Presented at StormCon 2015
Austin, TX, USA

PERFORMANCE EVALUATIONS OF EROSION AND SEDIMENT CONTROL BMPS USING INDEPENDENT FULL-SCALE SIMULATIONS

C. Joel Sprague, TRI/Environmental, Inc., Greenville, SC, USA,
James E. Sprague, TRI/Environmental's Denver Downs Research Facility, Anderson, SC, USA,

ABSTRACT

Sediment is the number one pollutant of US water resources even though erosion and sediment control best management practices (BMPs) are now commonly used. While a large amount of information on types of BMPs exists, quantitative information on performance effectiveness is difficult to find and not well documented. In order to help protect water quality from the effects of fugitive sediments, regulatory agencies and site designers are increasingly responsible for determining how well specific BMPs will perform, quantitatively, relative to alternatives.

To this end, the National Transportation Product Evaluation Program (NTPEP) was developed to provide quality and responsive engineering to the testing and evaluation of products, materials, and/or devices that are commonly used by the AASHTO Member Departments of Transportation. Among the critical objectives of the program is to improve the nation's transportation system by elevating the quality of available products and encouraging product innovation. NTPEP test reports assist engineers and site designers in approving products based on specification conformance and/or objective performance evaluations. NTPEP test reports contain data collected according to laboratory testing protocols selected through a consensus-based decision by AASHTO's NTPEP Committee.

There is keen interest in the selected testing protocols being standardized testing procedures, if available. Standardized test methods provide clear protocols so that future testing of BMPs can be easily compared to the results of existing BMPs. Thus, it is desirable that all BMP testing conform to existing ASTM procedures or be clear, easily implemented, modifications of the ASTM procedures.

This article describes the large-scale performance tests incorporated into NTPEP's program for erosion and sediment control products and reviews results of these tests on a range of erosion and sediment control BMPs. These large-scale tests were performed under the auspices of the National Transportation Product Evaluation Program (NTPEP) and the Georgia Soil and Water Conservation Commission (GSWCC).

Keywords: BMP, erosion control, sediment control, performance testing

INTRODUCTION

Sediment is the number one pollutant of US water resources even though erosion and sediment control best management practices (BMPs) are now commonly used. A large amount of information on BMP types exists, though the majority of this is currently with slope and channel rolled erosion control products (RECPs) and hydraulically applied erosion control products (HECPs). Less information is available for sediment retention devices (SRDs), but, as readers will see, new testing protocols are helping address this imbalance.

The responsibility for determining how well specific BMPs will perform, quantitatively, has increasingly fallen to regulatory agencies and site designers.

The National Transportation Product Evaluation Program (NTPEP) was developed to provide quality and responsive engineering to the testing and evaluation of products, materials, and devices that are commonly used by the AASHTO Member Departments of Transportation. One of the critical objectives of the program is to improve the nation's transportation system by elevating the quality of available products and encouraging product innovation. NTPEP test reports assist users in approving products based on specification conformance and/or objective performance evaluations. NTPEP test reports contain data collected according to laboratory testing protocols selected through a consensus-based decision by AASHTO's NTPEP Committee (NTPEP 2011).

Following is a summary of how NTPEP's system is structured and the current full-scale testing protocols offered, including the newer SRD protocols.

THE NTPEP APPROACH

NTPEP's testing protocol ensures independence by requiring the following:

- Product specimens are selected randomly
- State transportation agency personnel oversee specimen collection
- Samples are collected directly from manufacturing plants
- Multiple rolls/bales/units are selected from different lots or production dates and shipped to an independent laboratory
- Qualifying laboratories are annually audited by the independent Geosynthetic Accreditation Institute

NTPEP only tests products that have been voluntarily submitted by manufacturers. Manufacturers pay testing fees to reimburse AASHTO for conducting testing and reporting results. AASHTO member departments provide voluntary, yearly contributions to support the administrative functions of the program. AASHTO/NTPEP does not endorse any manufacturer's product, and there is no implied approval or disapproval in the results; rather, test data is furnished for the user's evaluation, such as for prequalification or approval with a transportation agency.

It's important to note that NTPEP is not intended as a tool for manufacturing R&D. Rather, submitted products should already be commercialized and have a record of being manufactured under standard operating procedures (SOPs) and rigorous quality control. Transportation agencies may request documentation of the SOPs and quality controls followed, and that documentation must be provided upon request.

