WatershedGeo®
Unearthing Solutions

Technical Note

FULL-SCALE WAVE OVERTOPPING TESTING OF HYDROTURF® ADVANCED REVETMENT TECHNOLOGY FOR LEVEE LANDWARD SIDE SLOPE PROTECTION

Extensive independent, third party wave 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, wave overtopping testing procedures and test results are provided in this document. Additional testing and evaluations performed on HydroTurf include steady state overtopping, hydraulic jump, large debris and multiple non-hydraulic tests. Those test descriptions and results are available in separate documents. Please contact Watershed Geosynthetics for additional information.

FULL-SCALE WAVE OVERTOPPING TESTING FOR LEVEE LANDWARD SIDE SLOPE PROTECTION

Full-scale wave overtopping testing for levee landward side slope protection was performed on HydroTurf at CSU. Testing was in accordance with the methodology developed for the U.S. Army Corps of Engineers (USACE). A diagram and photograph of the wave overtopping simulator facility are presented in Figure 1 and Figure 2, respectively.

Test Preparation

A testing tray set containing the HydroTurf Revetment System was prepared at the CSU Wave Overtopping Test Facility. Installation began with a 2-inch thick layer of pea gravel placed in the tray bottom and covered with a filter fabric geotextile to prevent soil migration into the pea gravel layer. A highly-erodible soil (silty sand) was then placed into the trays in two, five-inch thick layers. Each layer was compacted to a minimum of 98% of maximum dry density using the Standard Proctor (ASTM D 698) method.

