R.D. Morrow, Sr. Generating Station

CCR Landfill Closure and Post-Closure Plan

Submitted to:

Cooperative Energy
P.O. Box 15849
Hattiesburg, MS 39404

Submitted by:

Golder Associates Inc.
2247 Fox Heights Lane, Suite A,
Green Bay, Wisconsin, USA 54304

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19117989

August 26, 2020

CERTIFICATION

Professional Engineer Certification Statement [40 CFR 257.102(b)(4) & 40 CFR 257.104(d)(4)]

I hereby certify that, having reviewed the attached documents and being familiar with the provisions of Title 40 of the Code of Federal Regulations Section 257.102 and Section 257.104 (40 CFR Parts 257.102 and 104), this Closure and Post-Closure Plan (Plan) is accurate and has been prepared in accordance with good engineering practices, including the consideration of applicable industry standards, and with the requirements of 40 CFR Parts 257.102 and 104. The final cover design set forth in this Plan meets the technical requirements of 40 CFR 102(d)(3)(ii).

Golder Associates Inc.

Signature

August 26, 2020

Date of Report Certification

Jeffery R. Piaskowski, PE

Name

30525

Professional Engineer Certification Number

JEFFREY PIASKOWSKI
LICENSED PROFESSIONAL
ENGINEER
30525
STATE OF MISSISSIPPI

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1.0 INTRODUCTION AND SITE DESCRIPTION

The United States Environmental Protection Agency (USEPA) Coal Combustion Residual (CCR) Rule (CCR Rule) was published in the Code of Federal Regulations (CFR) Title 40 Part 257 (40 CFR Part 257, Subpart D) on April 17, 2015. The Rule identifies an effective date of October 19, 2015. The CCR Rule regulates CCR as nonhazardous waste under Subtitle D of the Resource Conservation and Recovery Act (RCRA) and applies to new and existing CCR landfills and CCR surface impoundments. The CCR Rule was modeled after Subtitle D of RCRA, which was initially established for Municipal Solid Waste (MSW) facilities (40 CFR § 258) in 1992. Cooperative Energy currently operates an existing CCR landfill regulated by the CCR Rule at the R.D. Morrow, Sr. Generating Station (RD Morrow); however, RD Morrow no longer combusts coal.

This written Closure and Post-Closure Plan (Plan) is being generated pursuant to the following applicable closure performance standards when leaving CCR in place:

- RCRA
  - 40 CFR 257.102(d)
  - 40 CFR 257.104(d)
- Mississippi Department of Environmental Quality (MDEQ)
  - Mississippi Nonhazardous Solid Waste Management Regulations (MNSWMR): Title 11 Mississippi Administrative Code, Part 4, Rule 1.4 E (Rule 1.4E)

This Plan provides for closure and post-closure care of the RD Morrow Nonhazardous Solid Waste CCR Landfill (Landfill) consistent with recognized and generally accepted good engineering practices. Specifically, this Plan ensures that the Landfill is closed in a manner that will:

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

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

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

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

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

The Landfill is located to the southwest of RD Morrow and is permitted for approximately 72 acres; however, approximately 46 acres have been utilized. The Landfill is bounded by Old Okahola Road to the north and undeveloped land to the southwest.

The proposed landfill final cover geometry was developed to accommodate the expected volume of CCR materials onsite. The components and the configuration of the final cover are designed to address the requirements of Rule 1.4 E and also meet the closure design and construction requirements set forth in 40 CFR 257.102(d)(3)(ii)(A) through (C).

2.0 CLOSURE PLAN

2.1 Closure Description

The Landfill will be closed with CCR in place and capped with a final cover system over the appropriate developed Landfill area. Prior to closure, the Landfill will be regraded as necessary to meet the closure grades presented in Appendix A – Closure Drawings. Once design grades are met, the ClosureTurf® system will be installed as an alternative to conventional compacted clay infiltration layers with a vegetated erosion layer as outlined in 40 CFR 257.102(d)(3)(ii) and Rule 1.4 E. The slopes are designed to be a minimum 4.0 percent to meet performance standard requirements per 40 CFR 257.102(d)(1) and Rule 1.4 E. Cooperative Energy plans to install ClosureTurf® over the entire developed Landfill footprint, including areas previously closed with State approval prior to the effective date of the CCR Rule. Details of the closure construction are provided in the following sections.

2.2 Landfill CCR Quantity and Final Cover Area

The maximum inventory of CCR on-site over the life of the CCR unit is approximately 2,343,000 cubic yards (cy). Approximately 3.2 million cy was originally permitted in 1977, with an additional approximate 2.1 million cy permitted as part of the 2004 expansion. CCR has been placed in the original permitted 36-acre-area of the landfill and in 10 acres of the permitted expansion area; therefore, the largest area requiring final cover is approximately 46 acres.

2.3 Closure Construction Sequence

2.3.1 Landfill Regrading

The Landfill requires regrading to achieve final cover grades that comply with 40 CFR 257.102(d)(1) and Rule 1.4 E. The regraded CCR will be placed in generally 12-inch-thick lifts and compacted until no excessive rutting or yielding is observed.

During regrading, appropriate dust control measures identified in the Coal Combustion Residuals Fugitive Dust Control Plan for R.D. Morrow posted on the publicly accessible website pursuant to 40 CFR 257.107(g)(1) will be followed.

The Landfill's southern topdeck closure surface will be raised or lowered as needed to accommodate the CCR from excavations that are difficult to quantify. The topdeck surface will maintain a minimum 4.0 percent grade and not exceed permitted waste elevations.

2.4 Final Cover Design

2.4.1 Final Cover Grades

The Landfill final cover grades range from approximately 4.0 percent to 33.0 percent in accordance with 40 CFR 257.102(d)(1). Rule 1.4 E requires that a maximum slope of 25.0 percent be maintained unless otherwise approved by the Department. Golder recognizes that this topic was discussed in the past and Golder has since evaluated both slope stability and drainage under the current proposed configuration of 33.0 percent maximum grades.

The positive drainage and 33.0 percent maximum slopes were designed to:

- Preclude the probability of future impoundment of water, sediment, or slurry

- Limit final cover settling and subsidence
- Provide for major slope stability to prevent the sloughing or movement of the final cover system during the closure and post-closure care period

Slope stability modeling was performed considering conditions that will likely be realized during and after closure. The short term (during closure prior to materials experiencing generally a drained condition) and long term (following closure when a drained condition may be realized) global stability model results indicate acceptable factors of safety greater than 1.5 when using the 33.0 percent final cover slopes. Additionally, long term seismic stability model results indicate acceptable factors of safety greater than 1.0 using recommended gravitational accelerations. The results of the slope stability assessment are provided in Appendix B – Slope Stability Analysis.

A veneer analysis was conducted to assess the ClosureTurf® stability on the 33.0 percent maximum slopes. The veneer analysis confirms ClosureTurf® will appropriately hold to the proposed grades. Details of the veneer analysis are provided in Appendix B – Slope Stability Analysis and indicate that the proposed final cover system provides an adequate factor of safety (FoS)

Calculations and hydraulic shear stress tests supporting the specified manufactured sand infill were conducted to support the internal stability of ClosureTurf® given the proposed closure grades and slope lengths. The calculations and the hydraulic shear stress tests are provided in a WatershedGeo technical note dated June 5, 2020 and is included in Appendix B.

Stormwater was also evaluated using the ClosureTurf® and the 33.0 percent maximum grades to ensure infiltration was minimized and yet the systems controlled the design storm events. A combination of drainage ditches and berms were designed to surround the top of the landfill to collect stormwater from the topdeck areas graded at 4.0 percent and convey it to Hydrobinder® lined downchutes designed to accommodate their respective drainage areas. The downchutes will direct stormwater to riprap lined perimeter ditches which ultimately empty into one of two equalization ponds before leaving the site. The site stormwater drainage pattern will be improved to allow the stormwater from the northwestern half of the landfill to flow northwest into a proposed northern retention pond that discharges to an existing stormwater ditch that flows south to Black Creek. The southeastern half of the landfill will maintain its current flow direction to the southern pond and ultimately to the permitted National Pollution Discharge Elimination System (NPDES) Outfall 007. All stormwater features were designed using the SCS Type II 100-year, 24-hour storm event (11.3 inches). The equalization pond design provides more volume and more retention time than the existing conditions. As a result, the equalization ponds will allow for better settling opportunities for suspended solids before discharge. The stormwater drainage patterns are provided in Appendix A – Closure Drawings (Sheet 5 – Final Restoration Plan).

2.4.2 Design

The final cover system, which is depicted in Figure 1 below, consists of the following components (from bottom to top):

- CCR with sufficient strength to support final cover construction
- ClosureTurf® system consisting of:
  - 50 mil microdrain geomembrane (sideslopes)
  - 40 mil microspike geomembrane (top deck)

- Artificial turf
- 0.5-inch-thick sand infill (ballast) layer

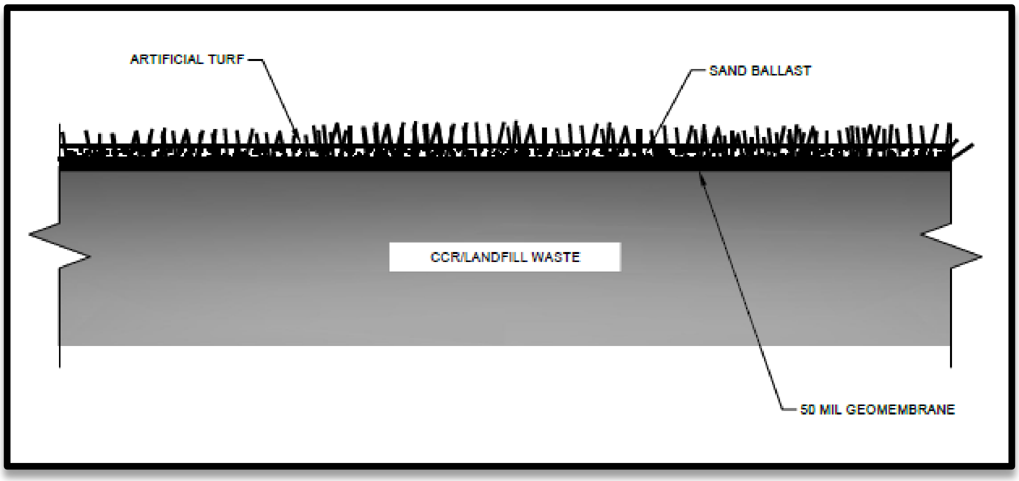

Figure 1: ClosureTurf® Cover Detail

The ClosureTurf® system will be approximately 0.55 inches thick and consist of a 50 mil microdrain geomembrane on the side slopes and 40 mil microspike geomembrane on the 4.0 percent top deck. The geomembranes will serve as the final cover infiltration layer. The infiltration layer will be overlain with artificial turf and 0.5-inch-thick sand infill layer. The artificial turf and sand infill provide protective cover and serve as an erosion layer for the landfill closure. Overall, the ClosureTurf® system reduces closure maintenance as the following are not required:

- Mowing
- Erosion control
- Reseeding
- Fertilizing
- Pond cleanout

The CCR Rule states in Section 257.102(d)(3)(i)(A) that the "permeability of the final cover system must be less than or equal to the permeability of any bottom liner system or natural subsoils present, or a permeability no greater than 1×10^{-5} centimeters per second (cm/sec), whichever is less." Since the Landfill was constructed with a natural clay liner, it has been conservatively assumed that the subgrade soils have a permeability of 1×10^{-7} cm/sec. Therefore, the final cover system was designed to have a permeability of 1×10^{-7} cm/sec or less using ClosureTurf®, which has a manufacturer reported permeability of 1×10^{-13} cm/sec. Additionally, the 40 mil geomembrane infiltration layer was compared to 18-inches of compacted clay with a permeability of 1×10^{-7} cm/sec. The results indicate that 40 mil geomembrane at 1×10^{-13} cm/sec has lower permeability compared to 18-inches of compacted clay. The results are presented in Appendix C – Alternative Liner Equivalency Calculation.

The final cover system is designed to provide a final cover permeability less than 1×10^{-7} cm/sec; minimize the need for maintenance; control, minimize, or eliminate post-closure infiltration of liquids; minimize releases of CCR and leachate into ground and surface waters or the atmosphere; preclude the probability of future impoundment of water, sediment, or slurry; prevent the sloughing or movement of the liner; and be completed in the shortest amount of time consistent with recognized and generally accepted good engineering practices.

2.4.3 Subgrade Layer

Once the Landfill is regraded to the liner design grades; the liner grade will be smooth drum rolled, inspected for protruding or angular stones, and accepted as the ClosureTurf® subgrade. The subgrade surface will be accepted by the owner's representative, earthwork contractor, and ClosureTurf® installer as a surface suitable for geomembrane placement that is generally free of ruts, soft areas, protruding or angular stones, dust, and/or excessive moisture.

2.4.4 ClosureTurf® Liner

The ClosureTurf® system is proposed for the final cover system. The membrane component of the ClosureTurf® will have the properties presented in the current GRI-GM17 Test Methods, Test Properties and Testing Frequencies for Smooth and Textured Geomembrane (Geosynthetic Institute, 2019). The sand infill component will have a maximum particle size of 0.375 inches and a specific gravity greater than or equal to 2.40.

The geomembrane in the ClosureTurf® System is designed consistent with section 40 CFR 257.102(d)(1)(i) to control, minimize or eliminate, to the maximum extent feasible both post-closure infiltration of liquids into the waste and also releases of CCR, leachate, or contaminated run-off to the ground or surface waters or to the atmosphere.

2.5 Schedule

Cooperative Energy intends to provide notification of intent to initiate closure pursuant to 40 CFR 257.102(e) within 30 days of when the Landfill receives the known final receipt of waste. In accordance with 40 CFR 257.102(f)(1)(i), closure activities are expected to be completed within six months of commencing closure activities.

It is anticipated that ClosureTurf® construction will begin within 30 days from closure commencement after the earthwork contractor has regraded approximately 10 acres for the geosynthetic installer to begin placing ClosureTurf® components.

Table 1 – Conceptual Final Cover Construction Schedule Milestones contains durations that were developed as part the of the closure construction schedule to demonstrate that closure will be completed within the self-implementing closure schedule per 40 CFR 257.102(f)(1)(i).

Table 1: Conceptual Final Cover Construction Schedule Milestones

Closure Component	Estimated Duration
Prepare Subgrade - Includes minor regrading - Includes smooth drum rolling - Include survey confirmation of grades	30 days
Install ClosureTurf® - Includes geomembrane installation - Includes artificial turf installation - Includes sand ballast installation	120 days

2.6 Closure Deadline Extension

Closure of existing CCR landfills must be completed within six months of commencing closure activities in accordance with 40 CFR 257.102(f)(1)(i). However, a deadline extension can be obtained as outlined in 40 CFR 257.102(f)(2) if completion of closure is not feasible within six months (e.g., shortened construction season, significant weather delays, time required for dewatering CCR, delays due to state or local permitting or approval, etc.). An extension must include a narrative description that demonstrates closure is not feasible in the required timeframe in accordance with 40 CFR 257.102(f)(2). The closure deadline for the Landfill may be extended up to two years in one-year increments per 40 CFR 257.102(f)(2)(ii)(C).

3.0 POST-CLOSURE CARE REQUIREMENTS

3.1 Site Contact

Environmental Department
P.O. Box 15849
Hattiesburg, MS 39404-5849
601-268-2083
environmental@cooperativeenergy.com

3.2 Monitoring and Maintenance

3.2.1 ClosureTurf®

Monitoring and maintenance of the ClosureTurf® system will be conducted in accordance with the latest edition of the ClosureTurf® Owner's Post-Closure Care Manual to ensure the integrity and effectiveness of the final cover system. The current manual is provided as Appendix D – ClosureTurf® Owner's Post-Closure Care Manual and covers the following topics:

- Differential settlement
- Exposed geotextile backing
- Exposed geomembrane
- Damage to engineered turf fibers in high traffic areas
- Sand migration and drainage channel materials
- Physical damage from equipment and/or animals

3.2.2 Groundwater and Leachate Collection Systems

- The groundwater monitoring system will be sampled in accordance with the latest revision of the RD Morrow Groundwater Monitoring Program and maintained in accordance with applicable requirements from 40 CFR 257.90 to 40 CFR 257.98 and State of Mississippi Solid Waste Management Permit SW0370020308.
- The leachate collection and removal system will be maintained in accordance with applicable requirements of Rule 1.4E.

3.3 Periodic Inspections

Periodic site inspections verifying the integrity and effectiveness of the final cover system will be conducted throughout the 30-year post-closure period on no less than an annual basis as recommended by the manufacturer in the ClosureTurf® Owner's Post-Closure Care Manual (Appendix D). If items requiring construction and/or maintenance are identified during an inspection, Cooperative Energy will schedule and conduct repairs promptly. During site inspections, the inspector will examine the Landfill area and document any items of concern. A sample inspection template entitled the "Post-Closure Monitoring and Maintenance Inspection Report Template" is included in the ClosureTurf® Owner's Post-Closure Care Manual (Appendix D).

If maintenance is required, rubber tire or rubber track equipment can be utilized to make repairs to the Landfill. ClosureTurf® recommends no more than 35 pounds per square inch (psi) on closed areas where slopes are more than 15 percent and recommends no more than 85 psi on closed areas where slopes are less than 15 percent. Larger equipment can be used, but the equipment loading cannot exert more than the pressures previously stated. If repairs to the geosynthetics (e.g., geomembrane, geotextile, etc.) are necessary, a certified geosynthetic installer must conduct the repairs under the direction of a quality assurance representative.

4.0 SITE USE

Cooperative Energy plans to continue to generate electricity on the collective site property while the Landfill, once closed, will be secured, and maintained as described in Sections 3.2 and 3.3. If the area is to be developed in the future, the integrity of the geomembrane cover liner will be confirmed with the proposed use; and institutional controls for maintaining the integrity of the geomembrane cover will be provided through an update to this Plan.

Once certified closed, Cooperative Energy in accordance with Rule 1.4E(2)(g), will record a notation and survey plat, prepared by a registered land surveyor, indicating the location and dimensions of the actual waste footprint with respect to permanently surveyed benchmarks or section corners, and notify MDEQ that the notation and plat have been recorded and a copy of each has been placed in the operating record. Use of the site will be restricted by either fencing and gating or procedures to prohibit access other than for inspections, maintenance, and monitoring; established easements; and use of intrusive vehicles and activities at the site.

5.0 GENERAL QUALIFICATIONS

This Plan has been prepared in general accordance with normally accepted civil engineering practices. Golder has prepared this Plan for the purposes intended by Cooperative Energy. Any values presented herein shall be considered nominal values and subject to applicable construction tolerances based on normally accepted civil construction practices. No other warranty, either expressed or implied, is made. The scope is limited to the specific project and location described herein, and our description of the project represents our understanding of the significant aspects relevant to the site. In the event that any changes in the design or location of the facility as outlined in this Plan are planned, Golder should be informed so that the changes can be reviewed and the conclusions of this Plan modified, as necessary, in writing by the engineer.

Signature Page

This Closure and Post-Closure Plan is respectfully submitted to Cooperative Energy. If you have any questions or require additional information, please contact Jeff Piaskowski at (920) 309-1548.

Sincerely,

Golder Associates Inc.

Jeff Piaskowski, P.E.
Senior Project Engineer

Dave List, P.E.
Senior Practice Leader

6.0 REFERENCES

Geosynthetic Institute, 2019. *GRI Test Method GM17 (GRI-GM17); Standard Specification for Test Methods, Test Properties and Testing Frequency for Linear Low Density Polyethylene (LLDPE) Smooth and Textured Geomembranes.* Revision 13, September 9, 2019.

APPENDIX A

Closure Drawings

COOPERATIVE ENERGY
R.D. MORROW, SR. GENERATING STATION
304 OLD OKAHOLA SCHOOL ROAD
PURVIS, LAMAR COUNTY, MISSISSIPPI
CCR LANDFILL CLOSURE PROJECT

DRAWING LIST	
SHEET NUMBER	DRAWING TITLE
1	COVER SHEET
2	PERMIT BOUNDARY PLAN
3	EXISTING CONDITIONS
4	CLOSURE PLAN
5	FINAL RESTORATION PLAN
6	CROSS SECTIONS
7	CLOSURE DETAILS
8	CLOSURE DETAILS

ISSUED FOR
REVIEW

REV.	YYYY-MM-DD	DESCRIPTION	DESIGNED	PREPARED	REVIEWED	APPROVED
B	2020-08-21	CLOSURE PLAN REVISION	AJD	AJD	JRP	DML
A	2020-04-03	CLOSURE PLAN	AJD	AJD	JRP	DML

SEAL

JEFFREY PIASKOWSKI
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PROJECT
R.D. MORROW, SR. GENERATING STATION
PURVIS, LAMAR COUNTY, MISSISSIPPI
CCR LANDFILL CLOSURE PROJECT

TITLE
COVER SHEET

PROJECT NO.	REV.		SHEET
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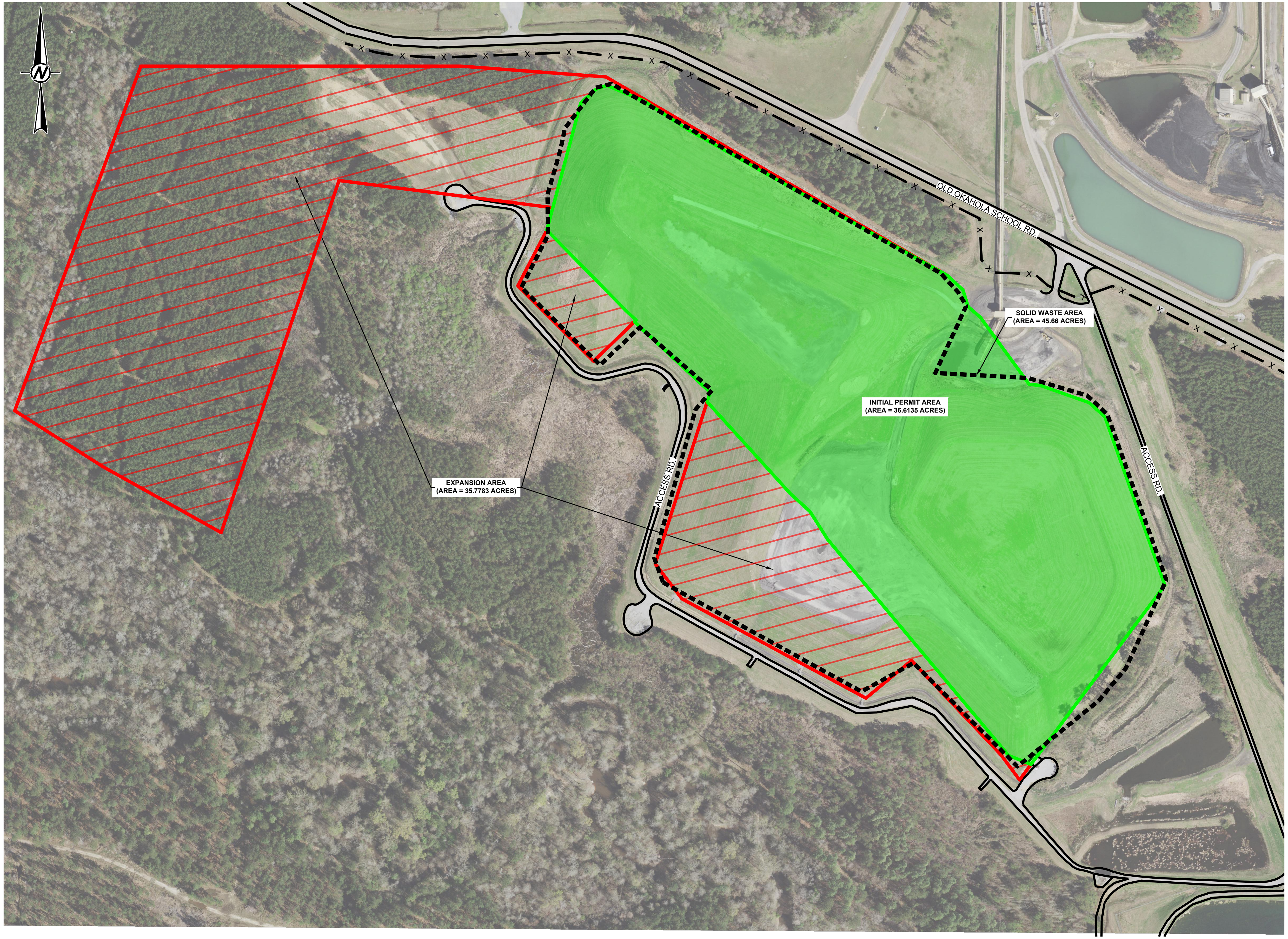

LEGEND

- EXISTING FENCE LINE
- SOLID WASTE BOUNDARY
- INITIAL PERMIT AREA
- EXPANSION AREA

REFERENCE(S)

COORDINATE SYSTEM:
VERTICAL: PLANT-BASED DATUM, NAVD88.
HORIZONTAL: PLANT-BASED DATUM.

ISSUED FOR
REVIEW

0 160 320
1" = 160' FEET

REV.	YYYY-MM-DD	DESCRIPTION	DESIGNED	PREPARED	REVIEWED	APPROVED
B	2020-08-21	CLOSURE PLAN REVISION	AJD	AJD	JRP	DML
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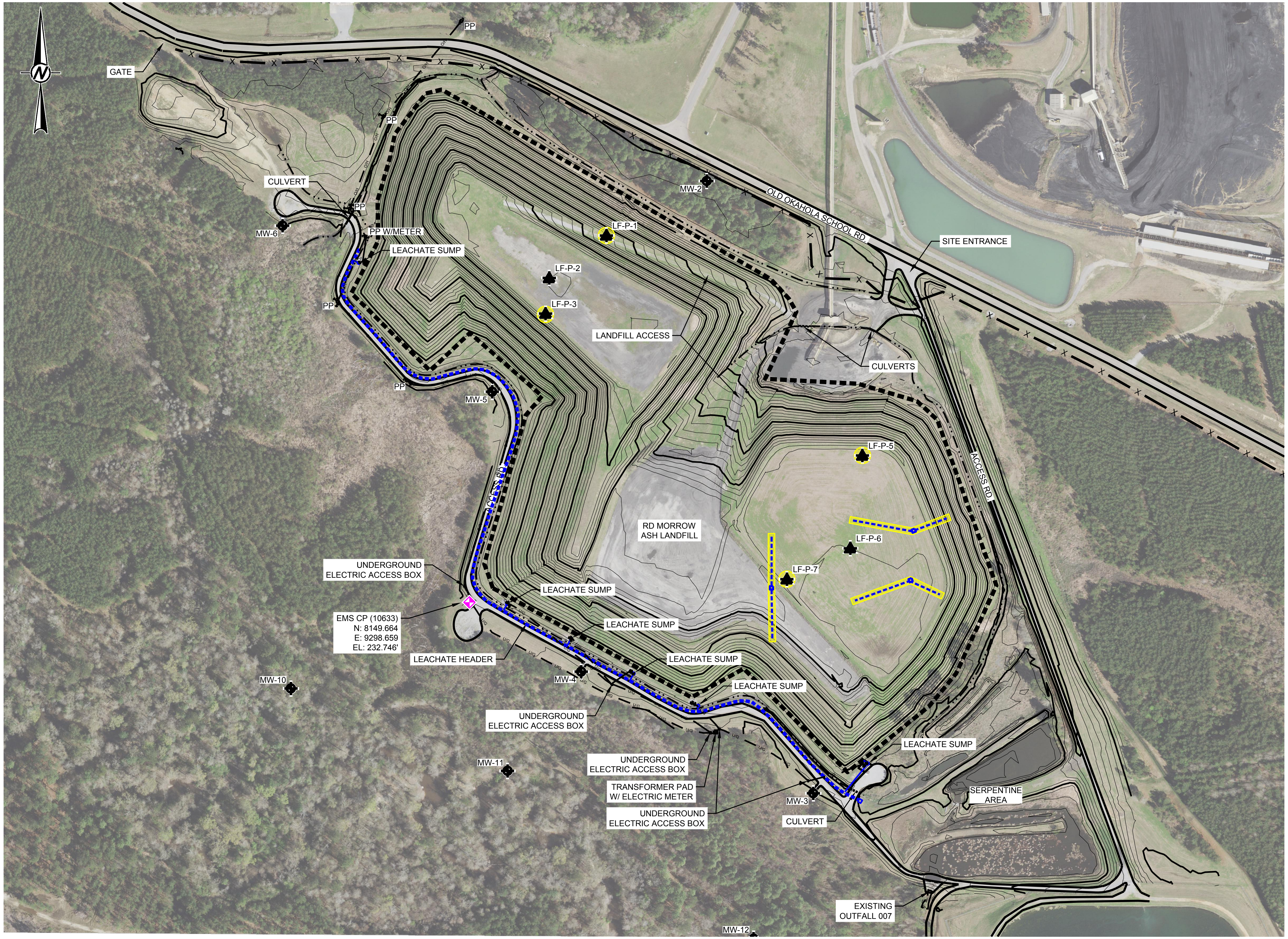
PROJECT
R.D. MORROW, SR. GENERATING STATION
PURVIS, LAMAR COUNTY, MISSISSIPPI
CCR LANDFILL CLOSURE PROJECT

TITLE
PERMIT BOUNDARY PLAN

PROJECT NO. 19117989 REV. B 2 of 8 SHEET 2



LEGEND

- EXISTING FENCE LINE
- EXISTING DRAINAGE DITCH
- EXISTING OVERHEAD ELECTRIC LINE
- EXISTING UNDERGROUND ELECTRIC LINE
- 260 — EXISTING SURFACE TOPOGRAPHY (10 FT INTERVAL)
- EXISTING SURFACE TOPOGRPAHY (2 FT INTERVAL)
- SOLID WASTE BOUNDARY
- EXISTING MONITORING WELL LOCATION
- EXISTING PIEZOMETER LOCATION
- EXISTING LEACHATE COLLECTION SYSTEM
- DEMOLITION / ABANDONMENT

REFERENCE(S)

COORDINATE SYSTEM:
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HORIZONTAL: PLANT-BASED DATUM.

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A	2020-04-03	CLOSURE PLAN	AJD	AJD	JRP	DML

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PROJECT
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CCR LANDFILL CLOSURE PROJECT

TITLE
EXISTING CONDITIONS

PROJECT NO. 19117989 | REV. B | 3 of 8 | SHEET 3

LEGEND

— x —	EXISTING FENCE LINE
— · · —	EXISTING DRAINAGE DITCH
— 260 —	EXISTING SURFACE TOPOGRAPHY (5 FT INTERVAL)
——	EXISTING SURFACE TOPOGRPAHY (1 FT INTERVAL)
⊕	EXISTING MONITORING WELL LOCATION
■ ■ ■	SOLID WASTE BOUNDARY
— 260 —	PROPOSED SURFACE TOPOGRAPHY (5 FT INTERVAL)
——	PROPOSED SURFACE TOPOGRAPHY (1 FT INTERVAL)
(yellow)	MICROSPIKE CLOSURE TURF AREA - AREAS GRADED AT 4% SLOPE (3D SURFACE AREA = 618,865.52 SF)
(green)	MICRODRAIN CLOSURE TURF AREA - AREAS BETWEEN 25% AND 33% (3D SURFACE AREA = 1,724,302.40 SF)
(cyan)	HYDROBINDER CLOSURE TURF AREA
(orange)	40 MIL LLDPE MICROSPIKE AREA (3D SURFACE AREA = 421,959.75 SF)
(grey)	ACCESS ROAD CLOSURE TURF AREA
(magenta line)	PROPOSED ANCHOR TRENCH
●	PROPOSED LEACHATE CONTROL WELL
(red line)	PROPOSED 3-INCH FUSION WELDED HDPE PIPE
(orange line)	PROPOSED 6-INCH FUSION WELDED HDPE PIPE

NOTE(S)

1. SOUTHERN AND NORTHERN TOP DECK SURFACES WILL BE A MINIMUM 4.0 PERCENT GRADE BUT MAY BE RAISED/LOWERED AS NEEDED TO ACCOMMODATE CCR FROM SURFACE IMPOUNDMENT CLOSURE.

REFERENCE(S)

COORDINATE SYSTEM:
VERTICAL: PLANT-BASED DATUM, NAVD88.
HORIZONTAL: PLANT-BASED DATUM.