NTPEP's large scale slope tests for hydraulically applied erosion control products (HECP) and rolled erosion control products (RECP), channel tests for RECPs and slope and channels tests for sediment retention devices (SRD) are design level tests that states can rely upon for consistent and unbiased results. In this way, agencies may use NTPEP information to determine a product's acceptability for their approved products list and for related projects.

NTPEPs LARGE-SCALE PERFORMANCE TESTS

Standardized, large-scale performance tests simulate expected field conditions. They provide a way to evaluate "as installed" BMP performance. Products are installed per the product manufacturer's published installation recommendations. The results of these tests are indicative of actual BMP field performance and are acceptable for use in performance specifications and, often, in design calculations.

Tests to evaluate products in both erosion control and sediment retention applications have been selected by NTPEP for product testing. The standards (or modified standards) selected by NTPEP for full-scale evaluations of BMPs currently include:

Erosion Control Product Performance:

- ASTM D 6459, "Standard Test Method for Determination of Rolled Erosion Control Product (RECP) Performance in Protecting Hillslopes from Rainfall-Induced Erosion"
- ASTM D 6460, "Standard Test Method for Determination of Rolled Erosion Control Product (RECP) Performance in Protecting Earthen Channels from Stormwater-Induced Erosion"

Sediment Retention Device Performance:

- ASTM D5141, "Standard Test Method for Determining Filtering Efficiency and Flow Rate of the Filtration Component of a Sediment Retention Device Using Site-Specific Soil"
- ASTM D7351, "Standard Test Method for Determination of Sediment Retention Device Effectiveness in Sheet Flow Applications"
- ASTM D7208, "Determination of Temporary Ditch Check Performance in Protecting Earthen Channels from Stormwater-Induced Erosion"
- TM11340, "Standard Test Method for Determination of Sediment Retention Device (SRDs) Performance in Reducing Sediment Loss from Rainfall-Induced Erosion during Perimeter Control Applications" (Georgia Soil and Water Conservation Commission)
- ASTM D7351 – Modified, "Standard Test Method for Determination of Sediment Retention Device Effectiveness in Inlet Protection Applications"

EROSION CONTROL PRODUCT TESTING

Conventional erosion control BMPs (e.g., crimped or tacked loose straw, rock riprap) continue to be used extensively, but the continual development and market use of alternative approaches—RECPs and HECPs— underscored the usefulness of large-scale testing for product/system comparison.

NTPEP began offering large-scale performance testing in 2009 of erosion control products to complement the commonly used index and bench-scale tests.

As noted, NTPEP selects test protocols that reasonably simulate expected field conditions in order to evaluate the "as installed" performance. These tests are standardized.

The slope erosion test (ASTM D6459), for example, is conducted on one bare soil control and three replicate RECP-protected soil 3:1 slopes. Rainfall is simulated at target intensities of 2, 4, and 6 inches per hour, which are applied in sequence for 20 minutes each. Runoff from each slope is collected and soil loss is measured. From this data, an appropriate C-factor can be calculated by comparing the RECP-protected soil loss to the soil loss of the bare soil control. Typical tests are shown in Figures 1 and 2.

For channel erosion (ASTM D6460), the test is conducted in a rectangular flume with at least four sequential increasing flows applied for 30 minutes each (unvegetated conditions) or 60 minutes each (vegetated conditions). Unvegetated RECP-protected channel testing is typically performed in a 10% slope flume. Vegetated RECP-protected channel tests are typically performed in a 20% slope flume. The limiting or permissible shear stress is defined as the shear stress necessary to cause an average of 0.5 inch of cumulative soil loss over the entire subject test area. Typical tests are shown in Figures 3 and 4.

Figure 1. Testing RECPs on a slope.

Figure 2. HECPs tested on a slope.

Figure 3. Triplicate testing of channels.

Figure 4. Vegetated turf reinforcement mats (TRMs) can be tested.

NTPEP LARGE-SCALE EROSION CONTROL PRODUCT TESTING TO-DATE

NTPEP now publishes large-scale performance testing information online at www.ntpep.org. The data is useful for better characterizing and differentiating between various RECP and HECP types. Figures 5 and 6 show the average results by product group of independent large-scale slope and channel testing, respectively, done under the NTPEP program. Both figures demonstrate quite convincingly that there is a hierarchy of performance among the commonly available product types.

