# Use of Engineered Turf Final Cover System in Landfills

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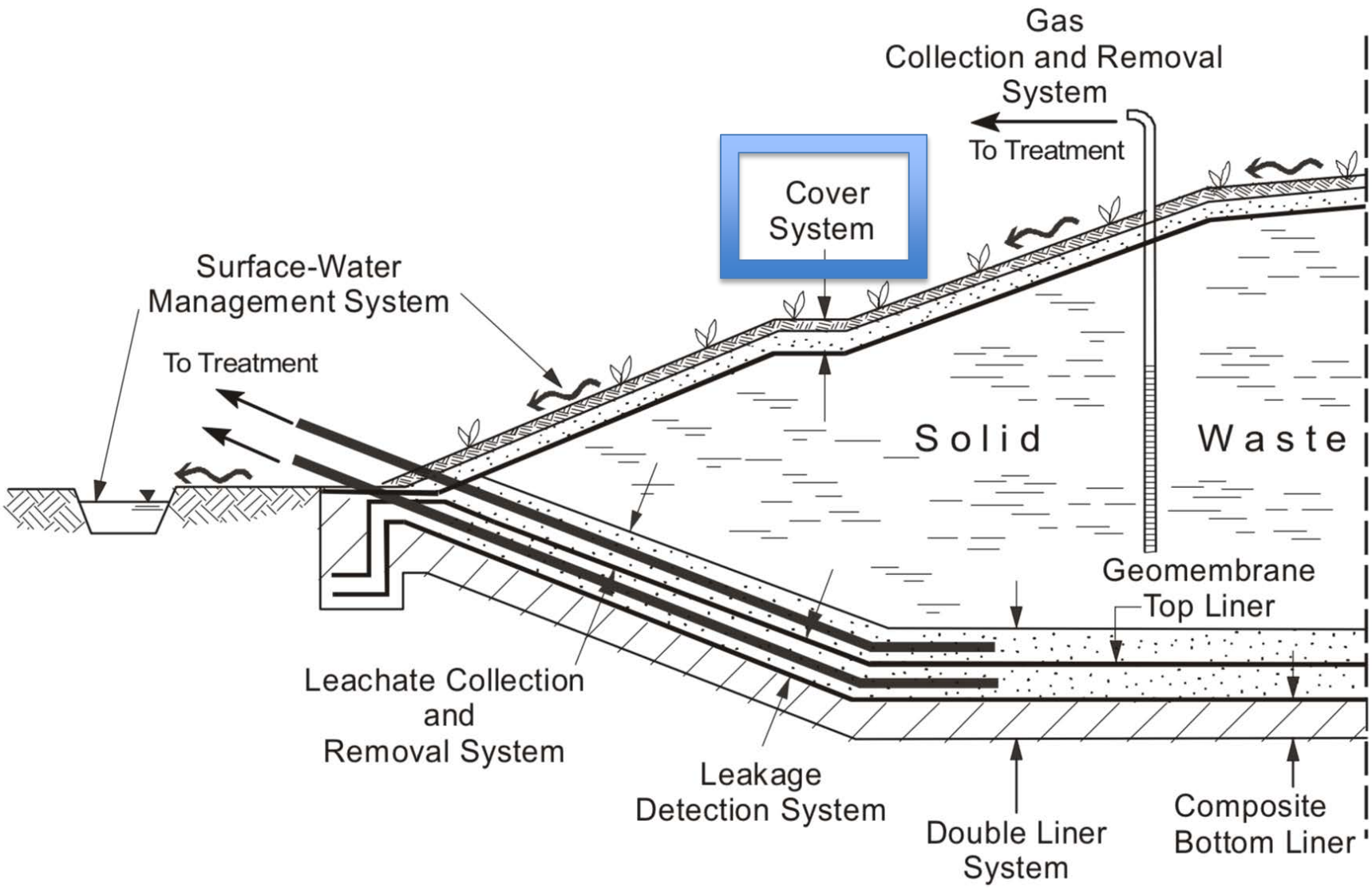
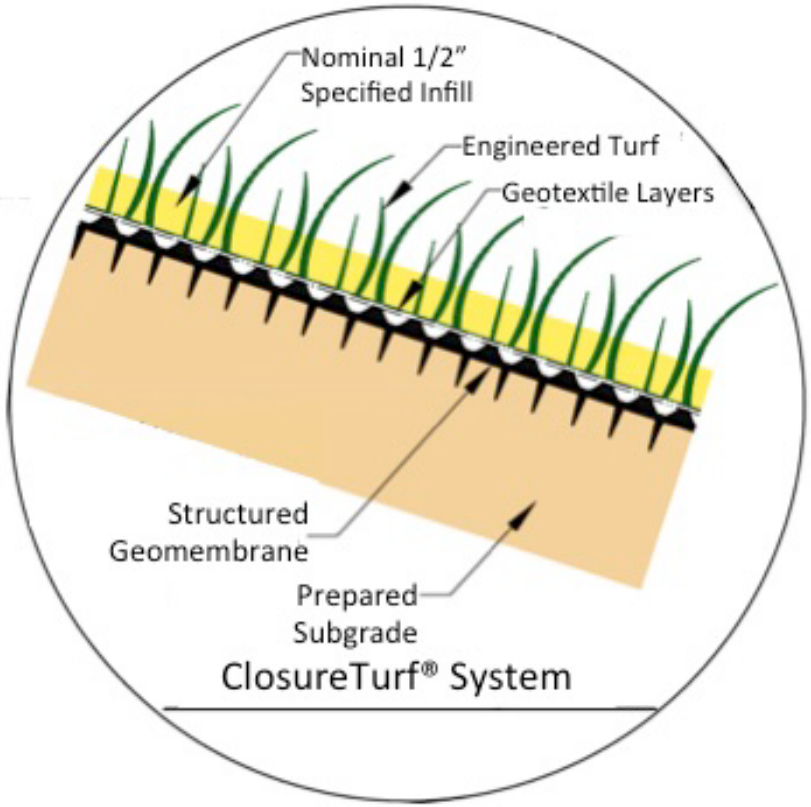
# Introduction




Bonaparte et al. (2004), Technical Guidance for RCRA/CERCLA Final Covers. EPA 540-R-04-007.

# Introduction

- An engineered turf final cover (ClosureTurf®) is a three-component system: structured geomembrane, engineered turf, and specified infill.

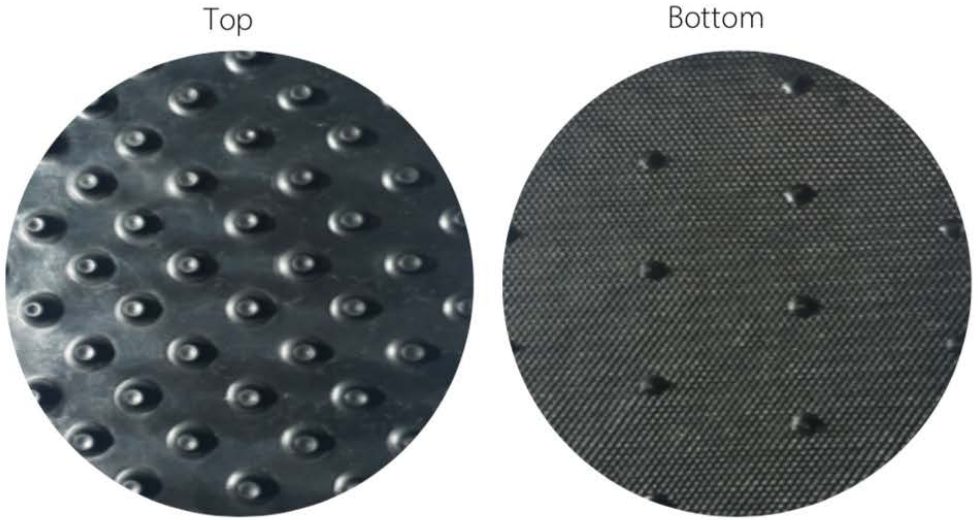



ClosureTurf® is a U.S. registered trademark which designates a product from Watershed Geosynthetics, LLC.

