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 H	**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 H.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)	901.68					
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)	**0.44**	**0.44**	**1.64**	**15.82**	**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)	**4.44**	**4.44**	**5.64**	**19.82**	**NA**	**NA**
Uplift @ TW (ft)	**4.23**	**4.23**	**5.38**	**19.82**	**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 H		

Monolith Structure

ITEM		UNIT	QUANITY	UNIT COST	TOTAL Cost
FURNISH HP14x73 WALL PILING		LF	784	0	$0
INSTALL HP14x73 WALL PILING		LF	784	0	$0
PILE TEST, 66.0 ft	Long	EA	2	0	$0
FOOTING CONCRETE		CY	81	0	$0
	Forming	SF	510		
STEM CONCRETE		CY	117	0	$0
	Forming	SF	1,736		
STEEL REINFORCEMENT		LB	21,083	0	$0
WALL RAILING		LF	50	0	$0
SHEET PILE CUT-OFF WALL		SF	1,000	0	$0
					$0

Structure Length = 50 ft

No. piles = 14 Each

Length = 56 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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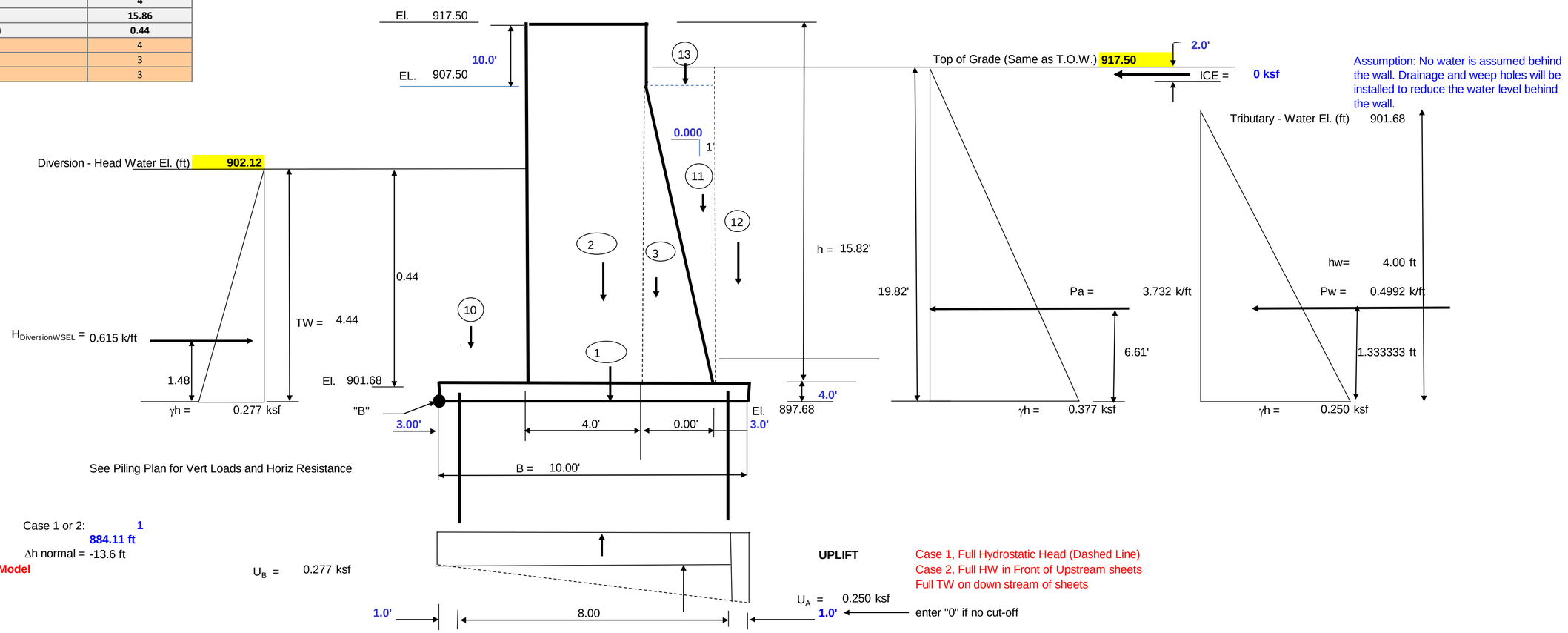
COMPUTED	CHECKED	SUBMITTED	PROJECT NUMBER	34091004	
MBI 2/11/11		MBI	SUBJECT	Sheyenne Aquaduct Structure - Retaining Walls Load Cases: Case 1 100 yr. flood Panel H	

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)	901.68
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)	0.44
Wall Thickness (ft)	4
Toe (Ft)	3
Heel (ft)	3

