WatershedGeo®
Unearthing Solutions

Technical Note

FULL-SCALE OVERTOPPING TESTING OF HYDROTURF® ADVANCED REVETMENT TECHNOLOGY

Extensive independent, third party overtopping testing has been performed on HydroTurf® Revetment Technology (HydroTurf) at the Colorado State University Engineering Research Center (CSU) in Fort Collins, Colorado. A description of full scale, steady state overtopping testing procedures and test results are provided in this document. Additional testing and evaluations performed on HydroTurf include wave overtopping and multiple non-hydraulic tests. Those testing descriptions and results are available in separate documents. Please contact Watershed Geosynthetics for additional information.

STEADY STATE OVERTOPPING TESTING

CSU tested HydroTurf in accordance with ASTM D 7277, *Standard Test Method for Performance Testing of Articulated Concrete Block (ACB) Revetment Systems for Hydraulic Stability in Open Channel Flow*. The results of the testing were analyzed in accordance with ASTM D 7276, *Standard Guide for Analysis and Interpretation of Test Data for Articulating Concrete Block (ACB) Revetment Systems in Open Channel Flow*.

The HydroTurf Revetment System was installed in general accordance with Watershed Geosynthetics installation guidelines in a flume at a 2H:1V (horizontal:vertical) slope. Installation occurs in four steps. Initially, a 1-foot thick layer of a sandy-loam subgrade was placed and compacted in the flume as presented in Figure 2. Second, a continuous sheet of the structured geomembrane was placed on the subgrade as presented in Figure 3. This geomembrane serves as the underlayer of the system. Third, the engineered synthetic turf was placed on the geomembrane. A horizontal seam was intentionally placed in the synthetic turf layer near the bottom of the flume. The purpose of the seam was to test seam strength under high flow velocity and shear stress conditions. The seam consisted of two sections of synthetic turf which were heat-bonded together using equipment similar to that used for field installations. The fourth step in testing preparation was applying approximately a ¾-inch thick layer of dry HydroBinder® into the fibers of the synthetic turf. The dry mixture was placed using a drop spreader and broomed against the turf grain to pull the fibers up through the infill. The HydroBinder infill was then hydrated by applying a light spray of water until saturation. The completed installation of the HydroTurf® System is shown in Figure 4.

Figure 2. Compacted Sandy-Loam Subgrade

Figure 3. Structured Geomembrane Installation

Figure 4. Installed HydroTurf® System

HydroTurf® System was tested on a 30-foot embankment at 1.5, 3.0, and 5.0-foot steady-state overtopping depths for a total of 12 hours in April 2013. To test under higher velocity and shear stress conditions, the System was also tested on a 60-foot embankment at 1.5, 5.0, and 5.5-foot steady-state overtopping depths for an additional 12 hours in September 2015. After both tests, the embankment flume was inspected. The system and underlying soil were determined to be intact. CSU reported stable performance at velocity values of 40 ft/s. Since no instability, deformation, loss of intimate contact or damage to the system occurred, and since no erosion of the underlying subgrade occurred; the reported velocity is not a maximum performance threshold. A summary of these results is shown in Table 1. A profile of the testing section is shown in Figure 5, and photographs of testing are shown in Figure 6.

Table 1. HydroTurf® Steady State Overtopping Testing Results

Overtop Depth (ft)	Q (cfs)	Embankment Length (ft)	Manning's "n" Value	Velocity (ft/s)
1.5	20	30	0.017	21
3.0	52	30	0.018	26
5.0	117	30	0.020	29
1.5	20	60	0.025	18
5.0	119	60	0.021	37
5.5	140	60	0.018	40