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0 150 300
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PURVIS, LAMAR COUNTY, MISSISSIPPI
CCR LANDFILL CLOSURE PROJECT

TITLE
CLOSURE PLAN

PROJECT NO. 19117989 | REV. B | 4 of 8 | SHEET 4

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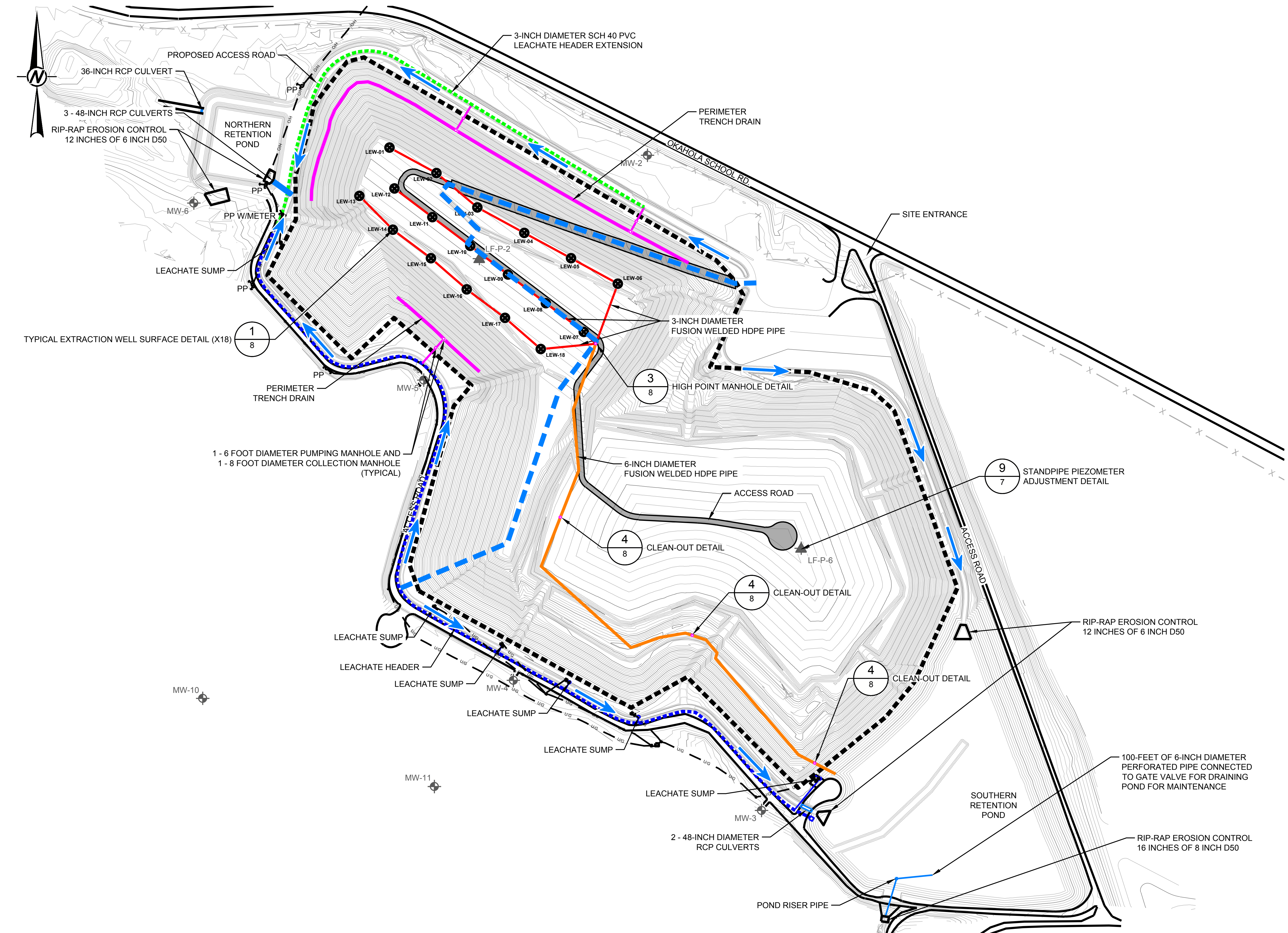

LEGEND

— x —	EXISTING FENCE LINE
— · · —	EXISTING DRAINAGE DITCH
— 260 —	FINISHED SURFACE TOPOGRAPHY (5 FT INTERVAL)
———	FINISHED SURFACE TOPOGRPAHY (1 FT INTERVAL)
⊕	EXISTING MONITORING WELL LOCATION
▲	EXISTING PIEZOMETER LOCATION
■ ■ ■	SOLID WASTE BOUNDARY
······	EXISTING 6-INCH PVC LEACHATE HEADER
······	PROPOSED LEACHATE HEADER EXTENSION
———	PROPOSED PERIMETER TRENCH DRAIN
○	PROPOSED SUMP LOCATION
●	PROPOSED LEACHATE CONTROL WELL
———	PROPOSED 3-INCH FUSION WELDED HDPE PIPE
———	PROPOSED 6-INCH FUSION WELDED HDPE PIPE
— — —	STORMWATER DRAINAGE DIVIDE
→	STORMWATER DRAINAGE FLOW DIRECTION

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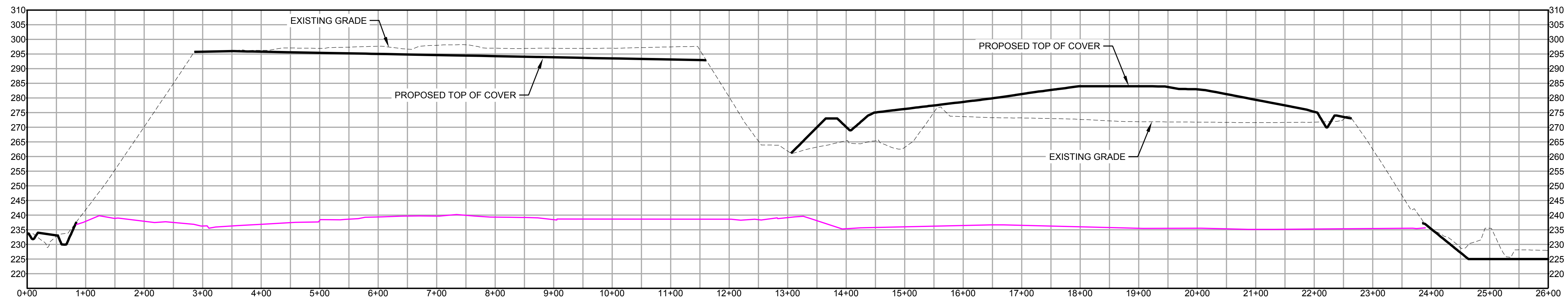
PURVIS, LAMAR COUNTY, MISSISSIPPI
CCR LANDFILL CLOSURE PROJECT

TITLE
FINAL RESTORATION PLAN

PROJECT NO.	REV.		SHEET
19117989	B	5 of 8	5

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI D

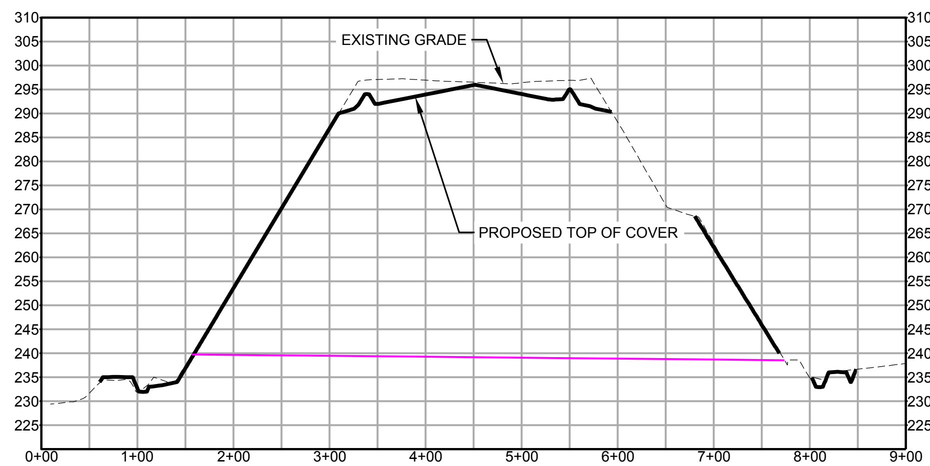
0 1 in



HOR. SCALE: 1"=100'
VER. SCALE: 1"=20'
A / 10 CROSS SECTION A-A'

LEGEND

- EXISTING GROUND SURFACE
- PROPOSED SURFACE
- LANDFILL LINER



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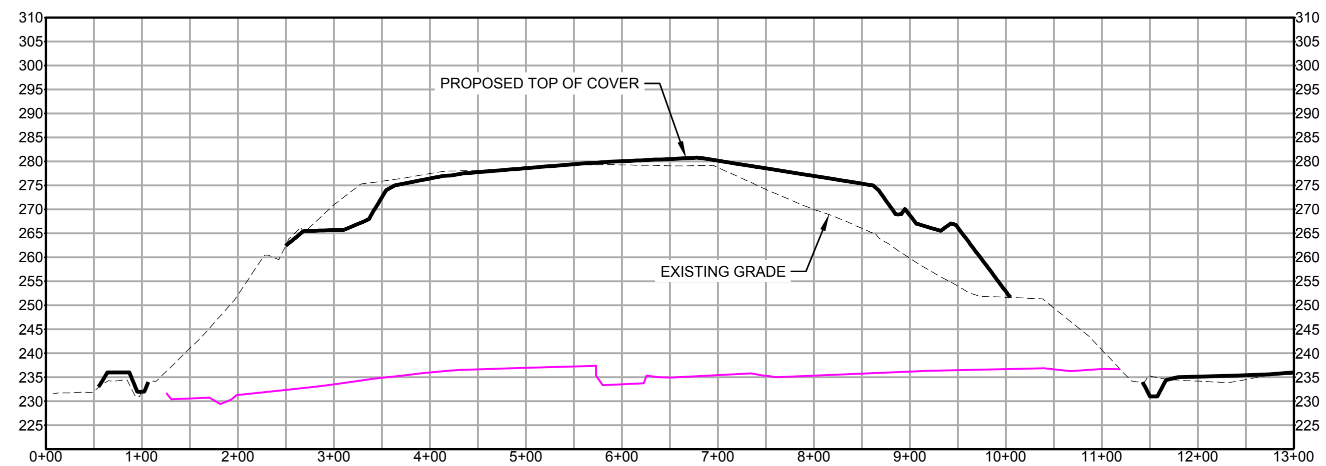

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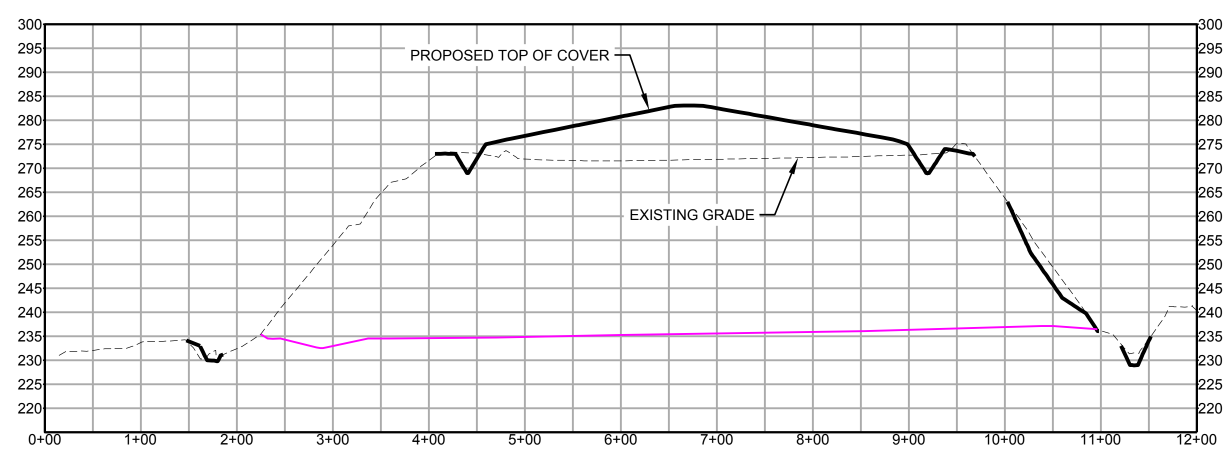
VER. SCALE: 1"=20'
C / 10 CROSS SECTION C-C'



HOR. SCALE: 1"=100'
VER. SCALE: 1"=20'
D / 10 CROSS SECTION D-D'

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0 20 40
1" = 20' FEET

0 100 200
1" = 100' FEET

REV.	YYYY-MM-DD	DESCRIPTION	DESIGNED	PREPARED	REVIEWED	APPROVED
B	2020-08-21	CLOSURE PLAN REVISION	AJD	AJD	JRP	DML
A	2020-04-03	CLOSURE PLAN	AJD	AJD	JRP	DML

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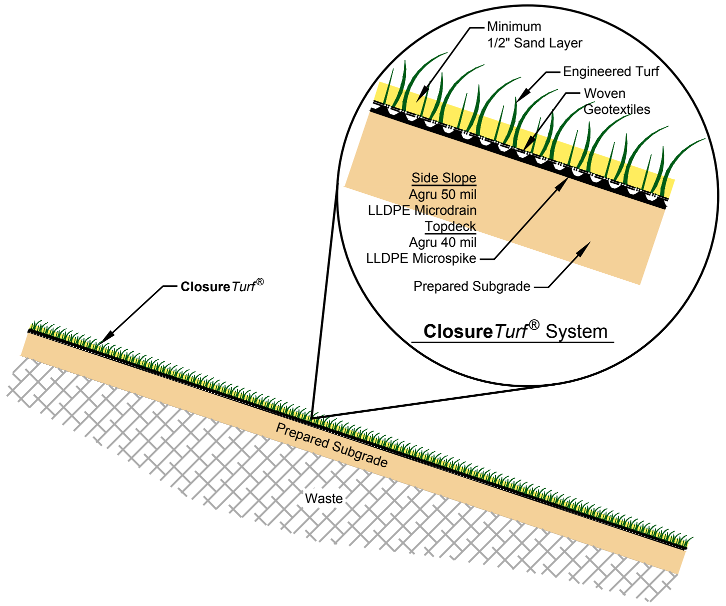
PURVIS, LAMAR COUNTY, MISSISSIPPI
CCR LANDFILL CLOSURE PROJECT

TITLE
CROSS SECTIONS

PROJECT NO.	REV.		SHEET
19117989	B	6 of 8	6



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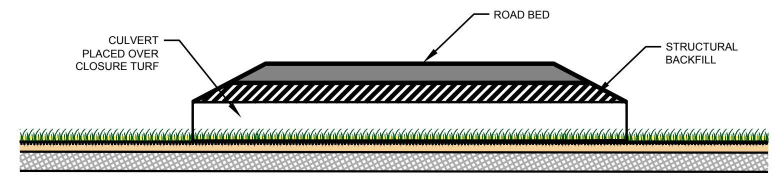
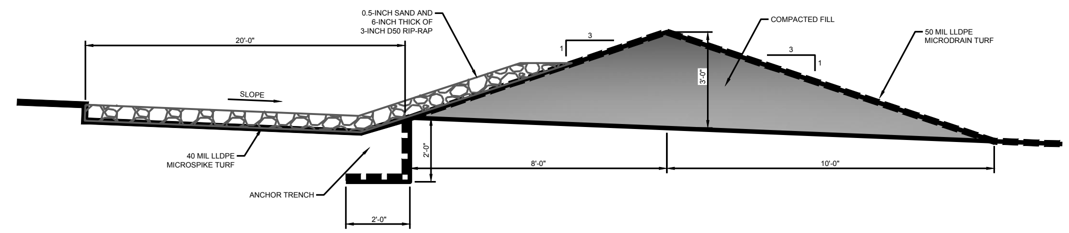
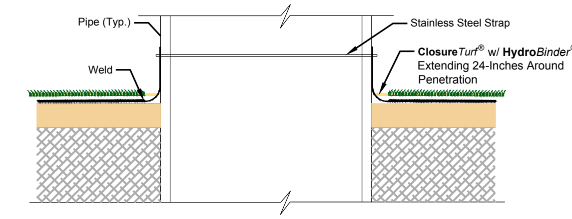


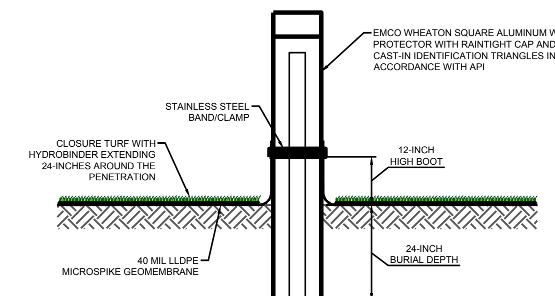
SCALE: NTS 4/7 CLOSURE TURF CULVERT DETAIL



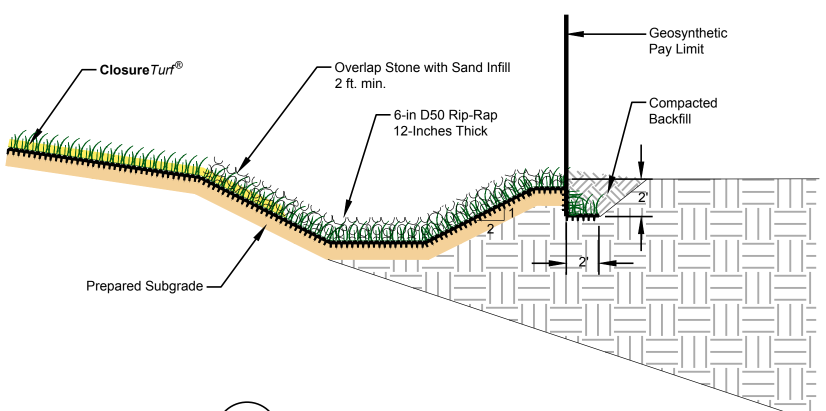
SCALE: NTS 5/7 STORMWATER TOPDECK DIVERSION BERM DETAIL



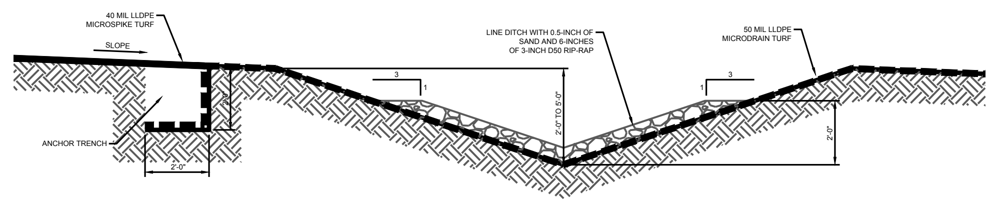
SCALE: NTS 8/7 TYPICAL PIPE BOOT DETAIL



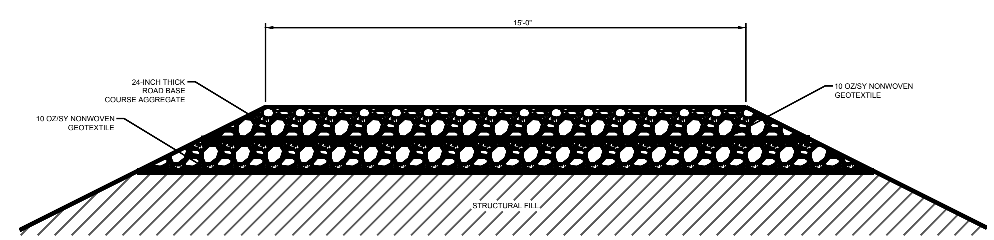
SCALE: NTS 9/7 STANDPIPE PIEZOMETER ADJUSTMENT DETAIL



SCALE: NTS 2/7 CLOSURE TURF WITH RIP RAP SECTION

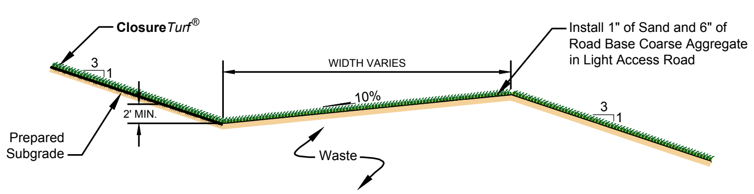


SCALE: NTS 6/7 STORMWATER TOPDECK DRAINAGE DITCH DETAIL

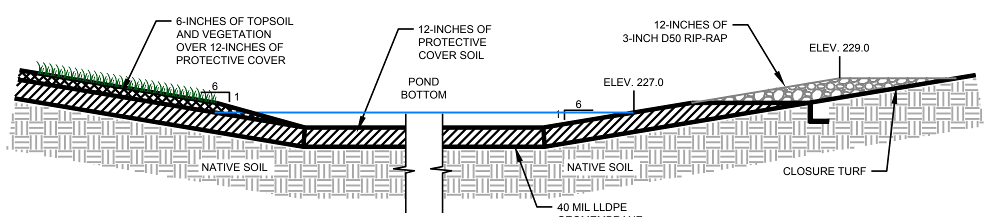


PERCENT PASSING	
SIEVE SIZE	ROAD BASE COURSE AGGREGATE
3"	100
1"	100
3/8"	60-80
No. 8	25-60
No. 4	-
No. 100	-
No. 200	9-16

SCALE: NTS 10/7 ACCESS ROAD DETAIL



SCALE: NTS 3/7 CLOSURE TURF LIGHT ACCESS ROAD SECTION



SCALE: NTS 7/7 POND COVER DETAIL

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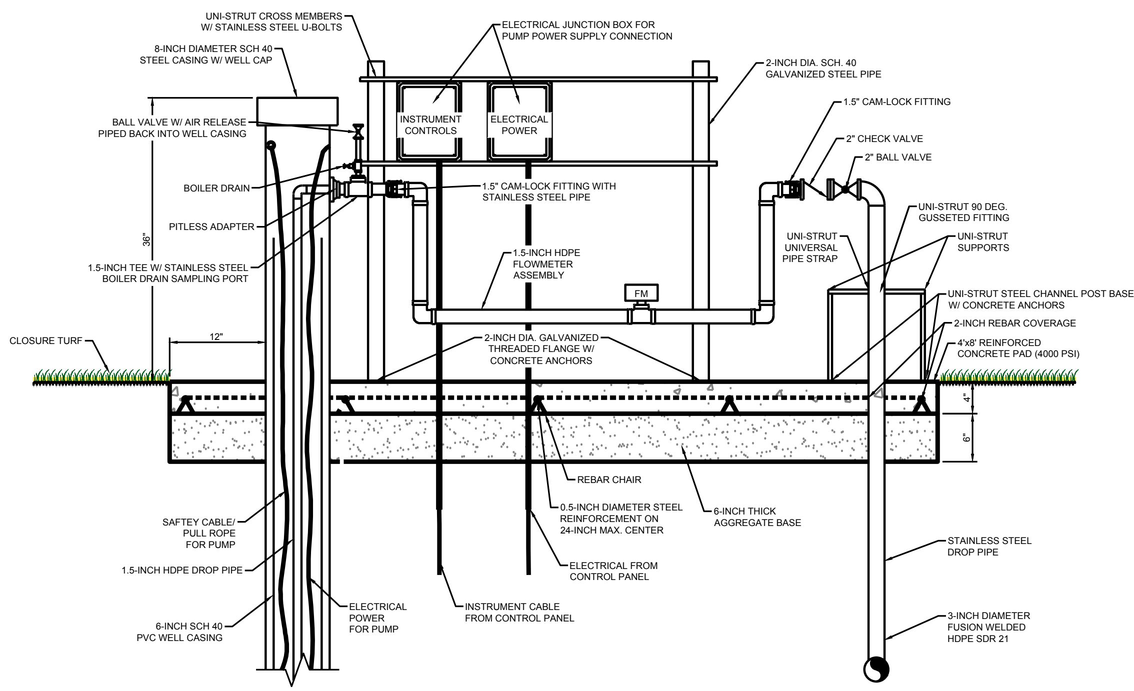
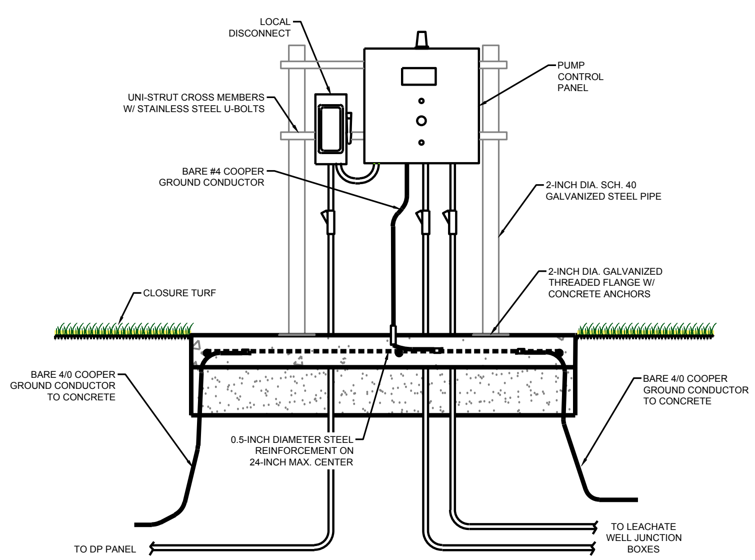
PURVIS, LAMAR COUNTY, MISSISSIPPI
CCR LANDFILL CLOSURE PROJECT

TITLE
CLOSURE DETAILS

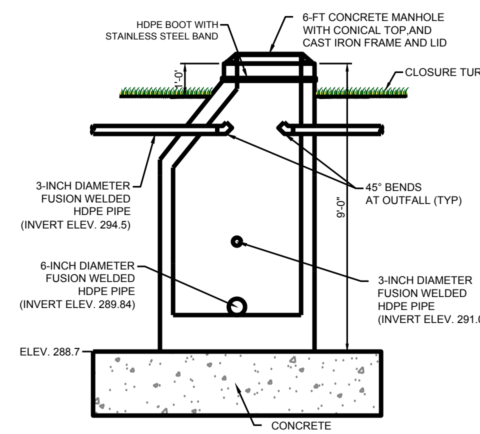
PROJECT NO. 19117989 REV. B 7 of 8 SHEET 7



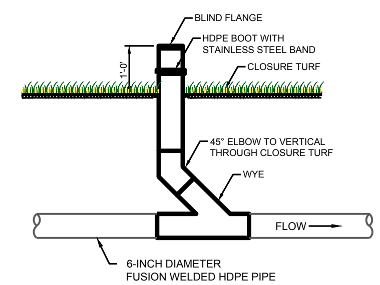
SCALE: NTS (1/8) TYPICAL EXTRACTION WELL SURFACE DETAIL
SECTION VIEW



SCALE: NTS (2/8) TYPICAL EXTRACTION WELL SURFACE DETAIL
SECTION VIEW

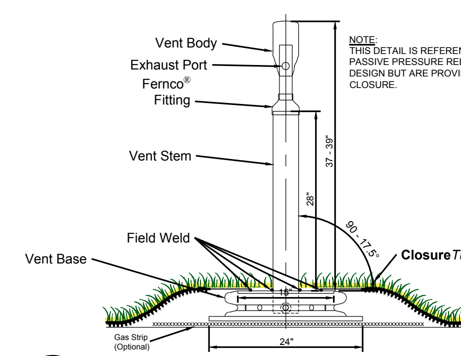


SCALE: NTS (3/8) HIGHPOINT MANHOLE DETAIL



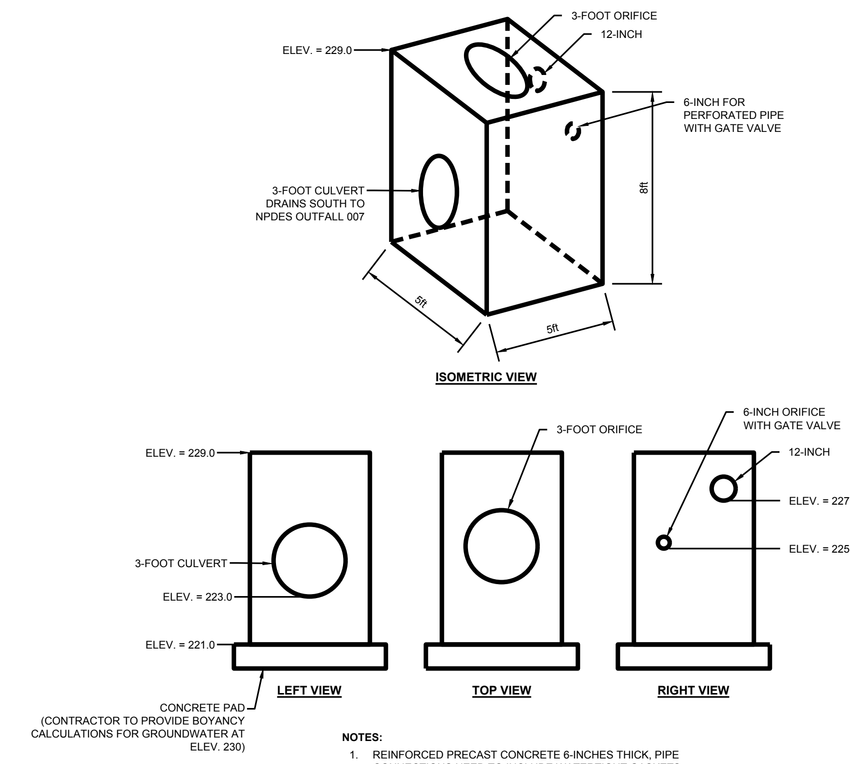
NOTE:
PLACE CLEAN-OUT EVERY 500-FEET ALONG 6-INCH WELDED HDPE PIPE ALIGNMENT.

SCALE: NTS (4/8) CLEAN-OUT DETAIL



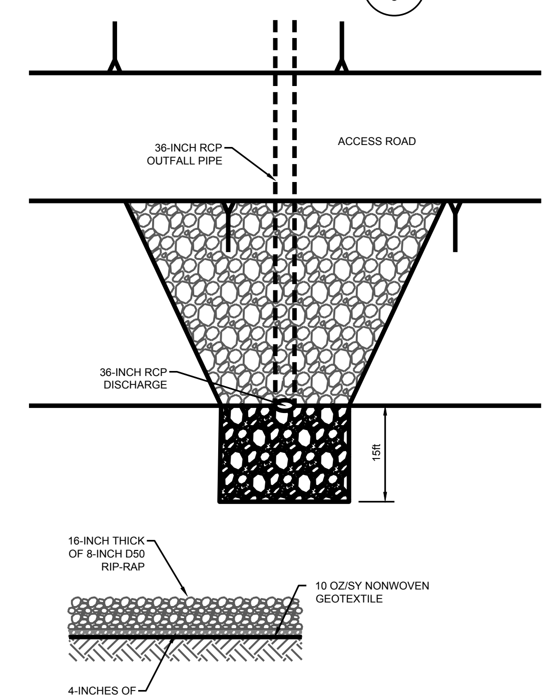
NOTE:
THIS DETAIL IS REFERENCED IN THE RD MORROW CCR LANDFILL POST-CLOSURE PLAN. PASSIVE PRESSURE RELIEF VALVES WILL NOT BE INCORPORATED INTO THE CLOSURE DESIGN BUT ARE PROVIDED IN THE EVENT GAS BUILDUP OCCURS DURING POST CLOSURE.

SCALE: NTS (5/8) PASSIVE PRESSURE RELIEF VALVE DETAIL



NOTES:
1. REINFORCED PRECAST CONCRETE 6-INCHES THICK, PIPE CONNECTIONS NEED TO INCLUDE WATERTIGHT GASKETS.

SCALE: NTS (6/8) POND RISER PIPE DETAIL



SCALE: NTS (7/8) OUTFALL DETAIL

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REV.	YYYY-MM-DD	DESCRIPTION	DESIGNED	PREPARED	REVIEWED	APPROVED
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PROJECT NO. 19117989 | REV. B | 8 of 8 | SHEET 8

APPENDIX B

Slope Stability Analysis

Slope Stability Analyses for the Proposed Closure Plan of R.D. Morrow Landfill

in Lamar County, Mississippi

Objective:

Analyze the short term seismic (psuedo-static) and long term static stability of the proposed closure conditions for Cooperative Energy (CoOp) R.D. Morrow Landfill in Lamar County, Mississippi.

Analysis Methods:

The static and psuedo-static stability of the proposed closure conditions for R.D. Morrow Landfill in Lamar County, Mississippi were evaluated using the computer program SLIDE Version 2018 8.032 (Rocscience, 2020). Generalized limit equilibrium method of stability analysis developed by Morgenstern and Price (Abramson et al., 2002) was utilized for the analysis. Block and circular search patterns were utilized to find failure surfaces that resulted in the minimum calculated factor of safety. Depending on the analyzed section, block search patterns were used to search for slip surfaces within a specific layer (e.g. CCR, sand-clay interface). The lowest factors of safety (FoS) were obtained for sliding block failure; therefore, discussion and results are only presented for sliding block failure mechanism.

Minimum required values of FoS for this analysis were taken as 1.5 for permanent loading conditions (short-term, undrained and long-term, drained) and 1.0 for temporary loading conditions (seismic, undrained), as recommended in the Naval Facilities Engineering Command Design Manual 7.01: Soil Mechanics (NAVFAC DM7.01, 1986). A seismic coefficient of 0.05 was included in the analysis to account for seismic loading. The seismic coefficient was determined using the USGS Unified Hazard Tool to generate a seismic hazard curve for the RD Morrow Landfill (USGS, 2020). A groundwater elevation of 220 feet was assumed outside of the landfill area increasing up to an elevation of 260 feet within the landfill area based on peizometer readings. This scenario represents the worst case groundwater scenario. All elevations presented are based on NAVD88.

Global slip surfaces or those impacting the crest of the slope were considered "Critical" surfaces that may compromise the stability of the impoundment. Shallow or surficial slip surfaces along the slope surface (i.e., not global or impacting the crest of the slope) with factors of safety lower than the "Critical" surface were often generated during the analyses; the shallow slip surfaces were considered "Non-Critical" and issues that could likely be addressed by maintenance (e.g. local regrading, riprap armoring, etc.). Both "Critical" and "Non-Critical" surfaces (as required) are shown on the stability output figures.

Analysis Sections:

One (1) cross-section (Section B) was selected to evaluate the stability for the RD Morrow Landfill. Section B is located through the steepest and longest proposed slopes, representing the critical section. Figure 1 provides an overview of the

Analysis Cases:

The following stability cases were analyzed for the current analysis:

- Proposed Fill Conditions - Short-term Strength Parameters (Undrained Conditions with Seismic)
- Proposed Fill Conditions - Short-term Strength Parameters (Undrained Conditions)
- Proposed Fill Conditions - Long-term Strength Parameters (Drained Conditions)

Material Properties:

The material properties used for this analysis are provided in the table below.

Material	Unit Weight (pcf)		Strength Properties		
	Dry	Saturated	Peak ϕ′ (°)	Cohesion (psf)	Undrained Shear Strength (psf)
CCR	85	100	30	-	-
Clay	110	130	29	-	2000
Silty Sand	115	120	34	-	-
Gravelly Clay	105	130	28	-	1600

Material properties including unit weight, friction angle, and cohesion were developed from correlations with SPT N-values and plasticity index provided in the NAVFAC DM7.01 and the Electric Power Research Institute Manual on Estimating Soil Properties for Foundation Design (EPRI, 1990). Strength parameters for the CCR (drained and undrained), clay (undrained), and gravelly clay (undrained) were based on UC, UU, and CU triaxial results provided in the 2014 Industrial Landfill Permit Application by Environmental Management Services, Inc. (EMS, 2014).

GOLDER	SUBJECT:	Stability Analyses - Closure Plan R.D. Morrow Landfill		
	Job No.:	19117989	Prepared:	MMJ
	Ref.:	CoopEnergy/RD Morrow LF Closure/MS	Checked:	JRP
	Date:	Mar-27-2020	Reviewed:	DML

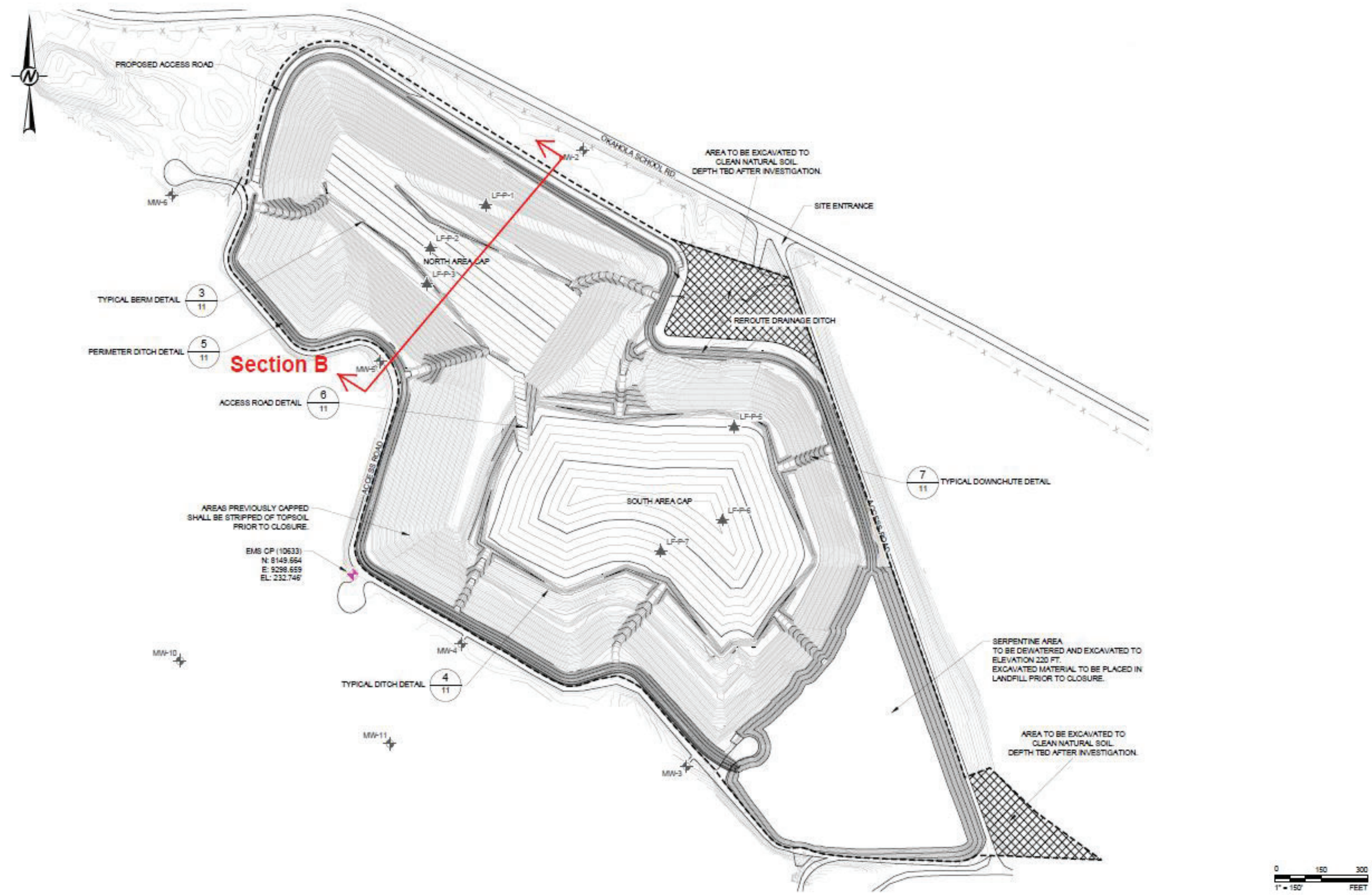
Summary of Stability Analyses Results

Section B

Analysis	Method	Calculated Value	Required FoS	Evaluation	Figure
PROPOSED CONDITIONS - 3H:1V side slopes (18.43 degrees)					
Pseudo-Static, Short-Term	Block	1.2	1.0	OK	1A
Static, Short-Term	Block	1.6	1.5	OK	1B
Static, Long-Term	Block	1.7	1.5	OK	1C

References:

1. Rocscience (2020), SLIDE Version 2018 8.032.
2. Abramson, L.W., T.S. Lee, S. Sharma, and G.M. Boyce (2002), Slope Stability and Stabilization Methods, 2nd edition, John Wiley & Sons, New York.
3. Naval Facilities Engineering Command (NAVFAC), 1986, Design Manual 7.01 (DM7.01): Soil Mechanics.
4. USGS, Seismic Hazard Curve for RD Morrow Landfill, generated using the Unified Hazard Tool from https://earthquake.usgs.gov/hazards/interactive/ on March 27, 2020.
5. Electric Power Research Institute (EPRI), 1990, Manual on Estimating Soil Properties for Foundation Design.
6. Environmental Management Services, Inc. (EMS, 2014, Industrial Landfill Permit Application for R.D. Morrow Sr. Generating Plant.