# Introduction

- **Structured Geomembrane**:
  - Barrier layer – minimizes (or eliminates) infiltration
  - Drainage layer – provides internal drainage and minimizes hydraulic head on liner, when Super GripNet is used

AGRU MicroSpike® (40 mil )
Used on slopes < 3.5H:1V




AGRU Super GripNet® (50 or 60 mil)
Used for drainage on slopes >3.5H:1V for increased interface friction

# Introduction

- **Engineered Turf**:
  - Protection layer – covers and protects the underlying geomembrane from UV degradation and wind uplift
  - Erosion layer – minimizes wind and water erosion of infill
  - Post-closure aesthetics – blends in with nature

Olive

Blend

Tan

# Introduction

- **Specified Infill**:
  - Protection layer – covers and protects underlying geotextile backing and geomembrane from UV degradation; provides additional wind uplift protection; improves vehicle drivability; and protects turf from fire

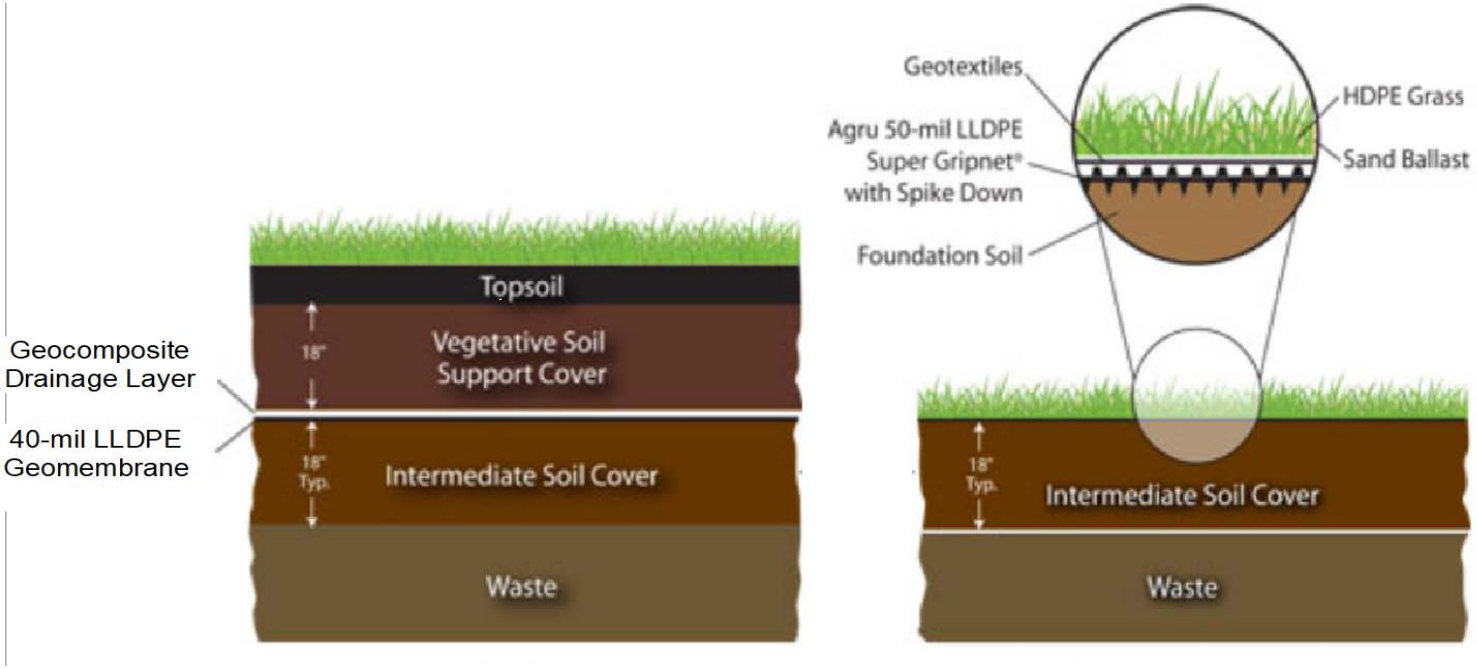
ASTM C-33 Sand - Flow velocity: <4 ft/sec

Sand with Polymeric Binder (ArmorFill®) – Flow velocity: 4 to 10 ft/sec

Cementitious Sand (HydroBinder®) – Flow velocity: >10 ft/sec

# Introduction

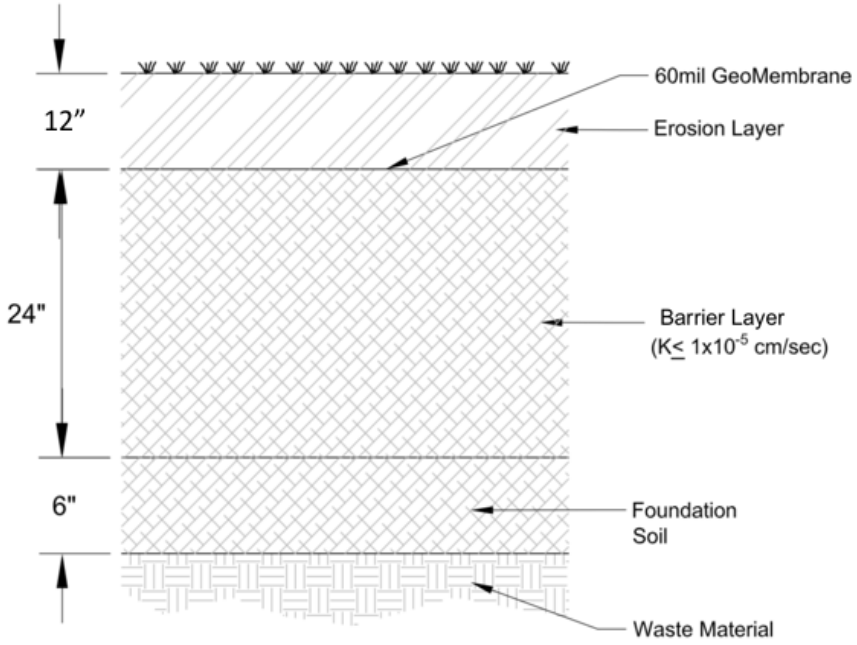
- ClosureTurf meets or exceeds the technical performance criteria established by EPA Subtitle D and individual state solid waste regulations for alternative final cover.



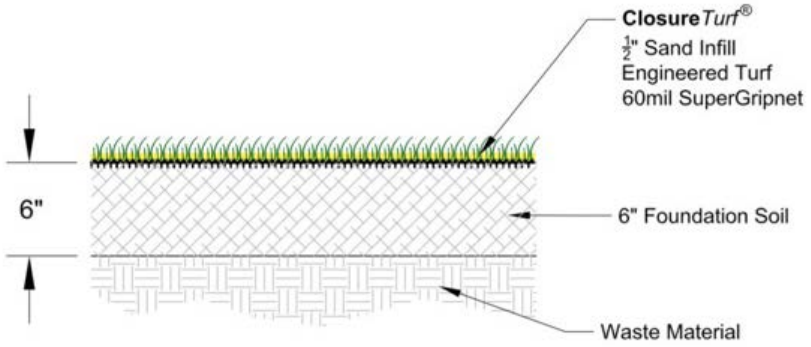

An Example of Traditional Soil Cover vs. Engineered Turf Cover

# Introduction

- HELP Analysis – Infiltration Equivalency Demonstration Example in accordance with the Oklahoma Solid Waste Regulations




Prescriptive Final Cover
(not to scale)




Alternative ClosureTurf Final Cover
(not to scale)

# Introduction

- HELP Analysis – Infiltration Equivalency Demonstration Example in accordance with the Oklahoma Solid Waste Regulations – **ClosureTurf outperforms the prescriptive cover.**

| Analyzed Cases | | Modeled Drainage Length (ft) | Calculated Average Infiltration Rate through Foundation Soil (gallon/acre/day) | Calculated Average Hydraulic Head on Geomembrane on Peak Day (inch) |
|---|---|---|---|---|
| **Side Slope (23%)** | Prescriptive | 730 | 2.73 | 12 |
| | Prescriptive (with geocomposite drainage) | 730 | 0.029 | 1.2 |
| | ClosureTurf | 730 | 0.004 | 0.03 |
| **Top Deck (4%)** | Prescriptive | 65 | 2.71 | 12 |
| | Prescriptive (with geocomposite drainage) | 65 | 0.021 | 0.40 |
| | ClosureTurf | 65 | 0.002 | 0.02 |

