SHEYENE AQUADUCT STRUCTURE

Client Name:	**U.S. ARMY CORPS OF ENGINEERS**	**Design By:**	**MBI**
Project Name:	**FARGO – MOORHEAD METRO FLOOD RISK MANAGEMENT PROJECT, FEASIBILITY STUDY, PHASE 4**	**Review By:**	
Work Describtion:	**Sheyenne Aquaduct Structure - Retaining Walls**	**Date:**	**2/10/2011**
	Panel F	**Job #:**	**34091004**
File Path:	P:\Mpls\34 ND\09\34091004 Fargo Moorhead Metropolitan Feas. Study\WorkFiles_Phase4\070 Structural\Aqueducts\Sheyene\[34091004 PH4 Sheyene Retaining Walls Panel F.xlsx]Load Cases		
REF.	**1**		
	2		

ID#	**Case 1**	**Case 2**	**Case 3**	**Case 4**	**Case 5**	**Case 6**
Name	100 yr. flood	100 yr. flood + ice	500 yr. flood	T.O. Levee	Normal flow + ice	Construction
Load Category	Usual	Unusual	Unusual	Extreme	Usual	Unusual
Tributary - Water El. (ft)	914.56	914.56	914.67	917.5	903.24	**NA**
Diversion - Head Water El. (ft)	902.12	902.12	903.32	917.5	**NA**	**NA**
Diversion - Tail Water El. (ft)	901.91	901.91	903.06	917.5	**NA**	**NA**
Tributary - T.O. Wall El. (ft)	917.5					
Tributary - T.O. Deck L.P. El.(ft)	898.7					
Tributary - T.O. Deck H.P. El.(ft)	900.7					
Diversion - T.O. Mat El. (ft)	895.68					
Tributary - Deck Slab thickness @ L.P. (ft)	2					
Tributary - Deck Slab thickness @ H.P. (ft)	4					
Diversion - Mat Slab thickness (ft)	4					
Tibutary - Water height (ft)	**15.86**	**15.86**	**15.97**	**18.8**	**4.54**	**NA**
Diversion - Head Water height (ft)	**6.44**	**6.44**	**7.64**	**21.82**	**NA**	**NA**
Ice	**NA**	2ft Ice	**NA**	**NA**	2ft Ice	**NA**
Ice Load	**NA**	10 kips/ft	**NA**	**NA**	10 kips/ft	**NA**
Ice Laod El. (ft)	**NA**	**914.56**	**NA**	**NA**	**903.24**	**NA**
Uplift @ HW (ft)	**10.44**	**10.44**	**11.64**	**25.82**	**NA**	**NA**
Uplift @ TW (ft)	**10.23**	**10.23**	**11.38**	**25.82**	**NA**	**NA**
Pile Condition	**Undrained**	**Undrained**	**Undrained**	**Undrained**	**Drained**	**Undrained**
Load Category	**Usual**	**Unusual**	**Unusual**	**Extreme**	**Usual**	**Unusual**
Safety Factors	2	1.5	1.5	1.15	2	1.5
Allwable Lateral Capacity (tons)	**18**	**20.5**	**20.5**	**24**	**11.5**	**20.5**
Allowable Pile Capacity (tons) - Axial	**61.95**	**82.60**	**82.60**	**107.74**	**36.525**	**82.60**
Allowable Pile Capacity (tons) - Uplift	**38.65**	**51.53**	**51.53**	**67.22**	**5.9**	**51.53**

Pile Capacity	**Ultimate Axial Capacity (kips)**	**Allowable Lateral Capacity (kips)**		
		0.5" (Usual)	**0.67" (Unusual)**	**0.875" (Extreme)**
Undrained - Axial	247.8	36	41	48
Undrained - Uplift	154.6			
Drained - Axial	146.1	23	29	36
Drained - Uplift	23.6			

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COMPUTED	CHECKED	SUBMITTED	PROJECT NUMBER	34091004		
MBI 2/11/11		MBI	SUBJECT	Sheyenne Aquaduct Structure - Retaining Walls Panel F		

Monolith Structure

ITEM		UNIT	QUANITY	UNIT COST	TOTAL Cost
FURNISH HP14x73 WALL PILING		LF	2,000	0	$0
INSTALL HP14x73 WALL PILING		LF	2,000	0	$0
PILE TEST, 60.0 ft	Long	EA	2	0	$0
FOOTING CONCRETE		CY	236	0	$0
	Forming	SF	757		
STEM CONCRETE		CY	217	0	$0
	Forming	SF	3,134		
STEEL REINFORCEMENT		LB	90,362	0	$0
WALL RAILING		LF	67	0	$0
SHEET PILE CUT-OFF WALL		SF	1,340	0	$0
					$0

Structure Length = 67 ft

No. piles = 40 Each

Length = 50 ft

Note: HP14x73 pile used for design, use HP14x73 to allow for corrosion

LENGTH

(FRONT & Back FACE) 10 FT

Native Soil has low permeability assume cut-off minimal to prevent scour

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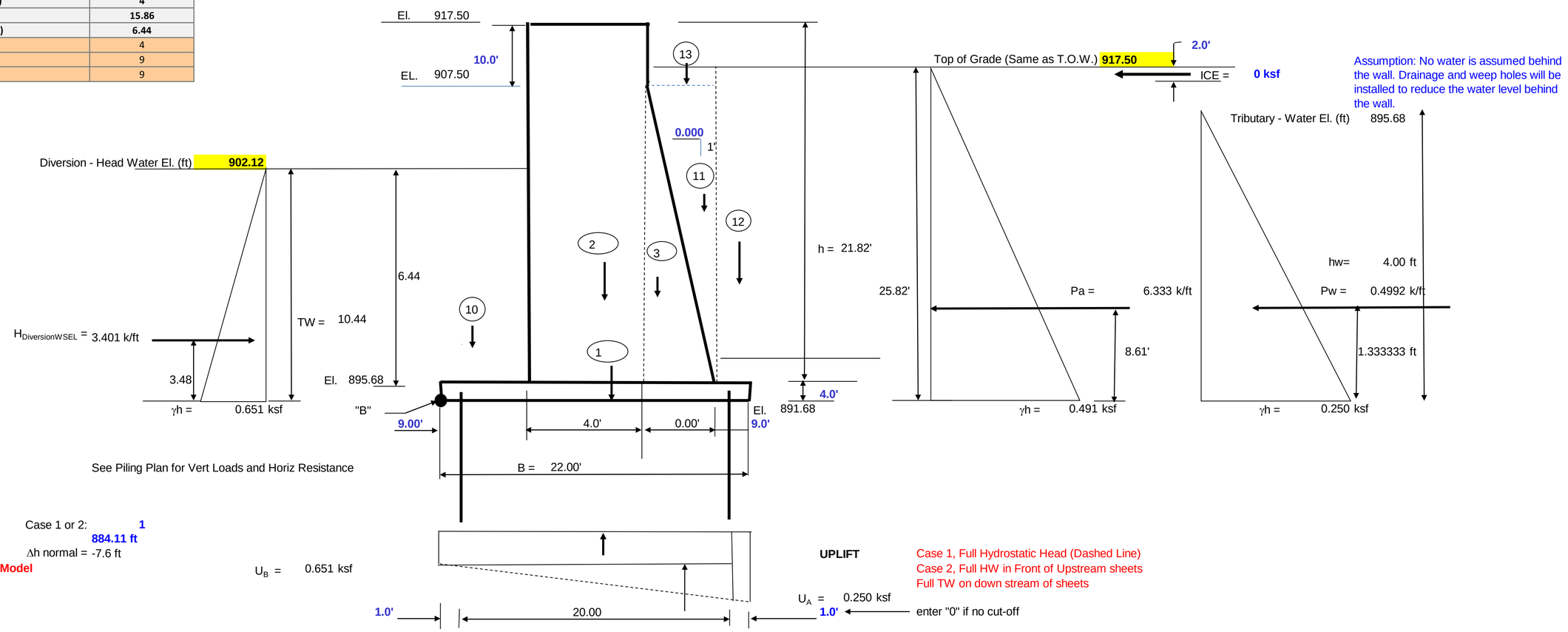
MBI 2/11/11		MBI	SUBJECT	Sheyenne Aquaduct Structure - Retaining Walls	
				Load Cases: Case 1 100 yr. flood	Panel F

ID#	Case 1
Name	100 yr. flood
Load Category	Usual
Tributary - Water El. (ft)	914.56
Diversion - Head Water El. (ft)	902.12
Diversion - Tail Water El. (ft)	901.91
Tributary - T.O. Wall El. (ft)	917.5
Tributary - T.O. Deck L.P. El.(ft)	898.7
Tributary - T.O. Deck H.P. El.(ft)	900.7
Diversion - T.O. Mat El. (ft)	895.68
Tributary - Deck Slab thickness @ L.P. (ft)	2
Tributary - Deck Slab thickness @ H.P. (ft)	4
Diversion - Mat Slab thickness (ft)	4
Tibutary - Water height (ft)	15.86
Diversion - Head Water height (ft)	6.44
Wall Thickness (ft)	4
Toe (Ft)	9
Heel (ft)	9

File:

MN State Building Codes
Frost Depth = **5.0 ft** provide min frost ftg protection during Dec, Jan, Feb, March
Water El. = **903.24 ft** DEC, JAN, FEB Mean Water Elevation

Non-Overflow Section **Length = 67.0 ft**
Stepped Ftg Ls = **2.0 ft** overlap distance at stepped ftg



See Piling Plan for Vert Loads and Horiz Resistance

Case 1 or 2: **1**
Normal Water Level, El. **884.11 ft**
Δh normal = -7.6 ft
See Geotechnical seepage Model

U_B = 0.651 ksf

UPLIFT
U_A = 0.250 ksf
1.0' ← enter "0" if no cut-off

Case 1, Full Hydrostatic Head (Dashed Line)
Case 2, Full HW in Front of Upstream sheets
Full TW on down stream of sheets

Vertical Loads	Section	L ft	W ft	H ft	γ kcf	shape	V K	arm ft	Mv ft-k
Ftg concrete	1	67	22.00	4.00	0.15	rec	884.4	11.00	9,728.4
Stem	2	67	4.00	21.82	0.15	rec	877.2	11.00	9,648.8
Batter	3	67	0.00	11.82	0.15	tri	0.0	13.00	0.0
					D.L. Concrete	ΣVc =	**1761.6**	ΣM_V =	**19,377.2**
T.W on ftg Stem	10	67	9.00	6.44	0.0624	rec	242.3	4.50	1,090.4
H.W. on Stem Slope	11	67	0.00	11.82	0.12	tri	0.0	13.00	0.0
H.W. Above Slope	13	67	0.00	10.00	0.12	rec	0.0	13.00	0.0
Soil on Footing	12s	67	9.00	21.82	0.0626	rec	823.7	17.50	14,414.0
H.W. on Footing	12w	67	9.00	0.00	0.0624	rec	0.0	17.50	0.0
					D.L. Water	ΣVw =	**1066.0**	ΣM_V =	**15,504.4**

← CONSTANT FOR ALL LOAD CASES

Uplift Loads		L ft	W ft	Pressure ksf		U K	arm ft	Mu ft-k
	U_B	67	22.00	0.651	rec	-960.2	11.00	-10,563
	U_A	67	22.00	-0.402	tri	296.2	14.67	4,344
					ΣU =	**-664.1**	ΣM_U =	**-6,219**

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MBI 2/11/11		MBI	SUBJECT	Sheyenne Aquaduct Structure - Retaining Walls	
				Load Cases: Case 1 100 yr. flood — Panel F	

Horizontal Loads

	L	H	Pressure		ICE	arm	Mu
	ft	ft	ksf		K	ft	ft-k
ICE	67	2.00	0.00	rec	0.0	24.82	0.0

	L	Force		H	arm	Mw
	ft	k/ft		K	ft	ft-k
SOIL	67	-6.333		-424.34	8.61	-3652.13
Water Loads						
H_{TW}	67	3.401	tri	227.84	3.48	792.88
H_{HW}	67	-0.499	tri	-33.45	1.33	-44.60
			ΣWater =	**194.39**	ΣM_W =	**-2903.8**