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 = 50.0 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 = -13.6 ft
See Geotechnical seepage Model

U_B = 0.277 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	50	10.00	4.00	0.15	rec	300.0	5.00	1,500.0
Stem	2	50	4.00	15.82	0.15	rec	474.6	5.00	2,373.0
Batter	3	50	0.00	5.82	0.15	tri	0.0	7.00	0.0
					D.L. Concrete	ΣVc =	**774.6**	ΣM_V =	**3,873.0**

← CONSTANT FOR ALL LOAD CASES

T.W on ftg Stem	10	50	3.00	0.44	0.0624	rec	4.1	1.50	6.2
H.W. on Stem Slope	11	50	0.00	5.82	0.12	tri	0.0	7.00	0.0
H.W. Above Slope	13	50	0.00	10.00	0.12	rec	0.0	7.00	0.0
Soil on Footing	12s	50	3.00	15.82	0.0626	rec	148.5	8.50	1,262.7
H.W. on Footing	12w	50	3.00	0.00	0.0624	rec	0.0	8.50	0.0
					D.L. Water	ΣVw =	**152.7**	ΣM_V =	**1,268.9**

Uplift Loads		L ft	W ft	Pressure ksf		**U** K	arm ft	**Mu** ft-k
	U_B	50	10.00	0.277	rec	-138.5	5.00	-693
	U_A	50	10.00	-0.027	tri	6.9	6.67	46
					ΣU =	**-131.7**	ΣM_U =	**-647**

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COMPUTED	CHECKED	SUBMITTED	PROJECT NUMBER	34091004	
MBI 2/11/11		MBI	SUBJECT	Sheyenne Aquaduct Structure - Retaining Walls	
				Load Cases: Case 1 100 yr. flood	Panel H

Horizontal Loads

	L	H	Pressure		ICE	arm	Mu
	ft	ft	ksf		K	ft	ft-k
ICE	50	2.00	0.00	rec	0.0	18.82	0.0

	L	Force		H	arm	Mw
	ft	k/ft		K	ft	ft-k
SOIL	50	-3.732		-186.60	6.61	-1232.77
Water Loads						
H_{TW}	50	0.615	tri	30.75	1.48	45.51
H_{HW}	50	-0.499	tri	-24.96	1.33	-33.28
			ΣWater =	**5.79**	ΣM_W =	**-1220.5**

Overturning Moments	$\Sigma M_{OT} = M_U + M_W + M_{ICE}$ =	-1867	kip-ft
Resisting Moments	$\Sigma M_R = M_V$ =	5142	kip-ft
Sum of Moments	$\Sigma Mnet = M_R + M_{OT}$ =	**3,274**	kip-ft
Sum of Vertical Forces	P = Conc + Water + Uplift =	**796**	kips
Sum of Horizontal Forces	H = Σhorizontal	**-181**	kips

Location of Resultant	Xr = ΣM / P =	4.12	ft from Toe
	e = B/2 - Xr =	0.88	ft
	B/6 =	1.667	ft

CONCRETE QUANTITIES

			forming	
Ftg conc:	77	cy (includes stepped)	510	sf
Stem Conc:	117	cy	1736	sf
Total =	194			

STEEL REINFORCEMENT: (assumed)

		Bar #	Spacing		Length	# of bars	Total wt		
a) Footing			in	LB /ft	ft	ea	lb		
Top mat	Transverse:	9	12	3.40	9.5	52	1,680		
	Longitudinal:	9	12	3.40	51.5	10	1,751		
Bot mat	Transverse:	9	12	3.40	9.5	52	1,680		
	Longitudinal:	9	12	3.40	51.5	10	1,751		
								cy	**LB/cy**
							6,861	77	89.06365385
b) Skin Reinf. On Monolith									
Vert Face	Vertical	9	12	3.40	15.32	50	2,604	5,208.80	
	Longitudinal:	9	12	3.40	49.5	16	2,693	5,385.60	
Top Face	Transverse:	9	12	3.40	3.5	50	595		
	Longitudinal:	9	12	3.40	49.5	4	673		
Dowels	Vertical I.F.	9	12	3.40	15.3	50	2,604		
	Vertical O.F.	9	12	3.40	15.3	50	2,604		
								cy	**LB/cy**
							11,774	117	100.475158
						Σ =	**18,635**		
	Lap Splices (long. Bars)	9		3.40	8	90	2,448		
						Σ Bar Wt=	21,083	lb	

FORCES AT THE BOTTOM OF THE STEM

Diversion Face	H	γ	Pbase	V	arm	Mv
	ft	kcf		K	ft	ft-k
Diversion WSEL	0.44	0.0624	0.027456	0.006	0.147	0.000886
Tributary SEL =	15.82	0.019	0.30058	2.378	5.273	12.53781
Tributary WSEL =	0.00	0.0624	0	0.000	0.000	0
Sum				2.378		12.53781
Net Forces				2.372		12.53693

