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14. Supplementary Notes		13. Sponsoring Agency Name and Address North Dakota DOT Materials and Research Division 300 Airport Road Bismarck ND 58504-6005	
15. Abstract Purpose and Need Storm water flow from culverts and pavement in urban and rural settings can accelerate soil scour and erosion in turn impeding proper drainage which then may require maintenance to restore. Rip-rap and TRM "turf reinforcement mat" is currently used as a permanent scour and erosion protection, but rip-rap revetment may erode away and disintegrate over time requiring periodic maintenance. Rip-rap also may pose a safety hazard to children in residential settings and can collect debris and weeds producing an aesthetically unappealing structure. Flow Transition Mats are designed to replace rip-rap revetment as a permanent maintenance free scour and erosion protection system at culverts, pipes, and pavement drainage areas. Mats allow vegetation to become established and protect flow paths from erosion. Objective The objective of this experimental project is to evaluate the performance of ScourStop® Flow Transition Mats as a permanent method for energy dissipation to prevent scour downstream from culverts, pipes, or pavement. Scope NDDOT plans to incorporate ScourStop® Flow Transition Mats as part of project SU-2-987(029)033. This project is located near Jamestown Business Loop East respectively. Summary The four installations of ScourStop® were successfully installed according to the plans and manufacturer's recommendation and are performing as designed with some sod distress. The top soil adjacent to the installations was eroded away during the flood of 2011 prior to installation. This resulted in a low success rate of the permanent seeding around the ScourStop® installations. The picture in photo 18 captures the state of the permanent seeding in August of 2012. The sod appears to be growing with the exception of the two installations at STA 47+90 and STA 53+00. The sod at these two locations is showing signs of distress; due to high amounts of precipitation pooling over the installation. The sod condition has not impacted the performance of these two installations ability to protect against scour.			
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**NORTH DAKOTA
DEPARTMENT OF TRANSPORTATION**

**MATERIALS AND RESEARCH
DIVISION**

Experimental Study ND 2010-03

**Evaluation of ScourStop® Flow Transition Mats
For Scour Protection**

Final Report

SU-2-987(029)033

February 2020

Prepared by

**NORTH DAKOTA DEPARTMENT OF TRANSPORTATION
BISMARCK, NORTH DAKOTA
www.dot.nd.gov**

**DIRECTOR
William Panos**

**MATERIALS AND RESEARCH DIVISION
Matt Linneman, P.E.**

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Disclaimer

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EXPERIMENTAL PROJECT REPORT

EXPERIMENTAL PROJECT	EXPERIMENTAL PROJECT NO.					CONSTRUCTION PROJ NO		LOCATION			
	1	STATE ND	Y EAR 2010	NUMBER -	SURF 03	SU-2-987(029)033		I-94 Jamestown business loop			
						8		28			
	EVALUATION FUNDING					NEEP NO.	PROPRIETARY FEATURE?				
	48	1	HP&R	3	X	DEMONSTRATION		X Yes			
	2	CONSTRUCTION	4		IMPLEMENTATION	49	51	No			
SHORT TITLE	TITLE 52 Evaluation of ScourStop® Flow Transition Mats for Scour Protection										
THIS FORM	DATE	MO.	YR.	REPORTING							
	140	January	--	2020	1	INITIAL	2	ANNUAL	3	X FINAL	
KEY WORDS	KEY WORD 1				KEY WORD 2						
	145 ScourStop				167 Flow Transition Mats						
	KEY WORD 3				KEY WORD 4						
	189 Scour				211						
	UNIQUE WORD				PROPRIETARY FEATURE NAME						
	233				255 ScourStop						
CHRONOLOGY	Date Work Plan Approved		Date Feature Constructed:		Evaluation Scheduled Until:		Evaluation Extended Until:		Date Evaluation Terminated:		
	277 August 2010		281 June 2012		285 September 2018		289		293		
QUANTITY AND COST	QUANTITY OF UNITS (ROUNDED TO WHOLE NUMBERS)			UNITS				UNIT COST (Dollars, Cents)			
	297			1 LIN. FT 2 X SY 3 SY-IN 4 CY 5 TON 6 LBS 7 EACH 8 LUMP SUM				\$160/SY			
AVAILABLE EVALUATION REPORTS	CONSTRUCTION			PERFORMANCE				FINAL			
	315 X			X							
EVALUATION	CONSTRUCTION PROBLEMS					PERFORMANCE					
	318	1	X	NONE		1		EXCELLENT			
		2		SLIGHT		2		GOOD			
		3		MODERATE		3	X	SATISFACTORY			
		4		SIGNIFICANT		4		MARGINAL			
		5		SEVERE		5		UNSATISFACTORY			
APPLICATION	1 ADOPTED AS PRIMARY STD.				4 X PENDING				<i>(Explain in remarks if 3, 4, 5, or 6 is checked)</i>		
	2 PERMITTED ALTERNATIVE				5 REJECTED						
320	3 ADOPTED CONDITIONALLY				6 NOT CONSTRUCTED						
REMARKS	321 The four installations of ScourStop® were successfully installed according to the plans and manufacturer's recommendation. The top soil adjacent to the installations was eroded away during the flood of 2011 prior to installation. This resulted in a low success rate of the permanent seeding around the ScourStop® installations. The picture in photo 6 captures the state of the permanent seeding in August of 2012. The four installations are performing satisfactory and are pictured in photo 23 as of July 2015.										