Overturning Moments	$\Sigma M_{OT} = M_U + M_W + M_{ICE}$ =	-9123	kip-ft
Resisting Moments	$\Sigma M_R = M_V$ =	34882	kip-ft
Sum of Moments	$\Sigma Mnet = M_R + M_{OT}$ =	**25,759**	kip-ft
Sum of Vertical Forces	P = Conc + Water + Uplift =	**2,163**	kips
Sum of Horizontal Forces	H = Σhorizontal	**-230**	kips

Location of Resultant	Xr = ΣM / P =	11.91	ft from Toe
	e = B/2 - Xr =	(0.91)	ft
	B/6 =	3.667	ft

CONCRETE QUANTITIES

			forming	
Ftg conc:	225	cy (includes stepped)	757	sf
Stem Conc:	217	cy	3134	sf
Total =	441			

STEEL REINFORCEMENT: (assumed)

		Bar #	Spacing		Length	# of bars	Total wt		
a) Footing			in	LB /ft	ft	ea	lb		
Top mat	Transverse:	9	6	3.40	21.5	138	10,088		
	Longitudinal:	9	6	3.40	68.5	44	10,248		
Bot mat	Transverse:	9	6	3.40	21.5	138	10,088		
	Longitudinal:	9	6	3.40	68.5	44	10,248		
								cy	**LB/cy**
							40,671	225	180.848419
b) Skin Reinf. On Monolith									
Vert Face	Vertical	9	6	3.40	21.32	134	9,713	19,426.78	
	Longitudinal:	9	6	3.40	66.5	43	9,722	19,444.60	
Top Face	Transverse:	9	6	3.40	3.5	134	1,595		
	Longitudinal:	9	6	3.40	66.5	8	1,809		
Dowels	Vertical I.F.	9	6	3.40	21.3	134	9,713		
	Vertical O.F.	9	6	3.40	21.3	134	9,713		
								cy	**LB/cy**
							42,266	217	195.1479972
						Σ =	**82,937**		
	Lap Splices (long. Bars)	9		3.40	8	273	7,426		
						Σ Bar Wt=	90,362	lb	

FORCES AT THE BOTTOM OF THE STEM

Diversion Face	H	γ	Pbase	V	arm	Mv
	ft	kcf		K	ft	ft-k
Diversion WSEL	6.44	0.0624	0.401856	1.294	2.147	2.777736
Tributary SEL =	21.82	0.019	0.41458	4.523	7.273	32.89778
Tributary WSEL =	0.00	0.0624	0	0.000	0.000	0
Sum				4.523		32.89778
Net Forces				3.229		30.12004

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MBI 2/11/11		MBI	SUBJECT	Sheyenne Aquaduct Structure - Retaining Walls Load Cases: Case 2 100 yr. flood + ice Panel F	

ID#	Case 2
Name	100 yr. flood + ice
Load Category	Unusual
Tributary - Water El. (ft)	914.56
Diversion - Head Water El. (ft)	902.12
Diversion - Tail Water El. (ft)	901.91
Tributary - T.O. Wall El. (ft)	917.5
Tributary - T.O. Deck L.P. El.(ft)	898.7
Tributary - T.O. Deck H.P. El.(ft)	900.7
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Tributary - Deck Slab thickness @ L.P. (ft)	2
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Diversion - Mat Slab thickness (ft)	4
Tibutary - Water height (ft)	15.86
Diversion - Head Water height (ft)	6.44
Wall Thickness (ft)	4
Toe (Ft)	9
Heel (ft)	9

File:

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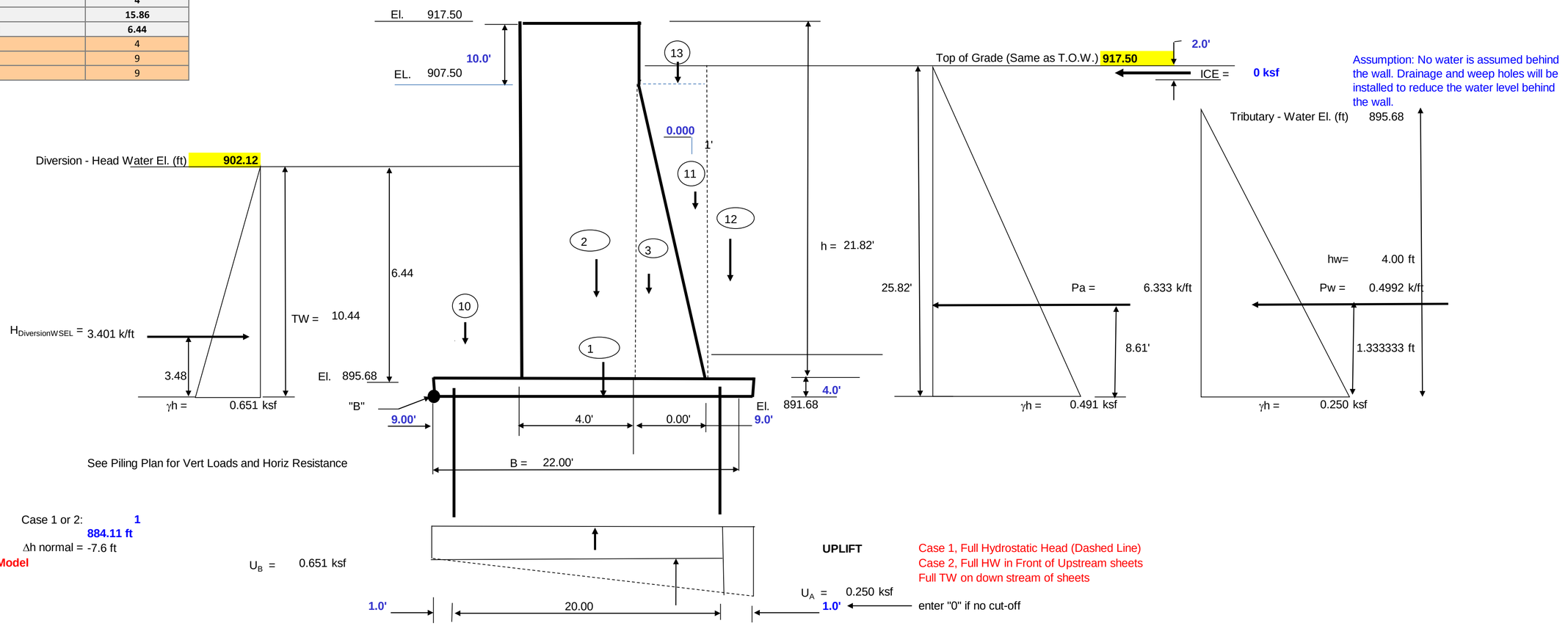
Frost Depth = 5.0 ft provide min frost ftg protection during Dec, Jan, Feb, March
Water El. = 903.24 ft DEC, JAN, FEB Mean Water Elevation

Non-Overflow Section **Length = 67.0 ft**
Stepped Ftg Ls = 2.0 ft overlap distance at stepped ftg



See Piling Plan for Vert Loads and Horiz Resistance

Case 1 or 2: 1
Normal Water Level, El. 884.11 ft
Δh normal = -7.6 ft
See Geotechnical seepage Model

UPLIFT
Case 1, Full Hydrostatic Head (Dashed Line)
Case 2, Full HW in Front of Upstream sheets
Full TW on down stream of sheets
enter "0" if no cut-off

Vertical Loads	Section	L ft	W ft	H ft	γ kcf	shape	V K	arm ft	Mv ft-k
Ftg concrete	1	67	22.00	4.00	0.15	rec	884.4	11.00	9,728.4
Stem	2	67	4.00	21.82	0.15	rec	877.2	11.00	9,648.8
Batter	3	67	0.00	11.82	0.15	tri	0.0	13.00	0.0
					D.L. Concrete	ΣVc =	**1761.6**	ΣM_V =	**19,377.2**

← CONSTANT FOR ALL LOAD CASES

T.W on ftg Stem	10	67	9.00	6.44	0.0624	rec	242.3	4.50	1,090.4
H.W. on Stem Slope	11	67	0.00	11.82	0.12	tri	0.0	13.00	0.0
H.W. Above Slope	13	67	0.00	10.00	0.12	rec	0.0	13.00	0.0
Soil on Footing	12s	67	9.00	21.82	0.0626	rec	823.7	17.50	14,414.0
H.W. on Footing	12w	67	9.00	0.00	0.0624	rec	0.0	17.50	0.0
					D.L. Water	ΣVw =	**1066.0**	ΣM_V =	**15,504.4**

Uplift Loads		L ft	W ft	Pressure ksf		U K	arm ft	Mu ft-k
	U_B	67	22.00	0.651	rec	-960.2	11.00	-10,563
	U_A	67	22.00	-0.402	tri	296.2	14.67	4,344
					ΣU =	**-664.1**	ΣM_U =	**-6,219**

Horizontal Loads	L ft	H ft	Pressure ksf	ICE K	arm ft	Mu ft-k

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				Load Cases: Case 2 100 yr. flood + ice	Panel F

ICE	67	2.00	0.00	rec	0.0	24.82	0.0	
	L		Force		**H**	arm	**Mw**	
	ft		k/ft		K	ft	ft-k	
SOIL	67		-6.333		-424.34	8.61	-3652.13	
Water Loads								
H_{TW}	67		3.401	tri	227.84	3.48	792.88	
H_{HW}	67		-0.499	tri	-33.45	1.33	-44.60	
				ΣWater =	**194.39**	ΣM_W =	**-2903.8**	

Overturning Moments	$\Sigma M_{OT} = M_U + M_W + M_{ICE}$ =	-9123	kip-ft
Resisting Moments	$\Sigma M_R = M_V$ =	34882	kip-ft
Sum of Moments	$\Sigma Mnet = M_R + M_{OT}$ =	**25,759**	kip-ft
Sum of Vertical Forces	P = Conc + Water + Uplift =	**2,163**	kips
Sum of Horizontal Forces	H = Σhorizontal	**-230**	kips

Location of Resultant	Xr = ΣM / P =	11.91	ft from Toe
	e = B/2 - Xr =	(0.91)	ft
	B/6 =	3.667	ft

CONCRETE QUANTITIES

			forming	
Ftg conc:	225	cy (includes stepped)	757	sf
Stem Conc:	217	cy	3134	sf
Total =	441			

STEEL REINFORCEMENT: (assumed)

		Bar #	Spacing		Length	# of bars	Total wt		
a) Footing			in	LB /ft	ft	ea	lb		
Top mat	Transverse:	9	6	3.40	21.5	138	10,088		
	Longitudinal:	9	6	3.40	68.5	44	10,248		
Bot mat	Transverse:	9	6	3.40	21.5	138	10,088		
	Longitudinal:	9	6	3.40	68.5	44	10,248		
								cy	**LB/cy**
							40,671	225	180.848419
b) Skin Reinf. On Monolith									
Vert Face	Vertical	9	6	3.40	21.32	134	9,713	19426.784	
	Longitudinal:	9	6	3.40	66.5	43	9,722	19444.6	
Top Face	Transverse:	9	6	3.40	3.5	134	1,595		
	Longitudinal:	9	6	3.40	66.5	8	1,809		
Dowels	Vertical I.F.	9	6	3.40	21.3	134	9,713		
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								cy	**LB/cy**
							42,266	217	195.1479972
						Σ =	**82,937**		
	Lap Splices (long. Bars)	9		3.40	8	273	7,426		
						Σ Bar Wt=	90,362	lb	

FORCES AT THE BOTTOM OF THE STEM

Diversion Face	H	γ	Pbase	**V**	arm	**Mv**
	ft	kcf		K	ft	ft-k
Diversion WSEL	6.44	**0.0624**	0.401856	1.294	2.147	2.777736
Tributary SEL =	21.82	**0.019**	0.41458	4.523	7.273	32.89778
Tributary WSEL =	0.00	**0.0624**	0	0.000	0.000	0
Sum				4.523		32.89778
Net Forces				3.229		30.12004

