

Attachment I-9: Diversion Channel Analysis – Phase 2



Fargo-Moorhead Metro Feasibility Study

Minnesota Diversion Modeling Results

Computed By: KAH
Date: 4-Sep-08

Revised By: KAH
Date: 28-Dec-09

Diversion Channel

- Analyzed using GeoStudio (SEEP/W & SLOPE/W)
- Cross Sections revised based on Moore's revision on 7/20/09
- 500 ft Bottom Width Analyzed
- Stratigraphy Based on Boring Logs taken by USACE

Elevations

- Ground Surface and Bottom of Channel Elevations Based on Moore Engineering Report, revision 7/20/09
 - * The 3 different capacities (45k, 35k, and 25k CFS) all have same bottom channel elevation, but the channel has different widths.

Spoil Area

- Spoil Embankment Top Width Varies with Depth & Width of Diversion Channel
- Spoil Embankment Height of 10' 10
- Landside Slope 1':10' (Vert/Horz) 0.10
- Diversion Channel Slope 1':7' (Vert/Horz) 0.14

Seepage Analysis

- Only one half of the diversion channel was modeled (1/2 space)
- Model extended to 1750' (~1/3 mile) beyond toe of ditch slope
- Total Head boundary conditions used at the extent of model.
 - * Total Head equals ground water elevation observed during drilling
 - * Total Head in sand formation equals observed piezometric level (or if not observed, ground surface elevation)

Diversion Channel Stability

- Slope Stability computed using Spencer's Method with the Optimization function
- Two Factors of Safety's were analyzed for slope stability using entry/exit slip surface
 - * Global Failure is indicated by slip surface initiating above 3/4 of the slope
 - * Localized Failure is indicated by slip surfaces initiating in below 3/4 of the slope and 5' above bottom of channel
- Undrained global failure is indicated by a slip surface initiating above 1/2 of the slope
- Factor of Safety against uplift/heave was calculated for Sections containing a sand seam. Both short and long term Factor of Safety's were computed.

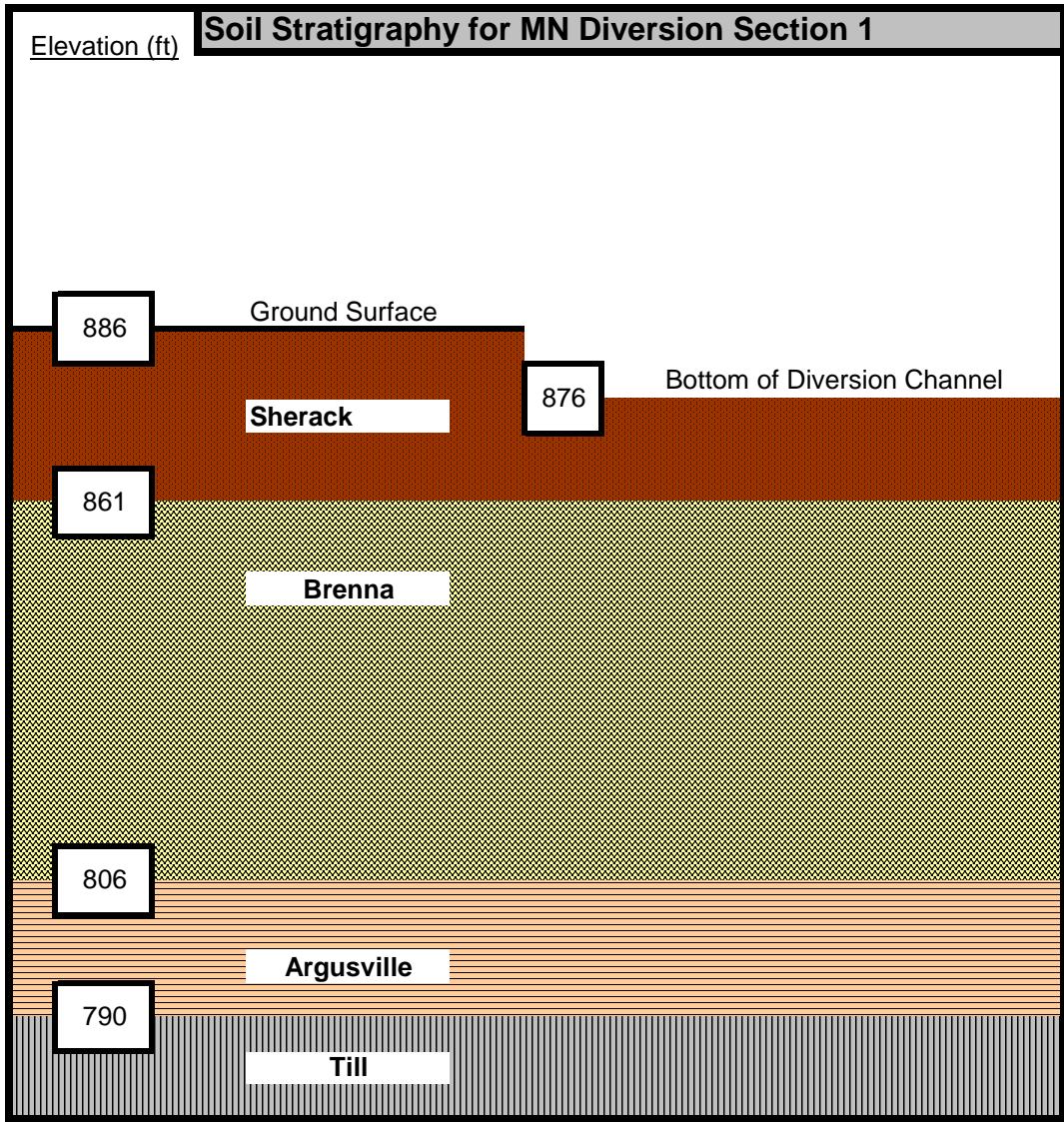
MN Diversion Channel Model Results

Cross-Section	Channel Bottom Width [ft]	Ground Surface Elevation [ft]	Water Table Depth [ft]	Channel Elevation [ft]	Elevation of Sand Formation [ft]	Channel Depth [ft]	Total Seepage into Channel		Y-Gradient	Total Head in Sand at Bottom of Channel [ft]	Piping	Factor of Safety												
							[ft ³ /sec]	[gal/day/LF]				Uplift/Heave		Long Term / Drained Slope Stability						Short Term / Undrained Slope Stability		Extents for Failure Surface		
												Short Term	Long Term	Global - Circular Opt	Global - Circular	Global Wedge Opt	Global Wedge	Localized Circular Opt	Localized Circular	Global Circular Opt	Global Circular	Global	Local	Undrained
1	500	886	881.5	876		10	9.8473E-09	0.013	0.012		55.56			1.722	1.746			1.887		1.935	1.967	891	881	886
2	500	911	906.1	882	848	29	3.4786E-06	4.497	0.51	894.676	1.30	1.21	1.79	0.886	0.928			0.386	0.408	1.607	1.693	911	892	902
3	500	913	906.9	886		27	4.5601E-08	0.059	0.09		7.36			1.201	1.206	1.204	1.321	1.083	1.098	1.325	1.350	914	895	905
4	500	910	906.6	892	864	18	1.6371E-06	2.116	0.10	893.061	6.80	1.61	17.59	2.689	2.705			2.484	2.536	2.874	3.142	913	899	906

$\gamma_{sat} = 104$

* Note: No Uplift/Heave was calculated for sections 1 and 3 due to the fact that there was no sand seam or permeable layer.

Cross-Section	Channel Bottom Width [ft]	Ground Surface Elevation [ft]	Water Table Depth [ft]	Channel Elevation [ft]	Elevation of Sand Formation [ft]	Channel Depth [ft]	Total Seepage into Channel		Y-Gradient	Total Head in Sand at Bottom of Channel [ft]	Piping	Factor of Safety												
							[ft ³ /sec]	[gal/day/LF]				Uplift/Heave		Long Term / Drained Slope Stability						Short Term / Undrained Slope Stability		Extents for Failure Surface		
												Short Term	Long Term	Global - Circular Opt	Global - Circular	Global Wedge Opt	Global Wedge	Localized Circular Opt	Localized Circular	Global Circular Opt	Global Circular	Global	Local	Undrained
2	500	911	906.1	882	848	29	3.7446E-06	4.840	0.44	893.501	1.52	1.25	1.97	1.390	1.577			1.041	1.138	2.189	2.662	911	892	902
3	500	913	906.9	886		27	4.4353E-08	0.057	0.08		8.70			1.370	1.463	1.434	1.581	1.452	1.503	1.467	1.511	914	895	905

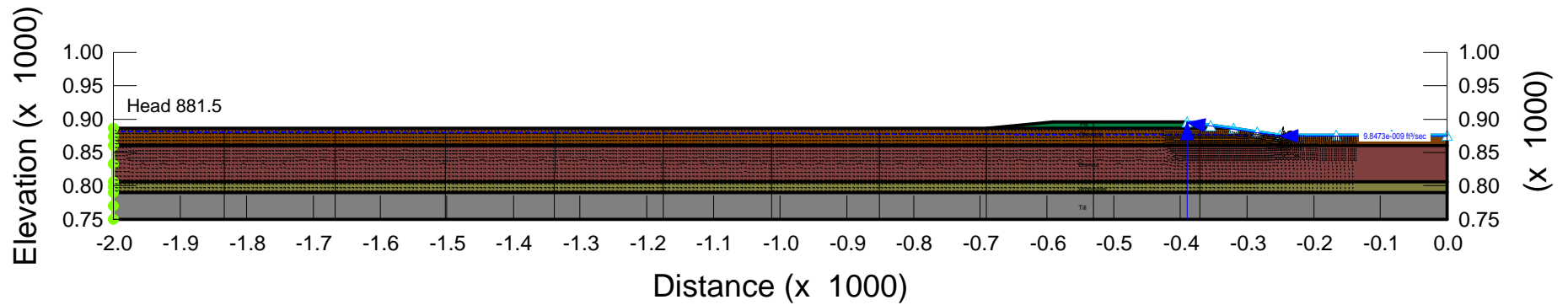


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Fargo-Moorhead Metro Feasibility Study Diversion Channel Stability (500') Cross-Section 1 Seepage Analysis

Soil Properties

Name: Fill Model: Saturated / Unsat K-Function: Sherack Vol. W/C. Function: Sherack K-Ratio: 1 K-Direction: 0*	Name: Brenna Model: Saturated Only K-Sat: 3.25e-008 ft/sec Volumetric Water Content: 0.615 H ₂ O Mr: 0 psf K-Ratio: 1 K-Direction: 0*	Name: Till Model: Saturated Only K-Sat: 2.65e-009 ft/sec Volumetric Water Content: 0.3 H ₂ O Mr: 0 psf K-Ratio: 1 K-Direction: 0*
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Soil Properties

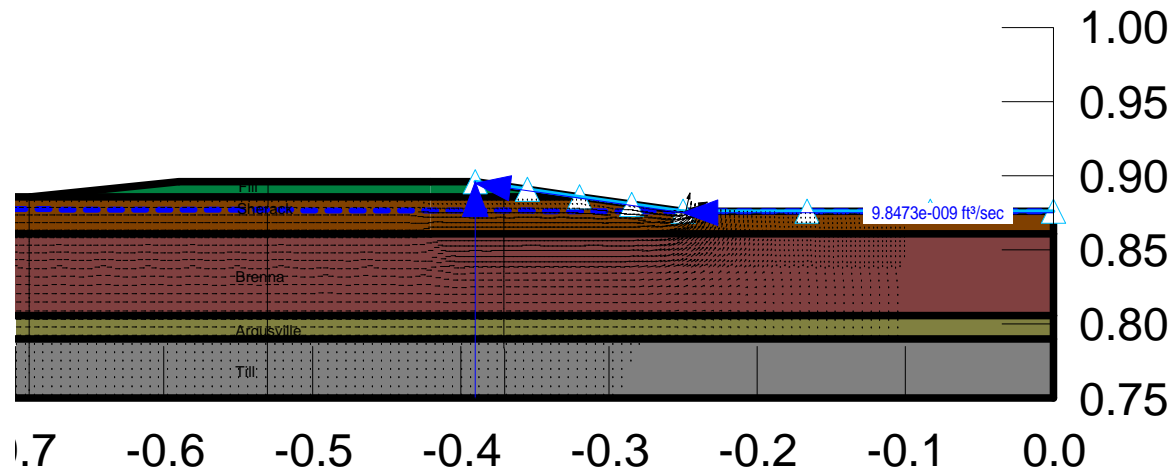
Name: Fill
Model: Saturated / Unsaturated
K-Function: Sherack
Vol. WC. Function: Sherack
K-Ratio: 1
K-Direction: 0 °

Name: Sherack
Model: Saturated / Unsaturated
K-Function: Sherack
Vol. WC. Function: Sherack
K-Ratio: 1
K-Direction: 0 °

Name: Brenna
Model: Saturated Only
K-Sat: 3.28e-008 ft/sec
Volumetric Water Content: 0.615 ft³/ft³
Mv: 0 /psf
K-Ratio: 1
K-Direction: 0 °

Name: Argusville
Model: Saturated Only
K-Sat: 3.28e-008 ft/sec
Volumetric Water Content: 0.59 ft³/ft³
Mv: 0 /psf
K-Ratio: 1
K-Direction: 0 °

Name: Till
Model: Saturated
K-Sat: 2.63e-009 f
Volumetric Water
Mv: 0 /psf
K-Ratio: 1
K-Direction: 0 °