TABLE OF CONTENTS

Purpose and Need	1
Objective	1
Location	2
Design	3
Evaluation	3
Construction	4
1st Evaluation	7
2nd Evaluation	14
Summary	17

Evaluation of ScourStop® Flow Transition Mats For Scour Protection

Purpose and Need

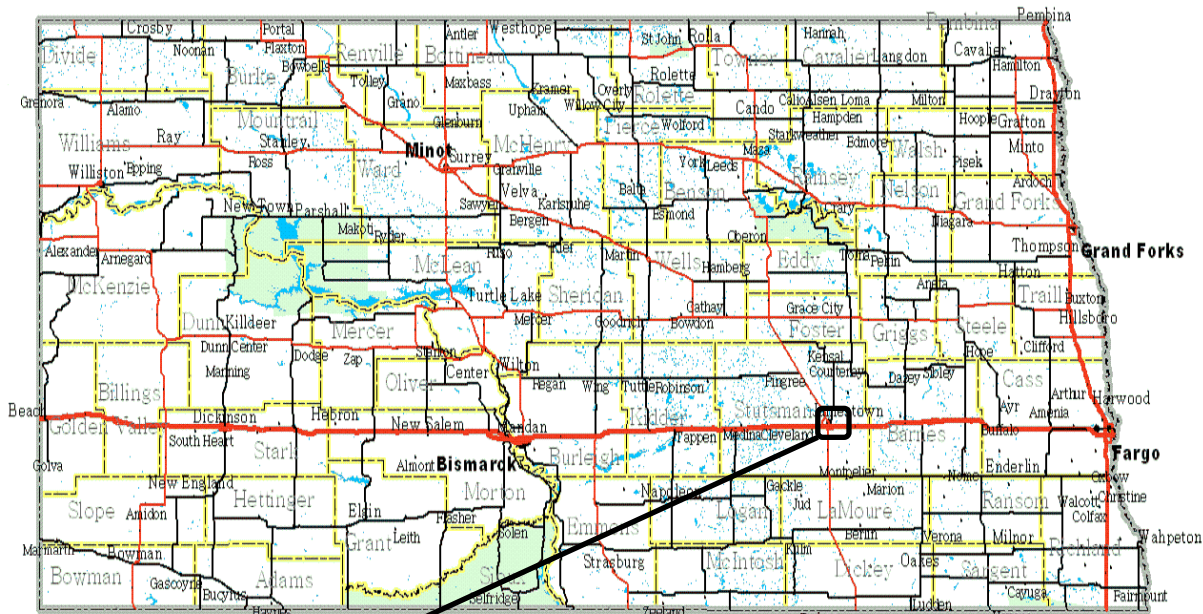
Storm water flow from culverts and pavement in urban and rural settings can accelerate soil scour and erosion impeding proper drainage which may require maintenance to restore. Rip-rap and TRM “turf reinforcement mat” is currently used as a permanent scour and erosion protection, but rip-rap revetment may erode away and disintegrate over time requiring periodic maintenance. Rip-rap also may pose a safety hazard to children in residential settings and can collect debris and weeds producing an aesthetically unappealing structure. Flow Transition Mats are designed to replace rip-rap revetment as a permanent maintenance free scour and erosion protection system at culverts, pipes, and pavement drainage areas. Mats allow vegetation to become established and protect flow paths from erosion.