# Benefits of ClosureTurf Final Cover System

# Construction

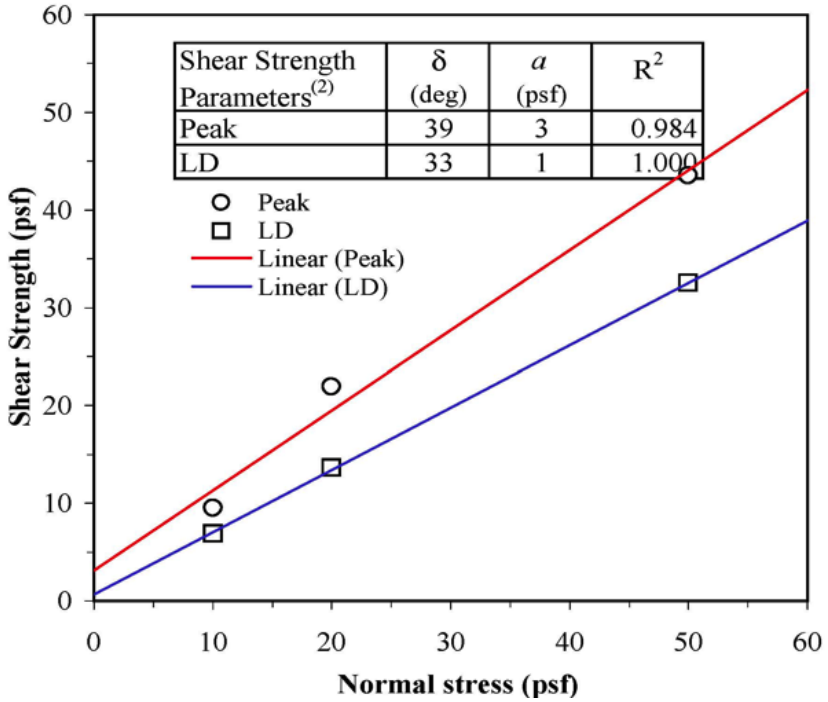
- Two to three times faster than a traditional soil cover
- No heavy construction equipment required
- Less affected by weather conditions during construction
- Not affected by availability or quality of soil
- Additional airspace due to removal of soil layers

**Site:** Saufley Field Landfill
**Owner:** Escambia County
**Location:** Pensacola, FL
**Completed:** 2013
**Closure Area:** 25 acres

**Installation of ClosureTurf was completed in 6 weeks.**

# Geotechnical Stability

- Improved geotechnical stability due to removal of overburden soil layers: no soil cover veneer failure




Interface between Engineered Turf and Super GripNet Geomembrane

| Slope Angle | Slope | Calculated Safety Factor |
|---|---|---|
| 33 | 1.5H:1V | 1.2 |
| 26 | 2.0H:1V | 1.6 |
| 18 | 3.0H:1V | 2.4 |
| 14 | 4.0H:1V | 3.2 |

Note: Site-specific interface testing should be performed to obtain in the interface shear strength between geomembrane and subgrade soil/waste in order to evaluate the potential slip surface through that interface.

# Geotechnical Stability

**Site**: Crazy Horse Landfill

**Owner**: Salinas Valley Solid Waste Authority

**Location**: Salinas, CA

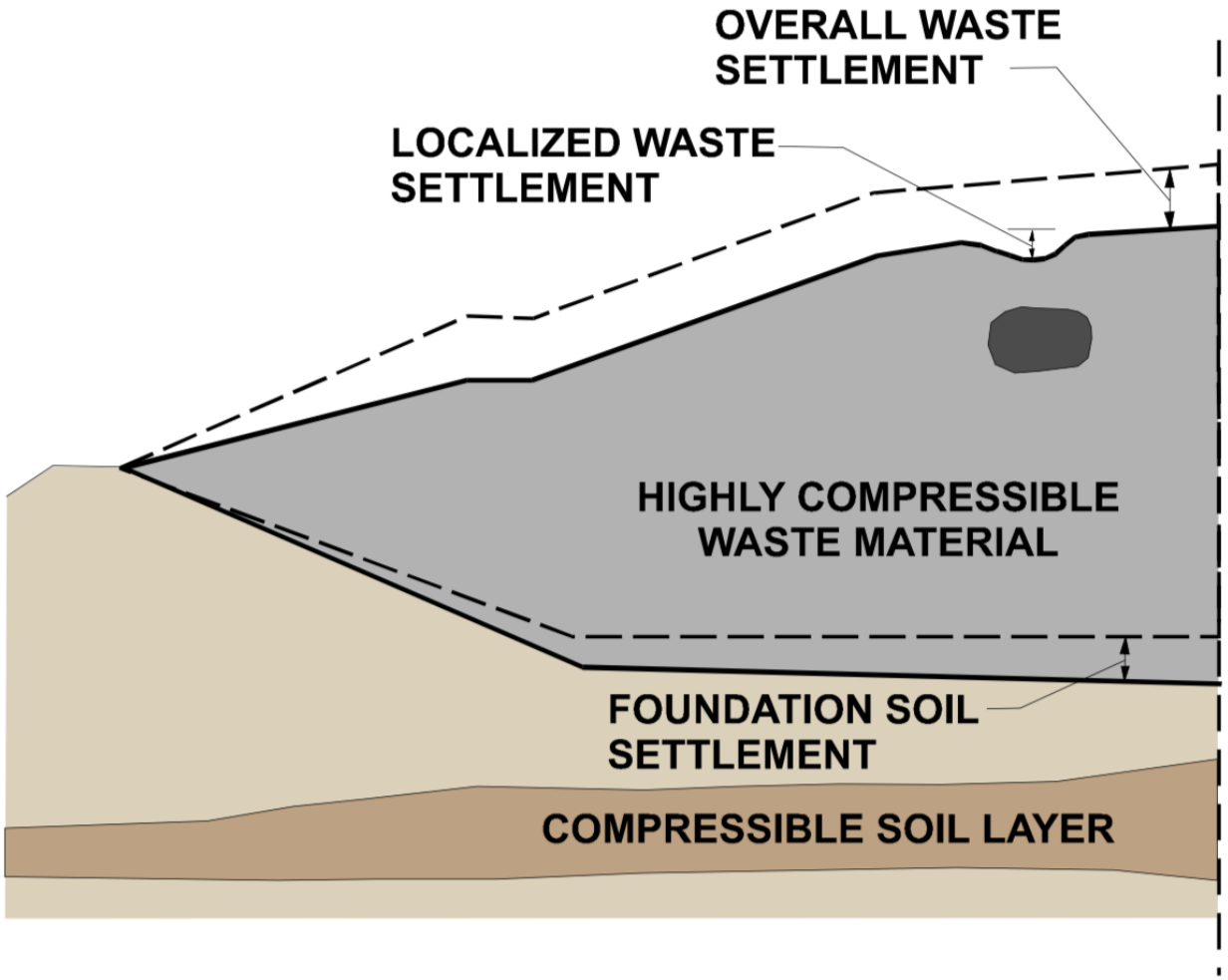
**Completed**: 2013

**Closure Area**: 68 acres

North side has ~2:1 Slopes

~5 miles from San Andreas Fault

# Differential Settlement



# Differential Settlement

- ClosureTurf tolerates much larger differential settlement than soil covers.

**Closure *Turf*® w/50 mil SuperGripnet®**

ClosureTurf

| Product Data | Test Method | LLDPE Values | HDPE Values |
|---|---|---|---|
| Thickness (nominal), mil (mm) | ASTM D5994 | 50 (1.27) | 50 (1.27) |
| Thickness (min. avg.), mil (mm) | ASTM D5994 | 47.5 (1.21) | 47.5 (1.21) |
| Thickness (lowest indiv.), mil (mm) | ASTM D5994 | 42.5 (1.08) | 42.5 (1.08) |
| Drainage Stud Height (min. avg.), mil (mm) | ASTM D7466 | 130 (3.30) | 130 (3.30) |
| Friction Spike Height (min. avg.), mil (mm) | ASTM D7466 | 175 (4.45) | 175 (4.45) |
| Density, g/cc | ASTM D792, Method B | 0.94 (max.) | 0.94 (min.) |
| Tensile Properties (avg. both directions) | ASTM D6693, Type IV | | |
| Strength @Yield (min. avg.), lb/in. width (N/mm) | ASTM D6693, Type IV | N/A | 110 (19.3) |
| Elongation @ Yield (min. avg.), % (GL=1.3 in.) | ASTM D6693, Type IV | N/A | 13 |
| Strength@Break (min. avg.), lb./in. width (N/mm) | ASTM D6693, Type IV | 105 (18.4) | 110 (19.3) |
| Elongation@Break (min. avg.), % (GL=2.0 in.) | ASTM D6693, Type IV | 300 | 200 |
| Tear Resistance (min. avg.), lbs. (N) | ASTM D1004 | 30 (133) | 38 (169) |

# Differential Settlement

- ClosureTurf tolerates much larger differential settlement than soil covers.