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Soil Properties

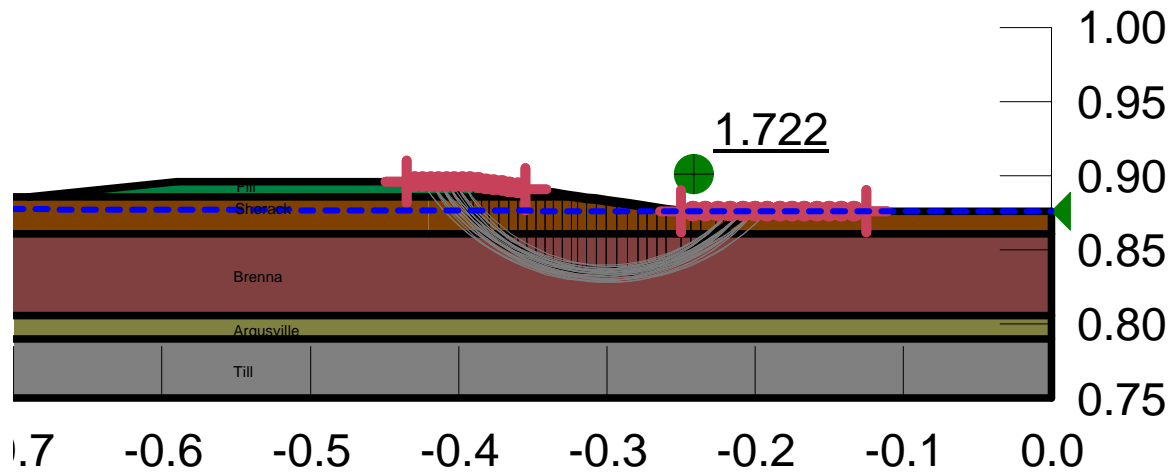
Name: Fill
Unit Weight: 118 pcf
Cohesion: 0 psf
Phi: 28 °

Name: Brenna
Unit Weight: 103 pcf
Cohesion: 0 psf
Phi: 13 °

Name: Sherack
Unit Weight: 118 pcf
Cohesion: 0 psf
Phi: 28 °

Name: Argusville
Unit Weight: 106 pcf
Cohesion: 0 psf
Phi: 15 °

Name: Till
Unit Weight: 122 pcf
Cohesion: 0 psf
Phi: 31 °



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Soil Properties

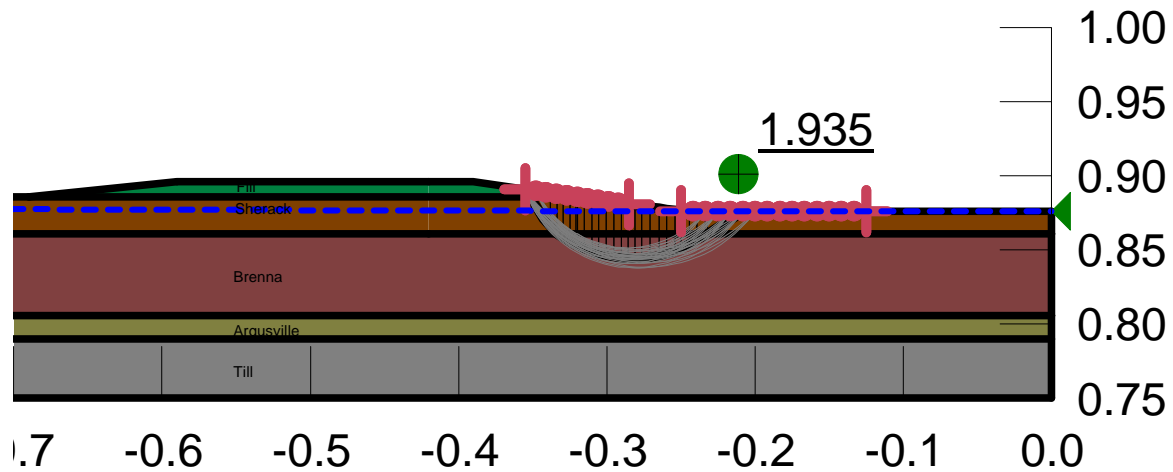
Name: Fill
Unit Weight: 118 pcf
Cohesion: 0 psf
Phi: 28 °

Name: Brenna
Unit Weight: 103 pcf
Cohesion: 0 psf
Phi: 13 °

Name: Sherack
Unit Weight: 118 pcf
Cohesion: 0 psf
Phi: 28 °

Name: Argusville
Unit Weight: 106 pcf
Cohesion: 0 psf
Phi: 15 °

Name: Till
Unit Weight: 122 pcf
Cohesion: 0 psf
Phi: 31 °



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Soil Properties

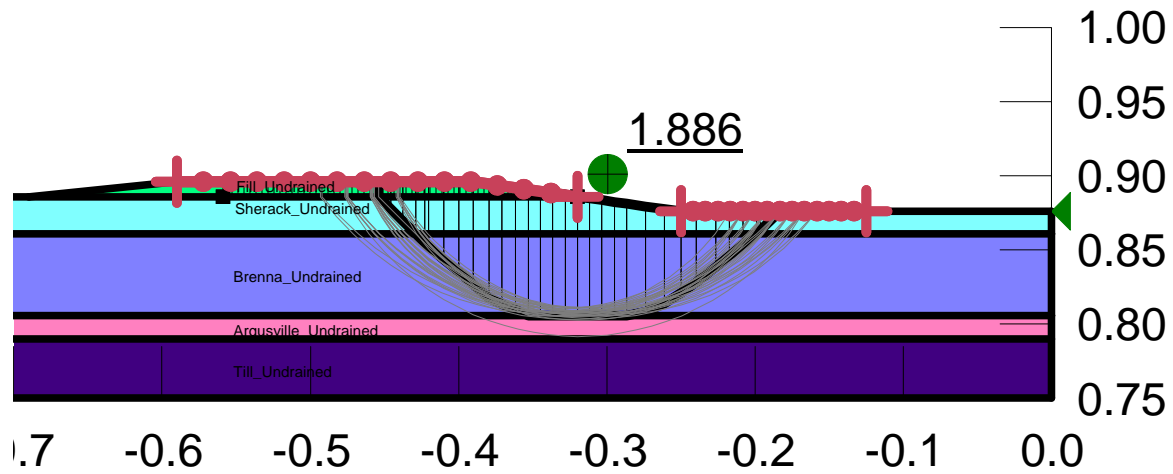
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Unit Weight: 118 pcf
Cohesion: 1400 psf

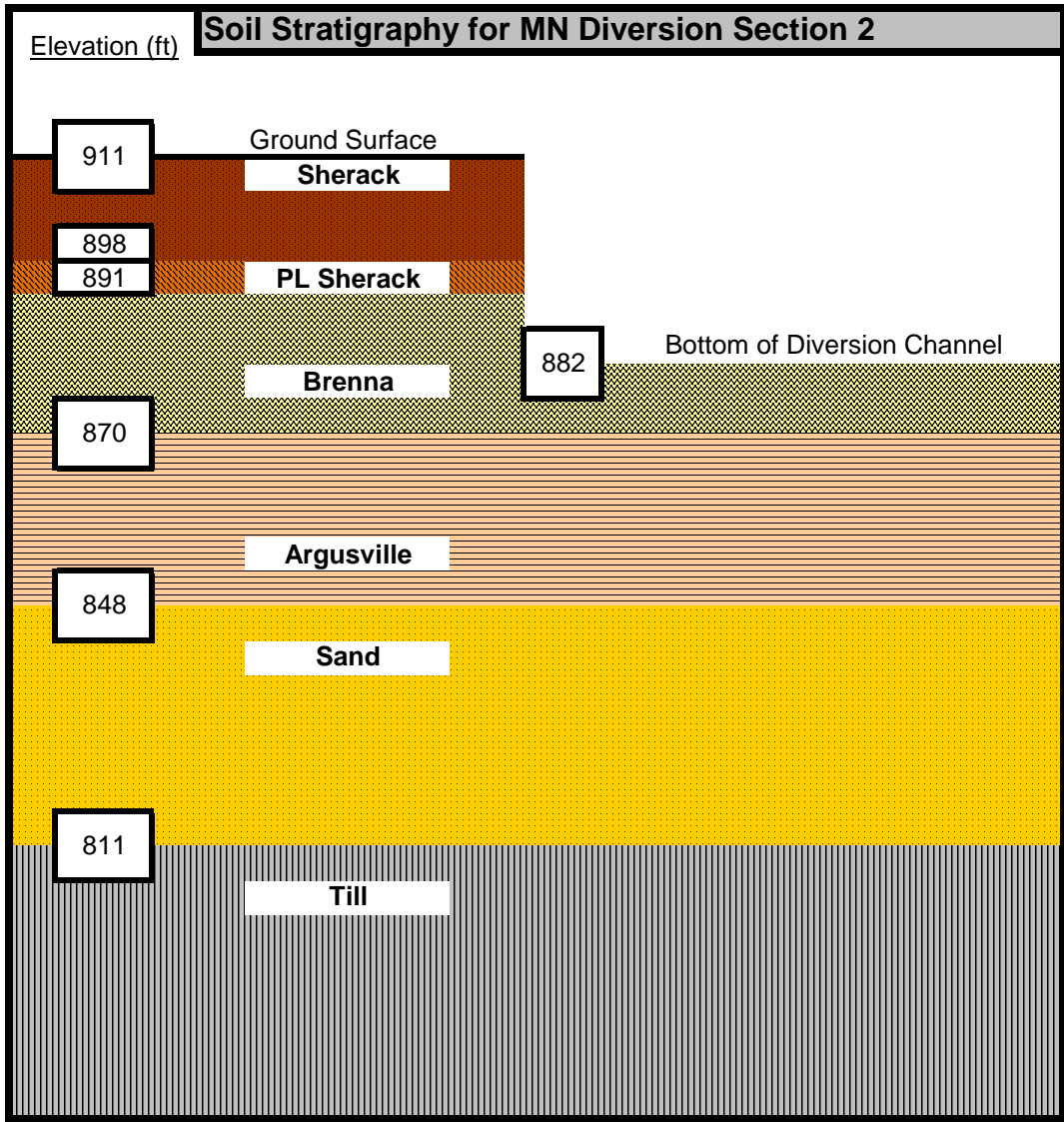
Name: Brenna_Undrained
Unit Weight: 103 pcf
Cohesion: 650 psf

Name: Sherack_Undrained
Unit Weight: 118 pcf
Cohesion: 1400 psf

Name: Argusville_Undrained
Unit Weight: 106 pcf
Cohesion: 825 psf

Name: Till_U
Unit Weight
Cohesion: 1

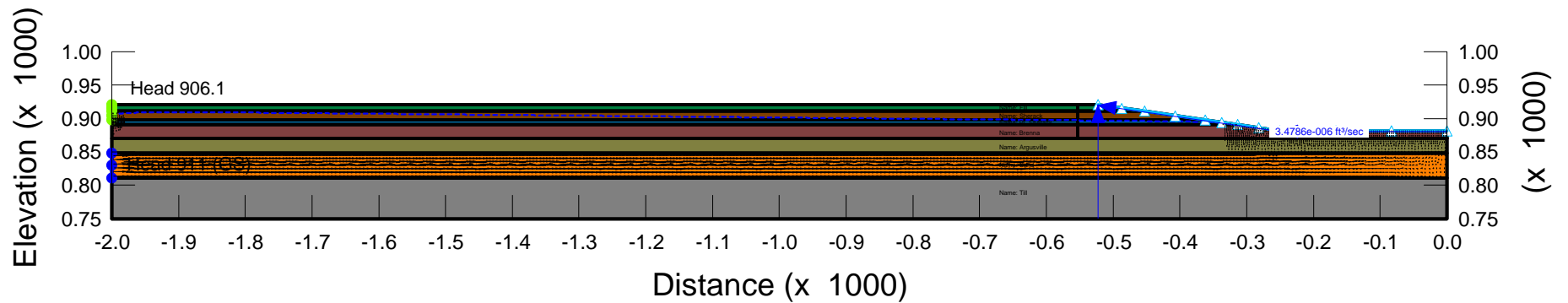




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Fargo-Moorhead Metro Feasibility Study Diversion Channel Stability (500') Cross-Section 2 Seepage Analysis

Soil Properties			
Name: Fill Model: Saturated / Unsaturated K-Function: Sherack Vol. WC. Function: Sherack K-Ratio: 1 K-Direction: 0°	Name: Sherack Model: Saturated / Unsaturated K-Function: Sherack Vol. WC. Function: Sherack K-Ratio: 1 K-Direction: 0°	Name: Argusville Model: Saturated Only K-Sat: 3.28e-008 ft/sec Volumetric Water Content: 0.59 H ₂ O M _r : 0.97 K-Ratio: 1 K-Direction: 0°	Name: Till Model: Saturated Only K-Sat: 2.83e-009 ft/sec Volumetric Water Content: 0.3 H ₂ O M _r : 0.97 K-Ratio: 1 K-Direction: 0°
Name: HL Sherack Model: Saturated / Unsaturated K-Function: Sherack Vol. WC. Function: Sherack K-Ratio: 1 K-Direction: 0°	Name: Brenna Model: Saturated / Unsaturated K-Function: Brenna Vol. WC. Function: Brenna K-Ratio: 1 K-Direction: 0°	Name: Sand Model: Saturated Only K-Sat: 1e-006 ft/sec Volumetric Water Content: 0.16 H ₂ O M _r : 0.97 K-Ratio: 1 K-Direction: 0°	