Objective

The objective of this experimental project is to evaluate the performance of ScourStop® Flow Transition Mats as a permanent method for energy dissipation to prevent scour downstream from culverts, pipes, or pavement.

Location

NDDOT plans to incorporate ScourStop® Flow Transition Mats as part of project SU-2-987(029)033. This project is located near Jamestown Business Loop East respectively.



SU-2-987(029)033
Begin Project

SU-2-987(029)033
End Project

Proposed ScourStop®
Location (south ditch)

Design

NDDOT plans to incorporate ScourStop® Flow Transition Mats on I-94 near Jamestown as part of project SU-2-987(029)033 designed by Ulteig Engineers, Inc. ScourStop® Flow Transition Mats shall be installed according to plan and abiding all manufacturers' recommendations. The plan note used to incorporate ScourStop® is included below.

709-P01 EROSION CONTROL TRANSITION MAT: The contractor shall install Erosion Control Transition Mat at the storm drain outlets indicated in the plan. The Erosion Control Transition Mat shall be ScourStop®.

Installation shall be in accordance with the following:

1. The Erosion Control Transition Mat shall butt directly against the flared end section.
2. The Erosion Control Transition Mat shall not be installed on bare soil. The Erosion Control Transition Mat shall be placed on sod. The cost of sod shall be included in the price bid for "Erosion Control Transition Mat."
3. Use flexible strapping with deadman anchor, flat washers (>2.5 inches) and one way stops to attach the Erosion Control Transition Mats to the soil a minimum of 24 inches. Firmly pull straps to snug the Erosion Control Transition Mat down against the soil with the washer and one-way stop.
4. Discharge area width shall be as level as possible to avoid water concentration and riling. Mats may be installed in partial lengths; downstream mats may be shingled to minimize anchors.

SU-2-987(029)033

This project consists of the reconstruction of the Jamestown Business Loop East from 12th Street SE to Country Club Drive. The roadway will have four installation of ScourStop®. For exact installations locations see Appendix A. The project will also have a control site with conventional rip rap; for exact installations locations see Appendix A.

Evaluation

The project will be evaluated during construction and then followed up with an annual evaluation for the next six years. The project will be evaluated on the following criteria:

- Visual Inspection
- Durability Issues
- Photos
- Maintenance cost

Materials and Research will publish a construction report followed by biennial reports documenting the criteria listed above and a final report summary.

Construction

Project SU-2-987(029)033 was a reconstruction administered by Ulteig Engineering. ScourStop® was installed June 12 and June 13 of 2012 by Pro Landscapers LLC. A small crew of landscapers was able to perform the four ScourStop® installations over two days. Installation sites required minimal grade preparation as pictured below.



Photo 1: Crew performing grade prep prior to install.

Once the grade was ready for installations the area was covered with sod.



Photo 2: Site with sod placed.

Once the sod had been placed the matrix of 4'x4' ScourStop® Panels was laid out; some panels were cut to achieve the desired dimension in the plans. No panels were overlapped as the contractor advised against overlapping panels.



Photo 3: Crew placing the ScourStop® panels.

