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Evaluation of ALDOT Ditch Check Practices using Large-Scale Testing Techniques

Large-scale Channel Testing (ASTM D 7208 – modified) of Evaluation of Sand Bag Ditch Checks over Poorly Graded Sand

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EXECUTIVE SUMMARY

Ditch checks are used to impound stormwater runoff in channelized flow areas on construction sites. The primary purpose of ditch checks is to control erosion in earthen runoff conveyances by decreasing velocity and therefore reducing or eliminating erosive shear stresses. This occurs by creating the longest impoundment area possible by causing supercritical flow to transform into subcritical flow, resulting in greater depths and decreased velocity. Creating large impoundments generates hydrostatic and hydrodynamic forces that can compromise the structural integrity of the ditch check. The standard ALDOT sand bag ditch check application relies on the weight of the sand bag to maintain the structural integrity of the ditch check through frictional resistance between bags, and between the bag and ground interface. When the impoundment forces overcome the frictional resistance created by sand bags, structural failure quickly occurs.

The structural integrity of the standard sand bag ditch check was maintained during the lowest test flow rate of 0.56 cfs. However, once flow was increased to 1.12 cfs, structural integrity was compromised and failure occurred. This failure occurred due to dislodgment of the sand bags located at the centerline of flow. To counteract this, the second installation that wraps the sand bags with an 8 oz. nonwoven filter fabric was also tested and showed increased structural stability. This installation was capable of impounding flow at the highest flow rate test of 1.12 cfs with one structural failure occurring once the test achieved a flow rate of 1.68 cfs. During the high flow rate portion of the test, the sand bags in the centerline of flow were dislodged similarly to the dislodgement of bags in the traditional installation. A third installation modification reoriented the sand bags within the middle layer of the installation. This resulted in increased structural stability, however, this installation failed during the highest flow of 1.68 cfs two out of the three test replications. Finally a fourth installation placed additional sand bags on the downstream side of the reoriented ditch check installation to reinforce the structural stability of the ditch check. This installation eliminated the structural deficiency of the ALDOT standard installation and was capable of impounding the highest test flow of 1.68 cfs.

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1 INTRODUCTION

Controlling erosion and sediment transport on construction sites has been deemed a top priority for environmental agencies such as the US Environmental Protection Agency (EPA) and the Alabama Department of Environmental Management (ADEM). Optimizing erosion and sediment control practices on construction sites has been the focus of this research study for the Alabama Department of Transportation (ALDOT). The use of ditch checks has been widely used on ALDOT construction sites and a need arose for determining the optimal practice and installation procedures for each ditch check.

Ditch checks are obstructions placed in paths of channelized flows that impound water. These water impoundments create subcritical, low velocity pools that reduce channel shear stress and channel erosion. As these pools increase, hydrostatic and hydrodynamic forces placed upon these structures also increase. Therefore, ditch check practices must be able to withstand these forces without loss of structural integrity in order to maximize performance.

2 BACKGROUND

Sand bag ditch checks are comprised of stacked rows of sand bags placed in channels to intercept flow and decrease runoff velocity. These ditch checks are not secured with stakes or staples, and therefore are ideal for hard bottom channels. Proper spacing of ditch checks within channels is critical to maximize their performance while minimizing the potential for channel erosion to occur. The spacing of ditch checks is to be no greater than the length of the ditch check's maximum pool length, which protects the greatest amount of channel as shown in Figure 1.

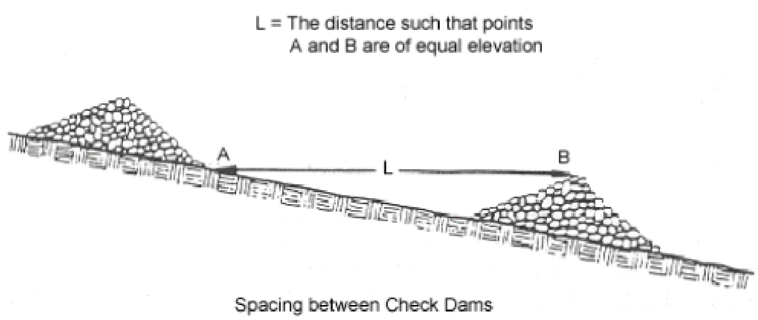


Figure 1: Alabama Handbook Recommended Ditch Check Spacing (*1*)

Sand bag ditch checks efficiently impound water at low flow rates due to very low flow through properties of the practice. However, due to the density and structure of the practice, traditional anchoring (i.e., the use of stakes, pins, or sod staples) to secure the practice in place is not practical. Therefore, sand bag ditch checks rely upon gravity and friction to remain in place. This can lead to structural failures when hydrostatic and hydrodynamic forces overcome the frictional force between bags causing bags to dislodge. Therefore, the focus of this testing was directed towards installation improvements for increasing structural stability instead of increasing impoundment lengths.