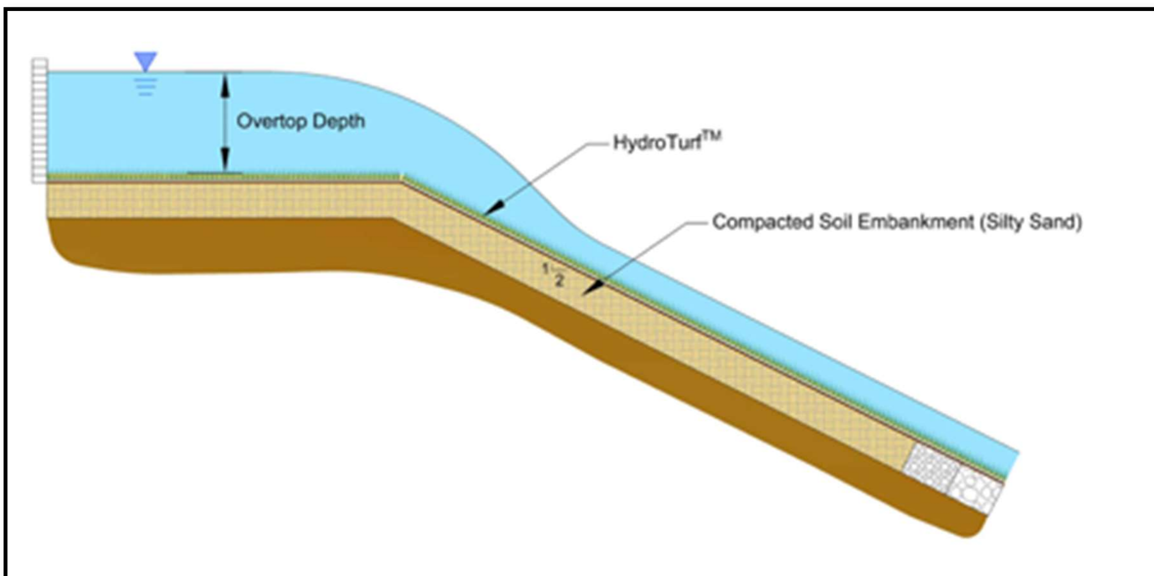

Figure 5. HydroTurf® Overtopping Testing Schematic

Figure 6. HydroTurf® Steady State Overtopping Testing at CSU

The HydroTurf® velocity performance value as measured in this steady state test is 40 ft/s at a 5.5 feet overtopping depth. When compared to published maximum performance thresholds / permissible design values of other erosion and revetment technologies, HydroTurf outperforms these other systems as presented in Figure 7.

Upon completion of the three 30-foot embankment steady state tests, additional testing was conducted using the already-installed HydroTurf® System in the flume. Additional testing evaluated the performance of HydroTurf when subjected to hydraulic jumps, flow entrained large debris, and intentional damage.