ScourStop® Bullet anchors were then inserted 18" deep into the soil with rebar and secured with locking washers; pictured below in photo 4. The depth of anchoring was inspected with a tape measure to insure proper embedment. The crew pounded the first few anchors in with a sledge hammer; this process was time consuming and an air hammer was brought over to speed up the process. It should also be noted that once the rebar was used to pound the anchors it often became stuck due to the confining pressure of the in place embankment. The process was slowed by the time required to remove the stuck rebar. A post puller could have been useful in speeding up anchor installation. The crew at the time did not have a post puller and used a skid steer bucket to remove stuck rebar.



Photo 4: ScourStop® bullet anchor.

The anchoring pattern recommended by the manufacturer was used. Each 4'x4' panel was secured with eight anchors. It should be noted to reduce the number of anchors panels can be overlapped in the direction of flow. The contractor opted to not overlap panels due to their past experience. The contractor felt the ScourStop® panels perform better when placed flush. Pictured in photo 5 is a completed installation of ScourStop®.



Photo 5: Completed ScourStop® installation.

1st Evaluation-2013

The four Scourstop® installations installed 6/12/2012 on the I-94 Jamestown Business loop in the Valley City District were inspected on October 15, 2013. All four installations have successfully provided scour protection and remain in service. Installations at STA 47+90 and STA 53+00 have exhibited signs of severe sod distress. This distress is likely a result of excess pooled runoff unable to drain due to ditch grades. This pooling from excessive moisture is captured in the photos from M&R last visual inspection. Photos of the four installations initial and current condition can be found on pages eight thru eleven of this report.

The control section experienced an increase in scour ranging from 2” to 4” of depth throughout the immediate outfall of the culvert. This increase in scour is likely a result from excess precipitation in 2013 scouring the unprotected outfall; which had been exposed by the flooding of 2011. Photos of the initial control installation and from M&R 2013 visual inspection can be found on pages twelve thru thirteen.



Photo 6: Installation at - Sta. 47+90 Rt. (09/25/2012)



Photo 7: Installation at - Sta. 47+90 Rt. 1st Evaluation (10/15/2013)



Photo 8: Installation at - Sta. 48+25 Rt. (9/25/2012)



Photo 9: Installation at - Sta. 48+25 Rt. 1st Evaluation (10/15/2013)



Photo 10: Installation at – Sta. 50+36 Rt. (9/25/2012)



Photo 11: Installation at – Sta. 50+36 Rt. 1st Evaluation (10/15/2013)



Photo 12: Installation at - Sta. 53+00 Rt. (9/25/2012)



Photo 13: Installation at – Sta. 53+00 Rt. 1st Evaluation (10/15/2013)



Photo 14-15: Control Installation Sta. 24+36 Rt. to Sta. 24+57 Rt. (2012/06/12)





Photo 16-17: 1st Evaluation Control Installation Sta. 24+36 Rt. to Sta. 24+57 Rt. (10/15/2013)



2nd Evaluation-2015

The four Scourstop® installations installed 6/12/2012 on the I-94 Jamestown Business loop in the Valley City District were last inspected on July 9, 2015. All four installations continue to provide scour protection and remain in service. Installations at STA 47+90 & STA 53+00 had exhibited signs of severe sod distress, but have started to recover. This sod recovery is likely a result of optimum growing conditions over the summers of 2014 and 2015 with an absence of pooled water. The pooling from excessive moisture captured in the photos from M&R 1st evaluation caused a minor amount of settlement of the soils at the STA 47+90 Rt. & STA 53+00 installations resulting in a few loose anchors illustrated in photo 24 and photo 25. Photos of the four installations from the 2nd evaluation can be found on pages 14 thru 16 of this report.

The control section experienced little to no increase in scour. Photos of the control installation from M&R last visual inspection can be found on page 16.



Photo 18: 2nd Evaluation Installation at - Sta. 47+90 Rt. (07/9/2015).



Photo 19: 2nd Evaluation Installation at - Sta. 48+25 Rt. (07/9/2015).



Photo 20: 2nd Evaluation Installation at - Sta. 50+36 Rt. (07/9/2015).



