2	0.00165	2.02	0.18
D.B3	0.01896	32.85	3.05
J.B1-I1	0.00807	12.95	2.43
J.B1-I2	0.01547	19.11	3.1
J.B1-I3	0.04396	57.65	11.63
J.B1-I4	0.00787	14.34	2.39
J.B1-I5	0.00424	7.74	1.29
J.B2-CV2E	0.03178	43.44	9.53
J.B2-l6 J.MH1	0.01189 0.04396	16.35 57.65	3.56
J.MH1 J.MH3	0.04396	57.65 14.34	11.63 2.39
S.1.1	0.00787	2.57	0.63
S.1.1	0.00212	9.01	2.36
S.1.3	0.00794	14.98	3.89
S.1.4	0.01791	20.74	5.33
S.1.5	0.02021	23.5	6.02
S.2.1	0.02021	2.26	0.55
S.2.2	0.00521	6.34	1.55
S.3.1	0.0016	1.92	0.48
S.3.2	0.00728	8.8	2.17
S.3.3	0.01066	12.8	3.17
S.3.4	0.01517	18.01	4.52
S.4.1	0.00272	3.25	0.81
S.4.2	0.00561	6.68	1.67
S.4.3	0.01007	12.1	3

Propo	sed Conditions -	100-Year, 24-Hour	Event
Hydrologic	Drainage Area	Peak Discharge	
Element	(mi2)	(ft3/s)	Volume (ac-ft)
B.B1	0.07147	49.90	19.95
B.B2	0.09322	50.13	20.99
B.B3	0.01896	0.69	2.86
C.E1	0.00588	14.21	2.39
C.E2	0.01661	36.80	6.74
C.E3	0.00182	5.46	0.75
C.PE1	0.02217	23.58	3.32
C.PW1 C.RR1	0.0074 0.05395	11.49 73.68	1.17 16.14
C.RR2	0.03393	24.14	4.79
C.RR3	0.06585	97.15	20.93
C.W1	0.00807	18.57	3.28
C.W2	0.00035	0.95	0.14
C.W3	0.00827	22.19	3.38
C.W4	0.00363	9.10	1.48
C.W5	0.00424	10.64	1.73
D.B1	0.01964	53.07	5.36
D.B1-C.W1	0.00807	19.51	3.28
D.B1-C.W2	0.00035	0.95	0.14
D.B1-C.W3	0.00792	21.38	3.23
D.B1-C.W4	0.00363	9.35	1.48
D.B1-C.W5	0.00424	10.98	1.73
D.B1-S1.1	0.00212	4.05	0.85
D.B1-S1.2	0.00582	10.38	2.33
D.B1-S1.3	0.00513	9.56	2.06
D.B1-S1.4	0.00484	9.19	1.94
D.B1-S1.5	0.0023	4.39	0.92
D.B1-1	0.0074	11.69	1.17
D.B2 D.B2-C.E1	0.02573	39.45 14.88	4.81 2.40
D.B2-C.E1	0.00588 0.00552	14.38	2.40
D.B2-C.E2	0.00332	5.61	0.75
D.B2-S2.1	0.00185	3.55	0.74
D.B2-S2.2	0.00336	6.43	1.35
D.B2-S3.1	0.0016	3.06	0.64
D.B2-S3.2	0.00568	10.85	2.28
D.B2-S3.3	0.00338	6.37	1.35
D.B2-S3.4	0.00451	8.36	1.81
D.B2-S4.1	0.00272	5.14	1.09
D.B2-S4.2	0.00288	5.44	1.16
D.B2-S4.3	0.00447	8.54	1.79
D.B2-1	0.02217	23.87	3.32
D.B2-2	0.00165	3.15	0.31
D.B3	0.01896	45.79	4.69
J.B1-I1	0.00807	18.57	3.28
J.B1-I2	0.01547	28.56	4.45
J.B1-l3 J.B1-l4	0.04396 0.00787	87.94 10.75	15.93
J.B1-I4 J.B1-I5	0.00787	19.75 10.64	3.21 1.73
J.B2-CV2E	0.00424	65.24	12.82
J.B2-I6	0.03178	24.51	4.79
J.MH1	0.04396	87.94	15.93
J.MH3	0.00787	19.75	3.21
S.1.1	0.00212	4.03	0.85
S.1.2	0.00794	14.34	3.18
S.1.3	0.01307	23.81	5.24
S.1.4	0.01791	32.91	7.18
S.1.5	0.02021	37.26	8.1
S.2.1	0.00185	3.54	0.74
S.2.2	0.00521	9.95	2.09
S.3.1	0.0016	3.03	0.64
S.3.2	0.00728	13.84	2.92
S.3.3	0.01066	20.15	4.27
S.3.4	0.01517	28.44	6.08
S.4.1	0.00272	5.13	1.09
S.4.2	0.00561	10.54	2.25
S.4.3	0.01007	19.05	4.04

Bremo FFCP - Part B

HEC-HMS Pond Model Results:

			1-yr					2-yr					10-yr					25-yr					100-yr		
Pond ID	Inflow	Inflow Volume	Water Elev.	Discharge	Discharge Volume	Inflow	Inflow Volume	Water Elev.	Discharge	Discharge Volume	Inflow	Inflow Volume	Water Elev.	Discharge	Discharge Volume	Inflow	Inflow Volume	Water Elev.	Discharge	Discharge Volume	Inflow	Inflow Volume	Water Elev.	Discharge	Discharge Volume
	ft ³ /s	ac-ft	ft	ft ³ /s	ac-ft	ft3/s	ac-ft	ft	ft3/s	ac-ft	ft3/s	ac-ft	ft	ft3/s	ac-ft	ft3/s	ac-ft	ft	ft3/s	ac-ft	ft3/s	ac-ft	ft	ft3/s	ac-ft
Basin 1	25.89	6.84	325.10	0.54	3.67	38.71	8.52	326.09	0.83	4.38	82.76	13.80	326.86	4.63	9.43	111.28	17.57	327.28	8.54	13.11	160.75	24.50	328.23	49.90	19.95
Basin 2	15.59	6.54	300.16	0.49	3.26	24.60	8.23	301.35	0.55	3.72	60.44	13.84	302.36	4.66	8.95	87.06	18.04	302.78	8.39	13.07	136.65	26.05	303.73	50.13	20.99
Basin 3	9.27	0.81	282.57	0.18	0.76	13.14	1.12	282.82	0.22	1.02	25.41	2.21	283.74	0.32	1.74	32.84	3.05	284.41	0.37	2.17	45.79	4.69	285.64	0.69	2.86

		25	-yr		100-yr						
Pond ID	Inflow	Inflow Volume	Water Elev.	Discharge	Inflow	Inflow Volume	Water Elev.	Discharge			
	ft ³ /s	ac-ft	ft	ft ³ /s	ft3/s	ac-ft	ft	ft3/s			
CSWP	129.78	15.76	290.60	3.34	205.36	22.20	293.97	3.34			

Note:

- Contact Water Basin will have pumped discharge of 1500 gallons per minute (3.34 cfs)
 Maximum contributing drainage area of 28 acres of open CCR with CN of 91
 Direct drainage area to Contact Water Basin is 12 acres with CN of 85

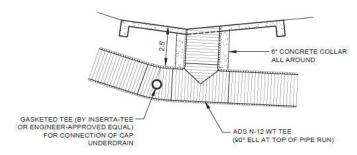
Stormwater Analysis Attachment 6
Slope Drains



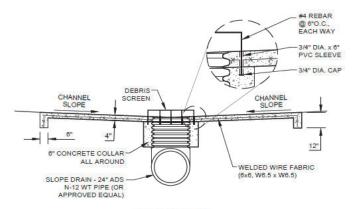
Non-Contact Slope Drain Drop Inlet - INPUTS											
Invert (ft):	0										
Diameter (in)	24										
Со	0.67	24" ADS N 12 Ding Opening w/ Dehvis									
Cw	3	24" ADS N-12 Pipe Opening w/ Debris									
Orifice Area (ft ²)	3.14	Screen									
Weir Perimeter (ft)	6.28										
% Area Clogged	5										

Note: Max Depth of Drainage Benches are 2 FT

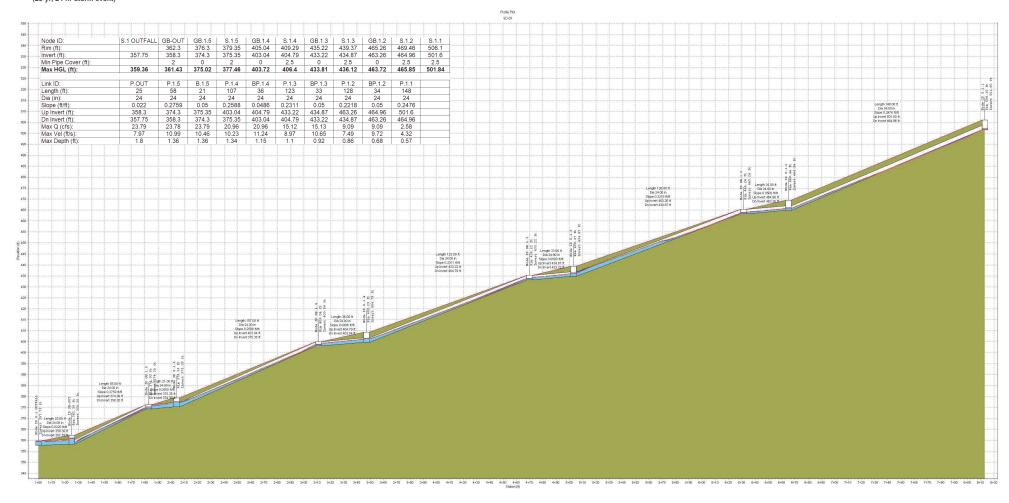
Water Elevation	Riser								
water Elevation	Drop Inlet	Flow (Orifice)	Flow (Weir)	Controlling Flow					
(ft)	(ft)	(cfs)	(cfs)						
0.00	0.00	0.00	0.00	(cfs)					
0.10	0.10	5.07	0.57	0.57					
0.20	0.20	7.18	1.60	1.60					
0.30	0.30	8.79	2.94	2.94					
0.40	0.40	10.15	4.53	4.53					
0.50	0.50	11.35	6.33	6.33					
0.60	0.60	12.43	8.32	8.32					
0.70	0.70	13.43	10.49	10.49					
0.80	0.80	14.35	12.81	12.81					
0.90	0.90	15.22	15.29	15.22					
1.00	1.00	16.05	17.91	16.05					
1.10	1.10	16.83	20.66	16.83					
1.20	1.20	17.58	23.54	17.58					
1.30	1.30	18.30	26.54	18.30					
1.40	1.40	18.99	29.66	18.99					
1.50	1.50	19.65	32.90	19.65					
1.60	1.60	20.30	36.24	20.30					
1.70	1.70	20.92	39.69	20.92					
1.80	1.80	21.53	43.24	21.53					
1.90	1.90	22.12	46.90	22.12					
2.00	2.00	22.69	50.65	22.69					



SECTION A-A'

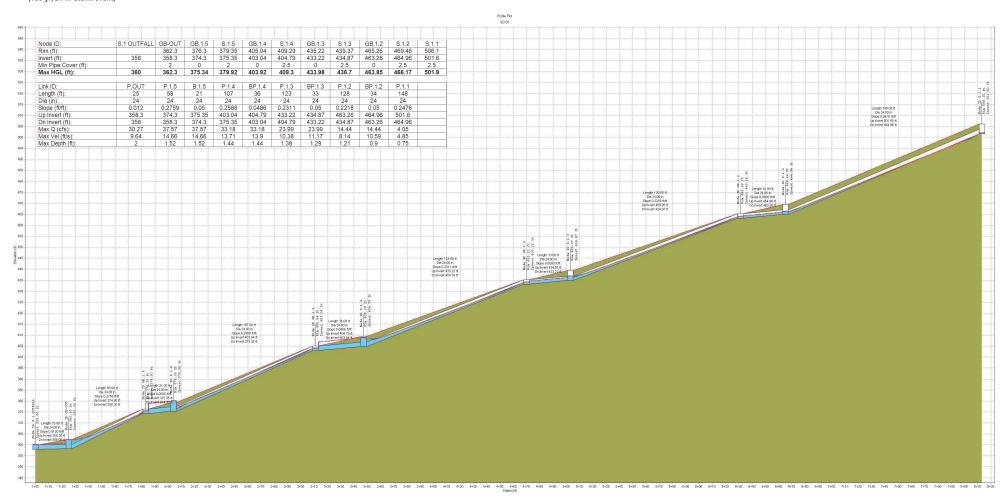


SECTION B-B'



Autodesk Storm and Sanitary Analysis

Attachment 06 - Slope Drains



Autodesk Storm and Sanitary Analysis

Attachment 06 - Slope Drains

Stormwater Analysis Attachment 7
Culvert Calculations



FFCP FACILITY CULVERT SCHEDULE															
Culvert Details					Channel Details Max Capacity		Design Flows								
Culvert Name/No.	Diameter (in) [A]	No. of Barrels	Type [B]	Slope (%) [C]	Length (ft)	Inv. In El. [I]	Inv. Out El. [0]	Reference Top El.	Reference HEC HMS Node	Q_{MAX}	Q_2	Q ₁₀	Q ₂₅	Q ₁₀₀	Notes
C1A	36	2	Class IV RCP	1.7%	80	360.2	358.8	364.2	C.W3	100.7	6.5	12.6	16.2	22.2	With Headwall and Endwall
C2A	18	1	Class III RCP	1.7%	60	304.0	303.0	308.0	D.B2-2	15.4	0.4	1.4	2.0	3.2	With Headwall
C2B	36	1	Class III RCP	3.3%	54	304.8	303.0	308.8	D.B2	53.1	6.5	17.3	25.1	39.5	With Headwall
C2C	36	2	Class III RCP	6.1%	56	305.4	302.0	309.4	C.RR3	169.2	17.7	42.0	61.0	97.2	With Headwall
C2D	36	2	Class III RCP	8.3%	96	332.0	324.0	336.0	C.RR3	103.2	17.7	42.0	61.0	97.2	With Headwall and Endwall
C2E	36	2	Class III RCP	5.1%	68	365.5	362.0	369.5	C.RR1	102.0	13.4	31.6	46.1	73.7	With Headwall and Endwall
C2F	24	1	Class III RCP	1.6%	208	354.3	351.0	362.3	C.RR2	40.0	4.4	11.4	16.0	24.1	Drop Inlet

HY-8 Culvert Analysis Report

Culvert Data: C1A

Site Data - C1A

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 360.20 ft

Outlet Station: 80.00 ft

Outlet Elevation: 358.80 ft

Number of Barrels: 2

Culvert Data Summary - C1A

Barrel Shape: Circular

Barrel Diameter: 3.00 ft

Barrel Material: Concrete

Embedment: 0.00 in

Barrel Manning's n: 0.0120

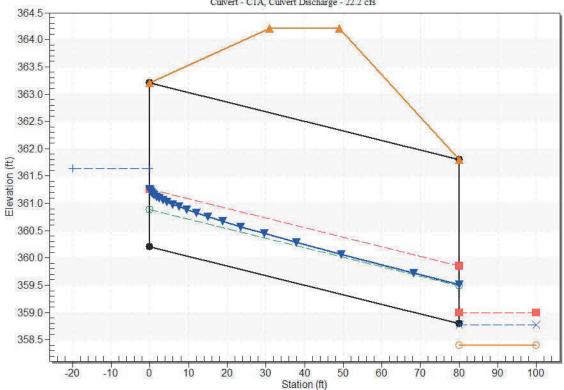
Culvert Type: Straight

Inlet Configuration: Square Edge with Headwall (Ke=0.5)

Inlet Depression: None

Water Surface Profile Plot for Culvert: C1A





Crossing Discharge Data

Discharge Selection Method: User Defined

Table 1 - Summary of Culvert Flows at Crossing: FFCP CLV.C1A

Headwater Elevation (ft)	Discharge Names	Total Discharge (cfs)	C1A Discharge (cfs)	Roadway Discharge (cfs)	Iterations
360.96	Q-2YR	6.50	6.50	0.00	1
361.27	Q-10YR	12.60	12.60	0.00	1
361.42	Q-25YR	16.20	16.20	0.00	1
361.64	Q-100YR	22.20	22.20	0.00	1
364.20	Overtopping	100.66	100.66	0.00	Overtopping

Culvert Data: C2A

Site Data - C2A

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 304.00 ft

Outlet Station: 60.00 ft

Outlet Elevation: 303.00 ft

Number of Barrels: 1

Culvert Data Summary - C2A

Barrel Shape: Circular

Barrel Diameter: 1.50 ft

Barrel Material: Concrete

Embedment: 0.00 in

Barrel Manning's n: 0.0120

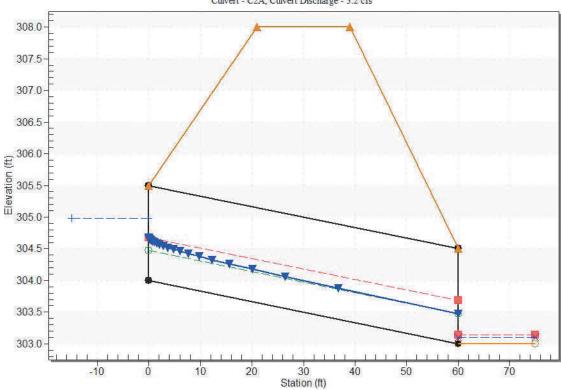
Culvert Type: Straight

Inlet Configuration: Square Edge with Headwall (Ke=0.5)

Inlet Depression: None

Water Surface Profile Plot for Culvert: C2A

Crossing - FFCP CLV.C2A, Design Discharge - 3.2 cfs
Culvert - C2A, Culvert Discharge - 3.2 cfs



Crossing Discharge Data

Discharge Selection Method: User Defined

Table 2 - Summary of Culvert Flows at Crossing: FFCP CLV.C2A

Headwater Elevation (ft)	Discharge Names	Total Discharge (cfs)	C2A Discharge (cfs)	Roadway Discharge (cfs)	Iterations
304.32	Q-2YR	0.41	0.41	0.00	1
304.60	Q-10YR	1.40	1.40	0.00	1
304.73	Q-25YR	2.00	2.00	0.00	1
304.98	Q-100YR	3.20	3.20	0.00	1
308.00	Overtopping	15.38	15.38	0.00	Overtopping

Culvert Data: C2B

Site Data - C2B

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 304.80 ft

Outlet Station: 54.00 ft

Outlet Elevation: 303.00 ft

Number of Barrels: 1

Culvert Data Summary - C2B

Barrel Shape: Circular

Barrel Diameter: 3.00 ft

Barrel Material: Concrete

Embedment: 0.00 in

Barrel Manning's n: 0.0120

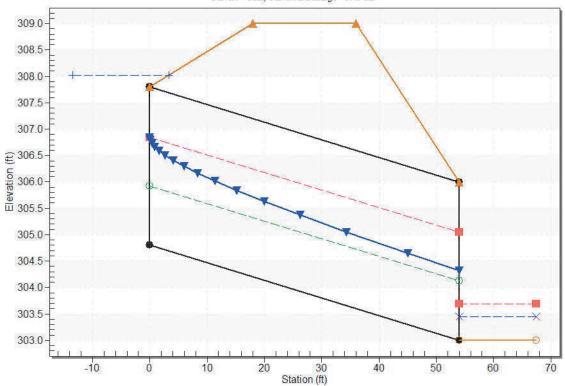
Culvert Type: Straight

Inlet Configuration: Square Edge with Headwall (Ke=0.5)