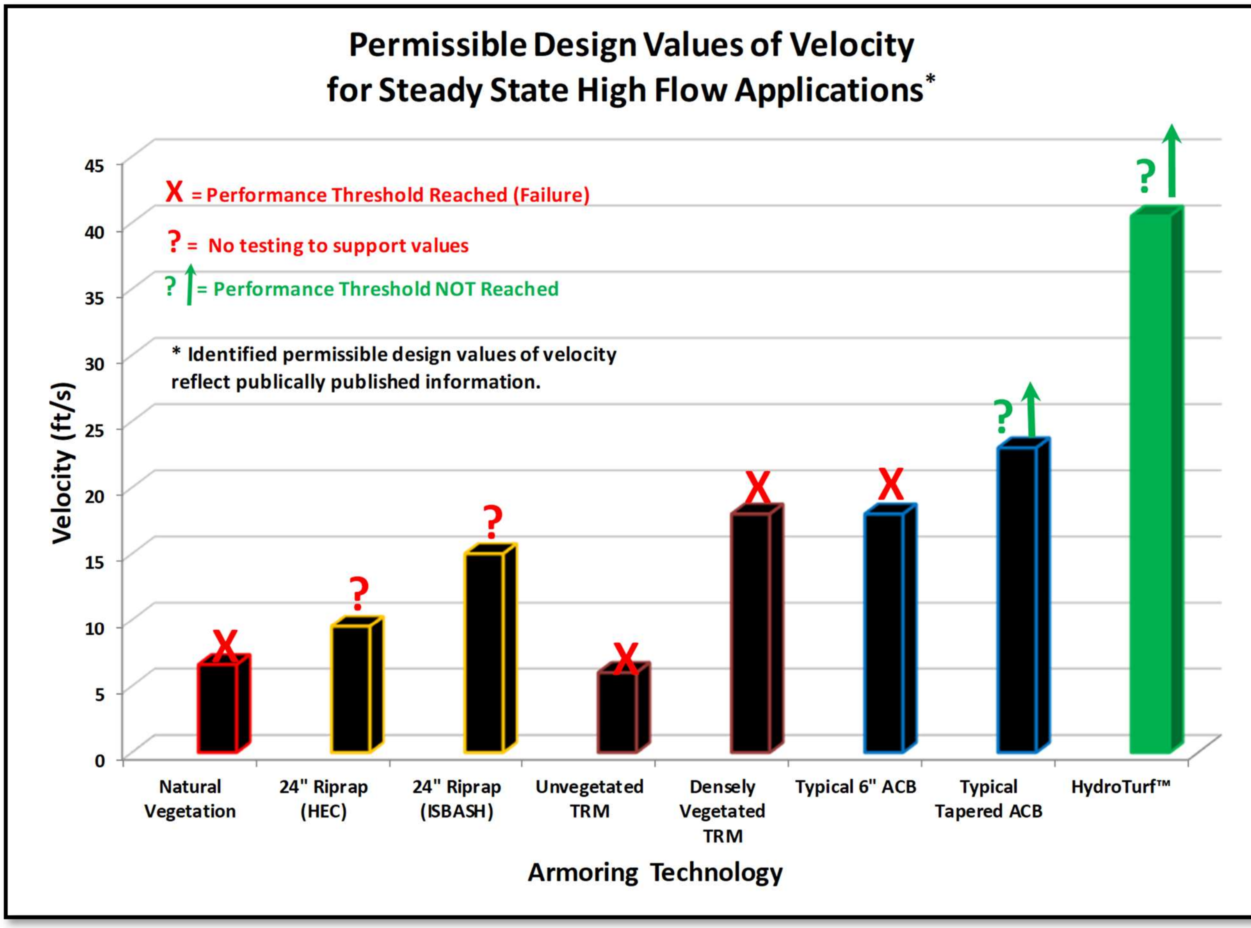

Figure 7. Accepted Velocity Design Values for Steady State, High Flow Applications

Hydraulic Jump Testing

Since there is no standard test method for measuring hydraulic jump, CSU developed a test program to adequately quantify the performance of HydroTurf® under a series of hydraulic jumps. A manually operated vertical sluice gate was installed approximately 22 feet from the top of the embankment to create a hydraulic jump on the HydroTurf as presented in Figure 8. The gate was placed and operated to induce a hydraulic jump on the lower one-third of the installed System. A profile diagram of the hydraulic jump test configuration is presented in Figure 9.

Figure 8. Hydraulic Jump Testing Sluice Gate Installation

A hydraulic jump test consisted of a minimum of 1.5 hours of continuous flow at each overtopping depth (1.5, 3.0, and 5.0-foot overtopping depths). Measurements of water surface elevation were taken at the gate and at 2-foot intervals upstream along the centerline of the slope to the upstream extent of the hydraulic jump. After at least 30 minutes of flow for a specific hydraulic jump, the sluice gate was adjusted to extend the jump further upstream. The procedure was repeated for three hydraulic jumps at each overtopping depth. Photographs of the hydraulic jump testing are shown in Figure 10.