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

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
Diversion - T.O. Mat El. (ft)	901.68
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)	0.44
Wall Thickness (ft)	4
Toe (Ft)	3
Heel (ft)	3

File:

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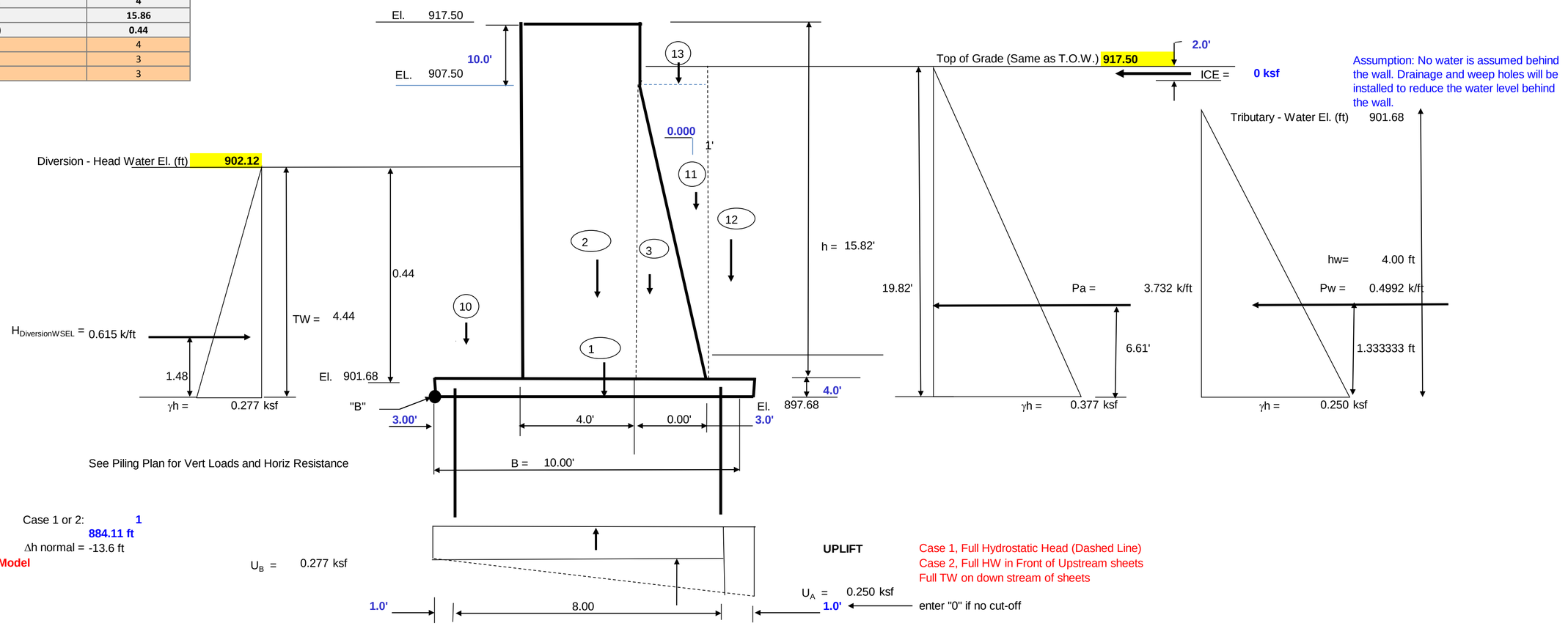
Frost Depth = 5.0 ft provide min frost ftg protection during Dec, Jan, Feb, March
Water El. = 903.24 ft DEC, JAN, FEB Mean Water Elevation

Non-Overflow Section **Length = 50.0 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 = -13.6 ft
See Geotechnical seepage Model

U_B = 0.277 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	50	10.00	4.00	0.15	rec	300.0	5.00	1,500.0
Stem	2	50	4.00	15.82	0.15	rec	474.6	5.00	2,373.0
Batter	3	50	0.00	5.82	0.15	tri	0.0	7.00	0.0
					D.L. Concrete	ΣVc =	**774.6**	ΣM_V =	**3,873.0**

← CONSTANT FOR ALL LOAD CASES

T.W on ftg Stem	10	50	3.00	0.44	0.0624	rec	4.1	1.50	6.2
H.W. on Stem Slope	11	50	0.00	5.82	0.12	tri	0.0	7.00	0.0
H.W. Above Slope	13	50	0.00	10.00	0.12	rec	0.0	7.00	0.0
Soil on Footing	12s	50	3.00	15.82	0.0626	rec	148.5	8.50	1,262.7
H.W. on Footing	12w	50	3.00	0.00	0.0624	rec	0.0	8.50	0.0
					D.L. Water	ΣVw =	**152.7**	ΣM_V =	**1,268.9**