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MBI 2/11/11		MBI	SUBJECT	Sheyenne Aquaduct Structure - Retaining Walls Load Cases: Case 3 500 yr. flood Panel F	

ID#	Case 3
Name	500 yr. flood
Load Category	Unusual
Tributary - Water El. (ft)	914.67
Diversion - Head Water El. (ft)	903.32
Diversion - Tail Water El. (ft)	903.06
Tributary - T.O. Wall El. (ft)	917.5
Tributary - T.O. Deck L.P. El.(ft)	898.7
Tributary - T.O. Deck H.P. El.(ft)	900.7
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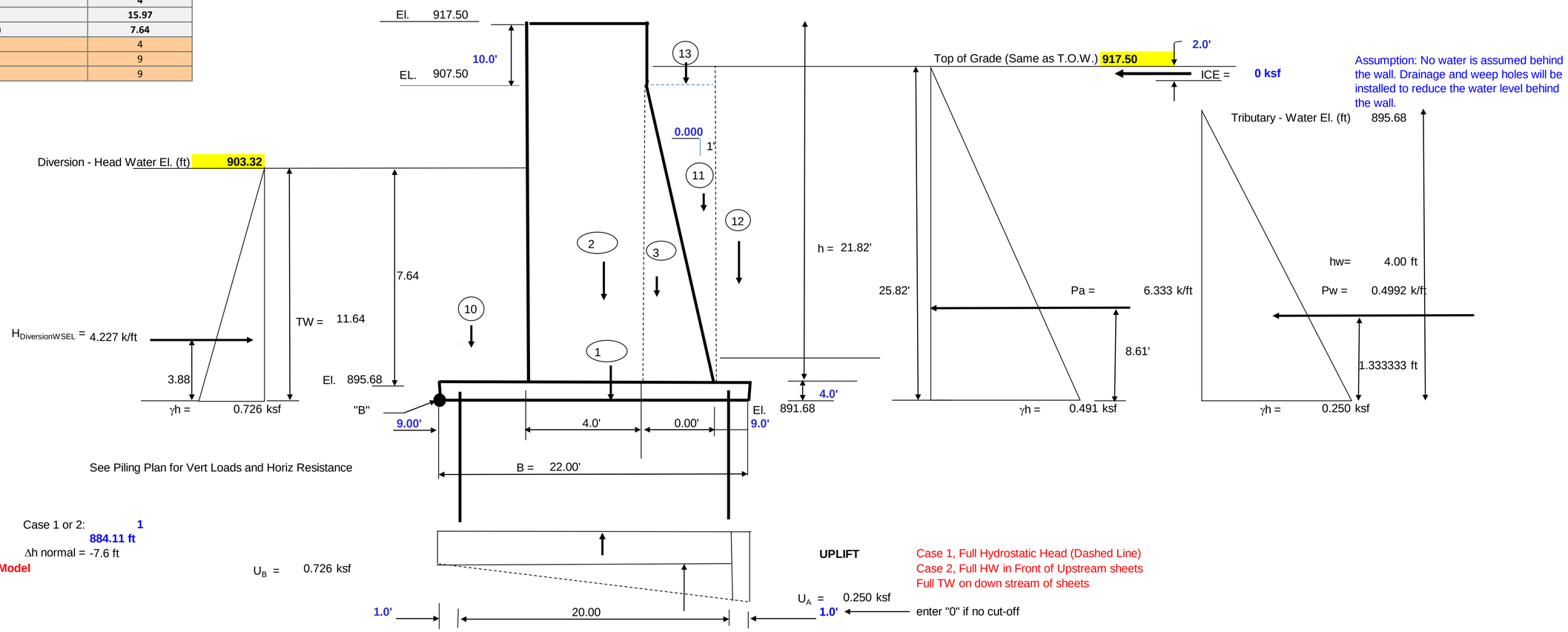
Tributary - Deck Slab thickness @ H.P. (ft)	4
Diversion - Mat Slab thickness (ft)	4
Tibutary - Water height (ft)	15.97
Diversion - Head Water height (ft)	7.64
Wall Thickness (ft)	4
Toe (Ft)	9
Heel (ft)	9

File:

MN State Building Codes
Frost Depth = **5.0 ft** provide min frost ftg protection during Dec, Jan, Feb, March
Water El. = **903.24 ft** DEC, JAN, FEB Mean Water Elevation

Non-Overflow Section **Length = 67.0 ft**
Stepped Ftg Ls = **2.0 ft** overlap distance at stepped ftg



See Piling Plan for Vert Loads and Horiz Resistance

Case 1 or 2: **1**
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Stem	2	67	4.00	21.82	0.15	rec	877.2	11.00	9,648.8
Batter	3	67	0.00	11.82	0.15	tri	0.0	13.00	0.0
					D.L. Concrete	ΣVc =	**1761.6**	ΣM_V =	**19,377.2**
T.W on ftg Stem	10	67	9.00	7.64	0.0624	rec	287.5	4.50	1,293.6
H.W. on Stem Slope	11	67	0.00	11.82	0.12	tri	0.0	13.00	0.0
H.W. Above Slope	13	67	0.00	10.00	0.12	rec	0.0	13.00	0.0
Soil on Footing	12s	67	9.00	21.82	0.0626	rec	823.7	17.50	14,414.0
H.W. on Footing	12w	67	9.00	0.00	0.0624	rec	0.0	17.50	0.0
					D.L. Water	ΣVw =	**1111.1**	ΣM_V =	**15,707.6**

CONSTANT FOR ALL LOAD CASES

Uplift Loads		L ft	W ft	Pressure ksf		U K	arm ft	Mu ft-k
	U_B	67	22.00	0.726	rec	-1070.6	11.00	-11,777
	U_A	67	22.00	-0.477	tri	351.4	14.67	5,153
					ΣU =	**-719.3**	ΣM_U =	**-6,624**

Horizontal Loads		L ft	H ft	Pressure ksf		ICE K	arm ft	Mu ft-k

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			PROJECT NAME	FARGO – MOORHEAD METRO FLOOD RISK MANAGEMENT PROJECT, FEASIBILITY STUDY, PHASE 4	
COMPUTED	CHECKED	SUBMITTED	PROJECT NUMBER	34091004	
MBI 2/11/11		MBI	SUBJECT	Sheyenne Aquaduct Structure - Retaining Walls	
				Load Cases: Case 3 500 yr. flood	Panel F

ICE	67	2.00	0.00	rec	0.0	24.82	0.0	
	L		Force		**H**	arm	**Mw**	
	ft		k/ft		K	ft	ft-k	
SOIL	67		-6.333		-424.34	8.61'	-3652.13	
Water Loads								
H_{TW}	67		4.227	tri	283.23	3.88	1098.92	
H_{HW}	67		-0.499	tri	-33.45	1.33	-44.60	
				ΣWater =	**249.78**	ΣM_W =	**-2597.8**	

Overturning Moments	$\Sigma M_{OT} = M_U + M_W + M_{ICE}$ =	-9221	kip-ft
Resisting Moments	$\Sigma M_R = M_V$ =	35085	kip-ft
Sum of Moments	$\Sigma Mnet = M_R + M_{OT}$ =	**25,863**	kip-ft
Sum of Vertical Forces	P = Conc + Water + Uplift =	**2,153**	kips
Sum of Horizontal Forces	H = Σhorizontal	**-175**	kips

Location of Resultant	Xr = ΣM / P =	12.01	ft from Toe
	e = B/2 - Xr =	(1.01)	ft
	B/6 =	3.667	ft

CONCRETE QUANTITIES

			forming	
Ftg conc:	225	cy (includes stepped)	757	sf
Stem Conc:	217	cy	3134	sf
Total =	441			

STEEL REINFORCEMENT: (assumed)

		Bar #	Spacing in	LB /ft	Length ft	# of bars ea	Total wt lb		
a) Footing									
Top mat	Transverse:	9	6	3.40	21.5	138	10,088		
	Longitudinal:	9	6	3.40	68.5	44	10,248		
Bot mat	Transverse:	9	6	3.40	21.5	138	10,088		
	Longitudinal:	9	6	3.40	68.5	44	10,248		
								cy	**LB/cy**
							40,671	225	180.848419
b) Skin Reinf. On Monolith									
Vert Face	Vertical	9	6	3.40	21.32	134	9,713	19426.784	
	Longitudinal:	9	6	3.40	66.5	43	9,722	19444.6	
Top Face	Transverse:	9	6	3.40	3.5	134	1,595		
	Longitudinal:	9	6	3.40	66.5	8	1,809		
Dowels	Vertical I.F.	9	6	3.40	21.3	134	9,713		
	Vertical O.F.	9	6	3.40	21.3	134	9,713		
								cy	**LB/cy**
							42,266	217	195.1479972
						Σ =	**82,937**		
	Lap Splices (long. Bars)	9		3.40	8	273	7,426		
						Σ Bar Wt=	90,362	lb	

FORCES AT THE BOTTOM OF THE STEM

Diversion Face	H ft	γ kcf	Pbase	**V** K	arm ft	**Mv** ft-k
Diversion WSEL	7.64	**0.0624**	0.476736	1.821	2.547	4.637815
Tributary SEL =	21.82	**0.019**	0.41458	4.523	7.273	32.89778
Tributary WSEL =	0.00	**0.0624**	0	0.000	0.000	0
Sum				4.523		32.89778
Net Forces				2.702		28.25996

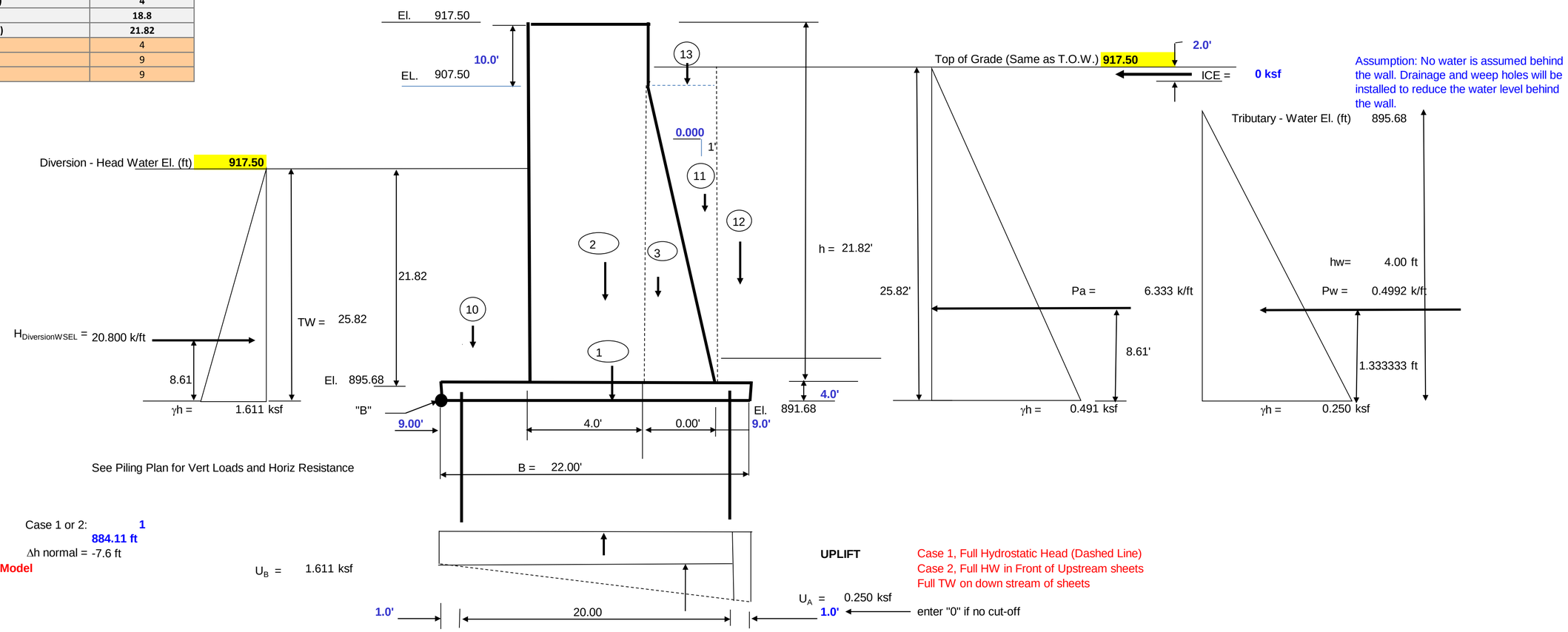
BARR ENGINEERING			DATE	2/11/2011	SHEET NO.
			PROJECT NAME	FARGO – MOORHEAD METRO FLOOD RISK MANAGEMENT PROJECT, FEASIBILITY STUDY, PHASE 4	
COMPUTED	CHECKED	SUBMITTED	PROJECT NUMBER	34091004	
MBI 2/11/11		MBI	SUBJECT	Sheyenne Aquaduct Structure - Retaining Walls	
				Load Cases: Case 4 T.O. Levee Panel F	