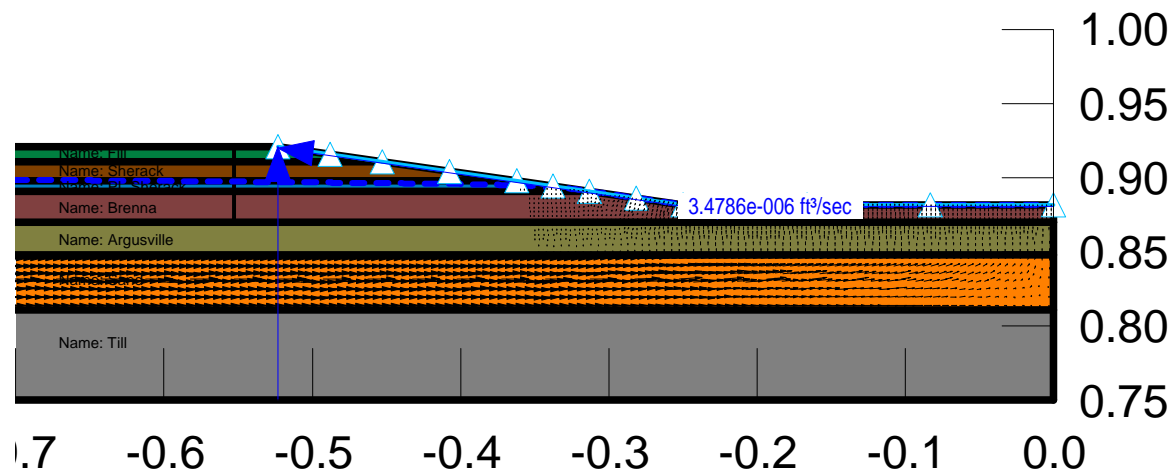


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Soil Properties

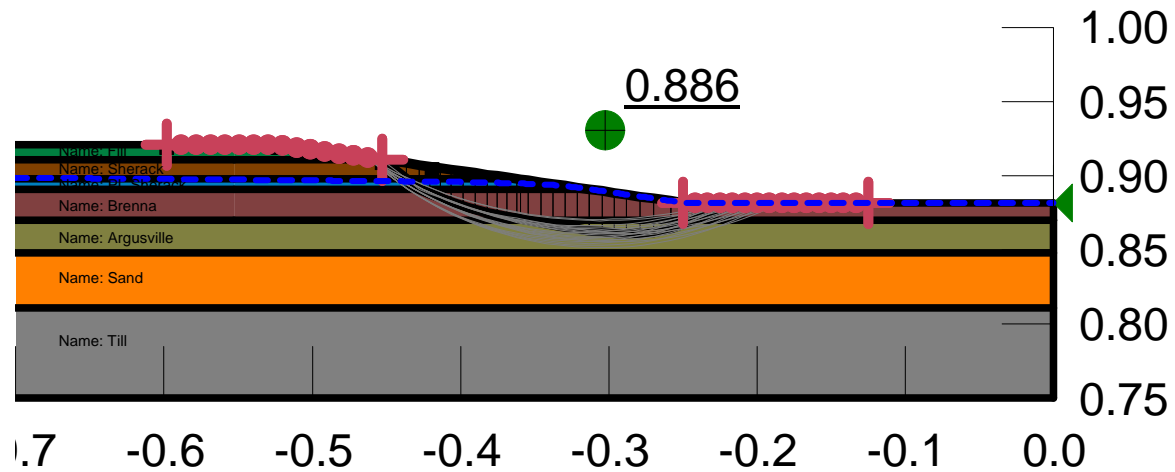
Name: Fill Model: Saturated / Unsaturated K-Function: Sherack Vol. WC. Function: Sherack K-Ratio: 1 K-Direction: 0 °	Name: Sherack Model: Saturated / Unsaturated K-Function: Sherack Vol. WC. Function: Sherack K-Ratio: 1 K-Direction: 0 °	Name: Argusville Model: Saturated Only K-Sat: 3.28e-008 ft/sec Volumetric Water Content: 0.59 ft ³ /ft ³ Mv: 0 /psf K-Ratio: 1 K-Direction: 0 °	Name: Sand Model: Saturated Only K-Sat: 1e-005 ft/sec Volumetric Water Content: 0.16 ft ³ /ft ³ Mv: 0 /psf K-Ratio: 1 K-Direction: 0 °	Name: Till Model: Saturated K-Sat: 2.63e-009 Volumetric Water Mv: 0 /psf K-Ratio: 1 K-Direction: 0 °
Name: PL Sherack Model: Saturated / Unsaturated K-Function: Sherack Vol. WC. Function: Sherack K-Ratio: 1 K-Direction: 0 °	Name: Brenna Model: Saturated / Unsaturated K-Function: Brenna Vol. WC. Function: Brenna K-Ratio: 1 K-Direction: 0 °			



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Soil Properties

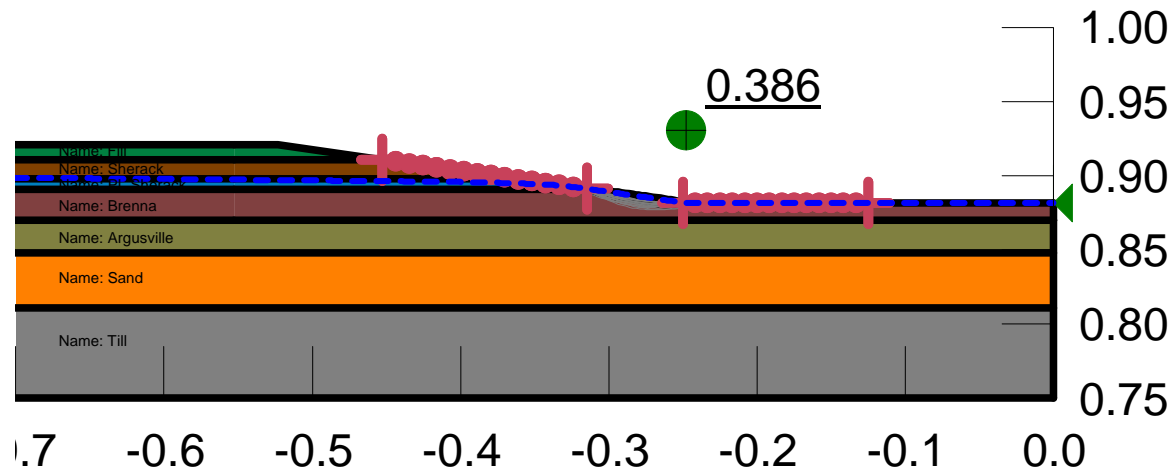
Name: Fill Model: Mohr-Coulomb Unit Weight: 118 pcf Cohesion: 0 psf Phi: 28 ° Phi-B: 0 °	Name: Sherack Model: Mohr-Coulomb Unit Weight: 118 pcf Cohesion: 0 psf Phi: 28 ° Phi-B: 0 °	Name: Argusville Model: Mohr-Coulomb Unit Weight: 106 pcf Cohesion: 0 psf Phi: 15 ° Phi-B: 0 °	
Name: PL Sherack Model: Mohr-Coulomb Unit Weight: 112 pcf Cohesion: 0 psf Phi: 19 ° Phi-B: 0 °	Name: Brenna Model: Mohr-Coulomb Unit Weight: 103 pcf Cohesion: 0 psf Phi: 13 ° Phi-B: 0 °	Name: Sand Model: Mohr-Coulomb Unit Weight: 128 pcf Cohesion: 0 psf Phi: 30 ° Phi-B: 0 °	Name: Till Model: Mohr-Coul Unit Weight: 122 pcf Cohesion: 0 psf Phi: 31 ° Phi-B: 0 °



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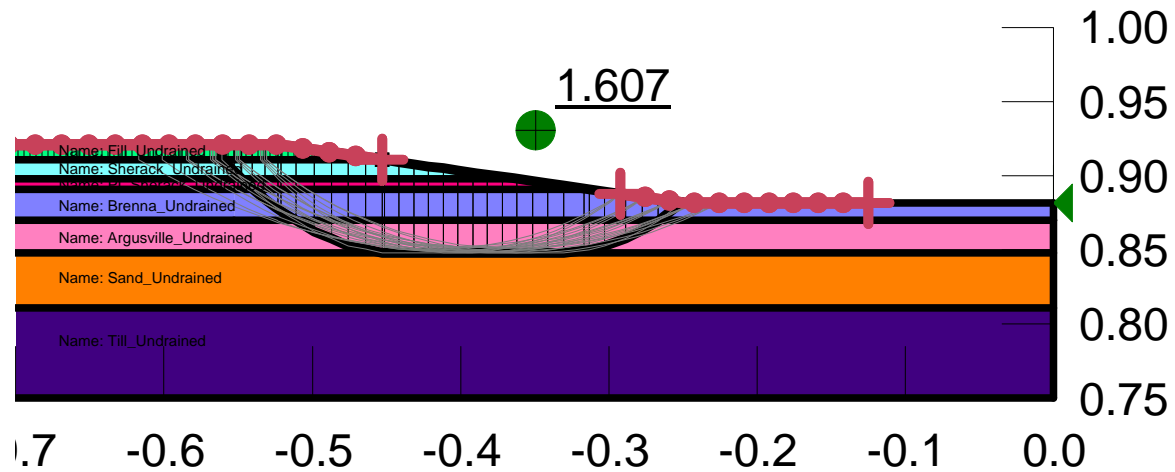
Name: Fill Model: Mohr-Coulomb Unit Weight: 118 pcf Cohesion: 0 psf Phi: 28 ° Phi-B: 0 °	Name: Sherack Model: Mohr-Coulomb Unit Weight: 118 pcf Cohesion: 0 psf Phi: 28 ° Phi-B: 0 °	Name: Argusville Model: Mohr-Coulomb Unit Weight: 106 pcf Cohesion: 0 psf Phi: 15 ° Phi-B: 0 °	
Name: PL Sherack Model: Mohr-Coulomb Unit Weight: 112 pcf Cohesion: 0 psf Phi: 19 ° Phi-B: 0 °	Name: Brenna Model: Mohr-Coulomb Unit Weight: 103 pcf Cohesion: 0 psf Phi: 13 ° Phi-B: 0 °	Name: Sand Model: Mohr-Coulomb Unit Weight: 128 pcf Cohesion: 0 psf Phi: 30 ° Phi-B: 0 °	Name: Till Model: Mohr-Coul Unit Weight: 122 pcf Cohesion: 0 psf Phi: 31 ° Phi-B: 0 °

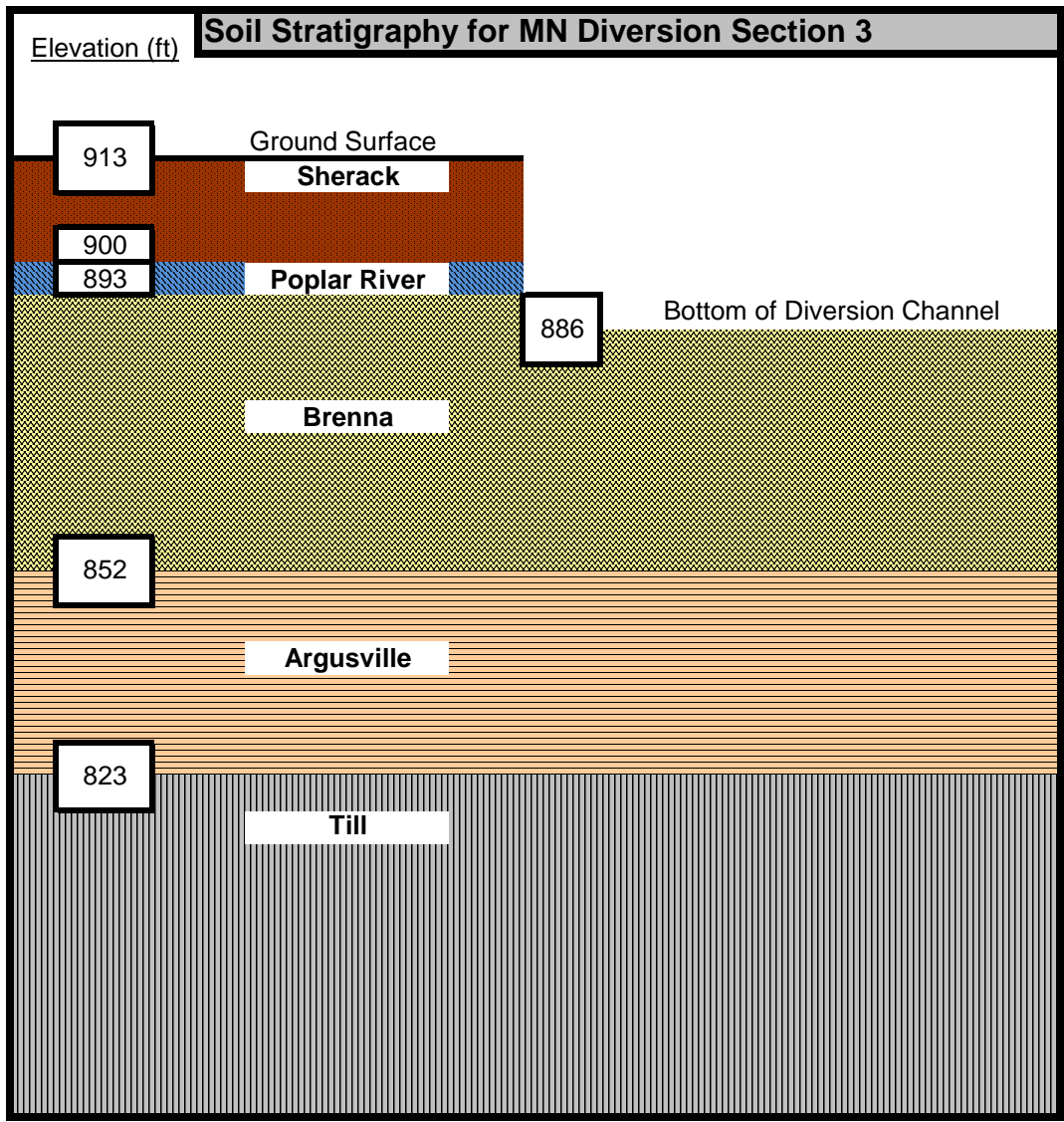


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Soil Properties

Name: Fill_Undrained Model: Undrained (Phi=0) Unit Weight: 118 pcf Cohesion: 1400 psf	Name: Sherack_Undrained Model: Undrained (Phi=0) Unit Weight: 118 pcf Cohesion: 1400 psf	Name: Argusville_Undrained Model: Undrained (Phi=0) Unit Weight: 106 pcf Cohesion: 825 psf	
Name: PL Sherack_Undrained Model: Undrained (Phi=0) Unit Weight: 112 pcf Cohesion: 1150 psf	Name: Brenna_Undrained Model: Undrained (Phi=0) Unit Weight: 103 pcf Cohesion: 650 psf	Name: Sand_Undrained Model: Mohr-Coulomb Unit Weight: 128 pcf Cohesion: 0 psf Phi: 30 ° Phi-B: 0 °	Name: Till_Undrained Model: Undrained Unit Weight: 122 pcf Cohesion: 1900 pcf