Uplift Loads		L ft	W ft	Pressure ksf		**U** K	arm ft	**Mu** ft-k
	U_B	50	10.00	0.277	rec	-138.5	5.00	-693
	U_A	50	10.00	-0.027	tri	6.9	6.67	46
					ΣU =	**-131.7**	ΣM_U =	**-647**

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

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COMPUTED	CHECKED	SUBMITTED	PROJECT NUMBER	34091004	
MBI		MBI	SUBJECT	Sheyenne Aquaduct Structure - Retaining Walls	
2/11/11				Load Cases: Case 2 100 yr. flood + ice	Panel H

ICE	50	2.00	0.00	rec	0.0	18.82	0.0	
	L		Force		**H**	arm	**Mw**	
	ft		k/ft		K	ft	ft-k	
SOIL	50		-3.732		-186.60	6.61	-1232.77	
Water Loads								
H_{TW}	50		0.615	tri	30.75	1.48	45.51	
H_{HW}	50		-0.499	tri	-24.96	1.33	-33.28	
				ΣWater =	**5.79**	ΣM_W =	**-1220.5**	

Overturning Moments	$\Sigma M_{OT} = M_U + M_W + M_{ICE}$ =	-1867	kip-ft
Resisting Moments	$\Sigma M_R = M_V$ =	5142	kip-ft
Sum of Moments	$\Sigma Mnet = M_R + M_{OT}$ =	**3,274**	kip-ft
Sum of Vertical Forces	P = Conc + Water + Uplift =	**796**	kips
Sum of Horizontal Forces	H = Σhorizontal	**-181**	kips

Location of Resultant	Xr = ΣM / P =	4.12	ft from Toe
	e = B/2 - Xr =	0.88	ft
	B/6 =	1.667	ft

FORCES AT THE BOTTOM OF THE STEM

	H	γ	Pbase	**V**	arm	**Mv**
	ft	kcf		K	ft	ft-k
Diversion Face						
Diversion WSEL	0.44	**0.0624**	0.027456	0.006	0.147	0.000886
Tributary SEL =	15.82	**0.019**	0.30058	2.378	5.273	12.53781
Tributary WSEL =	0.00	**0.0624**	0	0.000	0.000	0
Sum				2.378		12.53781
Net Forces				2.372		12.53693

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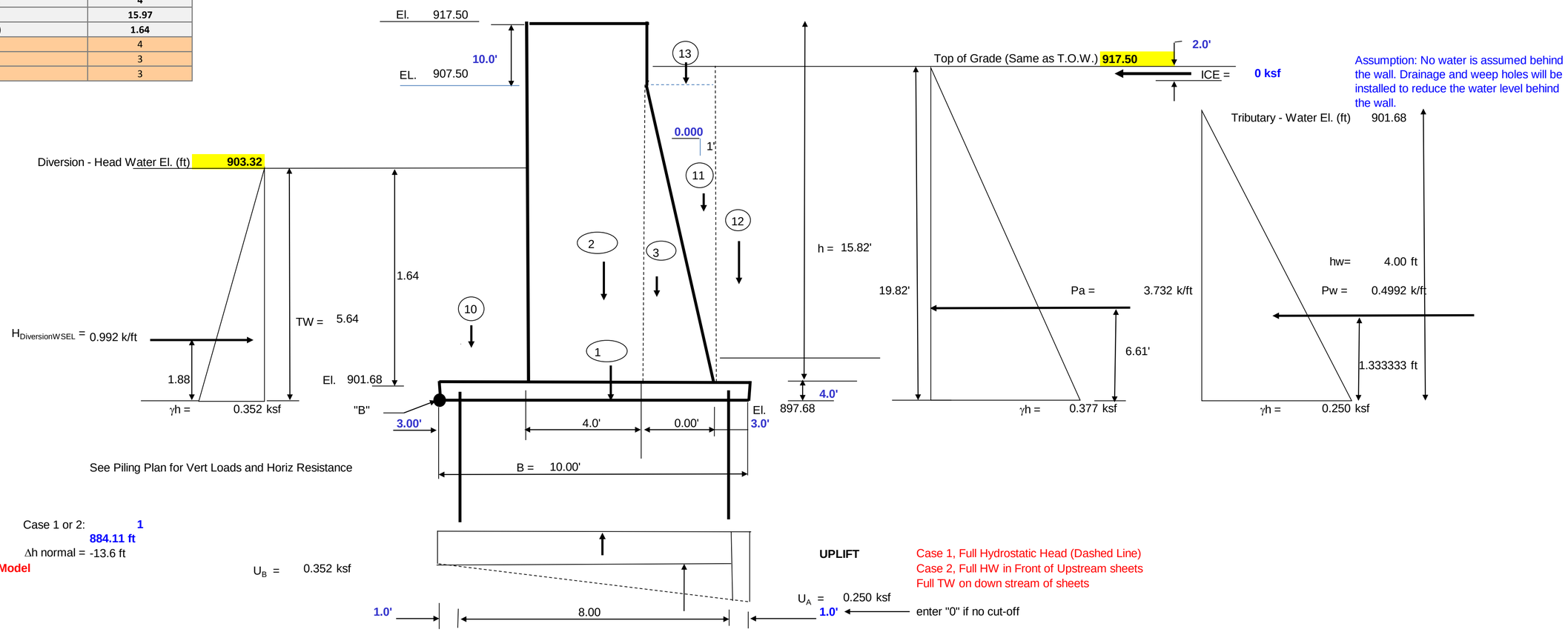
MBI 2/11/11		MBI	SUBJECT	Sheyenne Aquaduct Structure - Retaining Walls Load Cases: Case 3 500 yr. flood Panel H	