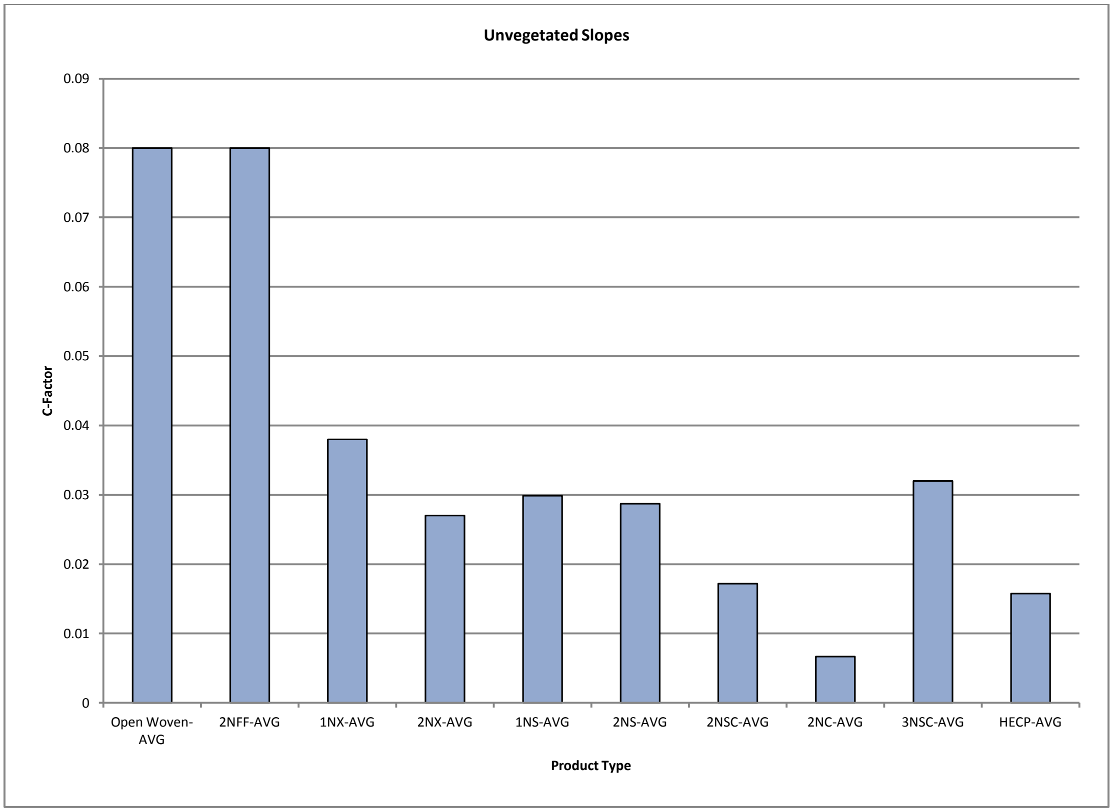

Figure 5. Large-scale Slope Performance Results

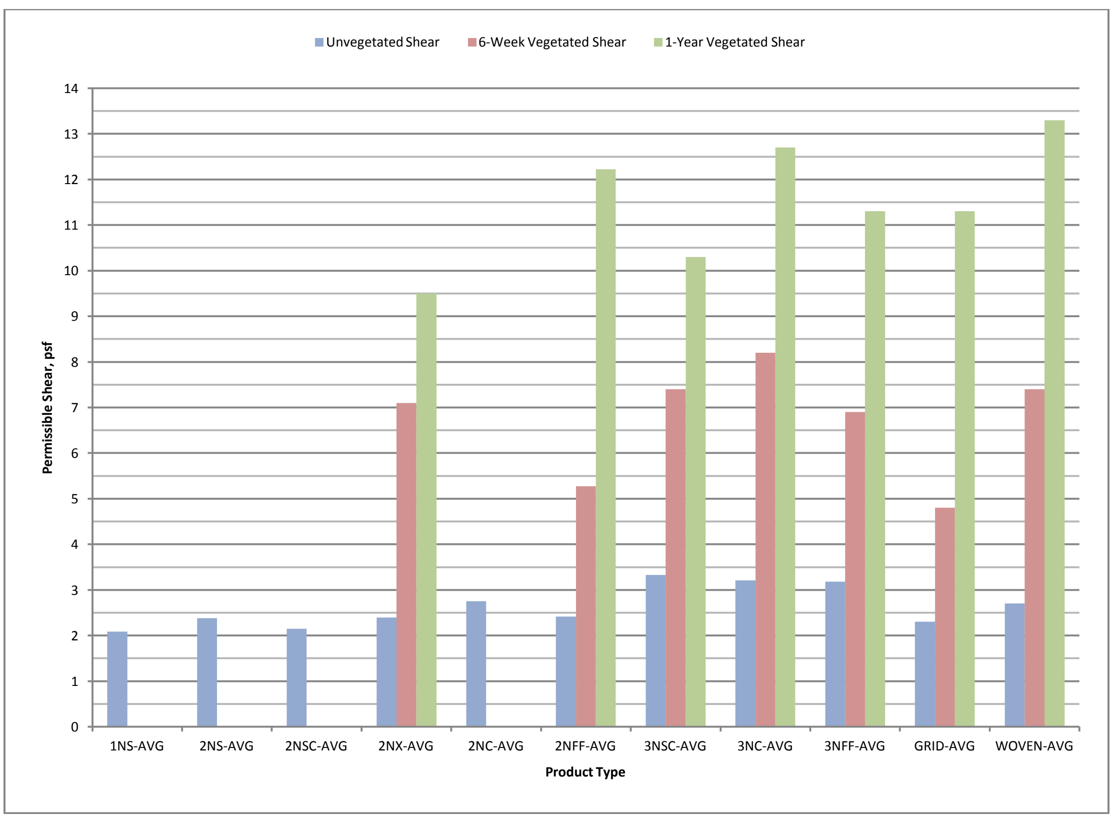

Figure 6. Large-scale Channel Performance Results

SEDIMENT RETENTION DEVICE TESTING

Sediment retention devices (SRDs) offer the potential to limit the migration of eroded sediments in runoff and, in so doing, to lessen the large area requirement and safety concerns of a sediment pond. The need for or value of SRDs has been recognized in the field, but, unfortunately, an independent quantitative means of testing performance has not been available.

In October 2014, NTPEP began offering independently verified large-scale performance testing of SRDs to complement the established large-scale RECP and HECP testing.

For SRDs, the initial large-scale tests include sheet flow, channel check, perimeter control, and inlet protection applications. As with the other large-scale tests, SRDs are installed per the manufacturer's published recommendations. The results of these tests are similarly considered indicative of actual field performance.

Testing is applicable to a wide range of sediment SRDs, including silt fence, wattles, filter logs, compost socks, compost and earth berms, and various types of stormwater inlet protectors.

SRD material components can be accurately evaluated for hydraulic properties using test method ASTM D5141, but the effectiveness of many SRDs is system or installation dependent. Therefore, large-scale tests that can incorporate the "as installed" system are also offered. The test apparatus is shown in Figure 7.

ASTM D7351 is a large-scale standard test method for SRD sheet flow evaluation. It quantifies both sediment removal and associated flow rate through an SRD, so the potential for either excessive sediment loss or the back-up of runoff can be assessed. A typical test setup is shown in Figure 8.