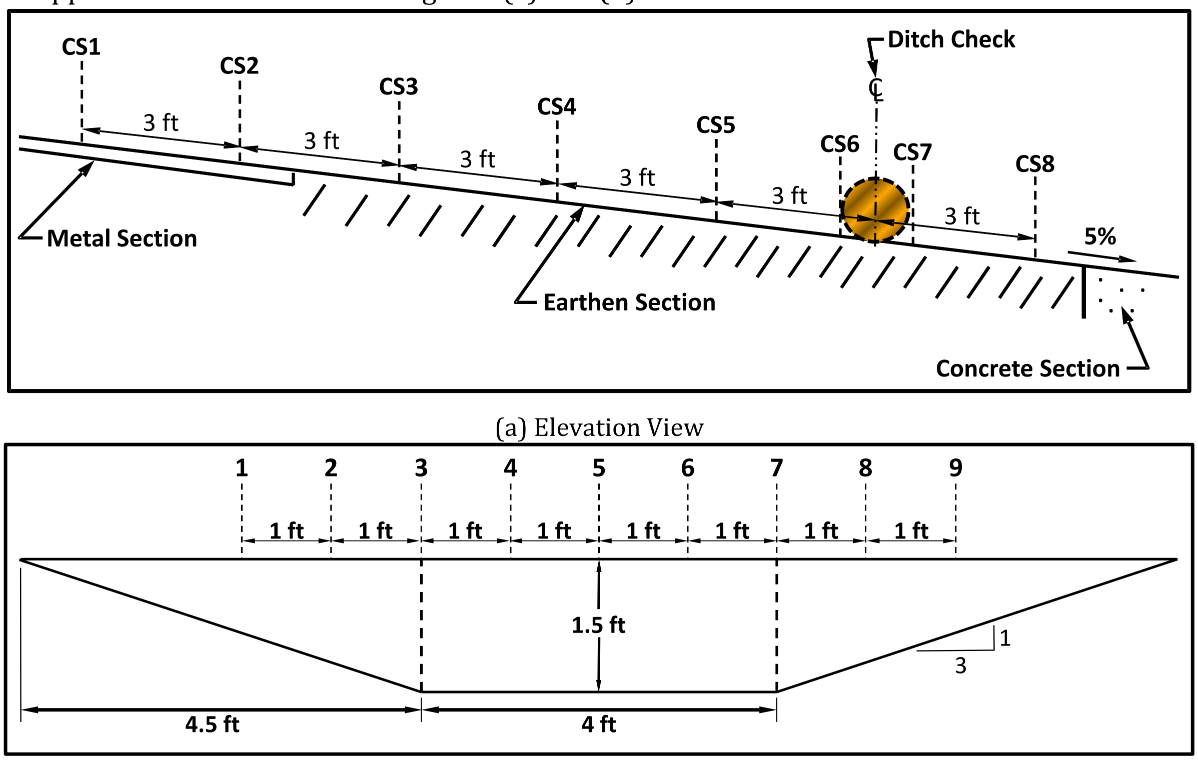
3 TESTING METHODOLOGY

All tests conducted as part of this research were performed at the Auburn University Erosion and Sediment Control Facility (AU-ESCTF) located at the National Center for Asphalt Technology (NCAT) in Opelika, AL.

The standard test method referenced for the development of the testing methodology used in this study was ASTM D 7208-06: *Standard Test Method for Determination of Temporary Ditch Check Performance in Protecting Earthen Channels from Stormwater-Induced Erosion* (*2*).

3.1 Test Channel

The AU-ESCTF has a test channel dedicated to performance testing of ditch checks in channelized flow applications and is shown in Figure 2(a) and (b).



(a) Elevation View

(b) Cross-Sectional View

Figure 2: Ditch Check Test Channel Dimensions and Configuration.