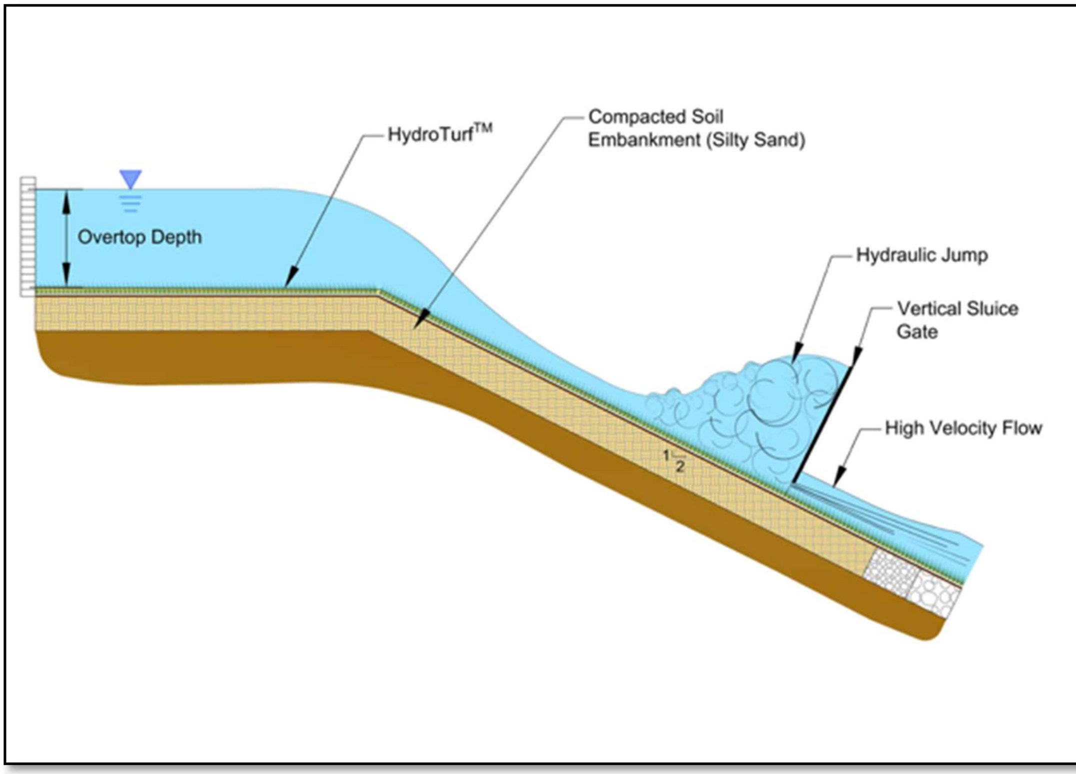

Figure 9. HydroTurf® Hydraulic Jump Testing Schematic

Figure 10. HydroTurf® Hydraulic Jump Testing at CSU

The hydraulic jump test program was implemented to quantify the performance of HydroTurf® under hydraulic loading caused by a range of hydraulic jumps over a range of overtopping depths and energy dissipation rates. A performance threshold was not reached; there was no instability, deformation, loss of intimate contact, erosion of the underlying subgrade or damage to the HydroTurf.

A relationship between the energy lost in the jump and the ratio of the upstream and downstream Froude numbers was developed. This relationship is shown in Figure 11. In addition, power dissipation was calculated for each hydraulic jump interval and plotted as a function of specific energy upstream of the jump as presented in Figure 12. The HydroTurf demonstrated the ability to withstand hydraulic loads caused by hydraulic jumps dissipating as much as 30 horsepower per foot of width.