Figure 7. ASTM D5141 Test Setup

Figure 8. The setup for an ASTM D7351 full-scale test.

Sprague and Lacina (2010) provided a strong example of how the component test and the system test complement one another while yielding different results (hence, underscoring the importance of each test). The test method ASTM D5141, was able to identified the clogging potential of different fabric types, while the test method ASTM D7351 was able to fully characterize the "installed" silt fence performance. This testing supports the use of both tests in concert with each other for both routine product acceptance and large-scale system performance.

CHECK DAMS & PERIMETER CONTROLS

Check dams have been used to slow concentrated flows in channels to make them less erosive until the associated channel can vegetate sufficiently to resist soil loss during concentrated flow events. Critical elements of this protection are the ability of the temporary check structure to: (a) slow and/or pond runoff to encourage sedimentation, thereby reducing soil particle transport downstream, (b) trap soil particles upstream of a structure, and (c) decrease soil erosion.

ASTM D 7208 has established a full-scale test for evaluation of temporary ditch check performance. The procedure uses full-scale channel flow (up to 3 ft^3/s) in a trapezoidal channel with check structure(s) installed. Continuous flow is maintained for 30 minutes, or until catastrophic failure of the check structure is experienced. Soil erosion and sediment deposition is measured along the channel and compared to an eroded control bare soil control (no SRD installed) channel to quantify the effectiveness of the check structure. A typical prepared channel and a test setup are shown in Figures 9 and 10.