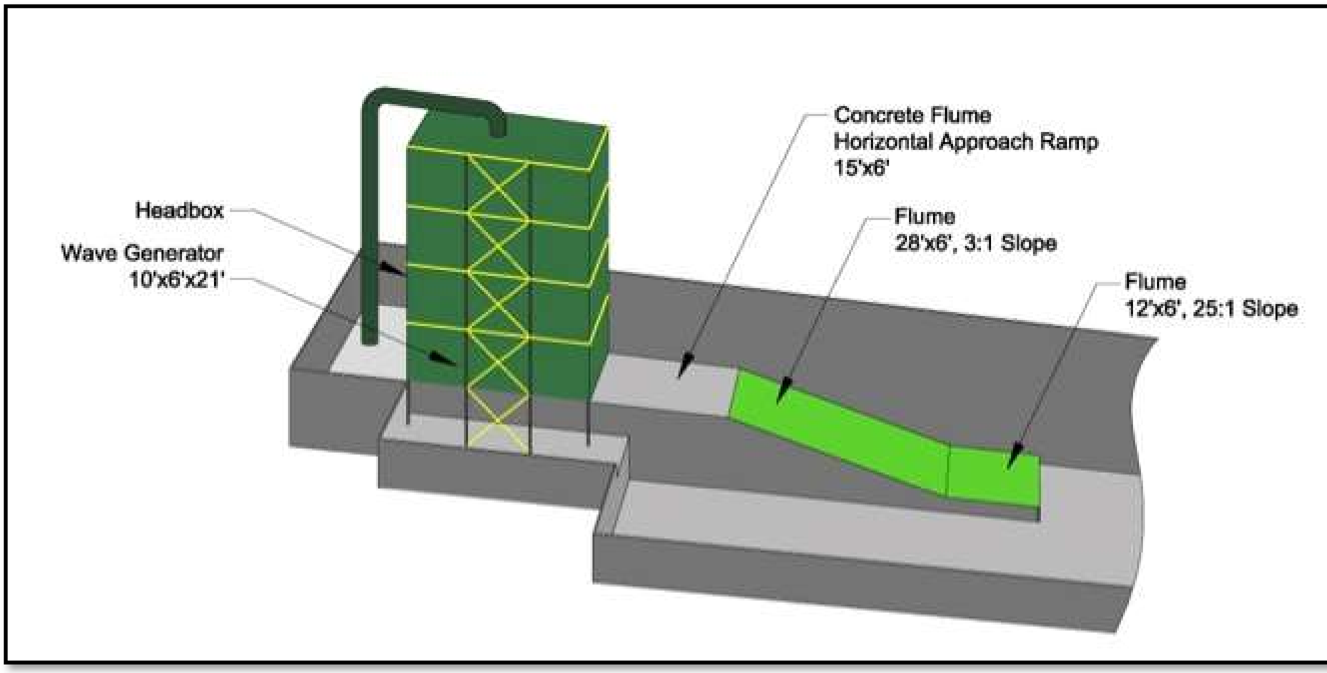

Figure 1. CSU Wave Overtopping Test Facility Diagram

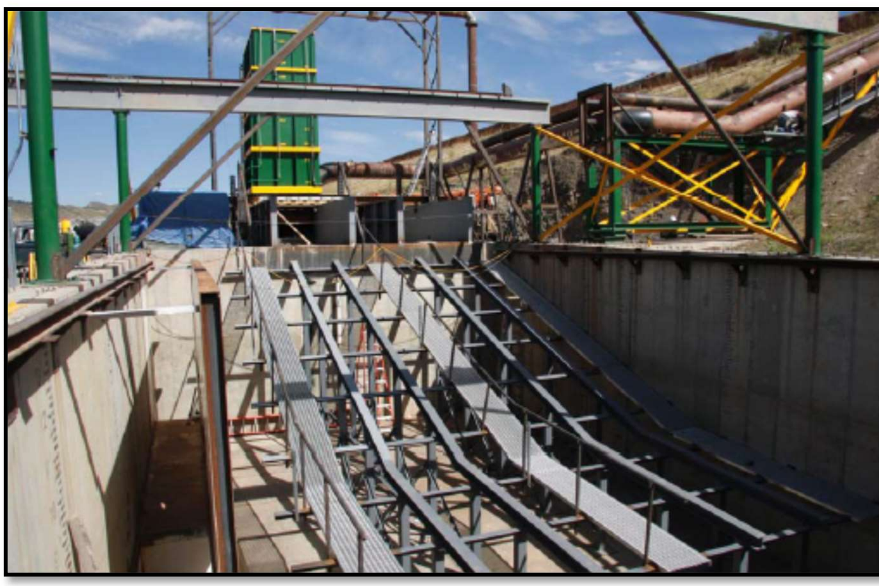

Figure 2. CSU Wave Overtopping Test Facility

HydroTurf® was installed on the compacted soil in the prepared trays. HydroTurf installation began with placing a continuous sheet of the structured geomembrane with the "spike" side down. The geomembrane serves as the underlayer of the system. The engineered synthetic turf was then placed on the geomembrane. A primary purpose of the testing was evaluation of the sewn seam strength between adjacent pieces of synthetic turf component. Two sections of the synthetic turf were sewn together using a machine similar to that used for field installations. The sewn piece was installed such that the seam direction was parallel to the slope (i.e. in the same direction as flow) along the centerline of the trays. Following turf installation, an approximately ¾ inch thick layer of dry HydroBinder® infill was brushed into the synthetic turf fibers. The dry mixture was placed using a drop spreader and broomed against the grain of the turf to pull the fibers up through the infill. The HydroBinder mix was then hydrated. Installation photos are presented in Figure 3.

Figure 3. HydroTurf® System Installation

Testing

Testing of the HydroTurf® Revetment System was conducted in four phases. The first phase tested the installed HydroTurf at the Wave Overtopping Simulator Facility limits. Upon completion of phase one, the previously tested HydroTurf installation was intentionally damaged before continued testing. Three types of intentional damage were inflicted simulating conditions that may occur after several years of service without maintenance. The Test Phases with intentional damage consisted of the following:

- Phase 2: Phase 2 was pulverization of the hardened HydroBinder® infill at the levee crest and toe simulating cracked infill and portions of the surface having been severely damaged. Intentional damage for Phase 2 is presented in Figure 4.

Figure 4. Intentional Damage by Pulverization of HydroBinder® Infill

- Phase 3: Phase 3 was bullet hole damage simulated by driving #4 rebar through the HydroTurf® system into the underlying subgrade. The resulting hole measured approximately 1 inch in diameter and penetrated the turf, infill and geomembrane. The hole is presented in Figure 5.

Figure 5. Intentional Damage Simulating a Bullet Hole through HydroTurf®

- Phase 4: In Phase 4, a pick axe was used to expand the simulated bullet hole creating a larger hole. The larger hole measured approximately 4 inches in diameter and 7-inches deep. The intentional pick axe damage is presented in Figure 6.