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
Diversion - T.O. Mat El. (ft)	901.68
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)	15.97
Diversion - Head Water height (ft)	1.64
Wall Thickness (ft)	4
Toe (Ft)	3
Heel (ft)	3

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 = 50.0 ft**
Stepped Ftg Ls = **2.0 ft** overlap distance at stepped ftg



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

Case 1 or 2: **1**
Normal Water Level, El. **884.11 ft**
Δh normal = -13.6 ft
See Geotechnical seepage Model

Vertical Loads		Section	L ft	W ft	H ft	γ kcf	shape	V K	arm ft	Mv ft-k
Ftg concrete		1	50	10.00	4.00	0.15	rec	300.0	5.00	1,500.0
Stem		2	50	4.00	15.82	0.15	rec	474.6	5.00	2,373.0
Batter		3	50	0.00	5.82	0.15	tri	0.0	7.00	0.0
						D.L. Concrete	ΣVc =	**774.6**	ΣM_V =	**3,873.0**
T.W on ftg Stem		10	50	3.00	1.64	0.0624	rec	15.4	1.50	23.0
H.W. on Stem Slope		11	50	0.00	5.82	0.12	tri	0.0	7.00	0.0
H.W. Above Slope		13	50	0.00	10.00	0.12	rec	0.0	7.00	0.0
Soil on Footing		12s	50	3.00	15.82	0.0626	rec	148.5	8.50	1,262.7
H.W. on Footing		12w	50	3.00	0.00	0.0624	rec	0.0	8.50	0.0
						D.L. Water	ΣVw =	**163.9**	ΣM_V =	**1,285.7**

← CONSTANT FOR ALL LOAD CASES

Uplift Loads		L ft	W ft	Pressure ksf		U K	arm ft	Mu ft-k
	U_B	50	10.00	0.352	rec	-176.0	5.00	-880
	U_A	50	10.00	-0.102	tri	25.6	6.67	171
					ΣU =	**-150.4**	ΣM_U =	**-709**

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

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

ICE	50	2.00	0.00	rec	0.0	18.82	0.0
	L		Force		**H**	arm	**Mw**
	ft		k/ft		K	ft	ft-k
SOIL	50		-3.732		-186.60	6.61'	-1232.77
Water Loads							
H_{TW}	50		0.992	tri	49.62	1.88	93.29
H_{HW}	50		-0.499	tri	-24.96	1.33	-33.28
				ΣWater =	**24.66**	ΣM_W =	**-1172.8**

Overturning Moments	$\Sigma M_{OT} = M_U + M_W + M_{ICE}$ =	-1882	kip-ft
Resisting Moments	$\Sigma M_R = M_V$ =	5159	kip-ft
Sum of Moments	$\Sigma Mnet = M_R + M_{OT}$ =	**3,277**	kip-ft
Sum of Vertical Forces	P = Conc + Water + Uplift =	**788**	kips
Sum of Horizontal Forces	H = Σhorizontal	**-162**	kips

Location of Resultant	Xr = ΣM / P =	4.16	ft from Toe
	e = B/2 - Xr =	0.84	ft
	B/6 =	1.667	ft

FORCES AT THE BOTTOM OF THE STEM

Diversion Face	H	γ	Pbase	**V**	arm	**Mv**
	ft	kcf		K	ft	ft-k
Diversion WSEL	1.64	**0.0624**	0.102336	0.084	0.547	0.045874
Tributary SEL =	15.82	**0.019**	0.30058	2.378	5.273	12.53781
Tributary WSEL =	0.00	**0.0624**	0	0.000	0.000	0
Sum				2.378		12.53781
Net Forces				2.294		12.49194