Inlet Depression: None

Water Surface Profile Plot for Culvert: C2B

Crossing - FFCP CLV.C2B, Design Discharge - 39.5 cfs Culvert - C2B, Culvert Discharge - 39.5 cfs



Crossing Discharge Data

Discharge Selection Method: User Defined

Table 3 - Summary of Culvert Flows at Crossing: FFCP CLV.C2B

Headwater Elevation (ft)	Discharge Names	Total Discharge (cfs)	C2B Discharge (cfs)	Roadway Discharge (cfs)	Iterations
305.87	Q-2YR	6.50	6.50	0.00	1
306.67	Q-10YR	17.30	17.30	0.00	1
307.17	Q-25YR	25.10	25.10	0.00	1
308.02	Q-100YR	39.50	39.50	0.00	1
309.00	Overtopping	53.13	53.13	0.00	Overtopping

Culvert Data: C2C

Site Data - C2C

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 305.40 ft

Outlet Station: 56.00 ft

Outlet Elevation: 302.00 ft

Number of Barrels: 2

Culvert Data Summary - C2C

Barrel Shape: Circular

Barrel Diameter: 3.00 ft

Barrel Material: Concrete

Embedment: 0.00 in

Barrel Manning's n: 0.0120

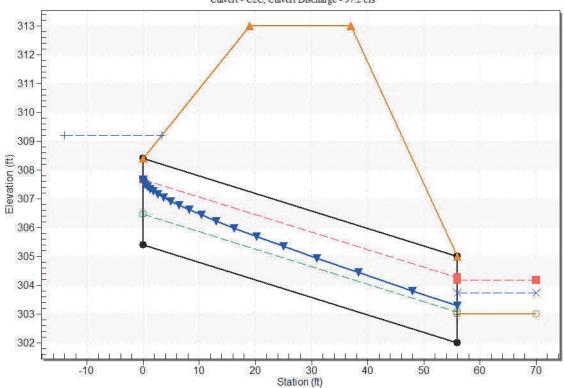
Culvert Type: Straight

Inlet Configuration: Square Edge with Headwall (Ke=0.5)

Inlet Depression: None

Water Surface Profile Plot for Culvert: C2C





Crossing Discharge Data

Discharge Selection Method: User Defined

Table 4 - Summary of Culvert Flows at Crossing: FFCP CLV.C2C

Headwater Elevation (ft)	Discharge Names	Total Discharge (cfs)	C2C Discharge (cfs)	Roadway Discharge (cfs)	Iterations
306.63	Q-2YR	17.70	17.70	0.00	1
307.48	Q-10YR	42.00	42.00	0.00	1
308.04	Q-25YR	61.00	61.00	0.00	1
309.20	Q-100YR	97.20	97.20	0.00	1
313.00	Overtopping	169.22	169.22	0.00	Overtopping

Culvert Data: C2D

Site Data - C2D

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 332.00 ft

Outlet Station: 96.00 ft

Outlet Elevation: 324.00 ft

Number of Barrels: 2

Culvert Data Summary - C2D

Barrel Shape: Circular

Barrel Diameter: 3.00 ft

Barrel Material: Concrete

Embedment: 0.00 in

Barrel Manning's n: 0.0120

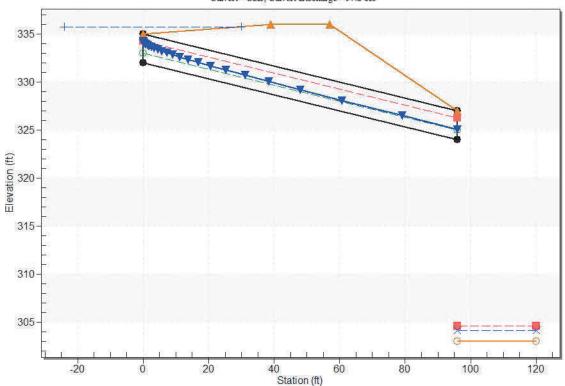
Culvert Type: Straight

Inlet Configuration: Square Edge with Headwall (Ke=0.5)

Inlet Depression: None

Water Surface Profile Plot for Culvert: C2D

Crossing - FFCP CLV.C2D, Design Discharge - 97.2 cfs Culvert - C2D, Culvert Discharge - 97.2 cfs



Crossing Discharge Data

Discharge Selection Method: User Defined

Table 5 - Summary of Culvert Flows at Crossing: FFCP CLV.C2D

Headwater Elevation (ft)	Discharge Names	Total Discharge (cfs)	C2D Discharge (cfs)	Roadway Discharge (cfs)	Iterations
333.21	Q-2YR	17.70	17.70	0.00	1
334.04	Q-10YR	42.00	42.00	0.00	1
334.61	Q-25YR	61.00	61.00	0.00	1
335.77	Q-100YR	97.20	97.20	0.00	1
336.00	Overtopping	103.15	103.15	0.00	Overtopping

Culvert Data: C2E

Site Data - C2E

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 365.50 ft

Outlet Station: 68.00 ft

Outlet Elevation: 362.00 ft

Number of Barrels: 2

Culvert Data Summary - C2E

Barrel Shape: Circular

Barrel Diameter: 3.00 ft

Barrel Material: Concrete

Embedment: 0.00 in

Barrel Manning's n: 0.0120

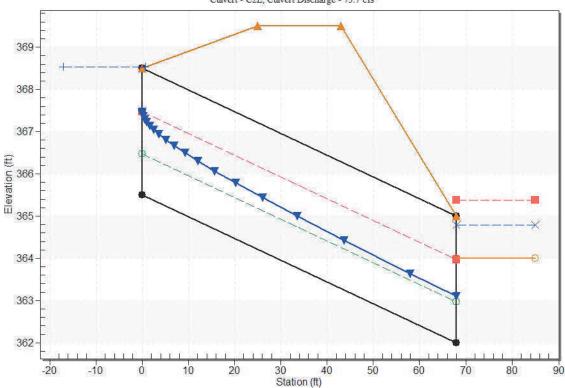
Culvert Type: Straight

Inlet Configuration: Square Edge with Headwall (Ke=0.5)

Inlet Depression: None

Water Surface Profile Plot for Culvert: C2E

Crossing - FFCP CLV.C2E, Design Discharge - 73.7 cfs
Culvert - C2E, Culvert Discharge - 73.7 cfs



Crossing Discharge Data

Discharge Selection Method: User Defined

Table 6 - Summary of Culvert Flows at Crossing: FFCP CLV.C2E

Headwater Elevation (ft)	Discharge Names	Total Discharge (cfs)	C2E Discharge (cfs)	Roadway Discharge (cfs)	Iterations
366.57	Q-2YR	13.40	13.40	0.00	1
367.24	Q-10YR	31.60	31.60	0.00	1
367.72	Q-25YR	46.10	46.10	0.00	1
368.53	Q-100YR	73.70	73.70	0.00	1
369.50	Overtopping	101.96	101.96	0.00	Overtopping

Culvert Data: C2F

Site Data - C2F

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 354.30 ft

Outlet Station: 208.00 ft

Outlet Elevation: 351.00 ft

Number of Barrels: 1

Culvert Data Summary - C2F

Barrel Shape: Circular

Barrel Diameter: 2.00 ft

Barrel Material: Concrete

Embedment: 0.00 in

Barrel Manning's n: 0.0120

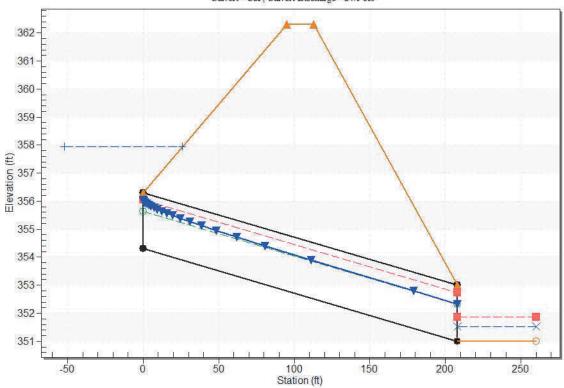
Culvert Type: Straight

Inlet Configuration: Square Edge with Headwall (Ke=0.5)

Inlet Depression: None

Water Surface Profile Plot for Culvert: C2F





Crossing Discharge Data

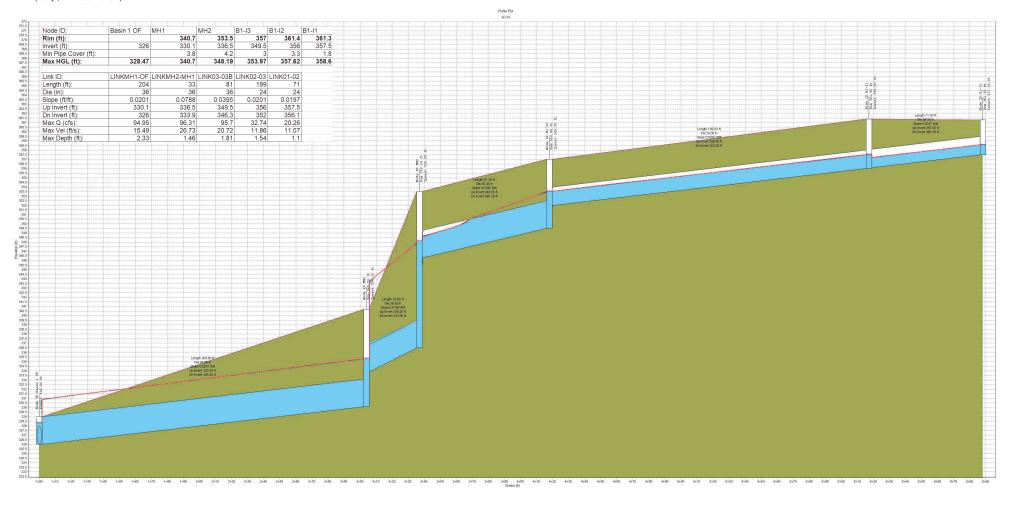
Discharge Selection Method: User Defined

Table 7 - Summary of Culvert Flows at Crossing: FFCP CLV.C2F

Headwater Elevation (ft)	Discharge Names	Total Discharge (cfs)	C2F Discharge (cfs)	Roadway Discharge (cfs)	Iterations
355.31	Q-2YR	4.40	4.40	0.00	1
356.14	Q-10YR	11.40	11.40	0.00	1
356.67	Q-25YR	16.00	16.00	0.00	1
357.94	Q-100YR	24.10	24.10	0.00	1
362.30	Overtopping	40.03	40.03	0.00	Overtopping

Stormwater Analysis Attachment 8 Storm Sewer System Profiles

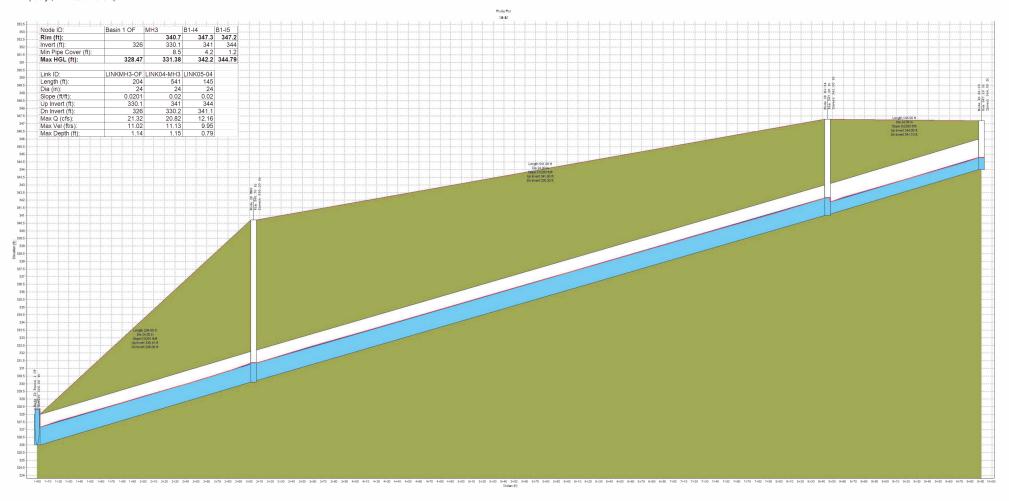




Autodesk Storm and Sanitary Analysis

Attachment 08 - Storm Sewer
System Profiles

FFCP Facility Storm Drain Profile B: (100-yr, 24-hr storm event)



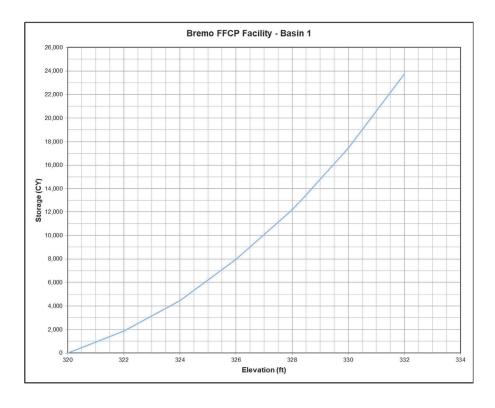
Stormwater Analysis Attachment 9
Pond Stage-Storage and Rating Curve



Bremo FFCP Facility - Basin 1

Stage-Storage Data

Elevation	Are	Area		Volume	Cumulative Volume				
(ft)	(sqft)	(acres)	(cuft)	(CY)	(cuft)	(CY)	(ac-ft)		
332.00	88,231.0	2.026	169,692	6,285	640,937	23,738	14.71		
330.00	81,505.0	1.871	142,698	5,285	471,245	17,454	10.82		
328.00	61,654.0	1.415	113,561	4,206	328,547	12,168	7.54		
326.00	52,043.0	1.195	94,854	3,513	214,986	7,962	4.94		
324.00	42,956.0	0.986	69,819	2,586	120,132	4,449	2.76		
322.00	27,440.0	0.630	50,313	1,863	50,313	1,863	1.16		
320.00	22,940.0	0.527							



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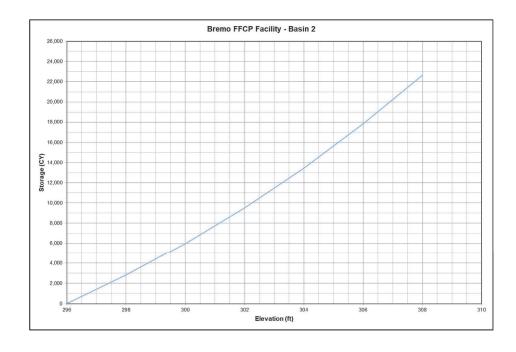
							FFCP Fac	cility Basin 1	Discharge Rating	; Table - INI	PUIS						
	Invert (ft):	320			Invert (ft):	326			Invert (ft):	327.5			Invert (ft): 320	Invert (ft):	330	NOTE: OUTFLOW
	Diameter (in)	3	1		Length (ft):	1.5	1		Diameter (in)	60			Outlet (ft		B. Width (ft):	15	CALCULATIONS DOI
	Diameter (ft)	0.250			Height (ft):	1.5			Diameter (ft)	5			Diameter (in)): 36	Top Width (ft):	23	NOT INCLUDE
	Co	0.61	011 015 0111		Co	0.61	RECTANGU	JLAR 18" X 18"	Co	0.61	COLLE		Length (ft	125	Side Slope (ft/ft): 4	EMERGENCY SPILLW
	Orifice Area (ft 2)	0.0491	3" CIRCUL	AR ORIFICE	Cw	3.33	1 N	ОТСН	Cw	3.33	60" F	liser	CALCULATE				FLOW
	Cw	3.33	1		Orifice Area (ft ²)		1	0.0	Orifice/Weir Area (ft ²)	19.63			CALCULATED				(Modeled as Separat
			1		OTTITUE / IFED (TE)		1		Weir Perimeter (ft)				CULVERT SPRE	ADSHEET	Trapezoidal	Spillway	Aux. Spillway in
			1				1		, ,								HEC-HMS)
ater Elevation		Disch	arge 1			Discharg	ge 2			Ris	er		Barre	l i	E. Spill	way	Outflow
ater Elevation	Head	Flow (Orifice)	Flow (Weir)	Controlling Flow	Head	Flow (Orifice)	Flow (Weir)	Controlling Flow	Head	Flow (Orifice)	Flow (Weir)	Controlling Flow	Head	Flow	Head	Flow	
(ft)	(ft)	(cfs)	(cfs)	(cfs)	(ft)	(cfs)	(cfs)	(cfs)	(ft)	(cfs)	(cfs)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(cfs)
320.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
320.25	0.25	0.12	0.00	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.30	0.00	0.00	0.12
320.50	0.50	0.17	0.00	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50	1.30	0.00	0.00	0.17
320.75	0.75	0.21	0.00	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.75	3.40	0.00	0.00	0.21
321.00	1.00	0.24	0.00	0.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	5.80	0.00	0.00	0.24
321.25	1.25	0.27	0.00	0.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.25	8.90	0.00	0.00	0.27
321.50	1.50	0.29	0.00	0.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.50	12.40	0.00	0.00	0.29
321.75	1.75	0.32	0.00	0.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.75	15.70	0.00	0.00	0.32
322.00	2.00	0.34	0.00	0.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00	19.40	0.00	0.00	0.34
322.25	2.25	0.36	0.00	0.36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.25	23.40	0.00	0.00	0.36
322.50	2.50	0.38	0.00	0.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.50	27.60	0.00	0.00	0.38
322.75	2.75	0.40	0.00	0.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.75	31.90	0.00	0.00	0.40
323.00	3.00	0.42	0.00	0.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.00	36.10	0.00	0.00	0.42
323.25	3.25	0.43	0.00	0.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.25	40.20	0.00	0.00	0.43
323.50	3.50	0.45	0.00	0.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.50	44.00	0.00	0.00	0.45
323.75	3.75	0.47	0.00	0.47	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.75	47.50	0.00	0.00	0.47
324.00	4.00	0.48	0.00	0.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.00	50.80	0.00	0.00	0.48
324.25	4.25	0.50	0.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.25	53.90	0.00	0.00	0.50
324.50	4.50	0.51	0.00	0.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.50	56.80	0.00	0.00	0.51
324.75	4.75	0.52	0.00	0.52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.75	59.60	0.00	0.00	0.52
325.00	5.00	0.54	0.00	0.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.00	62.20	0.00	0.00	0.54
325.25	5.25	0.55	0.00	0.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.25	64.70	0.00	0.00	0.55
325.50	5.50	0.56	0.00	0.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.50	67.10	0.00	0.00	0.56
325.75	5.75	0.58	0.00	0.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.75	69.40	0.00	0.00	0.58
326.00	6.00	0.59	0.00	0.59	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.00	71.60	0.00	0.00	0.59
326.25	6.25	0.60	0.00	0.60	0.25	5.51	0.62	0.62	0.00	0.00	0.00	0.00	6.25	73.80	0.00	0.00	1.23
326.50	6.50	0.61	0.00	0.61	0.50	7.79	1.77	1.77	0.00	0.00	0.00	0.00	6.50	75.90	0.00	0.00	2.38
326.75	6.75	0.62	0.00	0.62	0.75	9.54	3.24	3.24	0.00	0.00	0.00	0.00	6.75	77.90	0.00	0.00	3.87
327.00	7.00	0.64	0.00	0.64	1.00	11.01	5.00	5.00	0.00	0.00	0.00	0.00	7.00	79.90	0.00	0.00	5.63
327.25	7.25	0.65	0.00	0.65	1.25	12.31	6.98	6.98	0.00	0.00	0.00	0.00	7.25	81.80	0.00	0.00	7.63
327.50	7.50	0.66	0.00	0.66	1.50	13.49	9.18	13.49	0.00	0.00	0.00	0.00	7.50	83.70	0.00	0.00	14.15
327.75	7.75	0.67	0.00	0.67	1.75	14.57	11.56	14.57	0.25	48.06	6.54	6.54	7.75	85.50	0.00	0.00	21.78
328.00	8.00	0.68	0.00	0.68	2.00	15.58	14.13	15.58	0.50	67.97	18.49	18.49	8.00	87.30	0.00	0.00	34.75
328.25	8.25	0.69	0.00	0.69	2.25	16.52	16.86	16.52	0.75	83.24	33.97	33.97	8.25	89.10	0.00	0.00	51.19
328.50	8.50	0.70	0.00	0.70	2.50	17.42	19.74	17.42	1.00	96.12	52.31	52.31	8.50	90.80	0.00	0.00	70.42
328.75	8.75	0.71	0.00	0.71	2.75	18.27	22.78	18.27	1.25	107.46	73.10	73.10	8.75	92.50	0.00	0.00	92.08
329.00	9.00	0.72	0.00	0.72	3.00	19.08	25.95	19.08	1.50	117.72	96.10	96.10	9.00	94.20	0.00	0.00	94.20
329.25	9.25	0.73	0.00	0.73	3.25	19.86	29.27	19.86	1.75	127.15	121.09	121.09	9.25	95.80	0.00	0.00	95.80
329.50	9.50	0.74	0.00	0.74	3.50	20.61	32.71	20.61	2.00	135.93	147.95	135.93	9.50	97.30	0.00	0.00	97.30
329.75	9.75	0.75	0.00	0.75	3.75	21.33	36.27	21.33	2.25	144.18	176.54	144.18	9.75	98.80	0.00	0.00	98.80
330.00	10.00	0.76	0.00	0.76	4.00	22.03	39.96	22.03	2.50	151.98	206.76	151.98	10.00	100.30	0.00	0.00	100.30
330.25	10.25	0.77	0.00	0.77	4.25	22.71	43.76	22.71	2.75	159.39	238.54	159.39	10.25	101.80	0.25	6.11	101.80
330.50	10.50	0.78	0.00	0.78	4.50	23.36	47.68	23.36	3.00	166.48	271.80	166.48	10.50	103.20	0.50	18.19	103.20
330.75	10.75	0.79	0.00	0.79	4.75	24.01	51.71	24.01	3.25	173.28	306.47	173.28	10.75	104.70	0.75	35.08	104.70
331.00	11.00	0.80	0.00	0.80	5.00	24.63	55.85	24.63	3.50	179.82	342.50	179.82	11.00	106.10	1.00	56.58	106.10
331.25	11.25	0.81	0.00	0.81	5.25	25.24	60.09	25.24	3.75	186.13	379.85	186.13	11.25	107.50	1.25	82.66	107.50
331.50	11.50	0.81	0.00	0.81	5.50	25.83	64.43	25.83	4.00	192.24	418.46	192.24	11.50	108.80	1.50	113.37	108.80
331.75	11.75	0.82	0.00	0.82	5.75	26.41	68.87	26.41	4.25	198.15	458.30	198.15	11.75	110.20	1.75	148.81	110.20
332.00	12.00	0.83	0.00	0.83	6.00	26.98	73.41	26.98	4.50	203.90	499.32	203.90	12.00	111.50	2.00	189.08	111.50