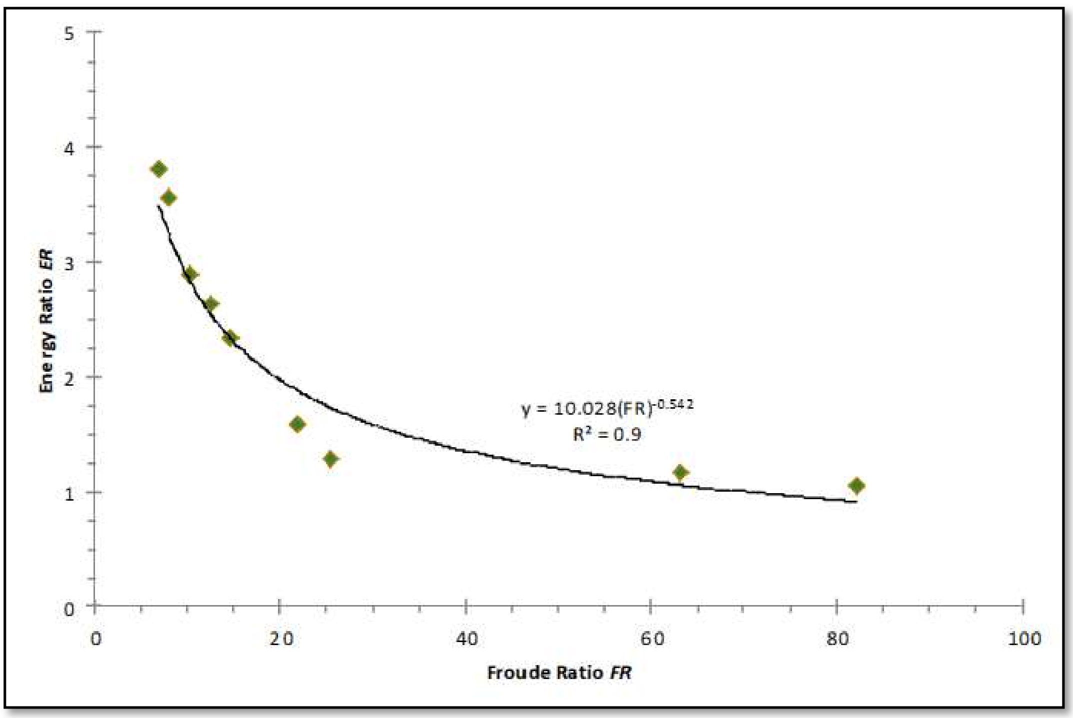

Figure 11. Energy Ratio as a Function of Froude Ratio for HydroTurf®

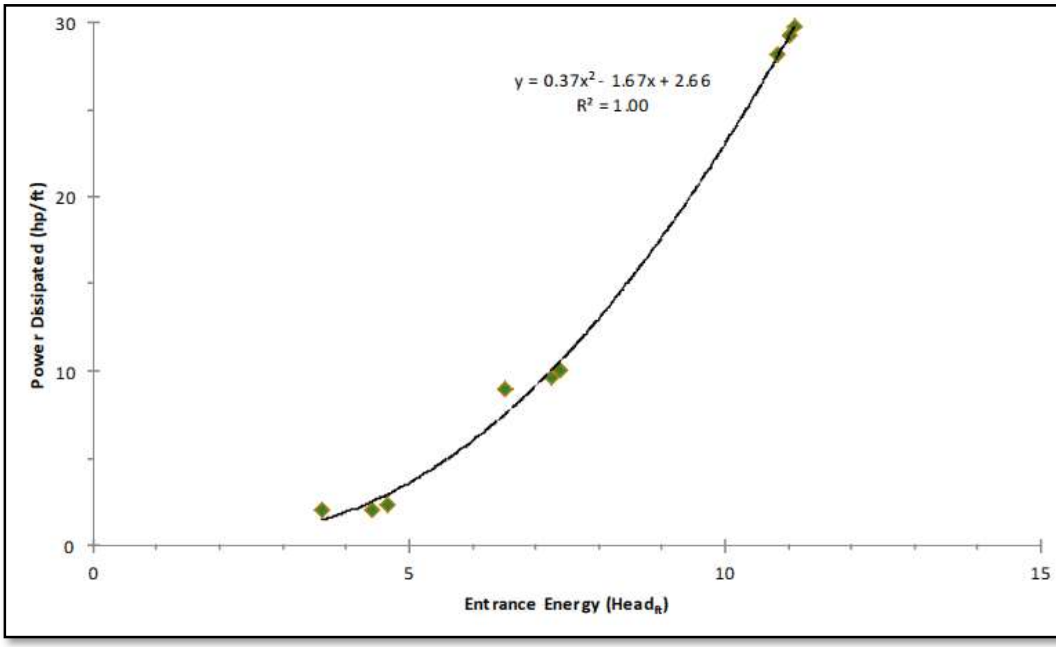

Figure 12. HydroTurf® Hydraulic Jump Power Dissipation Results

As a result of the small opening at the sluice gate base, flow immediately downstream of the gate was a pressurized "jet" impinging onto the HydroTurf® as presented Figure 13. Extreme turbulence of the flow made precise velocity measurements challenging, but water jet velocity exiting the sluice gate was approximately 35 fps based on continuity of flow. At the jet location, there was no instability, deformation, loss of intimate contact, erosion of the underlying highly-erodible subgrade or damage to the HydroTurf.

Figure 13. Pressurized "Jet" Impinging on HydroTurf®

Heavy Debris Loads

Upon completion of hydraulic jump testing, a simulation of heavy debris loads was performed. The test was performed to qualitatively assess the resilience to impact and abrasion from large debris of the HydroTurf®.

The evaluation was conducted by increasing flow until an overtopping depth of 5.0-foot was achieved. A Bobcat® S850 front-end loader was filled with broken, angular concrete rubble ranging from 3 to 15 inches in diameter as presented in Figure 14. Two full buckets of concrete rubble were dropped onto the HydroTurf from a height of approximately 12 feet near the embankment top as presented in Figure 15 and Figure 16. The concrete debris created a few minor surface impressions at the location of the 12-foot drop, but the integrity of the HydroTurf was not compromised and there was no observed damage to the system downstream of the drop location. No instability, loss of intimate contact, or erosion was observed.