ID#	Case 4
Name	T.O. Levee
Load Category	Extreme
Tributary - Water El. (ft)	NA
Diversion - Head Water El. (ft)	917.5
Diversion - Tail Water El. (ft)	917.5
Tributary - T.O. Wall El. (ft)	917.5
Tributary - T.O. Deck L.P. El.(ft)	898.7
Tributary - T.O. Deck H.P. El.(ft)	900.7
Diversion - T.O. Mat El. (ft)	895.68
Tributary - Deck Slab thickness @ L.P. (ft)	2
Tributary - Deck Slab thickness @ H.P. (ft)	4
Diversion - Mat Slab thickness (ft)	4
Tibutary - Water height (ft)	18.8
Diversion - Head Water height (ft)	21.82
Wall Thickness (ft)	4
Toe (Ft)	9
Heel (ft)	9

File:

MN State Building Codes
Frost Depth = **5.0 ft** provide min frost ftg protection during Dec, Jan, Feb, March
Water El. = **903.24 ft** DEC, JAN, FEB Mean Water Elevation

Non-Overflow Section **Length = 67.0 ft**
Stepped Ftg Ls = **2.0 ft** overlap distance at stepped ftg



See Piling Plan for Vert Loads and Horiz Resistance

Case 1 or 2: **1**
Normal Water Level, El. **884.11 ft**
Δh normal = -7.6 ft
See Geotechnical seepage Model

UPLIFT
Case 1, Full Hydrostatic Head (Dashed Line)
Case 2, Full HW in Front of Upstream sheets
Full TW on down stream of sheets
enter "0" if no cut-off

Vertical Loads	Section	L ft	W ft	H ft	γ kcf	shape	V K	arm ft	Mv ft-k
Ftg concrete	1	67	22.00	4.00	0.15	rec	884.4	11.00	9,728.4
Stem	2	67	4.00	21.82	0.15	rec	877.2	11.00	9,648.8
Batter	3	67	0.00	11.82	0.15	tri	0.0	13.00	0.0
					D.L. Concrete	ΣVc =	**1761.6**	ΣM_V =	**19,377.2**
T.W on ftg Stem	10	67	9.00	21.82	0.0624	rec	821.0	4.50	3,694.6
H.W. on Stem Slope	11	67	0.00	11.82	0.12	tri	0.0	13.00	0.0
H.W. Above Slope	13	67	0.00	10.00	0.12	rec	0.0	13.00	0.0
Soil on Footing	12s	67	9.00	21.82	0.0626	rec	823.7	17.50	14,414.0
H.W. on Footing	12w	67	9.00	0.00	0.0624	rec	0.0	17.50	0.0
					D.L. Water	ΣVw =	**1644.7**	ΣM_V =	**18,108.6**

← CONSTANT FOR ALL LOAD CASES

Uplift Loads		L ft	W ft	Pressure ksf		U K	arm ft	Mu ft-k
	U_B	67	22.00	1.611	rec	-2374.9	11.00	-26,123
	U_A	67	22.00	-1.362	tri	1003.5	14.67	14,718
					ΣU =	**-1371.4**	ΣM_U =	**-11,406**

Horizontal Loads	L ft	H ft	Pressure ksf	ICE K	arm ft	Mu ft-k

BARR ENGINEERING			DATE	2/11/2011	SHEET NO.
			PROJECT NAME	FARGO – MOORHEAD METRO FLOOD RISK MANAGEMENT PROJECT, FEASIBILITY STUDY, PHASE 4	
COMPUTED	CHECKED	SUBMITTED	PROJECT NUMBER	34091004	
MBI		MBI	SUBJECT	Sheyenne Aquaduct Structure - Retaining Walls	
2/11/11				Load Cases: Case 4 T.O. Levee Panel F	

ICE	67	2.00	0.00		rec	0.0	24.82	0.0
	L		Force			**H**	arm	**Mw**
	ft		k/ft			K	ft	ft-k
SOIL	67		-6.333			-424.34	8.61'	-3652.13
Water Loads								
H_{TW}	67		20.800		tri	1393.61	8.61	11994.35
H_{HW}	67		-0.499		tri	-33.45	1.33	-44.60
					ΣWater =	**1360.17**	ΣM_W =	**8297.6**

Overturning Moments	$\Sigma M_{OT} = M_U + M_W + M_{ICE}$ =	-3108	kip-ft
Resisting Moments	$\Sigma M_R = M_V$ =	37486	kip-ft
Sum of Moments	$\Sigma Mnet = M_R + M_{OT}$ =	**34,378**	kip-ft
Sum of Vertical Forces	P = Conc + Water + Uplift =	**2,035**	kips
Sum of Horizontal Forces	H = Σhorizontal	**936**	kips

Location of Resultant	Xr = ΣM / P =	16.89	ft from Toe
	e = B/2 - Xr =	(5.89)	ft
	B/6 =	3.667	ft

CONCRETE QUANTITIES

			forming	
Ftg conc:	225	cy (includes stepped)	757	sf
Stem Conc:	217	cy	3134	sf
Total =	441			

STEEL REINFORCEMENT: (assumed)

		Bar #	Spacing in	LB /ft	Length ft	# of bars ea	Total wt lb		
a) Footing									
Top mat	Transverse:	9	6	3.40	21.5	138	10,088		
	Longitudinal:	9	6	3.40	68.5	44	10,248		
								cy	**LB/cy**
							40,671	225	180.848419
b) Skin Reinf. On Monolith									
Vert Face	Vertical	9	6	3.40	21.32	134	9,713	19426.784	
	Longitudinal:	9	6	3.40	66.5	43	9,722	19444.6	
Top Face	Transverse:	9	6	3.40	3.5	134	1,595		
	Longitudinal:	9	6	3.40	66.5	8	1,809		
Dowels	Vertical I.F.	9	6	3.40	21.3	134	9,713		
	Vertical O.F.	9	6	3.40	21.3	134	9,713		
								cy	**LB/cy**
							42,266	217	195.1479972
						Σ =	**82,937**		
	Lap Splices (long. Bars)	9		3.40	8	273	7,426		
						Σ Bar Wt=	90,362	lb	

FORCES AT THE BOTTOM OF THE STEM

Diversion Face	H ft	γ kcf	Pbase	**V** K	arm ft	**Mv** ft-k
Diversion WSEL	21.82	**0.0624**	1.361568	14.855	7.273	108.0432
Tributary SEL =	21.82	**0.019**	0.41458	4.523	7.273	32.89778
Tributary WSEL =	0.00	**0.0624**	0	0.000	0.000	0
Sum				4.523		32.89778
Net Forces				-10.332		-75.1455

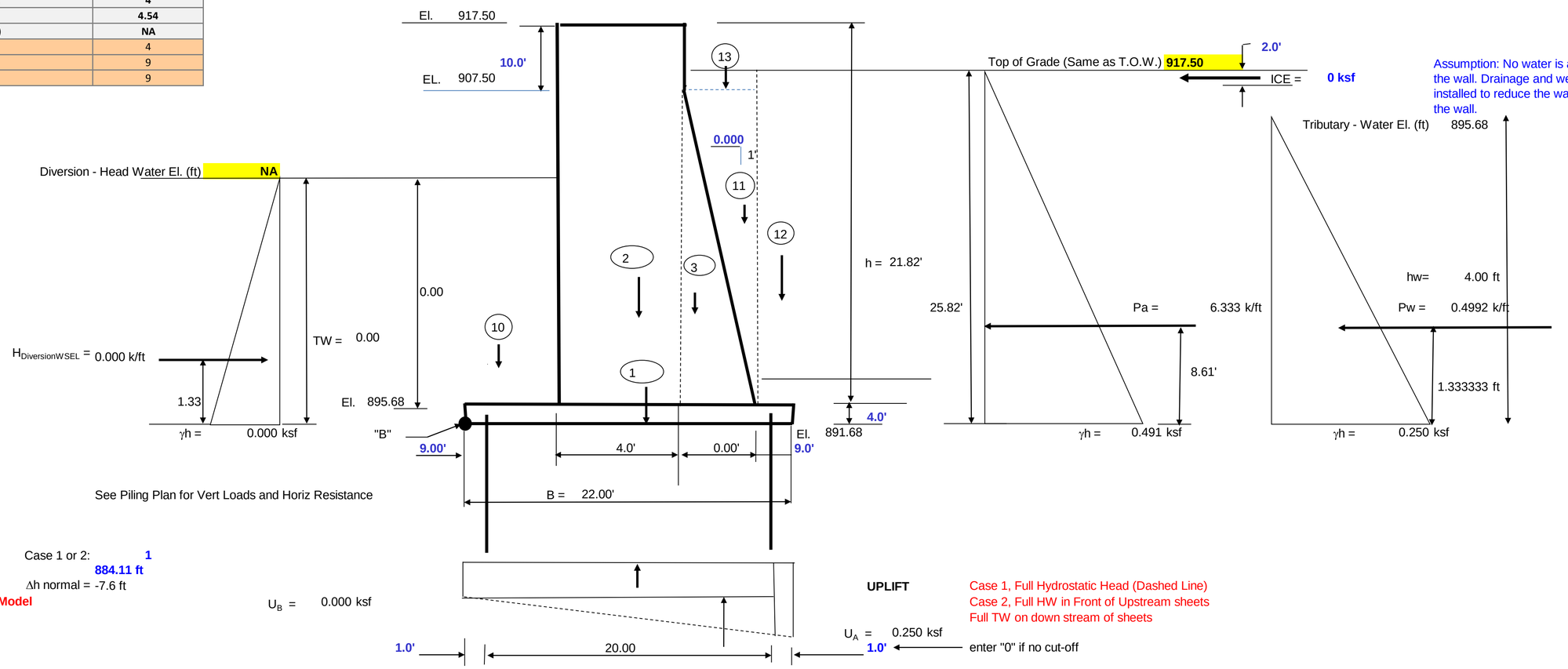
BARR ENGINEERING			DATE	2/11/2011	SHEET NO.
			PROJECT NAME	FARGO – MOORHEAD METRO FLOOD RISK MANAGEMENT PROJECT, FEASIBILITY STUDY, PHASE 4	
COMPUTED	CHECKED	SUBMITTED	PROJECT NUMBER	34091004	
MBI 2/11/11		MBI	SUBJECT	Sheyenne Aquaduct Structure - Retaining Walls Load Cases: Case 5 Normal flow + ice Panel F	

ID#	Case 5
Name	Normal flow + ice
Load Category	Usual
Tributary - Water El. (ft)	903.24
Diversion - Head Water El. (ft)	NA
Diversion - Tail Water El. (ft)	NA
Tributary - T.O. Wall El. (ft)	917.5
Tributary - T.O. Deck L.P. El.(ft)	898.7
Tributary - T.O. Deck H.P. El.(ft)	900.7
Diversion - T.O. Mat El. (ft)	895.68
Tributary - Deck Slab thickness @ L.P. (ft)	2
Tributary - Deck Slab thickness @ H.P. (ft)	4
Diversion - Mat Slab thickness (ft)	4
Tibutary - Water height (ft)	4.54
Diversion - Head Water height (ft)	NA
Wall Thickness (ft)	4
Toe (Ft)	9
Heel (ft)	9

File:

MN State Building Codes
Frost Depth = 5.0 ft provide min frost ftg protection during Dec, Jan, Feb, March
Water El. = 903.24 ft DEC, JAN, FEB Mean Water Elevation

Non-Overflow Section **Length = 67.0 ft**
Stepped Ftg Ls = 2.0 ft overlap distance at stepped ftg



See Piling Plan for Vert Loads and Horiz Resistance

Case 1 or 2: 1
Normal Water Level, El. 884.11 ft
Δh normal = -7.6 ft
See Geotechnical seepage Model

U_B = 0.000 ksf

U_A = 0.250 ksf

UPLIFT
Case 1, Full Hydrostatic Head (Dashed Line)
Case 2, Full HW in Front of Upstream sheets
Full TW on down stream of sheets
enter "0" if no cut-off

Vertical Loads	Section	L ft	W ft	H ft	γ kcf	shape	V K	arm ft	Mv ft-k
Ftg concrete	1	67	22.00	4.00	0.15	rec	884.4	11.00	9,728.4
Stem	2	67	4.00	21.82	0.15	rec	877.2	11.00	9,648.8
Batter	3	67	0.00	11.82	0.15	tri	0.0	13.00	0.0
					D.L. Concrete	ΣVc =	**1761.6**	ΣM_V =	**19,377.2**

CONSTANT FOR ALL LOAD CASES

T.W on ftg Stem	10	67	9.00	0.00	0.0624	rec	0.0	4.50	0.0
H.W. on Stem Slope	11	67	0.00	11.82	0.12	tri	0.0	13.00	0.0
H.W. Above Slope	13	67	0.00	10.00	0.12	rec	0.0	13.00	0.0
Soil on Footing	12s	67	9.00	21.82	0.0626	rec	823.7	17.50	14,414.0
H.W. on Footing	12w	67	9.00	0.00	0.0624	rec	0.0	17.50	0.0
					D.L. Water	ΣVw =	**823.7**	ΣM_V =	**14,414.0**

Uplift Loads		L ft	W ft	Pressure ksf		U K	arm ft	Mu ft-k
	U_B	67	22.00	0.000	rec	0.0	11.00	0
	U_A	67	22.00	0.250	tri	-184.0	14.67	-2,698
					ΣU =	**-184.0**	ΣM_U =	**-2,698**

Horizontal Loads	L ft	H ft	Pressure ksf	ICE K	arm ft	Mu ft-k

BARR ENGINEERING			DATE	2/11/2011	SHEET NO.
			PROJECT NAME	FARGO – MOORHEAD METRO FLOOD RISK MANAGEMENT PROJECT, FEASIBILITY STUDY, PHASE 4	
COMPUTED	CHECKED	SUBMITTED	PROJECT NUMBER	34091004	
MBI		MBI	SUBJECT	Sheyenne Aquaduct Structure - Retaining Walls	
2/11/11				Load Cases: Case 5 Normal flow + ice Panel F	

ICE	67	2.00	0.00	rec	0.0	24.82	0.0	
	L		Force		**H**	arm	**Mw**	
	ft		k/ft		K	ft	ft-k	
SOIL	67		-6.333		-424.34	8.61'	-3652.13	
Water Loads								
H_{TW}	67		0.000	tri	0.00	1.33	0.00	
H_{HW}	67		-0.499	tri	-33.45	0.00	0.00	
				ΣWater =	**-33.45**	ΣM_W =	**-3652.1**	

Overturning Moments	$\Sigma M_{OT} = M_U + M_W + M_{ICE}$ =	-6350	kip-ft
Resisting Moments	$\Sigma M_R = M_V$ =	33791	kip-ft
Sum of Moments	$\Sigma Mnet = M_R + M_{OT}$ =	**27,441**	kip-ft
Sum of Vertical Forces	P = Conc + Water + Uplift =	**2,401**	kips
Sum of Horizontal Forces	H = Σhorizontal	**-458**	kips

Location of Resultant	Xr = ΣM / P =	11.43	ft from Toe
	e = B/2 - Xr =	(0.43)	ft
	B/6 =	3.667	ft

CONCRETE QUANTITIES

			forming	
Ftg conc:	225	cy (includes stepped)	757	sf
Stem Conc:	217	cy	3134	sf
Total =	441			

STEEL REINFORCEMENT: (assumed)

		Bar #	Spacing		Length	# of bars	Total wt		
a) Footing			in	LB /ft	ft	ea	lb		
Top mat	Transverse:	9	6	3.40	21.5	138	10,088		
	Longitudinal:	9	6	3.40	68.5	44	10,248		
Bot mat	Transverse:	9	6	3.40	21.5	138	10,088		
	Longitudinal:	9	6	3.40	68.5	44	10,248		
								cy	**LB/cy**
							40,671	225	180.848419
b) Skin Reinf. On Monolith									
Vert Face	Vertical	9	6	3.40	21.32	134	9,713	19426.784	
	Longitudinal:	9	6	3.40	66.5	43	9,722	19444.6	
Top Face	Transverse:	9	6	3.40	3.5	134	1,595		
	Longitudinal:	9	6	3.40	66.5	8	1,809		
Dowels	Vertical I.F.	9	6	3.40	21.3	134	9,713		
	Vertical O.F.	9	6	3.40	21.3	134	9,713		
								cy	**LB/cy**
							42,266	217	195.1479972
						Σ =	**82,937**		
	Lap Splices (long. Bars)	9		3.40	8	273	7,426		
						Σ Bar Wt=	90,362	lb	

FORCES AT THE BOTTOM OF THE STEM

Diversion Face	H	γ	Pbase	**V**	arm	**Mv**
	ft	kcf		K	ft	ft-k
Diversion WSEL	0.00	**0.0624**	0	0.000	0.000	0
Tributary SEL =	21.82	**0.019**	0.41458	4.523	7.273	32.89778
Tributary WSEL =	0.00	**0.0624**	0	0.000	0.000	0
Sum				4.523		32.89778
Net Forces				4.523		32.89778

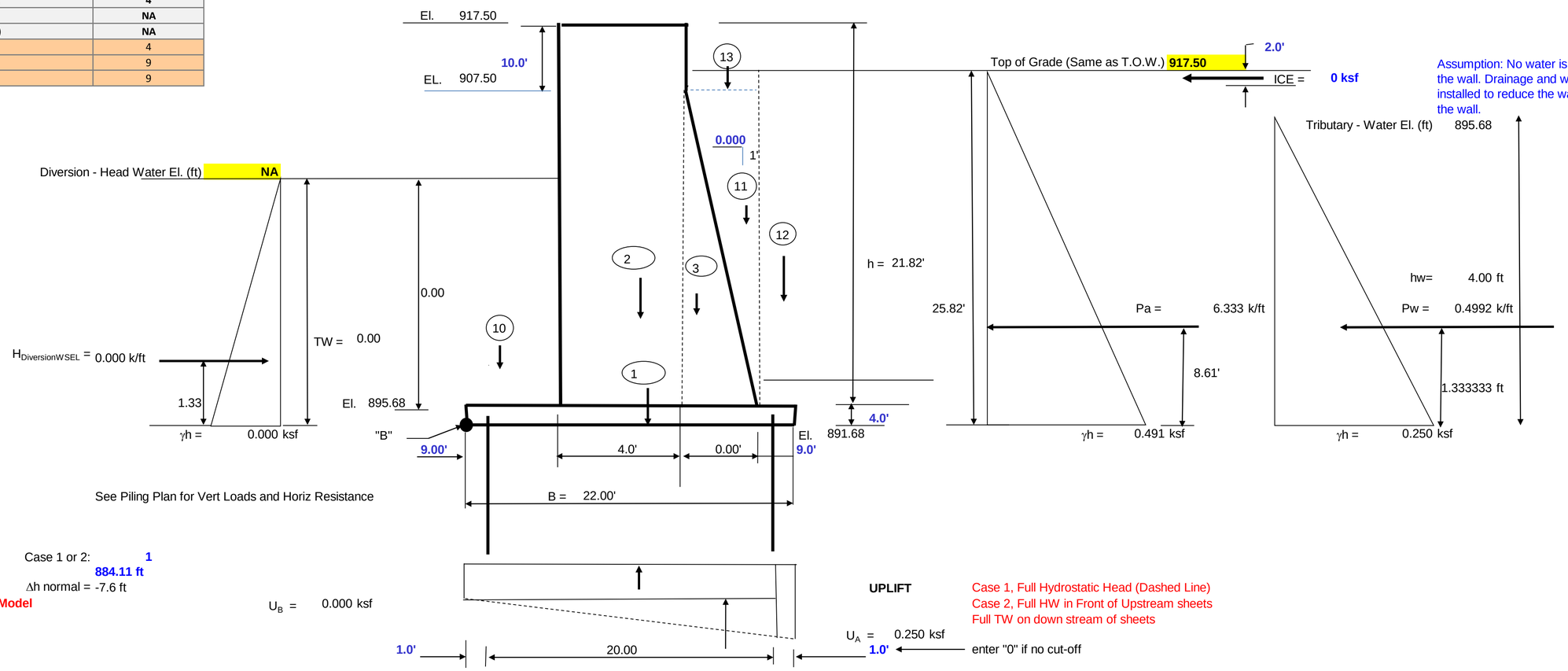
BARR ENGINEERING			DATE	2/11/2011	SHEET NO.
			PROJECT NAME	FARGO – MOORHEAD METRO FLOOD RISK MANAGEMENT PROJECT, FEASIBILITY STUDY, PHASE 4	
COMPUTED	CHECKED	SUBMITTED	PROJECT NUMBER	34091004	
MBI 2/11/11		MBI	SUBJECT	Sheyenne Aquaduct Structure - Retaining Walls Load Cases: Case 6 Construction Panel F	

ID#	Case 6
Name	Construction
Load Category	Unusual
Tributary - Water El. (ft)	NA
Diversion - Head Water El. (ft)	NA
Diversion - Tail Water El. (ft)	NA
Tributary - T.O. Wall El. (ft)	917.5
Tributary - T.O. Deck L.P. El.(ft)	898.7
Tributary - T.O. Deck H.P. El.(ft)	900.7
Diversion - T.O. Mat El. (ft)	895.68
Tributary - Deck Slab thickness @ L.P. (ft)	2
Tributary - Deck Slab thickness @ H.P. (ft)	4
Diversion - Mat Slab thickness (ft)	4
Tibutary - Water height (ft)	NA
Diversion - Head Water height (ft)	NA
Wall Thickness (ft)	4
Toe (Ft)	9
Heel (ft)	9

File:

MN State Building Codes
Frost Depth = **5.0 ft** provide min frost ftg protection during Dec, Jan, Feb, March
Water El. = **903.24 ft** DEC, JAN, FEB Mean Water Elevation

Non-Overflow Section **Length = 67.0 ft**
Stepped Ftg Ls = **2.0 ft** overlap distance at stepped ftg



See Piling Plan for Vert Loads and Horiz Resistance

Case 1 or 2: **1**
Normal Water Level, El. **884.11 ft**
Δh normal = -7.6 ft
See Geotechnical seepage Model

U_B = 0.000 ksf

UPLIFT
Case 1, Full Hydrostatic Head (Dashed Line)
Case 2, Full HW in Front of Upstream sheets
Full TW on down stream of sheets

U_A = 0.250 ksf
enter "0" if no cut-off

Vertical Loads	Section	L ft	W ft	H ft	γ kcf	shape	V K	arm ft	Mv ft-k
Ftg concrete	1	67	22.00	4.00	0.15	rec	884.4	11.00	9,728.4
Stem	2	67	4.00	21.82	0.15	rec	877.2	11.00	9,648.8
Batter	3	67	0.00	11.82	0.15	tri	0.0	13.00	0.0
					D.L. Concrete	ΣVc =	**1761.6**	ΣM_V =	**19,377.2**
T.W on ftg Stem	10	67	9.00	0.00	0.0624	rec	0.0	4.50	0.0
H.W. on Stem Slope	11	67	0.00	11.82	0.12	tri	0.0	13.00	0.0
H.W. Above Slope	13	67	0.00	10.00	0.12	rec	0.0	13.00	0.0
Soil on Footing	12s	67	9.00	21.82	0.0626	rec	823.7	17.50	14,414.0
H.W. on Footing	12w	67	9.00	0.00	0.0624	rec	0.0	17.50	0.0
					D.L. Water	ΣVw =	**823.7**	ΣM_V =	**14,414.0**