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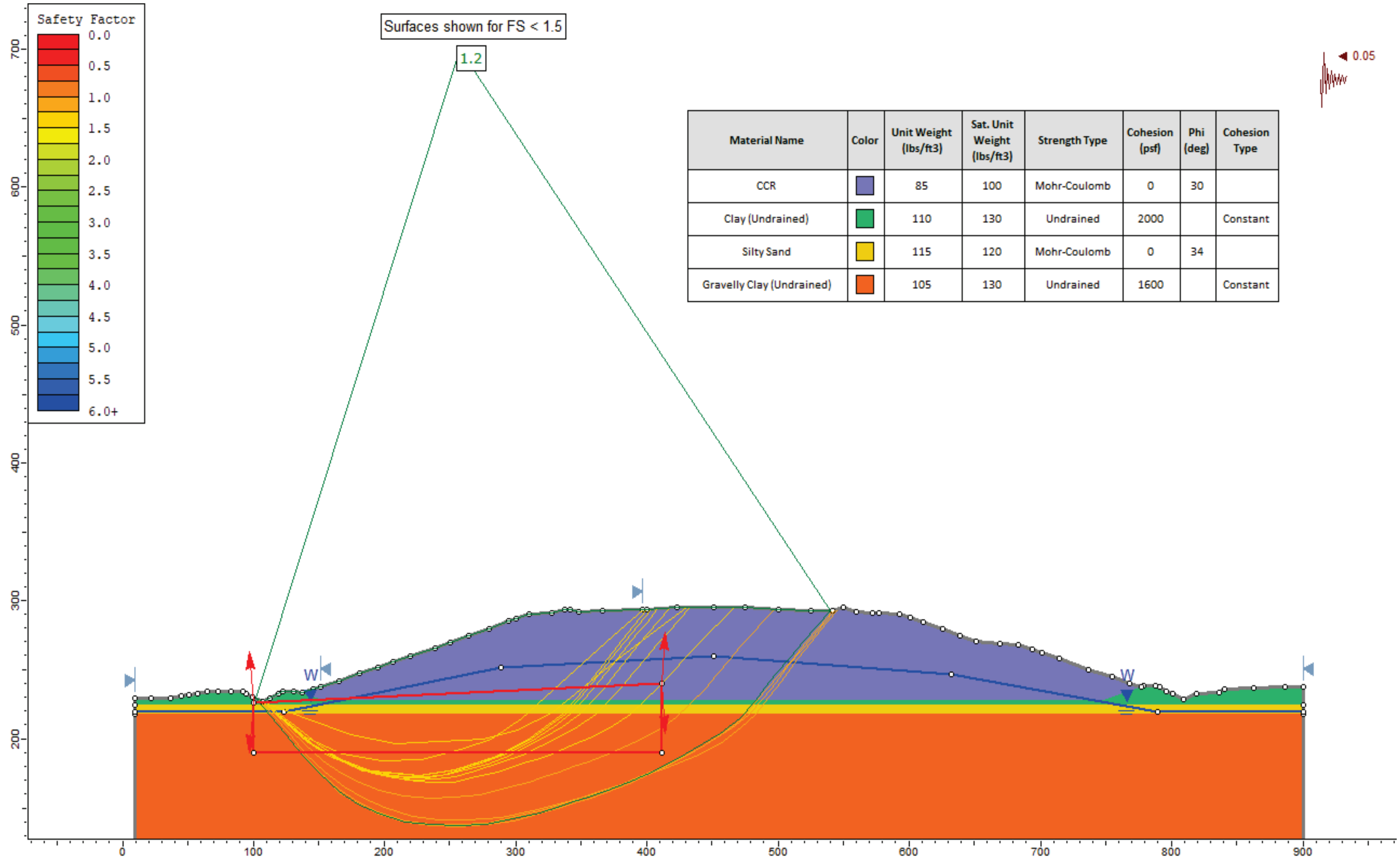
SCALE	AS SHOWN	TITLE	
DATE	Mar 2020		
MADE BY	MJ	**Stability Cross-Section Location Plan**	
CAD	AD		
FILE	STABILITY	CHECK	JP
PROJECT No.	19117989	REV.	0
REVIEW	DL	**Cooperative Energy**	FIGURE 1



Material Name	Color	Unit Weight (lbs/ft3)	Sat. Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Cohesion Type
CCR		85	100	Mohr-Coulomb	0	30	
Clay (Undrained)		110	130	Undrained	2000		Constant
Silty Sand		115	120	Mohr-Coulomb	0	34	
Gravelly Clay (Undrained)		105	130	Undrained	1600		Constant

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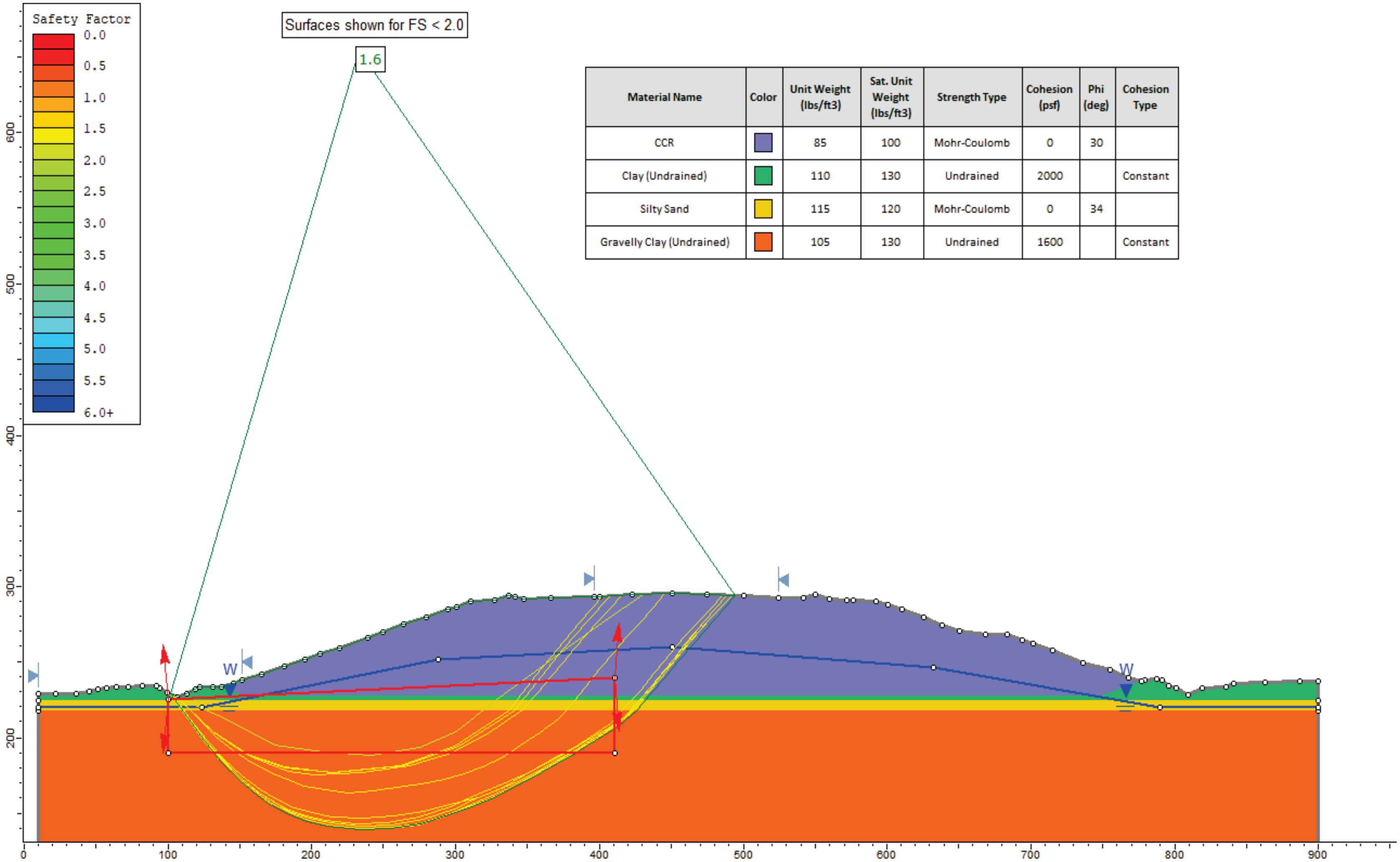
DATE	Mar 2020
MADE BY	MJ
CAD	AD
CHECK	JP
REVIEW	DL
FILE	STABILITY
PROJECT No.	19117989
REV.	0

TITLE

Section B - Pseudo-Static, Short-Term (Undrained) Conditions - Block Failure Search

Cooperative Energy

FIGURE **1A**



Material Name	Color	Unit Weight (lbs/ft3)	Sat. Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Cohesion Type
CCR		85	100	Mohr-Coulomb	0	30	
Clay (Undrained)		110	130	Undrained	2000		Constant
Silty Sand		115	120	Mohr-Coulomb	0	34	
Gravelly Clay (Undrained)		105	130	Undrained	1600		Constant

GOLDER

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DATE	Mar 2020
MADE BY	MJ
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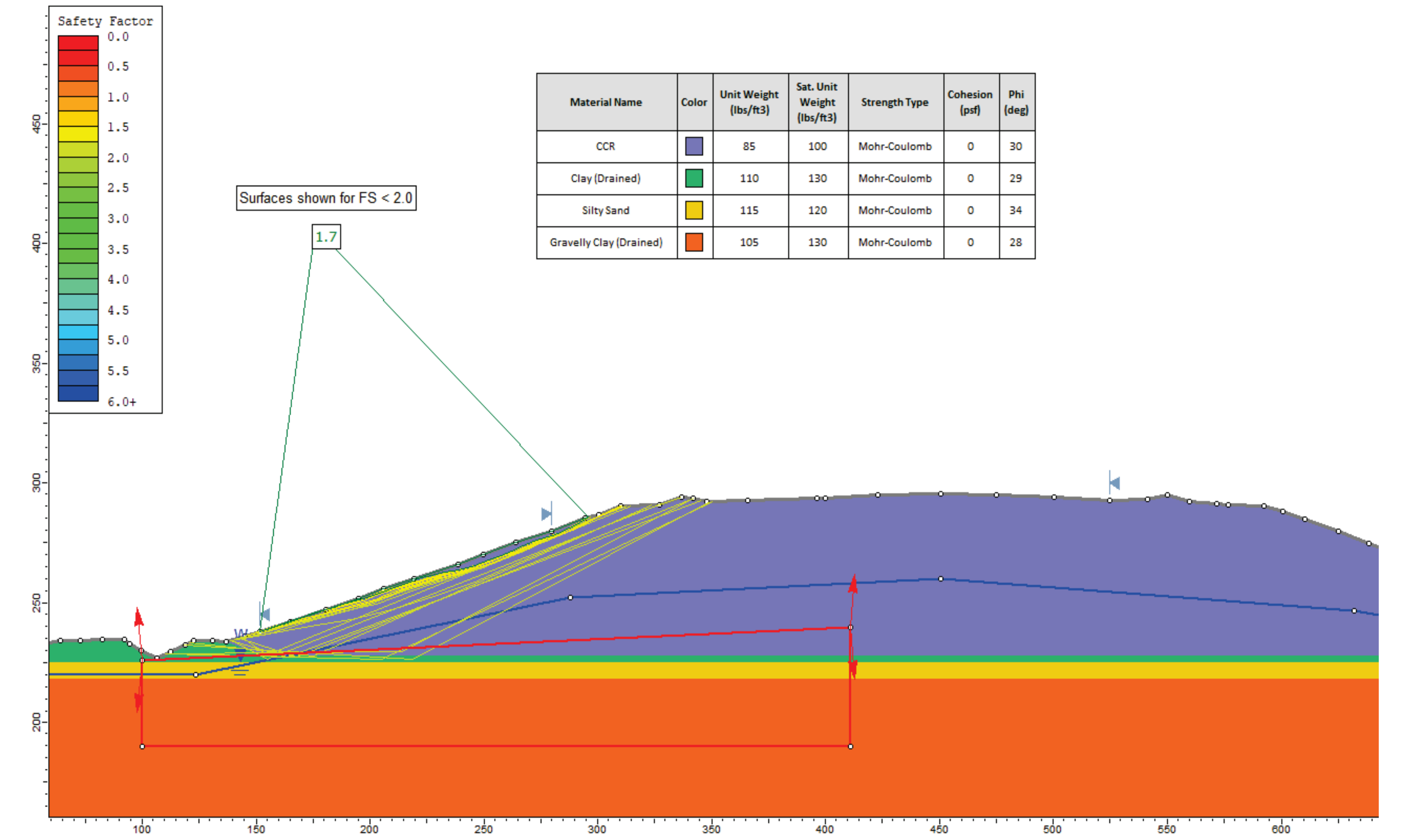
CHECK	JP
REVIEW	DL
FILE	STABILITY
PROJECT No.	19117989
REV.	0

TITLE

Section B - Static, Short-Term (Undrained) Conditions - Block Failure Search

Cooperative Energy

FIGURE **1B**



Material Name	Color	Unit Weight (lbs/ft3)	Sat. Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)
CCR		85	100	Mohr-Coulomb	0	30
Clay (Drained)		110	130	Mohr-Coulomb	0	29
Silty Sand		115	120	Mohr-Coulomb	0	34
Gravelly Clay (Drained)		105	130	Mohr-Coulomb	0	28

GOLDER

Golder Associates Inc.

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DATE	Mar 2020
MADE BY	MJ
CAD	AD
CHECK	JP
REVIEW	DL
FILE	STABILITY
PROJECT No.	19117989
REV.	0

TITLE

Section B - Static, Long-Term (Drained) Conditions - Block Failure Search

Cooperative Energy

FIGURE **1C**

R.D. Morrow Landfill Final Cover Stability Veneer Analysis

Objective:

Analyze the long-term stability of the final cover system considering long term normal load shear strengths with regards to wedge/block failure and sliding within the ClosureTurf cover system.

The proposed ClosureTurf cover system consists of (from top to bottom):

- 2-inch thick artificial turf
- 0.5-inch thick sand infill layer (protective cover soil)
- 50-mil thick Linear Low Density Polyethylene (LLDPE) textured geomembrane with 130-mil thick drainage studs acting as an internal drainage layer

Proposed Landfill Geometry:

$\beta := 18.43\ deg$ 3H:1V side slope

$L := 178\ ft$ Longest drainage path along 3H:1V slope

$H := L \cdot \sin(\beta)$

$H = 56.274\ ft$ Slope height based on longest drainage path and 3H:1V slope

Material Properties and Assumptions:

$\gamma_w := 62.4\ pcf$ Unit weight of water

$\gamma := 150\ pcf$ Unit of weight sand infill layer assuming specific gravity of 2.4

$c := 0\ psf$ Cohesion of cover soil, set to zero as cover soil will be composed of sand

$z_c := 0.5\ in$ Thickness of sand infill layer

$d_w := 0.5\ in$ Depth to water table, set equal to sand infill thickness such that z_c - d_w = 0 to represent unsaturated conditions

Veneer Analysis- Minimum Required Interface Friction Angle for Unsaturated Static Conditions

$n_g := 0$ Peak horizontal ground acceleration, set to zero for static conditions

$FS := 1.5$ Minimum required factor of safety for cover stability

$$\phi_{req} := \operatorname{atan}\left(\left(\left(FS \cdot \left(n_g + \tan(\beta)\right)\right) - \left(\frac{c}{\gamma \cdot z_c \cdot \cos(\beta)^2}\right)\right) \div \left(\left(1 - \frac{\left(\gamma_w \cdot \left(z_c - d_w\right)\right)}{\gamma \cdot z_c}\right) - \left(n_g \cdot \tan(\beta)\right)\right)\right)$$

$\phi_{req} = 26.558\ deg$

Results of direct shear testing performed on the MicroDrain geomembrane and site-specific CCR (see attached) show that the interface friction angle is 36.2 degrees, which exceeds the minimum required friction angle calculated above based on FS = 1.5.

Reference: Geotechnical Resource Group, 2004. Geotechnical and Stability Analyses for Ohio Waste Containment Facilities. Ohio Environmental Protection Agency.

Attachment - Interface Shear Strength Test (MicroDrain against Ash Subgrade)

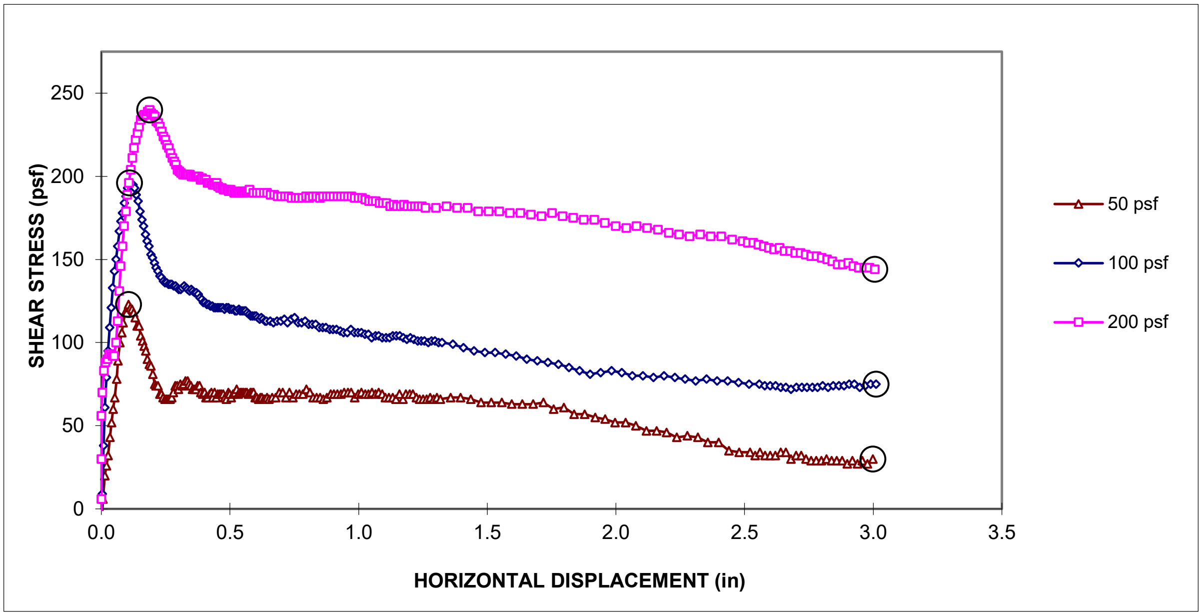
JANUARY 2020 19117989

DIRECT SHEAR TEST RESULTS

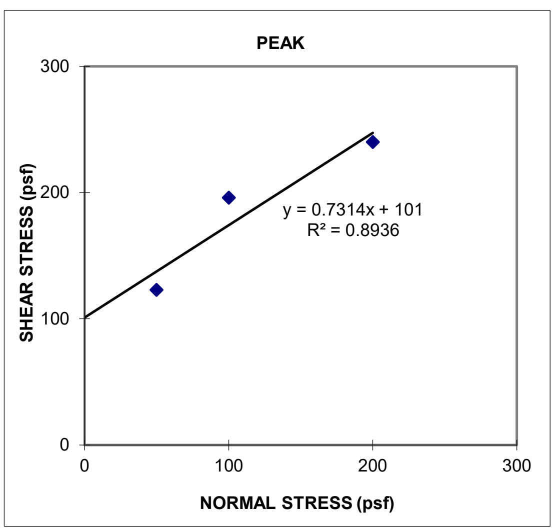
ASTM D5321

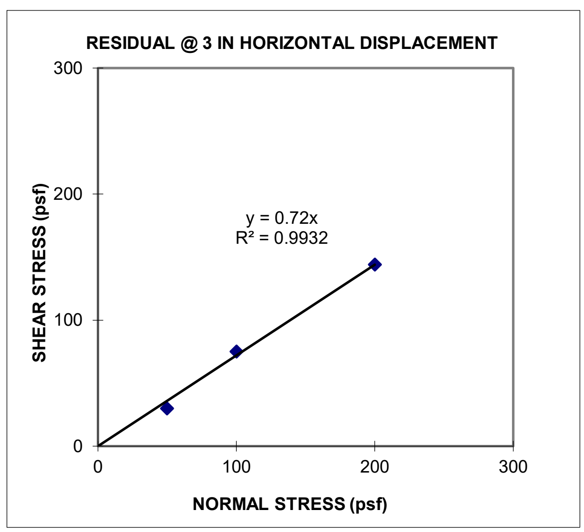
PROJECT NAME: COOP NRG/RD MORROW GENR PLANT/MS
SAMPLE NUMBER: DSHR -1

INTERFACE TESTED: AGRU 50 mil LLDPE MICRODRAIN GEOMEMBRANE (Microspike side)(GTA0032990007) vs ASH
SOIL CONDITIONS: PLACED AT A DRY DENSITY OF 66 pcf AT THE AS-RECEIVED MOISTURE CONTENT OF 23.9%
TEST CONDITIONS: INTERFACE WETTED, SEAT TIME OF 15 min AT THE NORMAL LOAD
SHEAR RATE: 0.04 in/min
SUBSTRATE: TEXTURED RIGID PLATES



Normal Stress (psf)	Shear Stress Peak[1] (psf)	Shear Stress Residual (psf)	Peak Friction Angle	Peak Adhesion[2] (psf)	Residual Friction Angle	Residual Adhesion[2] (psf)
50	123	30				
100	196	75	36.2	101	35.8	0
200	240	144				





Observations After Test

50 psf Shearing occurred between the Geomembrane and the Ash
100 psf: Shearing occurred between the Geomembrane and the Ash
200 psf: Shearing occurred between the Geomembrane and the Ash

(1) The peak shear stresses for 50, 100, and 200 psf normal stresses were chosen at 0.106, 0.109, and 0.187 in horizontal displacements, respectively.
(2) The adhesion value is based on the "best-fit" line which may not show true adhesion.

Golder Associates Inc.

June 5th, 2020

Technical Note

Hydraulic Shear Stress Calculations of ClosureTurf® Sand Infill
R.D. Morrow, Sr. Generating Station CCR Landfill Closure Project

This technical note is prepared by Watershed Geosynthetics® (Watershed Geo®) at the request of Golder Associates (Golder) in support of the R.D. Morrow, Sr. Generating Station (Plant Morrow) CCR landfill closure project located in Purvis, Lamar County, Mississippi. More specifically, the purpose of the technical note is to present the hydraulic shear stress calculations of the ClosureTurf sand infill. The calculation results indicate that the use of a specified sand infill with enhanced hydraulic performance provides sufficient erosion resistance and therefore, no binder additive (ArmorFill® or HydroBinder®) or additional erosion protection is required for the proposed ClosureTurf final cover, except for the stormwater downchutes and drainage ditches/channels.

Analysis Scenarios

Based on the final cover grading plan provided by Golder, three drainage scenarios are analyzed that represent the maximum drainage paths on the landfill top deck and side slope areas with varying slopes, as illustrated in Figure 1-1 of Attachment 1:

- Scenario 1: the top deck with a 4% slope and an estimated drainage length of approximately 275 ft. The proposed geomembrane component of ClosureTurf on the top deck is MicroSpike®.

- Scenario 2: a 4H:1V side slope with an estimated drainage length of approximately 250 ft. The proposed geomembrane component of ClosureTurf on the side slope is MicroDrain®.

- Scenario 3: a 3H:1V side slope with an estimated drainage length of approximately 172 ft. The proposed geomembrane component of ClosureTurf on the side slope is MicroDrain®.

It is noted that, according to the grading plan, the stormwater runoff from the top deck of the landfill does not continue onto the side slopes due to the construction of diversion berms that carry runoff from the top deck to several downchutes.

For each scenario, the maximum hydraulic shear stress in the sand infill is calculated and compared with the critical hydraulic shear stress selected based on hydraulic performance tests of ClosureTurf, as discussed in the following sections.

Hydraulic Performance of Enhanced Sand Infill

Manufactured Sand

Watershed Geo® has evaluated the use of manufactured sand as infill material to enhance the erosion resistance of ClosureTurf®. A manufactured sand is typically more angular and contains a higher percentage of coarser particles than a typical ASTM C 33 (C-33) sand, which was previously specified as the infill material. Though sometimes meeting the C-33 fine aggregate standard, a manufactured sand gradation curve may fall outside the C-33 gradation range. A photo of a manufactured sand sample is shown in Figure 1. For visual comparison, the photo of a C-33 concrete sand sample is shown below too.

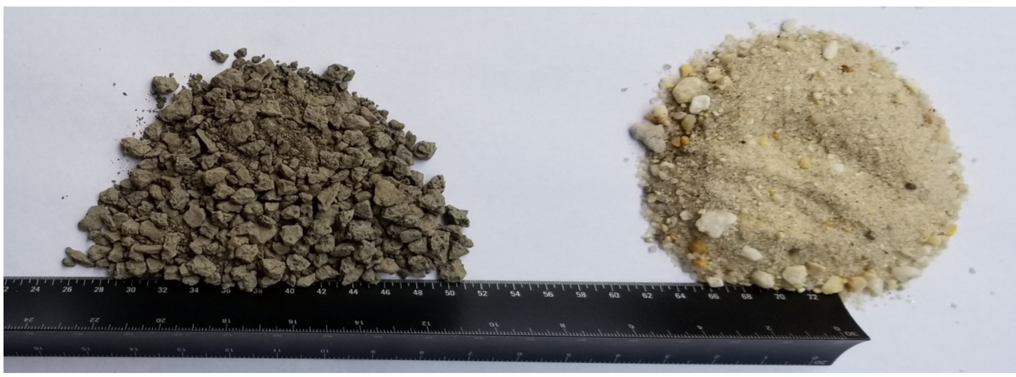


Figure 1. Manufactured Sand Sample vs. C-33 Concrete Sand Sample
(Note: Photos are for illustrative purposes only; actual infill for projects may vary depending on the sources.)

Hydraulic Performance Testing

Channel flow testing was conducted in January 2019 by TRI Environmental at the Denver Downs Research Facility in South Carolina on ClosureTurf with a manufactured sand in accordance with ASTM D 6460, *Standard Test Method for Determination of Rolled Erosion Control Product (RECP) Performance in Protecting Earthen Channels from Stormwater-Induced Erosion*. The test report is included as Attachment 2. The engineered turf used in the tests was denoted as CT32 in the report and the tests were performed with two types of geomembrane, Super Gripnet® and MicroSpike®. The test results for CT32/Super Gripnet and CT32/MicroSpike indicated that the manufactured sand withstood a shear stress of approximately 0.8 psf with 0.01 to 0.04-inch sand infill loss and approximately 1.4 psf with 0.11 to 0.18-inch sand infill loss. It is noted that the minimum required sand infill thickness of ClosureTurf is 0.5 inches. The test results for Super Gripnet are applicable to MicroDrain® because they have the same top-facing drainage stud surface.

Additional hydraulic tests were conducted at the TRI Environmental Denver Downs Research Facility to further investigate the hydraulic performance criteria and develop the technical specification for the enhanced sand infill. Detailed descriptions of the test procedures and results are provided in Attachment 3. Six sand samples were tested, and the measured sand infill loss is plotted as a function of hydraulic shear stress in Figure 2. The test results indicate less than 0.05-inch sand infill loss at a shear stress of approximately 0.8 psf and less than 0.1-inch sand infill loss at a shear stress of approximately 1.4 psf, which are consistent with the test results discussed in the section above.

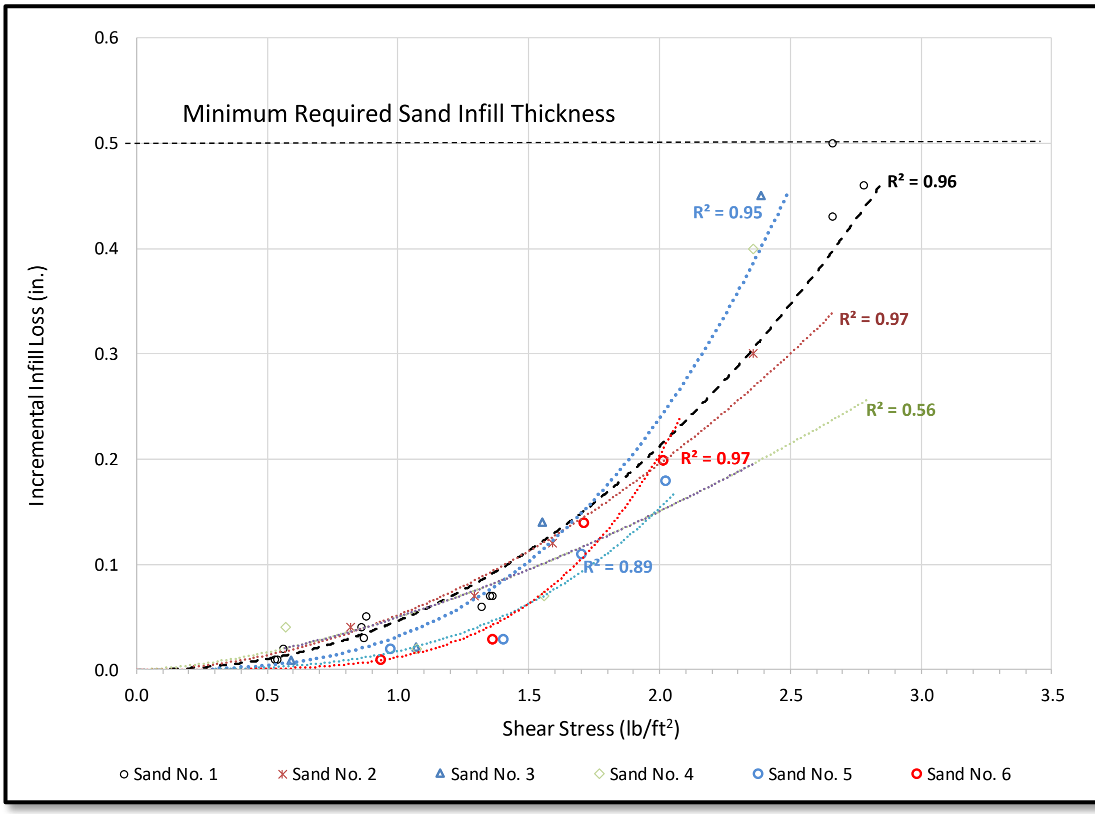


Figure 2. Measured Sand Infill Loss vs. Hydraulic Shear Stress

<u>Sand Infill Specification</u>

Watershed Geo®'s current sand infill specification has been developed based on the results of extensive hydraulic performance tests provided in Attachments 2 and 3. The specification, which is provided in Attachment 4, includes requirements of angularity, specific gravity, grain size distribution and conformance tests of the sand infill component of ClosureTurf®. For a sand infill that meets this specification, a shear stress of 0.8 psf was conservatively selected as the critical hydraulic shear stress for evaluation of maximum drainage length and potential sand infill movement.

Hydraulic Shear Stress Calculations

Detailed calculations utilizing site specific parameters to estimate the maximum hydraulic shear stress from rainfall runoff are provided as Attachment 1. The 100-year, 1-hour rainfall intensity is used in the calculations, which is estimated to be 4.33 inches/hour at the site. A sand infill that meets the specification in Attachment 4 is required to be used for this project. The calculation results are summarized in Table 1.

Table 1. Summary of Calculation Results

Analysis Scenario	Type of Geomembrane	Calculated Max. Hydraulic Shear Stress (psf)	Selected Critical Hydraulic Shear Stress (psf)	Hydraulic Shear Stress (Pass or Fail)
Scenario 1: Top deck with a slope of 4% and drainage length of ~275 ft.	MicroSpike®	0.24	0.8	Pass
Scenario 2: Side Slope with a 4H:1V slope and drainage length of ~250 ft.	MicroDrain®	0.38		Pass
Scenario 3: Side Slope with a 3H:1V slope and drainage length of ~172 ft.	MicroDrain®	0.18		Pass

The calculation results indicate that the calculated maximum hydraulic shear stresses for the three analysis scenarios are less than the selected critical hydraulic shear stress of ClosureTurf® with the enhanced sand infill.

It should be noted that the calculations presented in this technical note do not apply to the stormwater downchutes, top deck drainage ditches, or perimeter drainage channels, where concentrated water flow will occur. According to the engineering design drawings provided by Golder, HydroBinder®, a cementitious infill for ClosureTurf, is specified for the downchutes and riprap is specified for the top deck drainage ditches and perimeter drainage channels.

Remarks

The evaluation presented in this technical note demonstrates that no binder additive (ArmorFill® or HydroBinder®) or additional erosion protection is required for the proposed ClosureTurf final cover for the Plant Morrow CCR Landfill, except for the stormwater downchutes and drainage ditches/channels, as a result of the enhanced hydraulic performance of sand infill in accordance with Watershed Geo®'s current sand specification included in Attachment 4. It should be noted that localized sand movement may occur due to potential irregularity of water flow pattern, breaks in landfill grades, waste differential settlement/depression, landfill gas uplifting, and/or wrinkling of ClosureTurf®. Localized sand movement, if it occurs and causes exposure of the geotextile backing of ClosureTurf, can be repaired using ArmorFill® or HydroBinder® during post-closure maintenance.

A similar evaluation was performed for a confidential CCR landfill in North Carolina in February 2019, which has a side slope of 3H:1V with a maximum drainage slope length of approximately 145 ft. The original ClosureTurf final cover design was based on Watershed Geo's previous C-33 sand specification. ArmorFill was specified for the lower 20-ft section of the side slope to provide additional erosion protection of the sand infill. Removal of ArmorFill was approved by the design engineer after the hydraulic evaluation demonstrated that the enhanced sand infill provided sufficient hydraulic shear resistance. Construction of Phase 1 of ClosureTurf was completed in May 2020 and the site experienced multiple significant rain events during construction, including Hurricane Dorian in September 2019. Field observations indicated that the enhanced sand infill had performed as expected with minimal movement.

More recently, another evaluation was performed in December 2019 for the Lemons Sanitary Landfill located in Dexter, Missouri. The maximum drainage path included approximately 215 ft of the top deck with a 10% slope connecting to approximately 140 ft of the 4H:1V side slope. The original design of the ClosureTurf final cover was also based on the C-33 sand specification and required the use of ArmorFill. The request of changing the sand infill and removing ArmorFill was approved by the Missouri Department of Natural Resources (MDNR). The project is currently under construction.