Figure 9. Test Channel Setup (typical control)

Figure 10. Testing of a Compost Sock Check Structure

Sprague, et al (2014a) reported on a testing program performed for the Georgia Soil and Water Conservation Commission (GSWCC). In the program, a range of check dams were tested in accordance with ASTM D 7208 with single replicates at flow levels of 0.5, 1.0, and 2.0 ft^3/s. Systems tested included compost socks, straw bales, 2–10 inch rock checks, and a wire-backed silt fence check. In general, as a check dam gets taller it must provide greater structural integrity and adjacent scour resistance. The original straw bale system and the silt fence system configuration tested both offered taller damming, but even at the lowest flow level they provide insufficient structural integrity and scour resistance to function effectively. Conversely, the compost sock, rock check, and the enhanced (NRCS) straw bale systems provided the necessary balance between damming and scour resistance to perform effectively under all flow levels.

As silt fences and wattles are also used often as “perimeter devices” around construction sites to intercept modest sheet flows, characterization testing associated with this application has been established in Test Method 11340. The test protocol uses three replicate test slopes measuring 27 ft long x 8 ft wide with the sediment barrier installed at the bottom of the slope. Simulated rainfall is produced by “rain trees” arranged around the perimeter of each test plot. The slope is then exposed to sequential 20-minute rainfalls having target intensities of 2, 4, 6 in/hr. All runoff is collected during the testing. The sediment retention provided by the installed sediment barrier is obtained by comparing the protected slope results to control (bare soil, no sediment barrier installed) results. Rainfall versus soil loss relationships are generated from the accumulated data and used to determine the P-Factor, or Practice

Management Factor, as used in the Revised Universal Soil Loss Equation (RUSLE) to account for the benefit of having sediment control practices in place to limit the loss of soil from a construction site. A typical prepared slope and a test setup are shown in Figures 11 and 12.

Figure 11. Test Slopes (Control Setup)

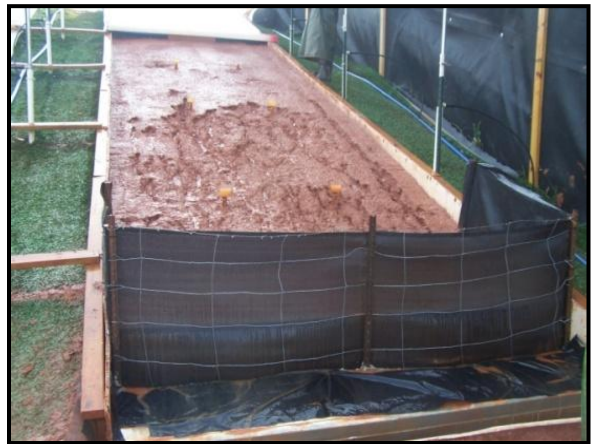

Figure 12. Type C End-of-Test

Sprague, et al (2014b) reported on a testing program performed for the Georgia Soil and Water Conservation Commission (GSWCC) using Method 11340. Systems tested included compost socks, straw bales, and a wide range of silt fence types and systems. The test results are presented as seepage versus P-Factor. The P-Factor is the sediment loss for the protected condition divided by the sediment loss from the control, or unprotected, condition. This is the reported performance value and is easily incorporated into soil loss calculations using the Universal Soil Loss Equation. As expected, a lower P-Factor is generally associated with the High Retention systems, while High Flow systems typically have higher seepage rates. Generally, the test results suggest that it is possible to specify high retention systems for applications that can accommodate the associated ponding and high flow systems where ponding would create a hazard or exceed the available area.

INLET PROTECTION

Another new addition to NTPEP’s full-scale testing protocols for product performance verification is one for inlet protection evaluation. The protocol is a modification of the ASTM D7351 protocol and setup. The modification is to discharge the initial sediment laden water as concentrated flow to a simulated inlet instead of as sheet flow to a toe-of-slope installation. The simulated inlet is comprised of an approximate 24 in x 24 in manhole opening positioned at the center of a containment area. The SRD is installed adjacent to, or inside, the opening. Sediment-laden water is piped and discharged into the fully contained area around the inlet opening and allowed to run up to and seep through, over, and/or under the SRD protecting the inlet. The amount of sediment-laden flow is measured both upstream and downstream of the SRD. The measurement of sediment and seepage that passes the SRD compared to the amount in the upstream flow is used to quantify the effectiveness of the SRD in retaining sediments while allowing continued seepage. A complete test on each installed SRD with each type of runoff includes 3 repeat flows, or events, separated by not less than 4 hours. The test procedure requires the same relatively large equipment as is used in ASTM D7351. The test apparatus and a typical test setup are shown in Figures 13 and 14.