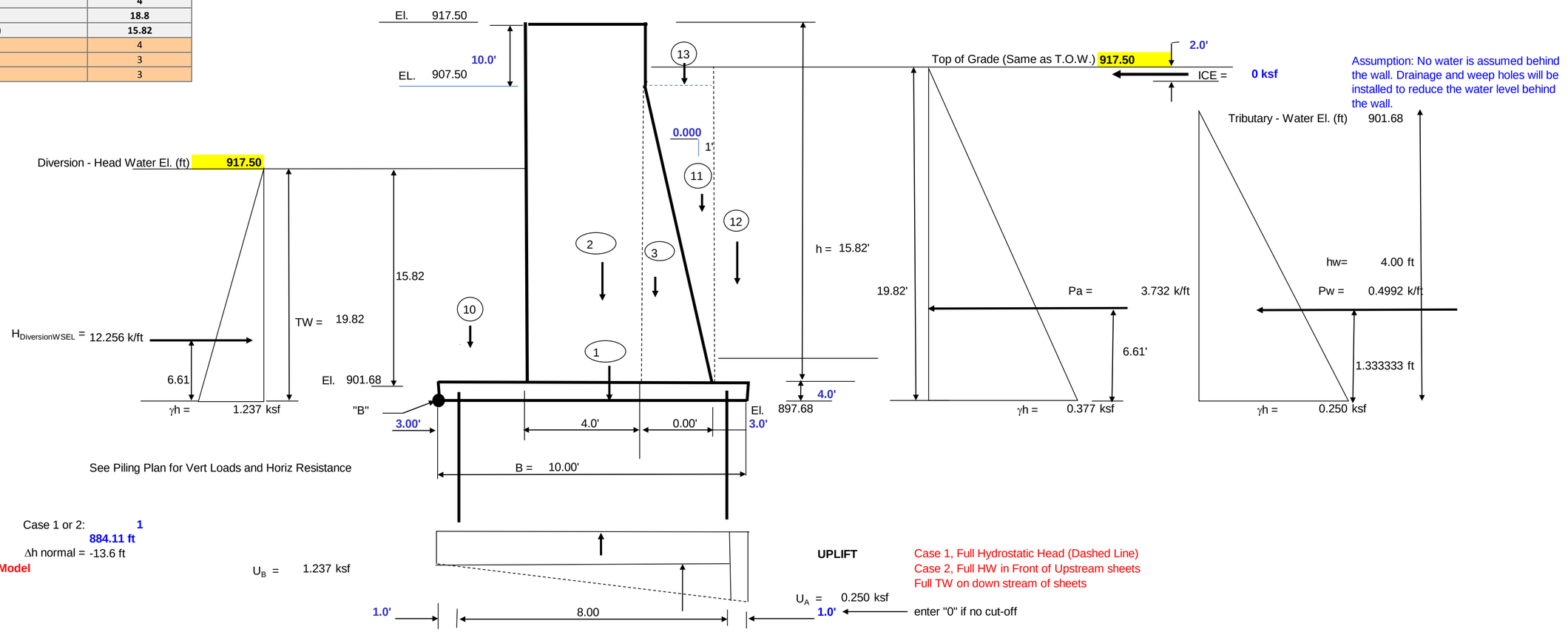
BARR ENGINEERING			DATE	2/11/2011	SHEET NO.
			PROJECT NAME	FARGO – MOORHEAD METRO FLOOD RISK MANAGEMENT PROJECT, FEASIBILITY STUDY, PHASE 4	
COMPUTED	CHECKED	SUBMITTED	PROJECT NUMBER	34091004	
MBI 2/11/11		MBI	SUBJECT	Sheyenne Aquaduct Structure - Retaining Walls	
				Load Cases: Case 4 T.O. Levee Panel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

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)	901.68
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)	15.82
Wall Thickness (ft)	4
Toe (Ft)	3
Heel (ft)	3

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 = 50.0 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 = -13.6 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	50	10.00	4.00	0.15	rec	300.0	5.00	1,500.0
Stem	2	50	4.00	15.82	0.15	rec	474.6	5.00	2,373.0
Batter	3	50	0.00	5.82	0.15	tri	0.0	7.00	0.0
					D.L. Concrete	ΣVc =	**774.6**	ΣM_V =	**3,873.0**
T.W on ftg Stem	10	50	3.00	15.82	0.0624	rec	148.1	1.50	222.1
H.W. on Stem Slope	11	50	0.00	5.82	0.12	tri	0.0	7.00	0.0
H.W. Above Slope	13	50	0.00	10.00	0.12	rec	0.0	7.00	0.0
Soil on Footing	12s	50	3.00	15.82	0.0626	rec	148.5	8.50	1,262.7
H.W. on Footing	12w	50	3.00	0.00	0.0624	rec	0.0	8.50	0.0
					D.L. Water	ΣVw =	**296.6**	ΣM_V =	**1,484.8**