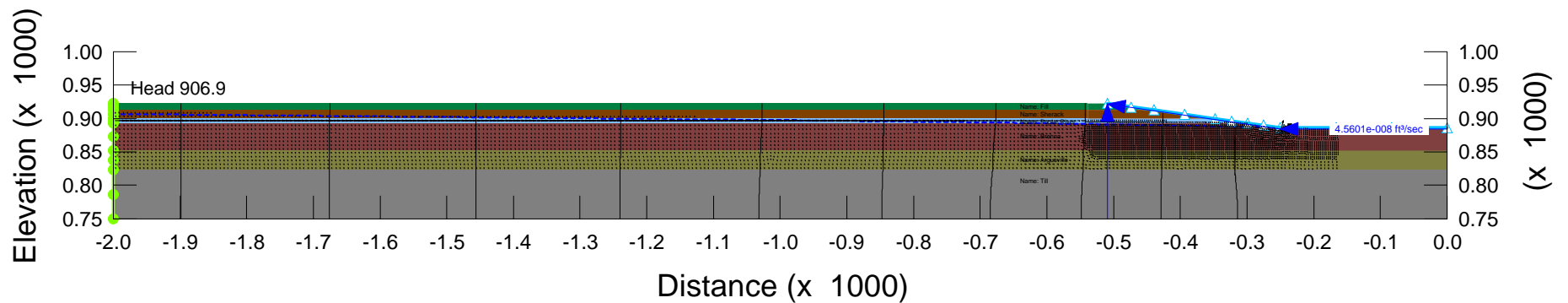


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Fargo-Moorhead Metro Feasibility Study Diversion Channel Stability (500') Cross-Section 3 Seepage Analysis

Soil Properties

Name: Sherack Model: Saturated / Unsaturated K-Function: Sherack Vol. WC: Function: Sherack K-Ratio: 1 K-Direction: 0*	Name: Till Model: Saturated Only K-Sat: 2.63e-009 ft/sec Volumetric Water Content: 0.3 ft ³ /ft ³ K-Ratio: 1 K-Direction: 0*	Name: Argusville Model: Saturated Only K-Sat: 3.28e-008 ft/sec Volumetric Water Content: 0.59 ft ³ /ft ³ K-Ratio: 1 K-Direction: 0*
Name: Sherack Model: Saturated / Unsaturated K-Function: Sherack Vol. WC: Function: Sherack K-Ratio: 1 K-Direction: 0*	Name: Brenna Model: Saturated / Unsaturated K-Function: Brenna Vol. WC: Function: Brenna K-Ratio: 1 K-Direction: 0*	Name: Till Model: Saturated Only K-Sat: 2.63e-009 ft/sec Volumetric Water Content: 0.3 ft ³ /ft ³ K-Ratio: 1 K-Direction: 0*



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Soil Properties

Name: Sherack
Model: Saturated / Unsaturated
K-Function: Sherack
Vol. WC. Function: Sherack
K-Ratio: 1
K-Direction: 0 °

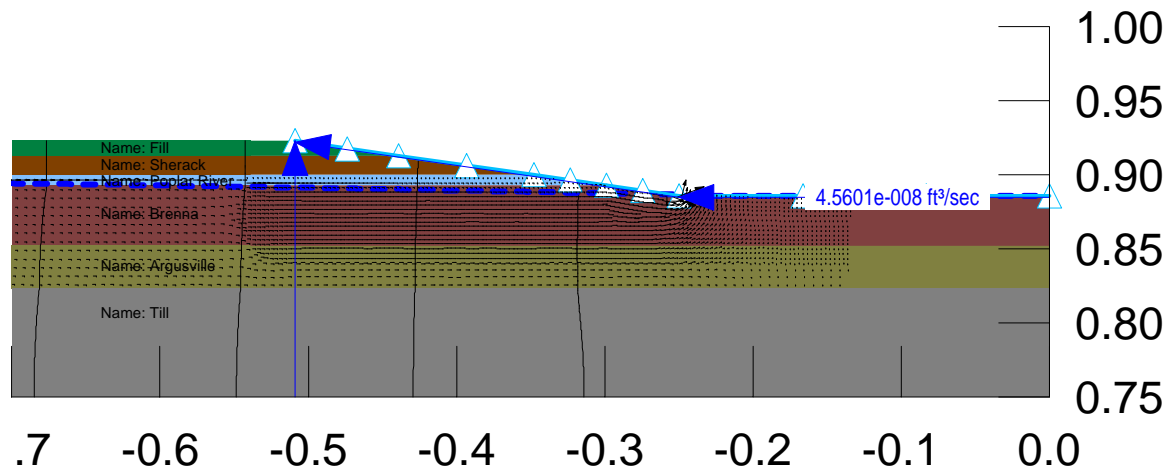
Name: Till
Model: Saturated Only
K-Sat: 2.63e-009 ft/sec
Volumetric Water Content: 0.3 ft³/ft³
K-Ratio: 1
K-Direction: 0 °

Name: Argusville
Model: Saturated Or
K-Sat: 3.28e-008 ft/s
Volumetric Water Cc
K-Ratio: 1
K-Direction: 0 °

Name: Sherack
Model: Saturated / Unsaturated
K-Function: Sherack
Vol. WC. Function: Sherack
K-Ratio: 1
K-Direction: 0 °

Name: Brenna
Model: Saturated / Unsaturated
K-Function: Brenna
Vol. WC. Function: Brenna
K-Ratio: 1
K-Direction: 0 °

Name: Till
Model: Saturated Or
K-Sat: 2.63e-009 ft/s
Volumetric Water Cc
K-Ratio: 1
K-Direction: 0 °



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Soil Properties

Name: Sherack
Model: Mohr-Coulomb
Unit Weight: 118 pcf
Cohesion: 0 psf
Phi: 28 °
Phi-B: 0 °

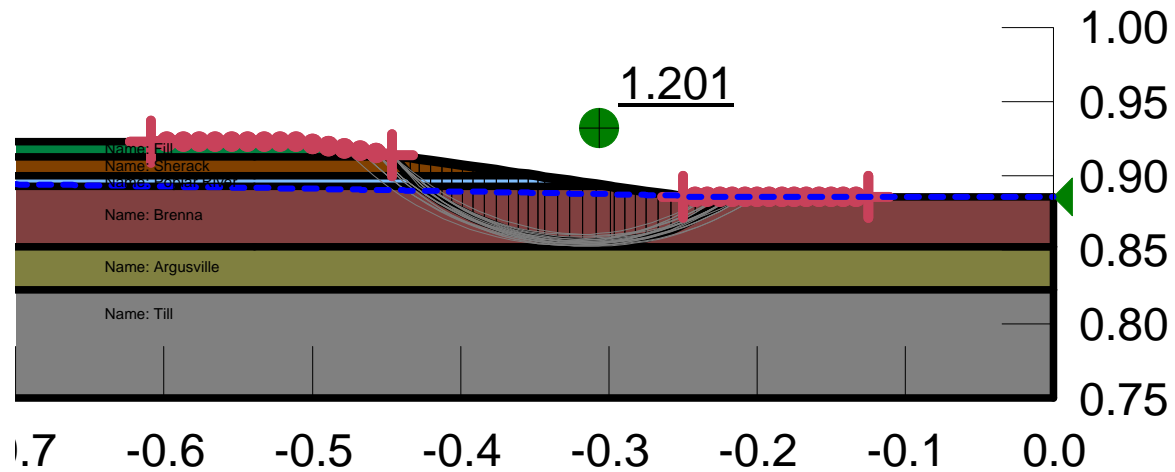
Name: Till
Model: Mohr-Coulomb
Unit Weight: 122 pcf
Cohesion: 0 psf
Phi: 31 °
Phi-B: 0 °

Name: Argusville
Model: Mohr-Coulomb
Unit Weight: 106 pcf
Cohesion: 0 psf
Phi: 15 °

Name: Sherack
Model: Mohr-Coulomb
Unit Weight: 118 pcf
Cohesion: 0 psf
Phi: 28 °
Phi-B: 0 °

Name: Brenna
Model: Mohr-Coulomb
Unit Weight: 103 pcf
Cohesion: 0 psf
Phi: 13 °
Phi-B: 0 °

Name: Till
Model: Mohr-Coulomb
Unit Weight: 122 pcf
Cohesion: 0 psf
Phi: 31 °
Phi-B: 0 °



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Soil Properties

Name: Sherack
Model: Mohr-Coulomb
Unit Weight: 118 pcf
Cohesion: 0 psf
Phi: 28 °
Phi-B: 0 °

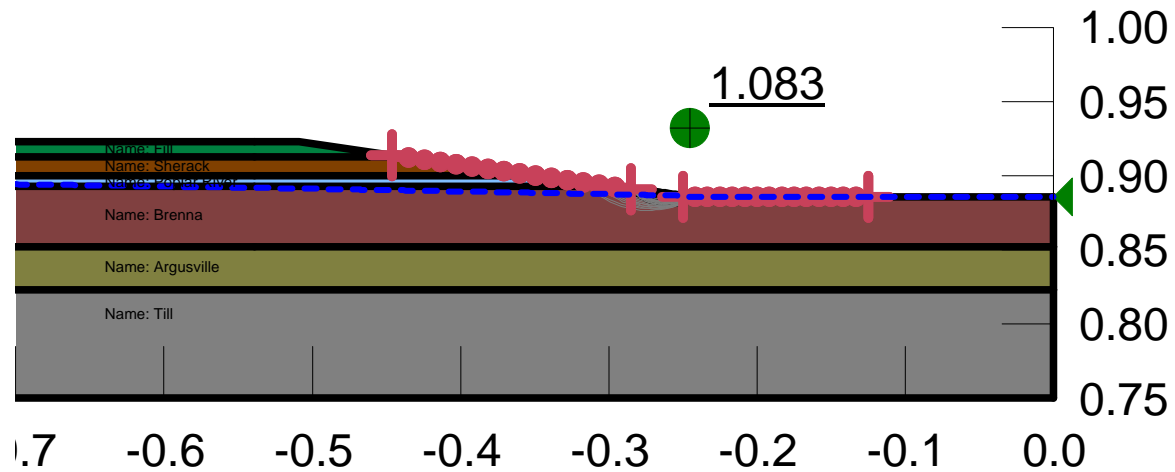
Name: Till
Model: Mohr-Coulomb
Unit Weight: 122 pcf
Cohesion: 0 psf
Phi: 31 °
Phi-B: 0 °

Name: Argusville
Model: Mohr-Coulomb
Unit Weight: 106 pcf
Cohesion: 0 psf
Phi: 15 °

Name: Sherack
Model: Mohr-Coulomb
Unit Weight: 118 pcf
Cohesion: 0 psf
Phi: 28 °
Phi-B: 0 °

Name: Brenna
Model: Mohr-Coulomb
Unit Weight: 103 pcf
Cohesion: 0 psf
Phi: 13 °
Phi-B: 0 °

Name: Till
Model: Mohr-Coulomb
Unit Weight: 122 pcf
Cohesion: 0 psf
Phi: 31 °
Phi-B: 0 °



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Soil Properties

Name: Sherack_Undrained
Model: Undrained (Phi=0)
Unit Weight: 118 pcf
Cohesion: 1400 psf

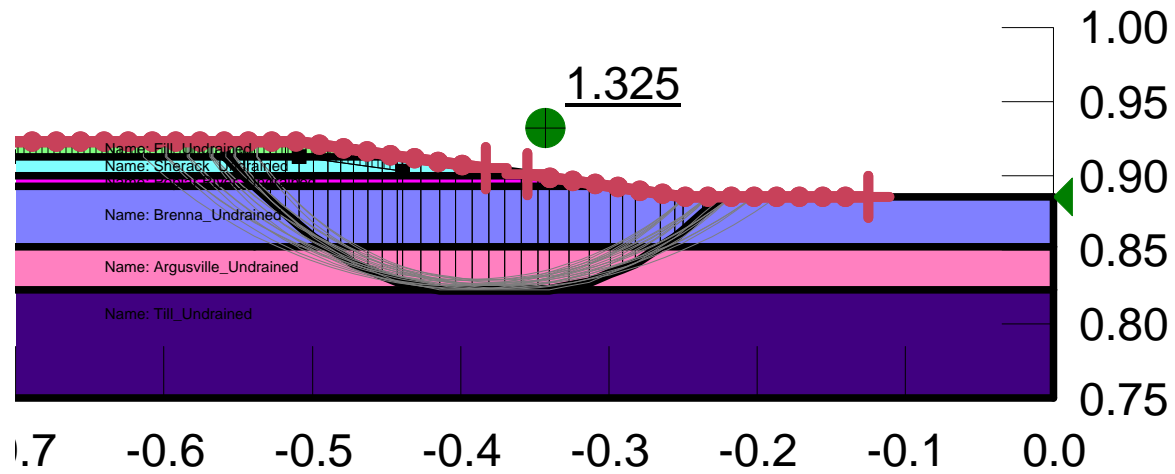
Name: Till_Undrained
Model: Undrained (Phi=0)
Unit Weight: 122 pcf
Cohesion: 1900 psf