Attachment 1

Hydraulic Shear Stress Calculations

Scenario 1 – 275 ft of Top Deck at a 4% Slope

The maximum drainage path under Scenario 1 consists of a top deck with a 4% slope and an estimated drainage length of approximately 275 ft that ends in a top deck drainage ditch.

Design Parameters:

Top Deck:

- Drainage length: L_1 = 275 ft (see Figure 1-1)
- Slope: S_1 = 4%
- Slope angle: $\alpha_1 = \tan^{-1}(4/100) = 2.29°$
- Hydraulic gradient: i_1 = 4% or 0.04
- Manning's roughness coefficient: n_1 = 0.22 (for slope ≤ 10%; See Watershed Geo's ClosureTurf Design Manual)
- Geomembrane type: MicroSpike (without internal drainage layer) (See Figure 1-2)

Other Design Parameters:

- Design rain fall intensity (see Figure 1-3, the 100-yr, 1-hr rainfall intensity map, and Figure 1-4):

$$R = 4.33\frac{in}{hr} = 0.361\frac{ft}{hr}$$

- Critical hydraulic shear stress of ClosureTurf with manufactured sand infill: $\tau_C = 0.8\,psf$ (see Attachment 2, the channel flow testing report by TRI)

Step 1: Calculate the maximum hydraulic shear stress of flow on the top deck

Flow rate on the top deck under the design rainfall intensity (assuming unit width of 1 ft of final cover):

$$q_1 = (L_1 \cdot R \cdot \cos\alpha_1) \cdot 1ft = 275ft \times 0.361\frac{ft}{hr} \times \cos 2.29° \times 1ft = 99.20\frac{ft^3}{hr} = 0.0276\frac{ft^3}{s}$$

The flow rate:

$$q_1 = v_1 \cdot A_1 = v_1 \cdot (H_1 \times 1\,ft) = v_1 \cdot H_1$$

Where, H_1 is flow depth on the top deck (ft). Using the Manning's Equation and assuming the hydraulic radius equals to the flow depth (in ft):

$$v_1 = \frac{1.49}{n_1} {H_1}^{\frac{2}{3}} \sqrt{S_1}$$

Therefore,

$$q_1 = v_1 \cdot H_1 = \frac{1.49}{n_1} H_1^{\frac{2}{3}} \sqrt{S_1} \cdot H_1 = \frac{1.49}{n} H_1^{\frac{5}{3}} \sqrt{S_1}$$

Solve the above equation for H_1,

$$H_1 = (\frac{q_1 \cdot n_1}{1.49 \cdot \sqrt{S_1}})^{\frac{3}{5}} = (\frac{0.0276 \times 0.22}{1.49 \cdot \sqrt{0.04}})^{\frac{3}{5}} = 0.0967\ ft$$

The maximum hydraulic shear stress by the water flow on the slope:

$$\tau_1 = \gamma_w \cdot H_1 \cdot S_1 = 62.4 \frac{lb}{ft^3} \times 0.0967 ft \times 0.04 = \mathbf{0.24\ psf} < \tau_c = 0.8\ psf, meets\ criteria$$

The calculated maximum hydraulic shear stress in the sand infill is less than the selected critical hydraulic shear stress, indicating that erosion of sand infill is not expected to occur.

Scenario 2 – 250 ft of Side Slope at 4H:1V

The maximum drainage path under Scenario 2 consists of a 4H:1V side slope with an estimated drainage length of approximately 250 ft.

<u>Design Parameters:</u>
Side Slope:

- Drainage length: L_1 = 250 ft (see Figure 1-1)
- Slope: S_1 = 25% (4H:1V)
- Slope angle: $\alpha_1 = \tan^{-1}(1/4) = 14.04°$
- Hydraulic gradient: i_1 = 25% or 0.25
- Manning's roughness coefficient: n_1 = 0.12 (for slope $>$ 10%; See Watershed Geo's ClosureTurf Design Manual)
- Geomembrane type: MicroDrain (with internal drainage layer) (See Figure 1-2)
- Transmissivity of ClosureTurf with MicroDrain (use the data in Figure 1-5, the ClosureTurf transmissivity test report by SGI to calculate the transmissivity at the slope of 25% or i = 0.25):
  - Flow Rate: $q = 12.28 \times i^{0.624} = 12.28 \times 0.25^{0.624} = 5.17\ gpm/ft$
  - Transmissivity: $\theta_{i=0.25} = 0.00020697 \times \frac{q}{i} = 0.00020697 \times \frac{5.17}{0.25} = 4.28 \times 10^{-3}\ m^2/sec$

Other Design Parameters:

- Design rain fall intensity (see Figure 1-3, the 100-yr, 1-hr rainfall intensity map, and Figure 1-4):
$$R = 4.33\frac{in}{hr} = 0.361\frac{ft}{hr}$$
- Critical hydraulic shear stress of ClosureTurf with manufactured sand infill: $\tau_C = 0.8\ psf$ (see Attachment 2, the channel flow testing report by TRI)

<u>Step 1: Calculate the maximum hydraulic shear stress of flow on the side slope</u>

Flow rate on the slope under the design rainfall intensity (assuming unit width of 1 ft of final cover):

$$q_1 = (L_1 \cdot R \cdot \cos\alpha_1) \cdot 1ft = 250ft \times 0.361\frac{ft}{hr} \times \cos 14.04° \times 1ft = 87.55\frac{ft^3}{hr} = 0.0243\frac{ft^3}{s}$$

Part of the flow is expected to be through the internal drainage channel of the MicroDrain (i.e., the space within the drainage studs of MicroDrain). The internal flow capacity of ClosureTurf with MicroDrain is:

$$q_{int} = \theta_{i=0.25} \cdot i_1 \cdot 1ft = 4.28 \times 10^{-3}\frac{m^2}{sec} \times 0.25 \times 1ft$$

$$= 4.28 \times 10^{-3} \times \frac{(3.28ft)^2}{\left(\frac{1}{3600}\right)hr} \times 0.25 \times 1ft = \ 41.44\frac{ft^3}{hr}$$

The remaining flow will be through the turf and sand infill:

$$q_1' = q_1 - q_{int} = 87.55\frac{ft^3}{hr} - 41.44\frac{ft^3}{hr} = 46.11\frac{ft^3}{hr} = \ 0.0128\frac{ft^3}{s}$$

The flow rate:

$$q_1' = v_1 \cdot A_1 = v_1 \cdot (H_1 \times 1\ ft) = v_1 \cdot H_1$$

Where, H_1 is flow depth on the slope (ft). Using the Manning's Equation and assuming the hydraulic radius equals to the flow depth (in ft):

$$v_1 = \frac{1.49}{n_1}H_1^{\frac{2}{3}}\sqrt{S_1}$$

Therefore,

$$q_1' = v_1 \cdot H_1 = \frac{1.49}{n_1}H_1^{\frac{2}{3}}\sqrt{S_1} \cdot H_1 = \frac{1.49}{n}H_1^{\frac{5}{3}}\sqrt{S_1}$$

Solve the above equation for H_1,

$$H_1 = \left(\frac{q_1' \cdot n_1}{1.49 \cdot \sqrt{S_1}}\right)^{\frac{3}{5}} = \left(\frac{0.0128 \times 0.12}{1.49 \cdot \sqrt{0.25}}\right)^{\frac{3}{5}} = 0.0245\ ft$$

The maximum hydraulic shear stress by the water flow on the slope:

$$\tau_1 = \gamma_w \cdot H_1 \cdot S_1 = 62.4\frac{lb}{ft^3} \times 0.0245\ ft \times 0.25 = \mathbf{0.38\ psf} < \tau_c = 0.8\ psf, meets\ criteria$$

The calculated maximum hydraulic shear stress in the sand infill is less than the selected critical hydraulic shear stress, indicating that erosion of sand infill is not expected to occur.

Scenario 3 – 172 ft of Side Slope at 3H:1V

The maximum drainage path under Scenario 3 consists of a 3H:1V side slope with an estimated drainage length of approximately 172 ft.

Design Parameters:

Side Slope:

- Drainage length: L_1 = 172 ft (see Figure 1-1)
- Slope: S_1 = 33.3% (3H:1V)
- Slope angle: $\alpha_1 = \tan^{-1}(1/3) = 18.43°$
- Hydraulic gradient: i_1 = 33.3% or 0.333
- Manning's roughness coefficient: n_1 = 0.12 (for slope $>$ 10%; See Watershed Geo's ClosureTurf Design Manual)
- Geomembrane type: MicroDrain (with internal drainage layer) (See Figure 1-2)
- Transmissivity of ClosureTurf with MicroDrain (use the data in Figure 1-5, the ClosureTurf transmissivity test report by SGI to calculate the transmissivity at the slope of 33.3% or i = 0.333):
  - Flow Rate: $q = 12.28 \times i^{0.624} = 12.28 \times 0.333^{0.624} = 6.18\, gpm/ft$
  - Transmissivity: $\theta_{i=0.333} = 0.00020697 \times \frac{q}{i} = 0.00020697 \times \frac{6.18}{0.333} = 3.84 \times 10^{-3}\, m^2/sec$

Other Design Parameters:

- Design rain fall intensity (see Figure 1-3, the 100-yr, 1-hr rainfall intensity map, and Figure 1-4):

$$R = 4.33\frac{in}{hr} = 0.361\frac{ft}{hr}$$

- Critical hydraulic shear stress of ClosureTurf with manufactured sand infill: $\tau_C = 0.8\, psf$ (see Attachment 2, the channel flow testing report by TRI)

Step 1: Calculate the maximum hydraulic shear stress of flow on the side slope

Flow rate on the slope under the design rainfall intensity (assuming unit width of 1 ft of final cover):

$$q_1 = (L_1 \cdot R \cdot \cos\alpha_1) \cdot 1ft = 172ft \times 0.361\frac{ft}{hr} \times \cos 18.43° \times 1ft = 58.91\frac{ft^3}{hr} = 0.0164\frac{ft^3}{s}$$

Part of the flow is expected to be through the internal drainage channel of the MicroDrain (i.e., the space within the drainage studs of MicroDrain). The internal flow capacity of ClosureTurf with MicroDrain is:

$$q_{int} = \theta_{i=0.333} \cdot i_1 \cdot 1ft = 3.84 \times 10^{-3}\frac{m^2}{sec} \times 0.333 \times 1ft$$

$$= 3.84 \times 10^{-3} \times \frac{(3.28ft)^2}{\left(\frac{1}{3600}\right)hr} \times 0.333 \times 1ft = \ 49.53\frac{ft^3}{hr}$$

The remaining flow will be through the turf and sand infill:

$$q_1' = q_1 - q_{int} = 58.91\frac{ft^3}{hr} - 49.53\frac{ft^3}{hr} = 9.38\frac{ft^3}{hr} = \ 0.0026\frac{ft^3}{s}$$

The flow rate:

$$q_1' = v_1 \cdot A_1 = v_1 \cdot (H_1 \times 1\,ft) = v_1 \cdot H_1$$

Where, H_1 is flow depth on the slope (ft). Using the Manning's Equation and assuming the hydraulic radius equals to the flow depth (in ft):

$$v_1 = \frac{1.49}{n_1} H_1^{\frac{2}{3}} \sqrt{S_1}$$

Therefore,

$$q_1' = v_1 \cdot H_1 = \frac{1.49}{n_1} H_1^{\frac{2}{3}} \sqrt{S_1} \cdot H_1 = \frac{1.49}{n} H_1^{\frac{5}{3}} \sqrt{S_1}$$

Solve the above equation for H_1,

$$H_1 = \left(\frac{q_1' \cdot n_1}{1.49 \cdot \sqrt{S_1}}\right)^{\frac{3}{5}} = \left(\frac{0.0026 \times 0.12}{1.49 \cdot \sqrt{0.333}}\right)^{\frac{3}{5}} = 0.0086\,ft$$

The maximum hydraulic shear stress by the water flow on the slope:

$$\tau_1 = \gamma_w \cdot H_1 \cdot S_1 = 62.4\frac{lb}{ft^3} \times 0.0086\,ft \times 0.333 = \mathbf{0.18\,psf} < \tau_c = 0.8\,psf, \textit{meets criteria}$$

The calculated maximum hydraulic shear stress in the sand infill is less than the selected critical hydraulic shear stress, indicating that erosion of sand infill is not expected to occur.

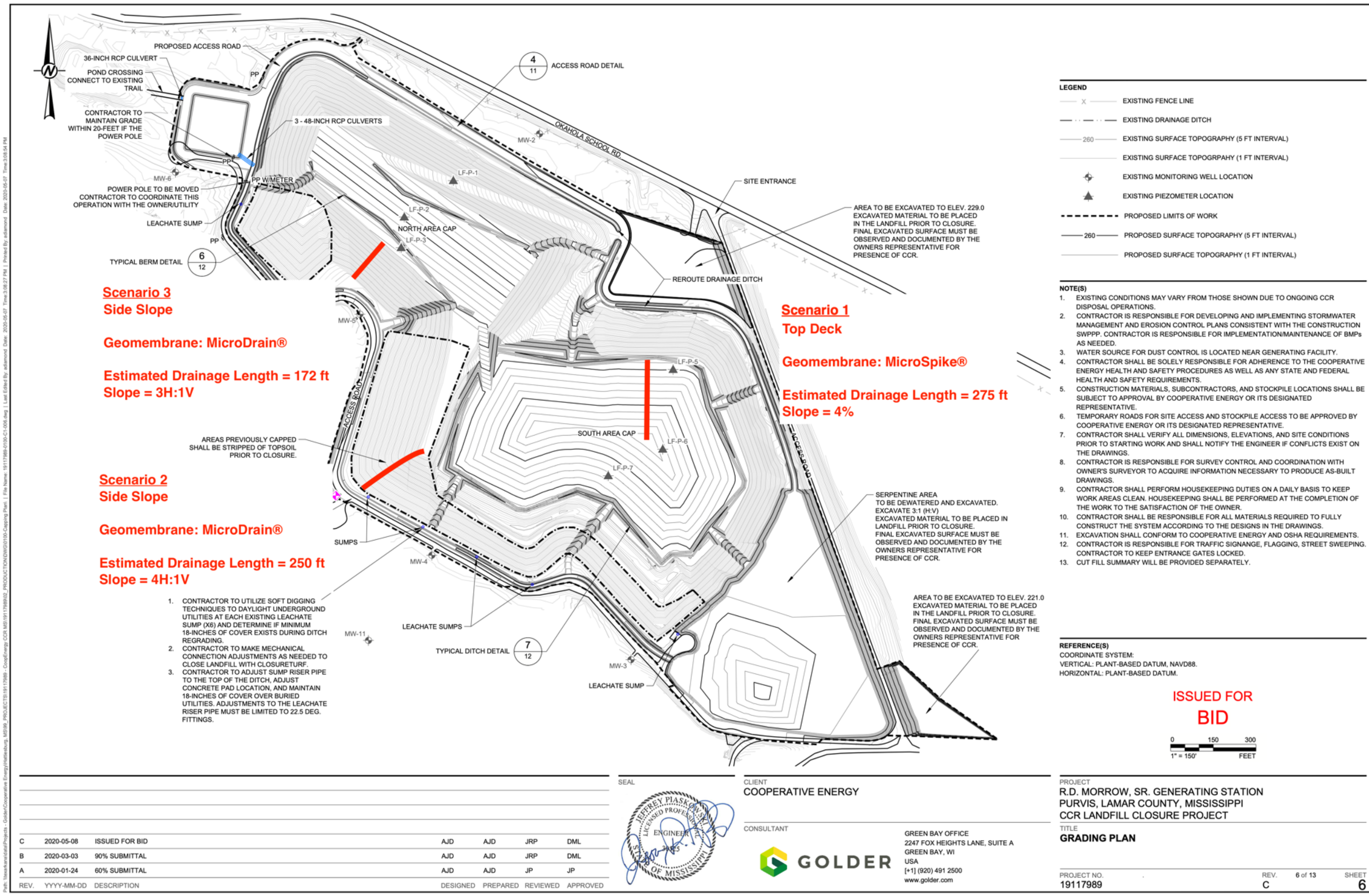


Figure 1-1. Locations of Drainage Paths Used in Hydraulic Shear Stress Calculations

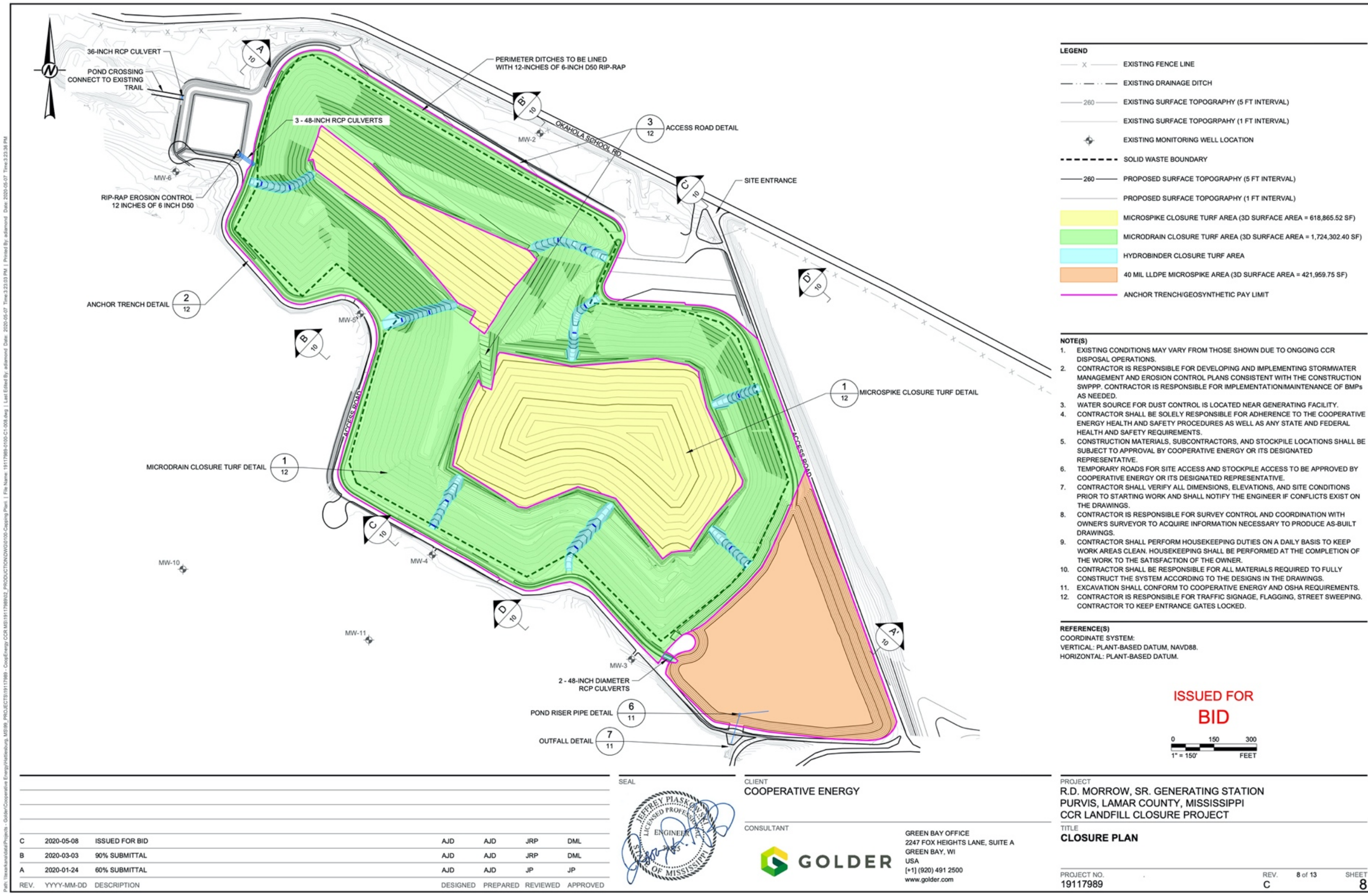


Figure 1-2. Closure Plan Showing Geomembrane Types for ClosureTurf

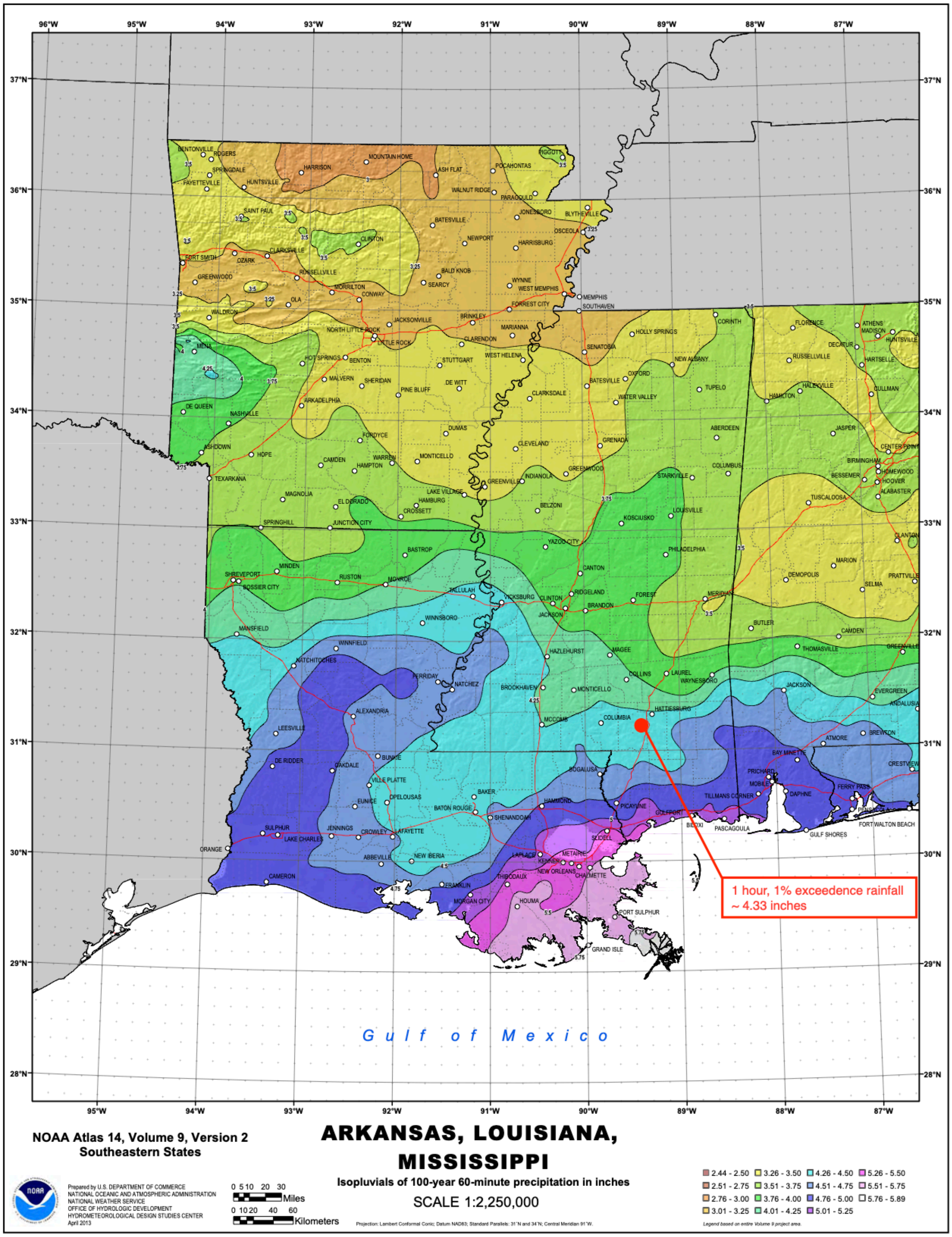


Figure 1-3. Estimated 100-year, 60-minute (1-hour) Rainfall Intensity at Plant Morrow based on NOAA Atlas 14

NOAA Atlas 14, Volume 9, Version 2
Location name: Purvis, Mississippi, USA*
Latitude: 31.2112°, Longitude: -89.3974°
Elevation: 263.88 ft**
* source: ESRI Maps
** source: USGS

POINT PRECIPITATION FREQUENCY ESTIMATES

Sanja Perica, Deborah Martin, Sandra Pavlovic, Ishani Roy, Michael St. Laurent, Carl Trypaluk, Dale Unruh, Michael Yekta, Geoffery Bonnin

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]										
Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	0.524 (0.435-0.640)	0.601 (0.499-0.734)	0.724 (0.599-0.886)	0.824 (0.678-1.01)	0.956 (0.762-1.19)	1.06 (0.826-1.33)	1.15 (0.876-1.48)	1.25 (0.915-1.63)	1.37 (0.972-1.82)	1.46 (1.01-1.97)
10-min	0.768 (0.637-0.937)	0.880 (0.730-1.08)	1.06 (0.877-1.30)	1.21 (0.992-1.48)	1.40 (1.12-1.75)	1.55 (1.21-1.95)	1.69 (1.28-2.16)	1.83 (1.34-2.38)	2.00 (1.42-2.67)	2.13 (1.49-2.89)
15-min	0.936 (0.777-1.14)	1.07 (0.890-1.31)	1.29 (1.07-1.58)	1.47 (1.21-1.80)	1.71 (1.36-2.13)	1.88 (1.47-2.37)	2.06 (1.56-2.64)	2.23 (1.63-2.91)	2.44 (1.74-3.26)	2.60 (1.81-3.52)
30-min	1.39 (1.15-1.69)	1.60 (1.32-1.95)	1.93 (1.60-2.36)	2.20 (1.81-2.70)	2.57 (2.04-3.20)	2.84 (2.22-3.58)	3.10 (2.36-3.98)	3.36 (2.47-4.39)	3.70 (2.63-4.93)	3.94 (2.75-5.33)
60-min	1.84 (1.52-2.24)	2.11 (1.75-2.58)	2.57 (2.13-3.14)	2.96 (2.43-3.62)	3.49 (2.79-4.38)	3.91 (3.07-4.95)	4.33 (3.31-5.58)	4.77 (3.51-6.26)	5.35 (3.82-7.17)	5.80 (4.04-7.85)
2-hr	2.29 (1.91-2.77)	2.63 (2.20-3.19)	3.21 (2.67-3.89)	3.71 (3.07-4.51)	4.42 (3.57-5.52)	4.98 (3.95-6.28)	5.57 (4.28-7.14)	6.18 (4.59-8.07)	7.01 (5.04-9.34)	7.66 (5.38-10.3)
3-hr	2.57 (2.15-3.09)	2.95 (2.47-3.55)	3.61 (3.02-4.36)	4.19 (3.49-5.07)	5.04 (4.11-6.30)	5.74 (4.57-7.22)	6.47 (5.01-8.28)	7.25 (5.41-9.45)	8.33 (6.02-11.1)	9.19 (6.47-12.3)
6-hr	3.08 (2.60-3.68)	3.54 (2.99-4.23)	4.36 (3.67-5.22)	5.09 (4.27-6.11)	6.19 (5.09-7.70)	7.11 (5.71-8.90)	8.08 (6.31-10.3)	9.13 (6.88-11.9)	10.6 (7.73-14.0)	11.8 (8.37-15.7)
12-hr	3.64 (3.10-4.31)	4.20 (3.58-4.98)	5.20 (4.41-6.17)	6.09 (5.15-7.26)	7.43 (6.15-9.16)	8.54 (6.91-10.6)	9.72 (7.63-12.3)	11.0 (8.33-14.1)	12.8 (9.36-16.8)	14.2 (10.1-18.8)
24-hr	4.23 (3.63-4.97)	4.90 (4.21-5.76)	6.08 (5.20-7.16)	7.13 (6.07-8.41)	8.68 (7.23-10.6)	9.96 (8.11-12.3)	11.3 (8.94-14.2)	12.8 (9.73-16.3)	14.8 (10.9-19.3)	16.4 (11.8-21.5)
2-day	4.86 (4.20-5.65)	5.62 (4.86-6.55)	6.95 (5.99-8.11)	8.13 (6.97-9.52)	9.86 (8.27-11.9)	11.3 (9.26-13.8)	12.8 (10.2-15.9)	14.4 (11.0-18.2)	16.6 (12.3-21.5)	18.4 (13.3-24.0)
3-day	5.29 (4.60-6.13)	6.10 (5.30-7.07)	7.50 (6.49-8.71)	8.73 (7.52-10.2)	10.5 (8.88-12.7)	12.0 (9.91-14.6)	13.6 (10.9-16.8)	15.3 (11.8-19.2)	17.6 (13.1-22.6)	19.4 (14.1-25.2)
4-day	5.66 (4.94-6.53)	6.50 (5.66-7.51)	7.95 (6.91-9.20)	9.23 (7.98-10.7)	11.1 (9.37-13.3)	12.6 (10.4-15.3)	14.2 (11.4-17.5)	15.9 (12.3-20.0)	18.3 (13.7-23.5)	20.2 (14.7-26.1)
7-day	6.60 (5.79-7.56)	7.53 (6.60-8.63)	9.11 (7.97-10.5)	10.5 (9.13-12.1)	12.5 (10.6-14.8)	14.1 (11.7-16.9)	15.8 (12.7-19.3)	17.6 (13.7-21.9)	20.0 (15.0-25.5)	22.0 (16.1-28.2)
10-day	7.46 (6.58-8.51)	8.45 (7.44-9.64)	10.1 (8.88-11.6)	11.6 (10.1-13.3)	13.6 (11.6-16.1)	15.3 (12.7-18.2)	17.0 (13.8-20.7)	18.8 (14.7-23.4)	21.3 (16.0-27.0)	23.3 (17.1-29.8)
20-day	10.0 (8.91-11.3)	11.1 (9.88-12.6)	13.0 (11.5-14.7)	14.5 (12.8-16.5)	16.7 (14.3-19.5)	18.4 (15.4-21.7)	20.1 (16.4-24.2)	21.9 (17.2-26.9)	24.3 (18.4-30.5)	26.2 (19.4-33.3)
30-day	12.2 (10.9-13.7)	13.5 (12.0-15.1)	15.5 (13.8-17.5)	17.2 (15.2-19.4)	19.5 (16.7-22.5)	21.2 (17.9-24.9)	23.0 (18.8-27.4)	24.8 (19.5-30.2)	27.1 (20.6-33.9)	28.9 (21.5-36.6)
45-day	14.9 (13.4-16.7)	16.5 (14.7-18.4)	18.9 (16.8-21.2)	20.8 (18.5-23.4)	23.4 (20.1-26.8)	25.3 (21.3-29.4)	27.2 (22.2-32.2)	29.0 (22.9-35.1)	31.3 (23.9-38.8)	33.0 (24.6-41.6)
60-day	17.3 (15.5-19.3)	19.1 (17.1-21.3)	21.9 (19.6-24.5)	24.1 (21.5-27.0)	27.0 (23.3-30.8)	29.1 (24.6-33.6)	31.1 (25.5-36.7)	33.0 (26.1-39.8)	35.4 (27.0-43.6)	37.1 (27.7-46.6)

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

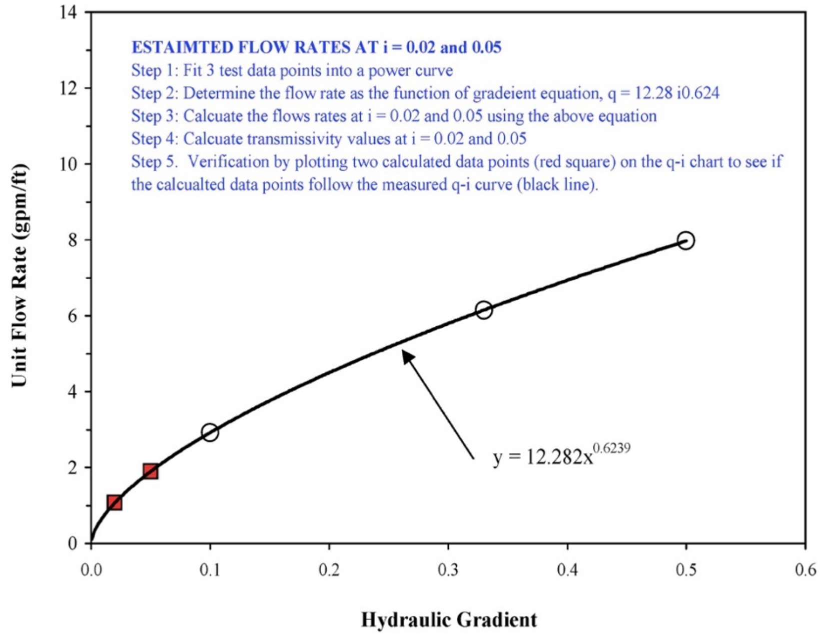
Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values.

Please refer to NOAA Atlas 14 document for more information.

Figure 1-4. NOAA Precipitation Data (Purvis, Mississippi)

CLOSURETURF LLC -LANDFILL COVER SYSTEM
HYDRAULIC TRANSMISSIVITY TESTING (ASTM D 4716)

Test Configuration (from Top to Bottom): Sand Layer/Polytex Artificial Grass with Geotextile Side Down/
Agru 50-mil Super Gripnet LLDPE Geomembrane with Studs Side Up



Test No.	Flow Direction	Specimen Size Width x Length (in. x in.)	Total Normal Stress[1] σ_n (psf)	Seating Time t (hour)	Hydraulic Gradient i (-)	Transmissivity $\theta = 0.00020697\left(\frac{q}{i}\right)$ (m²/sec)	Flow Rate $q = 12.28 i^{0.624}$ (gpm/ft)	Flow Rate q' (l/min/m)
					0.02	1.11E-02	1.07	
					0.05	7.84E-03	1.89	
1	MD	12 x12	47	0.25	0.10	6.04E-03	2.92	36.3
2	MD	12 x12	47	0.25	0.33	3.86E-03	6.15	76.4
3	MD	12 x12	47	0.25	0.50	3.30E-03	7.97	99.0

NOTE:
Total normal stress = total weight (sand + steel plate + surcharge) divided by the plan area of test specimen (1 square ft). A normal stress of 47 psf is approximately the minimum total stress required to keep the specimen from uplifting.

SGI TESTING SERVICES, LLC

DATE TESTED:	1/11/2013
FIGURE NO.	A-1
PROJECT NO.	SGI10007
DOCUMENT NO.	
FILE NO.	

Figure 1-5. Transmissivity Test Report of ClosureTurf

Note: The test was conducted with Super Gripnet, which has the same drainage studs as the MicroDrain.