Figure 14. Concrete Rubble for HydroTurf® Testing

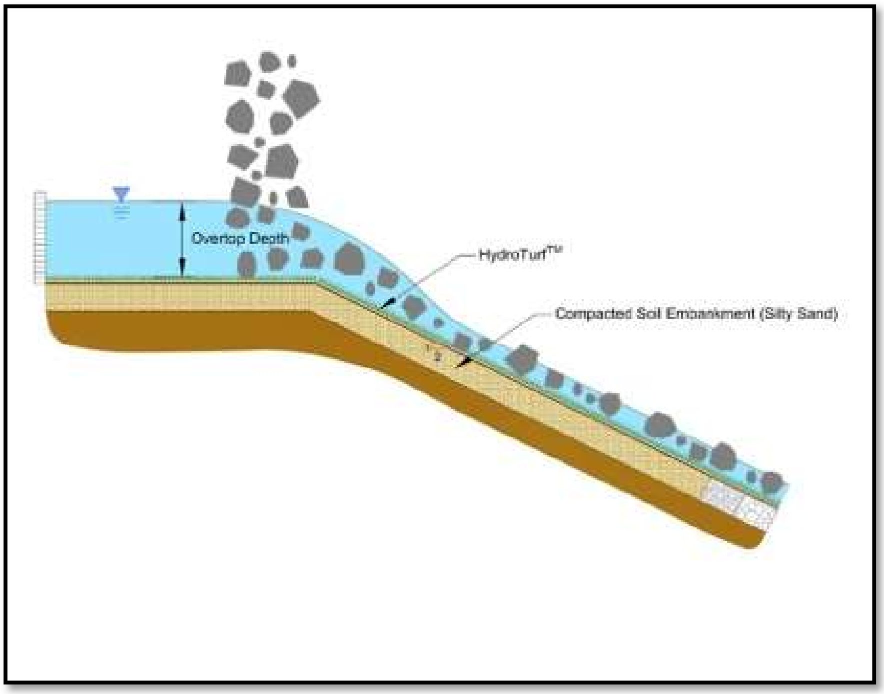

Figure 15. Heavy Debris Load Testing Schematic

Figure 16. Heavy Debris Load Evaluation (Concrete Rubble)

Intentionally Damaged State

HydroTurf® performance in a damaged state was also evaluated. A pick axe was intentionally driven through the HydroTurf and approximately 6-inch into the underlying sandy-loam subgrade. Figure 17 presents a photograph of the pick axe puncture. Testing was subsequently performed at 3 and 5-foot overtopping depths for a duration of 1 hour each (total of 2 hours). No instability or discernible erosion was observed.

Following removal of the HydroTurf, the subgrade was inspected. There was no erosion, the initial hole had closed, and the entire embankment subgrade showed no signs of erosion. Figure 18 presents the pick axe hole at the conclusion of testing and after the system was removed.

Figure 17. Intentionally Damaged HydroTurf®, Pre-test

Figure 18. Intentionally Damaged HydroTurf® Performance: System Surface and Sub-grade, Post-test

Summary

Full-scale hydraulic performance testing of the HydroTurf® Revetment Technology was completed at CSU under steady state, overtopping conditions. Testing was conducted in general accordance with standard procedures for ACB revetment system testing (ASTM D 7276 and ASTM D 7277). HydroTurf was tested under steady state flow conditions for a total of 32 hours and withstood flow velocities exceeding 40 ft/s. For these tests, a Manning's roughness value ranged between 0.017 and 0.025 for HydroTurf.

The test program also demonstrated the ability of HydroTurf to withstand hydraulic loads caused by hydraulic jumps dissipating as much as 30 horsepower per foot of width. Qualitative testing demonstrated the ability of HydroTurf to withstand impact and abrasion caused by large debris, as well as withstand puncture damage. Instability or failure of the system did not occur, and erosion of the subgrade did not happen. *Therefore, the HydroTurf® Revetment System was not tested to its performance threshold*. A photograph of the condition of the soil subgrade post-test is presented in Figure 19.

Figure 19. HydroTurf® Soil Subgrade, Post-test

LIMITATIONS

HydroTurf® 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.