← CONSTANT FOR ALL LOAD CASES

Uplift Loads		L ft	W ft	Pressure ksf		**U** K	arm ft	**Mu** ft-k
	U_B	67	22.00	0.000	rec	0.0	11.00	0
	U_A	67	22.00	0.250	tri	-184.0	14.67	-2,698
					ΣU =	**-184.0**	ΣM_U =	**-2,698**

Horizontal Loads	L ft	H ft	Pressure ksf	**ICE** K	arm ft	**Mu** ft-k

BARR ENGINEERING			DATE	2/11/2011	SHEET NO.
			PROJECT NAME	FARGO – MOORHEAD METRO FLOOD RISK MANAGEMENT PROJECT, FEASIBILITY STUDY, PHASE 4	
COMPUTED	CHECKED	SUBMITTED	PROJECT NUMBER	34091004	
MBI 2/11/11		MBI	SUBJECT	Sheyenne Aquaduct Structure - Retaining Walls	
				Load Cases: Case 6 Construction	Panel F

ICE	67	2.00	0.00	rec	0.0	24.82	0.0	
	L		Force		**H**	arm	**Mw**	
	ft		k/ft		K	ft	ft-k	
SOIL	67		-6.333		-424.34	8.61'	-3652.13	
Water Loads								
H_{TW}	67		0.000	tri	0.00	1.33	0.00	
H_{HW}	67		-0.499	tri	-33.45	1.33	-44.60	
				ΣWater =	**-33.45**	ΣM_W =	**-3696.7**	

Overturning Moments	$\Sigma M_{OT} = M_U + M_W + M_{ICE}$ =	-6395	kip-ft
Resisting Moments	$\Sigma M_R = M_V$ =	33791	kip-ft
Sum of Moments	$\Sigma Mnet = M_R + M_{OT}$ =	**27,396**	kip-ft
Sum of Vertical Forces	P = Conc + Water + Uplift =	**2,401**	kips
Sum of Horizontal Forces	H = Σhorizontal	**-458**	kips

Location of Resultant	Xr = ΣM / P =	11.41	ft from Toe
	e = B/2 - Xr =	(0.41)	ft
	B/6 =	3.667	ft

CONCRETE QUANTITIES

			forming	
Ftg conc:	225	cy (includes stepped)	757	sf
Stem Conc:	217	cy	3134	sf
Total =	441			

STEEL REINFORCEMENT: (assumed)

		Bar #	Spacing in	LB /ft	Length ft	# of bars ea	Total wt lb		
a) Footing									
Top mat	Transverse:	9	6	3.40	21.5	138	10,088		
	Longitudinal:	9	6	3.40	68.5	44	10,248		
Bot mat	Transverse:	9	6	3.40	21.5	138	10,088		
	Longitudinal:	9	6	3.40	68.5	44	10,248		
								cy	**LB/cy**
							40,671	225	180.848419
b) Skin Reinf. On Monolith									
Vert Face	Vertical	9	6	3.40	21.32	134	9,713	19426.784	
	Longitudinal:	9	6	3.40	66.5	43	9,722	19444.6	
Top Face	Transverse:	9	6	3.40	3.5	134	1,595		
	Longitudinal:	9	6	3.40	66.5	8	1,809		
Dowels	Vertical I.F.	9	6	3.40	21.3	134	9,713		
	Vertical O.F.	9	6	3.40	21.3	134	9,713		
								cy	**LB/cy**
							42,266	217	195.1479972
						Σ =	**82,937**		
	Lap Splices (long. Bars)	9		3.40	8	273	7,426		
						Σ Bar Wt=	90,362	lb	

FORCES AT THE BOTTOM OF THE STEM

Diversion Face	H ft	γ kcf	Pbase	**V** K	arm ft	**Mv** ft-k
Diversion WSEL	0.00	**0.0624**	0	0.000	0.000	0
Tributary SEL =	21.82	**0.019**	0.41458	4.523	7.273	32.89778
Tributary WSEL =	0.00	**0.0624**	0	0.000	0.000	0
Sum				4.523		32.89778
Net Forces				4.523		32.89778

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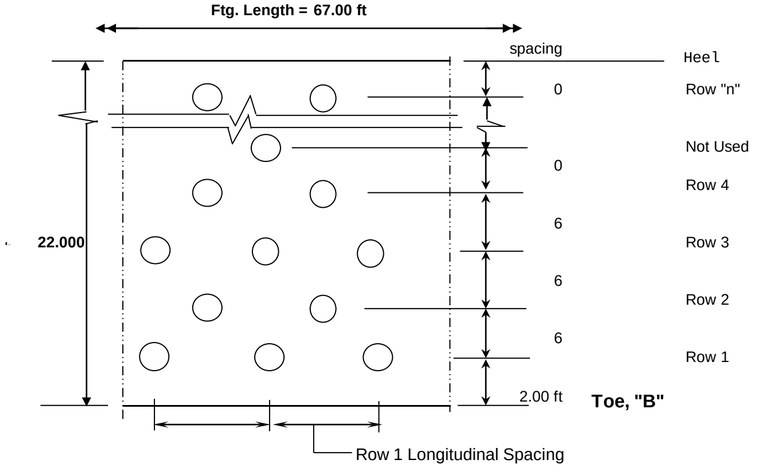
				Panel F	

PILE FOUNDATION DESIGN

FLOW



L = 67.00 ft

PILE PATTERN GEOMETRY

Transverse Spacing		Distance to Toe, d_{toe}	Longitudinal Spacing	Batter	Piles per Row (N)	Edge Dist (ft)		Trial N
Row 1 to Toe	2.00 ft	2.0 ft	2.50 ft	0 "/12"	10	22.25	1	27
Row 1 to Row 2	6.00 ft	8.0 ft	5.00 ft	0 "/12"	10	11.00	2	14
Row 2 to Row 3	6.00 ft	14.0 ft	5.00 ft	0 "/12"	10	11.00	3	14
Row 3 to Row 4	6.00 ft	20.0 ft	5.00 ft	0 "/12"	10	11.00	4	14
Row 4 to Row 5	0.00 ft	0.0 ft	0.00 ft	0 "/12"	0	33.50	0	0
Row 5 to Row 6	0.00 ft	0.0 ft	0.00 ft	0 "/12"	0	33.50	0	0
Row 6 to Row 7	0.00 ft	0.0 ft	0.00 ft	0 "/12"	0	33.50	0	0
Row 7 to Row 8	0.00 ft	0.0 ft	0.00 ft	0 "/12"	0	33.50	0	0
Row 8 to Row 9	0.00 ft	0.0 ft	0.00 ft	0 "/12"	0	33.50	0	0
Row 9 to Row 10	0.00 ft	0.0 ft	0.00 ft	0 "/12"	0	33.50	0	0
Row 10 to Row 11	0.00 ft	0.0 ft	0.00 ft	0 "/12"	0	33.50	0	0
Row 11 to Row 12	0.00 ft	0.0 ft	0.00 ft	0 "/12"	0	33.50	0	0
Row 12 to Row 13	0.00 ft	0.0 ft	0.00 ft	0 "/12"	0	33.50	0	0
Row 13 to Row 14	0.00 ft	0.0 ft	0.00 ft	0 "/12"	0	33.50	0	0
Row 14 to Row 15	0.00 ft	0.0 ft	0.00 ft	0 "/12"	0	33.50	0	0
Last Row to Heel	2.00 ft							
	22.00 ft				ΣN =	40		69

Note: Enter 0 for Longitudinal Spacing for Rows Not Used)

Pile Properties: Pile Type: **HP** (C.I.P or HP) Pile Length = **50.0 ft**

HP Nominal Depth, h = **14.0 in**

Wt. per ft, plf **73**

Ftg EL. 891.68

Pile Tip El. 842.68

Pile Cap Embed = **1.00 ft**

Total pile Length = 2,000 LF

Pile Group Properties

N.A. of Pile Group to Toe

$X_{NA} = (\Sigma N * d_{toe}) / \Sigma N =$ **11.00 ft**

	Dist. From N.A. to Pile Row	d	N	$I = N * d^2$
1	Dist. To Row 1	9.00 ft	10	810.0
2	Dist. To Row 2	3.00 ft	10	90.0
3	Dist. Row 3	-3.00 ft	10	90.0
4	Dist. Row 4	-9.00 ft	10	810.0
0	Row 5 (not used)	0.00 ft	0	0.0
0	Row 6 (not used)	0.00 ft	0	0.0
0	Row 7 (not used)	0.00 ft	0	0.0
0	Row 8 (not used)	0.00 ft	0	0.0
0	Row 9 (not used)	0.00 ft	0	0.0
0	Row 10 (not used)	0.00 ft	0	0.0
0	Row 11 (not used)	0.00 ft	0	0.0
0	Row 12 (not used)	0.00 ft	0	0.0
0	Row 13 (not used)	0.00 ft	0	0.0
0	Row 14 (not used)	0.00 ft	0	0.0
0	Row 15 (not used)	0.00 ft	0	0.0
			40	$\Sigma I =$ **1800.0**

ALLOWABLE LOADS (from Geotechnical)

	Service	Allowable Pile Loads					
	ID#	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
	Name	100 yr. flood	100 yr. flood + ice	500 yr. flood	T.O. Levee	Normal flow + ice	Construction
	Load Category	Usual	Unusual	Unusual	Extreme	Usual	Unusual
Allwable Lateral Capacity (tons)		18.0 tons	20.5 tons	20.5 tons	24.0 tons	11.5 tons	20.5 tons
Allowable Pile Capacity (tons) - Axial		62.0 tons	82.6 tons	82.6 tons	107.7 tons	36.5 tons	82.6 tons
Safety Factors		2.00	1.50	1.50	1.15	2.00	1.50

w/o Group effects

Summary Pile Reactions

Load Combinations	Allowable Pile Capacity (tons) - Axial	Pile Loads (tons/pile) 1	2	3	4	5	6	7	8	9	10	11	12	Max. Vertical Load (Tons)	Horiz Pile Group Capacity (k)	Check
Case 1	**62.0 tons**	22.1	25.4	28.7	31.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	31.9	1,440	**OK**
Case 2	**82.6 tons**	22.1	25.4	28.7	31.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	31.9	1,640	**OK**
Case 3	**82.6 tons**	21.5	25.1	28.7	32.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	32.4	1,640	**OK**
Case 4	**107.7 tons**	-4.5	15.4	35.4	55.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	55.4	1,920	**OK**
Case 5	**36.5 tons**	27.4	29.2	30.9	32.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	32.6	920	**OK**
Case 6	**82.6 tons**	27.6	29.2	30.8	32.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	32.5	920	**OK**

Max Service : P = **55.4**

Using solid mechanics equations adapted for discrete elements, the forces in the pile rows for different load combinations are determined.
The force in each pile row is found using:

$$\text{Pile Load} = P / N + M_{NA} / I$$

First, the moment about the toe must be translated to get the moment about the neutral axis of the pile group.

$$e_{toe} = M_{toe} / P$$

Then the eccentricity about the neutral axis of the pile group is

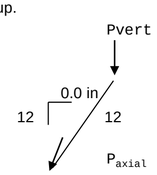
$$e_{NA} = X_{NA} - e_{toe}$$

The moment about the neutral axis of the pile group becomes

$$M_{NA} = P * e_{NA}$$

For battered pile, the Vertical pile load needs to be transformed to the axial load along the pile axis

Paxial = 1.000 Pvert



FORCE RESULTANT (see Stability Analysis)

CASE	Event		Vertical Load P (kips)	Horizontal	ΣM toe (kip-	$e_{toe} = M_{toe} / P$	$e_{NA} = X_{NA} - e_{toe}$	$M_{NA} = P * e_{NA}$