Sprague, et al (2015) reported on a testing program performed for the Georgia Soil and Water Conservation Commission (GSWCC) using Method D7351-modified for inlet protection. The test results suggest that in both paved and unpaved applications, it is possible to differentiate between SRDs that provide maximum sediment retention and those providing maximum seepage. For unpaved applications, the silt fence on posts SRD provides maximum sediment retention while the gravel-based SRDs provide maximum seepage. For paved applications, it appears that the more determinant height of concrete block assures maximum ponding prior to eventual overtopping. Thus, the so-called "pigs-in-a-blanket" – geotextile wrapped blocks - would appear to be a more dependable choice than geotextile-wrapped stone for curb inlet protection based solely on retention and seepage effectiveness.

Figure 13. Modifying D7351 for inlet protection testing.

Figure 14. Close-up of a Typical Installation

NTPEP CONTINUES TO DEFINE PRODUCT PERFORMANCE

Just as the slope and channel evaluations initiated in 2009 are now producing a wealth of valuable information to the field, the 2014 NTPEP protocols for SRDs are opening a new chapter for testing and product evaluation.

The results of the standard (and proposed standard) testing procedures now implemented by the NTPEP are readily available to assist the users of erosion and sediment control BMPs in establishing improved construction specifications that will guide owners and contractors to install the correct BMP for the expected site conditions. Not only do these test methods enable product manufacturers to confidently establishing relevant product capabilities, they can be used outside of NTPEP to develop new, higher performing products.

REFERENCES & RECOMMENDED READING

ASTM D5141, "Standard Test Method for Determining Filtering Efficiency and Flow Rate of the Filtration Component of a Sediment Retention Device Using Site-Specific Soil". ASTM, Conshohocken, PA.

ASTM D 6459, "Standard Test Method for Determination of Rolled Erosion Control Product (RECP) Performance in Protecting Hillslopes from Rainfall-Induced Erosion". ASTM, Conshohocken, PA.

ASTM D 6460, "Standard Test Method for Determination of Rolled Erosion Control Product (RECP) Performance in Protecting Earthen Channels from Stormwater-Induced Erosion". ASTM, Conshohocken, PA.

ASTM D7208, "Standard Test Method for Determination of Temporary Ditch Check Performance in Protecting Earthen Channels from Stormwater-Induced Erosion". ASTM, Conshohocken, PA.

ASTM D7351, “Standard Test Method for Determination of Sediment Retention Device Effectiveness in Sheet Flow Applications”. ASTM, Conshohocken, PA.

NTPEP (2011), “ECP User Guide,” National Transportation Product Evaluation Program, AASHTO, www.ntpep.org.

Sprague, C.J. and Lacina, B. (2010), “Performance Testing of Sediment Retention Devices”, Proceedings of Environmental Connection 2010, International Erosion Control Association.

Sprague, C.J. and Sprague, J.E. (2013), "Testing and Specifying Rolled Erosion Control Products", Proc. of Geosynthetics 2013, IFAI, Long Beach, CA (digital proceedings).

Sprague, C.J., Ruzowicz, B., and Sprague, J.E. (2014a), “Evaluating Channel Check Dams”, Conf. XXXXV, International Erosion Control Assoc., Nashville, TN, (digital proceedings).

Sprague, C.J., Ruzowicz, B., and Sprague, J.E. (2014b), “Evaluating Sediment Barriers”, Conf. XXXXV, International Erosion Control Assoc., Nashville, TN, (digital proceedings).

Sprague, C.J., Ruzowicz, B., and Sprague, J.E. (2015), “Evaluating Inlet Protection”, Conf. XXXXV, International Erosion Control Assoc., Portland, OR, (digital proceedings).

Sprague, C.J. and Sprague, J.E. (2015), "Testing and Specifying Sediment Retention Devices", Proc. of Geosynthetics 2015, IFAI, Portland, OR (digital proceedings).

TM11340, “Standard Test Method for Determination of Sediment Retention Device (SRDs) Performance in Reducing Sediment Loss from Rainfall-Induced Erosion during Perimeter Control Applications” (GSWCC),http://gaswcc.georgia.gov/sites/gaswcc.georgia.gov/files/related_files/document/BMP_TESTING-FinalReport.pdf.