INTRODUCTION TO HYDROTURF™ REVETMENT SYSTEM

HydroTurf™ was developed as an engineered revetment solution for use in preventing erosion in the following applications:

- Protection from Wave Overwash / Overtopping on the Landward Side of Levees and Embankments;
- Lining of Channels, Swales, Canals, and Spillways;
- Shoreline Protection within Basins, Impoundments, and Reservoirs; and
- Facings for Slopes and Mechanically Stabilized Earth Walls.

HydroTurf™ is a unique flexible concrete erosion prevention solution consisting of a high-friction, impermeable geomembrane layer with an integrated drainage layer overlain by an engineered synthetic turf. The geomembrane is placed directly on the subgrade soil. It is covered with the engineered turf whose fibers provide reinforcement for the HydroBinder™ cementitious infill. This infill is placed dry to a thickness of $\frac{3}{4}$-inch...
minimum. After placement, it is then hydrated with a light spray of water. A cross section of HydroTurf™ is shown in Figure 1.

Figure 1 – Section of HydroTurf™ Revetment System

BENEFITS

HydroTurf™ has a number of benefits over other revetment solutions. These benefits include the following:

- **Excellent Hydraulic Performance** – HydroTurf™ has been measured to have exceptional hydraulic performance over other hard armor revetment systems.

- **50+ Year Functional Longevity** – Through long term weathering tests, HydroTurf™ is extrapolated to have a 50+ year functional longevity.

- **Less Costly Construction** – HydroTurf™ is significantly less costly than hard armor revetment systems (i.e., concrete, rock riprap, and articulated concrete block (ACB)). The installed cost for HydroTurf™ is typically up to 50% less than that for traditional hard armor systems.

- **Rapid, Low Impact, and Scalable Construction** – Construction and installation of the HydroTurf™ System are rapid, low impact, and scalable. Only small, light
construction equipment is needed to install the system. On large projects, one (1) experienced construction crew is able to install approximately 1 acre per day. Additional crews can be added to increase this rate.

- **Significant Long Term Maintenance Cost Savings** – Vegetation management and erosion control are significant maintenance costs for Anchored Turf Reinforcement Mats (TRMs) products. Maintenance costs for these TRMs may be as high as $1500/acre/year. HydroTurf™ has minimal maintenance and will drastically lower long term maintenance costs.

- **Reduction in Carbon Footprint** - HydroTurf™ has a significantly lower carbon footprint (1/4 to 1/8) than that of the other revetment solutions.

- **Aesthetics** – HydroTurf™ looks and feels like natural vegetation.

**AERODYNAMIC EVALUATION**

HydroTurf™ has features that help mitigate the forces of wind. These include a porous surface to break the vacuum, and turf blades that will increase the aerodynamic boundary conditions and react against the wind causing a resistance to the uplift component. In order to quantify these features, the HydroTurf™ System was evaluated in the Subsonic Model Test Facility Wind Tunnel at the Georgia Tech Research Institute (GTRI). Testing was performed to evaluate the aerodynamic properties and ballast requirements (infill thickness). The material was tested under two (2) different configurations - a perimeter condition (up to 18-in from the edge of the installation) and an interior condition (beyond 18-in from the edge). Wind speeds were increased up to 170 ft/s (approximately 120 mph). Figure 2 shows the test at 170 ft/s (120 mph).

Based on these hurricane force wind speeds, the minimum infill ballast requirements are 0.40-in for the perimeter condition and 0.038-in for the interior condition. Since HydroTurf™ has a recommended HydroBinder™ infill thickness of ¾-in, it will resist wind speeds greater than 170 ft/s (120 mph) when properly designed, constructed, and maintained.
WEATHERING AND FUNCTIONAL LONGEVITY

The engineered synthetic turf layer with the HydroBinder™ Infill is the protection layer of the HydroTurf™ System. These components shield the underlying backing geotextiles and geomembrane from exposure. The synthetic turf yarns are the only synthetic component of the system that is directly exposed to the elements, specifically ultraviolet light (UV). Weathering tests of these yarns have been performed in accordance with ASTM G147 and G7 at Atlas Material Testing Laboratories in New River, AZ. Samples were exposed to direct UV by fastening them to a panel which faces south at a 45 degree angle. A photograph of the weathering apparatus is shown in Figure 3.
The samples were exposed for a given period and then the retained tensile strength was measured. To date, four (4) samples have been tested for the exposure periods of 1.3, 5, 7, and 10 years. The retained tensile strength at these exposure periods is 97.2%, 89.7%, 83.8%, and 82.5%, respectively. Retained tensile strength was plotted against exposure duration as shown in Figure 4.

Figure 4 –Retained Tensile Strength of Synthetic Turf Fibers vs. Weathering Exposure Duration

A logarithmic line was fit to the four (4) points and extrapolated out to 1,000,000 hours. At 50 years (438,000 hours), the retained tensile strength of the synthetic turf yarn is projected out to approximately 70%. At 70% retained tensile strength, it will continue to function as designed and provide reinforcement for the infill, protection of the geotextile backing layers, and protection of the underlying geomembrane. Therefore, it can be deduced that the HydroTurf™ System will have a 50+ year functional longevity, if properly maintained.
VEHICLE LOADING EVALUATIONS

Vehicle loading calculations have been performed on the HydroTurf™ system. These calculations are intended to determine puncture and tear resistance of the system to support vehicle loads. The vehicles used in the evaluation consist of the following:

- Pickup Truck weighing 6,000 lbs with 45 psi tire pressure.
- Fire Engine weighing 55,000 lbs on dual rear axles / wheels (tire pressure of 120 psi).