Figure 6. Intentional Damage Simulating a Large Hole through HydroTurf®

Test Conditions

The average wave overtopping rate (4 cfs/ft) and volume distribution represented a generic 500-year hurricane (0.2 percent annual exceedance probability) in New Orleans, LA. These wave volumes are the most energetic wave overtopping conditions that can be produced in any existing wave overtopping experimental facility. Testing continued for a total of 13 hours. The largest wave volumes simulated were approximately 1,000 cubic feet (165 ft^3/ft) and HydroTurf® was overtopped with over 993,000 ft^3 (165,600 ft^3/ft) of cumulative volume during the test program. Photos of testing in progress are presented in Figure 7.

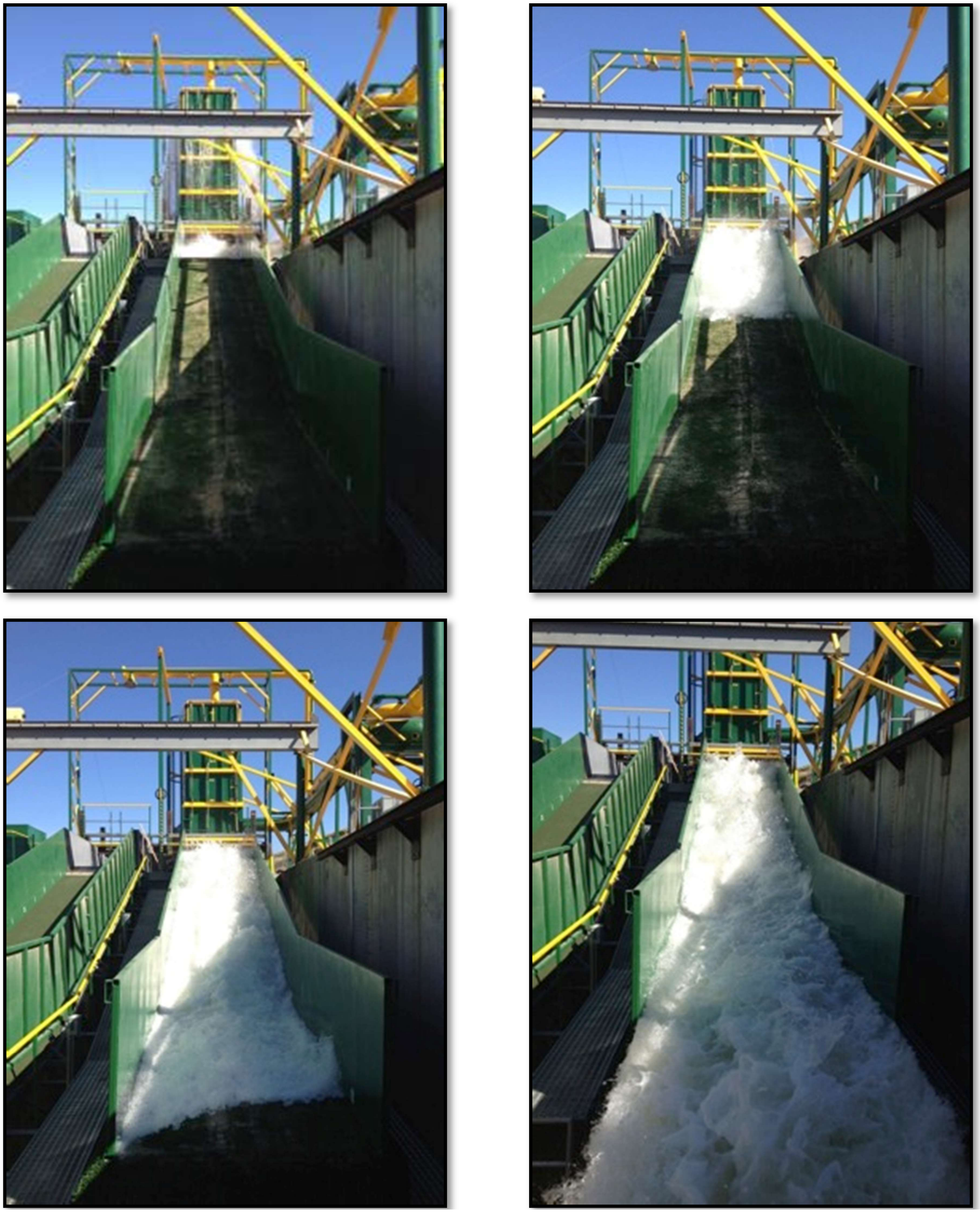

Figure 7. HydroTurf® Wave Overtopping Testing at CSU

Results

The HydroTurf® Revetment System withstood the largest wave overtopping flows that could be simulated by the CSU Wave Overtopping Simulator. Upon completion of testing, HydroTurf was removed and the underlying soil condition was documented. HydroTurf performed well in maintaining the underlying, highly-erodible soils under the extreme test conditions, even in an intentionally damaged state. Figure 8 presents the HydroTurf upon completion of testing. Figure 9 presents the highly-erodible, silty sand subgrade beneath the HydroTurf upon completion of testing.