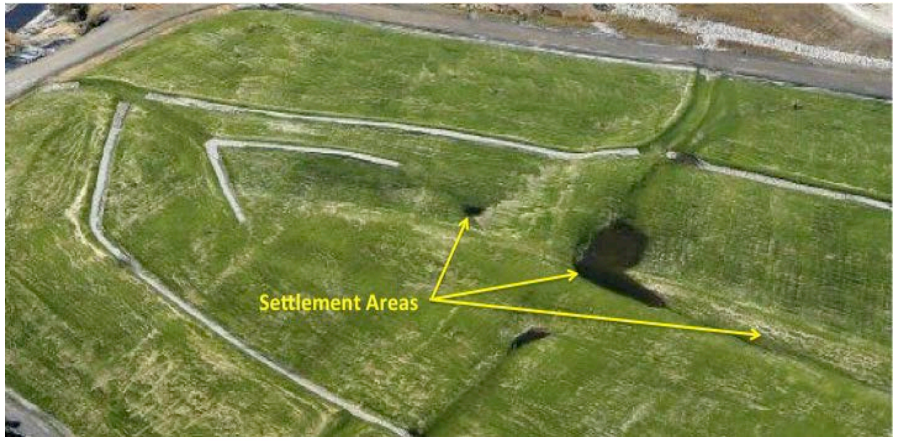
**Site**: Confidential Industry and Sludge Pond

**Location**: Southeast US

**Completed**: 2014

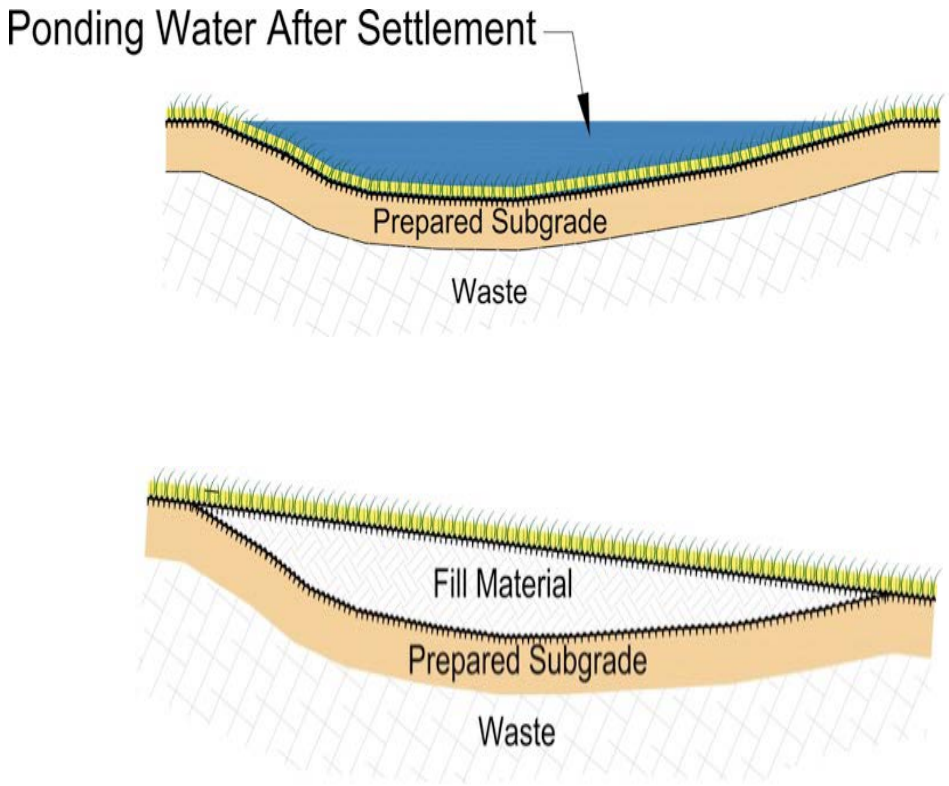
**Closure Area**: 70 acres

Top Photo: Completed Installation of Engineered Synthetic Turf Cover




Bottom Photo: Depression Areas (approximately two years after installation)

# Differential Settlement




Repair of Depression Area

# Soil Erosion

- No soil erosion due to removal of soil layers
- Significantly improved stormwater runoff quality

**Site:** Tangipahoa Landfill

**Owner:** Tangipahoa Parish Government

**Location:** Independence, LA

**Completed:** 2013

**Closure Area:** 22 acres

Vegetative Cover

ClosureTurf Cover

371 NTU 11 NTU

*Nephelometric Turbidity Units*

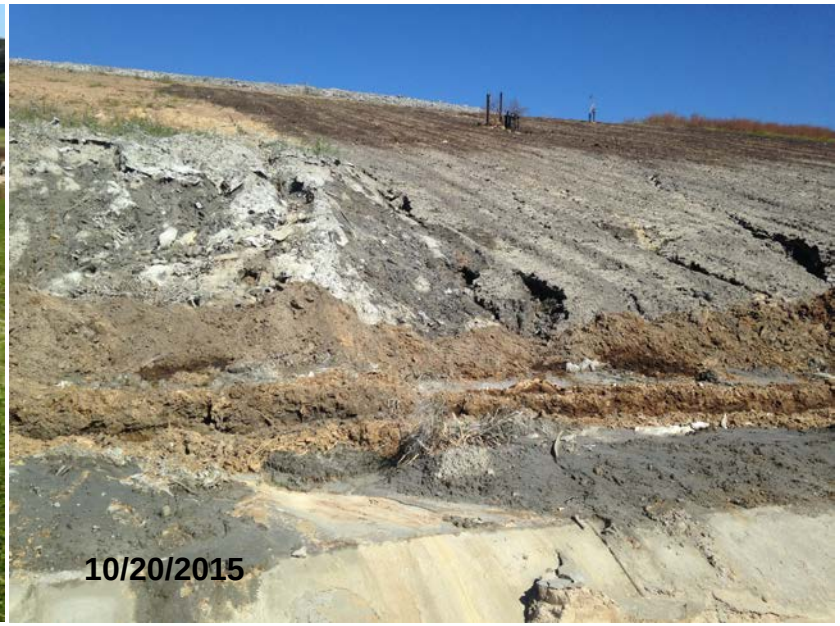
# Soil Erosion

**Site:** Berkeley County Landfill
**Owner:** Berkeley County
**Location:** Moncks Corner, SC
**Completed:** 2013
**Closure Area:** 12 acres

# Soil Erosion

- ClosureTurf survived more than 20 inches of rain over a four-day period in October 2015 (1-in-1000 event).
- No maintenance was required post event: small amount of sand migration to the bottom of the slope. Because there was enough coverage of sand, the sand did not have to be redistributed or replaced.