Attachment 09 - Pond Stage Storage
and Discharge Rating Curves

Bremo FFCP Facility - Basin 2

Stage-Storage Data

Elevation	Are	a	Incremental	Volume	Cumulative Volume				
(ft)	(sqft)	(acres)	(cuft)	(CY)	(cuft)	(CY)	(ac-ft)		
308.00	67,810.3	1.557	129,614	4,801	611,191	22,637	14.03		
306.00	61,849.0	1.420	117,915	4,367	481,577	17,836	11.06		
304.00	56,112.5	1.288	106,666	3,951	363,662	13,469	8.35		
302.00	50,600.8	1.162	95,866	3,551	256,996	9,518	5.90		
300.00	45,313.9	1.040	85,516	3,167	161,130	5,968	3.70		
298.00	40,251.7	0.924	75,615	2,801	75,615	2,801	1.74		
296.00	35,414.4	0.813							



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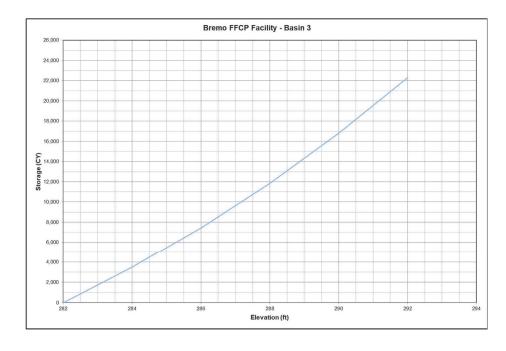
							FFCP Fa	cility Basin 2	Discharge Ratin	g Table - IN	IPUTS						
	Invert (ft):	296			Invert (ft):	301.5			Invert (ft)	: 303			Invert (ft):	296	Invert (ft):	306	NOTE: OUTFLOW
	Diameter (in)	3			Length (ft):	1.5			Diameter (in	1) 60			Outlet (ft)	290	B. Width (ft):	15	CALCULATIONS DOES
	Diameter (ft)	0.250			Height (ft):	1.5			Diameter (fi	t) 5			Diameter (in):	36	Top Width (ft):	23	NOT INCLUDE
	Co	0.61	011 012 0111		Co	0.61	RECTANG	ULAR 18" X 18"	C	0.61			Length (ft)	125	Side Slope (ft/ft)	: 4	EMERGENCY SPILLWAY
	Orifice Area (ft ²)	0.0491	3" CIRCULA	AR ORIFICE	Cw	3.33		NOTCH	C	w 3.33	60" R	iser	CALCULATED	IN LID			FLOW
	Cw	3.33	1		Orifice Area (ft ²)	2.25	1 .		Orifice/Weir Area (ft				CALCULATED		l		(Modeled as Separate
					Office Filed (10)				Weir Perimeter (fl	/			CULVERT SPREA	ADSHEET	Trapezoidal	Spillway	Aux. Spillway in
			1						,	1					1		HEC-HMS)
		Discha	arge 1			Discharg	e 2			Ri	ser		Barrel		E. Spillw	<i>r</i> ay	0.10
	Head	Flow (Orifice)	Flow (Weir)	Controlling Flow	Head	Flow (Orifice)	Flow (Weir)	Controlling Flow	Head	Flow (Orifice)	Flow (Weir)	Controlling Flow	Head	Flow	Head	Flow	Outflow
(ft)	(ft)	(cfs)	(cfs)	(cfs)	(ft)	(cfs)	(cfs)	(cfs)	(ft)	(cfs)	(cfs)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(cfs)
296.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
296.25	0.25	0.12	0.00	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.40	0.00	0.00	0.12
296.50	0.50	0.17	0.00	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50	1.30	0.00	0.00	0.17
296.75	0.75	0.21	0.00	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.75	3.40	0.00	0.00	0.21
297.00	1.00	0.24	0.00	0.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	5.90	0.00	0.00	0.24
297.25	1.25	0.27	0.00	0.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.25	9.00	0.00	0.00	0.27
297.50	1.50	0.29	0.00	0.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.50	12.60	0.00	0.00	0.29
297.75	1.75	0.32	0.00	0.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.75	15.90	0.00	0.00	0.32
298.00	2.00	0.34	0.00	0.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.00	19.60	0.00	0.00	0.34
298.25	2.25	0.36	0.00	0.36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.25	23.60	0.00	0.00	0.36
298.50	2.50	0.38	0.00	0.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.50	27.80	0.00	0.00	0.38
298.75	2.75	0.40	0.00	0.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.75	32.10	0.00	0.00	0.40
299.00	3.00	0.42	0.00	0.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.00	36.30	0.00	0.00	0.42
299.25	3.25	0.43	0.00	0.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.25	40.40	0.00	0.00	0.43
299.50	3.50	0.45	0.00	0.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.50	44.10	0.00	0.00	0.45
299.75	3.75	0.47	0.00	0.47	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.75	47.70	0.00	0.00	0.47
300.00	4.00	0.48	0.00	0.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.00	51.00	0.00	0.00	0.48
300.25	4.25	0.50	0.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.25	54.10	0.00	0.00	0.50
300.50	4.50	0.51	0.00	0.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.50	57.00	0.00	0.00	0.51
300.75	4.75	0.52	0.00	0.52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.75	59.70	0.00	0.00	0.52
301.00	5.00	0.54	0.00	0.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.00	62.30	0.00	0.00	0.54
301.25	5.25	0.55	0.00	0.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.25	64.80	0.00	0.00	0.55
301.50	5.50	0.56	0.00	0.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.50	67.20	0.00	0.00	0.56
301.75	5.75	0.58	0.00	0.58	0.25	5.51	0.62	0.62	0.00	0.00	0.00	0.00	5.75	69.50	0.00	0.00	1.20
302.00	6.00	0.59	0.00	0.59	0.50	7.79	1.77	1.77	0.00	0.00	0.00	0.00	6.00	71.80	0.00	0.00	2.35
302.25	6.25	0.60	0.00	0.60	0.75	9.54	3.24	3.24	0.00	0.00	0.00	0.00	6.25	73.90	0.00	0.00	3.85
302.50	6.50	0.61	0.00	0.61	1.00	11.01	5.00	5.00	0.00	0.00	0.00	0.00	6.50	76.00	0.00	0.00	5.61
302.75 303.00	6.75 7.00	0.62	0.00	0.62	1.25 1.50	12.31 13.49	6.98 9.18	6.98 13.49	0.00	0.00	0.00	0.00	6.75 7.00	78.00 80.00	0.00	0.00	7.61 14.13
303.00	7.00	0.64	0.00	0.64	1.50	13.49	9.18	13.49	0.00	48.06	6.54	6.54	7.00	81.90	0.00	0.00	14.13 21.76
303.25	7.50	0.66	0.00	0.66	2.00	15.58	14.13	15.58	0.25	67.97	18.49	18.49	7.25	83.80	0.00	0.00	34.73
303.50	7.50	0.66	0.00	0.67	2.00	16.52	16.86	16.52	0.50	83.24	33.97	33.97	7.75	85.60	0.00	0.00	51.17
304.00	8.00	0.68	0.00	0.68	2.50	17.42	19.74	17.42	1.00	96.12	52.31	52.31	8.00	87.40	0.00	0.00	70.40
304.00	8.25	0.69	0.00	0.69	2.75	18.27	22.78	18.27	1.25	107.46	73.10	73.10	8.25	89.20	0.00	0.00	89.20
304.50	8.50	0.70	0.00	0.70	3.00	19.08	25.95	19.08	1.50	117.72	96.10	96.10	8.50	90.90	0.00	0.00	90.90
304.75	8.75	0.71	0.00	0.71	3.25	19.86	29.27	19.86	1.75	127.15	121.09	121.09	8.75	92.60	0.00	0.00	92.60
305.00	9.00	0.72	0.00	0.72	3.50	20.61	32.71	20.61	2.00	135.93	147.95	135.93	9.00	94.30	0.00	0.00	94.30
305.25	9.25	0.73	0.00	0.73	3.75	21.33	36.27	21.33	2.25	144.18	176.54	144.18	9.25	95.90	0.00	0.00	95.90
305.50	9.50	0.74	0.00	0.74	4.00	22.03	39.96	22.03	2.50	151.98	206.76	151.98	9.50	97.40	0.00	0.00	97.40
305.75	9.75	0.75	0.00	0.75	4.25	22.71	43.76	22.71	2.75	159.39	238.54	159.39	9.75	99.00	0.00	0.00	99.00
306.00	10.00	0.76	0.00	0.76	4.50	23.36	47.68	23.36	3.00	166.48	271.80	166.48	10.00	100.40	0.00	0.00	100.40
306.25	10.25	0.77	0.00	0.77	4.75	24.01	51.71	24.01	3.25	173.28	306.47	173.28	10.25	101.90	0.25	6.11	101.90
306.50	10.50	0.78	0.00	0.78	5.00	24.63	55.85	24.63	3.50	179.82	342.50	179.82	10.50	103.40	0.50	18.19	103.40
306.75	10.75	0.79	0.00	0.79	5.25	25.24	60.09	25.24	3.75	186.13	379.85	186.13	10.75	104.80	0.75	35.08	104.80
307.00	11.00	0.80	0.00	0.80	5.50	25.83	64.43	25.83	4.00	192.24	418.46	192.24	11.00	106.20	1.00	56.58	106.20
307.25	11.25	0.81	0.00	0.81	5.75	26.41	68.87	26.41	4.25	198.15	458.30	198.15	11.25	107.60	1.25	82.66	107.60
307.50	11.50	0.81	0.00	0.81	6.00	26.98	73.41	26.98	4.50	203.90	499.32	203.90	11.50	108.90	1.50	113.37	108.90
307.75	11.75	0.82	0.00	0.82	6.25	27.54	78.05	27.54	4.75	209.48	541.51	209.48	11.75	110.30	1.75	148.81	110.30
308.00	12.00	0.83	0.00	0.83	6.50	28.08	82.78	28.08	5.00	214.93	584.82	214.93	12.00	111.60	2.00	189.08	111.60

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Bremo FFCP Facility - Basin 3

Stage-Storage Data

Elevation	Are	a	Incremental	Volume	Cumulative Volume				
(ft)	(sqft)	(acres)	(cuft)	(CY)	(cuft)	(CY)	(ac-ft)		
292.00	77,833.5	1.787	148,208	5,489	601,724	22,286	13.81		
290.00	70,436.5	1.617	133,701	4,952	453,516	16,797	10.41		
288.00	63,327.5	1.454	119,769	4,436	319,815	11,845	7.34		
286.00	56,506.5	1.297	106,413	3,941	200,046	7,409	4.59		
284.00	49,973.5	1.147	93,633	3,468	93,633	3,468	2.15		
282.00	43,728.5	1.004							



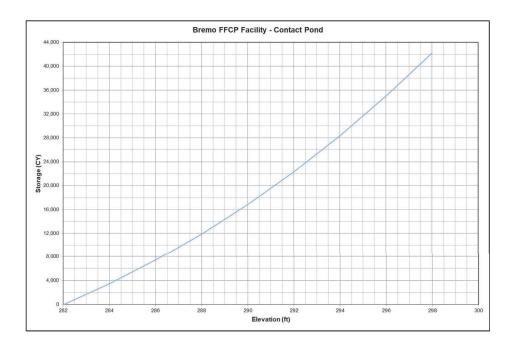
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							FFCP Fa	acility Basin 3	Discharge Ratin	g Table - IN	PUTS						
	Invert (ft):	282			Invert (ft):	285.5		-	Invert (ft):	287			Invert (ft):	282	Invert (ft):	290	NOTE: OUTFLOW
	Diameter (in)	3			Length (ft):	1	1		Diameter (in	48			Outlet (ft)		B. Width (ft):	15	CALCULATIONS DOES
	Diameter (ft)	0.250			Height (ft):		1		Diameter (ft				Diameter (in):		Top Width (ft):		NOT INCLUDE
	Co	0.61	1		Co		RECTANG	ULAR 12" X 18"	Co				Length (ft)		Side Slope (ft/ft)		EMERGENCY SPILLWAY
	Orifice Area (ft ²)	0.0491	3" CIRCUL	AR ORIFICE	Cw		-	NOTCH	Cv		48" F	liser					FLOW
	Cw	3.33	-		Orifice Area (ft ²)	1.5	'	NOTCH	Orifice/Weir Area (ft ²	12.57			CALCULATED				(Modeled as Separate
	CW	3.33			Office Area (IL)	1.5	1		Weir Perimeter (ft				CULVERT SPREA	ADSHEET	Trapezoidal	Spillway	Aux. Spillway in
			-				-		Well Fellilletel (It	12.37					1		HEC-HMS)
Water Elevation		Discha	arge 1	I		Discharg		1		Ri	ser	I	Barrel		E. Spillv		Outflow
(6)	Head	Flow (Orifice)	Flow (Weir)	Controlling Flow	Head			Controlling Flow	Head	Flow (Orifice)	Flow (Weir)	Controlling Flow	Head	Flow	Head	Flow	(-6-)
(ft)	(ft)	(cfs)	(cfs)	(cfs)	(ft)	(cfs)	(cfs)	(cfs)	(ft)	(cfs)	(cfs)	(cfs)	(ft)	(cfs)	(ft)	(cfs)	(cfs)
282.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
282.25	0.25	0.12	0.00	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.30	0.00	0.00	0.12
282.50	0.50	0.17	0.00	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50	1.30	0.00	0.00	0.17
282.75	0.75	0.21	0.00	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.75	2.70	0.00	0.00	0.21
283.00	1.00	0.24	0.00	0.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	4.60	0.00	0.00	0.24
283.25	1.25	0.27	0.00	0.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.25	6.30	0.00	0.00	0.27
283.50	1.50	0.29	0.00	0.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.50	8.40	0.00	0.00	0.29
283.75	1.75	0.32	0.00	0.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.75 2.00	10.70	0.00	0.00	0.32
284.00	2.00		0.00	0.34			0.00	0.00			0.00	0.00		13.00	0.00	0.00	0.34
284.25	2.25	0.36	0.00	0.36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.25	15.20	0.00	0.00	0.36
284.50	2.50	0.38	0.00	0.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.50	17.20	0.00	0.00	0.38
284.75	2.75	0.40	0.00	0.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.75	19.00	0.00	0.00	0.40
285.00	3.00	0.42	0.00	0.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.00	20.60	0.00	0.00	0.42
285.25	3.25	0.43	0.00	0.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.25 3.50	22.10	0.00	0.00	0.43
285.50	3.50	0.45	0.00	0.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		23.40	0.00	0.00	0.45
285.75	3.75	0.47	0.00	0.47	0.25	3.67	0.42	0.42	0.00	0.00	0.00	0.00	3.75	24.70	0.00	0.00	0.88
286.00	4.00 4.25	0.48	0.00	0.48	0.50	5.19 6.36	1.18	1.18	0.00	0.00	0.00	0.00	4.00	26.00	0.00	0.00	1.66
286.25			0.00	0.50	0.75		2.16	2.16	0.00	0.00	0.00	0.00	4.25	27.10	0.00	0.00	2.66
286.50	4.50	0.51	0.00	0.51	1.00	7.34	3.33	3.33	0.00	0.00	0.00	0.00	4.50	28.20	0.00	0.00	3.84
286.75	4.75	0.52	0.00	0.52	1.25	8.21	4.65	4.65	0.00	0.00	0.00	0.00	4.75	29.30	0.00	0.00	5.18
287.00	5.00	0.54	0.00	0.54	1.50	8.99	6.12	8.99	0.00	0.00	0.00	0.00	5.00	30.30	0.00	0.00	9.53
287.25	5.25	0.55	0.00	0.55	1.75	9.71	7.71	9.71	0.25	30.76	5.23	5.23	5.25	31.30	0.00	0.00	15.49
287.50	5.50 5.75	0.56 0.58	0.00	0.56	2.00	10.38	9.42	10.38	0.50 0.75	43.50 53.27	14.79 27.18	14.79 27.18	5.50	32.30	0.00	0.00	25.74 33.20
287.75				0.58	2.25	11.01	11.24	11.01					5.75	33.20	0.00	0.00	
288.00	6.00	0.59	0.00	0.59	2.50	11.61	13.16	11.61	1.00	61.52	41.85	41.85	6.00	34.20	0.00	0.00	34.20
288.25 288.50	6.25 6.50	0.60	0.00	0.60	2.75 3.00	12.18 12.72	15.19 17.30	12.18	1.25 1.50	68.78 75.34	58.48	58.48 75.34	6.25 6.50	35.10	0.00	0.00	35.10 35.90
288.75	6.75	0.61	0.00	0.61	3.00	12.72		12.72 13.24	1.50	75.34 81.38	76.88 96.87	75.34 81.38	6.50	35.90 36.70	0.00	0.00	35.90 36.70
288.75	7.00	0.62	0.00	0.62	3.25	13.24	19.51 21.80	13.24	2.00	81.38	118.36	81.38 87.00	7.00	36.70	0.00	0.00	36.70
289.00	7.00	0.64	0.00		3.50	13.74	21.80	13.74	2.00	92.27	118.36	92.27	7.00	38.30	0.00	0.00	37.50
289.25	7.25	0.65	0.00	0.65	4.00	14.22	26.64	14.22	2.25	92.27	141.23	97.26	7.25	39.00	0.00	0.00	38.30
289.50	7.50	0.66	0.00	0.66	4.00	14.69	26.64		2.50	102.01	165.41	102.01	7.50	39.00	0.00		39.00
289.75	7.75 8.00	0.67	0.00	0.67		15.14	29.18 31.79	15.14			190.83	102.01	8.00	40.50		0.00	39.80 40.50
290.00	8.00	0.68	0.00	0.68	4.50 4.75	15.58	31.79	15.58 16.00	3.00 3.25	106.55 110.90	217.44	106.55	8.00	40.50	0.00 0.25	0.00 6.11	40.50
290.25	8.50	0.69	0.00	0.69	5.00	16.42	37.23	16.42	3.50	110.90	274.00	115.08	8.25	41.20	0.50	18.19	41.20
290.50	8.50	0.70	0.00	0.70	5.00	16.42	40.06	16.82	3.50	115.08	303.88	115.08	8.75	42.60	0.50	35.08	41.90
															1		
291.00 291.25	9.00 9.25	0.72	0.00	0.72	5.50 5.75	17.22 17.61	42.95 45.91	17.22 17.61	4.00 4.25	123.03 126.82	334.77 366.64	123.03 126.82	9.00 9.25	43.30 44.00	1.00 1.25	56.58 82.66	43.30 44.00
291.25	9.50	0.73	0.00	0.73	6.00	17.61	48.94	17.99	4.50	130.49	399.46	130.49	9.25	44.60	1.50	113.37	44.60
291.50	9.50	0.74	0.00	0.74	6.25	17.99	52.03	18.36	4.50	130.49	433.21	130.49	9.50	45.30	1.75	148.81	45.30
291.75	10.00	0.75	0.00	0.75	6.25	18.36	52.03	18.36	4.75 5.00	134.07	433.21 467.85	134.07	9.75	45.30	2.00	148.81	45.30 45.90
292.00	10.00	U./b	0.00	U./b	b.5U	18.72	22.18	18.72	5.00	137.55	467.85	137.55	10.00	45.90	2.00	189.08	45.90