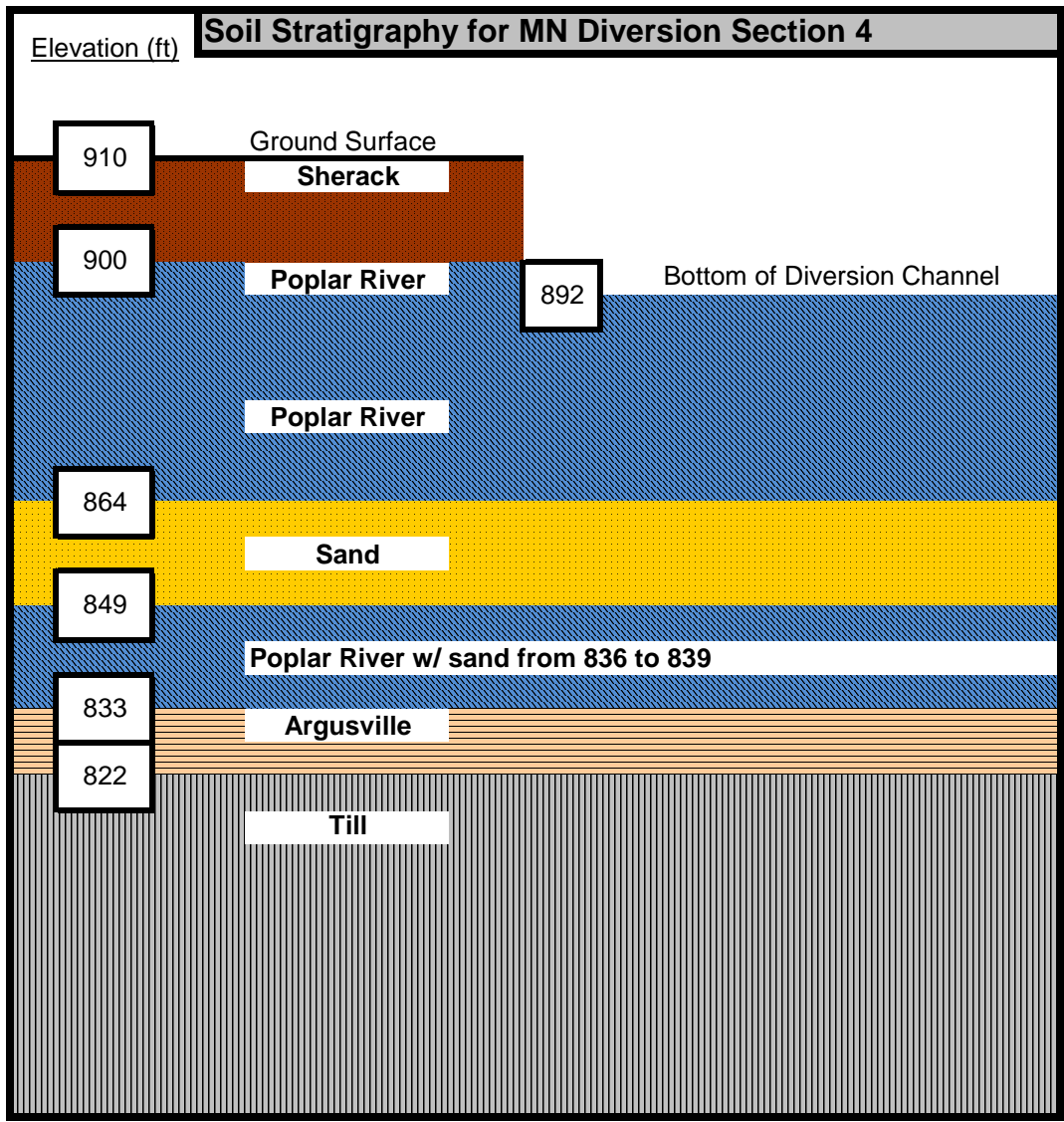
Name: Argusville_Ui
Model: Undrained (F
Unit Weight: 106 pcf
Cohesion: 825 psf

Name: Sherack_Undrained
Model: Undrained (Phi=0)
Unit Weight: 118 pcf
Cohesion: 1400 psf

Name: Brenna_Undrained
Model: Undrained (Phi=0)
Unit Weight: 103 pcf
Cohesion: 650 psf

Name: Till_Undraine
Model: Undrained (F
Unit Weight: 122 pcf
Cohesion: 1900 psf

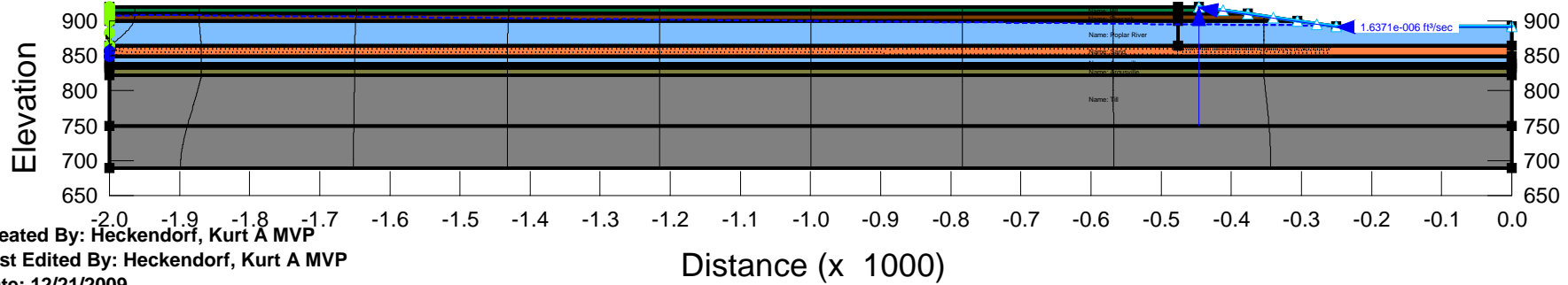




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Fargo-Moorhead Metro Feasibility Study Diversion Channel Stability (500') Cross-Section 4 Seepage Analysis

Soil Properties			
Name: Fill Model: Saturated / Unsat K-Function: Sherack Vol. WC. Function: Sherack K-Ratio: 1 K-Direction: 0°	Name: Poplar River Model: Saturated / Unsat K-Function: Poplar River Vol. WC. Function: Poplar River K-Ratio: 1 K-Direction: 0°	Name: Sand Delta Model: Saturated Only K-Sat: 3.25e-009 ft/sec Volumetric Water Content: 0.5 H ₂ O M _v : 0 g/g K-Ratio: 1 K-Direction: 0°	Name: Argoville Model: Saturated Only K-Sat: 2.03e-009 ft/sec Volumetric Water Content: 0.59 H ₂ O M _v : 0 g/g K-Ratio: 1 K-Direction: 0°
Name: Sherack Model: Saturated / Unsat K-Function: Sherack Vol. WC. Function: Sherack K-Ratio: 1 K-Direction: 0°	Name: Sand Model: Saturated Only K-Sat: 1e-008 ft/sec Volumetric Water Content: 0.5 H ₂ O M _v : 0 g/g K-Ratio: 1 K-Direction: 0°	Name: Tilt Model: Saturated Only K-Sat: 2.03e-009 ft/sec Volumetric Water Content: 0.3 H ₂ O M _v : 0 g/g K-Ratio: 1 K-Direction: 0°	Name: Tilt Model: Saturated Only K-Sat: 2.03e-009 ft/sec Volumetric Water Content: 0.3 H ₂ O M _v : 0 g/g K-Ratio: 1 K-Direction: 0°

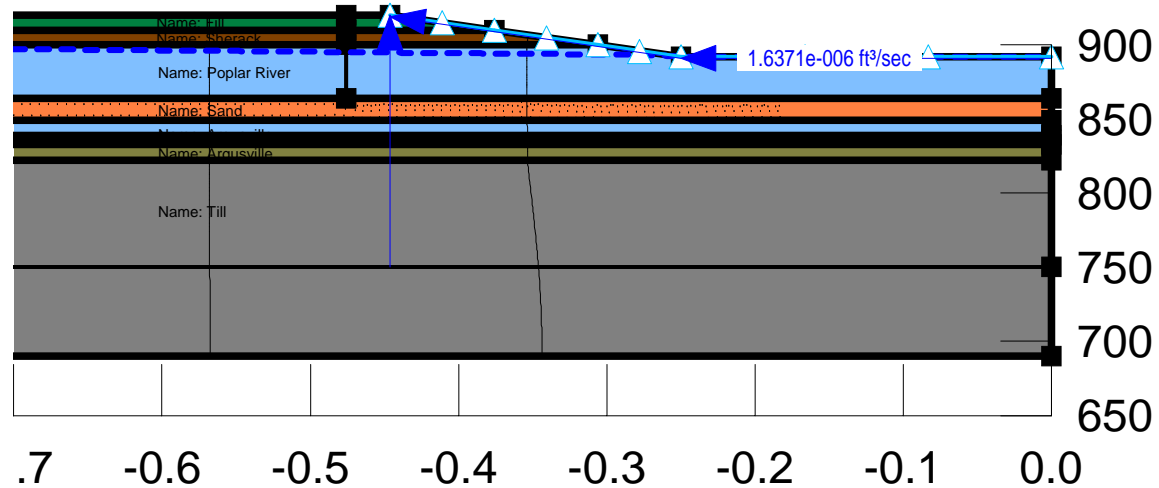


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Last Edited By: Heckendorf, Kurt A MVP
Date: 12/21/2009

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Soil Properties

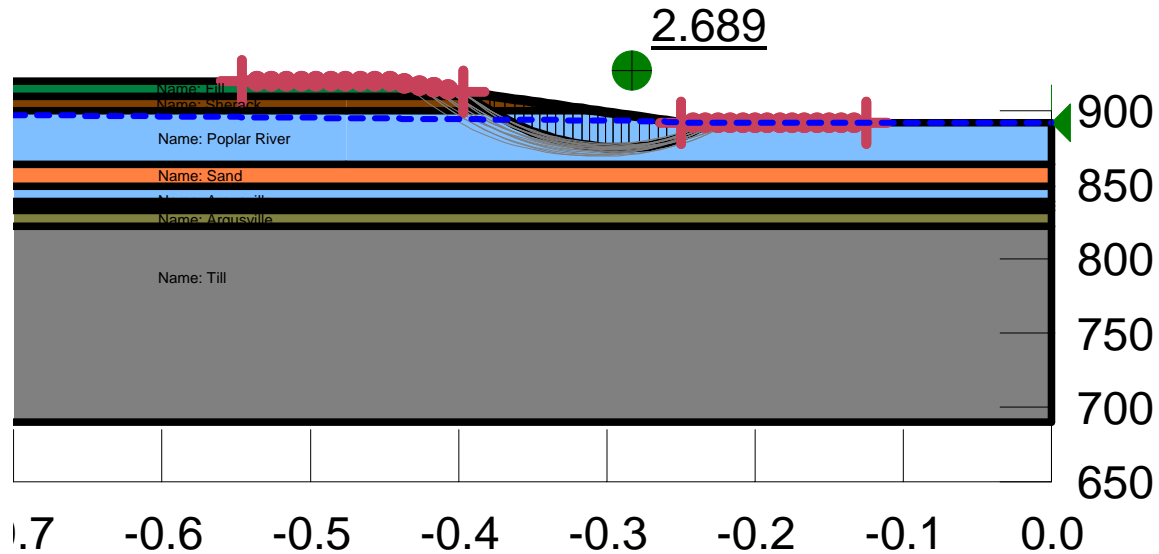
<p>Name: Fill Model: Saturated / Unsaturated K-Function: Sherack Vol. WC. Function: Sherack K-Ratio: 1 K-Direction: 0 °</p>	<p>Name: Poplar River Model: Saturated / Unsaturated K-Function: Poplar River Vol. WC. Function: Poplar River K-Ratio: 1 K-Direction: 0 °</p>	<p>Name: Sand Delta Model: Saturated Only K-Sat: 3.28e-006 ft/sec Volumetric Water Content: 0.5 ft³/ft³ Mv: 0 /psf K-Ratio: 1 K-Direction: 0 °</p>	
<p>Name: Sherack Model: Saturated / Unsaturated K-Function: Sherack Vol. WC. Function: Sherack K-Ratio: 1 K-Direction: 0 °</p>	<p>Name: Sand Model: Saturated Only K-Sat: 1e-005 ft/sec Volumetric Water Content: 0.5 ft³/ft³ Mv: 0 /psf K-Ratio: 1 K-Direction: 0 °</p>	<p>Name: Argusville Model: Saturated Only K-Sat: 3.28e-008 ft/sec Volumetric Water Content: 0.59 ft³/ft³ Mv: 0 /psf K-Ratio: 1 K-Direction: 0 °</p>	<p>Name: Till Model: Saturated Only K-Sat: 2.63e-009 ft/sec Volumetric Water Content: 0.59 ft³/ft³ Mv: 0 /psf K-Ratio: 1 K-Direction: 0 °</p>