Attachment 2

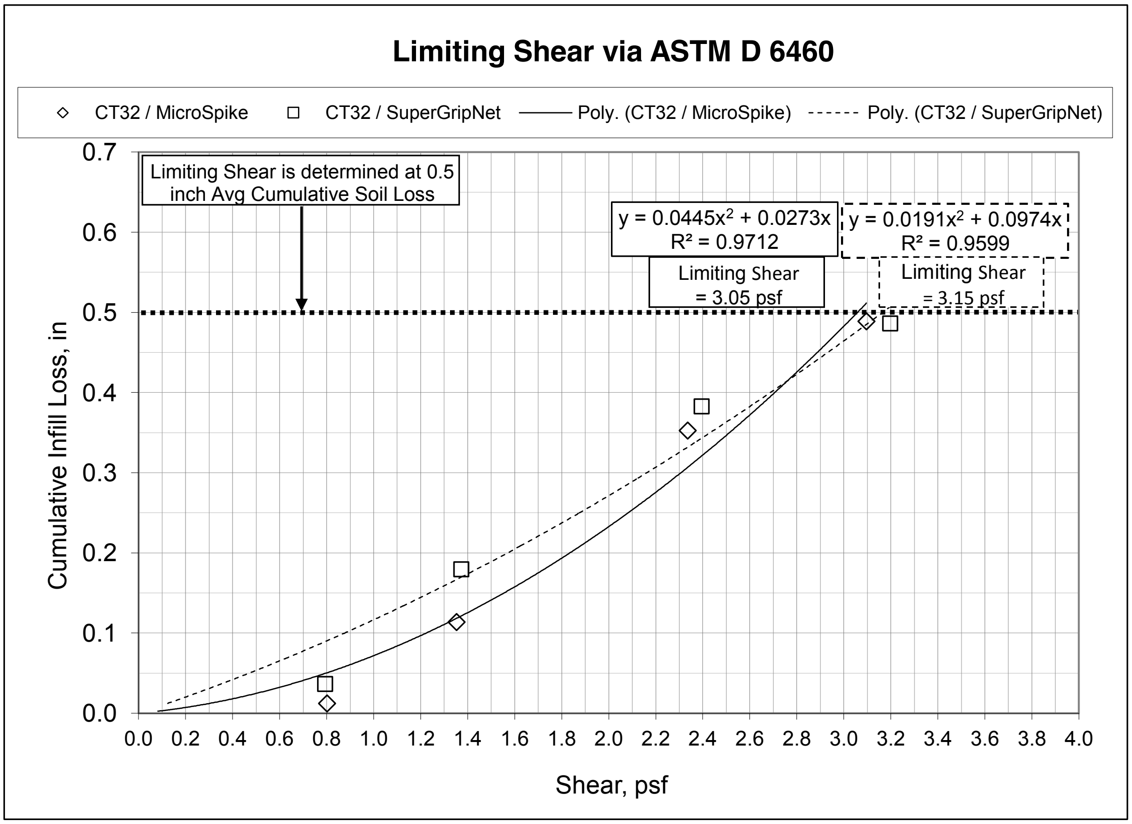
Channel Flow Testing Report for ClosureTurf with Manufactured Sand

ASTM D 6460 (modified for single replicates):
STANDARD TEST METHOD FOR DETERMINATION OF ROLLED EROSION CONTROL PRODUCT (RECP) PERFORMANCE IN PROTECTING EARTHEN CHANNELS FROM STORM-INDUCED EROSION

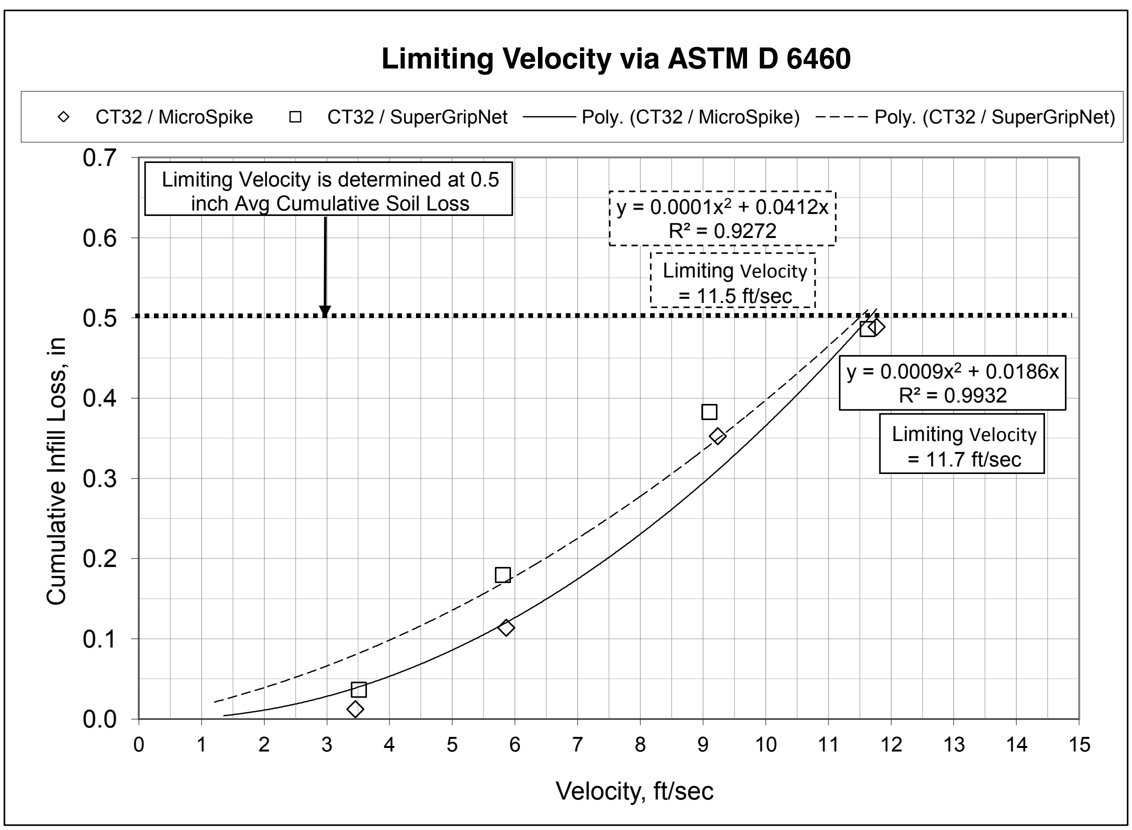
Client: Watershed Geo
Products: CT32 / MicroSpike   CT32 / SuperGripNet
Infill: 0.5 inches (nominal) Depth for All Products
Test Dates: 1/25/2019
Shear Range: 0.5 - 4.0 psf
Flume: 2-ft wide x 40-ft long; 10% Bed
Event: 30 minutes at each shear

Test Scenario	Shear Level	depth (in)	velocity (fps)	Flow (cfs)	Manning's roughness, n	Max Bed Shear Stress (psf)	Shear Level Infill Loss (in)	Cumulative Infill Loss (in)
CT32 / MicroSpike	1	1.57	3.45	0.90	0.035	0.80	0.01	0.01
	2	2.61	5.86	2.55	0.029	1.35	0.10	0.11
	3	4.55	9.24	7.00	0.027	2.34	0.24	0.35
	4	6.42	11.77	12.60	0.025	3.10	0.14	0.49
CT32 / SuperGripNet	1	1.54	3.51	0.90	0.034	0.79	0.04	0.04
	2	2.63	5.81	2.55	0.030	1.37	0.14	0.18
	3	4.61	9.10	7.00	0.027	2.40	0.20	0.38
	4	6.50	11.63	12.60	0.026	3.20	0.10	0.49

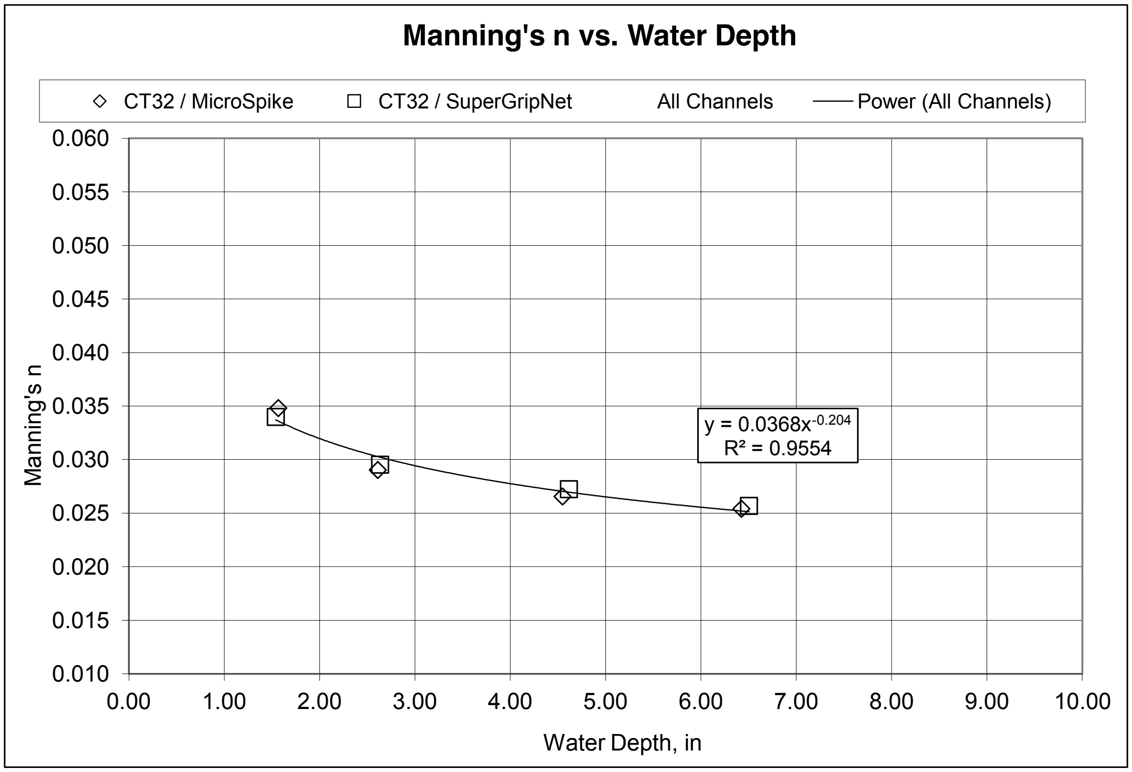
CJS 2/4/19
Quality Review / Date

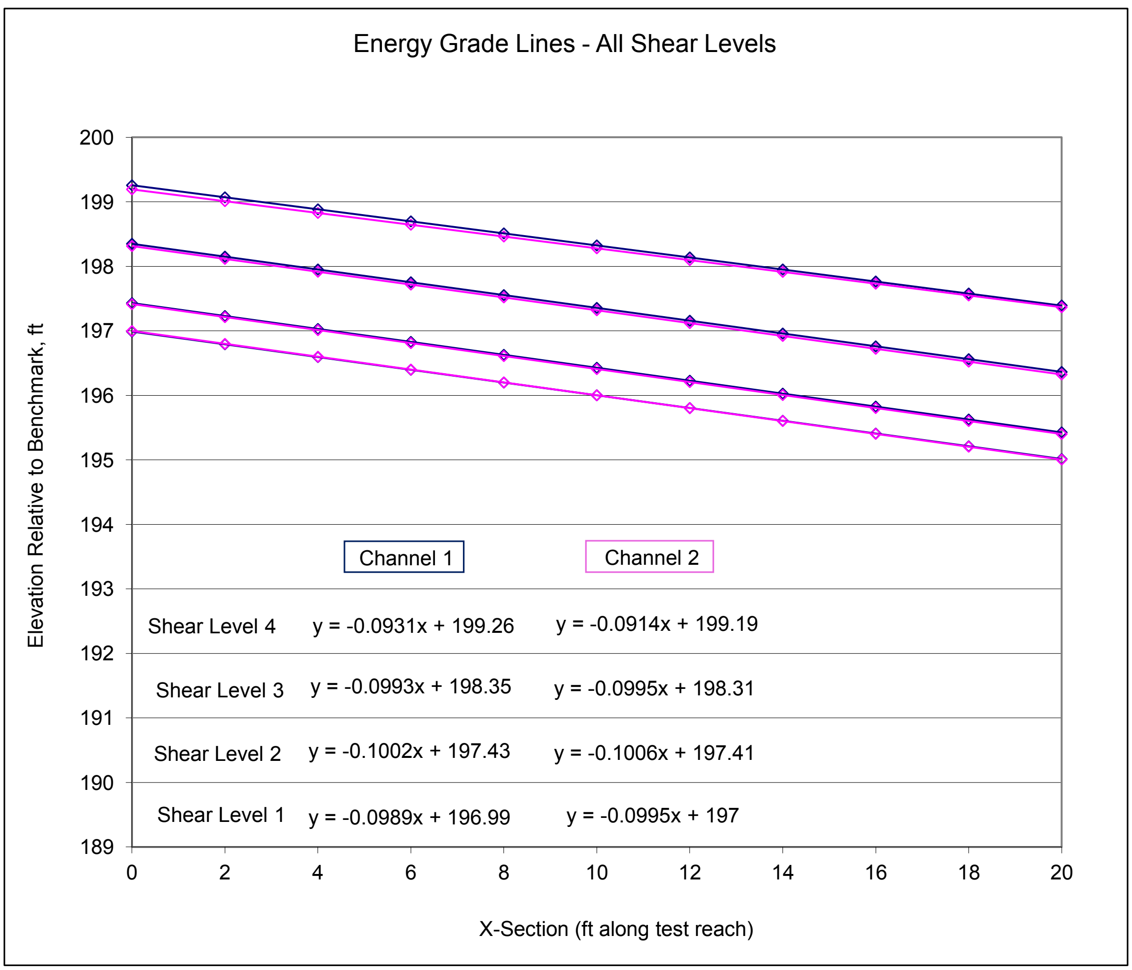


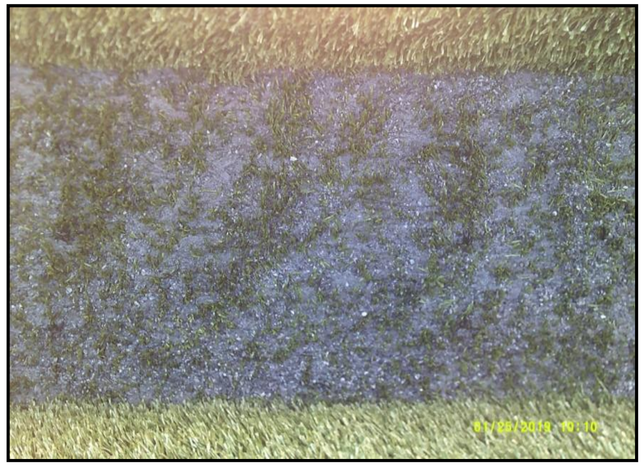
Limiting Shear via ASTM D 6460
CT32 / MicroSpike
CT32 / SuperGripNet
Poly. (CT32 / MicroSpike)
Poly. (CT32 / SuperGripNet)
Limiting Shear is determined at 0.5 inch Avg Cumulative Soil Loss
y = 0.0445x² + 0.0273x
R² = 0.9712
y = 0.0191x² + 0.0974x
R² = 0.9599
Limiting Shear = 3.05 psf
Limiting Shear = 3.15 psf
Cumulative Infill Loss, in
Shear, psf



Limiting Velocity via ASTM D 6460
CT32 / MicroSpike
CT32 / SuperGripNet
Poly. (CT32 / MicroSpike)
Poly. (CT32 / SuperGripNet)
Limiting Velocity is determined at 0.5 inch Avg Cumulative Soil Loss
y = 0.0001x² + 0.0412x
R² = 0.9272
Limiting Velocity = 11.5 ft/sec
y = 0.0009x² + 0.0186x
R² = 0.9932
Limiting Velocity = 11.7 ft/sec
Cumulative Infill Loss, in
Velocity, ft/sec

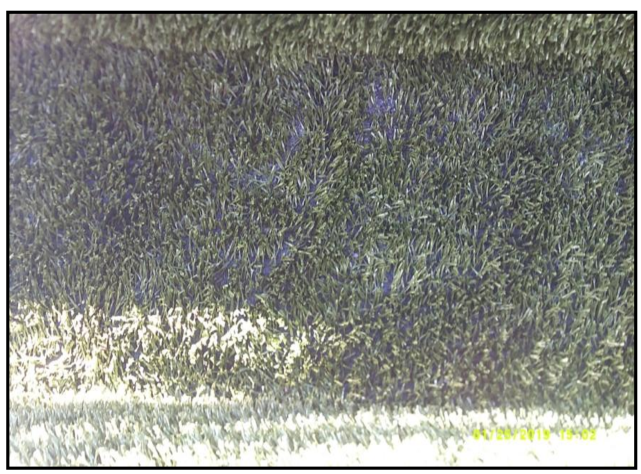

Manning's n vs. Water Depth
CT32 / MicroSpike
CT32 / SuperGripNet
All Channels
Power (All Channels)
0.060
0.055
0.050
0.045
0.040
0.035
0.030
0.025
0.020
0.015
0.010
Manning's n
y = 0.0368x^-0.204
R² = 0.9554
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
Water Depth, in


Energy Grade Lines - All Shear Levels
200
199
198
197
196
195
194
193
192
191
190
189
Elevation Relative to Benchmark, ft
Channel 1
Channel 2
Shear Level 4
y = -0.0931x + 199.26
y = -0.0914x + 199.19
Shear Level 3
y = -0.0993x + 198.35
y = -0.0995x + 198.31
Shear Level 2
y = -0.1002x + 197.43
y = -0.1006x + 197.41
Shear Level 1
y = -0.0989x + 196.99
y = -0.0995x + 197
0
2
4
6
8
10
12
14
16
18
20
X-Section (ft along test reach)



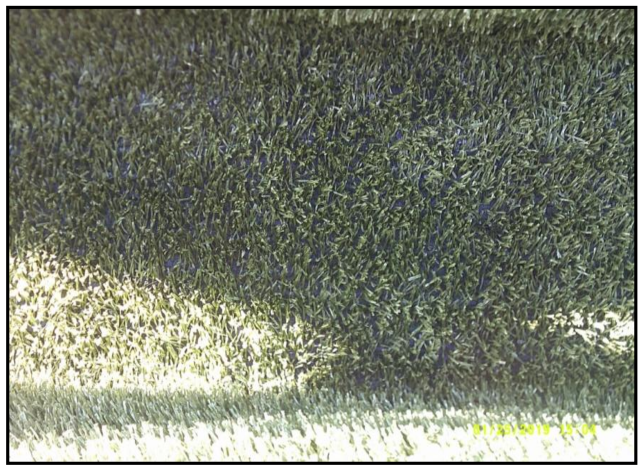
CT32 Micro Spike & Manufactured Sand - Before & Close-up

Typical Flows (low / high)



CT32 Micro Spike & Manufactured Sand - After & Close-up

CT32 Super Grip Net & Manufactured Sand - Before & Close-up

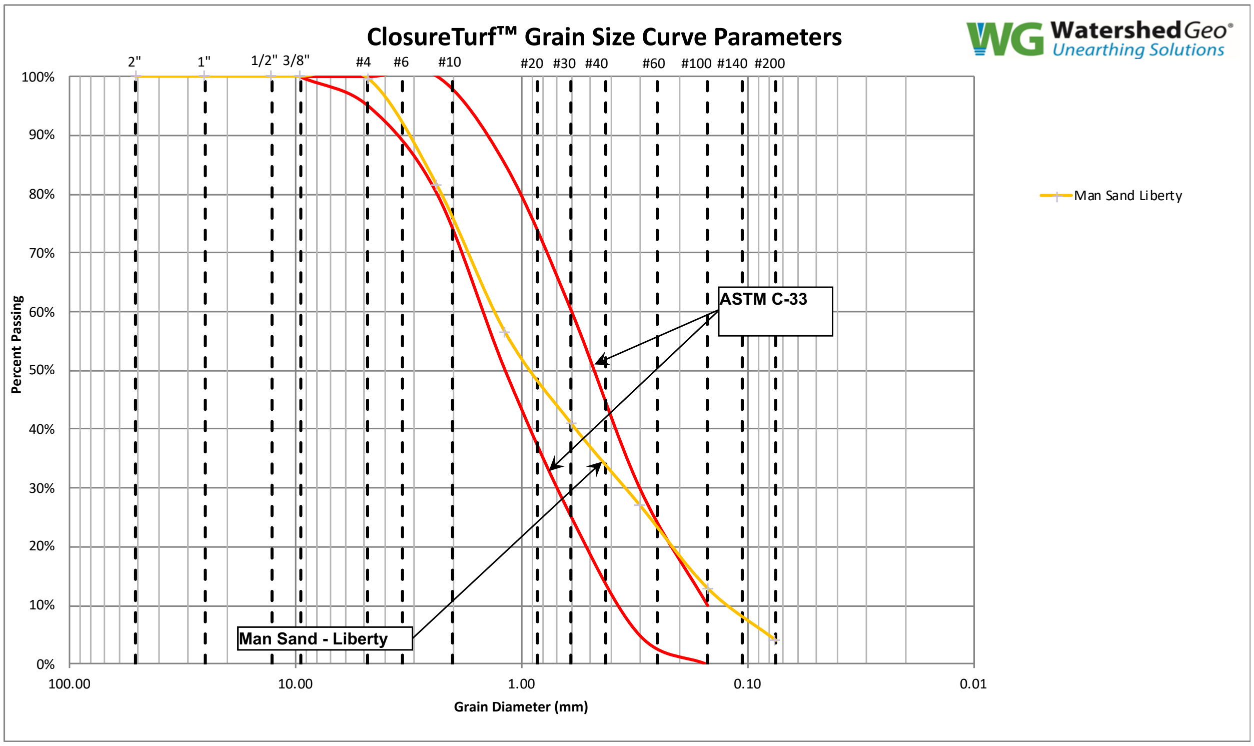


CT32 Super Grip Net & Manufactured Sand - After & Close-up

APPENDIX - DATA

Date:	1/25/19	RECP:	CT32 / MicroSpike			Lot #:				Anchorage:		(Nominal) Manufactur					
Slope:	10%	Start Time:	10:56 AM	Channel #	Shear #	Start Time:	12:53 PM	Channel #	Shear #	Start Time:	1:50 PM	Channel #	Shear #	Start Time:	2:41 PM	Channel #	Shear #
Width:	2	End Time:	11:26 AM	1	1	End Time:	1:23 PM	1	2	End Time:	2:40 PM	1	3	End Time:	3:11 PM	1	4
Cross-Section Measurements		Measured Volumetric Flow, cfs:			0.90	Measured Volumetric Flow, cfs:			2.55	Measured Volumetric Flow, cfs:			7.00	Measured Volumetric Flow, cfs:			12.60
#1 (Sta. 0+10.00)	To original Surface Elev, cm	70.1	70.5	70.5	Avg.				Avg.				Avg.				Avg.
	To eroded Surface Elev, cm	70.1	70.8	70.5	70.5	70.6	71.0	71.0	70.9	72.0	71.5	71.9	71.8	72.0	71.8	72.0	71.9
	Loss/Gain, sq.in./in. width	0.00	-0.12	0.00	-0.02	-0.20	-0.20	-0.20	-0.16	-0.75	-0.39	-0.55	-0.50	-0.75	-0.51	-0.59	-0.53
	CSLI, sq.in./in. width	0.00	-0.12	0.00	-0.02	-0.20	-0.20	-0.20	-0.16	-0.75	-0.39	-0.55	-0.50	-0.75	-0.51	-0.59	-0.53
	Velocity, ft/s		0.0		3.2		0.0		5.8		0.0		9.0		0.0		11.5
	Distance to Water Surface, cm		66.2		66.2		64.2		64.2		60.0		60.0		55.3		55.3
	Calculations	Flow, cfs	Depth, in			Flow, cfs	Depth, in			Flow, cfs	Depth, in			Flow, cfs	Depth, in		
		0.90	1.68			2.55	2.62			7.00	4.65			12.60	6.55		
#2 (Sta. 0+12.00)	To original Surface Elev, cm	70.5	70.0	70.2	Avg.				Avg.				Avg.				Avg.
	To eroded Surface Elev, cm	70.5	70.0	70.2	70.2	70.9	70.0	70.9	70.6	71.8	71.7	71.4	71.6	72.0	72.0	71.5	71.8
	Loss/Gain, sq.in./in. width	0.00	0.00	0.00	0.00	-0.16	0.00	-0.28	-0.14	-0.51	-0.67	-0.47	-0.44	-0.59	-0.79	-0.51	-0.50
	CSLI, sq.in./in. width	0.00	0.00	0.00	0.00	-0.16	0.00	-0.28	-0.14	-0.51	-0.67	-0.47	-0.44	-0.59	-0.79	-0.51	-0.50
	Velocity, ft/s		0.0		3.3		0.0		6.0		0.0		9.1		0.0		11.6
	Distance to Water Surface, cm		66.1		66.1		64.1		64.1		59.9		59.9		55.3		55.3
	Calculations	Flow, cfs	Depth, in			Flow, cfs	Depth, in			Flow, cfs	Depth, in			Flow, cfs	Depth, in		
		0.90	1.63			2.55	2.56			7.00	4.62			12.60	6.51		
#3 (Sta. 0+14.00)	To original Surface Elev, cm	70.4	70.1	70.5	Avg.				Avg.				Avg.				Avg.
	To eroded Surface Elev, cm	70.4	70.1	70.5	70.3	70.5	70.3	70.7	70.5	71.3	71.3	71.2	71.3	71.5	71.8	72.0	71.8
	Loss/Gain, sq.in./in. width	0.00	0.00	0.00	0.00	-0.04	-0.08	-0.08	-0.05	-0.35	-0.47	-0.28	-0.29	-0.43	-0.67	-0.59	-0.45
	CSLI, sq.in./in. width	0.00	0.00	0.00	0.00	-0.04	-0.08	-0.08	-0.05	-0.35	-0.47	-0.28	-0.29	-0.43	-0.67	-0.59	-0.45
	Velocity, ft/s		0.0		3.3		0.0		5.6		0.0		9.5		0.0		11.7
	Distance to Water Surface, cm		66.2		66.2		63.5		63.5		60.0		60.0		55.3		55.3
	Calculations	Flow, cfs	Depth, in			Flow, cfs	Depth, in			Flow, cfs	Depth, in			Flow, cfs	Depth, in		
		0.90	1.63			2.55	2.76			7.00	4.44			12.60	6.48		
#4 (Sta. 0+16.00)	To original Surface Elev, cm	69.5	69.7	69.8	Avg.				Avg.				Avg.				Avg.
	To eroded Surface Elev, cm	69.6	69.8	69.8	69.7	69.9	70.0	69.8	69.9	70.6	70.7	70.5	70.6	71.1	71.1	71.3	71.2
	Loss/Gain, sq.in./in. width	-0.04	-0.04	0.00	-0.02	-0.16	-0.12	0.00	-0.07	-0.43	-0.39	-0.28	-0.30	-0.63	-0.55	-0.59	-0.50
	CSLI, sq.in./in. width	-0.04	-0.04	0.00	-0.02	-0.16	-0.12	0.00	-0.07	-0.43	-0.39	-0.28	-0.30	-0.63	-0.55	-0.59	-0.50
	Velocity, ft/s		0.0		3.3		0.0		5.9		0.0		9.3		0.0		11.7
	Distance to Water Surface, cm		65.6		65.6		63.3		63.3		59.1		59.1		54.8		54.8
	Calculations	Flow, cfs	Depth, in			Flow, cfs	Depth, in			Flow, cfs	Depth, in			Flow, cfs	Depth, in		
		0.90	1.63			2.55	2.60			7.00	4.53			12.60	6.44		
#5 (Sta. 0+18.00)	To original Surface Elev, cm	70.5	70.2	70.0	Avg.				Avg.				Avg.				Avg.
	To eroded Surface Elev, cm	70.5	70.2	70.0	70.2	70.8	70.3	70.0	70.4	71.4	70.6	70.9	71.0	71.7	71.8	71.3	71.6
	Loss/Gain, sq.in./in. width	0.00	0.00	0.00	0.00	-0.12	-0.04	0.00	-0.05	-0.35	-0.16	-0.35	-0.26	-0.47	-0.63	-0.51	-0.43
	CSLI, sq.in./in. width	0.00	0.00	0.00	0.00	-0.12	-0.04	0.00	-0.05	-0.35	-0.16	-0.35	-0.26	-0.47	-0.63	-0.51	-0.43
	Velocity, ft/s		0.0		3.4		0.0		5.9		0.0		9.3		0.0		11.6
	Distance to Water Surface, cm		66.2		66.2		63.8		63.8		59.5		59.5		55.1		55.1
	Calculations	Flow, cfs	Depth, in			Flow, cfs	Depth, in			Flow, cfs	Depth, in			Flow, cfs	Depth, in		
		0.90	1.59			2.55	2.59			7.00	4.51			12.60	6.50		
#6 (Sta. 0+20.00)	To original Surface Elev, cm	70.3	70.4	70.6	Avg.				Avg.				Avg.				Avg.
	To eroded Surface Elev, cm	70.4	70.4	70.6	70.5	70.9	71.1	71.2	71.1	72.0	71.2	71.5	71.6	72.0	72.2	71.8	72.0
	Loss/Gain, sq.in./in. width	-0.04	0.00	0.00	-0.01	-0.24	-0.28	-0.24	-0.20	-0.67	-0.31	-0.35	-0.39	-0.67	-0.71	-0.47	-0.50
	CSLI, sq.in./in. width	-0.04	0.00	0.00	-0.01	-0.24	-0.28	-0.24	-0.20	-0.67	-0.31	-0.35	-0.39	-0.67	-0.71	-0.47	-0.50
	Velocity, ft/s		0.0		3.5		0.0		5.9		0.0		9.4		0.0		11.8
	Distance to Water Surface, cm		66.5		66.5		64.5		64.5		60.2		60.2		55.7		55.7
	Calculations	Flow, cfs	Depth, in			Flow, cfs	Depth, in			Flow, cfs	Depth, in			Flow, cfs	Depth, in		
		0.90	1.56			2.55	2.59			7.00	4.48			12.60	6.42		
#7 (Sta. 0+22.00)	To original Surface Elev, cm	70.9	70.6	70.5	Avg.				Avg.				Avg.				Avg.
	To eroded Surface Elev, cm	70.9	70.7	70.5	70.7	71.1	71.1	70.5	70.9	72.2	71.6	71.1	71.6	72.3	72.3	71.9	72.2
	Loss/Gain, sq.in./in. width	0.00	-0.04	0.00	-0.01	-0.08	-0.20	0.00	-0.06	-0.51	-0.39	-0.24	-0.31	-0.55	-0.67	-0.55	-0.48
	CSLI, sq.in./in. width	0.00	-0.04	0.00	-0.01	-0.08	-0.20	0.00	-0.06	-0.51	-0.39	-0.24	-0.31	-0.55	-0.67	-0.55	-0.48
	Velocity, ft/s		0.0		3.5		0.0		6.1		0.0		9.0		0.0		11.7
	Distance to Water Surface, cm		66.8		66.8		64.5		64.5		59.8		59.8		55.8		55.8
	Calculations	Flow, cfs	Depth, in			Flow, cfs	Depth, in			Flow, cfs	Depth, in			Flow, cfs	Depth, in		
		0.90	1.54			2.55	2.52			7.00	4.66			12.60	6.44		
#8 (Sta. 0+24.00)	To original Surface Elev, cm	71.0	70.5	71.1	Avg.				Avg.				Avg.				Avg.
	To eroded Surface Elev, cm	71.0	70.5	71.1	70.9	71.4	70.5	71.4	71.1	71.8	72.4	71.8	72.0	72.5	72.4	72.0	72.3
	Loss/Gain, sq.in./in. width	0.00	0.00	0.00	0.00	-0.16	0.00	-0.12	-0.09	-0.31	-0.75	-0.28	-0.32	-0.59	-0.75	-0.35	-0.44
	CSLI, sq.in./in. width	0.00	0.00	0.00	0.00	-0.16	0.00	-0.12	-0.09	-0.31	-0.75	-0.28	-0.32	-0.59	-0.75	-0.35	-0.44
	Velocity, ft/s		0.0		3.4		0.0		5.9		0.0		9.2		0.0		11.9
	Distance to Water Surface, cm		66.8		66.8		64.5		64.5		60.4		60.4		56.1		56.1
	Calculations	Flow, cfs	Depth, in			Flow, cfs	Depth, in			Flow, cfs	Depth, in			Flow, cfs	Depth, in		
		0.90	1.60			2.55	2.60			7.00	4.57			12.60	6.38		
#9 (Sta. 0+26.00)	To original Surface Elev, cm	70.2	70.6	70.0	Avg.				Avg.				Avg.				Avg.
	To eroded Surface Elev, cm	70.6	70.6	70.1	70.4	70.8	71.0	70.3	70.7	72.0	71.7	70.7	71.5	72.0	71.7	71.9	71.9
	Loss/Gain, sq.in./in. width	-0.16	0.00	-0.04	-0.07	-0.24	-0.16	-0.12	-0.14	-0.71	-0.43	-0.28	-0.40	-0.71	-0.43	-0.75	-0.56
	CSLI, sq.in./in. width	-0.16	0.00	-0.04	-0.07	-0.24	-0.16	-0.12	-0.14	-0.71	-0.43	-0.28	-0.40	-0.71	-0.43	-0.75	-0.56
	Velocity, ft/s		0.0		3.7		0.0		5.8		0.0		9.5		0.0		12.0
	Distance to Water Surface, cm		66.7		66.7		64.0		64.0		60.2		60.2		55.8		55.8
	Calculations	Flow, cfs	Depth, in			Flow, cfs	Depth, in			Flow, cfs	Depth, in			Flow, cfs	Depth, in		
		0.90	1.47			2.55	2.64			7.00	4.44			12.60	6.33		
#10 (Sta. 0+28.00)	To original Surface Elev, cm	70.6	70.2	70.4	Avg.				Avg.				Avg.				Avg.
	To eroded Surface Elev, cm	70.6	70.4	70.4	70.5	70.9	70.7	70.9	70.8	72.1	72.0	70.9	71.7	72.1	72.0	72.1	72.1
	Loss/Gain, sq.in./in. width	0.00	-0.08	0.00	-0.01	-0.12	-0.20	-0.20	-0.14	-0.59	-0.71	-0.20	-0.38	-0.59	-0.71	-0.67	-0.54
	CSLI, sq.in./in. width	0.00	-0.08	0.00	-0.01	-0.12	-0.20	-0.20	-0.14	-0.59	-0.71	-0.20	-0.38	-0.59	-0.71	-0.67	-0.54
	Velocity, ft/s		0.0		3.6		0.0		5.8		0.0		9.1		0.0		11.9
	Distance to Water Surface, cm		66.7		66.7		64.1		64.1		60.0		60.0		55.9		55.9
	Calculations	Flow, cfs	Depth, in			Flow, cfs	Depth, in			Flow, cfs	Depth, in			Flow, cfs	Depth, in		
		0.90	1.48			2.55	2.65			7.00	4.59			12.60	6.36		
#11 (Sta. 0+30.00)	To original Surface Elev, cm	70.8	70.6	70.8	Avg.				Avg.				Avg.				Avg.
	To eroded Surface Elev, cm	70.8	70.9	70.8	70.8	71.0	70.9	70.8	70.9	71.9	71.4	70.8	71.4	72.0	71.6	72.1	71.9
	Loss/Gain, sq.in./in. width	0.00	-0.12	0.00	-0.02	-0.08	-0.12	0.00	-0.05	-0.43	-0.31	0.00	-0.20	-0.47	-0.39	-0.51	-0.39
	CSLI, sq.in./in. width	0.00	-0.12	0.00	-0.02	-0.08	-0.12	0.00	-0.05	-0.43	-0.31	0.00	-0.20	-0.47	-0.39	-0.51	-0.39
	Velocity, ft/s		0.0		3.8		0.0		5.9		0.0		9.2		0.0		12.1
	Distance to Water Surface, cm		67.2		67.2		64.3		64.3		59.8		59.8		56.0		56.0
	Calculations	Flow, cfs	Depth, in			Flow, cfs	Depth, in			Flow, cfs	Depth, in			Flow, cfs	Depth, in		
		0.90	1.43			2.55	2.60			7.00	4.55			12.60	6.26		