Attachment 09 - Pond Stage Storage
and Discharge Rating Curves

Bremo FFCP Facility - Contact Pond Stage-Storage Data

Elevation	Area	1	Increme Volun		Cumulative Volume				
(ft)	(sqft)	(acres)	(cuft)	(CY)	(cuft)	(CY)	(ac-ft)		
298.00	101,752.8	2.336	195,182	7,229	1,139,145	42,191	26.15		
296.00	93,487.6	2.146	178,947	6,628	943,963	34,962	21.67		
294.00	85,518.6	1.963	163,292	6,048	765,016	28,334	17.56		
292.00	77,833.5	1.787	148,208	5,489	601,724	22,286	13.81		
290.00	70,436.5	1.617	133,701	4,952	453,516	16,797	10.41		
288.00	63,327.5	1.454	119,769	4,436	319,815	11,845	7.34		
286.00	56,506.5	1.297	106,413	3,941	200,046	7,409	4.59		
284.00	49,973.5	1.147	93,633	3,468	93,633	3,468	2.15		
282.00	43,728.5	1.004							



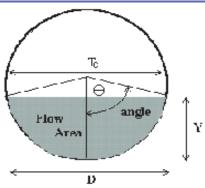
Page 7 of 7

Stormwater Analysis Attachment 10 Contact Stormwater Pipes



CIRCULAR CONDUIT FLOW (Normal & Critical Depth Computation)

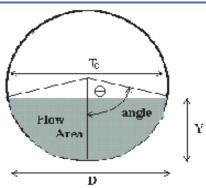
Project: Bremo FFCP - Part B
Pipe ID: Contact Stormwater Piping @ 1.5%



Design Information (Input)	_		_
Pipe Invert Slope	So =	0.0150	ft/ft
Pipe Manning's n-value	n =	0.0130	
Pipe Diameter	D =	36.00	inches
Design discharge	Q =	81.91	cfs
Full-flow Capacity (Calculated)			
Full-flow area	Af =	7.07	sq ft
Full-flow wetted perimeter	Pf =	9.42	ft
Half Central Angle	Theta =	3.14	radians
Full-flow capacity	Qf =	81.91	cfs
Calculation of Normal Flow Condition			
Half Central Angle (0 <theta<3.14)< td=""><td>Theta =</td><td>2.26</td><td>radians</td></theta<3.14)<>	Theta =	2.26	radians
Flow area	An =	6.20	sq ft
Top width	Tn =	2.31	ft
Wetted perimeter	Pn =	6.79	ft
Flow depth	Yn =	2.46	ft
Flow velocity	Vn =	13.21	fps
Discharge	Qn =	81.91	cfs
Percent Full Flow	Flow =	100.0%	of full flow
Normal Depth Froude Number	Fr _n =	1.42	supercritical
Calculation of Critical Flow Condition			
Half Central Angle (0 <theta-c<3.14)< td=""><td>Theta-c =</td><td>2.60</td><td>radians</td></theta-c<3.14)<>	Theta-c =	2.60	radians
Critical flow area	Ac =	6.85	sq ft
Critical top width	Tc =	1.54	ft
Critical flow depth	Yc =	2.79	ft
Critical flow velocity	Vc =	11.96	fps
Critical Depth Froude Number	Fr _c =	1.00	7

CIRCULAR CONDUIT FLOW (Normal & Critical Depth Computation)

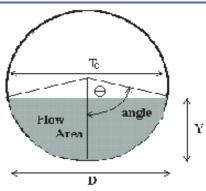
Project: Bremo FFCP - Part B
Pipe ID: Contact Slope Drain @ 5.0%



So = n = D = Q = Af =	0.0500 0.0130 24.00 50.72	ft/ft inches cfs
n = D = Q = Af =	0.0130 24.00 50.72	inches
D = Q = Af =	24.00 50.72	
Q =	50.72	
Af =		cfs
	2.44	
	0.44	
	3.14	sq ft
Pf =	6.28	ft
Theta =	3.14	radians
Qf =	50.72	cfs
Theta =	2.26	radians
An =	2.76	sq ft
Tn =	1.54	ft
Pn =	4.53	ft
Yn =	1.64	ft
Vn =	18.40	fps
Qn =	50.72	cfs
Flow =	100.0%	of full flow
Fr _n =	2.42	supercritical
Theta-c =	2.95	radians
Ac =	3.14	sq ft
Tc =	0.39	ft
Yc =	1.98	ft
Vc =	16.17	fps
Fr _c =	1.00	_
_	Theta = Qf = Theta = Qf = Theta = An = Tn = Yn = Yn = Yn = Yn = Theta = Fr _n = Theta-c = Ac = Tc = Yc = Yc = Vc = Yc = Yc = Yc = Yc = Y	Pf = 6.28 Theta = 3.14 Qf = 50.72 Theta = 2.26 An = 2.76 Tn = 1.54 Pn = 4.53 Yn = 1.64 Vn = 18.40 Qn = 50.72 Flow = 100.0% Fr _n = 2.42 Theta-c = 2.95 Ac = 3.14 Tc = 0.39 Yc = 1.98 Vc = 16.17

CIRCULAR CONDUIT FLOW (Normal & Critical Depth Computation)

Project: Bremo FFCP - Part B
Pipe ID: Contact Slope Drain @ 33.3%



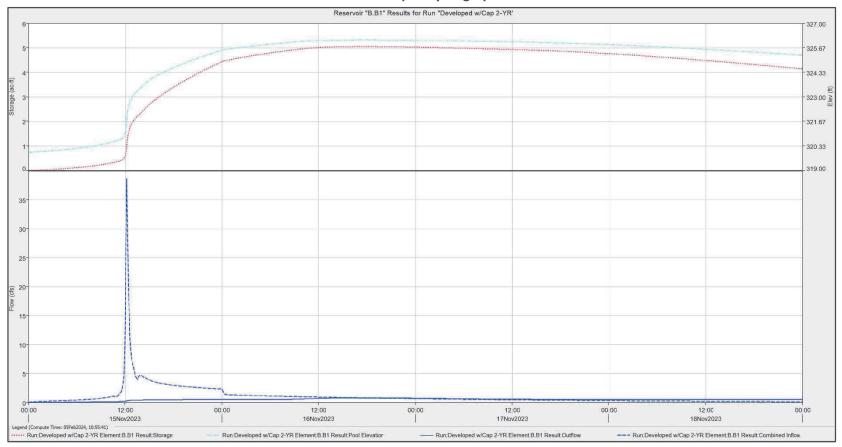
Design Information (Input)	_		_
Pipe Invert Slope	So =	0.3333	ft/ft
Pipe Manning's n-value	n =	0.0130	
Pipe Diameter	D =	24.00	inches
Design discharge	Q =	130.96	cfs
Full-flow Capacity (Calculated)	_		
Full-flow area	Af =	3.14	sq ft
Full-flow wetted perimeter	Pf =	6.28	ft
Half Central Angle	Theta =	3.14	radians
Full-flow capacity	Qf =	130.96	cfs
Calculation of Normal Flow Condition	_		_
Half Central Angle (0 <theta<3.14)< td=""><td>Theta =</td><td>2.26</td><td>radians</td></theta<3.14)<>	Theta =	2.26	radians
Flow area	An =	2.76	sq ft
Top width	Tn =	1.54	ft
Wetted perimeter	Pn =	4.53	ft
Flow depth	Yn =	1.64	ft
Flow velocity	Vn =	47.52	fps
Discharge	Qn =	130.96	cfs
Percent Full Flow	Flow =	100.0%	of full flow
Normal Depth Froude Number	Fr _n =	6.26	supercritical
Calculation of Critical Flow Condition	_		_
Half Central Angle (0 <theta-c<3.14)< td=""><td>Theta-c =</td><td>3.11</td><td>radians</td></theta-c<3.14)<>	Theta-c =	3.11	radians
Critical flow area	Ac =	3.14	sq ft
Critical top width	Tc =	0.06	ft
Critical flow depth	Yc =	2.00	ft
Critical flow velocity	Vc =	41.69	fps
Critical Depth Froude Number	Fr _c =	1.00	

Stormwater Analysis Attachment 11

Basin Hydrographs

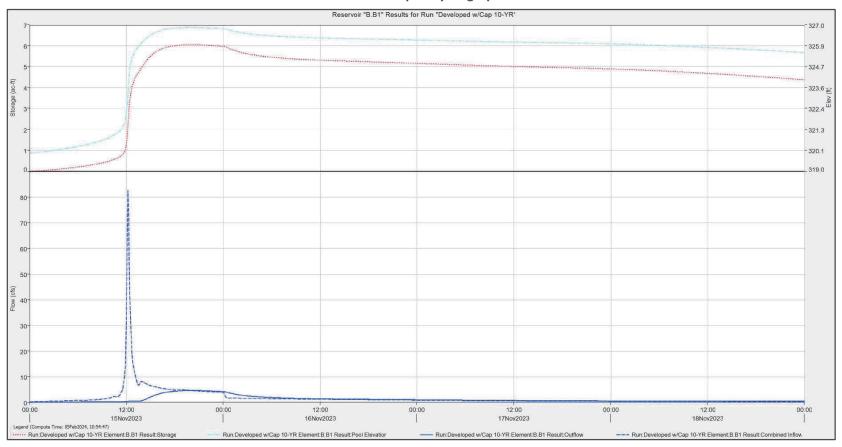


FFCP Facility Basin 1
2-YR Output Hydrograph



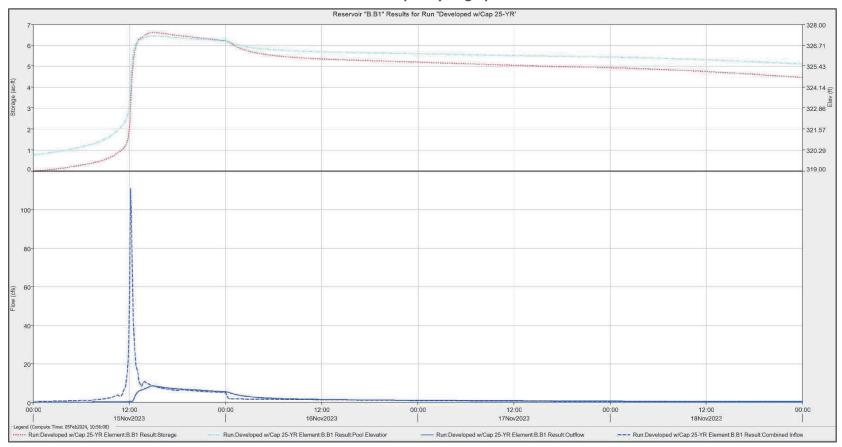
Attachment 11 - Basin Hydrographs Page 1 of 14

FFCP Facility Basin 1 10-YR Output Hydrograph



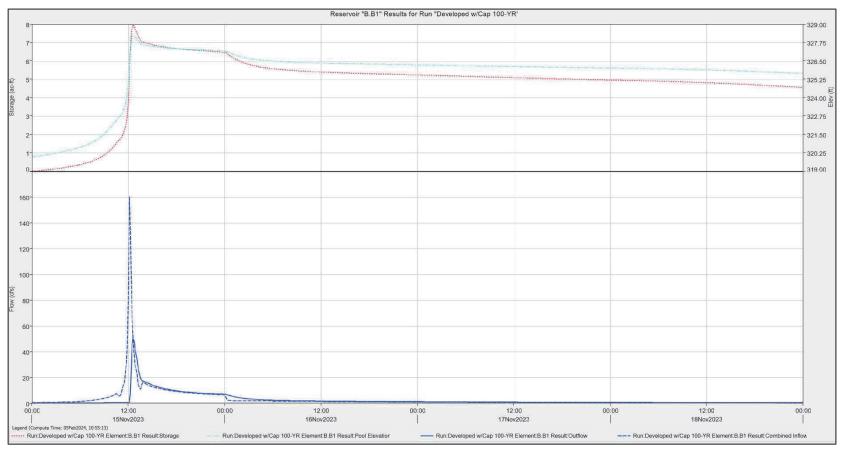
Attachment 11 - Basin Hydrographs Page 2 of 14

FFCP Facility Basin 1 25-YR Output Hydrograph



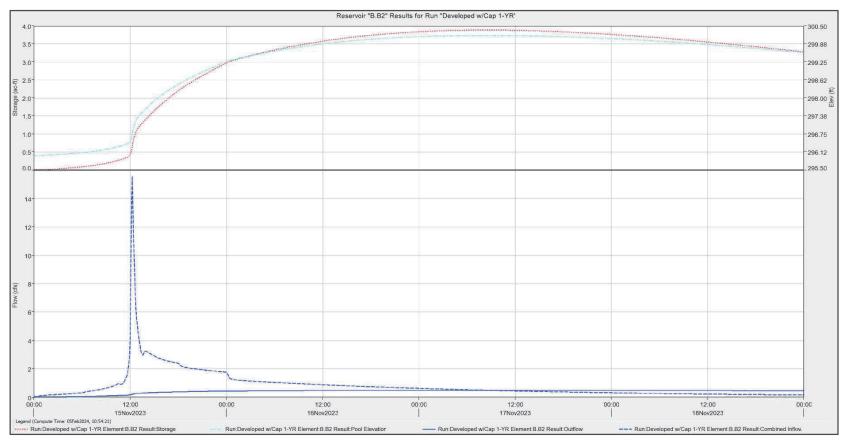
Attachment 11 - Basin Hydrographs Page 3 of 14

FFCP Facility Basin 1 100-YR Output Hydrograph



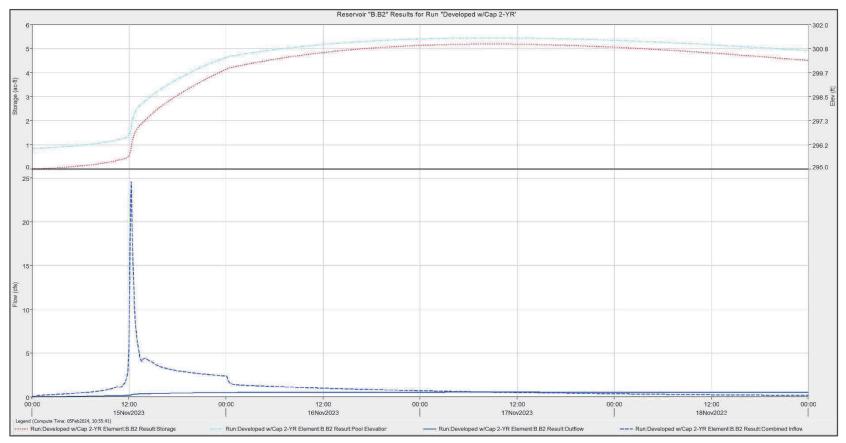
Page 4 of 14

FFCP Facility Basin 2
1-YR Output Hydrograph

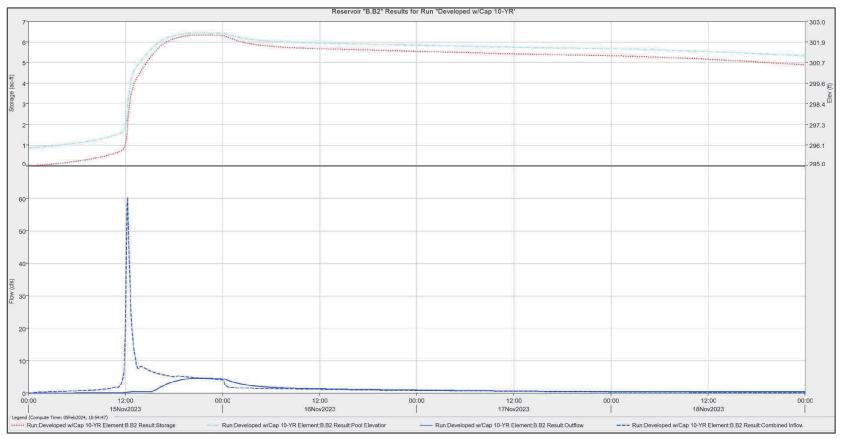


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FFCP Facility Basin 2 2-YR Output Hydrograph