Photos of these vehicles are show in Figure 5.

Figure 5 – Vehicles Used in Loading Evaluations

These calculations are based on the methodologies presented in Koerner (2005)\(^1\). The calculated results for the puncture and tear resistance of the geosynthetic components are presented in the Table 1.

\(^1\) Koerner, Robert M. (2005), “Designing with Geosynthetics”.
A braking evaluation was also performed. This evaluation was performed with the following assumed conditions:

- Pickup Truck was moving at 10 mph and stopped on a 3H:1V slope within 2 sec.
- Fire Engine was moving at 10 mph and stopped on an 8% slope within 2 sec.

Factors of Safety against static and dynamic movement of the geosynthetic layers were calculated. A schematic of the breaking forces used to calculate the Factors of Safety is shown in Figure 6. The results or the evaluation are shown in Table 2.

### Table 1 – Results of Puncture and Tear Resistance Calculations

<table>
<thead>
<tr>
<th></th>
<th>Light Vehicle (Pick Up Truck)</th>
<th>Heavy Vehicle (Fire Engine)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Applied Pressure / Load – Deformation of Geotextile Backing*</td>
<td>4.37</td>
<td>1.64</td>
</tr>
<tr>
<td>Tensile Strength (Lateral Movement)*</td>
<td>1.85</td>
<td>1.90***</td>
</tr>
<tr>
<td>Puncture Resistance – Geotextile Backing Component*</td>
<td>239</td>
<td>90</td>
</tr>
<tr>
<td>Puncture Resistance on Roadways – Geomembrane Component</td>
<td>4 oz/sy GT</td>
<td>12 oz/sy GT</td>
</tr>
</tbody>
</table>

* Factor of Safety
** Methodology per Koerner (2005)
*** Reduction Factors of 1.5 for Installation Damage
**** 200 lb geotextile required

**Figure 6 – Schematic of Breaking Forces**
Table 2 – Factors of Safety of Braking Resistance

<table>
<thead>
<tr>
<th>Vehicle</th>
<th>Slope Angle</th>
<th>Static FS</th>
<th>Dynamic FS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fire Engine</td>
<td>8 Degrees</td>
<td>4.6</td>
<td>1.8</td>
</tr>
<tr>
<td>Pick Up Truck</td>
<td>18 Degrees</td>
<td>2.0</td>
<td>1.2</td>
</tr>
</tbody>
</table>

Based on these evaluations, factors of safety against damage of the HydroTurf™ System on account of traffic loading with rubber tired vehicles were ≥1.2. Typically, on slopes we suggest vehicles with tire pressures less than 45 psi, and on flatter areas (8% or less) and designed access roads, we suggest vehicles with tire pressures less than 100 psi.

It should be noted that the resistance of HydroTurf™ to traffic / vehicle loading is more a function of the underlying subgrade conditions (i.e., soil type, bearing capacity, bearing ratio, particle size, etc.). Therefore, it is important to perform a site specific analysis and specify proper compaction and grading of the subgrade surface.

CARBON FOOTPRINT FOR VARIOUS REVETMENT SYSTEMS

An estimated carbon footprint was evaluated for the following revetment systems:

- 24-inch Thick Rock Riprap
- 6-inch Thick Articulated Concrete Block (ACB) – Closed Cell
- 6-inch Thick ACB – Open Cell
- 6-inch Thick Concrete Paving
- 4-inch Thick Concrete Paving
- HydroTurf™
The evaluation included the calculation of the amount of CO$_2$ (lbs) per square foot (sf) of revetment surface area. For each system, the following CO$_2$ producing activities were analyzed:

- Subgrade preparation;
- Manufacture of the materials;
- Hauling of materials to the project site; and,
- Placing and installing the materials.

Values of CO$_2$ production were primarily derived from EPA (2005)$^2$ and University of Bath (2008)$^3$.

Based on this evaluation, HydroTurf™ has a significantly lower carbon footprint (1/4 to 1/8) than that of the other revetment solutions. The graph in Figure 7 shows the carbon footprint for each of the various revetment systems. Also for every one (1) acre of revetment, the use of HydroTurf™ will remove from the roads approximately 55 truck trips of ACB, 85 truck trips for concrete paving, or 200 truck trips for rock riprap.

![Graph showing estimated carbon footprint for various revetment systems](image)

**Figure 7 – Estimated Carbon Footprint for Various Revetment Systems**

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LIMITATIONS

HydroTurf™ product (US Patent No. 7,682,105; Canadian Patent No. 2,663,170; and other Patents Pending) and trademark are the property of Watershed Geosynthetics LLC. All information, recommendations and suggestions appearing in this letter 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.