The ditch check testing channel has a trapezoidal cross-section with a top width of 13 ft (4 m) and a bottom width of 4 ft (1.2 m) with 3H:1V side slopes. The depth of the channel is 1.5 ft (0.5 m) and is 39.5 ft (12 m) long. The channel is divided into a galvanized steel plated section 24.5 ft (7.5 m) long and an earthen section 15 ft (4.6 m) long. The longitudinal slope of the channel is 5%. The earthen section allowed for field quality installations and performance observations of the ditch checks. The metal lined portioned allowed the ditch checks to be tested regardless of channel performance.

3.1.1 Preparation of the Test Channel

Before each test, the 15 ft (4.6 m) earthen section is tilled using a rear tine tiller, hand raked, hand tamped, and then mechanically compacted using an upright rammer hammer with a compaction plate of 14 x 11.5 in. (36 x 29 cm), a blow count of 600 blows/minute and a compaction force of 2,700 lbs (1,225 kg). The soil within the earthen section was classified as a poorly graded sand using the USCS Soil Classification System. The maximum density of 123.8 lbs/ft^3 (19.44 kN/m^3) was determined by the method described in ASTM D698-07, *Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort* (*3*). In-place density samples were taken with a density drive hammer and thin walled Shelby tubes to verify that at least 95% of standard Proctor density was achieved.

3.2 Test Flows

The test for sand bag ditch check installation evaluation for this study used tiered flow test regime of 0.56, 1.12, and 1.68 cfs (16, 32, and 48 L/s) of clean water for 10 minutes each for a duration of 30 minutes. Prior to testing, eight level string lines were stretched across the channel at 8 cross-sectional (CS) locations (Figure 2(a): CS-1 to CS-8), six upstream and two downstream of the ditch check. The measurement points were spaced 1 ft (0.3 m) apart along each string line. These string lines were used to determine erosion and deposition at each point, and water depth and velocity measurements at points 4, 5, and 6 shown in Figure 2(b) during each test.

3.3 Installation Evaluation Regime

A series of tier flow, large-scale ditch check experiments were performed to evaluate each installation configuration. These tests were performed to comparatively analyze the different sand bag ditch check installation configurations. For each installation configuration, replicate tests were performed to determine average performance. These installations were modified as needed once an installation modification was deemed inadequate to withstand the impoundment pressure placed on the ditch check structure. Many installation modifications were set up and evaluated to determine structural stability only. Once an installation appeared to be capable of withstanding the impoundment pressure, full installation tests with replications were performed to determine average performance. However, certain installation deficiencies were not apparent until replicate testing was performed, resulting in structural failures and required further installation modifications. From this, four installations were tested with replications totaling 12 full, large-scale tests.

3.3.1 Materials for Installations

The following is a list of materials used for the various sand bag installation configurations:

- *sand bags*: 19.5 x 12 x 4 in. (49.5 x 30.5 x 10 cm) woven polypropylene bags filled with a sandy soil, stacked in a three layer configuration, oriented dependent upon the particular installation.
- *sod staples and pins*: 11 gauge metal, 6 in. long x 1 in. (15 cm x 2.5 cm) wide U-shape staples or 11 gauge metal, 6 in. long x $1^3/_8$ in. (15 cm x 3.5 cm) round-top sod pin , used to secure the filter fabric, and
- *filter fabric (FF)*: 8 oz. (225 gram), nonwoven FF, 8 ft (2.4 m) long, 15 ft (4.6 m) wide. The edges of FF were secured with sod staples spaced 5 in. (12 cm) apart.

3.3.2 Sand Bag Ditch Check Installation Tests

The channel was prepared to experimental specifications for all tests performed on the three different sand bag ditch check installation configurations so direct comparisons could be made between each configuration. The following three sand bag installation configurations were tested:

(1) *Standard Sand Bag Installation*: current ALDOT installation [Figure 3(a)] that consists of two rows of sand bags placed perpendicular to flow, with a second layer of sand bags, also consisting of two rows, stacked on top. A third layer of sand bags is placed in the seam of the sand bag rows. No stakes, pins, or staples are used to secure the bags in place (*5*).

(2) *Sand Bag "Burrito"*: sand bags are placed on a section of filter fabric approximately 8 ft by 15 ft (2.4 m x 4.6 m) using the same configuration as the "standard sand bag installation." The bags are wrapped with the fabric, tucking the edge under the bags on the downstream side as shown in Figure 3(b),

(3) *Sand Bag Orientation Modification*: installation modifies the "standard sand bag installation" by reorienting the middle layer of bags 90° as shown in Figure 3(c). Both rows of the middle layer of sand bags are reoriented into one row by placing the bags across the bottom layer of bags parallel with the flow while the bottom and top layers are oriented perpendicular to flow. Due to the impoundment capabilities of the sand bags, which minimized undercutting, the filter

fabric underlay was removed from the installation to determine if it was necessary for this installation in an effort to minimize cost and installation time.