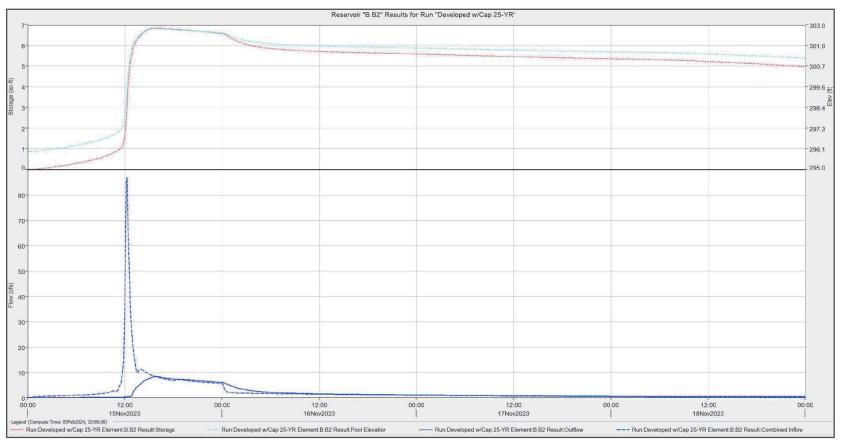


FFCP Facility Basin 2 10-YR Output Hydrograph



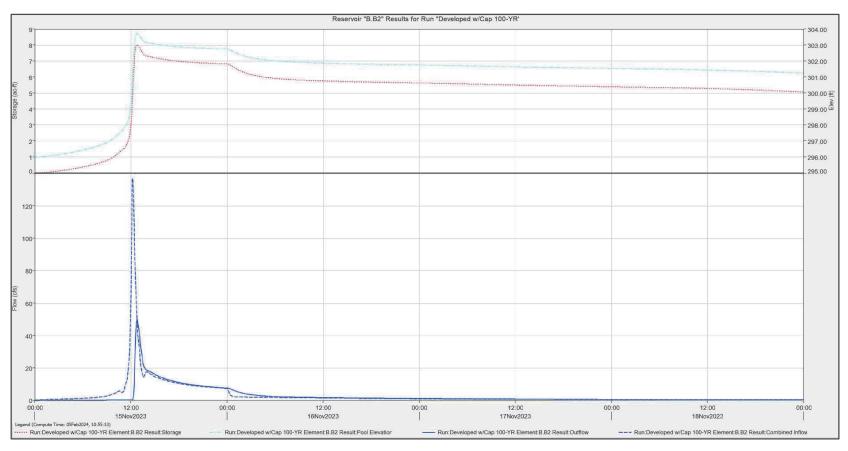
Attachment 11 - Basin Hydrographs Page 7 of 14

FFCP Facility Basin 2 25-YR Output Hydrograph

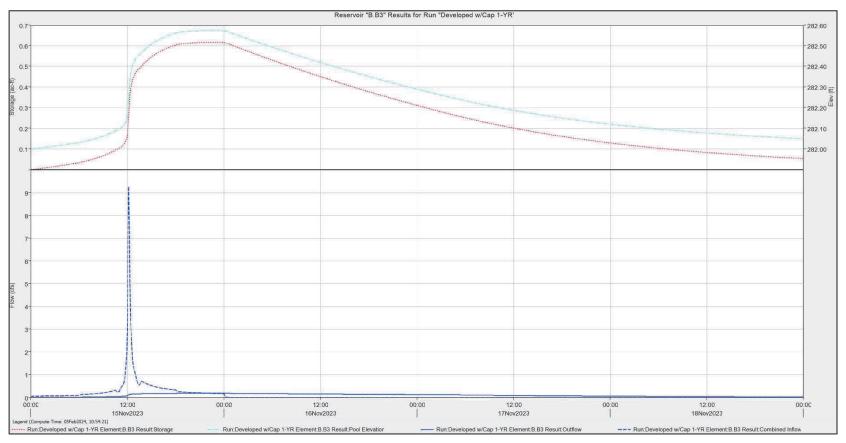


Attachment 11 - Basin Hydrographs Page 8 of 14

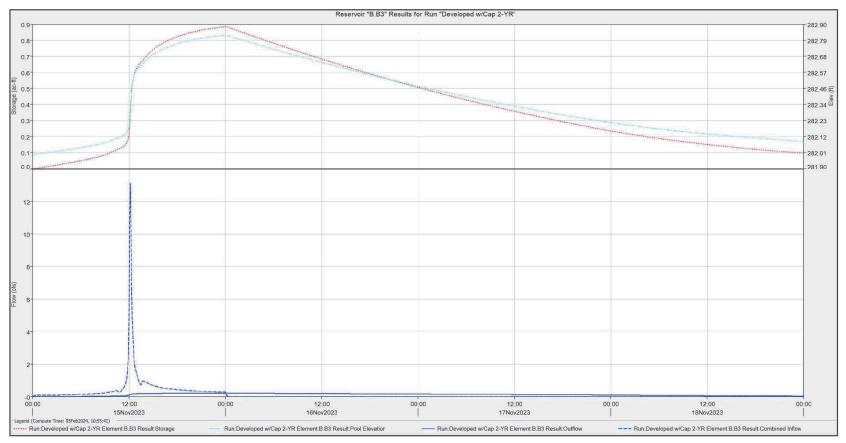
FFCP Facility Basin 2 100-YR Output Hydrograph



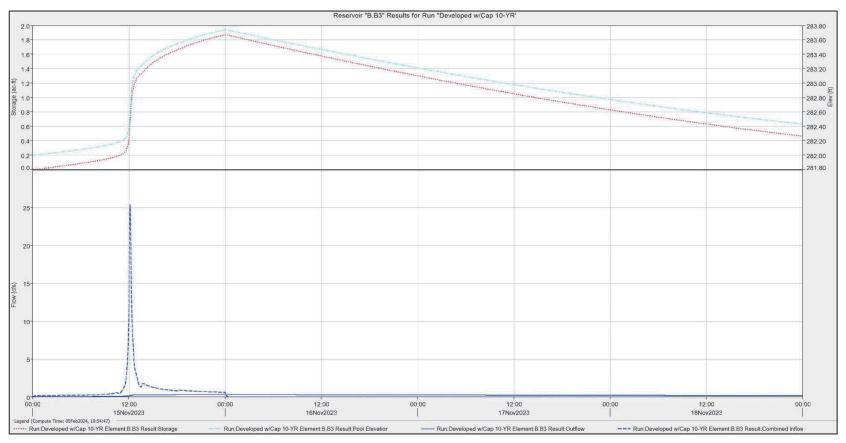
FFCP Facility Basin 3
1-YR Output Hydrograph



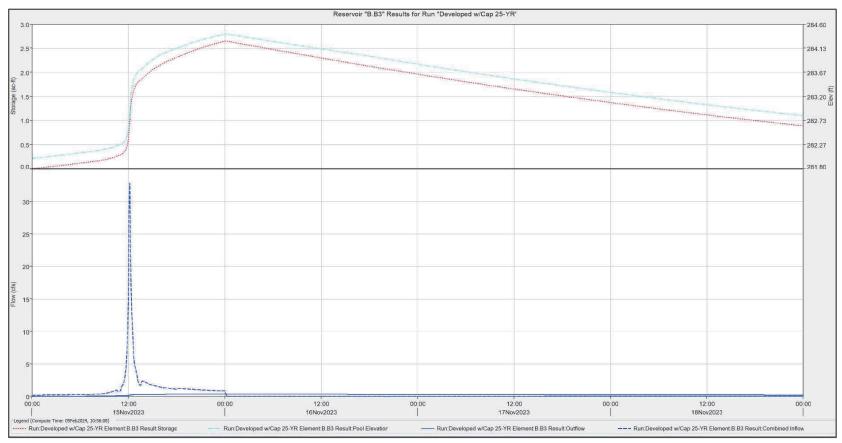
FFCP Facility Basin 3
2-YR Output Hydrograph



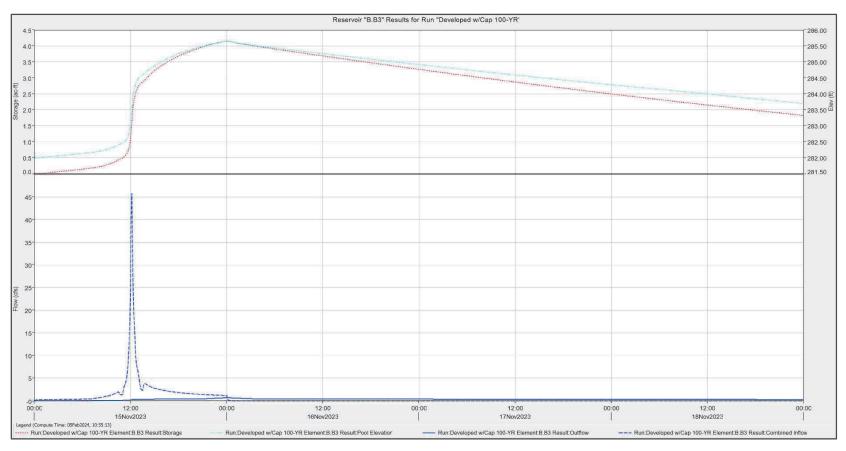
FFCP Facility Basin 3 10-YR Output Hydrograph



FFCP Facility Basin 3 25-YR Output Hydrograph

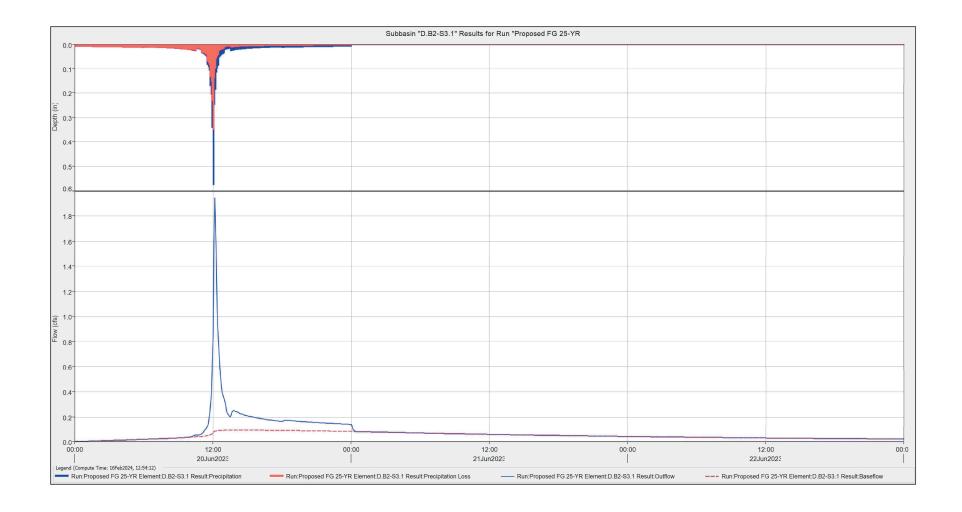


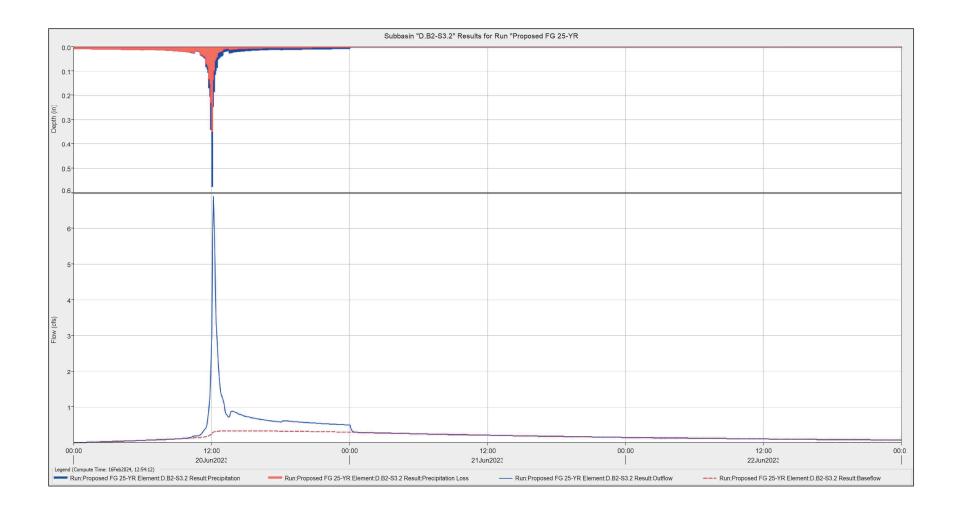
FFCP Facility Basin 3 100-YR Output Hydrograph

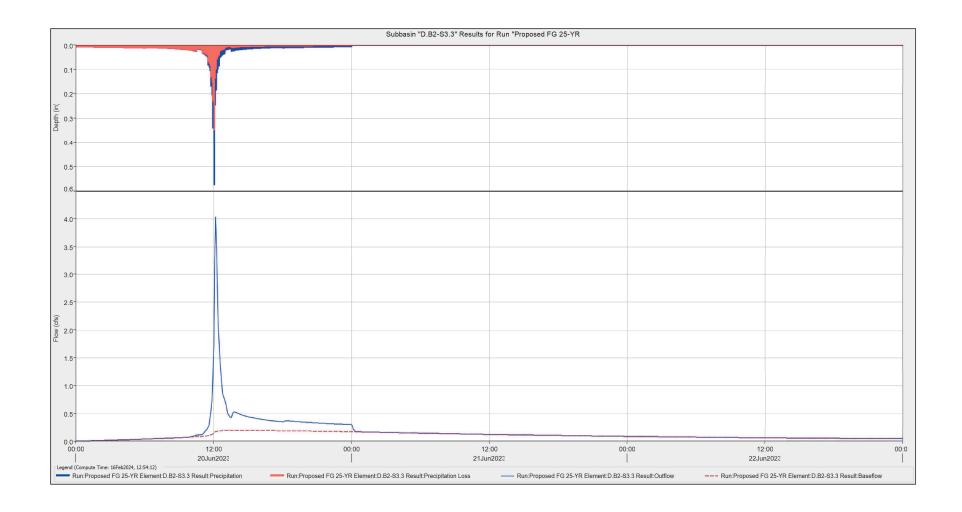


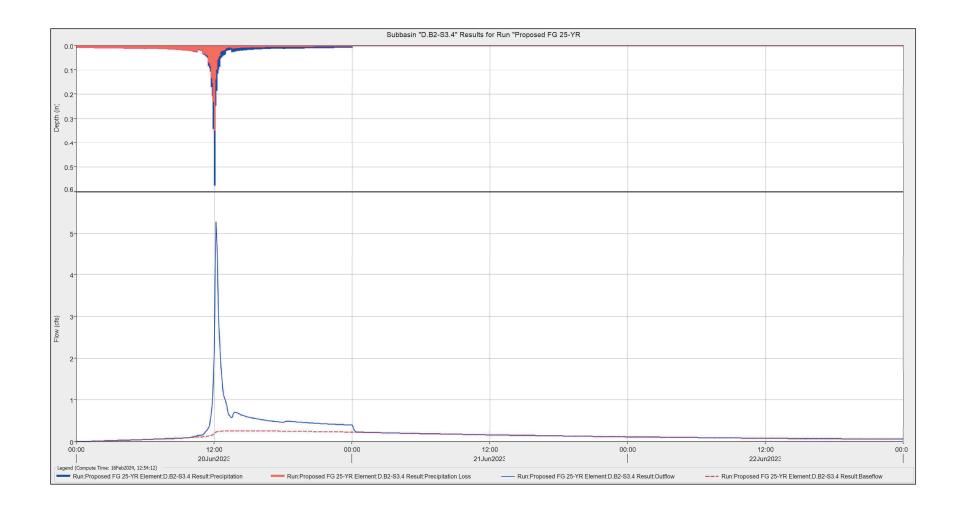
Stormwater Analysis Attachment 12 Final Cover Area Subbasin Hydrographs