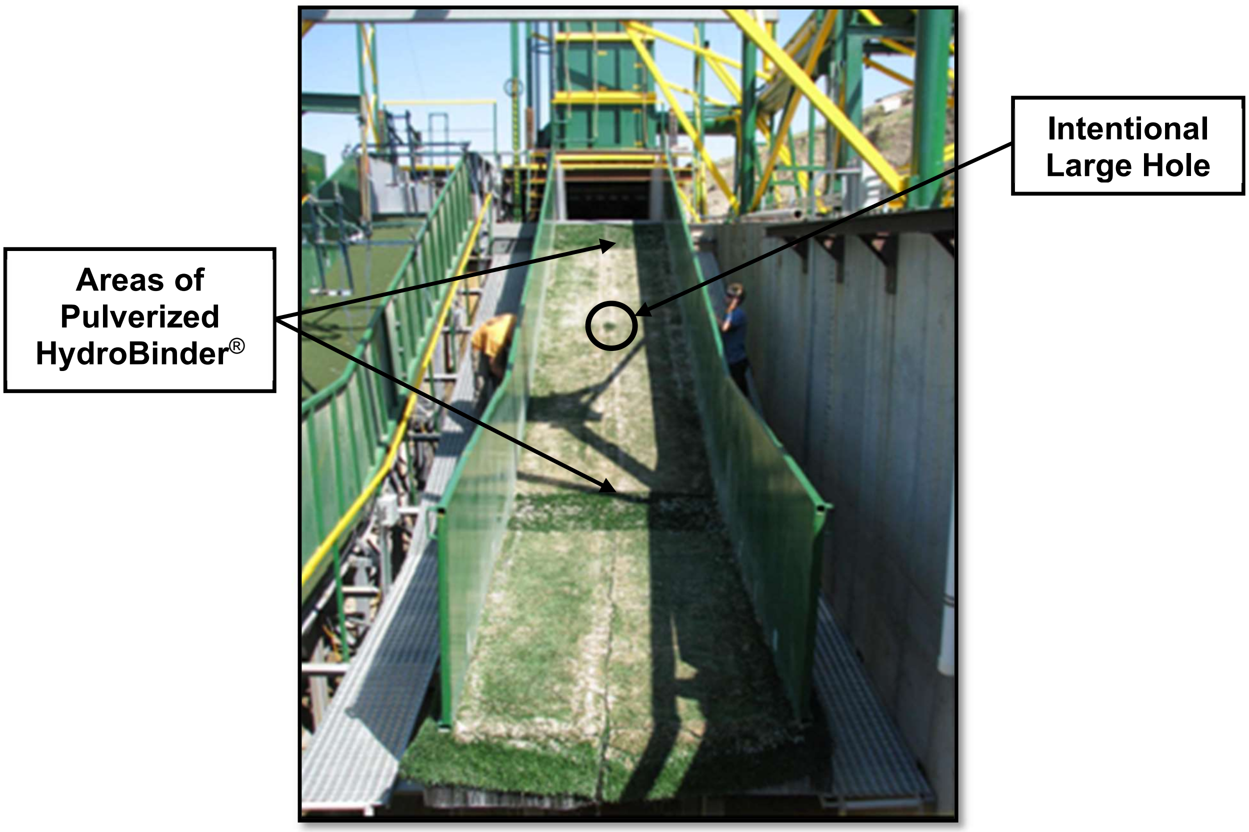

Figure 8. HydroTurf® System upon Completion of Wave Overtopping Testing

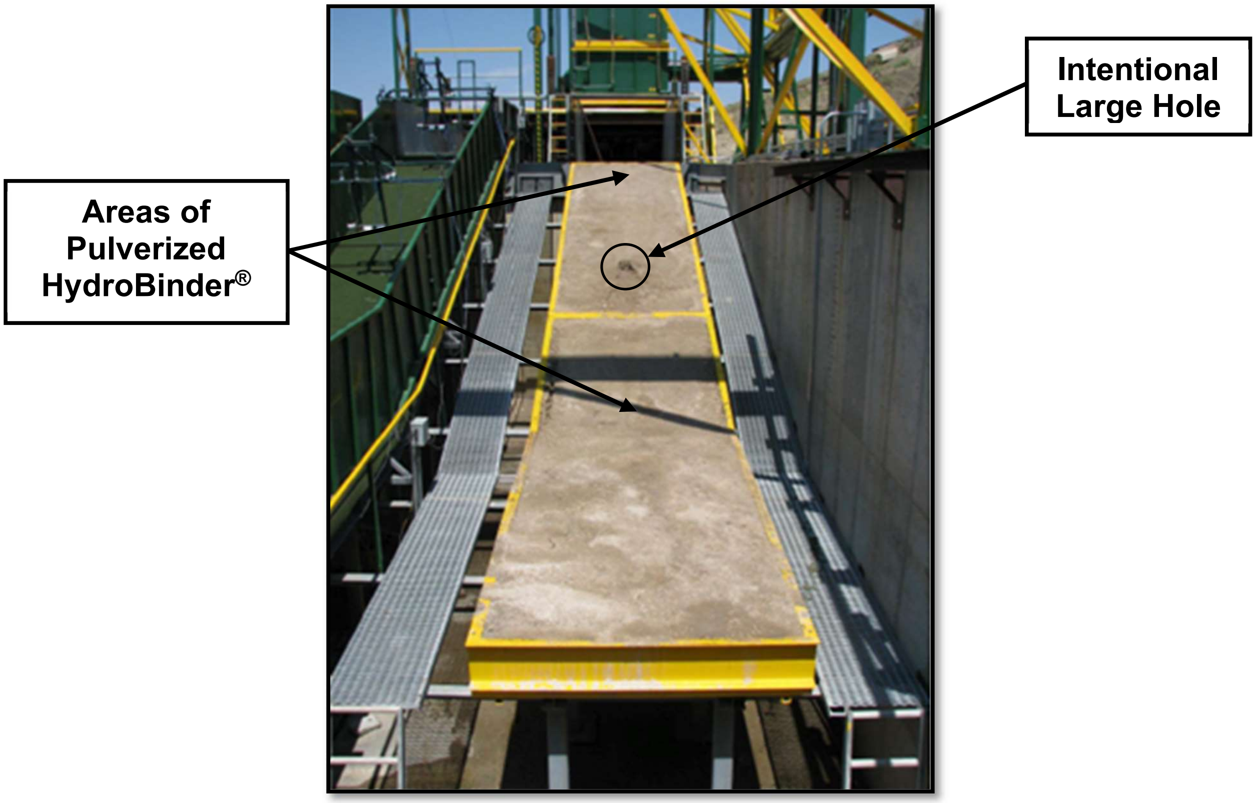

Figure 9. Highly Erodible Silty Sand Subgrade upon Completion of Wave Overtopping Testing

Results for each testing phase are as follows:

- **Phase 1: Intact HydroTurf®**: Simulated testing lasted 6 hours with no erosion. Wave overtopping conditions and highly erodible subgrade condition after Phase 1 are presented in Table 1.

- **Phase 2: Pulverized HydroBinder® Infill**. An additional five hours of testing with intentionally damaged HydroTurf infill resulted in no observed erosion of the silty sand beneath the damaged HydroTurf. Wave overtopping conditions and highly erodible subgrade condition after Phase 2 are presented in Table 1

- **Phase 3. Pulverized HydroBinder Infill and Simulated Bullet Hole**. An additional hour of testing at the maximum facility capacity with pulverized infill and a simulated bullet hole in the HydroTurf resulted in no observed erosion of the silty sand beneath the damaged HydroTurf. The intentional hole did not expand or result in localized erosion. Wave overtopping conditions and highly erodible subgrade condition after Phase 3 are presented in Table 1

- **Phase 4. Pulverized HydroBinder® Infill and Large Hole**. An additional hour of testing at the maximum facility capacity resulted in minimal erosion of the silty sand localized around and downstream of the large hole. No head-cutting was observed at the location of the hole. Wave overtopping conditions and highly erodible subgrade condition after Phase 4 are presented in Table 1.