(4) *Sand Bag Orientation Modification w/ Support Bags*: installation modifies the “sand bag orientation modification” by adding support bags on the downstream side of the ditch check. Eighteen support bags are placed on the downstream side of the ditch check to reinforce the middle bags located along the 4 ft channel bottom as shown in Figure 3(d).

(a) ALDOT standard installation (b) Filter fabric “burrito” method

(c) Reorientation of middle sand bag layer (d) Addition of downstream support bags

Figure 3: Sand Bag Ditch Check Installation Configurations

3.4 Data Collected

Once steady-state flow conditions were achieved, water depth and velocity measurements were taken at cross-sectional measurements points, 4, 5, and 6 for cross sections CS1 – CS8 shown in Figure 2(a) and (b). Measurements at these points were averaged to determine the average water depth and average velocity for each cross section. The distance from the upstream face of the ditch check to the hydraulic jump was also recorded once a steady-state condition was achieved to determine subcritical flow length created by the installation’s ability to impound water.

Using the collected data, the slope of the energy grade line (EGL) for the water profile was plotted as specified by ASTM D 7208-06. The EGL is defined using equation 1 (*2*).

$$EGL = WSE + v^2/2g \quad \text{[EQ. 1]}$$

where,

EGL = energy grade line (ft)
WSE = water surface elevation (ft)
v = average water velocity (ft/sec)
g = gravitational constant (32.2 ft/sec^2)

The potential energy and resulting hydrostatic and hydrodynamic pressure built up by the subcritical flow must be supported by the installation before it is returned to kinetic energy as the impounded water goes under, through and/or over the ditch check. For sand bag ditch checks, the flow travels either through or over the ditch check.

4 RESULTS AND DISCUSSION

The following section is a summary of the results and comparisons that were made from the experiments using flows of 0.56, 1.12, and 1.68 cfs. Table 1 shows the comparative results of the impoundments resulting from the various sand bag installation configurations. The burrito method produced the longest impoundment, which would be expected since the filter fabric would restrict flow-through, forcing the impoundment to overtop. Table A.1, shown in the appendix summarizes the individual tests results of each test for the various installation types

Table 1: Comparative Results of Each Sand Bag Installation Configuration

Installation Type	Avg. Pool Length (ft)			Avg. % Efficiency(1)
	0.56 cfs	1.12 cfs	1.68 cfs	
Standard ALDOT	29.0	*failed*	*failed*	N/A
Burrito Method	32.7	33.2	33.5	109%
Orientation Modification	29.2	29.5	*failed*	98%
Support Bag Modification	29.0	29.5	30.8	99%

(1) Efficiency of impoundment was calculated against the spacing requirement (30 ft) for a 18 in. tall ditch check installed on a 5% slope

Since the sand bags restrict flow-through, maximizing the impoundment is not necessarily the main concern for optimizing the installation due to the sand bags ability to impound flow. However, as shown for the middle and highest flow tested for the "Standard ALDOT Sand Bag" installation, structural failure became a concern once flow was increased above 0.56 cfs. Structural stability of the bags is reliant upon gravitational and frictional forces to maintain the structural integrity of the ditch check. The result of structural failure for the "Standard ALDOT Sand Bag" installation is shown in Figure 4(a). ALDOT has used a modified installation to try to inhibit this structural failure by wrapping the sand bags in an 8 oz. (225 grams) nonwoven filter fabric as shown on an ALDOT project in Franklin County, AL in Figure 4(b). The sand bags were installed in the same manner as the ALDOT standard installation on top of a piece of filter fabric, and the extra fabric was wrapped over the sand bags and tucked under the bags on the downstream side. This method garnered some success in the field, and therefore warranted further investigation to compare to the original standard installation.

(a) standard installation configuration (b) sand bag burrito–Franklin Co, AL

Figure 4: Current ALDOT Sand Bag Practices.

This new installation was tested using the three tier flow regime. However, during the high flow condition of 1.68 cfs during the third replicate test, the sand bags dislodged at the center, within the filter fabric wrapping, causing partial dewatering of the impoundment, shown in Figure 5. A fourth replication was tested without failure occurring. Even though the addition of the filter fabric proved to increase the overall structural integrity of this installation when compared to the standard ALDOT installation, there was still concern about the stability of the sand bags.