ClosureTurf




Soil Cover

# Post-Closure Care

- 80-90% less maintenance cost than a traditional soil cover

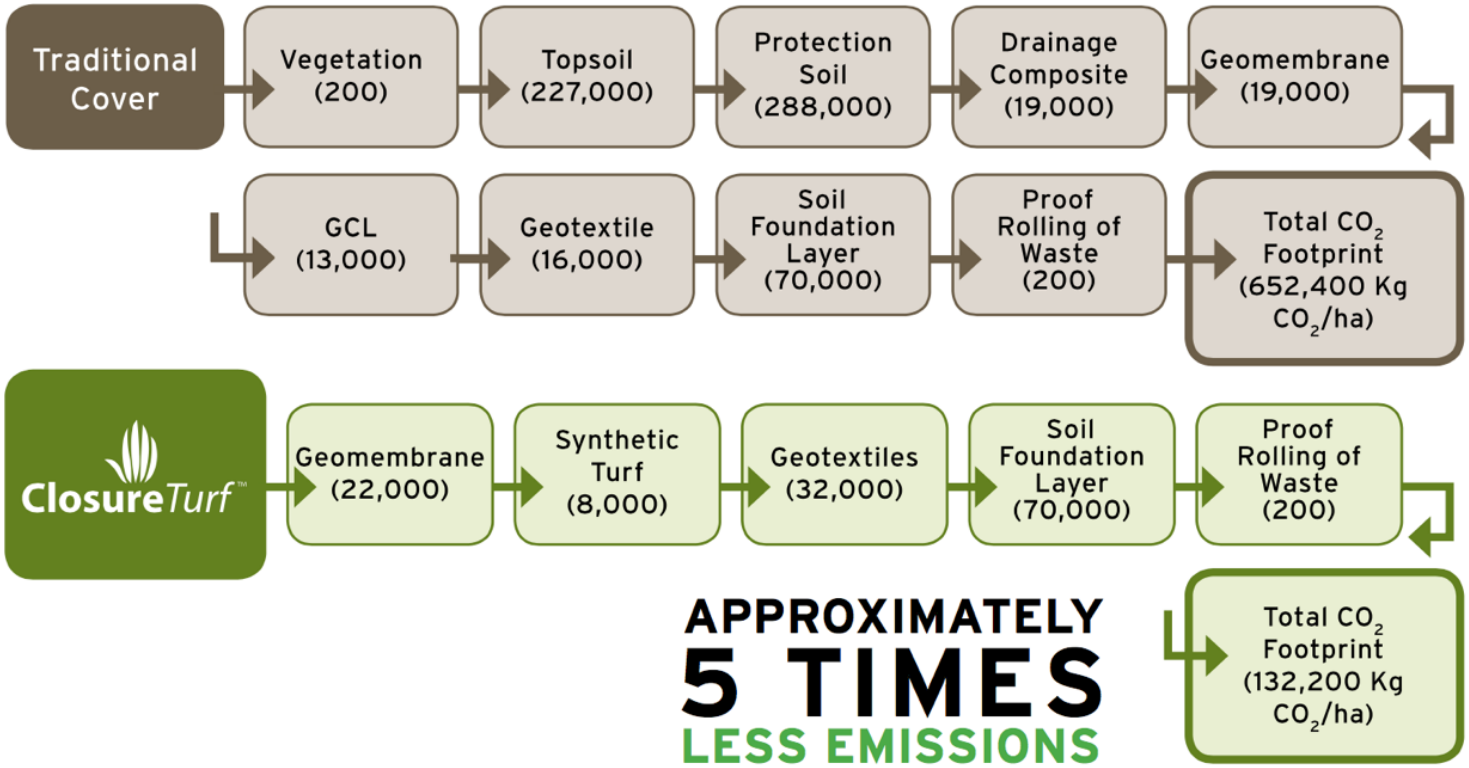
| Traditional Cap | Advanced Engineered System |
|---|---|
| Mowing (4 events per year) | Not Required |
| Erosion Control (1 event per 25 acres, twice per year) | Not Required |
| Reseeding (1/3 area, twice per year) | Not Required |
| Fertilizing (1/3 area once per year) | Not Required |
| Soil Replacement (typical 1 ton/per acre per year average- per EPA) | Sand Infill Replacement (<2% total area every 5 years) |
| Pond Cleanout (avg once per every 4 years) | Not Required |
| Major Storm Repair (4 hours equipment after 1 event/year) | Not Required |
| Site Inspection (1 inspection per quarter) | Site Inspection (Every 5 to 10 years) |

Berkeley County Site Manager's Comment on ClosureTurf:

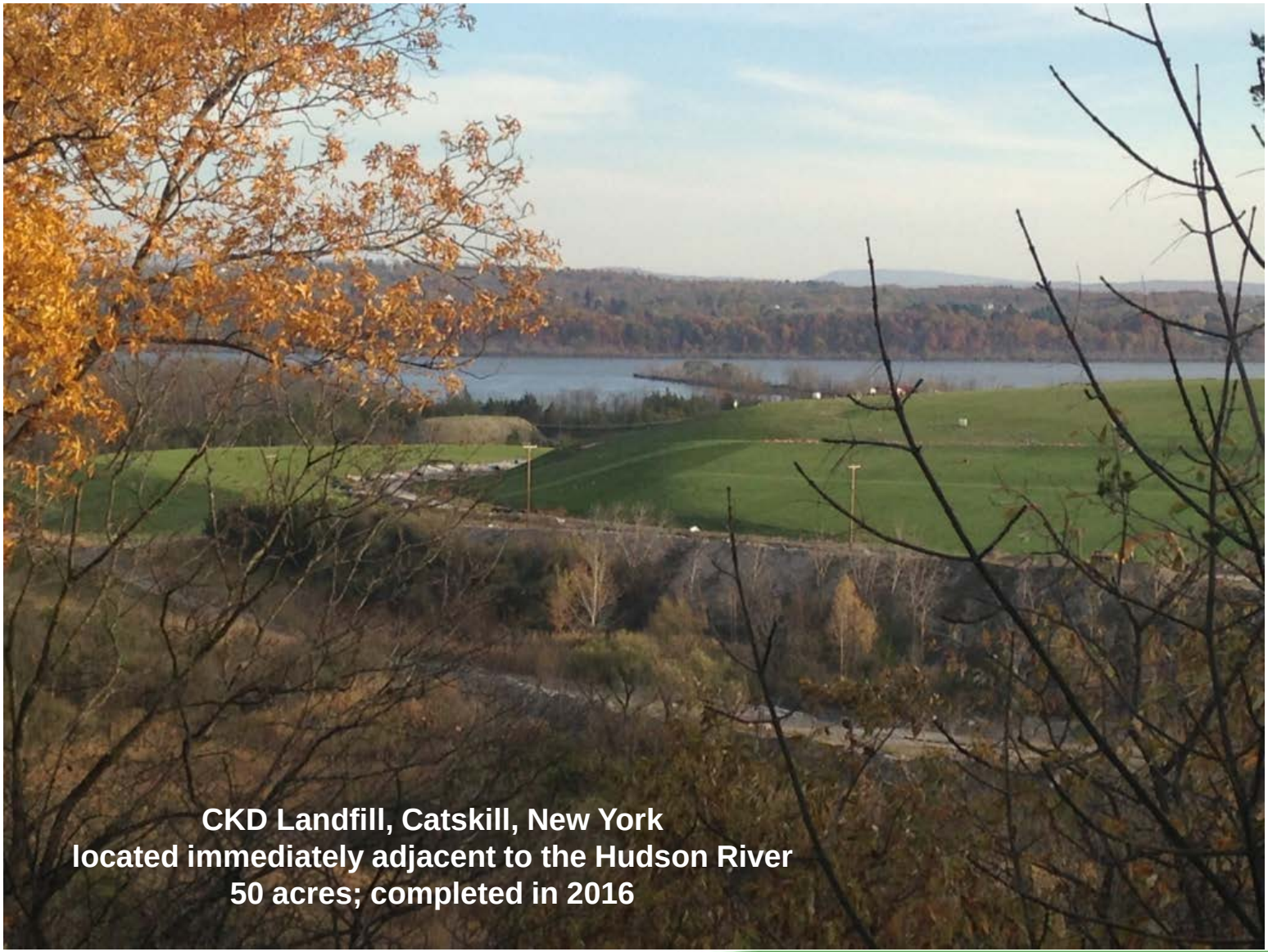
***"The reduction in maintenance is our biggest gain. We're saving around $24,000 a year in maintenance. We have absolutely zero eroded slopes to repair and we have eliminated mowing and grass upkeep."***

# Sustainability

- Less environmental impact as a result of land and water conservations and less truck trips
- 5 times less $CO_2$ emissions due to less use of trucks, construction materials, and equipment