Table 1. HydroTurf® Wave Overtopping Test Results

	Test Hour	Average Wave Overtopping Discharge (ft^3/sec/ft)	Number of Simulated Overtopping Waves	Silty Sand Subgrade Condition
Phase 1: Intact HydroTurf	1	2.0	195	no erosion
	2	3.0	214	no erosion
	3	4.0*	268	no erosion
	4	4.0*	268	no erosion
	5	4.0*	268	no erosion
	6	4.0*	268	no erosion
Phase 2: HydroBinder Infill	7	2.0	195	no erosion
	8	3.0	214	no erosion
	9	4.0*	268	no erosion
	10	4.0*	268	no erosion
	11	4.0*	268	no erosion
Phase 3: Pulverized HydroBinder Infill and Simulated Bullet Hole.	12	4.0*	268	no erosion
Phase 4: Pulverized HydroBinder Infill and Large Hole	13	4.0*	268	very localized erosion at intentional large puncture, no head cutting
Total	**13**	**n/a**	**3,230**	**no erosion****

*maximum facility capacity

**token (minimal) erosion was observed beneath the large hole intentionally punctured in the HydroTurf

- The field sewn seam connecting adjacent panels of engineered turf proved successful. There were no signs of stress or damage to the seam from the high stresses exerted during 13 hours of testing.

- Cumulative overtopping volume, time and product performance were used as product evaluation tools during the wave overtopping test program. Figure 10 presents the cumulative wave overtopping progression during the 13-hour test program.