← CONSTANT FOR ALL LOAD CASES

Uplift Loads		L ft	W ft	Pressure ksf		U K	arm ft	Mu ft-k
	U_B	50	10.00	1.237	rec	-618.4	5.00	-3,092
	U_A	50	10.00	-0.987	tri	246.8	6.67	1,645
					ΣU =	**-371.6**	ΣM_U =	**-1,447**

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 H

ICE	50	2.00	0.00	rec	0.0	18.82	0.0
	L		Force		**H**	arm	**Mw**
	ft		k/ft		K	ft	ft-k
SOIL	50		-3.732		-186.60	6.61'	-1232.77
Water Loads							
H_{TW}	50		12.256	tri	612.82	6.61	4048.69
H_{HW}	50		-0.499	tri	-24.96	1.33	-33.28
				ΣWater =	**587.86**	ΣM_W =	**2782.6**

Overturning Moments	$\Sigma M_{OT} = M_U + M_W + M_{ICE}$ =	1336	kip-ft
Resisting Moments	$\Sigma M_R = M_V$ =	5358	kip-ft
Sum of Moments	$\Sigma Mnet = M_R + M_{OT}$ =	**6,694**	kip-ft
Sum of Vertical Forces	P = Conc + Water + Uplift =	**700**	kips
Sum of Horizontal Forces	H = Σhorizontal	**401**	kips

Location of Resultant	Xr = ΣM / P =	9.57	ft from Toe
	e = B/2 - Xr =	(4.57)	ft
	B/6 =	1.667	ft

FORCES AT THE BOTTOM OF THE STEM

	H	γ	Pbase	**V**	arm	**Mv**
	ft	kcf		K	ft	ft-k
Diversion Face						
Diversion WSEL	15.82	**0.0624**	0.987168	7.808	5.273	41.17682
Tributary SEL =	15.82	**0.019**	0.30058	2.378	5.273	12.53781
Tributary WSEL =	0.00	**0.0624**	0	0.000	0.000	0
Sum				2.378		12.53781
Net Forces				-5.431		-28.639

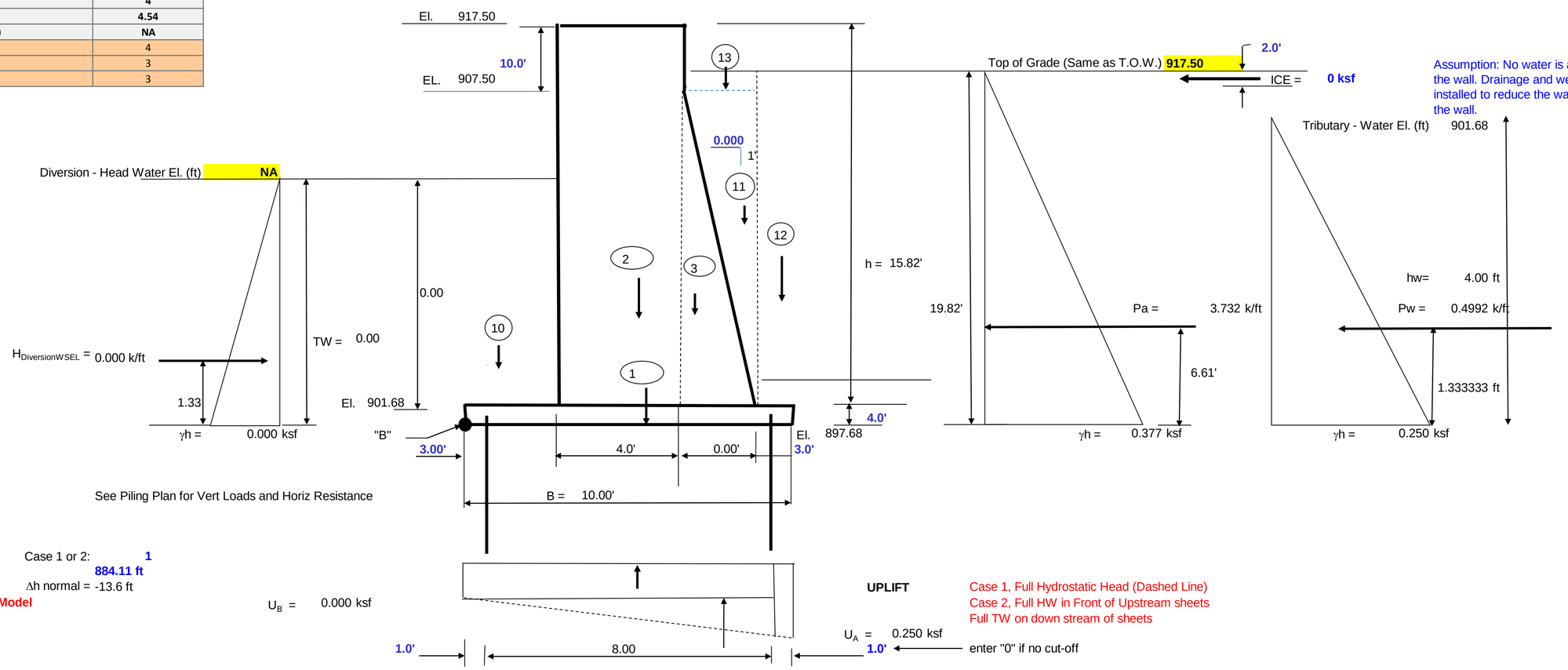
BARR ENGINEERING			DATE	2/11/2011	SHEET NO.
			PROJECT NAME	FARGO – MOORHEAD METRO FLOOD RISK MANAGEMENT PROJECT, FEASIBILITY STUDY, PHASE 4	
COMPUTED	CHECKED	SUBMITTED	PROJECT NUMBER	34091004	
MBI 2/11/11		MBI	SUBJECT	Sheyenne Aquaduct Structure - Retaining Walls Load Cases: Case 5 Normal flow + ice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