Date:	1/25/19	RECP:	CT32 / SuperGripNet			Lot #:				Anchorage:		(Nominal) Manufactur					
Slope:	10%	Start Time:	10:56 AM	Channel #	Shear #	Start Time:	12:53 PM	Channel #	Shear #	Start Time:	1:50 PM	Channel #	Shear #	Start Time:	2:41 PM	Channel #	Shear #
Width:	2	End Time:	11:26 AM	2	1	End Time:	1:23 PM	2	2	End Time:	2:40 PM	2	3	End Time:	3:11 PM	2	4
Cross-Section Measurements		Measured Volumetric Flow, cfs:			0.90	Measured Volumetric Flow, cfs:			2.55	Measured Volumetric Flow, cfs:			7.00	Measured Volumetric Flow, cfs:			12.60
#1 (Sta. 0+10.00)	To original Surface Elev, cm	70.4	70.4	70.5	Avg.				Avg.				Avg.				Avg.
	To eroded Surface Elev, cm	70.4	70.4	70.5	70.4	71.3	71.2	71.3	71.3	71.6	71.6	71.5	71.6	71.7	71.7	71.6	71.7
	Soil Loss / Gain, in	0.00	0.00	0.00	0.00	-0.35	-0.31	-0.31	-0.28	-0.47	-0.47	-0.39	-0.37	-0.51	-0.51	-0.43	-0.40
	CSLI, in	0.00	0.00	0.00	0.00	-0.35	-0.31	-0.31	-0.28	-0.47	-0.47	-0.39	-0.37	-0.51	-0.51	-0.43	-0.40
	Velocity, ft/s		0.0		3.2		0.0		5.7		0.0		8.6		0.0		11.9
	Distance to Water Surface, cm		66.2		66.2		64.5		64.5		59.1		59.1		55.5		55.5
	Calculations	Flow, cfs	Depth, in			Flow, cfs	Depth, in			Flow, cfs	Depth, in			Flow, cfs	Depth, in		
		0.90	1.67			2.55	2.66			7.00	4.91			12.60	6.36		
#2 (Sta. 0+12.00)	To original Surface Elev, cm	70.5	70.4	70.8	Avg.				Avg.				Avg.				Avg.
	To eroded Surface Elev, cm	70.6	70.4	70.8	70.6	70.8	70.5	70.8	70.7	71.7	71.6	71.3	71.5	71.7	71.9	72.0	71.9
	Soil Loss / Gain, in	-0.04	0.00	0.00	-0.01	-0.12	-0.04	0.00	-0.05	-0.47	-0.47	-0.20	-0.30	-0.47	-0.59	-0.47	-0.41
	CSLI, in	-0.04	0.00	0.00	-0.01	-0.12	-0.04	0.00	-0.05	-0.47	-0.47	-0.20	-0.30	-0.47	-0.59	-0.47	-0.41
	Velocity, ft/s		0.0		3.3		0.0		5.7		0.0		9.2		0.0		11.1
	Distance to Water Surface, cm		66.5		66.5		63.9		63.9		59.9		59.9		54.5		54.5
	Calculations	Flow, cfs	Depth, in			Flow, cfs	Depth, in			Flow, cfs	Depth, in			Flow, cfs	Depth, in		
		0.90	1.61			2.55	2.68			7.00	4.58			12.60	6.84		
#3 (Sta. 0+14.00)	To original Surface Elev, cm	69.9	69.8	69.6	Avg.				Avg.				Avg.				Avg.
	To eroded Surface Elev, cm	69.9	69.8	69.8	69.8	70.4	70.6	70.6	70.5	71.0	70.8	71.2	71.0	71.0	71.5	71.7	71.4
	Soil Loss / Gain, in	0.00	0.00	-0.08	-0.03	-0.20	-0.31	-0.39	-0.25	-0.43	-0.39	-0.63	-0.42	-0.43	-0.67	-0.83	-0.53
	CSLI, in	0.00	0.00	-0.08	-0.03	-0.20	-0.31	-0.39	-0.25	-0.43	-0.39	-0.63	-0.42	-0.43	-0.67	-0.83	-0.53
	Velocity, ft/s		0.0		3.4		0.0		5.8		0.0		9.3		0.0		11.6
	Distance to Water Surface, cm		65.8		65.8		63.8		63.8		59.5		59.5		54.8		54.8
	Calculations	Flow, cfs	Depth, in			Flow, cfs	Depth, in			Flow, cfs	Depth, in			Flow, cfs	Depth, in		
		0.90	1.59			2.55	2.65			7.00	4.53			12.60	6.54		
#4 (Sta. 0+16.00)	To original Surface Elev, cm	70.4	70.8	70.8	Avg.				Avg.				Avg.				Avg.
	To eroded Surface Elev, cm	70.4	70.8	70.8	70.7	70.4	71.0	70.8	70.7	71.6	71.8	71.9	71.8	71.6	72.2	72.0	71.9
	Soil Loss / Gain, in	0.00	0.00	0.00	0.00	0.00	-0.08	0.00	-0.01	-0.47	-0.39	-0.43	-0.37	-0.47	-0.55	-0.47	-0.41
	CSLI, in	0.00	0.00	0.00	0.00	0.00	-0.08	0.00	-0.01	-0.47	-0.39	-0.43	-0.37	-0.47	-0.55	-0.47	-0.41
	Velocity, ft/s		0.0		3.5		0.0		5.8		0.0		9.1		0.0		11.3
	Distance to Water Surface, cm		66.7		66.7		64.0		64.0		60.1		60.1		54.9		54.9
	Calculations	Flow, cfs	Depth, in			Flow, cfs	Depth, in			Flow, cfs	Depth, in			Flow, cfs	Depth, in		
		0.90	1.56			2.55	2.65			7.00	4.59			12.60	6.71		
#5 (Sta. 0+18.00)	To original Surface Elev, cm	70.2	70.3	70.1	Avg.				Avg.				Avg.				Avg.
	To eroded Surface Elev, cm	70.2	70.5	70.7	70.5	71.0	70.7	70.7	70.8	71.3	71.2	71.3	71.3	71.8	71.8	71.7	71.8
	Soil Loss / Gain, in	0.00	-0.08	-0.24	-0.09	-0.31	-0.16	-0.24	-0.21	-0.43	-0.35	-0.47	-0.36	-0.63	-0.59	-0.63	-0.52
	CSLI, in	0.00	-0.08	-0.24	-0.09	-0.31	-0.16	-0.24	-0.21	-0.43	-0.35	-0.47	-0.36	-0.63	-0.59	-0.63	-0.52
	Velocity, ft/s		0.0		3.5		0.0		5.9		0.0		9.1		0.0		11.3
	Distance to Water Surface, cm		66.6		66.6		64.2		64.2		59.6		59.6		54.7		54.7
	Calculations	Flow, cfs	Depth, in			Flow, cfs	Depth, in			Flow, cfs	Depth, in			Flow, cfs	Depth, in		
		0.90	1.52			2.55	2.60			7.00	4.59			12.60	6.72		
#6 (Sta. 0+20.00)	To original Surface Elev, cm	70.3	70.5	70.5	Avg.				Avg.				Avg.				Avg.
	To eroded Surface Elev, cm	70.3	70.5	70.5	70.4	70.5	70.7	71.0	70.7	72.0	71.5	71.1	71.5	71.8	72.3	72.0	72.0
	Soil Loss / Gain, in	0.00	0.00	0.00	0.00	-0.08	-0.08	-0.20	-0.10	-0.67	-0.39	-0.24	-0.37	-0.59	-0.71	-0.59	-0.51
	CSLI, in	0.00	0.00	0.00	0.00	-0.08	-0.08	-0.20	-0.10	-0.67	-0.39	-0.24	-0.37	-0.59	-0.71	-0.59	-0.51
	Velocity, ft/s		0.0		3.6		0.0		5.9		0.0		9.1		0.0		11.5
	Distance to Water Surface, cm		66.6		66.6		64.1		64.1		59.8		59.8		55.4		55.4
	Calculations	Flow, cfs	Depth, in			Flow, cfs	Depth, in			Flow, cfs	Depth, in			Flow, cfs	Depth, in		
		0.90	1.51			2.55	2.61			7.00	4.62			12.60	6.55		
#7 (Sta. 0+22.00)	To original Surface Elev, cm	70.6	70.2	70.4	Avg.				Avg.				Avg.				Avg.
	To eroded Surface Elev, cm	70.6	70.2	70.5	70.4	71.1	70.7	70.7	70.8	71.8	71.0	71.0	71.3	72.1	72.2	72.0	72.1
	Soil Loss / Gain, in	0.00	0.00	-0.04	-0.01	-0.20	-0.20	-0.12	-0.14	-0.47	-0.31	-0.24	-0.29	-0.59	-0.79	-0.63	-0.54
	CSLI, in	0.00	0.00	-0.04	-0.01	-0.20	-0.20	-0.12	-0.14	-0.47	-0.31	-0.24	-0.29	-0.59	-0.79	-0.63	-0.54
	Velocity, ft/s		0.0		3.6		0.0		5.9		0.0		9.6		0.0		11.7
	Distance to Water Surface, cm		66.6		66.6		64.2		64.2		60.2		60.2		55.7		55.7
	Calculations	Flow, cfs	Depth, in			Flow, cfs	Depth, in			Flow, cfs	Depth, in			Flow, cfs	Depth, in		
		0.90	1.51			2.55	2.61			7.00	4.36			12.60	6.46		
#8 (Sta. 0+24.00)	To original Surface Elev, cm	69.8	69.9	70.0	Avg.				Avg.				Avg.				Avg.
	To eroded Surface Elev, cm	70.6	69.9	70.0	70.2	71.2	71.1	70.8	71.0	71.5	71.2	71.4	71.4	71.8	71.2	71.4	71.5
	Soil Loss / Gain, in	-0.31	0.00	0.00	-0.10	-0.55	-0.47	-0.31	-0.37	-0.67	-0.51	-0.55	-0.49	-0.79	-0.51	-0.55	-0.53
	CSLI, in	-0.31	0.00	0.00	-0.10	-0.55	-0.47	-0.31	-0.37	-0.67	-0.51	-0.55	-0.49	-0.79	-0.51	-0.55	-0.53
	Velocity, ft/s		0.0		3.8		0.0		5.7		0.0		8.9		0.0		11.9
	Distance to Water Surface, cm		66.6		66.6		64.2		64.2		59.4		59.4		55.3		55.3
	Calculations	Flow, cfs	Depth, in			Flow, cfs	Depth, in			Flow, cfs	Depth, in			Flow, cfs	Depth, in		
		0.90	1.40			2.55	2.69			7.00	4.71			12.60	6.36		
#9 (Sta. 0+26.00)	To original Surface Elev, cm	69.8	69.8	70.0	Avg.				Avg.				Avg.				Avg.
	To eroded Surface Elev, cm	70.0	69.8	70.0	69.9	70.1	70.9	70.0	70.3	71.0	71.2	71.4	71.2	71.2	71.3	71.4	71.3
	Soil Loss / Gain, in	-0.08	0.00	0.00	-0.03	-0.12	-0.43	0.00	-0.11	-0.47	-0.55	-0.55	-0.43	-0.55	-0.59	-0.55	-0.47
	CSLI, in	-0.08	0.00	0.00	-0.03	-0.12	-0.43	0.00	-0.11	-0.47	-0.55	-0.55	-0.43	-0.55	-0.59	-0.55	-0.47
	Velocity, ft/s		0.0		3.3		0.0		5.9		0.0		9.1		0.0		11.8
	Distance to Water Surface, cm		65.8		65.8		63.8		63.8		59.5		59.5		55.0		55.0
	Calculations	Flow, cfs	Depth, in			Flow, cfs	Depth, in			Flow, cfs	Depth, in			Flow, cfs	Depth, in		
		0.90	1.63			2.55	2.57			7.00	4.61			12.60	6.42		
#10 (Sta. 0+28.00)	To original Surface Elev, cm	69.7	69.5	69.4	Avg.				Avg.				Avg.				Avg.
	To eroded Surface Elev, cm	70.0	69.5	69.4	69.6	70.8	70.8	69.9	70.5	70.8	70.8	70.3	70.6	71.0	71.2	71.0	71.1
	Soil Loss / Gain, in	-0.12	0.00	0.00	-0.04	-0.43	-0.51	-0.20	-0.30	-0.43	-0.51	-0.35	-0.35	-0.51	-0.67	-0.63	-0.49
	CSLI, in	-0.12	0.00	0.00	-0.04	-0.43	-0.51	-0.20	-0.30	-0.43	-0.51	-0.35	-0.35	-0.51	-0.67	-0.63	-0.49
	Velocity, ft/s		0.0		3.6		0.0		5.8		0.0		9.2		0.0		12.0
	Distance to Water Surface, cm		65.8		65.8		63.8		63.8		59.0		59.0		55.0		55.0
	Calculations	Flow, cfs	Depth, in			Flow, cfs	Depth, in			Flow, cfs	Depth, in			Flow, cfs	Depth, in		
		0.90	1.51			2.55	2.64			7.00	4.58			12.60	6.33		
#11 (Sta. 0+30.00)	To original Surface Elev, cm	69.4	69.7	69.3	Avg.				Avg.				Avg.				Avg.
	To eroded Surface Elev, cm	69.8	70.2	69.8	69.9	71.0	70.8	70.1	70.6	71.4	70.9	71.3	71.2	71.5	71.3	71.4	71.4
	Soil Loss / Gain, in	-0.16	-0.20	-0.20	-0.15	-0.63	-0.43	-0.31	-0.39	-0.79	-0.47	-0.79	-0.60	-0.83	-0.63	-0.83	-0.66
	CSLI, in	-0.16	-0.20	-0.20	-0.15	-0.63	-0.43	-0.31	-0.39	-0.79	-0.47	-0.79	-0.60	-0.83	-0.63	-0.83	-0.66
	Velocity, ft/s		0.0		3.8		0.0		5.9		0.0		9.0		0.0		12.1
	Distance to Water Surface, cm		66.3		66.3		64.0		64.0		59.3		59.3		55.5		55.5
	Calculations	Flow, cfs	Depth, in			Flow, cfs	Depth, in			Flow, cfs	Depth, in			Flow, cfs	Depth, in		
		0.90	1.43			2.55	2.61			7.00	4.69			12.60	6.26		



Gradation of Tested Manufactured Sand

Attachment 3

Evaluation of Sand Infill Criteria for ClosureTurf®

Technical Note

EVALUATION OF SAND INFILL CRITERIA FOR CLOSURETURF®

Fine aggregate infill (sand) is one component of the ClosureTurf® three component system. An extensive testing program was implemented to evaluate the criteria and performance properties for the sand infill in the ClosureTurf system. The program included large scale performance testing by an independent third party laboratory, TRI Environmental (TRI) at the Denver Downs Research facility in Greeneville, South Carolina. A description of the testing procedures and results are provided in this document.

SAND INFILL FUNCTION

The sand infill component of ClosureTurf is utilized as a protective layer for the geotextile backing of the engineered turf component. The polypropylene geotextile backing material contains ultraviolet (UV) radiation degradation inhibitors protecting it against UV damage. Sand infill functions as an additional protective layer against UV degradation of the geotextile backing. Optimal sand infill performance occurs with minimal sand movement.

TRI tested sand infill mobilization in ClosureTurf in general accordance with ASTM D 6460, *Standard Test Method for Determination of Rolled Erosion Control Product (RECP) Performance in Protecting Earthen Channels from Stormwater-Induced Erosion* and ASTM D 6459 *Standard Test Method for Determination of Rolled Erosion Control Product (RECP) Performance in Protecting Hillslopes from Rainfall-Induced Erosion*. The results of the testing were also analyzed in accordance with each Standard to quantify infill mobilization during tested conditions. Photographs of tested sands are provided as Attachment A.

SAND INFILL LARGE SCALE HYDRAULICS TESTING

The TRI large-scale hydraulic testing (ASTM D 6460) was conducted in a rectangular flume having a 0.10 ft/ft slope. The subgrade was a loamy soil over which ClosureTurf with a ½ inch sand infill was installed following installation guidelines. Water is supplied to the facility by gravity flow and controlled and measured through upstream sluice gates as presented in Figure 1.

A test consists of measuring infill thickness, opening the sluice gates a predetermined amount allowing overtopping flow on the ClosureTurf for a period of 30 minutes, closing the sluice gate to stop overtopping flow and measuring infill depth to evaluate sand loss. The test procedure is repeated a minimum of four times with increasing overtopping flow amounts or until enough sand infill has been removed to expose the majority of the geotextile backing.

Figure 1. ClosureTurf® TRI Flume Test Installation

Reported test results include sand infill loss during each 30-minute overtopping period and the corresponding hydraulic shear stress during the 30-minute test period. The testing was conducted on six different sand infills having a range of grain size distributions, fine aggregate angularities and specific gravities. Sand infill angularity and specific gravity are presented in Table 1. Tested sand infill grain size distributions are presented in Figure 2. Hydraulic shear stress results are presented in Figure 3.

Table 1. Tested Sand Infill Angularity and Specific Gravity

Test Sand No.	Fine Aggregate Angularity (FAA) (%) (ASTM C 1252 / AASHTO T 304) (Method A)	Bulk Specific Gravity, Dry (SG) (ASTM C 128 / AASHTO T 84)
1	47.2	2.64
2	40.5	2.60
3	43.1	2.59
4	45.7	2.64
5	47.1	2.85
6	43.7	1.96

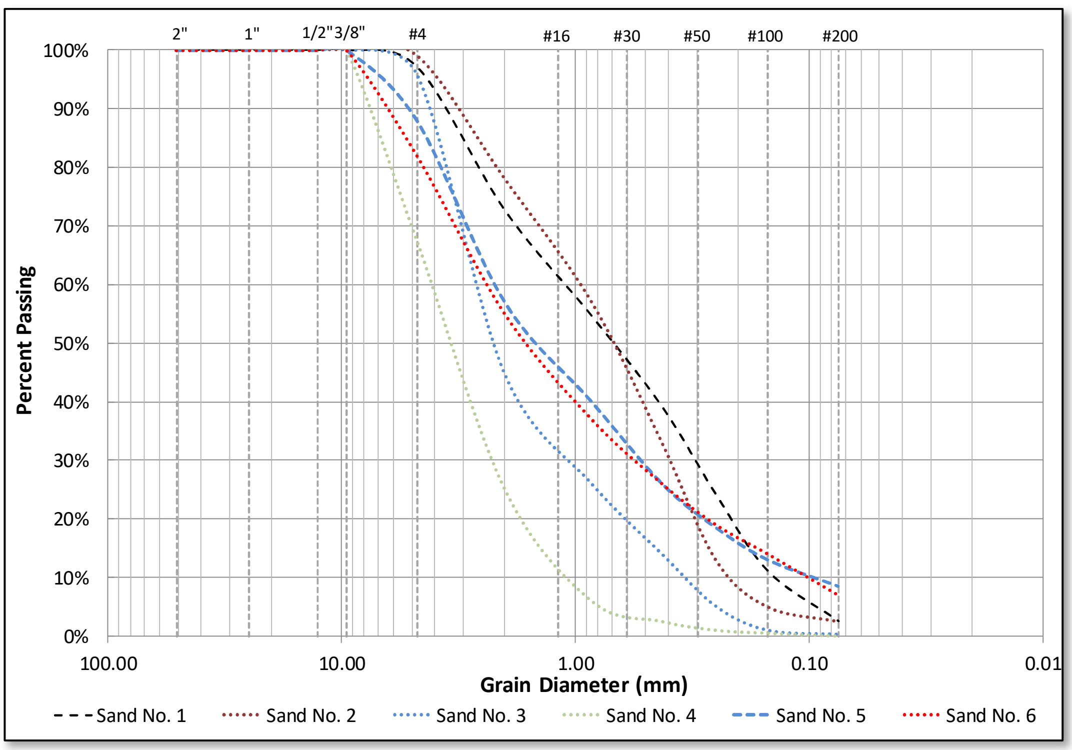


Figure 2. Tested Sand Infill Grain Size Distributions (ASTM C 136 / AASHTO T 27)

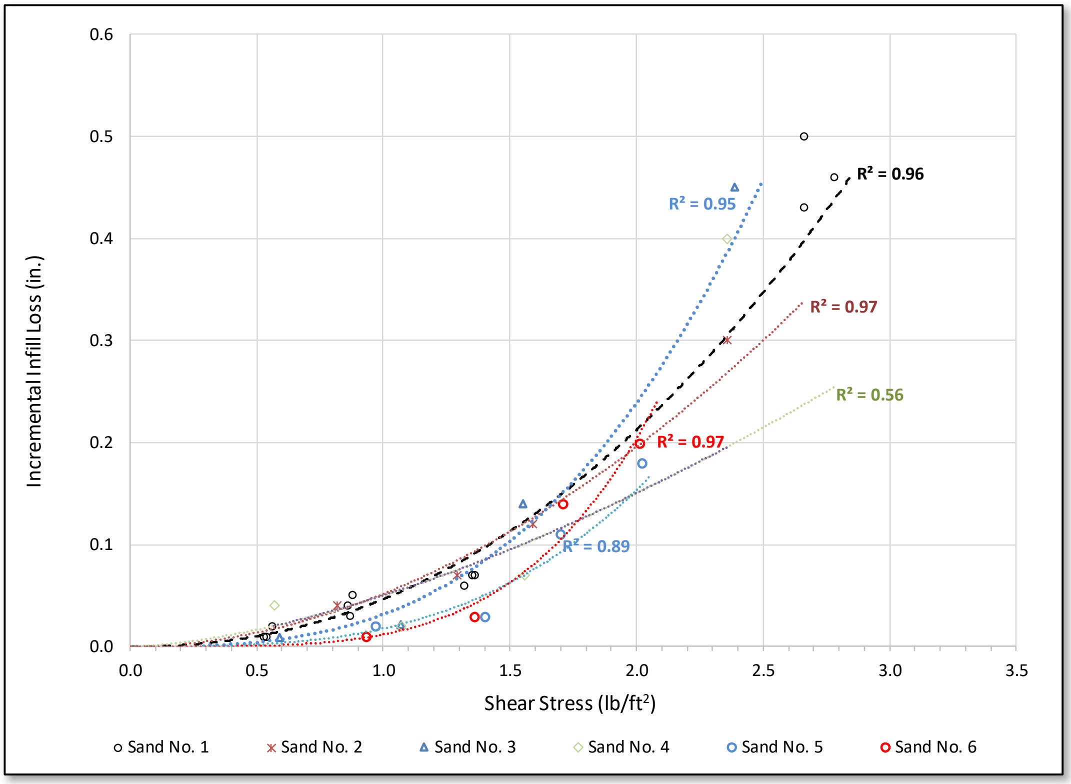


Figure 3. Infill Loss Due to Hydraulic Shear

SAND INFILL LARGE SCALE RAINFALL EROSION TESTING

The TRI large-scale rainfall erosion testing (ASTM D 6459) was conducted on a rectangular plot measuring 40 feet by 8 feet (length x width) and having a 0.33 ft/ft slope. The subgrade was a loamy soil over which ClosureTurf with a ½ inch sand infill was installed following installation guidelines as presented in Figure 4a. Artificial rainfall is produced by ten "rain trees" arranged around the perimeter of the test slope. Each rain tree has four sprinkler heads atop a 15 ft. riser pipe. The rainfall system produces target rainfall intensities of 2-, 4-and 6-inches per hour at pre-calibrated rain drop size distributions for a period of 20 minutes per intensity resulting in a one hour test. Testing in progress is presented in Figure 4b. All runoff was collected during testing to quantify sediment mobilization. Incremental infill losses are presented in Table 2.

(a) Infill Installation **(b) Testing in Progress**

Figure 4. ClosureTurf® TRI Rainfall Erosion Testing

Table 2. Tested Sand Infill Rainfall Erosion Results

Test Sand No.	Rainfall Intensity (in./hr)	Incremental Infill Loss (%)
1	2.0	0.01
1	4.0	0.02
1	6.1	0.04
3	2.0	0.00
3	4.2	0.00
3	6.1	0.00
4	2.1	0.00
4	4.1	0.00
4	6.0	0.00

Based on the TRI large scale rainfall erosion and hydraulic shear test results and sand infill material properties, a sand infill specification was developed as summarized in Figure 5 and as appears in the WatershedGeo CSI specification, SECTION 31 05 16, *ClosureTurf® SAND INFILL COMPONENT*.

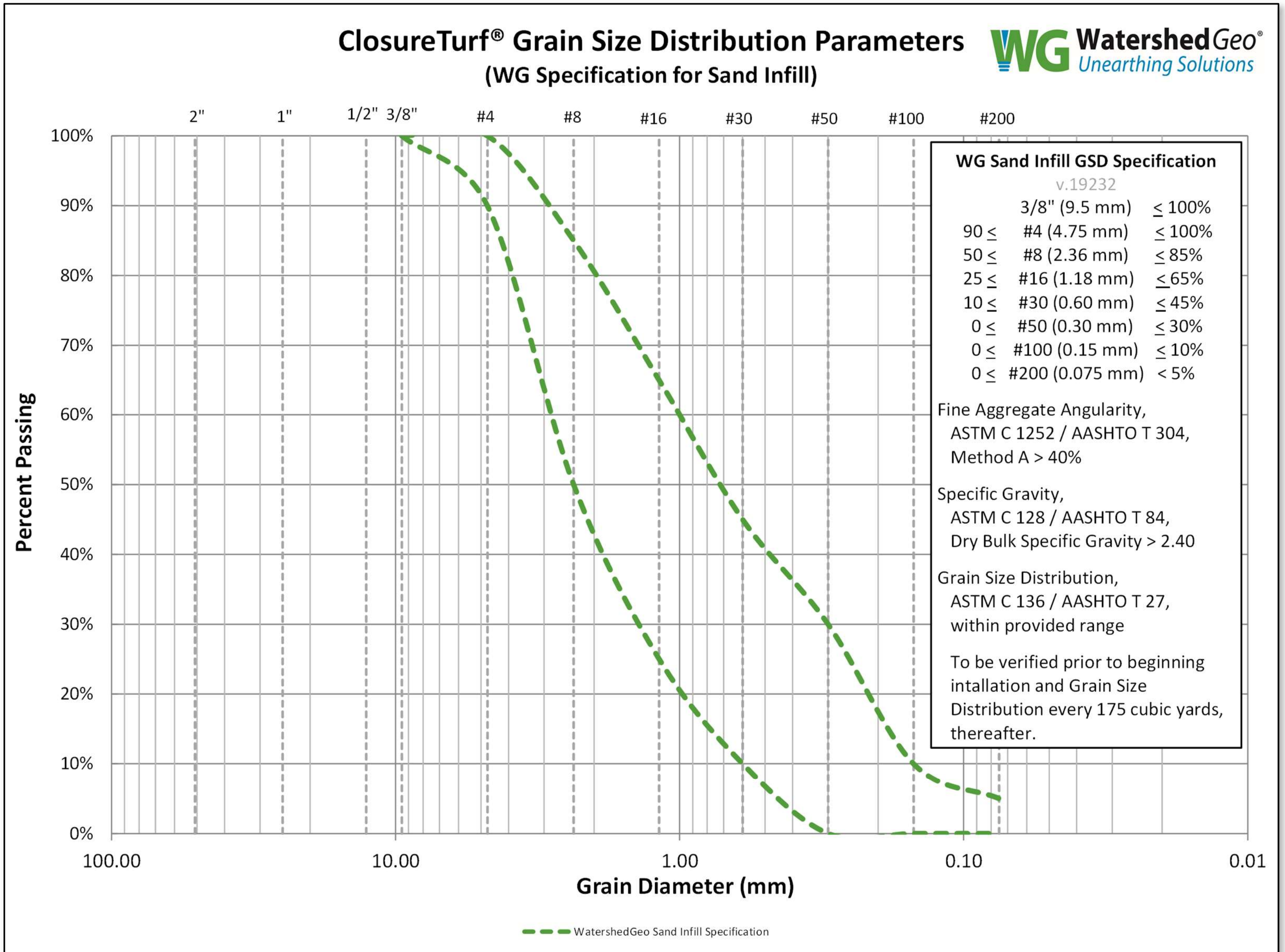


Figure 5. ClosureTurf® Sand Infill Specification

Attachment A

Figure A1. Tested Sand No. 1

Figure A2. Tested Sand No. 2

Figure A3. Tested Sand No. 3

Figure A4. Tested Sand No. 4

Figure A5. Tested Sand No. 5

Figure A6. Tested Sand No. 6

LIMITATIONS

ClosureTurf® is a U.S. registered trademark which designates a product from Watershed Geosynthetics LLC. This product is the subject of issued U.S. and foreign patents and/or pending U.S. and foreign patent applications. All information, recommendations and suggestions appearing in this literature concerning the use of our products are based upon tests and data believed to be reliable; however, this information should not be used or relied upon for any specific application without independent professional examination and verification of its accuracy, suitability and applicability. Since the actual use by others is beyond our control, no guarantee or warranty of any kind, expressed or implied, is made by Watershed Geosynthetics LLC as to the effects of such use or the results to be obtained, nor does Watershed Geosynthetics LLC assume any liability in connection herewith. Any statement made herein may not be absolutely complete since additional information may be necessary or desirable when particular or exceptional conditions or circumstances exist or because of applicable laws or government regulations. Nothing herein is to be construed as permission or as a recommendation to infringe any patent.

Attachment 4

ClosureTurf® Sand Infill Specification

This ClosureTurf® Specification document has been prepared to provide the Owner, Design Engineer, Construction Quality Assurance Professional of Record, and the Contractor / Installer with a general guidance specification. All information, recommendations and suggestions appearing in this specification concerning the use of our products are based upon experience, tests and data believed to be reliable; however, this information should not be used or relied upon for any specific application without independent professional examination and verification of its accuracy, suitability and applicability. The independent professional shall edit this document to suit the site-specific project design criteria. Since the actual use by others is beyond our control, no guarantee or warranty of any kind, expressed or implied, is made by Watershed Geosynthetics LLC as to the effects of such use or the results to be obtained, nor does Watershed Geosynthetics LLC assume any liability in connection herewith. Any statement made herein may not be absolutely complete since additional information may be necessary or desirable when particular or exceptional conditions or circumstances exist or because of applicable laws or government regulations. ClosureTurf® is a U.S. registered trademark which designates a product from Watershed Geosynthetics LLC. This product is the subject of issued U.S. and foreign patents and/or pending U.S. and foreign patent applications. Nothing herein is to be construed as permission to grant license or as a recommendation to infringe any patent.

SECTION 31 05 16

ClosureTurf® SAND INFILL COMPONENT

PART 1: GENERAL

1.01 SUMMARY

A. Section Includes:

Specifications for approved Sand Infill Component of the patented ClosureTurf® System.

1.02 RELATED SECTIONS

Section 31 23 13 - Subgrade preparation (Upper 6 inches of subgrade only)

Section 01 42 00 - References and Definitions

Section 01 60 00 - ClosureTurf® Product Specification

Section 01 60 00 - ClosureTurf® MicroDrain® Product Specification

Section 01 60 01 - ClosureTurf® MicroSpike® Product Specification

Section 01 73 19 - ClosureTurf® Installation Specification

Section 31 05 16 - ClosureTurf® Sand Infill Specification

Section 03 49 01 - Alternate HydroBinder® Infill Specification

Section 23 51 23 - ClosureTurf® HDPE Pressure Relief Valve Specification

PART 2: PRODUCTS

2.01 DESCRIPTION

Sand Infill Component of the ClosureTurf® System shall meet the fine aggregate angularity, specific gravity and grain size distribution as specified by WatershedGeo in this Specification.

A. Fine aggregate angularity shall be tested in accordance with ASTM C 1252 / AASHTO T 304, *Standard Test Methods for Uncompacted Void Content of Fine Aggregate (as Influenced by Particle Shape, Surface Texture, and Grading). Method A.* Method A uncompacted void content shall be greater than or equal to 40%.

B. Sand infill specific gravity shall be tested in accordance with ASTM C 128 / AASHTO T 84, *Standard Test Method for Relative Density (Specific Gravity) and Absorption of Fine Aggregate.* Bulk oven-dry specific gravity shall be greater than or equal to 2.40.

C. Sand infill grain size distribution shall be tested in accordance with ASTM C 136 / AASHTO T 27, *Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates.* The grain size distribution shall be as prescribed in Table 1 and presented in Figure 1.

Table 1. Sand Infill Grain Size Distribution

		3/8" (9.5 mm)	≤	100%
90%	≤	#4 (4.75 mm)	≤	100%
50%	≤	#8 (2.36 mm)	≤	85%
25%	≤	#16 (1.18 mm)	≤	65%
10%	≤	#30 (0.60 mm)	≤	45%
0	≤	#50 (0.30 mm)	≤	30%
0	≤	#100 (0.15 mm)	≤	10%
0	≤	#200 (0.075 mm)	≤	5%

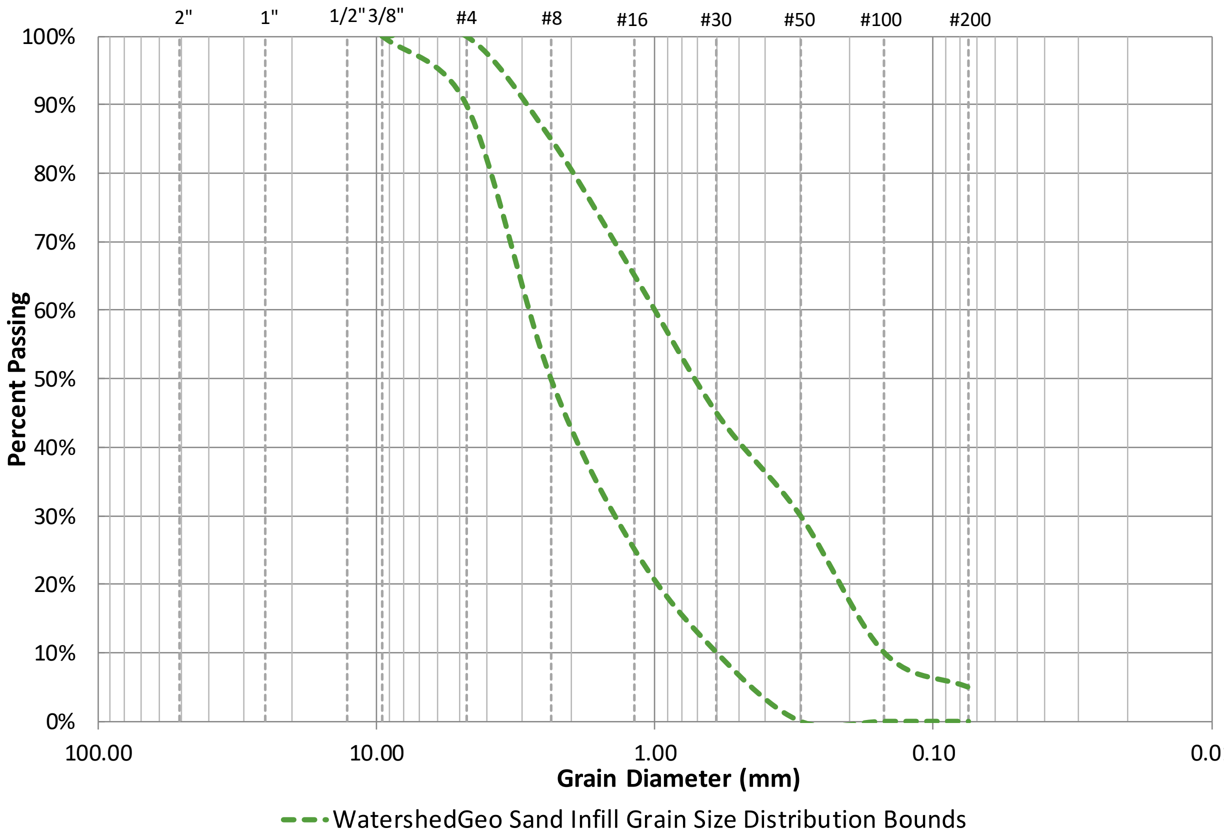


Figure 1: ClosureTurf® Specified Infill Grain Size Distribution

D. Documentation of sand infill conformance with ASTM C 136 / AASHTO T 27, ASTM C 128 / AASHTO T 84 and ASTM C 1252 / AASHTO T 304 shall be submitted to the specified CQA personnel.

E. Subsequent to initial verification of specification conformance, sand infill shall have grain size distribution conformance verified and documented for each 175 cubic yards to be installed.

PART 3: EXECUTION:

Not Used. See Section 01 73 19 ClosureTurf® Installation Specifications.