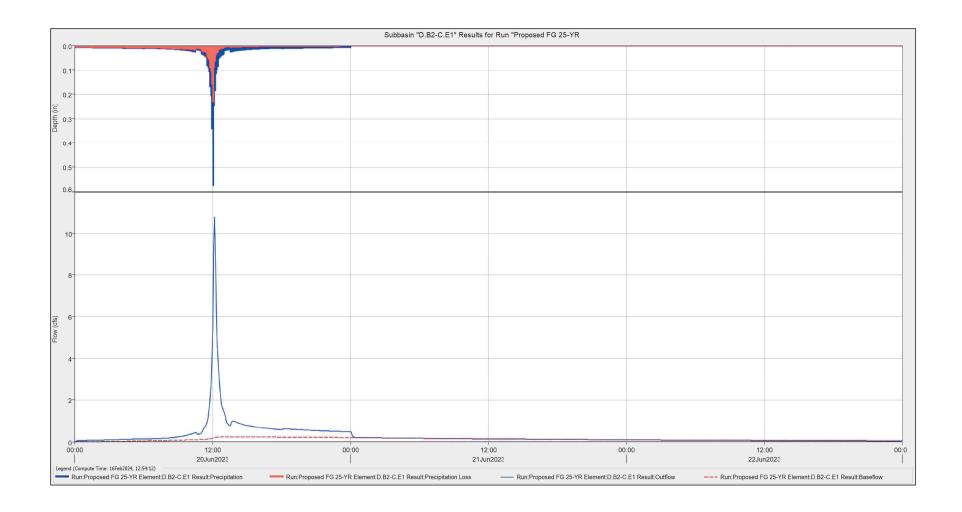


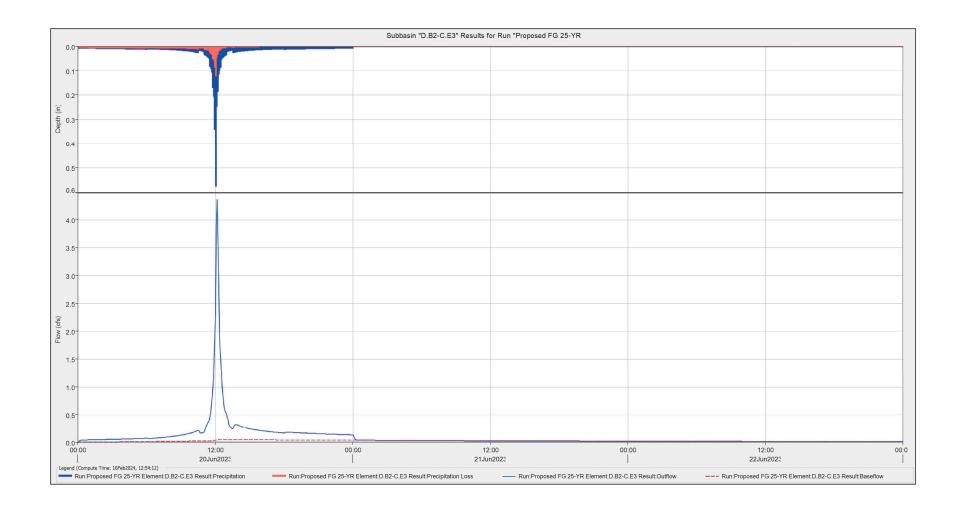


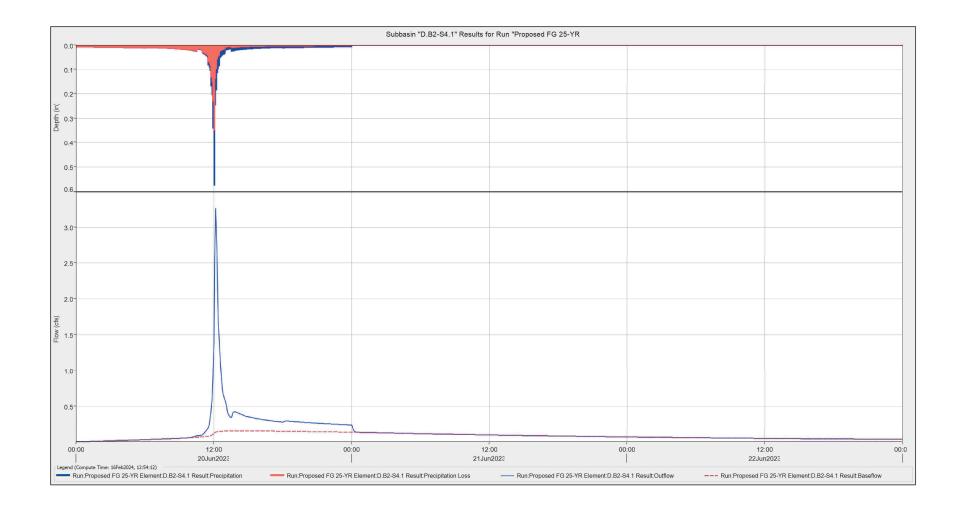


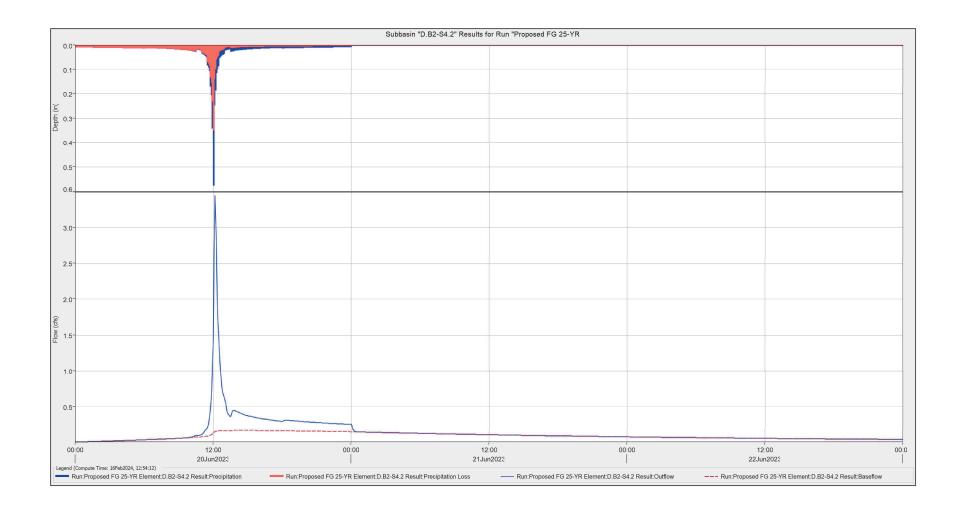


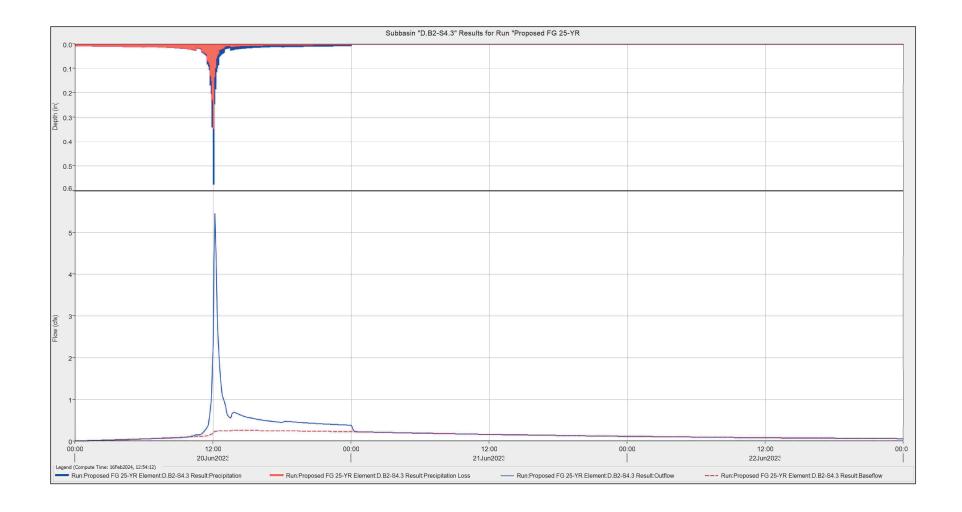


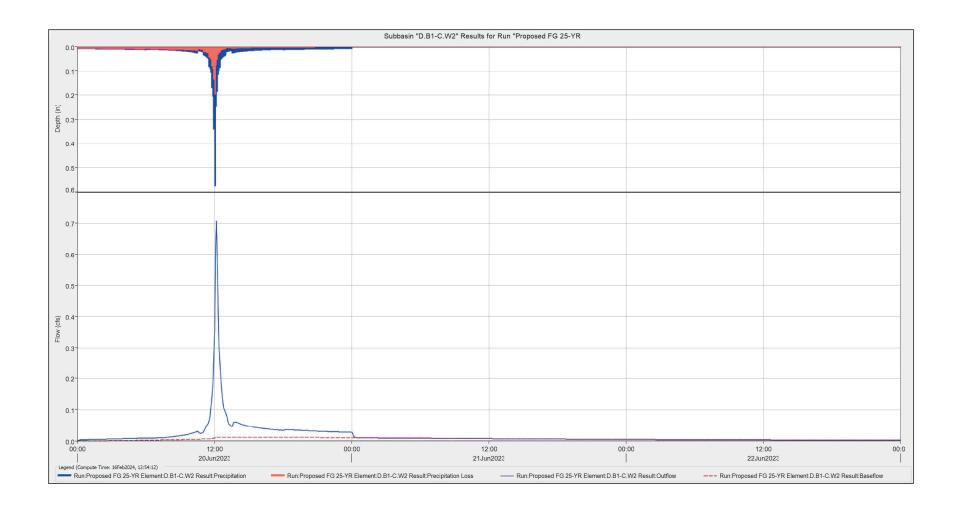








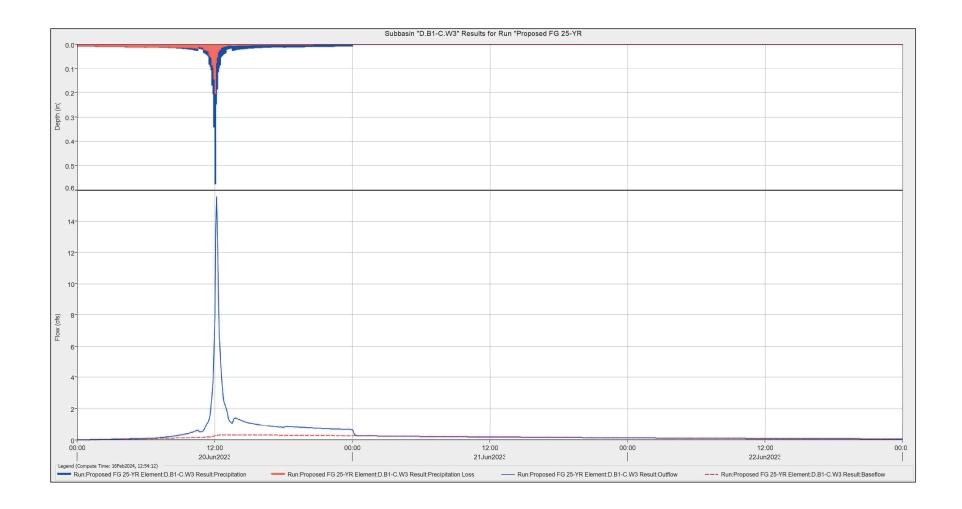




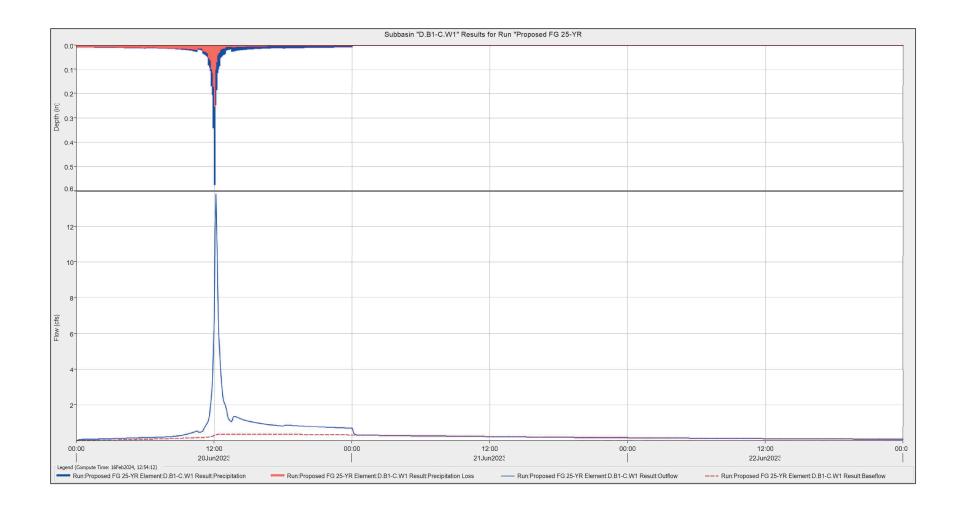
Attachment 12 - Final Cover

Subbasin Hydrographs

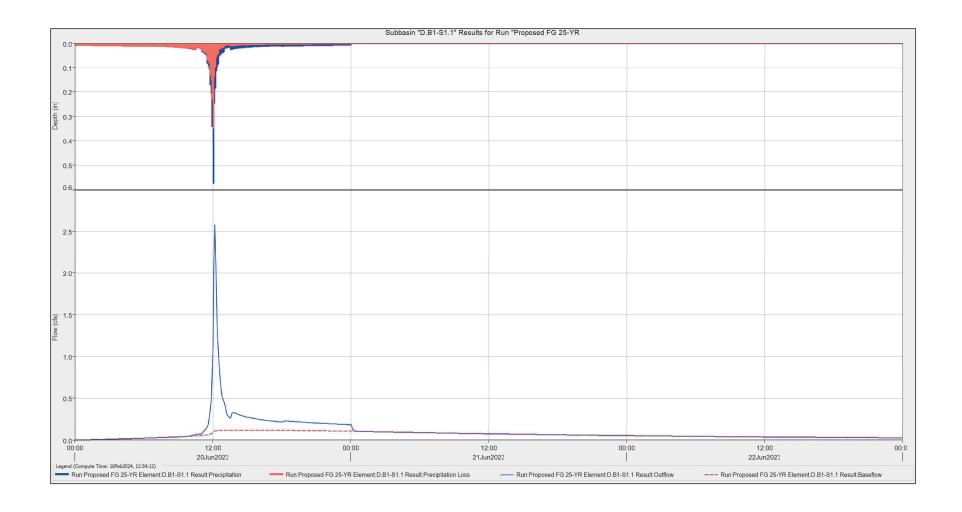
Page 10 of 19



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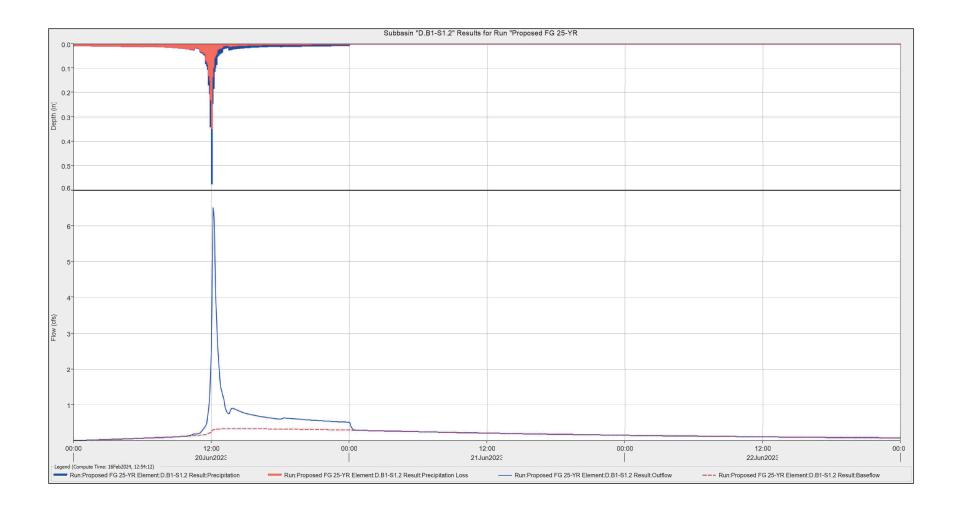
Attachment 12 - Final Cover



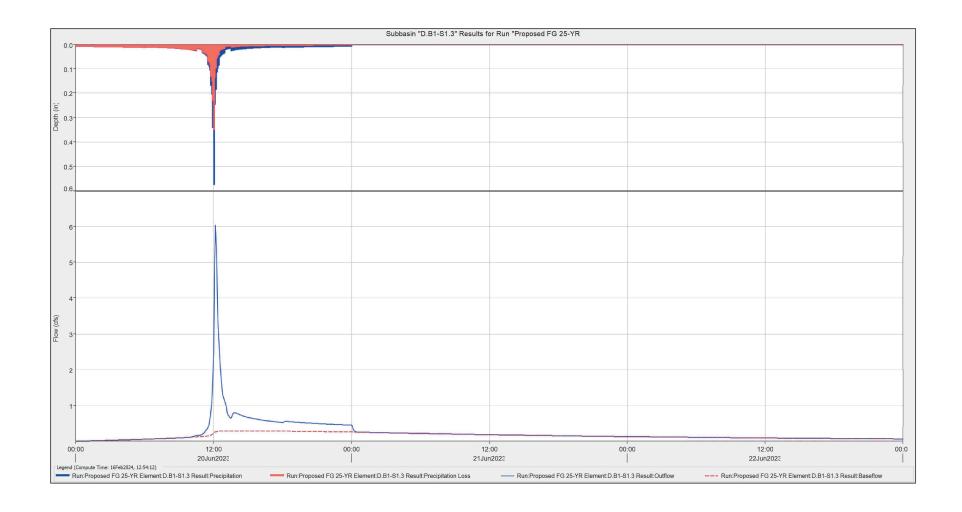
Attachment 12 - Final Cover

Subbasin Hydrographs

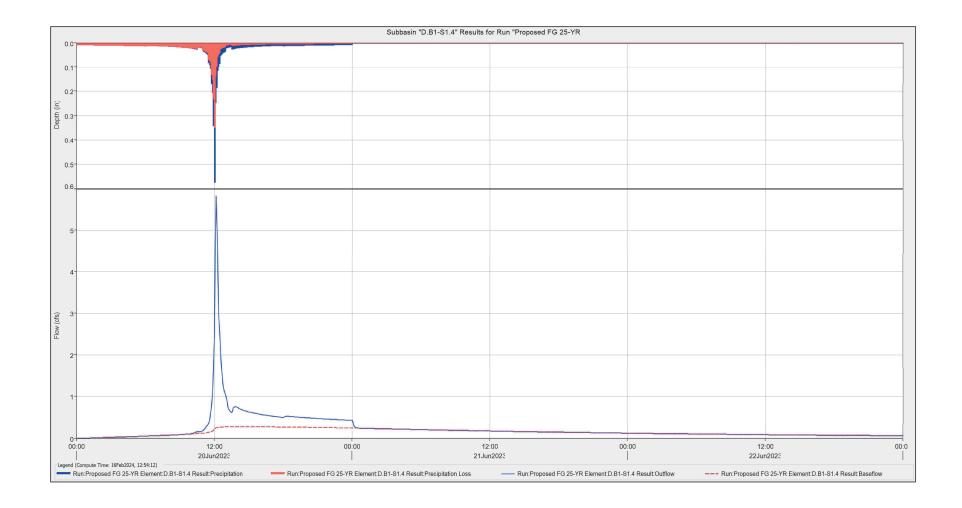
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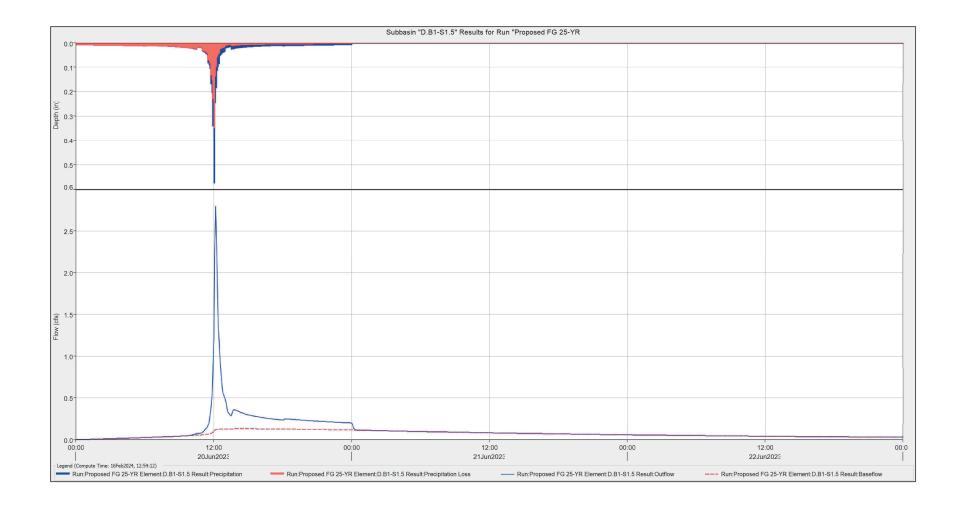


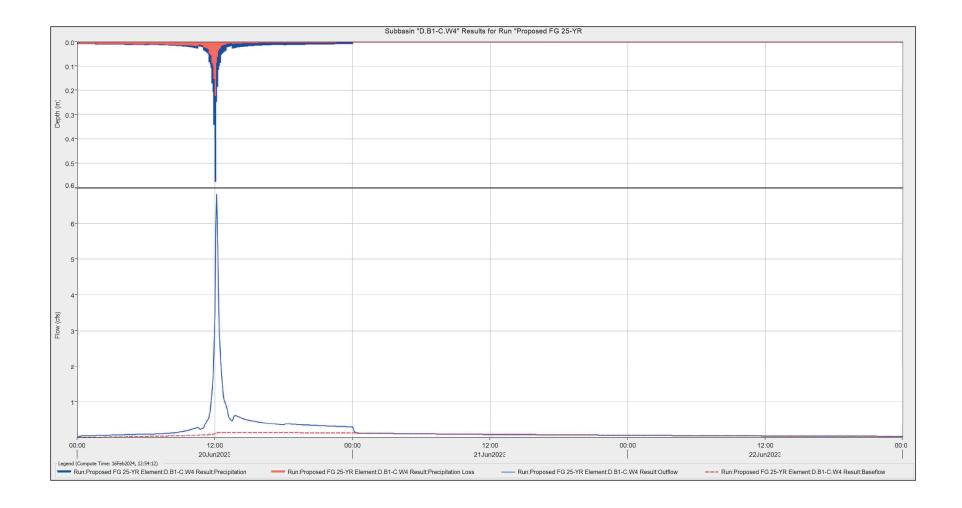
Attachment 12 - Final Cover

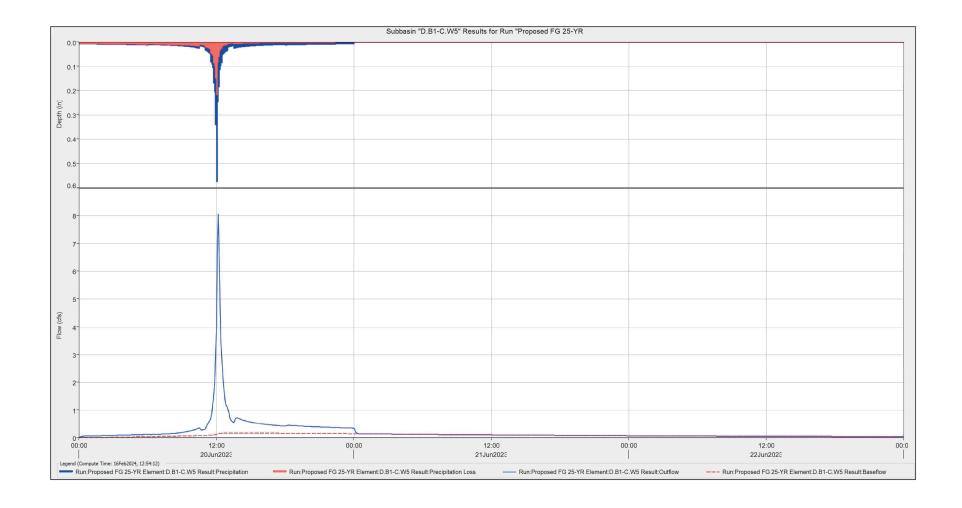


Attachment 12 - Final Cover









ATTACHMENT 8 UNDERDRAIN PIPE CALCULATIONS

Pipe Capacity Pipe Strength





Calculations					
PROJECT: Bremo Bluff FFCP Management Facility	REFERENCE NO: 22130437.031				
SUBJECT: Underdrain Pipe Capacity	DATE : 02/01/2024				

1.0 OBJECTIVE

The objective of this analysis is to confirm the proposed underdrain piping has the capacity to convey anticipated emergent groundwater flows below the proposed Coal Combustion Residuals (CCR) Unit at the Bremo Bluff Fossil Fuel Combustion Products (FFCP) Management Facility (Facility).