# Post-Closure Aesthetics



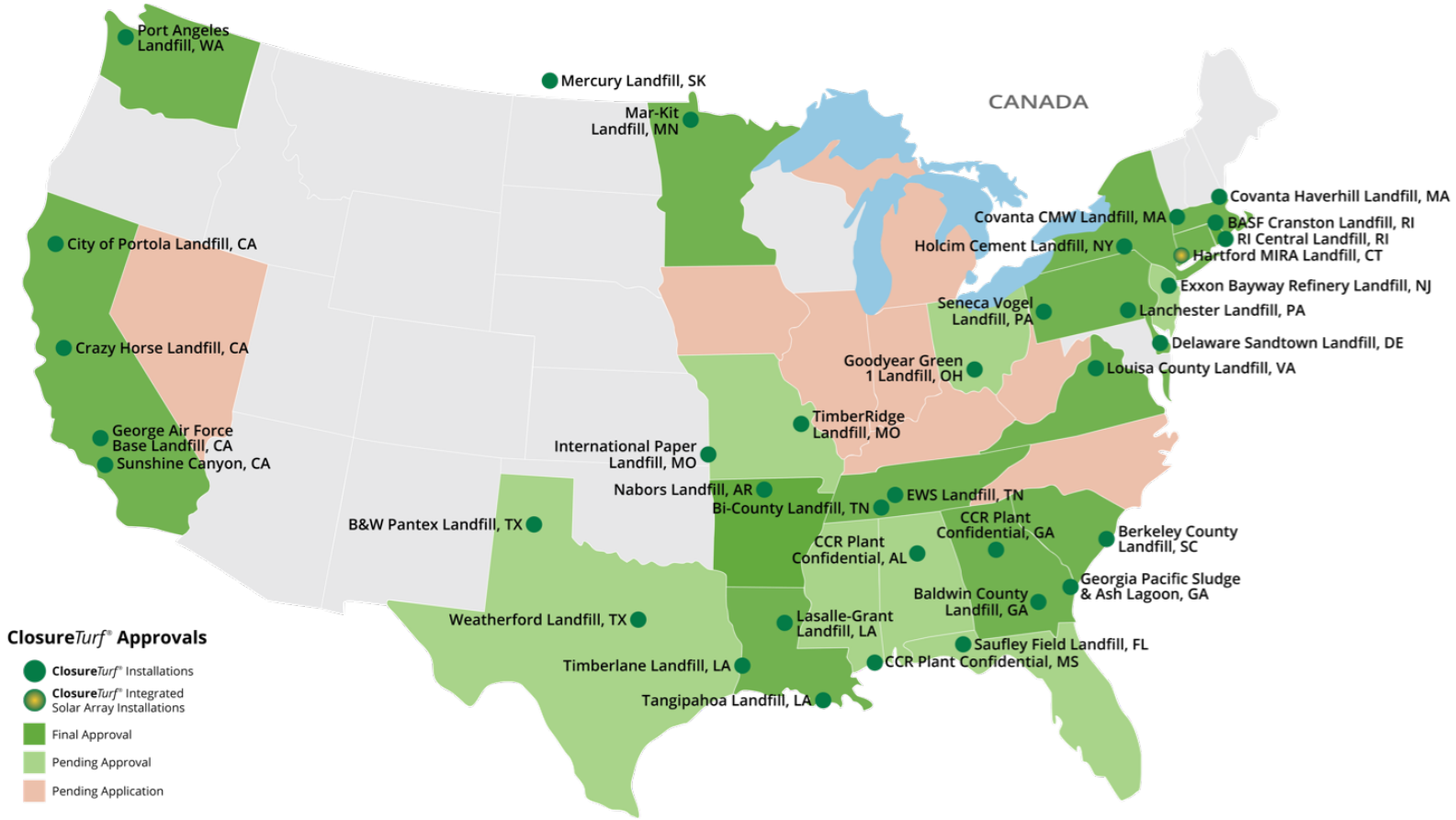
**CKD Landfill, Catskill, New York**
**located immediately adjacent to the Hudson River**
**50 acres; completed in 2016**

# Post-Closure Aesthetics

# Post-Closure Aesthetics

# Post-Closure Beneficial Use

# ClosureTurf Projects

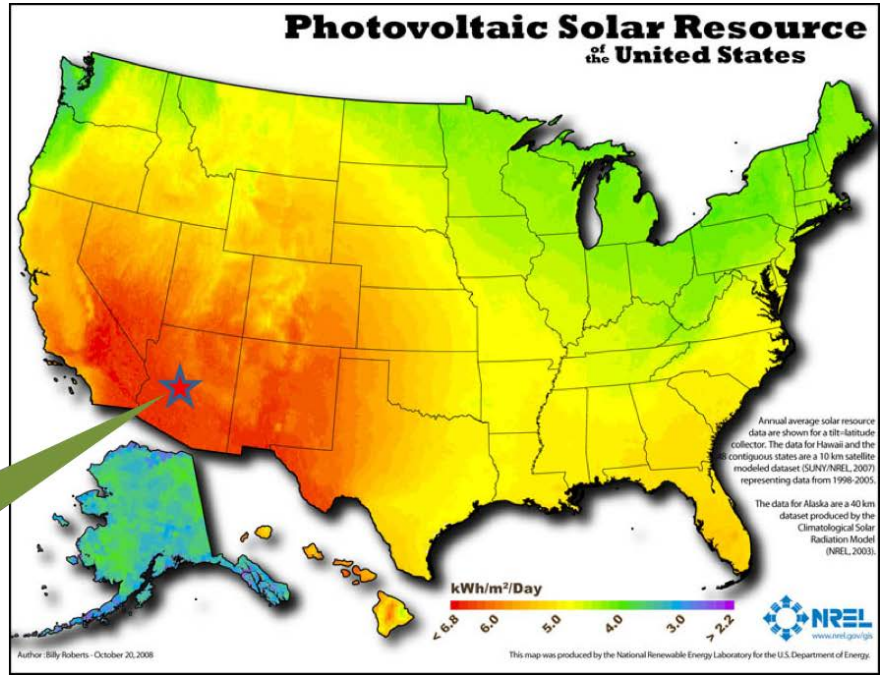



- First ClosureTurf installation completed in 2009 at the LaSalle-Grant Landfill in Louisiana
- More than 1,200 acres installed at ~40 sites in 21 states and 1 in Canada
- Project size ranging from several acres to over 150 acres
- Municipal, industrial and hazardous waste landfills and coal ash impoundments
- Warm and cold climates and severe weather conditions (hurricanes, storms, and high winds)