END OF SECTION

APPENDIX C

Alternative Liner Equivalency Calculation

GOLDER

CALCULATIONS

Date:	3/27/2020	**Made by:**	MMJ
Project No.:	19117989	**Checked by:**	JRP
Subject:	Liquid Flow Rate Equivalency Calculation	**Reviewed by:**	DML
Project Short Title:	RD Morrow Landfill Closure		

OBJECTIVE:

Verify the liquid flow rate through the lower component of the alternative cover is less than or equal to the liquid flow rate through 1.5 feet (45.72 cm) of compacted soil with a hydraulic conductivity of 1×10^{-7} cm/s.

ASSUMPTIONS:

1) The alternative cover design for the RD Morrow landfill consists of a welded 40-mil HDPE geomembranbe with a synthetic turf and 0.5-inch thick sand layer to promote surface drainage and prevent erosion. The selected geomembrane has an approximate hydraulic conductivity of 1×10^{-13} cm/s.

2) The maximum hydraulic head expected above the cover system is 0.5 inches (1.27 cm) based on the design thickness of the sand layer component of the alternative cover system.

METHODS:

The liquid flow rate will be calculated using Darcy's Law:

$$\frac{Q}{A} = q = k\left(\frac{h}{t} + 1\right)$$

where:

Q	=	flow rate through layer (cm^3/s)
A	=	surface area of layer (cm^2)
q	=	flow rate through layer per unit area ($cm^3/s/cm^2$)
k	=	saturated vertical hydraulic conductivity of the layer (cm/s)
h	=	hydraulic head above the liner system (cm)
t	=	thickness of the layer (cm)

CALCULATIONS:

1) Liquid flow rate through 1.5 feet of compacted soil with a hydraulic conductivity of 1×10^{-7} cm/s:

k	=	1.00E-07	cm/s
h	=	1.27	cm
t	=	45.72	cm
q_1	=	1.0E-07	$cm^3/s/cm^2$

2) Liquid flow rate through 0.1-cm thick geomembrane with a hydraulic conductivity of 1×10^{-13} cm/s:

k	=	1.00E-13	cm/s
h	=	1.27	cm
t	=	0.1	cm
q_2	=	1.4E-12	$cm^3/s/cm^2$

3) Flow rate comparison:

$q_1 \geq q_2$

1.0E-07 $cm^3/s/cm^2$ > 1.4E-12 $cm^3/s/cm^2$

CONCLUSIONS:

The liquid flow rate through a 0.1-cm thick geomembrane with a hydraulic conductivity of 1×10^{-13} cm/s is less than the liquid flow rate through 1.5 feet of compacted soil with a hydraulic conductivity of 1×10^{-7} cm/s. Therefore, the alternative cover design for the RD Morrow landfill has a lower flow than a typical compacted clay cover with a hydraulic conductivity of 1×10^{-7} cm/s.

REFERENCES:

1) "Standards for the Disposal of Coal Combustion Residuals in Landfills and Surface Impoundments," Title 40 – Protection of the Environment Part 257 – Criteria for Classification Solid Waste Disposal Facilities and Practices Subpart D – Standards for the Disposal of Coal Combustion Residuals in Landfills and Surface Impoundments.

APPENDIX D

ClosureTurf® Owner's Post-Closure Care Manual

ClosureTurf®
OWNER'S POST-CLOSURE CARE MANUAL
November 2019

ClosureTurf®

INTRODUCTION

The ClosureTurf® closure system has an anticipated service life of more than 100 years with proper design, installation, and maintenance. This document provides guidance and procedures required to adequately inspect and maintain the ClosureTurf system for projects that were completed in accordance with Watershed Geosynthetics' (Watershed Geo's) Design Guidelines Manual, Installation Guidelines Manual, and Specifications.

ClosureTurf inspection and maintenance involves periodic evaluation and correction, if needed, of the specified infill and engineered turf conditions. The goal is to preserve longevity of the engineered turf geotextile backing by reducing exposure to weathering forces and maintain adequate tensile strength of the turf fibers to achieve the anticipated 100+ years of service life.

DEFINITIONS

ArmorFill®

ArmorFill® is a proprietary product used to bind the sand infill component of the ClosureTurf® System.

ClosureTurf®

A patented 3-component system consisting of a structured geomembrane, an engineered turf, and a specified sand infill (or alternatively a HydroBinder®).

Construction Quality Assurance (CQA) Engineer

The CQA Engineer is an authorized representative of the Owner and has overall responsibility for CQA efforts and to confirm the project was constructed in general accordance with site-specific specifications approved by the regulatory authority and contract documents. The CQA Engineer must be licensed as a Professional Engineer in the State where the project is located and experienced in geosynthetics.

Contractor

The entity that agrees to furnish materials or perform services at a specified price, especially for construction work.

Engineered Turf

A component of the ClosureTurf system. A synthetic structured material consisting of one or more layers of geotextiles tufted with polyethylene yarns that resemble grass blades.

Geomembrane

A synthetic lining material that is a component of the ClosureTurf system and used as the primary barrier to infiltration and exfiltration of covered materials.

HydroBinder®

A proprietary cementitious infill utilized where higher surface water velocities may occur, such as downchutes, as well as in anchor trenches where specified.

Geosynthetics Contractor / Installer

The entity responsible for geosynthetic installation.

Operator

The entity in control and responsible for the facility.

Owner

The entity that owns facility and land.

DEFINITIONS

Owner's or Operator's Representative
An official representative of the Owner or Operator responsible for planning, organizing, and controlling construction activities.

Wrinkle
A portion of the geomembrane that does not lay relatively flat and is not a result of subgrade irregularity, which can be folded over.

PERFORMANCE AGREEMENT

Owners who have chosen a Watershed Geo Performance Agreement will have support pertaining to the monitoring and maintenance of the ClosureTurf closure system.

Support provided by a Performance Agreement includes periodic inspection performed by Watershed Geo representatives that will document both existing and potential issues that should be addressed either immediately or during the next maintenance event.

Additionally, Watershed Geo will maintain the ClosureTurf components at a maintenance interval defined in the Performance Agreement.

For more information concerning the Watershed Geo Performance Agreement, contact a Watershed Geo Representative.

INSPECTION AND MAINTENANCE PERIODS

Annual inspection should be performed by the Owner or Owner's representative. Exhibit A, Post Closure Monitoring and Maintenance Inspection Report, can be used to document issues found during the inspection.

ClosureTurf maintenance includes correcting any identified areas of exposed geotextile backing during the prior inspection intervals. Areas of concern should be corrected at a frequency of at least every 5 years.

VISUAL INSPECTION MONITORING

Annual visual inspections will be completed by physically walking the surface of the ClosureTurf installation and documenting observed issues (See Exhibit A).

The personnel can use the following list to note when an issue should be documented:

- Differential settlement (to the extent of grade reversal or ponding of water),
- Exposed geotextile backing,
- Exposed geomembrane,
- Damage to engineered turf fibers in high traffic access areas,
- Significant sand migration and drainage channel ballast materials (HydroBinder, rip rap, stone, etc.), and
- Physical damage from equipment or animals.

CORRECTIVE ACTION RESPONSIBILITY

Corrective actions should be performed by Watershed Geo trained individuals. While some corrective procedures can be performed by trained site personnel, a complete list of certified ClosureTurf installers is available upon request.

GUIDANCE

Repair techniques will follow Watershed Geo's Installation Guidelines Manual and Specifications. Note that Watershed Geo's Installation Guidelines Manual are provided as Exhibit B to this document.

DOCUMENTATION

Documentation will include completion of the ClosureTurf Post Closure Inspection Report. The checklist will include details of the corrective measures or repairs made to damaged areas, if any.

EQUIPMENT ON ENGINEERED TURF

Post-closure equipment operation should be limited to those with rubber tires or tracks. The following are suggested load limits based on grade conditions:

- No equipment will be allowed on slopes exceeding 15% until the sand infill is in place.
- On slopes less than 15%, such as top decks, ATV type vehicles will be allowed prior to infill placement if the rubber tire or track pressure is less than 5 psi.
- Post-construction (with full specified sand infill thickness) drivability:
    - Rubber tire or track pressures on slopes greater than 15% should be limited on the ClosureTurf system to less than 35 psi.
    - On slopes less than 15%, allowable rubber tire or track pressures should be limited to less than 85 psi, when sustained traffic load is not expected.

Equipment used on the ClosureTurf product will not be allowed to change speed or direction in a manner that could displace or damage the ClosureTurf system. Higher traffic areas will require sand to be placed at the full height of the turf. Regularly trafficked areas will be designed and approved by the engineer.

It should be noted that the above load limits assume that the subgrade, which is not part of the ClosureTurf system, is adequate to support the anticipated vehicle loading without creating rutting or bearing capacity issues.

WILDLIFE DAMAGE

Determine the causes as to how wildlife is gaining access to the site and correct the access issue. Instructions to fix exposed geotextile backing and geomembrane, if any, are provided in the sections below.

UNAUTHORIZED ACCESS - VANDALISM

Determine the causes as to how the site is being accessed illegally and correct the access issue. Instructions to fix exposed geotextile backing and geomembrane, if any, are provided in the sections below.

DRAINAGE CHANNEL BALLAST MOVEMENT

When the geotextile backing is exposed due to ballast movement in the drainage channels, replace with new ballast in the exposed area.

EXPOSED GEOTEXTILE BACKING

Repairs will be documented on the inspection report (Exhibit A). Installation to make the correction will follow the techniques and procedures suggested in Watershed Geo's ClosureTurf Installation Guidelines Manual (Exhibit B):

- For areas where sand has migrated, replace sand during the 5-year maintenance interval.

- Replace sand by hand or using equipment listed in Exhibit C.
- For areas with exposed geotextile backing at the crest of wrinkles, sand movement within a seam, and isolated small voids, correct by placing new sand with ArmorFill or HydroBinder to stabilize the sand from future migration.
- For exposed geotextile backing due to missing tufted fibers, the exposed geotextile area will first be covered with a new piece of engineered turf sized to be approximately 6 inches larger in all directions; the engineered turf will then be heat-bonded using a heat gun as illustrated in the attached equipment list (Exhibit C); and new sand infill will be placed in the tufts of the engineered turf of the repaired area to the specified thickness.

DAMAGED ENGINEERED TURF - EXPOSED GEOMEMBRANE

Installation will follow the techniques and procedures suggested in Watershed Geo's ClosureTurf Installation Guidelines Manual:

- Define the causes for exposed geomembrane.
- Have trained personnel repair the area where geomembrane is exposed by cutting a patch of new engineered turf and placing it over the exposed area.
- Seam the new engineered turf to the existing engineered turf by heat-bonding.
- After seaming is complete, install new sand infill over the engineered turf patch.
- Document the repairs on the inspection report.

DAMAGED GEOMEMBRANE

If possible, define the causes of damage so that it may be proactively addressed. Repair the damaged geomembrane areas as follows:

- Clean the affected area by removing loose infill (sand or HydroBinder).
- Cut back and remove the overlying engineered turf to access the damaged geomembrane.
- Cut a patch of new geomembrane that is the same material as the existing geomembrane. The patch will extend a minimum of 4 inches beyond the damaged area in all directions and have rounded corners.
- Use extrudate rod that has the same resin type as the resin of the existing geomembrane.
- Clean the geomembrane and properly grind the areas to be welded to have smooth surfaces for welding.
- Extrusion weld the patch to the existing geomembrane. The welding technician shall be Certified Welding Technician (CWT) for polyethylene geomembrane.
- Test the extrusion weld using a vacuum box for leaks in accordance with ASTM D5641.
- Replace the engineered turf and sand or HydroBinder infill (see Exhibit B for more detailed guidelines).
- Document the repairs and include photos taken before and after the repairs.

Installation will follow the techniques and procedures suggested in Watershed Geo's ClosureTurf Installation Guidelines Manual.

DIFFERENTIAL SETTLEMENT- PONDING OF WATER AND GRADE REVERSAL

If ponding water or grade reversal on slopes or in ditches occurs as a result of differential settlement, corrective options are presented below. Options 2 & 3 are intended for small isolated areas. Installation will follow the techniques and procedures suggested in Watershed Geo's ClosureTurf Installation Guidelines Manual.

Option 1 - Remove standing water, if any, sand infill, and engineered turf over the depressed area and leave the existing geomembrane in place; fill the depressed area with sand, soil, or other fill materials approved by the engineer until designated grades are achieved; weld a patch of geomembrane over the newly graded fill to the existing geomembrane; place a new, fitted piece of engineered turf over the depressed area and heat-bond the adjacent turf materials; and install new sand infill to the specified thickness.

Option 2 - Remove the sand infill, engineered turf, and geomembrane over the depressed area; fill in the depressed area with approved fill materials to designated grades; install new geomembrane and engineered turf; and install new sand infill to the specified thickness.

Option 3 - Cut a small area of the engineered turf around the depressed area and flip the turf to expose the geomembrane; cut a small hole in the geomembrane and insert a hose or pipe to pump a flowable backfill into the depression area to "jack up" the geomembrane and turf; once they are pushed back to the desired grade, stop the backfill and repair the hole in the geomembrane by welding a new fitted piece of geomembrane; repair the engineered turf by a heat-bonded seam. Note that depending on the size of the depression area, multiple holes may be needed in order to pump the flowable backfill to completely fill the depressed area; and the flowable backfill should not set up too hard as to potentially damage the geomembrane.

CLOSURETURF® AESTHETICS

Wrinkling of the ClosureTurf may occur over time because of expansion/contraction of the polyethylene geomembrane component and landfill settlement. Wrinkles do not affect the engineering performance of ClosureTurf. In the event the Owner determines a wrinkle should be repaired due to aesthetics, the following method is suggested by Watershed Geo:

- Cut the engineered turf and geomembrane components along the top of wrinkle;
- Overlap excess geomembrane until the area lays flat;
- Extrusion weld and vacuum test the geomembrane seam;
- Overlap excess engineered turf and heat-bond the turf seam; and
- Place new sand infill with ArmorFill or HydroBinder, as required.

EXHIBIT A

POST-CLOSURE MONITORING AND MAINTENANCE INSPECTION REPORT TEMPLATE

EXHIBIT A

A. Site Information	B. Contact Information
Facility Name:	Site Operator:
Address:	Phone:
Closure Date:	Inspected By:
Date of Last Inspection:	Date of Inspection

C. ClosureTurf® Maintenance Checklist

		Yes	No	NA
1	Evidence of damage due to wildlife?			
2	Evidence of damage due to unauthorized post-closure use?			
3	Evidence of ponding water?			
4	Do all drainage swales have positive drainage?			
5	Noticeable drainage channel ballast movement?			
6	Areas with exposed geotextile backing?			
7	Areas with exposed geomembrane?			

Documented Repairs:

Inspected by:________________________ Approved by: ________________________

Note:

- If "Yes" is checked, please see Owner's Post-Closure Care Manual for a complete list of instructions for remediation.
- The owner's designated representative shall be responsible for the monitoring/reporting of field observations and incorporating proper maintenance procedures.

EXHIBIT B

CLOSURETURF® INSTALLATION GUIDELINES MANUAL

ClosureTurf®

Installation Guidelines Manual

August 2019

Before utilizing this document as an installation tool, Installer should download the latest version of the Installation Guidelines Manual from the website at www.watershedgeo.com.

WatershedGeo®
Unearthing Solutions

Table of Contents

1.0 Introduction

ClosureTurf® is a patented, 3-component system* that serves as the final cover system on landfills. The 3 components of this unique system are:

Component 1 - An Agru Super Gripnet® LLDPE (or HDPE) geomembrane liner, or other liner approved for use by WatershedGeo.

Component 2 - An Engineered Turf

Component 3 - A sand infill (and/or alternatively, Hydrobinder®)

*A Watershed Geosynthetics® patented (patent no. 8,585,322) gas collection system is a separate component to be utilized on sites that produce gas emissions. Pressure Relief Valves are provided at one per acre of ClosureTurf® on landfills where gas emissions are expected.

1.1 Purpose and Scope

The ClosureTurf® Installation Guidelines document has been prepared to provide the Engineer / Contractor / Installer general guidance to the proper installation of the ClosureTurf® System. This document should be used in conjunction with the ClosureTurf® CSI (Construction Standards Institute) Specifications for the proper installation of the product.

This manual is meant as a guideline only. Watershed Geosynthetics LLC cannot anticipate the many ways this product may be applied either in design or installation. Varying site conditions will require close coordination between the engineer and the installer to account for site conditions and adjust accordingly. When required by state and/or local regulations, a licensed professional engineer or architect will be required.

2.0 Definitions

Whenever the terms listed below are used, the intent and meaning will be interpreted as indicated.

Acclimation

Physiological/thermal adjustment. Required in the geomembrane deployment process.

ArmorFill®

Armor-Fill® Liquid Emulsion is a proprietary Polymer Emulsion product used to bind the ASTM-C33 sand infill component of the ClosureTurf® System.

ASTM

ASTM International, known until 2001 as the American Society for Testing and Materials, is an international standards organization that develops and publishes voluntary consensus technical standards for a wide range of materials, products, systems, and services.

ClosureTurf®

A patented 4 component system consisting of a Watershed Geosynthetics specific Gas Management System (if applicable), a Structured Geomembrane (LLDPE or HDPE), an Engineered Turf, and a specific grade of sand infill (or alternatively a HydroBinder®).

Construction Quality Assurance (CQA)

Construction Quality Assurance includes but is not limited to observations and documentation of materials and workmanship necessary to show that a particular project is being constructed according to site-specific specifications and within regulatory guidelines.

Construction Quality Assurance (CQA) Personnel

Construction Quality Assurance (CQA) personnel are representatives of the Professional of Record (POR) who work under direct supervision of the POR. The CQA personnel are responsible for quality assurance monitoring, applicable conformance sampling and performing onsite tests and observations.

Construction Quality Assurance Professional of Record (POR)

The POR is an authorized representative of the Owner and has overall responsibility for CQA efforts and to confirm the project was constructed in general accordance with site-specific specifications approved by the regulatory authority and contract documents. The POR must be licensed as a Professional Engineer in the State the project is located and experienced in geosynthetics.

Construction Quality Control (CQC) Personnel

CQC Personnel are representatives of the Geosynthetics Installer who work under direct supervision of the Geosynthetics Installer. The Geosynthetics Installers' CQC Personnel are responsible for construction quality control, applicable conformance sampling and performing onsite tests and observations.

Contract Documents

Written, printed, or electronic matter that provides information or evidence that serves as an official record and are issued by the owner or operator. The documents include bidding requirements that include but are not limited to, contract forms, contract conditions, contract specifications, CQA plan, contract drawings, addenda, and contract modifications.

Contract Specifications

The requirements which are to be followed in the construction of the ClosureTurf® System. The standard specifications, supplemental specifications, special provisions, and all written or printed agreements and instructions that pertain to the method and manner of performing the work.

Contractor

One that agrees to furnish materials or perform services at a specified price, especially for construction work.

Design Engineer

An individual licensed to practice as a Professional Engineer or a Professional Service Firm that is responsible for the preparation of the project construction drawings and specifications.

Earthwork

A general engineering term relating to the relocation and utilization of soil during the process of construction.

Engineered Turf

A component of the ClosureTurf® System. A synthetic structured material consisting of one or more geotextiles tufted with polyethylene yarns that resemble grass blades.

Final Cover System Evaluation Report (FCSER)

Upon substantial completion of closure activities, the POR is responsible for the documentation of construction activities relating to the project, and any other inspections or verifications required by the regulatory authority. The FCSER will be signed and stamped by the POR and include documentation necessary for certification closure.

Fish Mouth

A semi-conical opening of the seam that is formed by an edge wrinkle in one sheet of the geomembrane component.

Geomembrane

A synthetic lining material that is a component of the ClosureTurf® System. Used as the primary barrier to infiltration and exfiltration of covered materials.

GSI

Geosynthetic Institute

475 Kedron Avenue

Folsom, PA 19033-1208 USA

TEL (610) 522-8440

FAX (610) 522-8441

HydroTurf®

A patented 3 component system consisting of a Structured Geomembrane Liner, a specialized Engineered Turf, and HydroBinder® infill material.

HydroBinder®

A proprietary pozzolanic infill utilized where higher surface water velocities may occur as well as in anchor trenches where specified.

Geosynthetics Contractor / Installer

The entity responsible for geosynthetic installation.

Independent Testing Laboratory

An organization, person, or company that tests products and materials, etc. according to agreed requirements. The entity shall be independent of ownership or control by the Owner or any party to the construction of the final cover or the manufacturer of the final cover products used. The entity shall also have proper legal authority where required to issue opinions and document the results of tests requested by the Owner.

Installation Supervisor

The person on-site who works for the Geosynthetics Installer and is in charge of the Geosynthetics Personnel and following the site specifications for the installation of the geosynthetics.

Manufacturing Quality Control (MQC)

A planned system of inspection and verification to ensure the quality of the final product.

Nonconformance

A deficiency in characteristics, documentation, or procedures that render the quality of an item or activity unacceptable or indeterminate. Examples of non-conformances include, but are not limited to, physical defects, test failures, and inadequate documentation.

Operator

The entity in control and responsible for the facility.

Owner

The entity that owns facility and land.

Owner's or Operators Representative

An official representative of the Owner or Operator responsible for planning, organizing, and controlling construction activities.

Panel

A general reference to a unit area of either the Structured Geomembrane (LLDPE or HDPE), or the Engineered Turf component of the ClosureTurf® System.

Quality Assurance

A planned and systematic pattern of procedures and documentation to ensure that items of work or services meet the requirements of the contract documents.

Quality Control

These actions provide a means to measure and regulate the characteristics of an item or service to comply with the requirements of the contract documents.

Relief Valve

A mechanical device used specifically to relieve gas buildup pressure underneath the ClosureTurf® system.

Representative Sample

(With respect to geomembrane destructive testing) - A random specimen of either the Structured Geomembrane (LLDPE or HDPE) or the Engineered Turf component consisting of 1 or more cut pieces (commonly referred to as coupons) from the same rectangular portion of material, oriented along a seam that is removed for field or laboratory testing purposes.

Ripple

Smaller in nature than a wrinkle. A result of thermal/or manufacturing that cannot be folded over.

Snapping

A manual method to an open-ended seam to remove tenting as a result of the welding of the geomembrane seams.

Spike

A systematic design for interface friction located on the bottom of the Super Gripnet®.

Specimen

(With respect to geomembrane destructive testing) - A specimen is the individual test strip (sometimes called coupon) from a sample location. A sample location can consist of many specimens.

Studs

A systematic design for drainage located on the top side of the Super Gripnet®.

Surficial Collection Foot

A manufactured device utilized specifically for collection of gas beneath the Super Gripnet®.

Surficial Strip

A strip of Super Gripnet® used for gas conveyance below the ClosureTurf® system.

Tenting

A vertical ridge that is caused by wedge welding geomembrane.

Wrinkle

A portion of the geomembrane that does not lay relatively flat and is not a result of subgrade irregularity and which can be folded over.

3.0 Subgrade Preparation

Prior to ClosureTurf® system installation, the subgrade (e.g., protective cover soil) will be inspected. Observe the following:

- The protective cover soil is substantially free of surface irregularities and protrusions.
- The protective cover soil surface does not contain stones or other objects that could damage any of the ClosureTurf® components.
- The surface will be substantially smooth and free of foreign and organic material, sharp objects, particles or other deleterious material.
- Maximum particle size (e.g. rocks) will be specified by the by the design and contract specifications.
- The anchor trench dimensions have been checked, and the trenches are free of sharp objects and other deleterious material.
- Construction stakes and hubs have been removed and the resultant holes have been backfilled.
- The geosynthetics contractor, POR or his representative, and the permittee or his representatives have certified in writing that the surface on which the ClosureTurf® System will be installed is acceptable.
- Final grades on the slopes as well as benches dimensions and grades conform to the design grades.
- Survey shots and as-built drawings will be carefully reviewed and evaluated to insure the surface grades will drain as intended in the design drawings.

4.0 Installation – Surficial Gas Management System

4.1 Minimum Requirements

The gas management plan will include at a minimum, the use of provided ClosureTurf® Pressure Relief Valves, (See Figure 3) to meet the specific needs of the intended site. The minimum required gas emission venting devices will be installed at a rate of at least one vent per acre of installed ClosureTurf® (See Figure 1). Watershed Geosynthetics LLC supplies the minimum number of Pressure Relief Valves with delivery of the ClosureTurf® product.

The valves must be installed on sites that produce gas to validate any warranties. Design Engineer will be responsible for designing the correct amount of Pressure Relief Valves as well as any other design elements required for the site.

Pressure Relief Valves are designed to convey approx. 50 SCFM (Standard Cubic Feet Per Minute) under 1 inch of water column. Design Engineer will be responsible for designing the correct amount of Pressure Relief Valves required for the site.

4.2 Surficial Collection Design (Where Applicable)

While it should be noted that not all projects will incorporate a surficial collection design, the ClosureTurf® system serves as an effective tool for control of fugitive emissions and can be incorporated into a conventional gas collection system or in some cases as a standalone gas collection and control system. A ClosureTurf® surficial collection design will incorporate the use of surficial collection strips (See Figure 1) that provide high flow capacity (See Figure 2) and a larger radius of influence. The system design will also incorporate the surficial collection foot (See Figure 4) that serves as a wellhead base, geomembrane interface and gas conveyance path from the strips to the collection wellhead (not provided).

4.2.1 Surficial Strips (Where Applicable)

Surficial strips are to be placed prior to the placement of geomembrane. Surficial Strips may consist of SuperGripnet®, single sided geocomposite or other techniques that will allow for the proper flow of gas without causing ballooning. The placement of the strips will be determined by the design engineer and included in the gas management plan.

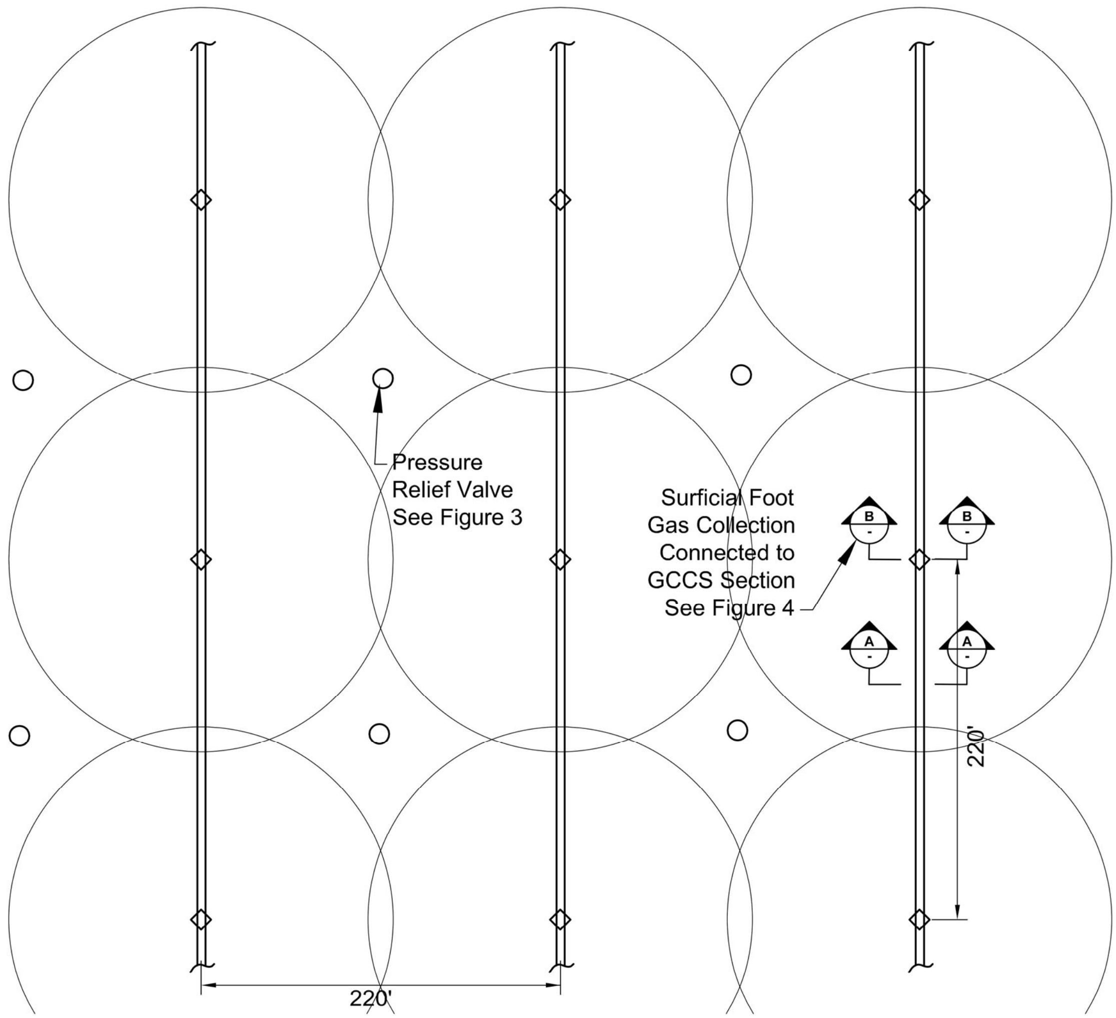


Figure 1: Typical Surficial Collection Strip Placement

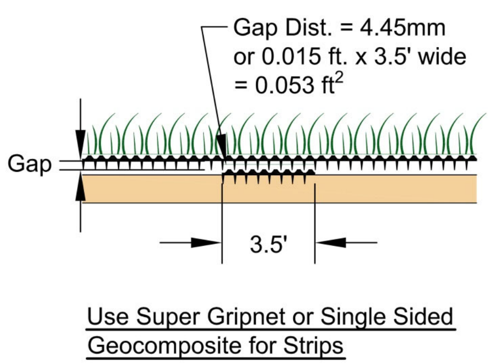


Figure 2: Effective Cross Sectional Area: Surficial Strips

4.2.2 ClosureTurf® Pressure Relief Valve

The Pressure Relief Valve is a mandatory component of the ClosureTurf® System. The primary purpose of this component is to provide for necessary release of pressure in the event the gas collection system malfunctions. The number of Pressure Relief Valves required will be determined by the POR and installed during construction of the **Closure***Turf*® System.

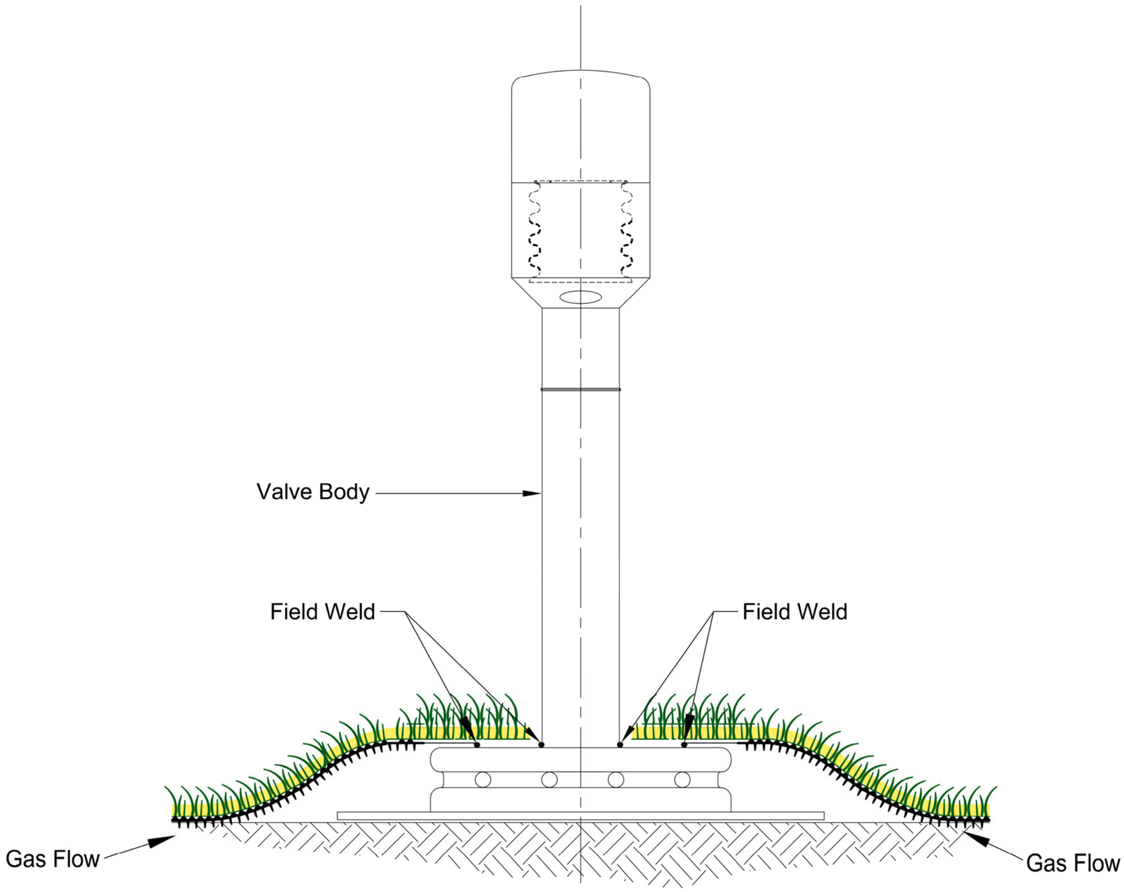


Figure 3: ClosureTurf® Pressure Relief Valve (Patent Pending)

4.2.3 ClosureTurf® Collection Foot

This device is designed to be the interface between the surficial collection strips, the geomembrane and a gas collection wellhead (not provided). The unit allows vacuum to flow in from beneath the geomembrane and from the surficial collection strips to create a larger radius of influence for gas collection. Placement will be determined by the gas collection system design.