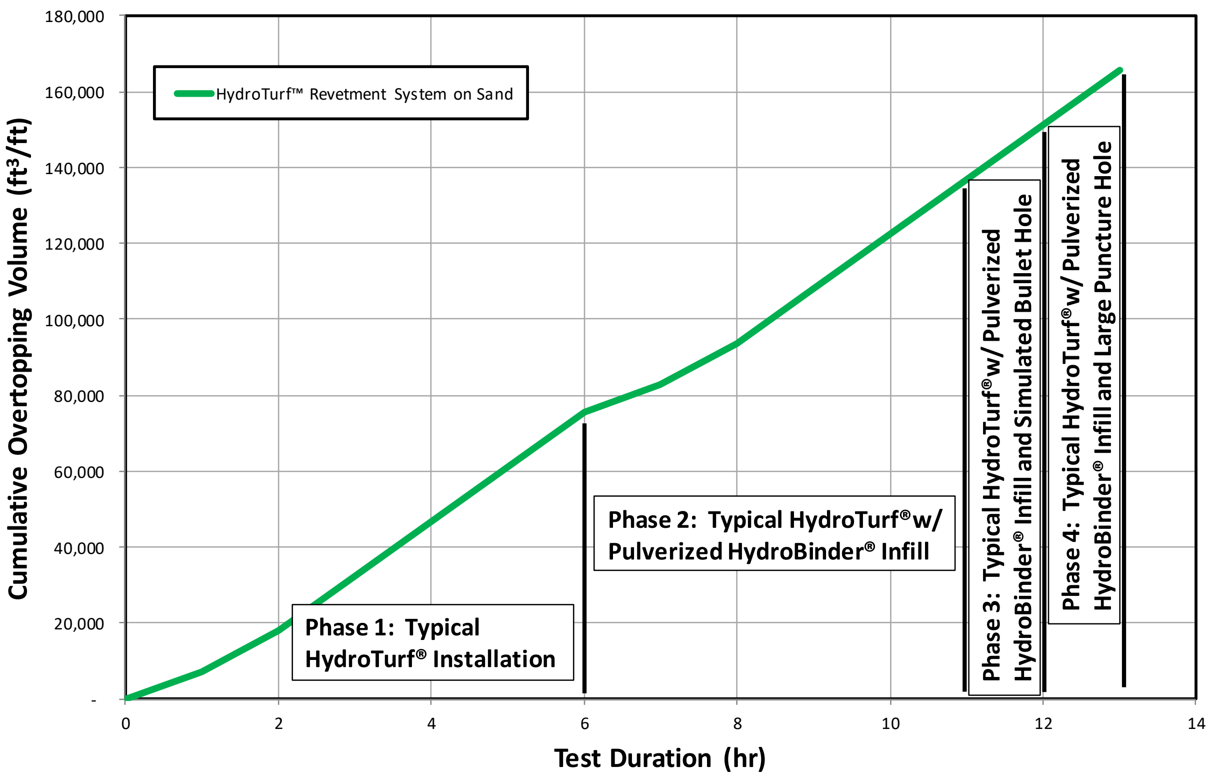

Figure 10. HydroTurf® Cumulative Wave Overtopping Volume Progression

Other erosion control products have also been tested in the CSU Wave Overtopping Simulator. Figure 11 presents a comparison of armoring performance for levee landward-side protection for various technologies tested in the CSU Wave Overtopping Simulator. HydroTurf® outperformed the other systems. In addition, HydroTurf outperformed other systems even though HydroTurf was tested on a more highly erodible subgrade than the clay used for testing other technologies.

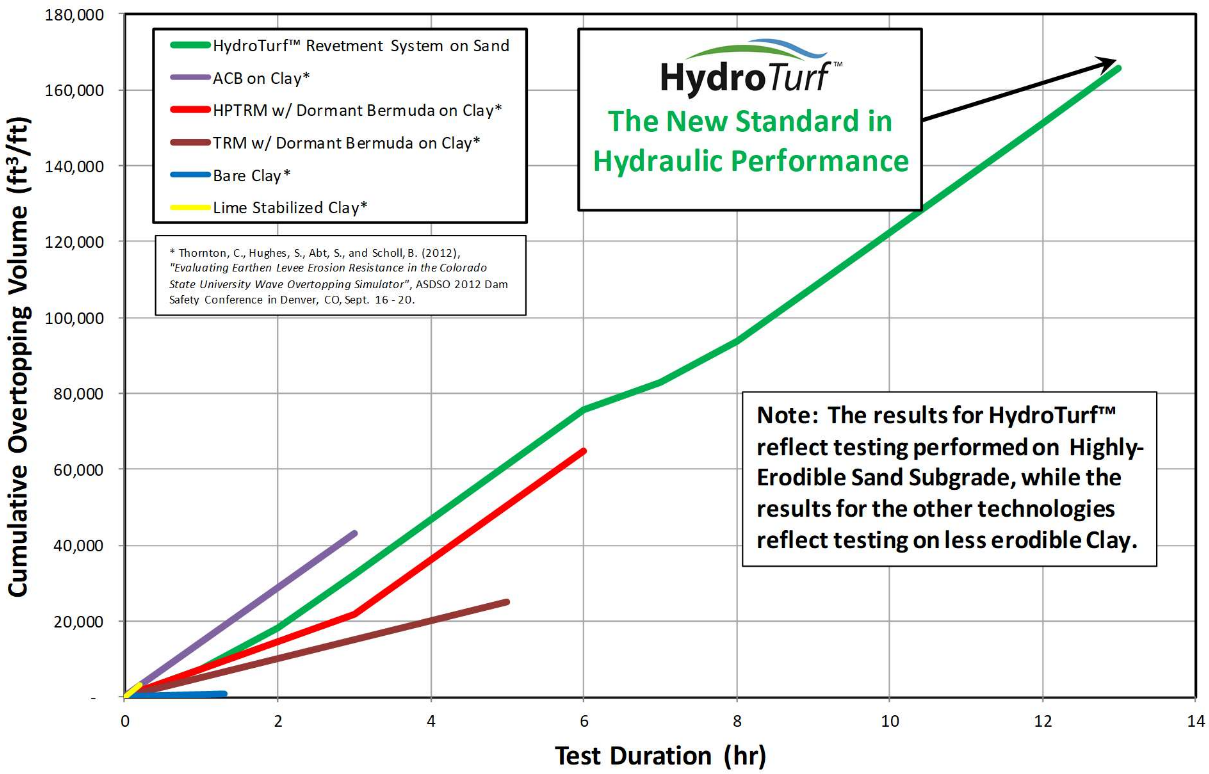

Figure 11. Armoring Performance for Levee Landward-Side Protection from Wave Overtopping

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.