# Longevity and Wind Uplift

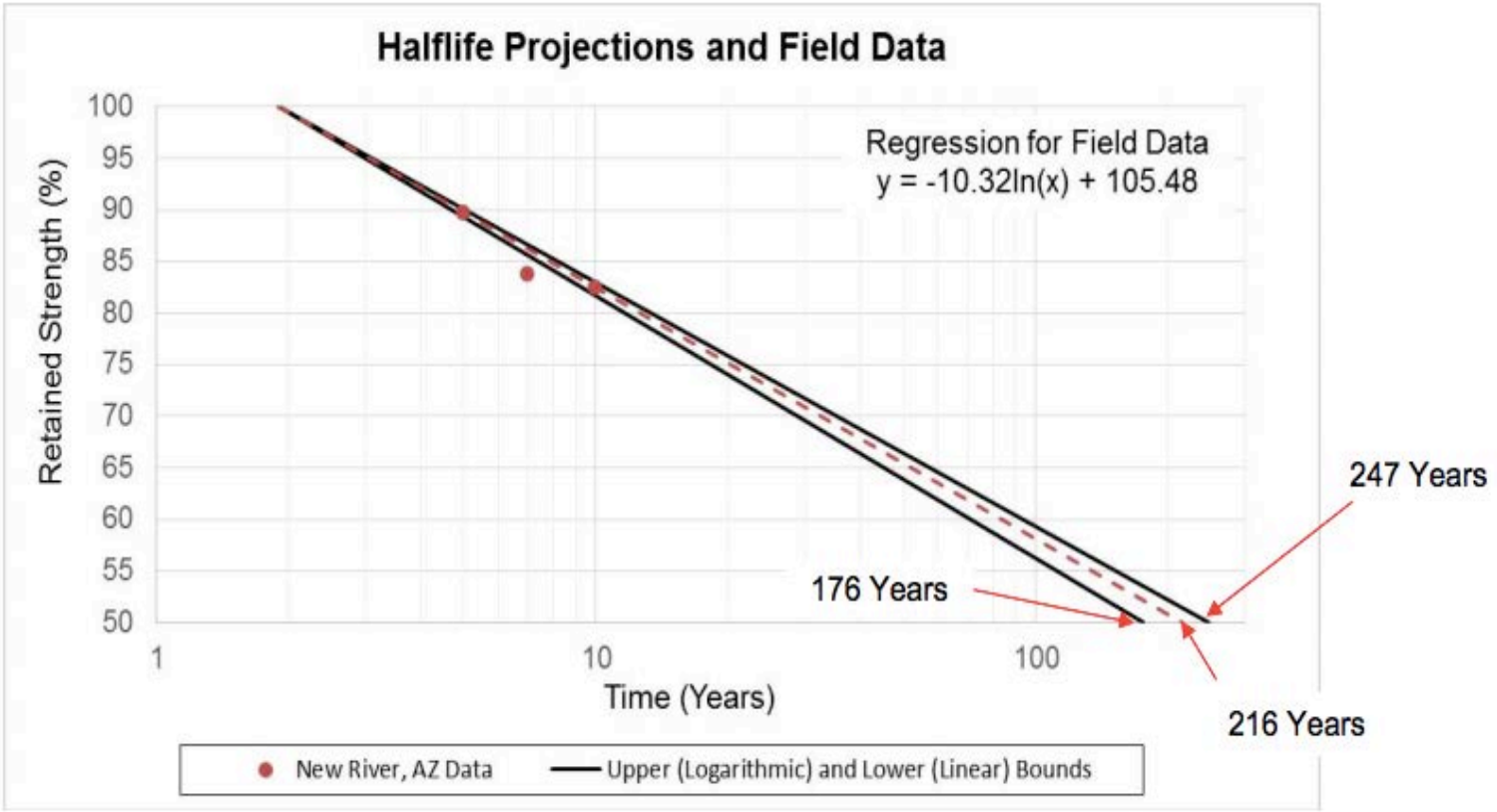
# Longevity

- Real world testing conducted at the Atlas Weathering Facility in New River, AZ
  - Direct Exposure 45° South
  - ASTM G147 and G7
- Over ten years of data collected
  - 1.3 years
  - 5 years
  - 7 years
  - 10 years



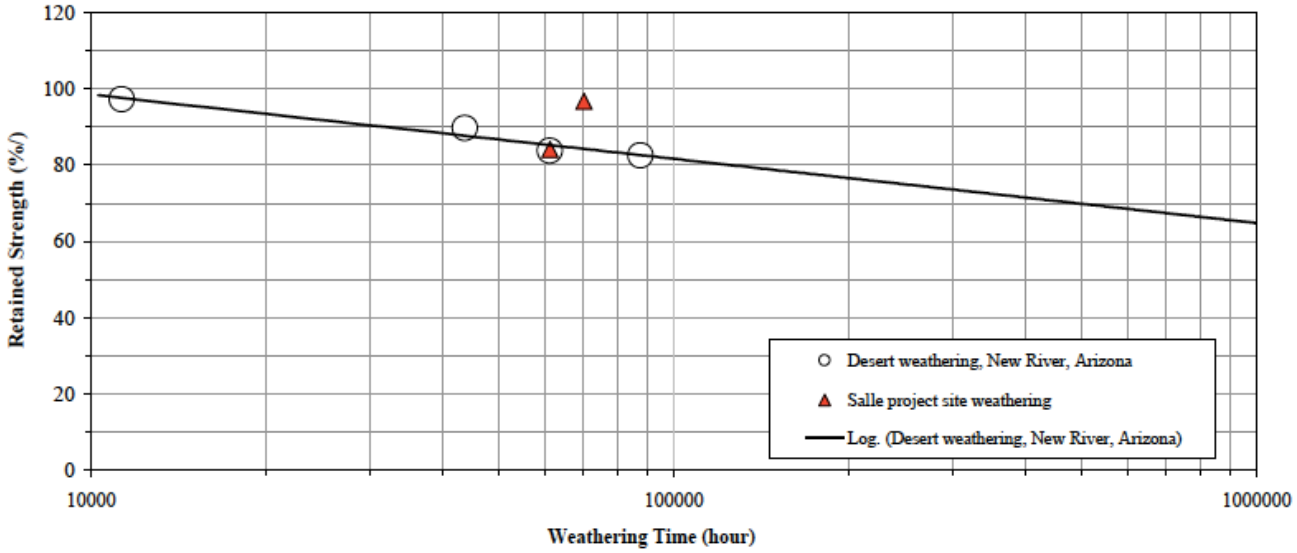

Atlas Weathering Laboratory in New River, AZ

# Longevity


Halflife Projections and Field Data
Retained Strength (%)
100
95
90
85
80
75
70
65
60
55
50
1
10
100
Time (Years)
Regression for Field Data
y = -10.32ln(x) + 105.48
247 Years
176 Years
216 Years
New River, AZ Data
Upper (Logarithmic) and Lower (Linear) Bounds

# Longevity

**CLOSURE TURF LLC -LANDFILL COVER SYSTEM**
**RETAINED TENSILE STRENGTH VS. WEATHERING TIME**
Desert Weathering VS. Salle Project Site Weathering




| Weathered ClosureTuff ™ | Weathered Conditions | Test Specimen | Weathering Time | | Tensile Strength | | |
|---|---|---|---|---|---|---|---|
| | | | (year) | (hours) | Control (lbs) | Weathered (lbs) | Weathered (%) |
| 1 | Desert weathering, New River, Arizona | Top Portion | 1.3 | 11280 | 25.4 | 24.7 | 97.2 |
| 2 | Direct 45 deg South with plywood packing | 2" long | 5.0 | 43800 | 20.2 | 18.2 | 89.7 |
| 3 | | green yarn | 7.0 | 61320 | 20.2 | 17.0 | 83.8 |
| 4 | | | 10.0 | 87600 | 20.2 | 16.7 | 82.5 |
| 5 | Salle project site exposure | 3" long | 7.0 | 61320 | 20.2 | 17.0 | 84.2 |
| 6 | facing south on slope | green yarn | 8.0 | 70080 | 46.2(1) | 44.7 | 96.8 |

*NOTE (1) control strength determined from the trench sample from the same site.*

SGI TESTING SERVICES, LLC

| | |
|---|---|
| DATE REPORTED | 10/27/2016 |
| FIGURE NO. | 1 |
| PROJECT NO. | SGI16014 |
| DOCUMENT NO. | |
| FILE NO. | |