2.0 METHODOLOGY

Manning's equation was used to determine the capacity of the underdrain pipe. A Manning's coefficient of 0.011 was used.

$$Q = \frac{1.49}{n} A R^{\frac{2}{3}} S^{\frac{1}{2}}$$

Where:

Q = Flow Rate [cubic feet per second, (cfs)]

n = Manning's Roughness Coefficient

A = Cross-Sectional Flow Area [square feet (sf)]

R = Hydraulic Radius [feet (ft)]

S = Longitudinal Slope (ft/ft)

Due to the nature of the subgrade below the underdrain, settlement is anticipated to have a negligible effect on underdrain slopes; therefore, the underdrain piping was evaluated at the minimum design slope, i.e. 1.5%.

3.0 ASSUMPTIONS

The anticipated flow to the underdrain pipe was previously determined in field investigations by others to be a maximum of 1 cubic foot per second (cfs). Detailed information and calculations are included in the Part A Permit Application (by others).

The collection pipe has a 12-inch diameter nominal pipe size. Per the JM Eagle high-density polyethylene (HDPE) pipe catalog (JM Eagle, 2018), standard dimension ratio (SDR) 11 pipe with a 12-inch nominal size has an inside diameter of 10.29 inches.

4.0 ANALYSIS

The underdrain pipe conveys flow from underneath the CCR Unit at an anticipated peak flowrate of 1 cfs. This peak flow was used to verify capacity. The maximum estimated flow depth during peak flow is 4.33 inches in the underdrain pipe. The design parameters and results are summarized in the table below.

Table 1: Flowrate Summary

Collection Pipe	Slope (%)	Pipe Capacity (cfs)	Peak Flowrate (cfs)	Peak Flow Depth (inch)
12-inch Perforated HDPE	1.5	6.3	1.0	4.33

Design Report Underdrain Pipe Capacity

7.0 CONCLUSION

The proposed underdrain pipe has the capacity to convey the anticipated maximum flowrate.

Attachments:

(1) Underdrain Pipe Capacity Calculation Spreadsheet

References:

(1) JM Eagle (2018). HDPE Water/Sewer IPS. June 2018.

Underdrain Pipe Capacity Attachment 1
Underdrain Pipe Capacity Calculation Spreadsheet



CALCULATIONS

Date: 02/01/2024Made by:E. RudasillProject No.: 22130437.031Checked by:S. McHenrySubject: Underdrain Pipe CapacityReviewed by:R. DiFrancesco

Project Title: Bremo Bluff FFCP Management Facility

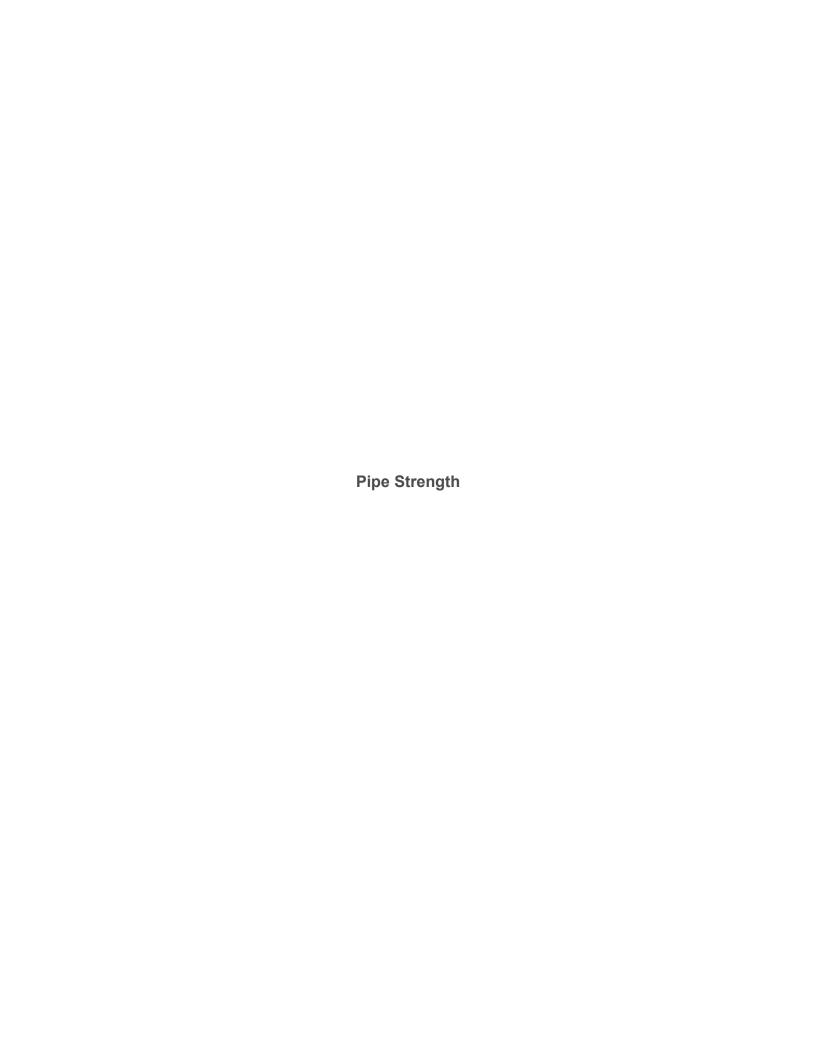
Methodology: Use Manning's Equation for uniform channel flow to determine pipe capacity.

Table 1: Pipe Dimensions						
Input	Value	Unit	Notes:			
Inside Diameter, D	10.29	in				
	0.858	ft				
Radius, r	0.429	ft	r = D/12			
Longitudinal Slope, S	0.0150	ft/ft				

Table 2: Flow Depth				
Input	Value	Unit	Notes:	
Flow Depth, y	4.326	in		
	0.360	ft		
Θ:	2.821	821 rads	More than 1/2 full flow: $\theta = 2 \arccos(\frac{r - (2r - y)}{r})$	
6.			Less than 1/2 full flow: $\theta = 2 \arccos(\frac{r-y}{r})$	

Table 3: Manning's Equation					
Input	Value	Unit	Notes:		
Manning's Roughness Coefficient, n _{full}	0.011				
Cross Sectional Flow Area, A	0.230	sf	More than 1/2 full flow: $A=\pi r^2-rac{r^2(\theta-sin\theta)}{2}$		
	0.200	01	Less than 1/2 full flow: $A = \frac{r^2(\theta - \sin \theta)}{2}$		
Watted Derimeter D	1.210	ft	More than 1/2 full flow: $A=2\pi r\ -r\theta$		
Wetted Perimeter, P	1.210	i il	Less than 1/2 full flow: $A = r\theta$		
Hydraulic Radius, R	0.190	ft	R = A/P		
Variable Manning's Roughness Coefficient; n	0.014		Function of $\frac{y}{D}$		

Table 4: Results					
Input	Value	Unit	Notes:		
Flow Rate, Q	1.0000	CFS	$Q = \frac{1.49}{n} A R^{2/3} S^{1/2}$		
Velocity, V	4.3386	ft/s	V = Q/A		





Calculations					
PROJECT: Bremo Bluff FFCP Management Facility	REFERENCE NO: 22130437.031				
SUBJECT: Underdrain Pipe Strength	DATE : 02/01/2024				

1.0 OBJECTIVE

The objective of this analysis is to confirm the proposed underdrain piping satisfies the design limits for compressive ring thrust, ring deflection, and wall buckling for the overburden pressure caused by the proposed Coal Combustion Residuals (CCR) Unit at the Bremo Bluff Fossil Fuel Combustion Products (FFCP) Management Facility (Facility).

2.0 METHODOLOGY

The methodology presented in the Plastic Pipe Institute Handbook for Polyethylene Pipe (Plastic Pipe Institute, 2008) was used to calculate the compressive ring thrust, ring deflection, and wall buckling. Pipe strength is calculated with the maximum estimated CCR waste thickness, *i.e.*, maximum overburden pressure, for the perforated and solid wall underdrain pipes. Solid wall pipes have been evaluated separately from perforated underdrain pipes due to the differences in pipe bedding and overburden pressure.

3.0 ASSUMPTIONS

Pipe strength calculations were based on the following assumptions and input parameters:

- Base grade and final grade elevations were based on the grading in Attachment III of this Part B Permit Application (Design Plans).
- The maximum height of structural fill soils above the perforated underdrain pipe and the solid underdrain pipe was estimated to be approximately 28.5 ft and 78 ft, respectively.
- Structural fill soils were assigned a unit weight of 112 pcf based on the United States Department of Interior Bureau of Reclamation's Design of Small Dams Unified Soil Classification System (USBR, 1987) for the silty sand or sand-silt mixtures (SM) on-site.
- The maximum CCR waste thickness above the perforated underdrain pipe was estimated to be approximately 173 feet (ft).
- CCR waste was assigned a unit weight of 110 pounds per cubic foot (pcf) based on results presented in the Bremo Power Station CCR Surface Impoundments, Impounding Structure Design Report, DCR Inventory #06520 (Golder, 2017).
- Two feet of final cover soil will be placed on top of the CCR. These soils were assigned a unit weight of 112 pcf based on the United States Department of Interior Bureau of Reclamation's Design of Small Dams Unified Soil Classification System (USBR, 1987) for the SM material on-site.
- Aggregate in the bottom liner system was assigned a unit weight is 120 pcf.
- Perforated underdrain pipe is bedded in crushed rock that will be compacted to 95% of the standard proctor.
- Solid underdrain pipe is bedded in SM soils that will be compacted to 90% of the standard proctor.
- Underdrain piping is high density polyethylene (HDPE) standard dimension ratio (SDR) 11 with a Standard Design Code of PE4710.

Design Report Underdrain Pipe Strength

Underdrain piping has a 12-inch nominal diameter, with the perforated portion having 3/8-inch diameter holes spaced 6 inches from center-to-center.

4.0 ANALYSIS

Pipe design criteria was based on the methodology presented in the Plastic Pipe Institute Handbook for Polyethylene Pipe (Plastic Pipe Institute, 2008) for pipe burial greater than 50 ft. Compressive ring thrust strength, ring deflection, and wall buckling were calculated to determine the adequacy of the proposed underdrain piping under the overburden stress of the proposed CCR Unit.

The Moore-Selig and modified Luscher methods were used to evaluate wall buckling. The Moore-Selig method is used to evaluate pipes in a dry condition, while the modified Luscher method is used for pipes buried beneath the groundwater table. Depending on emergent groundwater conditions, water could overtop the pipe, creating conditions corresponding to burial beneath the groundwater table.

The design overburden stress was determined at the location of the maximum CCR waste height above the perforated underdrain pipe and the maximum structural fill height above the solid wall underdrain pipe. The height of the soil, stone, and CCR waste was multiplied by the unit weight of each respective material. An overburden correction factor was applied to account for the underdrain pipe perforations.

The following formulas were used to evaluate the proposed underdrain pipes with the calculated overburden pressure.

4.1 Compressive Ring Thrust Strength

$$S = \frac{P_{RD}D_o}{288t}$$

Where:

S = Pipe Wall Compressive Stress [pounds per square inch (psi)]

P_{RD} = Radial Directed Earth Pressure (psi)

Do = Pipe Outside Diameter (in)

t = Wall Thickness (in)

4.2 Ring Deflection (Watkins-Gaube)

$$\frac{\Delta X}{D_M}(100) = D_F \in_{\mathcal{S}}$$

Where:

D_M = Pipe Mean Diameter (in)

 ΔX = Change in Pipe Diameter (in)

D_F = Deformation Factor

E_s = Soil Strain (%)

4.3 Moore-Selig Constrained Pipe Wall Buckling:

$$P_{CR} = \frac{2.4 \varphi R_H}{D_M} (EI)^{\frac{1}{3}} (E_S^*)^{\frac{2}{3}}$$

Where:

P_{CR} = Critical constrained buckling pressure (psi)

Design Report Underdrain Pipe Strength

 φ = Calibration Factor; 0.55 for granular soils

R_H = Geometry Factor; 1.0 for deep burial in uniform soils

 E_S^* = Modified Secant Modulus of Soil (psi)

E = Apparent Modulus of Elasticity of Pipe Material (psi)

I = Pipe Wall Moment of Inertia [quartic inch per inch (in⁴/in)]

4.4 Modified Luscher Constrained Pipe Wall Buckling:

$$P_{WC} = \frac{5.65}{N} \sqrt{RB'E' \frac{E}{12(DR - 1)^3}}$$

Where:

P_{WC} = Allowable Constrained Buckling Pressure (psi)

N = Safety Factor; 2.0

R = Buoyancy Reduction Factor

B' = Soil Support Factor

E = Soil Reaction Modulus (psi)

E = Apparent Modulus of Elasticity of Pipe Material (psi)

DR = Pipe Dimension Ratio

5.0 RESULTS

The design overburden stresses were calculated to be approximately 170 psi for the perforated underdrain pipe and 61 psi for the solid wall underdrain pipe. Compressive ring strength, ring deflection, and wall buckling for the underdrain piping was calculated and compared to allowable design limits. The maximum compressive ring thrust was calculated to be approximately 725 psi for the perforated SDR-11 pipe and 323 psi for the solid SDR-11 pipe, well below the 1,150 psi allowable compressive stress for a PE pipe with a PE4710 Standard Designation Code. The maximum ring deflections of the perforated and solid wall SDR-11 pipes are 4.1 and 3.3 percent, which are within the safe deflection limits for the pipe. The Moore-Selig and Luscher wall buckling critical pressures were higher than the design overburden pressure for the pipe and represent acceptable factors of safety. The following table summarizes the calculated results and critical design values.

Wall Buckling Stress **Compressive Ring Ring Deflection** (psi) Underdrain **Thrust Strength** (%) **Moore-Selig Modified Luscher Pipe** (psi) Calculated Critical Calculated Critical Calculated Critical Calculated Critical Perforated 725 1,150 4.1 5.0 170 663.1 170 240.3 SDR-11 Solid SDR-11 3.3 323 1.150 5.0 61 350.7 61 136.9

Table 1: Pipe Strength Summary Table

7.0 CONCLUSION

The underdrain piping satisfies the acceptable limits and factors of safety with the overburden stress from the proposed CCR Unit.

Attachments:

(1) Underdrain Pipe Strength Calculation Spreadsheet

Design Report Underdrain Pipe Strength

References:

- (1) EJ Prescott. PE 3408 Industrial Piping System Pipe Data Pressure Ratings.
- (2) Golder Associates (Golder, 2017). Bremo Power Station CCR Surface Impoundments, Impounding Structure Design Report, DCR Inventory #06520. March 2015, Revised March 2017.
- (3) Howard, A. Constrained Modulus of Crushed Rock for Pipeline Embedment. In *Pipelines 2011: A Sound Conduit for Sharing Solutions*; ASCE, 2011.
- (4) Plastic Pipe Institute (2008). Handbook of Polyethylene Pipe, 2nd Edition. 2008.
- (5) United States Department of Interiors Bureau of Reclamation (USBR, 1987). Design of Small Dams, Third Edition, 1987.

Underdrain Pipe Strength Attachment 1 Underdrain Pipe Strength Calculation Spreadsheet



Calculations

Project:Bremo Bluff FFCP Management FacilityMade by:ERRSubject:Pipe Strength Calculations - Perforated PipeChecked by:JAFReference No.:22130437.031Reviewed by:JRD

Date: 2/01/2024

Based on methodology presented in the Plastic Pipe Institute Handbook for Polyethylene Pipe, 2nd Edition, Section 3 - Deep Pipe Burial > 50 feet.