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Case 1	**100 yr. flood**	**Usual**	2,163	230	25,759	11.91	-0.91	-1961
Case 2	**100 yr. flood + ice**	**Unusual**	2,163	230	25,759	11.91	-0.91	-1961
Case 3	**500 yr. flood**	**Unusual**	2,153	175	25,863	12.01	-1.01	-2176
Case 4	**T.O. Levee**	**Extreme**	2,035	-936	34,378	16.89	-5.89	-11994
Case 5	**Normal flow + ice**	**Usual**	2,401	458	27,441	11.43	-0.43	-1027
Case 6	**Construction**	**Unusual**	2,401	458	27,396	11.41	-0.41	-983

SERVICE

Case **Case 1**
Flood Event **100 yr. flood**
Usual

Vertical Load, P = 2163 kips
Horizontal Load, H = 230 kips
M_{NA} = -1961 kip-ft

40

	Vertical Pile Loading	P / N	+	M_{NA}* d / Σ I	= Pile Loads		**Axial Pile Load**
1	Row 1	54.1		-9.8	44.3 kips/pile	22.1 tons/pile	22.1 tons/pile
2	Row 2	54.1		-3.3	50.8 kips/pile	25.4 tons/pile	25.4 tons/pile
3	Row 3	54.1		3.3	57.4 kips/pile	28.7 tons/pile	28.7 tons/pile
4	Row 4	54.1		9.8	63.9 kips/pile	31.9 tons/pile	31.9 tons/pile
5	Row 5	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
6	Row 6	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
7	Row 7	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
8	Row 8	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
9	Row 9	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
10	Row 10	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
11	Row 11	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
12	Row 12	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
13	Row 13	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
14	Row 14	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
15	Row 15	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
					max:	**31.9 tons/pile**	**max: 31.9 tons/pile**

Assumed lateral Capacity: 36.0 kips/pile

	Horizontal Pile Capacity	**Batter "/ft**	**N**	Resistance due to Batter, kips	Resitance due to Bending, kips	Group Efficiency	Lateral Resitance
1	Row 1	0	10	0.0	360	1.000	360 kips
2	Row 2	0	10	0.0	360	1.000	360 kips
3	Row 3	0	10	0.0	360	1.000	360 kips
4	Row 4	0	10	0.0	360	1.000	360 kips
5	Row 5	0	0	0.0	0	1.000	0 kips
6	Row 6	0	0	0.0	0	1.000	0 kips
7	Row 7	0	0	0.0	0	1.000	0 kips
8	Row 8	0	0	0.0	0	1.000	0 kips
9	Row 9	0	0	0.0	0	1.000	0 kips
10	Row 10	0	0	0.0	0	1.000	0 kips
11	Row 11	0	0	0.0	0	1.000	0 kips
12	Row 12	0	0	0.0	0	1.000	0 kips
13	Row 13	0	0	0.0	0	1.000	0 kips
14	Row 14	0	0	0.0	0	1.000	0 kips
15	Row 15	0	0	0.0	0	1.000	0 kips
			40		1440		**1440 kips**

OK

Case **Case 2**
Flood Event **100 yr. flood + ice**
Unusual

Vertical Load, P = 2163 kips
Horizontal Load, H = 230 kips
M_{NA} = -1961 kip-ft

40

	Vertical Pile Loading	P / N	+	M_{NA}* d / Σ I	= Pile Loads		**Axial Pile Load**
1	Row 1	54.1		-9.8	44.3 kips/pile	22.1 tons/pile	22.1 tons/pile
2	Row 2	54.1		-3.3	50.8 kips/pile	25.4 tons/pile	25.4 tons/pile
3	Row 3	54.1		3.3	57.4 kips/pile	28.7 tons/pile	28.7 tons/pile
4	Row 4	54.1		9.8	63.9 kips/pile	31.9 tons/pile	31.9 tons/pile
5	Row 5	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
6	Row 6	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
7	Row 7	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
8	Row 8	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
9	Row 9	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
10	Row 10	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
11	Row 11	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
12	Row 12	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
13	Row 13	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
14	Row 14	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
15	Row 15	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
					max:	**31.9 tons/pile**	**max: 31.9 tons/pile**

Assumed lateral Capacity: 41.0 kips/pile

	Horizontal Pile Capacity	**Batter "/ft**	**N**	Resistance due to Batter, kips	Resitance due to Bending, kips	Group Efficiency	Lateral Resitance
1	Row 1	0	10	0.0	410	1.000	410 kips
2	Row 2	0	10	0.0	410	1.000	410 kips
3	Row 3	0	10	0.0	410	1.000	410 kips

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4	Row 4	0	10	0.0	410	1.000	410 kips	
5	Row 5	0	0	0.0	0	1.000	0 kips	
6	Row 6	0	0	0.0	0	1.000	0 kips	
7	Row 7	0	0	0.0	0	1.000	0 kips	
8	Row 8	0	0	0.0	0	1.000	0 kips	
9	Row 9	0	0	0.0	0	1.000	0 kips	
10	Row 10	0	0	0.0	0	1.000	0 kips	
11	Row 11	0	0	0.0	0	1.000	0 kips	
12	Row 12	0	0	0.0	0	1.000	0 kips	
13	Row 13	0	0	0.0	0	1.000	0 kips	
14	Row 14	0	0	0.0	0	1.000	0 kips	
15	Row 15	0	0	0.0	0	1.000	0 kips	
			40		1640		**1640 kips**	**OK**

Case **Case 3**
Flood Event **500 yr. flood**
Unusual

Vertical Load, P = 2153 kips
Horizontal Load, H = 175 kips
M_{NA} = -2176 kip-ft

	Vertical Pile Loading	P / N	+	M_{NA}* d / Σ I	= Pile Loads		**Axial Pile Load**
1	Row 1	53.8		-10.9	43.0 kips/pile	21.5 tons/pile	21.5 tons/pile
2	Row 2	53.8		-3.6	50.2 kips/pile	25.1 tons/pile	25.1 tons/pile
3	Row 3	53.8		3.6	57.5 kips/pile	28.7 tons/pile	28.7 tons/pile
4	Row 4	53.8		10.9	64.7 kips/pile	32.4 tons/pile	32.4 tons/pile
5	Row 5	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
6	Row 6	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
7	Row 7	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
8	Row 8	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
9	Row 9	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
10	Row 10	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
11	Row 11	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
12	Row 12	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
13	Row 13	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
14	Row 14	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
15	Row 15	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
						max: **32.4 tons/pile**	**max:** **32.4 tons/pile**

Assumed lateral Capacity: 41.0 kips/pile

	Horizontal Pile Capacity	**Batter "/ft**	**N**	Resistance due to Batter, kips	Resitance due to Bending, kips	Group Efficiency	Lateral Resitance	
1	Row 1	0	10	0.0	410	1.000	410 kips	
2	Row 2	0	10	0.0	410	1.000	410 kips	
3	Row 3	0	10	0.0	410	1.000	410 kips	
4	Row 4	0	10	0.0	410	1.000	410 kips	
5	Row 5	0	0	0.0	0	1.000	0 kips	
6	Row 6	0	0	0.0	0	1.000	0 kips	
7	Row 7	0	0	0.0	0	1.000	0 kips	
8	Row 8	0	0	0.0	0	1.000	0 kips	
9	Row 9	0	0	0.0	0	1.000	0 kips	
10	Row 10	0	0	0.0	0	1.000	0 kips	
11	Row 11	0	0	0.0	0	1.000	0 kips	
12	Row 12	0	0	0.0	0	1.000	0 kips	
13	Row 13	0	0	0.0	0	1.000	0 kips	
14	Row 14	0	0	0.0	0	1.000	0 kips	
15	Row 15	0	0	0.0	0	1.000	0 kips	
			40		1640		**1640 kips**	**OK**

Case **Case 4**
Flood Event **T.O. Levee**
Extreme

Vertical Load, P = 2035 kips
Horizontal Load, H = -936 kips
M_{NA} = -11994 kip-ft

	Vertical Pile Loading	P / N	+	M_{NA}* d / Σ I	= Pile Loads		**Axial Pile Load**
1	Row 1	50.9		-60.0	-9.1 kips/pile	-4.5 tons/pile	-4.5 tons/pile
2	Row 2	50.9		-20.0	30.9 kips/pile	15.4 tons/pile	15.4 tons/pile
3	Row 3	50.9		20.0	70.9 kips/pile	35.4 tons/pile	35.4 tons/pile
4	Row 4	50.9		60.0	110.8 kips/pile	55.4 tons/pile	55.4 tons/pile
5	Row 5	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
6	Row 6	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
7	Row 7	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
8	Row 8	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
9	Row 9	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
10	Row 10	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
11	Row 11	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
12	Row 12	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
13	Row 13	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
14	Row 14	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
15	Row 15	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
						max: **55.4 tons/pile**	**max:** **55.4 tons/pile**

Assumed lateral Capacity: 48.0 kips/pile

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	Horizontal Pile Capacity	Batter "/ft	N	Resistance due to Batter, kips	Resitance due to Bending, kips	Group Efficiency	Lateral Resitance	
1	Row 1	0	10	0.0	480	1.000	480 kips	
2	Row 2	0	10	0.0	480	1.000	480 kips	
3	Row 3	0	10	0.0	480	1.000	480 kips	
4	Row 4	0	10	0.0	480	1.000	480 kips	
5	Row 5	0	0	0.0	0	1.000	0 kips	
6	Row 6	0	0	0.0	0	1.000	0 kips	
7	Row 7	0	0	0.0	0	1.000	0 kips	
8	Row 8	0	0	0.0	0	1.000	0 kips	
9	Row 9	0	0	0.0	0	1.000	0 kips	
10	Row 10	0	0	0.0	0	1.000	0 kips	
11	Row 11	0	0	0.0	0	1.000	0 kips	
12	Row 12	0	0	0.0	0	1.000	0 kips	
13	Row 13	0	0	0.0	0	1.000	0 kips	
14	Row 14	0	0	0.0	0	1.000	0 kips	
15	Row 15	0	0	0.0	0	1.000	0 kips	
			40		1920		**1920 kips**	**OK**

Case **Case 5**
Flood Event **Normal flow + ice**
Usual

Vertical Load, P = 2401 kips
Horizontal Load, H = 458 kips
M_{NA} = -1027 kip-ft

	Vertical Pile Loading	P / N	+	M_{NA}* d / Σ I	= Pile Loads		Axial Pile Load
1	Row 1	60.0		-5.1	54.9 kips/pile	27.4 tons/pile	27.4 tons/pile
2	Row 2	60.0		-1.7	58.3 kips/pile	29.2 tons/pile	29.2 tons/pile
3	Row 3	60.0		1.7	61.7 kips/pile	30.9 tons/pile	30.9 tons/pile
4	Row 4	60.0		5.1	65.2 kips/pile	32.6 tons/pile	32.6 tons/pile
5	Row 5	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
6	Row 6	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
7	Row 7	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
8	Row 8	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
9	Row 9	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
10	Row 10	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
11	Row 11	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
12	Row 12	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
13	Row 13	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
14	Row 14	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
15	Row 15	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
					max:	**32.6 tons/pile**	**max: 32.6 tons/pile**

Assumed lateral Capacity: 23.0 kips/pile

	Horizontal Pile Capacity	Batter "/ft	N	Resistance due to Batter, kips	Resitance due to Bending, kips	Group Efficiency	Lateral Resitance	
1	Row 1	0	10	0.0	230	1.000	230 kips	
2	Row 2	0	10	0.0	230	1.000	230 kips	
3	Row 3	0	10	0.0	230	1.000	230 kips	
4	Row 4	0	10	0.0	230	1.000	230 kips	
5	Row 5	0	0	0.0	0	1.000	0 kips	
6	Row 6	0	0	0.0	0	1.000	0 kips	
7	Row 7	0	0	0.0	0	1.000	0 kips	
8	Row 8	0	0	0.0	0	1.000	0 kips	
9	Row 9	0	0	0.0	0	1.000	0 kips	
10	Row 10	0	0	0.0	0	1.000	0 kips	
11	Row 11	0	0	0.0	0	1.000	0 kips	
12	Row 12	0	0	0.0	0	1.000	0 kips	
13	Row 13	0	0	0.0	0	1.000	0 kips	
14	Row 14	0	0	0.0	0	1.000	0 kips	
15	Row 15	0	0	0.0	0	1.000	0 kips	
			40		920		**920 kips**	**OK**