# Wind Tunnel Testing

Tested at Georgia Tech Research Institute up to 120 mph

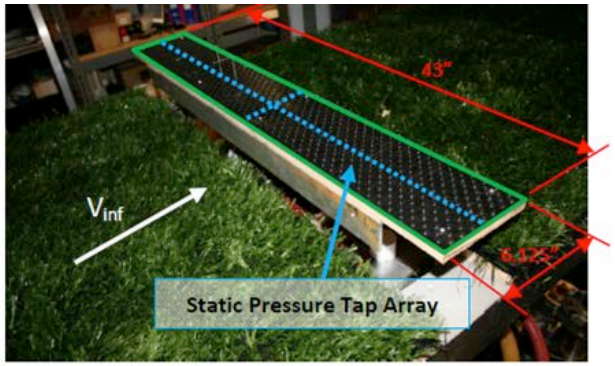



Figure 1a – Model Before Final Turf Layer

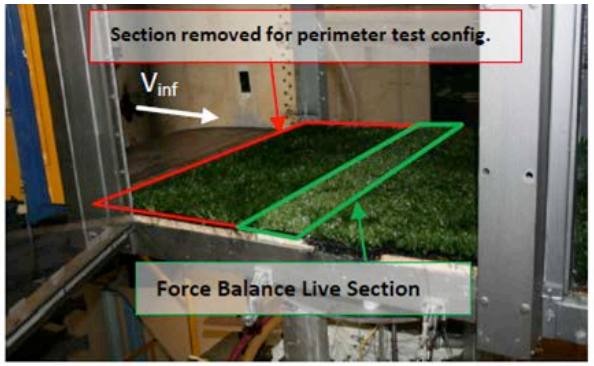



Figure 1b – Turf Installed & Model Lowered

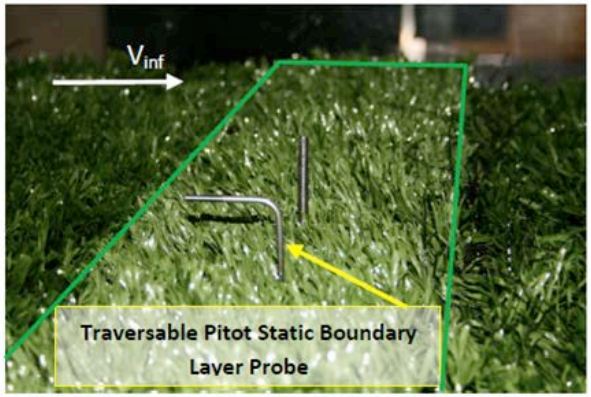



Figure 1c - Pitot Static Boundary Layer Probe

Figure 1d – Full Installation Looking Downstream

# Wind Tunnel Testing

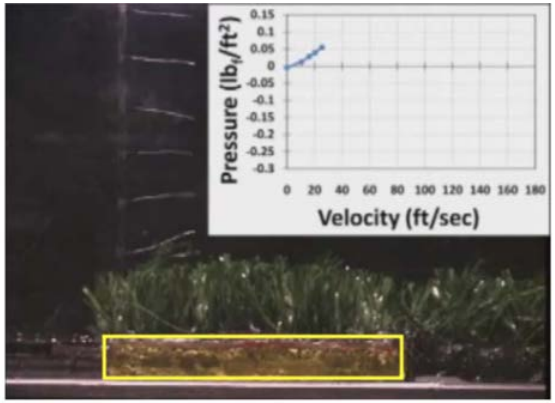



Figure 3a: Vinf = 25 ft/sec

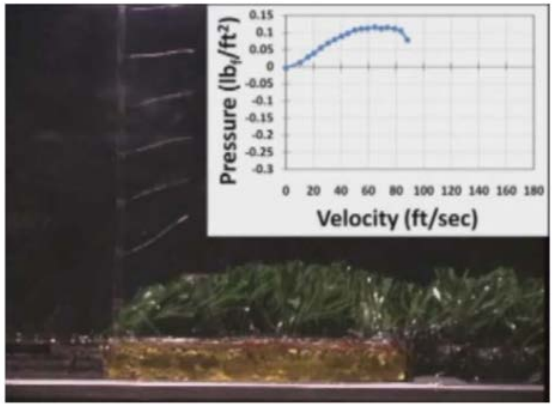



Figure 3c: Vinf = 90 ft/sec

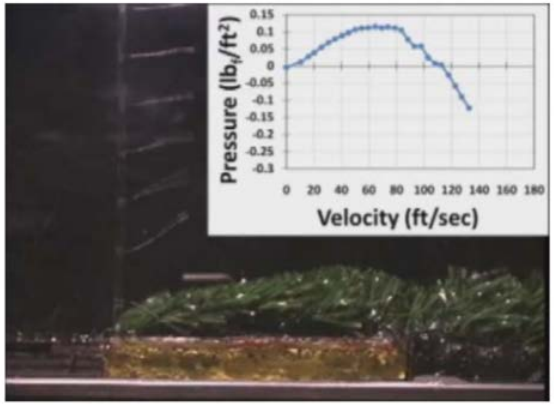



Figure 3e: Vinf = 135 ft/sec

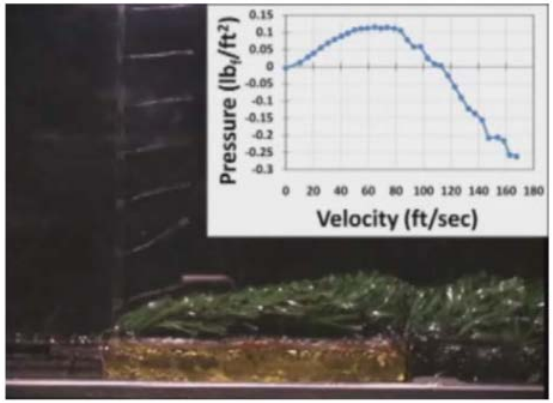
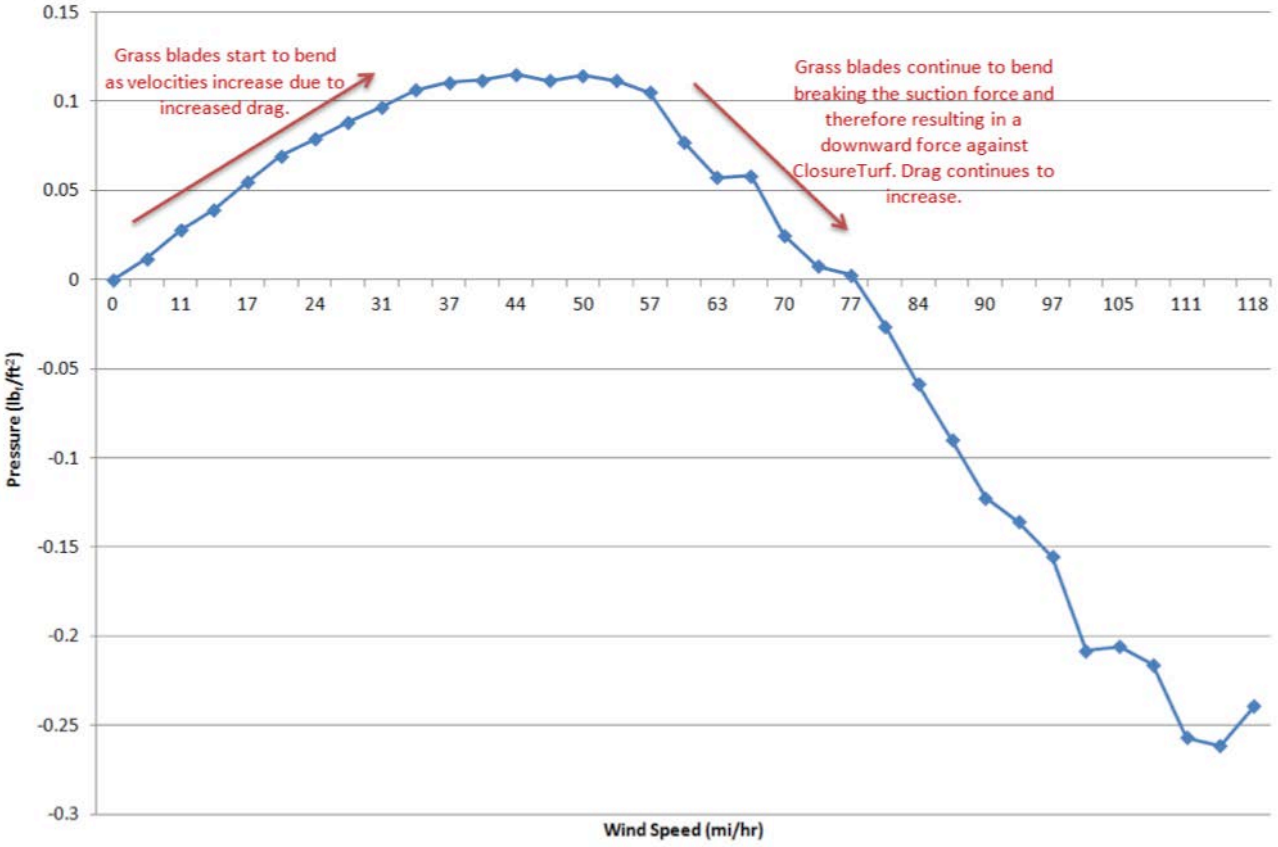



Figure 3f: Vinf = 170 ft/sec

# Wind Tunnel Testing




Resists Hurricane Force Winds (Category 3)

# Summary

- An engineered turf final cover (ClosureTurf®) meets or exceeds the regulatory criteria established for alternative final cover through technical performance equivalency demonstration.
- Field performance of ClosureTurf has demonstrated a number of benefits compared to conventional soil covers, e.g., construction speed, geotechnical stability, settlement, soil erosion, water quality, post-closure maintenance, etc.
- More than 1,200 acres of ClosureTurf have been or are being installed and the technology is gaining more and more acceptance by regulators, site owners, and engineers.

WG Watershed Geo®
Unearthing Solutions

# QUESTIONS?

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- Dr. Ming Zhu is the Director of Engineering with WatershedGeo located in Alpharetta, Georgia. He has more than 12 years of experience in geotechnical and geoenvironmental engineering, including landfill design, contaminated site remediation, and coal combustion residuals (CCR) impoundment closure.
- Dr. Zhu is currently serving on several professional committees, including the ASCE Geosynthetics Committee, ASCE Geotechnics of Soil Erosion Committee, and TRB AFP40 Geo-Environmental Processes.
- Dr. Zhu received his Ph.D. from the University of Michigan, Ann Arbor and is a registered Professional Engineer in Georgia.