July

Soil Properties

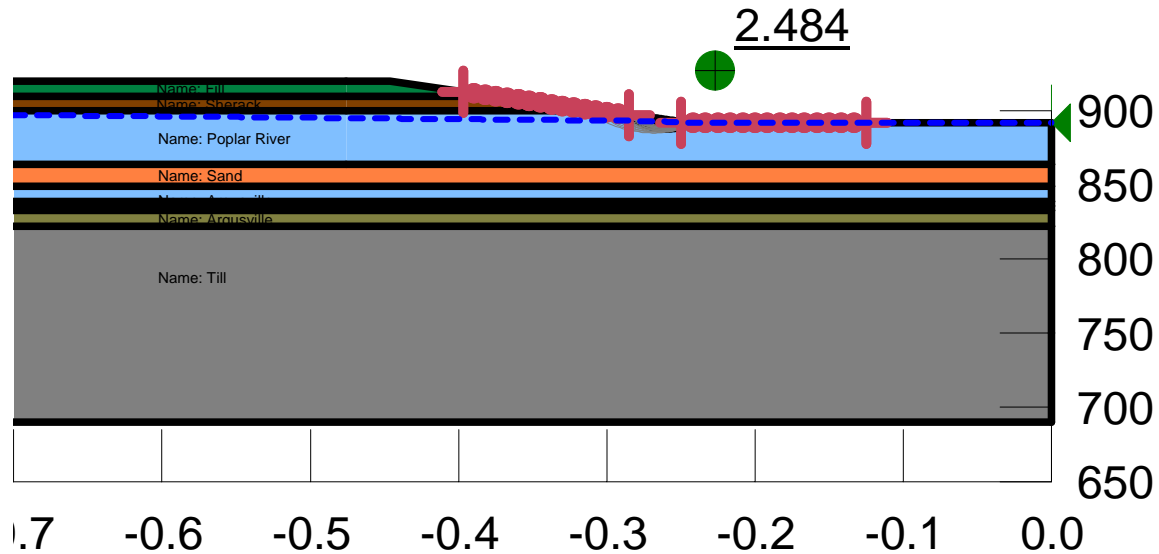
Name: Fill Model: Mohr-Coulomb Unit Weight: 118 pcf Cohesion: 0 psf Phi: 28 ° Phi-B: 0 °	Name: Poplar River Model: Mohr-Coulomb Unit Weight: 116 pcf Cohesion: 0 psf Phi: 26 ° Phi-B: 0 °	Name: Sand Delta Model: Mohr-Coulomb Unit Weight: 128 pcf Cohesion: 0 psf Phi: 26 ° Phi-B: 0 °	Name: Till Model: Mohr-Coulomb Unit Weight: 122 pcf Cohesion: 0 psf Phi: 31 ° Phi-B: 0 °
Name: Sherack Model: Mohr-Coulomb Unit Weight: 118 pcf Cohesion: 0 psf Phi: 28 ° Phi-B: 0 °	Name: Sand Model: Mohr-Coulomb Unit Weight: 128 pcf Cohesion: 0 psf Phi: 30 ° Phi-B: 0 °	Name: Argusville Model: Mohr-Coulomb Unit Weight: 106 pcf Cohesion: 0 psf Phi: 15 ° Phi-B: 0 °	



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Soil Properties

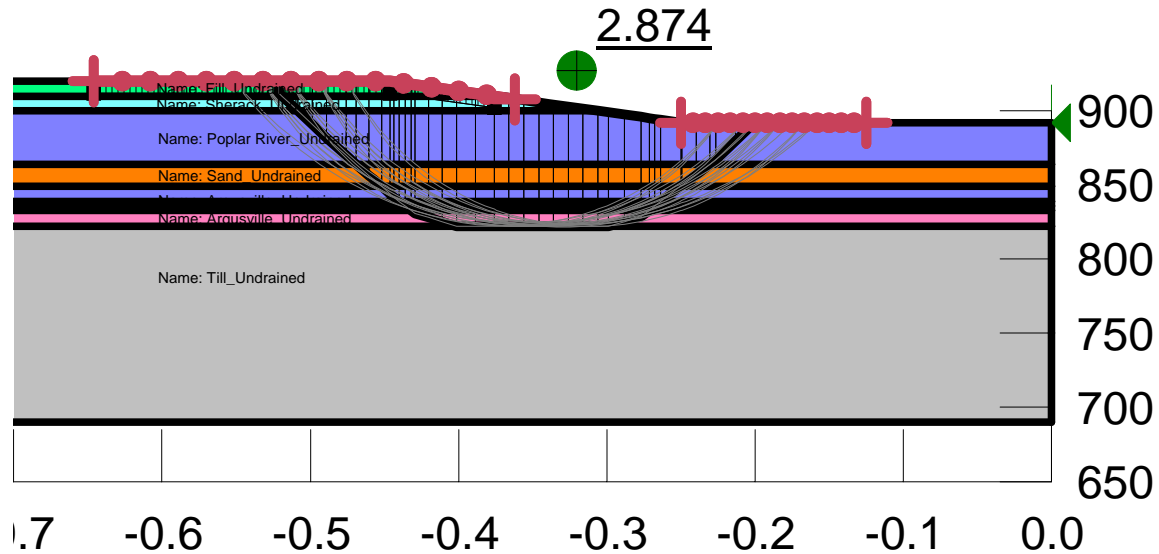
Name: Fill Model: Mohr-Coulomb Unit Weight: 118 pcf Cohesion: 0 psf Phi: 28 ° Phi-B: 0 °	Name: Poplar River Model: Mohr-Coulomb Unit Weight: 116 pcf Cohesion: 0 psf Phi: 26 ° Phi-B: 0 °	Name: Sand Delta Model: Mohr-Coulomb Unit Weight: 128 pcf Cohesion: 0 psf Phi: 26 ° Phi-B: 0 °	Name: Till Model: Mohr-Coulomb Unit Weight: 122 pcf Cohesion: 0 psf Phi: 31 ° Phi-B: 0 °
Name: Sherack Model: Mohr-Coulomb Unit Weight: 118 pcf Cohesion: 0 psf Phi: 28 ° Phi-B: 0 °	Name: Sand Model: Mohr-Coulomb Unit Weight: 128 pcf Cohesion: 0 psf Phi: 30 ° Phi-B: 0 °	Name: Argusville Model: Mohr-Coulomb Unit Weight: 106 pcf Cohesion: 0 psf Phi: 15 ° Phi-B: 0 °	



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Soil Properties

Name: Fill_Undrained Model: Undrained (Phi=0) Unit Weight: 118 pcf Cohesion: 1400 psf	Name: Poplar River_Undrained Model: Undrained (Phi=0) Unit Weight: 116 pcf Cohesion: 1450 psf	Name: Sand Delta Model: Mohr-Coulomb Unit Weight: 128 pcf Cohesion: 0 psf Phi: 26 ° Phi-B: 0 °	
Name: Sherack_Undrained Model: Undrained (Phi=0) Unit Weight: 118 pcf Cohesion: 1400 psf	Name: Sand_Undrained Model: Mohr-Coulomb Unit Weight: 128 pcf Cohesion: 0 psf Phi: 30 ° Phi-B: 0 °	Name: Argusville_Undrained Model: Undrained (Phi=0) Unit Weight: 106 pcf Cohesion: 825 psf	Name: Till_Undrained Model: Undrained (Phi=0) Unit Weight: 122 pcf Cohesion: 1900 psf



FARGO-MOORHEAD METRO FEASIBILITY STUDY
 EAST DIVERSION
 REVISED ALTERNATIVE FOR SECTION 2

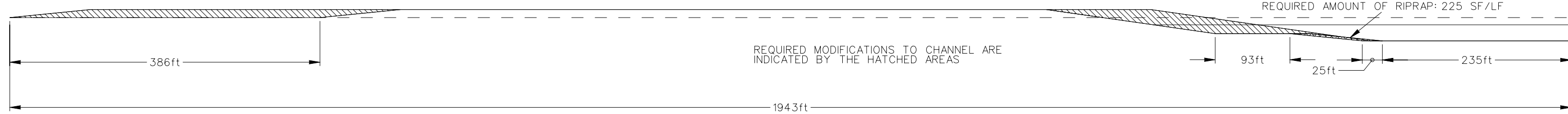
FLOW AREA OF UNMODIFIED CHANNEL: 6400 SF/LF
 FLOW AREA OF MODIFIED CHANNEL: 7817 SF/LF

ADDITIONAL REAL ESTATE: 386 FT/LF

AREA OF UNMODIFIED CHANNEL: 10193 SF/LF
 AREA OF MODIFIED CHANNEL: 12780 SF/LF

REQUIRED AMOUNT OF RIPRAP: 225 SF/LF

REQUIRED MODIFICATIONS TO CHANNEL ARE
 INDICATED BY THE HATCHED AREAS



FARGO-MOORHEAD METRO FEASIBILITY STUDY
 EAST DIVERSION
 REVISED ALTERNATIVE FOR SECTION 3

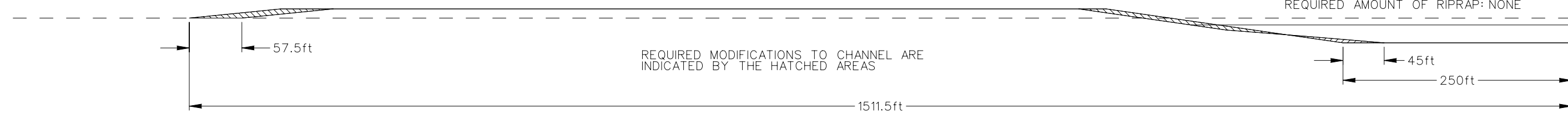
FLOW AREA OF UNMODIFIED CHANNEL: 6205.875 SF/LF
 FLOW AREA OF MODIFIED CHANNEL: 6248.375 SF/LF

ADDITIONAL REAL ESTATE: 57.5 FT/LF

AREA OF UNMODIFIED CHANNEL: 9301.5 SF/LF
 AREA OF MODIFIED CHANNEL: 9569 SF/LF

REQUIRED AMOUNT OF RIPRAP: NONE

REQUIRED MODIFICATIONS TO CHANNEL ARE
 INDICATED BY THE HATCHED AREAS





Fargo-Moorhead Metro Feasibility Study

Minnesota Diversion Alternative Configurations

Computed By: KAH
Date: 4-Sep-08

Revised By: KAH
Date: 19-Mar-10

Due to seepage & slope stability concerns, the configuration of the diversion channel had to be modified
Based on discussion with Mike Leshner (3 SEP 09), the configuration of the channel could be modified but the flow area should be kept the same
Elevations for the ground surface, channel bottom, and water surface profile along the diversion were obtained from Moore Engineering's MN Short Diversion calculation:

Summary of Required Modifications

MN Short Diversion					Quantities Based on 1/2 of the Diversion Channel													
Section	Location (FT)	Ground Elevation (FT)	Bottom of Channel (FT)	Water Profile (FT)	Required Modification	Original Channel Width (FT)	Modified Channel Width (FT)	% Decrease	Original Flow Area (SF/LF)	Modified Flow Area (SF/LF)	% Increase	Original Excavation (SF/LF)	Modified Excavation (SF/LF)	% Increase	Original Real Estate (FT)	Modified Real Estate (FT)	% Increase	Required Riprap (SF/LF)
2	69000	911	882	902	Slope in Brenna flatten to 1V:10H, 9 FT up; 25 FT wide riprap berm added to slope cut in Brenna; 118 FT bench	250	235	6.0%	6,400	7,817	22.13%	10,193	12,780	25.38%	1,557	1,943	24.79%	225
3	96000	913	886	905.5	Slope in Brenna flatten to 1V:12H, 14 FT up	250	205	18.0%	6,206	6,248	0.68%	9,302	9,569	2.88%	1,454	1,512	3.95%	0

MN Short Diversion					Quantities Based on the FULL Diversion Channel													
Section	Location (FT)	Ground Elevation (FT)	Bottom of Channel (FT)	Water Profile (FT)	Required Length of Modification (FT)	Original Channel Width (FT)	Modified Channel Width (FT)	% Decrease	Original Flow Area (SF/LF)	Modified Flow Area (SF/LF)	% Increase	Original Excavation (CY)	Modified Excavation (CY)	% Increase	Original Real Estate (ACRE)	Modified Real Estate (SF)	% Increase	Required Riprap (CY)
2	69000	911	882	902	16,000	500	470	6.0%	12,800	15,633	22.13%	12,080,593	15,146,667	25.38%	1,144	1,427	24.79%	266,667
3	96000	913	886	905.5	73,500	500	410	18.0%	12,412	12,497	0.68%	50,641,500	52,097,889	2.88%	4,907	5,101	3.95%	0

Mod Type	Start	End	Length	
3	35,500	65,000	29,500	22%
2	65,000	81,000	16,000	12%
3	81,000	125,000	44,000	33%
			89,500	66.9%

Total Diversion Channel Length 133,745
44,245

Weighted Average for Increased Quantities				
	Length	Increased Excavation	Increased Real Estate	Required Riprap (CY)
No Mod	44,245	0	0	0
Mod 2	16,000	25.4%	24.8%	266,667
Mod 3	73,500	2.9%	4.0%	0
Total Length	133,745			
Weighted Average Increase		4.6%	5.1%	266,667



Fargo-Moorhead Metro Feasibility Study

Minnesota Diversion Alternative Lengths

Computed By: KAH
Date: 4-Sep-09

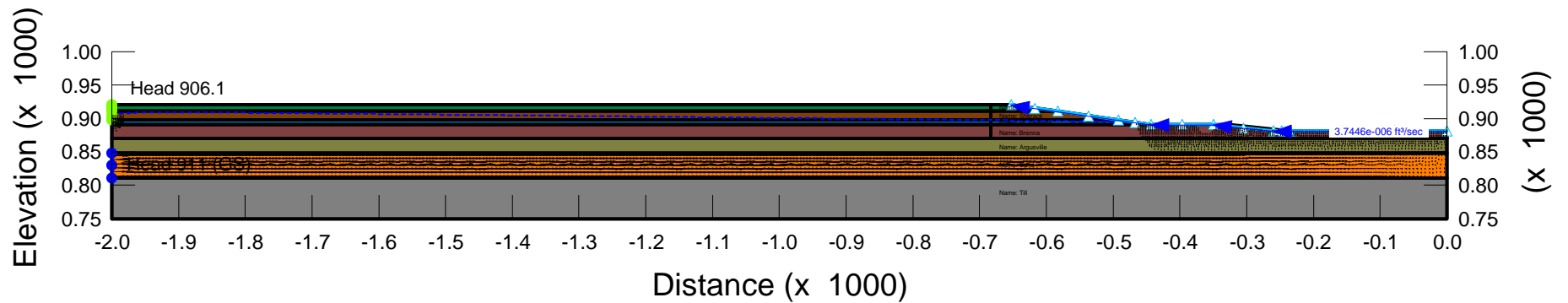
Revised By:
Date:

Sounding	Location	Elevation	Bottom Elevation	Top of Sherack		Top of Brenna		Notes	
09-11C	0	888.2	875	-6	882.2	-25	863.2		
09-27C	3400	886.2	875	-5	881.2	-29	857.2		
09-28C	9000	888.4	876	-8	880.4	-30	858.4		
09-30C	15000	892.4	877	-6	886.4	-33	859.4		
09-29C	20100	891	877	-6	885	-38	853		
09-12C	24500	894	878	-2	892	-29.5	864.5		
09-31C	30100	895.8	878	-3	892.8	-26	869.8		
09-35C	35500	902.4	878	-4	898.4	-28	874.4	Questionable	Start Mod #3 at 35500
09-33C	50000	907.3	880	-2	905.3	-32	875.3	Questionable	
09-37C	57100	909.7	880	-2	907.7	-17	892.7	Brenna exposed	
09-38C	62500	907.8	881		907.8	-23	884.8	Brenna exposed	Continue with Mod #3 to 65000
09-14C	67600	913.1	882	-3	910.1	-28	885.1	Sand below	Start Mod #2 at 65000
09-39C	73000	910.5	882		910.5	-17	893.5	Brenna exposed	
09-40C	78700	912.8	883	-3	909.8	-20	892.8	Sand below	Continue with Mod #2 to 81000
09-42C	84100	912.2	884		912.2	-15	897.2	Brenna exposed	Start Mod #3 at 81000
09-43C	90000	912.7	885		912.7	-17	895.7	Brenna exposed	
09-15C	95000	914.9	886	-3.5	911.4	-14.5	900.4	Brenna exposed	
09-44C	100000	915.8	887		915.8	-15	900.8	Brenna exposed	
09-45C	108000	920.4	888		920.4	-19	901.4	Brenna exposed	
09-46C	114000	916.5	890		916.5	-18	898.5	Brenna exposed	
09-48C	120000	912.7	891		912.7	-20	892.7	Brenna exposed	Continue with Mod #3 to 125000
09-50C	130250	913.4	893		913.4	-26	887.4		
09-51C	133000	911.8	893		911.8	-25	886.8		

File Name: revFMMFS_ED_02_Steps.gsz

Fargo-Moorhead Metro Feasibility Study Diversion Channel Stability (500') Cross-Section 2 Seepage Analysis

Soil Properties			
Name: Fill Model: Saturated / Unsaturated K-Function: Sherack Vol. WC. Function: Sherack K-Ratio: 1 K-Direction: 0°	Name: Sherack Model: Saturated / Unsaturated K-Function: Sherack Vol. WC. Function: Sherack K-Ratio: 1 K-Direction: 0°	Name: Argusville Model: Saturated Only K-Sat: 3.28e-008 ft/sec Volumetric Water Content: 0.59 H ₂ O M _r : 0.97 K-Ratio: 1 K-Direction: 0°	Name: Sand Model: Saturated Only K-Sat: 1e-006 ft/sec Volumetric Water Content: 0.16 H ₂ O M _r : 0.97 K-Ratio: 1 K-Direction: 0°
Name: HL Sherack Model: Saturated / Unsaturated K-Function: Sherack Vol. WC. Function: Sherack K-Ratio: 1 K-Direction: 0°	Name: Brenna Model: Saturated / Unsaturated K-Function: Brenna Vol. WC. Function: Brenna K-Ratio: 1 K-Direction: 0°	Name: Tilt Model: Saturated Only K-Sat: 2.83e-009 ft/sec Volumetric Water Content: 0.3 H ₂ O M _r : 0.97 K-Ratio: 1 K-Direction: 0°	

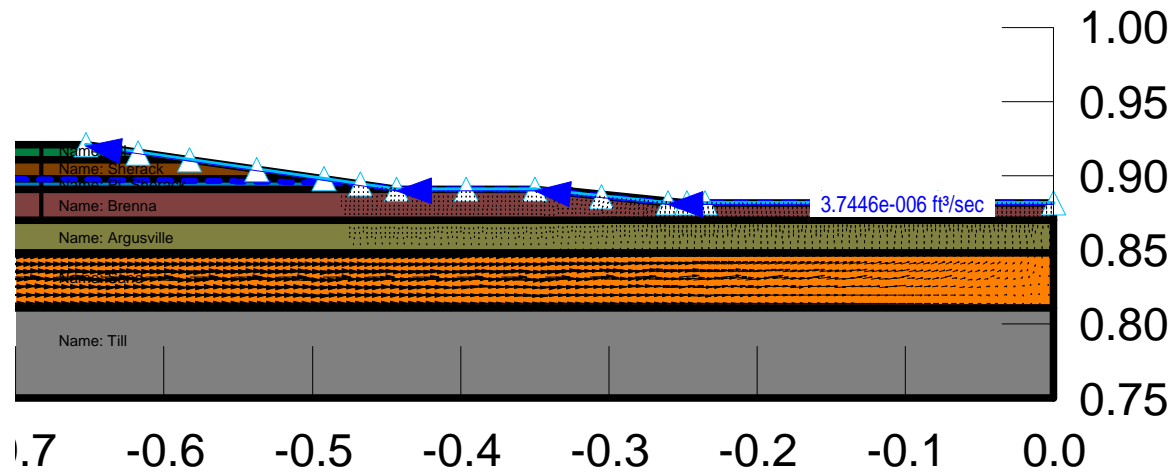


Created By: Heckendorf, Kurt A MVP
Last Edited By: Heckendorf, Kurt A MVP
Date: 12/28/2009

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Soil Properties

Name: Fill Model: Saturated / Unsaturated K-Function: Sherack Vol. WC. Function: Sherack K-Ratio: 1 K-Direction: 0 °	Name: Sherack Model: Saturated / Unsaturated K-Function: Sherack Vol. WC. Function: Sherack K-Ratio: 1 K-Direction: 0 °	Name: Argusville Model: Saturated Only K-Sat: 3.28e-008 ft/sec Volumetric Water Content: 0.59 ft ³ /ft ³ Mv: 0 /psf K-Ratio: 1 K-Direction: 0 °	Name: Sand Model: Saturated Only K-Sat: 1e-005 ft/sec Volumetric Water Content: 0.16 ft ³ /ft ³ Mv: 0 /psf K-Ratio: 1 K-Direction: 0 °	Name: Till Model: Saturated K-Sat: 2.63e-009 Volumetric Water Mv: 0 /psf K-Ratio: 1 K-Direction: 0 °
Name: PL Sherack Model: Saturated / Unsaturated K-Function: Sherack Vol. WC. Function: Sherack K-Ratio: 1 K-Direction: 0 °	Name: Brenna Model: Saturated / Unsaturated K-Function: Brenna Vol. WC. Function: Brenna K-Ratio: 1 K-Direction: 0 °			



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Soil Properties

Name: Fill
Model: Mohr-Coulomb
Unit Weight: 118 pcf
Cohesion: 0 psf
Phi: 28 °
Phi-B: 0 °

Name: Sherack
Model: Mohr-Coulomb
Unit Weight: 118 pcf
Cohesion: 0 psf
Phi: 28 °
Phi-B: 0 °

Name: Argusville
Model: Mohr-Coulomb
Unit Weight: 106 pcf
Cohesion: 0 psf
Phi: 15 °
Phi-B: 0 °

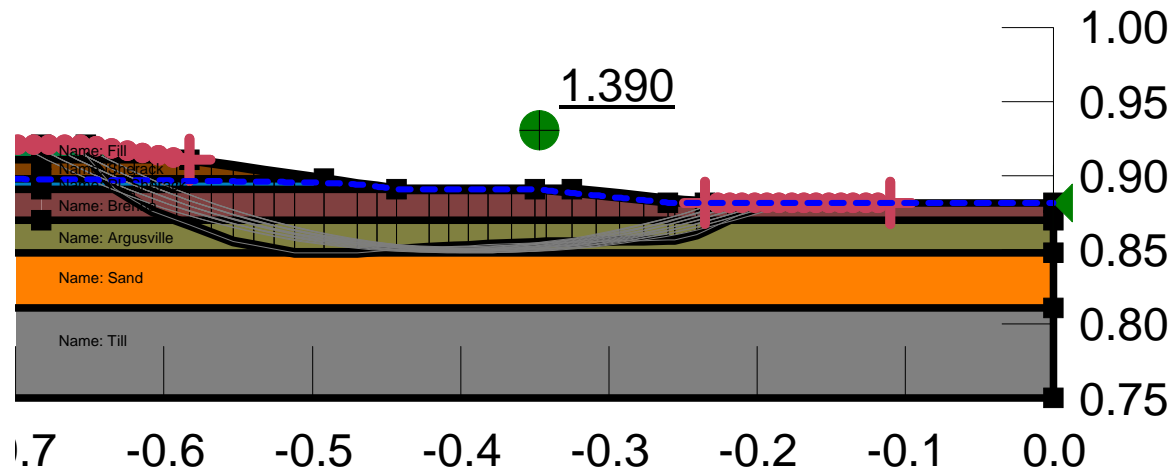
Name: Riprap
Model: Mohr-Coul
Unit Weight: 125 pcf
Cohesion: 0 psf
Phi: 30 °
Phi-B: 0 °

Name: PL Sherack
Model: Mohr-Coulomb
Unit Weight: 112 pcf
Cohesion: 0 psf
Phi: 19 °
Phi-B: 0 °

Name: Brenna
Model: Mohr-Coulomb
Unit Weight: 103 pcf
Cohesion: 0 psf
Phi: 13 °
Phi-B: 0 °

Name: Sand
Model: Mohr-Coulomb
Unit Weight: 128 pcf
Cohesion: 0 psf
Phi: 30 °
Phi-B: 0 °

Name: Till
Model: Mohr-Coul
Unit Weight: 122 pcf
Cohesion: 0 psf
Phi: 31 °
Phi-B: 0 °



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Soil Properties

Name: Fill
Model: Mohr-Coulomb
Unit Weight: 118 pcf
Cohesion: 0 psf
Phi: 28 °
Phi-B: 0 °

Name: Sherack
Model: Mohr-Coulomb
Unit Weight: 118 pcf
Cohesion: 0 psf
Phi: 28 °
Phi-B: 0 °

Name: Argusville
Model: Mohr-Coulomb
Unit Weight: 106 pcf
Cohesion: 0 psf
Phi: 15 °
Phi-B: 0 °

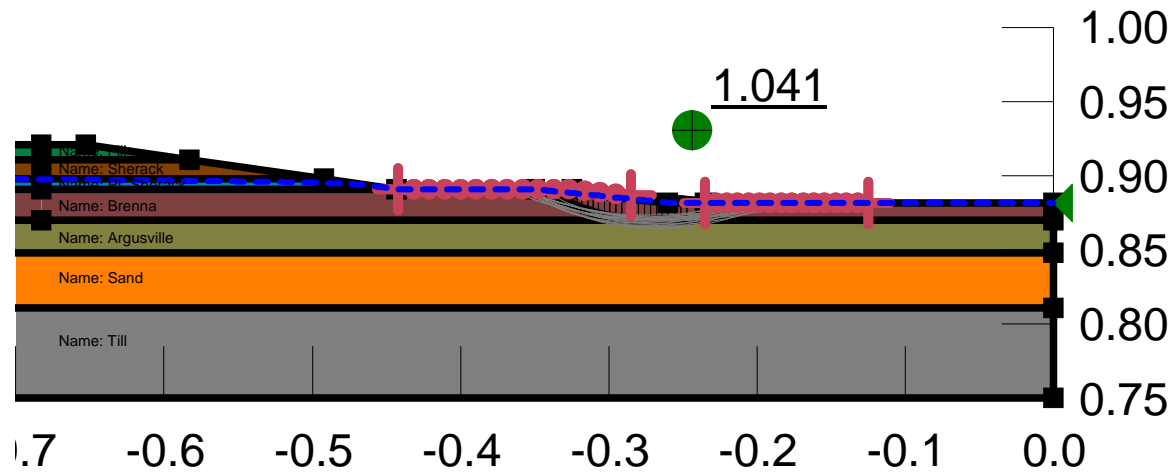
Name: Riprap
Model: Mohr-Coul
Unit Weight: 125 pcf
Cohesion: 0 psf
Phi: 30 °
Phi-B: 0 °

Name: PL Sherack
Model: Mohr-Coulomb
Unit Weight: 112 pcf
Cohesion: 0 psf
Phi: 19 °
Phi-B: 0 °

Name: Brenna
Model: Mohr-Coulomb
Unit Weight: 103 pcf
Cohesion: 0 psf
Phi: 13 °
Phi-B: 0 °

Name: Sand
Model: Mohr-Coulomb
Unit Weight: 128 pcf
Cohesion: 0 psf
Phi: 30 °
Phi-B: 0 °

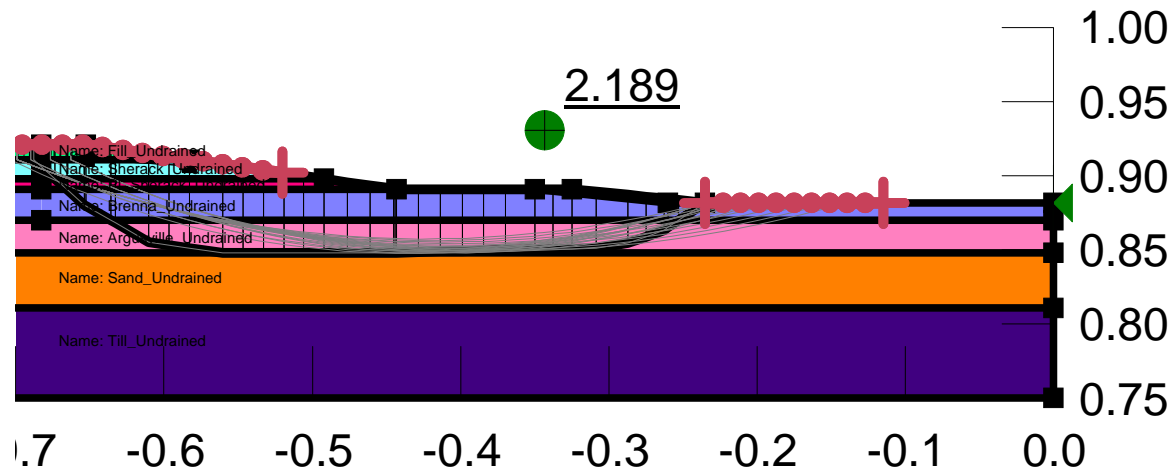
Name: Till
Model: Mohr-Coul
Unit Weight: 122 pcf
Cohesion: 0 psf
Phi: 31 °
Phi-B: 0 °