Table 1: Compressive Ring Thrust Strength

Table 1 : Compressive Ring Thrust Strength Input	Unit	12-in DR11	Notes:
Protective Cover Unit Weight, γ _{pc}	pcf	112	
Protective Cover Height, hpc	ft	2	
Waste Unit Weight, γ _w	pcf	110	
Waste Height, h _w	ft	173	
Drainage Stone Unit Weight, γ _{ds}	pcf	120	
Drainage Stone Height, h _{ds}	ft	4.0	
Subgrade Unit Weight, γ _s	pcf	112.0	
Subgrade Height, h _s	ft	28.5	
Overburden Stress, δ _v	psf	22,926	$\sigma_v = (\gamma_{pc} * h_{pc}) + (\gamma_w * h_w) + (\gamma_{ds} * h_{ds}) + (\gamma_s * h_s)$
Overburden Stress, δ _ν	psi	159.2	
Pipe Outer Diameter, D _o	in	12.750	
Mean Diameter, D _m	in	11.591	$D_M = D_o - t$
Dimension Ratio, DR		11.0	Per Part B Design Plans
Wall Thickness, t	in	1.159	$t = \frac{D_o}{DR *}$
Radius to centroid, r _{CENT}	in	5.80	$r_{CENT} = \frac{D_o - t}{2}$
Hole Diameter	in	0.38	Per Part B Design Plans
Hole Spacing	in	6	Per Part B Design Plans
Number of holes around perimeter		4	Per Part B Design Plans
Reduced pipe length to account for			
perforations, L _p		0.75	
Length based overburden correction, L _{cp}		1.07	$L_{cp} = \frac{12}{12 - L_p}$
L _a		0.88	Length correction greater than area correction
Area based overburden correction, L _{ca}		1.01	$L_{ca} = \frac{D_o x 12}{(D_o x 12) - 2 * D_o}$
Design Overburden Stress, δ_d	psf	24,454	$\sigma_d = L_{cp} * \sigma_v$
Design Overburden Stress, δ_d	psi	169.8	
Constrained Modulus of Soil, M _s	psi	6,500	From Table 3-12, assumes 95% compaction
Assumed Pipe Temperature	°F	73	
Assumed Load Duration	years	50	
Apparent Modulus of Elasticity, E	psi	29,000	From Table B.1.1, assumes PE4XXX
Temperature Multiplier		1.00	From Table B.1.2
Hoop Thrust Stiffness Ratio, S _A		1.60	$S_A = \frac{1.43 M_S r_{CENT}}{Et}$
Vertical Arching Factor, VAF		0.78	$VAF = 0.88 - 0.71 \frac{S_A - 1}{S_A + 2.5}$
Radial Directed Earth Pressure, P _{RD}	psf	18,970	$P_{RD} = (VAF) * \sigma_d$



Calculations

Project:Bremo Bluff FFCP Management FacilityMade by:ERRSubject:Pipe Strength Calculations - Perforated PipeChecked by:JAFReference No.:22130437.031Reviewed by:JRD

Date: 2/01/2024

Pipe Wall Compressive Stress, S	psi	724.5	$S = \frac{P_{RD} * (Do)}{288t}$
Allowable Compressive Strength	psi	1,150	From Table C.1, assumes 4710
COMPRESSIVE STRESS CHECK		PASS	

Calculation References



Calculations

Project:Bremo Bluff FFCP Management FacilityMade by:ERRSubject:Pipe Strength Calculations - Perforated PipeChecked by:JAFReference No.:22130437.031Reviewed by:JRD

Date: 2/01/2024

Table 2: Ring Deflection (Watkins-Gaube)

Input	Unit	12-in DR11	Notes:
Poisson's ratio of backfill, μ		0.15	From Table 3-13 for coarse sand (Void Ratio 0.4-0.7)
Secant modulus of soil, E _S	psi	6,156	$E_S = M_S * \frac{(1+\mu) * (1-2\mu)}{(1-\mu)}$
Rigidity factor, R _F		2,547	$R_F = \frac{12 * E_s * (DR - 1)^3}{E}$
Deformation Factor D _F		1.50	From R _F and Figure 3-6
Soil strain, ϵ_{S}	%	2.759	$\epsilon_s = \frac{\sigma_d}{144 * E_s} * 100$
Deflection, D	%	4.1	$D(\%) = D_F * \epsilon_S$
Acceptable deflection limit	%	5.0	From Table 3-11 for DR-11
DEFLECTION CHECK		PASS	

Table 3: Moore- Selig Constrained Pipe Wall Buckling

Input	Unit	12-in DR11	Notes:
Calibration factor, φ		0.55	0.55 for granular soils
Geometry factor, R _H		1.0	1.0 for deep burial in uniform soils
Pipe wall Moment of Inertial, I	in ³	0.130	$I = \frac{t^3}{12}$
Modified Secant Modulus of soil, E _s *	psi	7,242	$E_S^* = \frac{E_S}{(1-\mu)}$
Critical constrained buckling pressure, P _{CR}	psi	663.1	$P_{CR} = \frac{2.4\varphi R_H}{D_M} (EI)^{1/3} \left(E_{S} \right)^{2/3}$
Factor of safety against buckling		3.9	$FS = \frac{P_{CR}}{\sigma_d}$
Acceptable factor of safety against buckling		2.0	
BUCKLING CHECK		PASS	

Table 4: Modified Luscher Constrained Pipe Wall Buckling

Table 4. Modified Education Constrained 1 the Wall Backling				
Input	Unit	12-in DR11	Notes:	
Height of groundwater, H _{GW}	ft	1.00	Maximum allowable leachate head	
Elastic support coefficient, B'		1.0	$B' = \frac{1}{1 + 4e^{-(0.065)(h)}}$	
Soil Reaction Modulus, E'	psi	3,000	From table 3-7 for crushed rock	
Bouyancy reduction factor, R		0.998	$R = 1 - 0.33 \frac{H_{GW}}{h}$	
Allowable constrained buckling pressure, P _{WC}	psi	240.3	$P_{WC} = \frac{5.65}{N} \sqrt{RB'E' \frac{E}{12(DR - 1)^3}}$ N = 2 for Thermoplastic Pipe	
BUCKLING CHECK		PASS		



Calculations

Project:Bremo Bluff FFCP Management FacilityMade by:ERRSubject:Pipe Strength Calculations - Solid PipeChecked by:JAFReference No.:22130437.031Reviewed by:JRD

Date: 2/01/2024

Based on methodology presented in the Plastic Pipe Institute Handbook for Polyethylene Pipe, 2nd Edition, Section 3 - Deep Pipe Burial > 50 feet.

Table 1: Compressive Ring Thrust Strength

Table 1 : Compressive Ring Thrust Strength Input	Unit	12-in DR11	Notes:
Protective Cover Unit Weight, γ _{pc}	pcf	0	
Protective Cover Height, hpc	ft	0	
Waste Unit Weight, γ _w	pcf	0	
Waste Height, h _w	ft	0	
Unit Weight, γ _{ds}	pcf	0	
Drainage Stone Height, h _{ds}	ft	0.0	
Subgrade Unit Weight, γ _s	pcf	112.0	
Subgrade Height, h _s	ft	78.0	
Overburden Stress, δ _v	psf	8,736	$\sigma_v = (\gamma_{pc} * h_{pc}) + (\gamma_w * h_w) + (\gamma_{ds} * h_{ds}) + (\gamma_s * h_s)$
Overburden Stress, δ _ν	psi	60.7	
Pipe Outer Diameter, D _o	in	12.750	
Mean Diameter, D _m	in	11.591	$D_M = D_o - t$
Dimension Ratio, DR		11.0	Per Part B Design Plans
Wall Thickness, t	in	1.159	$t = \frac{D_o}{DR *}$
Radius to centroid, r _{CENT}	in	5.80	$r_{CENT} = \frac{D_o - t}{2}$
Hole Diameter	in	0.00	Per Part B Design Plans
Hole Spacing	in	0	Per Part B Design Plans
Number of holes around perimeter		0	Per Part B Design Plans
Reduced pipe length to account for			
perforations, L _p		0.00	
Length based overburden correction, L _{cp}		1.00	$L_{cp} = \frac{12}{12 - L_p}$
L _a		0.00	Length correction greater than area correction
Area based overburden correction, L _{ca}		1.00	$L_{ca} = \frac{D_o x 12}{(D_o x 12) - 2 * D_o}$
Design Overburden Stress, δ _d	psf	8,736	$\sigma_d = L_{cp} * \sigma_v$
Design Overburden Stress, δ_d	psi	60.7	
Constrained Modulus of Soil, M _s	psi	2,500	From Table 3-12, assumes 90% compaction
Assumed Pipe Temperature	°F	73	
Assumed Load Duration	years	50	
Apparent Modulus of Elasticity, E	psi	29,000	From Table B.1.1, assumes PE4XXX
Temperature Multiplier		1.00	From Table B.1.2
Hoop Thrust Stiffness Ratio, S _A		0.62	$S_A = \frac{1.43 M_S r_{CENT}}{Et}$
Vertical Arching Factor, VAF		0.97	$VAF = 0.88 - 0.71 \frac{S_A - 1}{S_A + 2.5}$
Radial Directed Earth Pressure, P _{RD}	psf	8,451	$P_{RD} = (VAF) * \sigma_d$

Calculation References



Calculations

Project:Bremo Bluff FFCP Management FacilityMade by:ERRSubject:Pipe Strength Calculations - Solid PipeChecked by:JAFReference No.:22130437.031Reviewed by:JRD

Date: 2/01/2024

Pipe Wall Compressive Stress, S	psi	322.8	$S = \frac{P_{RD} * (Do)}{288t}$
Allowable Compressive Strength	psi	1,150	From Table C.1, assumes 4710
COMPRESSIVE STRESS CHECK		PASS	

Calculation References



Calculations

Project:Bremo Bluff FFCP Management FacilityMade by:ERRSubject:Pipe Strength Calculations - Solid PipeChecked by:JAFReference No.:22130437.031Reviewed by:JRD

Date: 2/01/2024

Table 2: Ring Deflection (Watkins-Gaube)

Input	Unit	12-in DR11	Notes:
Poisson's ratio of backfill, μ		0.15	From Table 3-13 for coarse sand (Void Ratio 0.4-0.7)
Secant modulus of soil, E _S	psi	2,368	$E_S = M_S * \frac{(1+\mu) * (1-2\mu)}{(1-\mu)}$
Rigidity factor, R _F		980	$R_F = \frac{12 * E_s * (DR - 1)^3}{E}$
Deformation Factor D _F		1.30	From R _F and Figure 3-6
Soil strain, ϵ_{S}	%	2.562	$\epsilon_S = \frac{\sigma_d}{144 * E_S} * 100$
Deflection, D	%	3.3	$D(\%) = D_F * \epsilon_S$
Acceptable deflection limit	%	5.0	From Table 3-11 for DR-11
DEFLECTION CHECK		PASS	

Table 3: Moore- Selig Constrained Pipe Wall Buckling

Table 5. Moore- Selig Constrained Fipe Wall Buckling					
Input	Unit	12-in DR11	Notes:		
Calibration factor, φ		0.55	0.55 for granular soils		
Geometry factor, R _H		1.0	1.0 for deep burial in uniform soils		
Pipe wall Moment of Inertial, I	in ³	0.130	$I = \frac{t^3}{12}$		
Modified Secant Modulus of soil, E _s *	psi	2,785	$E_S^* = \frac{E_S}{(1-\mu)}$		
Critical constrained buckling pressure, P _{CR}	psi	350.7	$P_{CR} = \frac{2.4\varphi R_H}{D_M} (EI)^{1/3} \left(E_{S_{\perp \perp}}^* \right)^{2/3}$		
Factor of safety against buckling		5.8	$FS = \frac{P_{CR}}{\sigma_d}$		
Acceptable factor of safety against buckling		2.0			
BUCKLING CHECK		PASS			

Table 4: Modified Luscher Constrained Pipe Wall Buckling

Table 4. Modified Edserier Constrained ripe Wall Backling							
Input	Unit	12-in DR11	Notes:				
Height of groundwater, H _{GW}	ft	1.00	Maximum allowable leachate head				
Elastic support coefficient, B'		1.0	$B' = \frac{1}{1 + 4e^{-(0.065)(h)}}$				
Soil Reaction Modulus, E'	psi	1,000	From table 3-7 for SM				
Bouyancy reduction factor, R		0.996	$R = 1 - 0.33 \frac{H_{GW}}{h}$				
Allowable constrained buckling pressure, P _{WC}	psi	136.9	$P_{WC} = \frac{5.65}{N} \sqrt{RB'E' \frac{E}{12(DR-1)^3}}$ N = 2 for Thermoplastic Pipe				
BUCKLING CHECK		PASS	V				

TABLE 3-12
Typical Values of M₅, One-Dimensional Modulus of Soil

Vertical Soil Stress1 (psi)	Gravelly Sand/Gravels 95% Std. Proctor (psi)	Gravelly Sand/Gravels 90% Std. Proctor (psi)	Gravelly Sand/Gravels 85% Std. Proctor (psi)
.10	3000	1800	550
20	3500	1800	650
40	4200	2100	800
60	5000	2500	1000
80	6000	2900	1300
100	6500	3200	1450

^{*} Adapted and extended from values given by McGrath^(XI). For depths not shown in McGrath^(XI), the MS values were approximated using the hyperbolic soil model with appropriate values for K and n where n=0.4 and K=200, K=100, and K=45 for 95% Proctor, 90% Proctor, and 85% Proctor, respectively.

TABLE B.1.1 Apparent Elastic Modulus for 73°F (23°C)

Duration of	Design Values For 73°F (23°C) (1,2,3)							
Sustained Loading	PE 2XXX		PE3XXX		PE4XXX			
	psi	MPa	psi	MPa	psi	MPa		
0.5hr	62,000	428	78,000	538	82,000	565		
1hr	59,000	407	74,000	510	78,000	538		
2hr	57,000	393	71,000	490	74,000	510		
10hr	50,000	345	62,000	428	65,000	448		
12hr	48,000	331	60,000	414	63,000	434		
24hr	46,000	317	57,000	393	60,000	414		
100hr	42,000	290	52,000	359	55,000	379		
1,000hr	35,000	241	44,000	303	46,000	317		
1 year	30,000	207	38,000	262	40,000	276		
10 years	26,000	179	32,000	221	34,000	234		
50 years	22,000	152	28,000	193	29,000	200		
100 years	21,000	145	27,000	186	28,000	193		

- (1) Although there are various factors that determine the exact apparent modulus response of a PE, a major factor is its ratio of crystalline to amorphous content a parameter that is reflected by a PE's density. Hence, the major headings PE2XXX, PE3XXX and, PE4XXX, which are based on PE's Standard Designation Code. The first numeral of this code denotes the PE's density category in accordance with ASTM D3350 (An explanation of this code is presented in Chapter 5).
- (2) The values in this table are applicable to both the condition of sustained and constant loading (under which the resultant strain increases with increased duration of loading) and that of constant strain (under which an initially generated stress gradually relaxes with increased time).
- (3) The design values in this table are based on results obtained under uni-axial loading, such as occurs in a test bar that is being subjected to a pulling load. When a PE is subjected to multi-axial stressing its strain response is inhibited, which results in a somewhat higher apparent modulus. For example, the apparent modulus of a PE pipe that is subjected to internal hydrostatic pressure – a condition that induces bi-axial stressing – is about 25% greater than that reported by this table. Thus, the Uni-axial condition represents a conservative estimate of the value that is achieved in most applications.

It should also be kept in mind that these values are for the condition of continually sustained loading. If there is an interruption or a decrease in the loading this, effectively, results in a somewhat larger modulus.

In addition, the values in this table apply to a stress intensity ranging up to about 400psi, a value that is seldom exceeded under normal service conditions.

Vertical Soil Stress (psi) = [soil depth (ft) x soil density (pcf)]/144

TABLE B.1.2

Temperature Compensating Multipliers for Determination of the Apparent Modulus of Elasticity at Temperatures Other than at 73°F (23°C)

Equally Applicable to All Stress-Rated PE's

(e.g., All PE2xxx's, All PE3xxx's and All PE4xxx's)

Maximum Sustained Temperature of the Pipe °F (°C)	Compensating Multiplier
-20 (-29)	2.54
-10 (-23)	2.36
0 (-18)	2.18
10 (-12)	2.00
20 (-7)	1.81
30 (-1)	1.65
40 (4)	1.49
50 (10)	1.32
60 (16)	1.18
73.4 (23)	1.00
80 (27)	0.93
90 (32)	0.82
100 (38)	0.73
110 (43)	0.64
120 (49)	0.58
130 (54)	0.50
140 (60)	0.43

TABLE C.1
Allowable Compressive Stress for 73°F (23°C)

		Pe Pi	pe Material D	esignation C	ode (1)		
	PE	2406	PE3	408			
	PE 2708		PE 3608				
			PE 3	3708	PE 4710		
			PE 3	3710			
			PE 4	1708			
	psi	MPa	psi	MPa	psi	MPa	
Allowable Compressive Stress	800	5.52	1000	6.90	1150	7.93	

⁽¹⁾ See Chapter 5 for an explanation of the PE Pipe Material Designation Code.

TABLE 3-13
Typical range of Poisson's Ratio for Soil (Bowles (21))

Soil Type	Poisson's Ratio, µ
Saturated Clay	0.4-0.5
Unsaturated Clay	0.1-0.3
Sandy Clay	0.2-0.3
Silt	0.3-0.35
Sand (Dense)	0.2-0.4
Coarse Sand (Void Ratio 0.4-0.7)	0.15
Fine-grained Sand (Void Ratio 0.4-0.7)	0.25

TABLE 3-7
Values of E' for Pipe Embedment (See Howard (8))

		E' for Degree of Embedment Compaction, lb/in ²					
Soil Type-pipe Embedment Material (Unified Classification System) ¹	Dumped	Slight, <85% Proctor, <40% Relative Density	Moderate, 85%-95% Proctor, 40%-70% Relative Density	High, >95% Proctor, >70% Relative Density			
Fine-grained Soils (LL > 50) ² Soils with medium to high plasticity; CH, MH, CH-MH	No data available: consult a competent soils engine otherwise, use E' = 0.						
Fine-grained Soils (LL < 50) Soils with medium to no plasticity, CL, ML, ML- CL, with less than 25% coarse grained particles.	50	200	400	1000			
Fine-grained Soils (LL < 50) Soils with medium to no plasticity, CL, ML, ML-CL, with more than 25% coarse grained particles; Coarse-grained Soils with Fines, GM, GC, SM, SC ³ containing more than 12% fines.	100	400	1000	2000			
Coarse-grained soils with Little or No Fines GW, GP, SW, SP ³ containing less than 12% fines	200	1000	2000	3000			
Crushed Rock	1000	3000	3000	3000			
Accuracy in Terms of Percentage Deflection ⁴	±2%	±2%	±1%	±0.5%			

ASTM D-2487, USBR Designation E-3

Note: Values applicable only for fills less than 50 ft (15 m). Table does not include any safety factor. For use in predicting initial deflections only; appropriate Deflection Lag Factor must be applied for long-term deflections. If embedment falls on the borderline between two compaction categories, select lower E' value, or average the two values. Percentage Proctor based on laboratory maximum dry density from test standards using 12,500 ft-lb/ou ft (598,000 J/m²) (ASTM D-698, AASHTO T-99, USBR Designation E-11), 1 psi = 8.9 KPa.

TABLE 3-11
Safe Deflection Limits for Pressurized Pipe

DR or SDR	Safe Deflection as % of Diameter
32.5	7.5
26	7.5
21	7.5
17	6.0
13.5	6.0
11	5.0
9	4.0
7.3	3.0

^{*}Based on Long-Term Design Deflection of Buried Pressurized Pipe given in ASTM F1962.

² LL = Liquid Limit

³ Or any borderline soil beginning with one of these symbols (i.e., GM-GC, GC-SC).

⁴ For ±1% accuracy and predicted deflection of 3%, actual deflection would be between 2% and 4%.

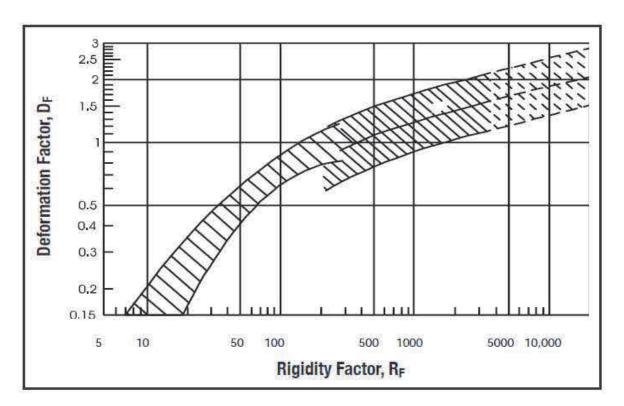


Figure 3-6 Watkins-Gaube Graph