Case **Case 6**
Flood Event **Construction**
Unusual

Vertical Load, P = 2401 kips
Horizontal Load, H = 458 kips
M_{NA} = -983 kip-ft

	Vertical Pile Loading	P / N	+	M_{NA}* d / Σ I	= Pile Loads		Axial Pile Load
1	Row 1	60.0		-4.9	55.1 kips/pile	27.6 tons/pile	27.6 tons/pile
2	Row 2	60.0		-1.6	58.4 kips/pile	29.2 tons/pile	29.2 tons/pile
3	Row 3	60.0		1.6	61.7 kips/pile	30.8 tons/pile	30.8 tons/pile
4	Row 4	60.0		4.9	64.9 kips/pile	32.5 tons/pile	32.5 tons/pile
5	Row 5	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
6	Row 6	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
7	Row 7	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
8	Row 8	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
9	Row 9	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
10	Row 10	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile

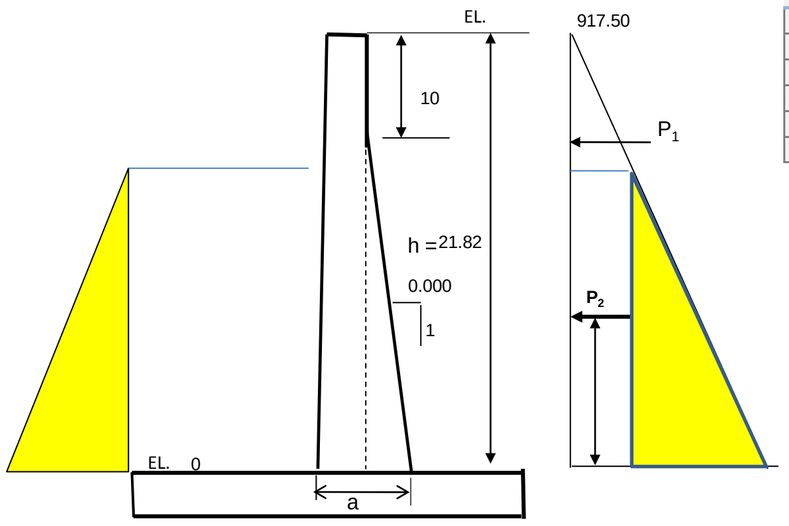
BARR ENGINEERING			DATE	2/11/2011	SHEET NO.
			PROJECT NAME	FARGO – MOORHEAD METRO FLOOD RISK MANAGEMENT PROJECT, FEASIBILITY STUDY, PHASE 4	
COMPUTED	CHECKED	SUBMITTED	PROJECT NUMBER	34091004	
MBI		MBI	SUBJECT	Sheyenne Aquaduct Structure - Retaining Walls	
2/11/11				Panel F	

11	Row 11	0.0	0.0	0.0 kips/pile		0.0 tons/pile		0.0 tons/pile	
12	Row 12	0.0	0.0	0.0 kips/pile		0.0 tons/pile		0.0 tons/pile	
13	Row 13	0.0	0.0	0.0 kips/pile		0.0 tons/pile		0.0 tons/pile	
14	Row 14	0.0	0.0	0.0 kips/pile		0.0 tons/pile		0.0 tons/pile	
15	Row 15	0.0	0.0	0.0 kips/pile		0.0 tons/pile		0.0 tons/pile	
					max:	**32.5 tons/pile**		**max:**	**32.5 tons/pile**

Assumed lateral Capacity: 41.0 kips/pile

	Horizontal Pile Capacity	**Batter "/ft**	**N**	Resistance due to Batter, kips	Resitance due to Bending, kips	Group Efficiency	Lateral Resitance	
1	Row 1	0	10	0.0	230	1.000	230 kips	
2	Row 2	0	10	0.0	230	1.000	230 kips	
3	Row 3	0	10	0.0	230	1.000	230 kips	
4	Row 4	0	10	0.0	230	1.000	230 kips	
5	Row 5	0	0	0.0	0	1.000	0 kips	
6	Row 6	0	0	0.0	0	1.000	0 kips	
7	Row 7	0	0	0.0	0	1.000	0 kips	
8	Row 8	0	0	0.0	0	1.000	0 kips	
9	Row 9	0	0	0.0	0	1.000	0 kips	
10	Row 10	0	0	0.0	0	1.000	0 kips	
11	Row 11	0	0	0.0	0	1.000	0 kips	
12	Row 12	0	0	0.0	0	1.000	0 kips	
13	Row 13	0	0	0.0	0	1.000	0 kips	
14	Row 14	0	0	0.0	0	1.000	0 kips	
15	Row 15	0	0	0.0	0	1.000	0 kips	
			40		920		**920 kips**	**OK**

BARR ENGINEERING			DATE	2/11/2011	SHEET NO.
			PROJECT NAME	FARGO – MOORHEAD METRO FLOOD RISK MANAGEMENT PROJECT, FEASIBILITY STUDY, PHASE 4	
COMPUTED	CHECKED	SUBMITTED	PROJECT NUMBER	34091004	
MBI 2/11/11		MBI	SUBJECT	Sheyenne Aquaduct Structure - Retaining Walls Panel F 0	



CASE	Event		HW	TW	Dh	TW -ftg
Case 1	100 yr. flood	Usual	902.12	901.91	0.21	901.91
Case 2	100 yr. flood + ice	Unusual	902.12	901.91	0.21	901.91
Case 3	500 yr. flood	Unusual	914.670	903.06	11.61	903.06
Case 4	T.O. Levee	Extreme	917.500	917.50	0.00	917.50
Case 5	Normal flow + ice	Usual	0.000	0.000	0.00	0.00
Case 6	Construction	Unusual	0.000	0.000	0.00	0.00

LOAD FACTORS

Hf =	1.30	hydraulic Factor
LF =	1.70	
Unsual & Extreme =	0.75	
TOP THICK =	4.0 ft	48.0 in
Batter at Base =	0.00 ft	0.0 in
a =	4.00 ft	48.0 in

Load Factors - Hydraulic Structures	
live load, LL =	1.7
dead load, DL =	1.4
flood level , FL =	1
Fluid, F =	1.7
hydraulic, Hf =	1.3
direct tension hydraulic, Hf =	1.65
ICE =	1.7

WALL DESIGN:

Horizontal Load Components and Moments about Bottom of Stem (Service)

CASE	Event	Condition	Load Factor	H (kips/ft)	Moment (kip-ft/ ft)	Vu (kips/ft)	Mu (kip-ft/ ft)
Case 1	100 yr. flood	Usual	1	3.23	30.120	7.14	66.57
Case 2	100 yr. flood + ice	Unusual	0.75	3.23	30.120	5.35	49.92
Case 3	500 yr. flood	Unusual	0.75	2.70	28.260	4.48	46.84
Case 4	T.O. Levee	Extreme	0.75	-10.33	-75.145	17.12	124.55
Case 5	Normal flow + ice	Usual	1	4.52	32.898	10.00	72.70
Case 6	Construction	Unusual	0.75	4.52	32.898	7.50	54.53

STEM DESIGN VALUES

MU, k-ft/ft	124.55	k-ft/ft
VU, k/ft	17.12	k/ft

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COMPUTED	CHECKED	SUBMITTED	PROJECT NUMBER	34091004	
MBI 2/11/11		MBI	SUBJECT	Sheyenne Aquaduct Structure - Retaining Walls Panel F 0	

ACI 318-05 w/ Modifications per EM 1110-2-2104 ref. EM 110-2-2104

9.3 - Design Strength

ϕ = **0.9** 9.3.2.1 - Tension Controlled sections

0.75 9.3.2.3 - Shear and torsion

FLEXURAL STEEL FOR RECTANGULAR CONCRETE SECTIONS

fy=	60	ksi	
Fc'=	4	ksi	
B1=	0.85		
Muh =	125	k-ft /ft	Includes: hf = 1.3
Vuh=	17.12	k / ft	
bw=	12	in.	
h=	48	in	
cover=	4	in (include correct stirrup bar dia.)	
d=	43.50	in	
pb=	0.0285		pb=0.85*B1*Fc'/ fy*(87 / (87+fy))
.75*pb=	0.0214		
m=fy / 0.85*Fc'=	17.647		

TRIAL

Ru=Mn/bd^2 = 73.137

REQ'D p= 0.0012 **O.K.**

p= 0.0016

As (REQ'D)= 0.86 in^2

ACI 10.5.1

p(min)= 3*SQRT(Fc')/fy 0.00316

200* / fy 0.00333

ACI 10.5.3

4/3*p 0.0016

EM 110-2-2104 2-8 c. (not less than Temp & Shrinkage, half in each face)

p(min)= 0.0028 /2 ▶ As =0.5*$p_{T\&S}$bh = 0.8064 in^2

As = #9 @ 12 = 1.00 in^2

SELECT STEEL

bar #=	9		
spacing, s=	6	in	
# OF BAR=	1	(ENTER 1 IF PER FT, b=12")	a
As=	1.999	in^2	
d=	43.4375	in	
p = As/bd =	0.0038	**O.K. < 0.375pb**	**EM 110-2-2104**
p =	**0.135**	**pb**	**MAXIMUM TENSILE REINFORCEMENT**
T= As*fy =	119.9	k	a) For singly reinforced flexural members
C= B1*Fc' *b*a =	423.5	**a**	1) p = **0.25** pb Recommended limit
a= T/C =	0.283	in	2) p = **0.375** pb Max. permitted upper limit not requiring special study
Mn= T(d - a/2)/12 =	432.7	ft-k	3) p = **0.5** pb Max. permitted upper limit when excessive deflections are not predicted In ACI 318
ϕ Mn=	389.4	ft-k	4) p = >**0.5** pb but ≤ 0.375 pb permitted only if detailed serviceability analysis incl. deflect. Calc.
			b) Use of compression reinf. shall be per ACI 318
			> Mu O.K.

CHECK SHEAR REINFORCEMENT (ACI 11.3 & EM 110-2-2104 3-3a)

Vuh =	17.1	k		NO SHEAR REINF. REQUIRED
Vn = Vuh / ϕ =	22.8	k		
Vc = 2*sqrt(Fc') bw * d =	65.9	k		11.3.1.1
Vs =Vuh / f - 1.3Vc =	No Shear Reinf. Req.	k	NG	Vs(max) ≤ 8*sqrt(fc')bd = 263.7 k

Trial Stirrup Sizes:

# of stirrup legs =	2	(single stirrup = 2, Dbl stirrup = 4……..)
Stirrup bar size =	4	
Av=	0.393	in^2
s=		in s = Av * fy * d / (Vu / f - Vc)

11.5.5 - Spacing limits for shear reinforcement

s = d/2 =	21.719	in	OR 24	in
s(max)=	10.859	in		
4*sqrt(Fc')*bw*d=	131.9	k	< Vs Reduce Spacing	
USE s=	**10.86**	in		
Vs = (Av * Fy * d) / s =	0.0	k		

11.5.6 - MINIMUM SHEAR REINFORCEMENT

A minimum area of shear reinforcement, Av,min shall be provided in all reinforced concrete flexural members where **Vu** exceeds **0.5 f Vc**

NOT REQUIRED IF:

a) SLAB OR FOOTING, vc>vn **O.K.**

b) CONCRETE JOIST ACI 8.11

c) BEAMS W/ h <= 10"

h <= 2.5*Bf

h <= 0.5*tw

d) WALLS (SEE ACI 11.10.1); vc>vn **O.K.**

11.5.6.3

Av,min = 0.75 sqrt(fc') bw*s/fy = 0.55 * s

but not less than 50bw*s/ fy = 18.33333333 * s

s max = Av fy / 0.75 sqrt(fc') bw = 0.00 in

s max = Av fy /50 bw = 0.00 in

11.5.5.3

Where Vs exceeds 4*sqrt(Fc')*bw*d maximum spacings shall be reduced by one-half