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Soil Properties

Name: Fill_Undrained Model: Undrained (Phi=0) Unit Weight: 118 pcf Cohesion: 1400 psf	Name: Sherack_Undrained Model: Undrained (Phi=0) Unit Weight: 118 pcf Cohesion: 1400 psf	Name: Argusville_Undrained Model: Undrained (Phi=0) Unit Weight: 106 pcf Cohesion: 825 psf	Name: Riprap Model: Mohr-Coul Unit Weight: 125 pcf Cohesion: 0 psf Phi: 30 ° Phi-B: 0 °
Name: PL Sherack_Undrained Model: Undrained (Phi=0) Unit Weight: 112 pcf Cohesion: 1150 psf	Name: Brenna_Undrained Model: Undrained (Phi=0) Unit Weight: 103 pcf Cohesion: 650 psf	Name: Sand_Undrained Model: Mohr-Coulomb Unit Weight: 128 pcf Cohesion: 0 psf Phi: 30 ° Phi-B: 0 °	Name: Till_Undrained Model: Undrained Unit Weight: 122 pcf Cohesion: 1900 pcf

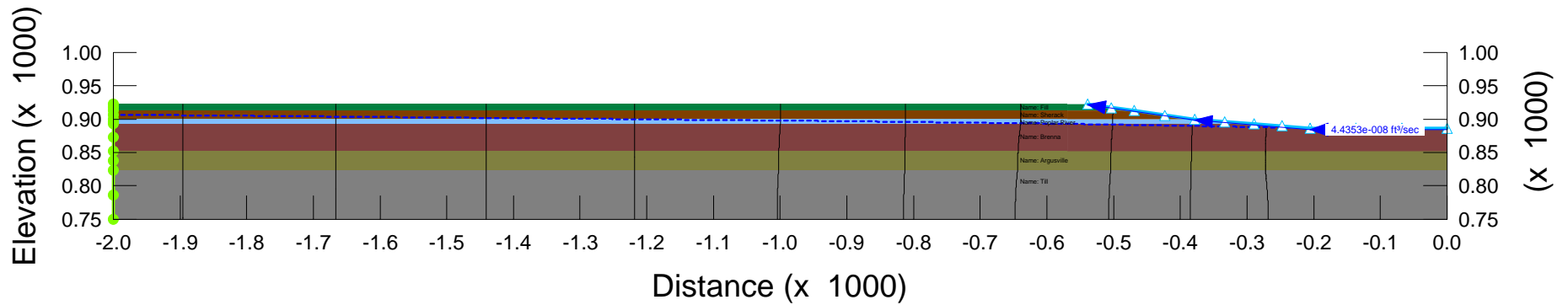


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Fargo-Moorhead Metro Feasibility Study Diversion Channel Stability (500') Cross-Section 3 Seepage Analysis

Soil Properties

Name: Fill Model: Saturated / Unsaturated K-Function: Sherack Vol. WC: Function: Sherack K-Ratio: 1 K-Direction: 0*	Name: Poplar River Model: Saturated / Unsaturated K-Function: Poplar River Vol. WC: Function: Poplar River K-Ratio: 1 K-Direction: 0*	Name: Argusville Model: Saturated Only K-Sat: 2.28e-008 ft/sec Volumetric Water Content: 0.59 H ₂ O M _v : 0 ipsl K-Ratio: 1 K-Direction: 0*
Name: Sherack Model: Saturated / Unsaturated K-Function: Sherack Vol. WC: Function: Sherack K-Ratio: 1 K-Direction: 0*	Name: Brenna Model: Saturated / Unsaturated K-Function: Brenna Vol. WC: Function: Brenna K-Ratio: 1 K-Direction: 0*	Name: Till Model: Saturated Only K-Sat: 2.63e-009 ft/sec Volumetric Water Content: 0.3 H ₂ O M _v : 0 ipsl K-Ratio: 1 K-Direction: 0*



Created By: Heckendorf, Kurt A MVP
Last Edited By: Heckendorf, Kurt A MVP
Date: 12/28/2009

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Soil Properties

Name: Fill
Model: Saturated / Unsaturated
K-Function: Sherack
Vol. WC. Function: Sherack
K-Ratio: 1
K-Direction: 0 °

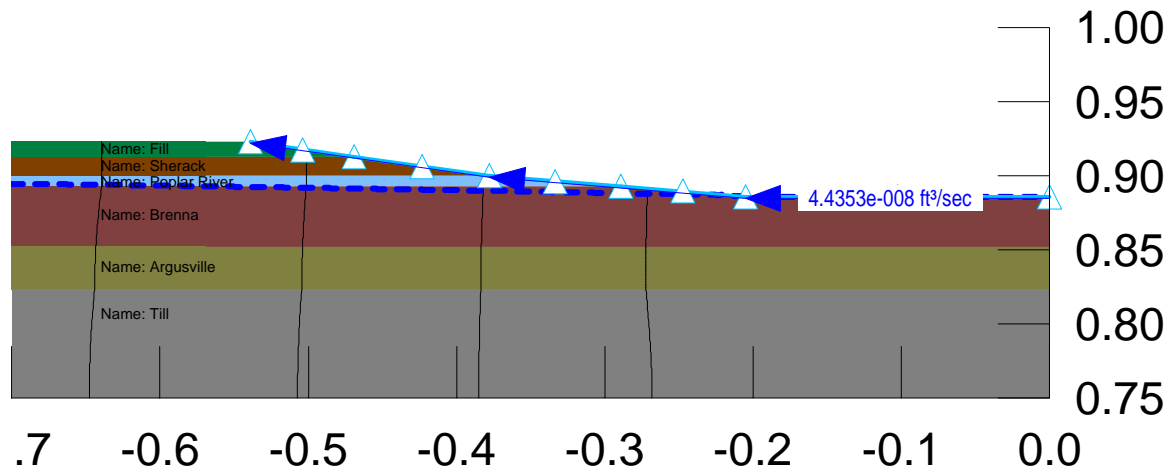
Name: Poplar River
Model: Saturated / Unsaturated
K-Function: Poplar River
Vol. WC. Function: Poplar River
K-Ratio: 1
K-Direction: 0 °

Name: Argusville
Model: Saturated Or
K-Sat: 3.28e-008 ft/s
Volumetric Water Cc
Mv: 0 /psf
K-Ratio: 1
K-Direction: 0 °

Name: Sherack
Model: Saturated / Unsaturated
K-Function: Sherack
Vol. WC. Function: Sherack
K-Ratio: 1
K-Direction: 0 °

Name: Brenna
Model: Saturated / Unsaturated
K-Function: Brenna
Vol. WC. Function: Brenna
K-Ratio: 1
K-Direction: 0 °

Name: Till
Model: Saturated Or
K-Sat: 2.63e-009 ft/s
Volumetric Water Cc
Mv: 0 /psf
K-Ratio: 1
K-Direction: 0 °



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Soil Properties

Name: Fill
Model: Mohr-Coulomb
Unit Weight: 118 pcf
Cohesion: 0 psf
Phi: 28 °
Phi-B: 0 °

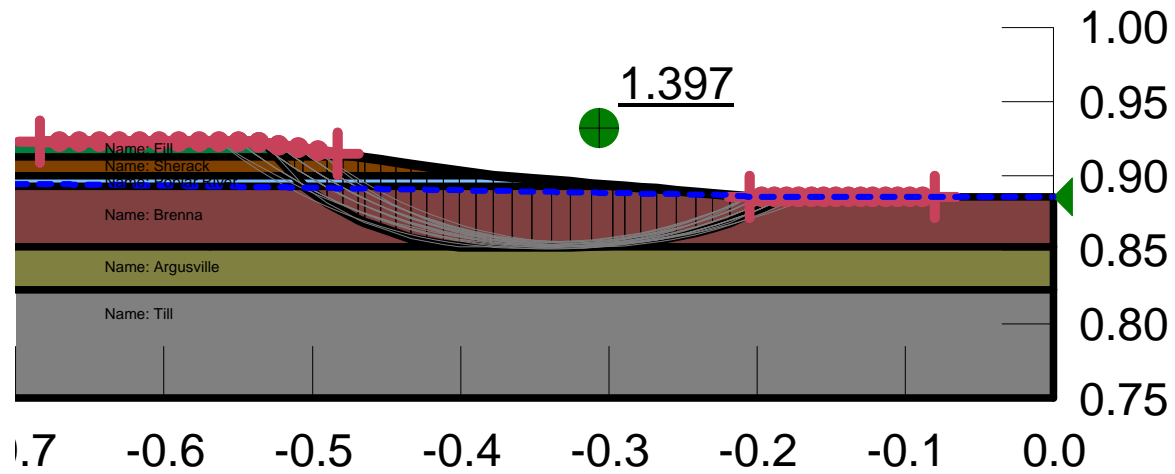
Name: Poplar River
Model: Mohr-Coulomb
Unit Weight: 116 pcf
Cohesion: 0 psf
Phi: 26 °
Phi-B: 0 °

Name: Argusville
Model: Mohr-Coulomb
Unit Weight: 106 pcf
Cohesion: 0 psf
Phi: 15 °
Phi-B: 0 °

Name: Sherack
Model: Mohr-Coulomb
Unit Weight: 118 pcf
Cohesion: 0 psf
Phi: 28 °
Phi-B: 0 °

Name: Brenna
Model: Mohr-Coulomb
Unit Weight: 103 pcf
Cohesion: 0 psf
Phi: 13 °
Phi-B: 0 °

Name: Till
Model: Mohr-Coulomb
Unit Weight: 122 pcf
Cohesion: 0 psf
Phi: 31 °
Phi-B: 0 °



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Soil Properties

Name: Fill
Model: Mohr-Coulomb
Unit Weight: 118 pcf
Cohesion: 0 psf
Phi: 28 °
Phi-B: 0 °

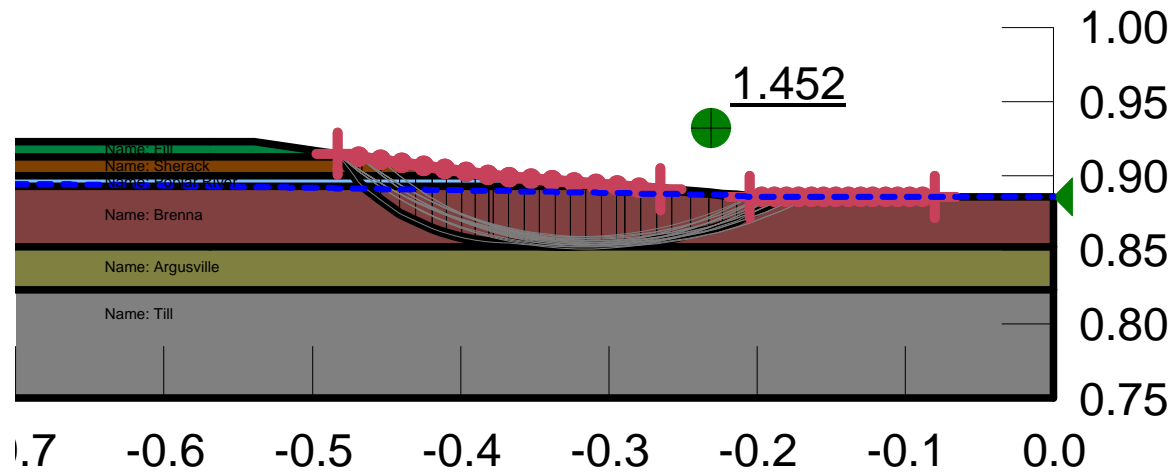
Name: Poplar River
Model: Mohr-Coulomb
Unit Weight: 116 pcf
Cohesion: 0 psf
Phi: 26 °
Phi-B: 0 °

Name: Argusville
Model: Mohr-Coulomb
Unit Weight: 106 pcf
Cohesion: 0 psf
Phi: 15 °
Phi-B: 0 °

Name: Sherack
Model: Mohr-Coulomb
Unit Weight: 118 pcf
Cohesion: 0 psf
Phi: 28 °
Phi-B: 0 °

Name: Brenna
Model: Mohr-Coulomb
Unit Weight: 103 pcf
Cohesion: 0 psf
Phi: 13 °
Phi-B: 0 °

Name: Till
Model: Mohr-Coulomb
Unit Weight: 122 pcf
Cohesion: 0 psf
Phi: 31 °
Phi-B: 0 °



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Soil Properties

Name: Fill_Undrained
Model: Undrained (Phi=0)
Unit Weight: 118 pcf
Cohesion: 1400 psf

Name: Poplar River_Undrained
Model: Undrained (Phi=0)
Unit Weight: 116 pcf
Cohesion: 1450 psf

Name: Argusville_Ui
Model: Undrained (F
Unit Weight: 106 pcf
Cohesion: 825 psf

Name: Sherack_Undrained
Model: Undrained (Phi=0)
Unit Weight: 118 pcf
Cohesion: 1400 psf

Name: Brenna_Undrained
Model: Undrained (Phi=0)
Unit Weight: 103 pcf
Cohesion: 650 psf

Name: Till_Undraine
Model: Undrained (F
Unit Weight: 122 pcf
Cohesion: 1900 psf