(a) successful test (b) failure at 1.68 cfs

Figure 5: Sand Bag Burrito Ditch Check Test.

Failure of both the standard installation and the burrito installation occurred when the sand bags in the middle layer within the primary flow path on the downstream side of the ditch check were finally pushed off the back by the force of the flowing water. The frictional forces holding the sand bags in place were in the direction across the width of the sand bags due to the orientation of the sand bags with regards to the direction of flow.

Therefore, a third installation was developed by changing the orientation of the middle row of sand bags. This reorientation made the resistance of frictional forces across the length of the bags by placing the middle row of sand bags parallel to the flow rather than perpendicular. This reorientation would also keep the bags from rolling off the back of the installation. The first modification to the new installation configuration was created by reorienting the bottom and middle layer to be parallel to the direction of flow. The filter fabric underlay was removed from the installation (Fig. 6) to determine if it was necessary for this installation in an effort to minimize cost and installation time. This installation performed better than the standard ditch check installation, however in the third flow tier, the sand bags in the middle of the channel were pushed downstream and spread apart, eventually causing structural failure. From this, it was determined that having the bottom layer oriented perpendicular to flow would help deter the bags from being pushed down stream by the flow. Therefore the second modification to the installation configuration shown in Figure 6 used sand bags that were oriented perpendicular to the flow in the bottom layer and parallel to the flow in the second layer. The single row third layer of sand bags was also oriented perpendicular to flow to minimize the number of sand bags required while still increasing the overall height of the ditch check.

(a) top sand bag layer perpendicular to flow (b) test during third flow tier of 1.68 cfs

Figure 6: Second Iteration of the Modified ALDOT Sand Bag Installation.

The test shown in Figure 6 was successful in that the installation was structurally stable throughout the entire tier flow test. However, two subsequent replicate tests were unable to meet this performance stability and structural failure occurred for both tests during the highest flow tier phase. Though this would be an improved installation when compared to the standard ALDOT installation, however it did not perform as well as the sand bag burrito installation.

A final installation modification was performed to try to address this structural failure issue. Additional sand bags were placed on the downstream side of the ditch check to help reinforce the sand bags in the middle portion of the channel. This installation modification is shown in Figure 7.

(a) downstream reinforcement sand bags (b) 1.68 cfs flow tier

Figure 7: Modified ALDOT Sand Bag Installation.

This new modification reinforced the portion of the ditch check most susceptible to failure since the greatest amount of hydrostatic and hydrodynamic pressure force from flow is located in the middle portion of the channel. By adding this reinforcement and by reorienting the middle layer of the sand bags, the middle portion was stabilized, and the reinforcement bags actually act as a spillway and dissipate energy from the water flowing over the ditch check similar to the downstream side of the rip rap ditch check installation.