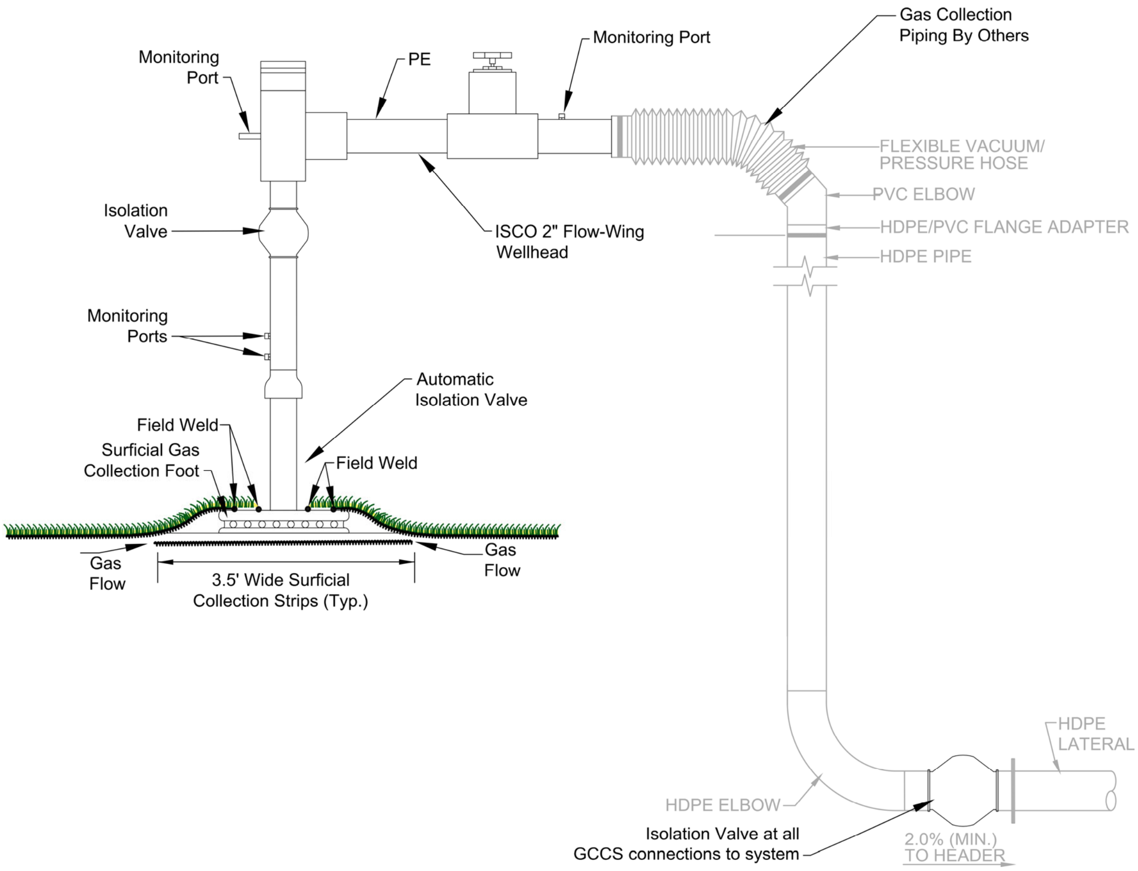


Figure 4: ClosureTurf® Surficial Collection Foot Connection to GCCS System

4.2.4 ClosureTurf® Passive Gas Vent

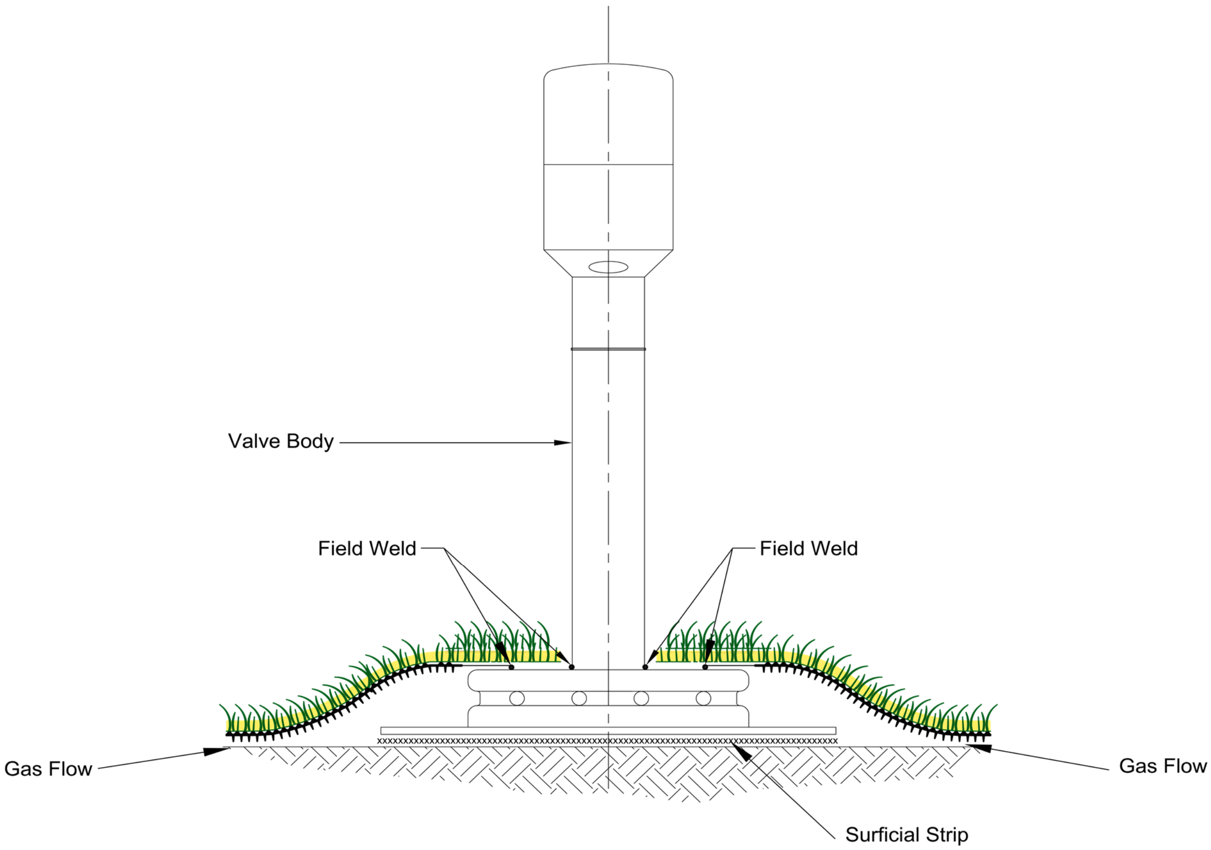


Figure 5: Passive Gas Vent

When a GCCS system is not required, Passive Gas Vents may be utilized in lieu of the Pressure Relief Valves. The number of Passive Gas Vents required will be determined by the POR and installed during construction of the **Closure***Turf*® System.

5.0 Installation - Geomembrane Liner

Installation of the Geomembrane Liner must be completed by a geosynthetics contractor approved by Watershed Geosynthetics. Qualification requirements for geosynthetics personnel are shown in WatershedGeo Installation Specification 01 73 19. Each component of the ClosureTurf® system will require specific testing and submittals before, during and after installation of the component. For information concerning submittals, see contract specifications. It is the responsibility of the contractor to ensure that each prior component installation has been approved by the POR before continuing with installation of the next ClosureTurf® component.

5.1 Delivery – Geomembrane Liner

Upon delivery of the geomembrane, observe that:

- The geomembrane is delivered in rolls and not folded. Any evidence of folding or other shipping damage is cause for rejection of the material.
- Equipment used to unload and store the rolls or pallets does not damage the geomembrane component.

- The geomembrane is stored in an acceptable location in accordance with the specifications and stacked no more than five rolls high.
- The geomembrane component is protected from puncture, dirt, grease, water, moisture, mud, mechanical abrasions, excessive heat, or other damage.
- Manufacturing documentation required by the specifications has been received and reviewed for compliance with the technical specifications. This documentation will be included in the FCSER.
- The geosynthetics receipt log form has been completed for materials received.
- Geomembrane component that is damaged or has been rejected due to improper manufacturer documentation will be removed from the site or stored at a location separate from the accepted geomembrane component.

5.2 Installation - Panel Deployment and Field Seaming

ClosureTurf® installation requires some additional care and techniques beyond those of the typical geomembrane installation. General panel deployment techniques as well as special techniques are listed below. The contractor should always notify Watershed Geo prior to installing the geomembrane and afford the opportunity to be present at the initial startup to support the approved installer program.

General

- Observe that the geomembrane component is placed in direct and uniform contact with underlying protective cover soil or subgrade soil.
- Observe the sheet surface as it is deployed and record panel defects and repair of the defects (e.g. panel rejected, patch installed, etc.) on the repair sheet. Repairs must be made in accordance with the contract specifications and located on a repair drawing.
- Observe that support equipment is not allowed on the geomembrane component during handling (See Section 6.4).
- Observe that the subgrade beneath the geomembrane component has not deteriorated since previous acceptance.
- Observe that there are no stones, construction debris, soil clogs or other deleterious items on the subgrade that could cause damage to the geomembrane component.
- The geomembrane component will not be deployed during inclement weather conditions as defined in the site-specific specifications.
- Observe that people working on the geomembrane component do not smoke, wear boots/shoes that could damage the ClosureTurf® system components or engage in activities that could damage the ClosureTurf® system components.
- Observe that the method used to deploy the sheet reduces wrinkles but does not cause bridging and that the sheets are anchored to prevent lifting or movement by the wind (geosynthetics contractor is responsible for any damage to or from windblown geomembrane).
- Observe that horizontal or cross seams on the side slopes are staggered so that long horizontal seams across the slope are not produced.
- The POR shall be responsible for approving the integrity of horizontal seams.

Acclimation and Adjustments

- The geomembrane component requires acclimation to ambient temperature after being deployed and before seaming operations begin.
- Acclimation time is dependent on the current weather conditions.
- By allowing the panels to acclimate, excessive wrinkling can be avoided.
- Final panel adjustments can be completed after the panel has properly acclimated to ambient temperature.
- After the panel has acclimated and before seaming operations begin, wrinkles will be worked toward the toe of slope. Either manpower or equipment may be utilized for working out excess material.
- Reduce seam bridging by placing sand bags along concave areas.

Wedge Welding

- After proper acclimation and final adjustments/wrinkle removal, wedge welding may proceed.
- Wedge welding machines are a low-profile machine with a vertical height (wedge height) not to exceed 3 inches, measured from flat surface to top of heating wedge.
- Wedge welding will be completed in accordance with the contract specifications.
- Sand bags will be applied as the wedge welding progresses to reduce tenting.

Snapping

- As a result of wedge welding, “ridges” or “tenting” of the seams may occur. A process called “snapping” must be employed to remove the excess slack caused by the welding process.
- Normally, this technique requires several people lined up along the open seam at the edge of the geomembrane and applying clamps to the edge. The panel is then “snapped” into position and when applied properly, the excess slack is removed.
- The snapping technique will be applied while the welding seam is still warm.
- Previously applied sand bags along the wedge welded seam will reduce rebound tenting.

5.3 Anchor Trench Backfill

ClosureTurf® only relies on the anchor trenches to serve as a termination point. Top anchor trenches should be backfilled as quickly as practical after Engineered Turf Component is installed (prior to sand infill placement).

Vertical anchor trenches as well as anchor trenches along the toe will not be backfilled until sand infill of the engineered turf is in place, unless previously approved by the POR. Anchor trench dimensions will be shown in the drawings.

Backfilling or sand bag loading the bottom and side anchor trenches should be considered and applied when cool temperatures are anticipated to assist with creep reduction.

When HDPE material is utilized, additional anchoring methods may be required to reduce wrinkling due to the overnight contraction of the material. Contraction of the HDPE material may be site specific/seasonal and should be discussed onsite to develop an effective method to alleviate potential issues.

5.4 Equipment on ClosureTurf® Geomembrane

Construction equipment on the ClosureTurf® geomembrane component will be limited to reduce the potential for geosynthetics damage. Observe/provide the following:

- Use power source generators capable of providing constant voltage to all required equipment under combined-line load.
- Secondary containment to catch spilled fuel under equipment where applicable.
- No equipment with tire or track pressures exceeding 5 psi will be allowed on the partially constructed ClosureTurf® system until after the completed installation of the sand infill component.
- No equipment will be left running and unattended over the constructed geomembrane component.
- Equipment operators shall check for sharp edges, embedded rocks, or other foreign materials stuck into or protruding from tires prior to operating equipment on the geomembrane component.
- Path driven on geomembrane component will be as straight as possible with no sharp turns, sudden stops or quick starts.

5.5 Wrinkles

Wrinkles occur during the geomembrane installation due to changes in geomembrane temperatures and deployment methods. The wrinkles may interfere with the installation of the engineered turf layer as well as the final appearance of the ClosureTurf® system. Observe that:

- Snapping procedures are followed.

- Wrinkles are repaired if they can be folded over as defined the morning after the seam is developed and the liner is in a cool state.

6.0 Installation – Engineered Turf

Qualification requirements for the personnel who install the Engineered Turf component are shown in WatershedGeo Installation Specification 01 73 19.

6.1 Delivery – Engineered Turf

Box trucks will deliver 27 rolls per truck. Rolls will be strapped in groups of 9 allowing equipment (i.e. pick-up truck, skid steer) to pull the grouped rolls to the front of the truck. Rolls can be pulled directly to the ground or carpet stingers can move the rolls to a designated area. Observe the following:

Observe the following:

- The engineered turf is wrapped in rolls with protective covering.
- The rolls are not stacked more than 3 high.
- The rolls are not damaged during unloading.
- Protect the engineered turf from mud, soil, dirt, dust, debris, cutting, or impact forces.
- Each roll must be marked or tagged with proper identification.
- Rolls that have been rejected due to damage are be removed from the site or stored at a location separate from accepted rolls, designated by the Owner/Operator.

- Rolls that do not have proper manufacturer's documentation will be stored at a separate location until documentation has been received and approved.

6.2 Installation – Engineered Turf - Surface Preparation

Prior to installation of Engineered Turf, observe the following:

- ClosureTurf® geomembrane has been installed in accordance with the contract specifications.
- The geomembrane installation documentation has been completed and approved by the POR for areas were the Engineered Turf is to be installed.
- The supporting surface (i.e., the geomembrane) does not contain stones, debris, membrane grindings or large scraps left over from the installation process that could damage or impede surface water flow through the Engineered Turf.

6.2.1 Installation – Engineered Turf – Deployment & Field Seaming

During deployment of Engineered Turf, observe the following:

- Observe the turf as it is deployed.
- Verify that equipment used does not damage the turf or underlying geomembrane by handling, trafficking, leakage of hydrocarbons, or by other means.
- Verify that during deployment, the Engineered Turf filaments point upslope.
- Verify that the turf is anchored to prevent movement by the wind (the contractor is responsible for any damage resulting to or from windblown Engineered Turf).
- Verify that the turf remains free of contaminants such as soil, grease, fuel, etc.
- Observe that the turf is laid substantially smooth and substantially free of tension, stress, folds, wrinkles, or creases.
- Observe the deployment of the sewn seam panel process to insure proper flipping to expose the turf surface up after seaming operations. After the first panel of the project is deployed, deployment will be done on the adjacent turf panel to avoid damage.
- Horizontal cross seam/panel extension on slopes will not be more than one aligned side by side (i.e., no adjacent cross seams on slopes).
- At least one complete panel shall separate any horizontal cross seam/panel extension.
- Horizontal cross seam connection will be performed prior to the vertical production seaming.
- Once the horizontal cross seam/panel extension is completed, the excess seam overlap on the bottom of the weld or seam shall be cut off.

6.2.1.1 Installation – Engineered Turf – Fusion Seaming Method

- Engineered Turf fusion seaming device will be a DemTech VM20/4/A fusion welder only.
- Fusion seams require an approx. 4 inches of overlap.
- Frayed or loose geotextile strands will be cut off or removed.
- Prior to starting the production fusion seaming, trial seams must be performed as outlined in Section 7.2.1.3 below.
- Demonstrate the preparation methods and equipment utilized for removal of the salvage from the outside edge of the rolls of turf (i.e. trimming & cutting devices).
- Electrical trimming and cutting devices will be utilized for salvage trimming.
- Box blades and knives will not be utilized for salvage trimming.

- Demonstrate and control the fraying of geotextile strands when performing the removal of salvage.
- Any damage that occurs due to production seaming will be repaired as outlined in WG Installation Guidance Documents.
- Any defects will be repaired as outlined in 7.2.2.

6.2.1.2 Installation – Engineered Turf – Fusion Seaming Method Trial Seam Requirements

1. Prior to turf component welding, CQA personnel shall observe and document the following:
    a. Turf welding apparatus are tested;
    b. at daily start-up; and
    c. immediately after any break; or
    d. anytime the machine is turned off for more than 30 minutes.
2. Procedures:
    a. The turf trial weld will be completed under conditions like the panels that will be welded.
    b. If at any time, the CQA Personnel believe that an operator or fusion welding apparatus is not functioning properly, a Field Trial Seam Test must be performed.
    c. Any dispute concerning proper installation techniques, or the proper function of fusion welding equipment will be resolved by the OWNER'S REPRESENTATIVE.
    d. The trial weld must be allowed to cool to ambient temperature before seam snapping or panel adjustments are applied.
3. Trial Sample Test Results:
    a. Trial weld samples must comply with "VISUAL PASSING CRITERIA" Visual passing criteria is verified when a manual peel/pull test is performed, and the top turf panel tufts transfer to the bottom turf panel. The transfer of approx. 75% of the tufts constitutes a passing trial weld.
4. Field Seam Test Failure:
    a. Less than approx.75% of the top turf panel tufts do not transfer to the bottom turf panel.
5. Additional Trial Sample Testing Requirements:
    a. Two consecutive trial welds meet the visual passing criteria.
6. The trial weld sample must be a minimum of 3 feet long and 12 inches wide, with the seam centered lengthwise.
7. If a welding apparatus exceeds 5 hours in the second half of the day, another trial seam must be performed.
8. CQA documentation of trial seam procedures will include the following:
    a. The names of the seaming personnel;
    b. The name of the fusion seaming technician;
    c. the welding apparatus number, time, date;
    d. ambient air temperature; and
    e. welding apparatus temperature & speed setting.

6.2.1.3 Installation – Engineered Turf – Sewn Seam Method

- A single stitch prayer type seam is constructed using an American Newlong sewing machine or equivalent.
- The thread will be Polyester or equivalent.
- Sewing will occur between the 1st and 2nd row of tufts from the edge.

6.2.2 Installation – Engineered Turf Repairs and Tie-In Procedures

When Repairs and Tie-Ins to Engineered Turf occur, observe the following:

- Tie-In's to Engineered Turf will be completed by using a fusion seam.
- Seaming equipment for Engineered Turf will be a DemTech VM 20/4/A welder and/or Varimat V2.
- A hand-held heat gun should be used in smaller/concentrated areas.

6.2.3 Installation – Equipment on Engineered Turf

No equipment will be allowed on slopes exceeding 15% until Sand Infill is in place. On slopes less than 15%, such as top decks, ATV type vehicles will be allowed prior to infill placement if the rubber tire or track pressure is less than 5 psi. Post construction (full specified sand infill thickness) drivability tire pressures on slopes greater than 15% should be limited on the ClosureTurf® system to less than 35 psi. On slope less than 15% allowable tire/track ground contact pressures will be limited to less than 85psi. Allowable tire/track ground contact pressures may be increased with the written approval of the engineer.

In all phases of construction, equipment used on the ClosureTurf® product will not be allowed to change speed or direction in a manner that could displace or damage the ClosureTurf® system. Higher traffic areas will require sand to be placed at the full height of the turf. Regularly trafficked areas will be designed and approved by the engineer.

It should be noted that the above-recommended load limits assume that the subgrade, which is not part of the ClosureTurf system, is adequate to support the anticipated vehicle loading without creating rutting or bearing capacity issues.

7.0 Installation – Sand Infill

This component of the ClosureTurf® system is a specialized mixture of sand infill that is placed between the tufts of the Engineered Turf component.

Observe that the following general requirements regarding Sand Infill are met:

- Sand Infill will meet ASTM C-33 specifications.
- Areas that are to receive sand infill must be inspected and accepted by the POR or CQA Personnel before placement of sand infill takes place.

7.1 Submittals and Testing – Sand Infill

See contract specifications for Sand Infill MQC Submittals and submittal/testing requirements regarding the Sand Infill.

7.2 Installation – Sand Infill Deployment

Observe that the following installation guidelines regarding the Sand Infill:

- Sand infill thickness will be verified at a frequency of 20 measurements per acre of final cover installed.
- The sand infill layer will be placed to a ½ inch minimum thickness not to exceed ¾ inch thick.
- The sand infill will be worked into Engineered Turf as infill between the synthetic yarn blades.
- No equipment will be allowed on slopes exceeding 15% until the sand infill is in place.
- Conveyor systems and/or Express Blowers are the preferred method to spread and place the sand infill.
- Contractor shall explain in detail in the pre-construction meeting the method of sand infill deployment to be used.
- The sand infill deployment method will be approved prior to installation of the sand infill.
- For slopes 3H: 1V or steeper the sand infill will be placed using high speed conveyor belts or using air express blower methods that demonstrate achievable results.
- The sand infill placement will be done in front of the deployment equipment to improve the bearing capacity of the previously installed ClosureTurf® components.
- Sand infill placement cannot occur with snow or ice on the Engineered Turf component.
- Verify that underlying geosynthetics installations are not damaged during placement operations. Mark damaged geosynthetics and verify that damage is repaired.
- Verify no geotextiles are exposed once the sand infill is complete.

The method for measuring the Sand Infill thickness will be performed utilizing a digital caliper with depth rod capabilities, or a POR approved alternate measuring device.

7.3 Closure*Turf*® with Rock Rip Rap Infill for Ditches

When **Closure***Turf* ® is installed in ditches and rock rip rap infill is placed in lieu of sand infill, it creates a ditch lining armor that will allow high flow velocities to convey without damage or maintenance to the liner system. See Figure 5.

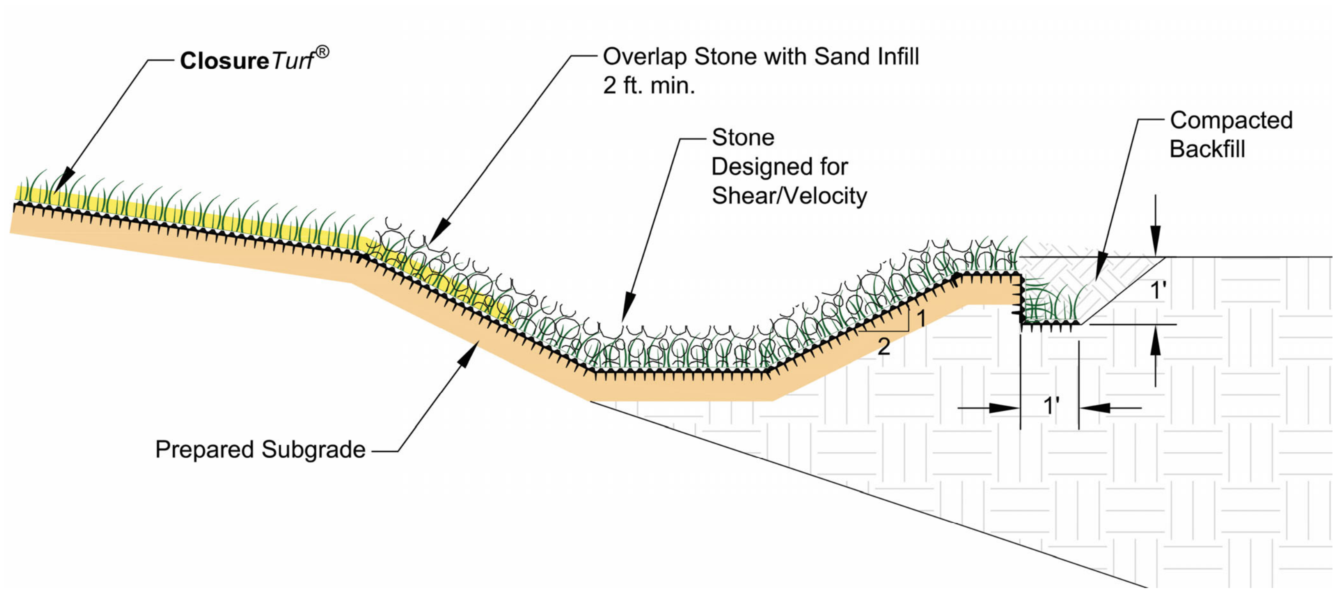


Figure 5: Typical ClosureTurf® with Rip Rap Ditch Section

7.3.1 Installation – Alternate Infill - HydroBinder® for Downslope Channels

HydroBinder® is typically delivered to the jobsite on pallets in either 3000# bulk bags (1 per pallet) or 80# bags (42 per pallet). It is delivered on a flatbed with 16 pallets (typical) per truckload.

Verify the following regarding installation of HydroBinder® Infill:

- The HydroBinder® infill layer may be placed using any appropriate equipment capable of completing the work while meeting loading requirements specified herein.
- Manual hand spreading is acceptable when equipment isn't practical.
- Contractor / Installer will explain in detail in the pre-construction meeting the method of HydroBinder® infill deployment.
- Installation of HydroBinder® infill will only be performed by a Watershed Geosynthetics' licensed and approved infill installer.
- The HydroBinder® will be installed into the turf while it is in a dry state.
- Prior to placing the HydroBinder®, the engineered turf will be dry.
- If the turf is wet from rain or dew, the installer shall wait until it is dry.
- The installer may attempt to speed up the drying process by using a blower (i.e., leaf blower, industrial blower, etc.).
- The HydroBinder® will be worked into the tufts so the tufts are in an upright position.
- The HydroBinder® infill layer will be placed to a ¾ inch minimum thickness not to exceed 1 inch thick.
- Reduce trapped tufts as much as practical.
- Do not backfill anchor trenches until turf has been installed with HydroBinder® infill unless approved by the POR.

- The hydration process must occur the day of the HydroBinder® infill placement.
- The desired HydroBinder® infill thickness will be achieved prior to the hydration process.
- The cemented infill is hydrated thoroughly however care must be taken to avoid displacement of the non-hydrated infill.
- The objective is to soak the area to start the hydration process but not to inundate with water beyond saturation.
- Once hydration is completed as described, backfill and compaction of the vertical anchor trenches should take place.
- The infill is to be placed / spread using a manual drop spreader, top-dresser and/or drop spreader attached to low ground pressure equipment with adequate dust control.
- If weep holes are required for draining the internal drainage layer through the engineered turf, remove the HydroBinder® in the areas of the weep holes prior to hydration or block the weep hole locations prior to infilling. Blocks may consist of pipe, dowels, etc. Weep holes are typically ½ to ¾-in diameter and are located at the toe of slope on 2-ft centers.

7.3.2 Installation – Brushing in the HydroBinder® Infill

The HydroBinder® infill will need to be worked into the tufted fibers of the engineered turf such that the turf fibers are in an upright position. This can be achieved as follows:

- The infill will be worked into the tuft fibers so the tuft fibers are in an upright position with the infill at a measurable ¾ inch minimum depth. This is achieved with common mechanical turf broom, power broom, shop broom, yard rakes, or greens groomer rakes.
- Brushing should be performed in all four directions starting with the direction against the lay of the fibers. Multiple passes may be required.
- The HydroBinder® may need to be placed in 2 to 3 lifts with brushing in between lifts to effectively work the material into the tufts and achieve fibers that are upright.
- The engineered turf will be visually inspected to confirm that the turf fibers are upright and that there are no trapped fibers.
- Thickness measurements of the HydroBinder® infill will be taken using a caliper or equivalent device.
- Measurements will be taken at a minimum frequency of 10 measurements per 1,000 sf (for smaller projects) or 20 per acre (for larger projects) of installed area.
- The desired HydroBinder® infill thickness will be achieved prior to the hydration process.

ClosureTurf with HydroBinder contains a unique drainage system where some water will drain on the Super Gripnet® liner. This water may build up and cause the Engineered Turf and HydroBinder® infill to lift. This is not normally an issue to the overall performance of the product. However, the Super Gripnet® must be allowed to drain at all times. If surface water flows are pinched off by various construction techniques such as placing rip rap check dams in channels, the Turf and HydroBinder® will lift as needed until the pressure can be alleviated.

7.3.3 Installation – Hydration of the HydroBinder® Infill

The HydroBinder® infill will be hydrated in place as follows:

- The hydration process will occur on the same day as the HydroBinder® infill placement.
- Hydrate the infill thoroughly without causing displacement of the product. This may require another pass after waiting momentarily to allow the initial water application to soak in.
- Estimated application rate is approx. 0.12 to 0.20 gallons per square foot of area.

- The installer shall not overhydrate the infill so that water begins to runoff and cause loss of cement infill during the process.
- Visual verification can be performed that the HydroBinder® infill has been fully hydrated, and not over hydrated.
- Visually observe that the top of the HydroBinder® has a wet sheen (denoting saturation) but that water is not ponding on top.
- Excavate (with finger or small tool) into the HydroBinder® at a rate of 1 probe per 100 sq. ft. on smaller jobs and 20 per acre on large jobs to confirm full hydration of the section has been achieved.
- An additional method to check saturation is to tap the surface a few minutes after saturation. Water should be brought up and pool at the surface.
- To improve curing, the hydrated area may be covered with plastic sheeting.
- If freezing temperatures are expected, the hydrated area should be covered with burlap and / or plastic sheeting.
- The HydroBinder® infill will harden within 24 hours following hydration.
- The 28-day compressive strength is tested by the HydroBinder® manufacturer before shipping.
- If the HydroBinder® should harden to the touch within 24 hours.
- Personnel access on the HydroBinder® infilled surface will be prohibited for 24-hr following the hydration of the HydroBinder®.
- Once hydration is completed and the HydroBinder® has set up, backfill and compaction of the anchor trenches may be performed.

7.3.4 Installation – Cold Weather Placement and Curing of the HydroBinder®

Cold weather placement and curing techniques for HydroBinder® shall be consistent with industry standard techniques used for concrete and cement products. The following guidelines are suggested:

- Follow the procedures in American Concrete Institute (ACI) 306 – Guide to Cold Weather Concreting.
- ACI 306 defines cold weather as three consecutive days of the following:
  - Average daily temperature falls below 40 deg F; or
  - The air temperature does not rise above 50 deg F for more than half of a day in one 2-hour period.
- At the time of HydroBinder® placement, the subgrade and surface of the engineered turf will be at a temperature of at least 36 deg F and rising.
- Ensure that frost or frozen surfaces are thawed with no standing water.
- If the temperature can fall below 32 °F within 24 hours of application, heated tarps and/or insulated blankets are required to maintain the temperature above 55 deg F for at least 7 days.
- If heated tarps begin to dry out the HydroBinder®, water may need to be added to keep it moist.

The project design engineer and/or resident engineer shall provide technical specifications and guidance for cold weather concreting based upon project specific details (i.e., geographical location, weather, and time of year), and the engineer shall review and approve all proposed installation methods.

7.3.5 Installation – Alternate Infill - ArmorFill®

Verify the following regarding installation of ArmorFill® Infill:

- Installation of ArmorFill® will be completed by or managed by an infill installer certified by Watershed Geosynthetics.

- Apply ArmorFill® under dry weather conditions and when precipitation is not expected for at least 72 hours after installation.

- Apply ArmorFill® on a previously installed ClosureTurf® system that is free of leaves and other material that may inhibit the penetration of the ArmorFill® into the sand component.

- Apply ArmorFill® only after approval of the finished ClosureTurf® product installation.

- Verify ArmorFill® and water mix ratio by logging volume mixed of each component.

- Verify that ArmorFill® has saturated the sand by inserting a probe and displacing a 1 square inch area of sand for inspection.

- Check saturation randomly at a rate of 20 probes per acre.

- Verify proper application rate by marking a known area and applying the proper volume to that area.

- Adjust delivery rate to match the delivery volume per area.

- Mix in a hydraulic conveyance system such as a water truck or portable tank.

- Utilize a small agitation pump to mix and recirculate the ArmorFill® within the tank to impede separation.

- Reduce the number of equipment set-ups required and take care with the application hose so as previously applied ArmorFill® is not displaced by dragging of the hose.

- Spray product evenly.

- Apply ArmorFill® at a ratio of 6 parts water to one-part ArmorFill® on slopes.

- Do not apply ArmorFill® in inclement weather or in freezing temperatures.

- At the completion of ArmorFill® placement activities, clean the equipment thoroughly and purge the tank and hoses of the product.

- All waste product will be disposed of in accordance to site regulations

- Avoid unnecessary foot traffic on the applied product for 24 hours.

- No vehicle traffic is allowed on the applied product for 7 calendar days.

7.4 Installation – Coverage - ArmorFill®

For most applications, use a 6:1 mix ratio and 3400 gallons/acre.

7.4.1 Installation – Coverage - HydroBinder®

Table 1

Approximate Coverage Area for HydroBinder™ Infill

Product	Bag Size	Yield (Cubic Feet)	Coverage in Sq. Ft. for 3/4 in. Thick[1]	Coverage in Sq. Ft. for 1 in. Thick[1]	Amount of Water to Mix per Bag (gal)	Amount of Water (gal) to Apply per Sq. Ft. (3/4 in. Thick)[1]	Amount of Water (gal) to Apply per Sq. Ft. (1 in. Thick)[1]
HydroBinder Infill	40 lbs.	0.3	4.8	3.6	0.6	0.12	0.16
	60 lbs.	0.45	7.2	5.4	0.9	0.12	0.16
	80 lbs.	0.6	9.6	7.2	1.2	0.12	0.16
	1 Cubic Yard (Super Sack)	27	432	324	55	0.13	0.17

[1] - Values are approximate

EXHIBIT C

CLOSURETURF® MAINTENANCE EQUIPMENT LIST

Closure*Turf*® Maintenance Equipment

Introduction

Maintenance equipment types will vary according to the scale of the maintenance activity. Maintenance may include repair of geomembrane, engineered turf, sand infill (with or without ArmorFill™), or HydroBinder® infill. The various equipment types are listed below under the category they are typically used. A presentation document including video of install techniques is available by contacting WatershedGeo at 770 777 0386.

Corrective Action

Corrective actions should be performed by Watershed Geosynthetics LLC, trained individuals. While some corrective procedures can be performed by trained site personnel, a complete list of certified installers is available upon request.

Infill Repair

There are several Infill types available. A list of typical equipment used for infill repair is shown below.

CAS AT7 Sand Slinger

Broadcast Spreader attached to a Kubota Tractor

Dakota Broadcast Spreader

GT 100 Cushman Spreader

Toro Utility Mounted Spreaders

SP-100 Topdresser

Earth & Turf Topdresser

24D TruFlow Spreader

Topdresser attached to SkidSteer

Mete-r-Matic

Sweep-n-Fill Brush ATV

Stihl Walk Behind Power Broom

CAS AT7 Sand Slinger

The AT7 is normally used for large area deployments of sand infill. Other equipment utilized for sand deployment is dependent of job size. Examples are shown below.

Broadcast Spreader attached to a Kubota Tractor

Dakota Broadcast Spreader

GT 100 Cushman Spreader

Toro Utility Mounted Spreaders

SP-100 Topdresser

New!

Earth & Turf
TOPDRESSERS

100SP Self-Propelled Topdresser

- 10 Cu. Ft. Struck-Level Capacity – Fewer Loads per Job
- 18-9.5-8 Drive Tires – Easy on the Turf
- 13-6.5-6 Steering Tires – Sure-footed Control
- Hydrostatic Drive – for Positive Traction & Ultimate Flexibility
- Easy Drive Engagement – for Convenience
- Engine – 10.5 HP (7.8 kw) Briggs & Stratton
- 30″ Brush Expeller – for Even Spread Distribution
- 35½″ Overall Width – For Narrow Access Paths

Earth & Turf Topdresser

New!

Earth & Turf
24D TruFlow™

PUSH-TYPE TOPDRESSER FOR DRY, FLOWABLE MATERIALS

- Adjustable Front Gate Opening
- Set Unit on All Four Wheels to Spread
- Tip Unit Back on Its Rear Wheels for Transport

SPECIFICATIONS

3 Cu. Ft. Capacity
4.80/4.00-8 Drive Tires
4.00-6 Transport Tires
8-Inch-Diameter Dispersal Drum
24-Inch Wide Spreading Pattern
Simple, Four-Wheel Design

24D TruFlow Spreader

Topdresser attached to SkidSteer

Mete-r-Matic

Sweep-n-Fill Brush ATV

Stihl Walk Behind Power Broom

Engineered Turf Repair

Below are examples of equipment used to repair Engineered Turf.

Hand held Leister (i.e. Model No. CH-6060 Sarnen) w/ Wide Slot Nozzle

Hand Held Heat Gun

Geomembrane Repair

Any damage to the Geomembrane component of ClosureTurf® should be repaired by trained individuals approved by Watershed Geosynthetics, LLC. The typical types of equipment utilized are shown below.

Varimat VM-20 by Demtech

Pro-X Extrusion Welder

Hyperlinks

Links to Manufacturer/Dealer Websites are listed below. Note that these links may change over time.

Sand infill deployment equipment manufacturers / supplier types:

- CAS AT7 Sand Slinger www.slingers.com/CAS/Slingers
- Express Blowers www.expressblower.com
- Dakota Broadcast Spreader www.dakotapeat.com
- Earth and Turf earthandturf.com
- Cushman www.cushman.com
- John Deere www.deere.com/Golf
- Turf Co www.turfco.com/products
- Toro www.toro.com/en/golf
- Kubota www.kubota-global.net/products/turf

Sand infill brooms and brushes

- Sweep-n-fill Weaver Golf & Sports Turf www.weavergolf.com
- STIHL Power Brushes (local dealer provide equipment) www.stihlusa.com/products/multi-task-tools/yard-boss.../powersweep/

Turf Repair Heat Guns & Geomembrane Welding Equipment

- Leister Heat Guns www.leister.com
- DemTech www.demtech.com
- Dewalt & Wagner Heat guns as other models can be purchased through Amazon www.amazon.com

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