Photo 21: 2nd Evaluation Installation at – Sta. 53+00 Rt. (07/9/2015)



Photo 22: 2nd Evaluation Control Installation Sta. 24+36 Rt. to Sta. 24+57 Rt. (7/9/15)

Final Evaluation

The four Scourstop® installations installed 6/12/2012 on the I-94 Jamestown Business loop in the Valley City District were last inspected on August 9, 2017. All four installations continue to provide scour protection and remain in service. All of the installations have been covered by upstream erosion and are barely visible upon inspection. This is likely a result of poor seeding success upstream in conjunction with spring runoff from a heavy snowpack during the 2016-2017 winter resulting in an excess of deposited material. The installations at Sta. 48+25 Rt., Sta. 50+36 Rt. and Sta. 53+00 Rt. have accumulated an excess of vegetation in the deposited material and are holding water. Photos of the four installations from the 2nd evaluation can be found on pages 17 thru 19 of this report.

The control section experienced little to no increase in scour. Photos of the control installation from M&R last visual inspection can be found on page 19.



Photo 23: Final Evaluation Installation at - Sta. 47+90 Rt. (08/9/2017).



Photo 24: Final Evaluation Installation at - Sta. 48+25 Rt. (08/9/2017).



Photo 25: Final Evaluation Installation at - Sta. 50+36 Rt. (08/9/2017).



Photo 26: Final Evaluation Installation at – Sta. 53+00 Rt. (08/9/2017)



Photo 27: Final Evaluation Control Installation Sta. 24+36 Rt. to Sta. 24+57 Rt. (8/9/17)

Summary

The four installations of ScourStop® were successfully installed according to the plans and manufacturer's recommendation, and have performed as designed despite experiencing sod distress in the past. The top soil adjacent to the installations was eroded away during the flood of 2011 prior to installation. This resulted in a low success rate of the permanent seeding around the ScourStop® installations. The picture in photo 23 captures the state of the permanent seeding as of July 2015. The sod appears to be growing with the exception of the two installations at STA 47+90 Rt. & STA 53+00 illustrated in photo 24 and 25. The sod at these locations had exhibited signs of severe distress during the first evaluation, but is now starting to recover. These two installations also settled a minor amount during the second evaluation resulting in a few loose anchors; both distresses are likely due to high amounts of precipitation pooling over the installation over the past years.



Photo 28: ScourStop® installations (July 9, 2015.)

As a result of the poor seeding success and pooling water resulted in an excess of material being deposited over the scour stop installations. Vegetation has grown in this deposited material and is causing water to hold in the culvert.



Photo 29: ScourStop® STA 47+90 Rt. Installation (July 9, 2015.)



Photo 30: ScourStop® STA 53+00 Rt. Installation (July 9, 2015.)



Photo 31: ScourStop® STA 47+90 Rt. Installation (August 9, 2017).



Photo 32: ScourStop® Sta. 50+36 Rt. Installation (August 9, 2017).

Recommendation

It is recommended that the NDDOT continue using the proprietary ScourStop® on a project-by-project basis. ScourStop® transition mats offer a biotechnical replacement for rock rip-rap that provides permanent protection against scour and erosion at drainage outlets. The four installations have had no durability issues and no additional maintenance cost and have successfully prevented scour over the five year evaluation period.

It is recommended that urban projects where ScourStop® could provide an aesthetically appealing scour revetment option. ScourStop® could also provide an option for culverts that require riprap repair every spring after the heavy snow pack melts displacing the riprap. The ScourStop® system is easily installed with minimal man power and little to no heavy machinery and could be done by district maintenance staff.

It is also recommended that sod should be placed if the ScourStop® is to be placed on a grade that is not vegetated. Culvert outflow intensity should be factored as ScourStop® is an engineered solution. The use of a turf reinforcement mat in conjunction with the ScourStop® may be required if heavy outflows are anticipated. ScourStop® installations should be designed using the manufacturer's recommendations. These concerns should be addressed in the Special Provisions for future ScourStop® projects.