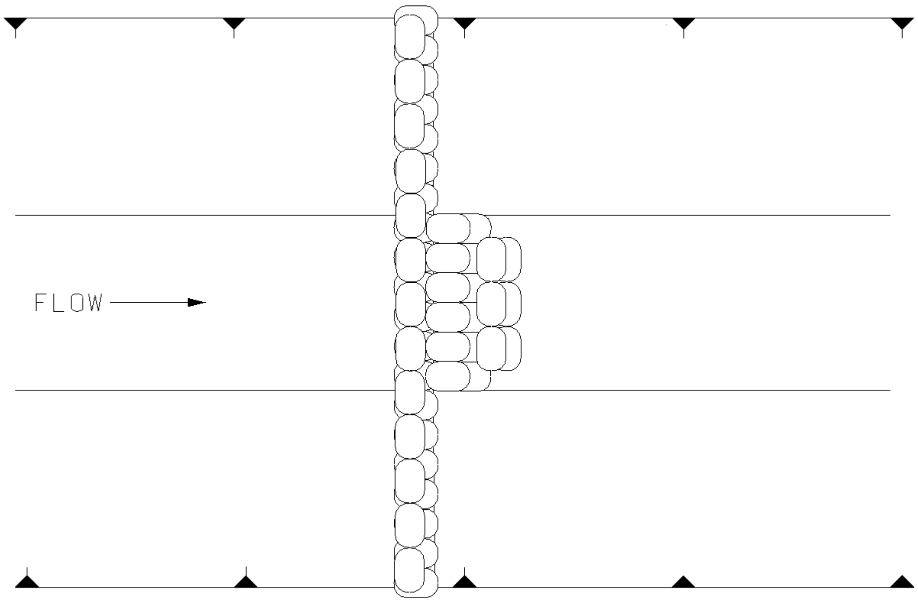
5 CONCLUSIONS

Sand bag ditch checks rely upon their weight and friction to hold the sand bags in place and resist dislodgment. Because of this, structural integrity was compromised for higher flow rates when all the sand bags were oriented perpendicular to the flow. Wrapping the ditch check in filter fabric provided extra stability, however the issue of sand bags being pushed off the downstream side from the middle layer was still an issue in one of the sand bag burrito installation replicate tests. Due to this, additional tests were performed on modified installations that reoriented bags in the middle layer parallel with the flow without using a filter fabric wrapping. This modification improved stability, but the center of the ditch check was unstable in high flow conditions of 1.68 cfs. Finally additional bags were added to the downstream side of the ditch check to reinforce the stability of the middle sand bags.

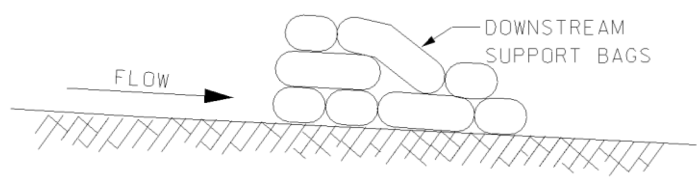
These installations were all capable of efficiently impounding water, as evident from Table 1. However, the sand bag burrito installation did outperform the installations that did not use a filter fabric wrapping from an impoundment standpoint. This is most likely due to the filter fabric reducing the flow-through rate of the installation as flow was unable to pass through the filter fabric and between the sand bags.

6 RECOMMENDATIONS FOR IMPLEMENTATION

As a result of this testing effort, the research team's recommendation is to incorporate the 'Sand Bag Orientation Modification w/Support Bags' installation into the ALDOT Standard Drawings. Based upon the results of the testing this installation resulted in a greatly improved installation structural stabilization. The reorientation of the bags increased the frictional resistance to dislodgment, while the support bags on the downstream side reinforced the middle section of sand bags most susceptible to dislodgement from the greatest amount of hydrostatic and hydrodynamic pressure. An optional variation to this installation could be to add a filter fabric choker similar to the rip rap ditch check installation, however this was not evaluated with the reorientation and support bag installation. The recommended installation variation is shown in Figure 8.



(a) plan view



(b) elevation view

Figure 8: Sand Bag Installation Modifications CADD Drawing.

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4. *Standard Specifications for Highway Construction*, Alabama Department of Transportation (ALDOT), Montgomery, AL, 2012, sec. 665, pp. 463 & 467.
5. *ESC-300 Ditch Check Structures, Typical Applications and Details*, Alabama Department of Transportation (ALDOT), Montgomery, AL, 2012, sheets 1 & 3 of 7.

8 APPENDIX A

Table A.1: Comparative Results of All Sand Bag Tests

Installation	Pool Length (ft)			% Efficiency			EGL Slope (ft/ft)		
Flow Rate (cfs)	**0.56**	**1.12**	**1.68**	**0.56**	**1.12**	**1.68**	**0.56**	**1.12**	**1.68**
Standard ALDOT	29.0	*fail*	*Fail*	97%	N/A	N/A	0.014	N/A	N/A
	29.0	*fail*	*Fail*	97%	N/A	N/A	0.015	N/A	N/A
	Did Not Perform the 3rd Replication Test Due to Previous Failures								
Burrito Method	32.0	33.0	33.5	106%	110%	112%	0.018	0.021	0.023
	33.0	33.2	33.5	110%	111%	112%	0.021	0.021	0.021
	33.0	33.3	*Fail*	110%	111%	N/A	0.021	0.021	N/A
	33.0	33.3	33.5	110%	111%	112%	0.020	0.020	0.020
Modified Orientation	29.1	29.4	*29.8*	97%	98%	99%	0.014	0.017	0.020
	29.2	29.7	*Fail*	97%	99%	N/A	0.016	0.019	N/A
	29.1	29.5	*Fail*	97%	98%	N/A	0.015	0.016	N/A
Modified w/ Support Bags	29.0	30.3	32.0	97%	101%	106%	0.014	0.016	0.014
	29.0	29.5	30.8	97%	98%	103%	0.013	0.013	0.012
	29.0	29.5	30.8	97%	98%	103%	0.015	0.016	0.013