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)	901.68
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)	3
Heel (ft)	3

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 = 50.0 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 = -13.6 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	50	10.00	4.00	0.15	rec	300.0	5.00	1,500.0
Stem	2	50	4.00	15.82	0.15	rec	474.6	5.00	2,373.0
Batter	3	50	0.00	5.82	0.15	tri	0.0	7.00	0.0
					D.L. Concrete	ΣVc =	**774.6**	ΣM_V =	**3,873.0**
T.W on ftg Stem	10	50	3.00	0.00	0.0624	rec	0.0	1.50	0.0
H.W. on Stem Slope	11	50	0.00	5.82	0.12	tri	0.0	7.00	0.0
H.W. Above Slope	13	50	0.00	10.00	0.12	rec	0.0	7.00	0.0
Soil on Footing	12s	50	3.00	15.82	0.0626	rec	148.5	8.50	1,262.7
H.W. on Footing	12w	50	3.00	0.00	0.0624	rec	0.0	8.50	0.0
					D.L. Water	ΣVw =	**148.5**	ΣM_V =	**1,262.7**

← CONSTANT FOR ALL LOAD CASES

Uplift Loads		L ft	W ft	Pressure ksf		U K	arm ft	Mu ft-k
	U_B	50	10.00	0.000	rec	0.0	5.00	0
	U_A	50	10.00	0.250	tri	-62.4	6.67	-416
					ΣU =	**-62.4**	ΣM_U =	**-416**

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 H	

ICE	50	2.00	0.00	rec	0.0	18.82	0.0	
	L		Force		**H**	arm	**Mw**	
	ft		k/ft		K	ft	ft-k	
SOIL	50		-3.732		-186.60	6.61'	-1232.77	
Water Loads								
H_{TW}	50		0.000	tri	0.00	1.33	0.00	
H_{HW}	50		-0.499	tri	-24.96	0.00	0.00	
				ΣWater =	**-24.96**	ΣM_W =	**-1232.8**	

Overturning Moments	$\Sigma M_{OT} = M_U + M_W + M_{ICE}$ =	-1649	kip-ft
Resisting Moments	$\Sigma M_R = M_V$ =	5136	kip-ft
Sum of Moments	$\Sigma Mnet = M_R + M_{OT}$ =	**3,487**	kip-ft
Sum of Vertical Forces	P = Conc + Water + Uplift =	**861**	kips
Sum of Horizontal Forces	H = Σhorizontal	**-212**	kips

Location of Resultant	Xr = ΣM / P =	4.05	ft from Toe
	e = B/2 - Xr =	0.95	ft
	B/6 =	1.667	ft

FORCES AT THE BOTTOM OF THE STEM

	H	γ	Pbase	**V**	arm	**Mv**
	ft	kcf		K	ft	ft-k
Diversion Face						
Diversion WSEL	0.00	**0.0624**	0	0.000	0.000	0
Tributary SEL =	15.82	**0.019**	0.30058	2.378	5.273	12.53781
Tributary WSEL =	0.00	**0.0624**	0	0.000	0.000	0
Sum				2.378		12.53781
Net Forces				2.378		12.53781

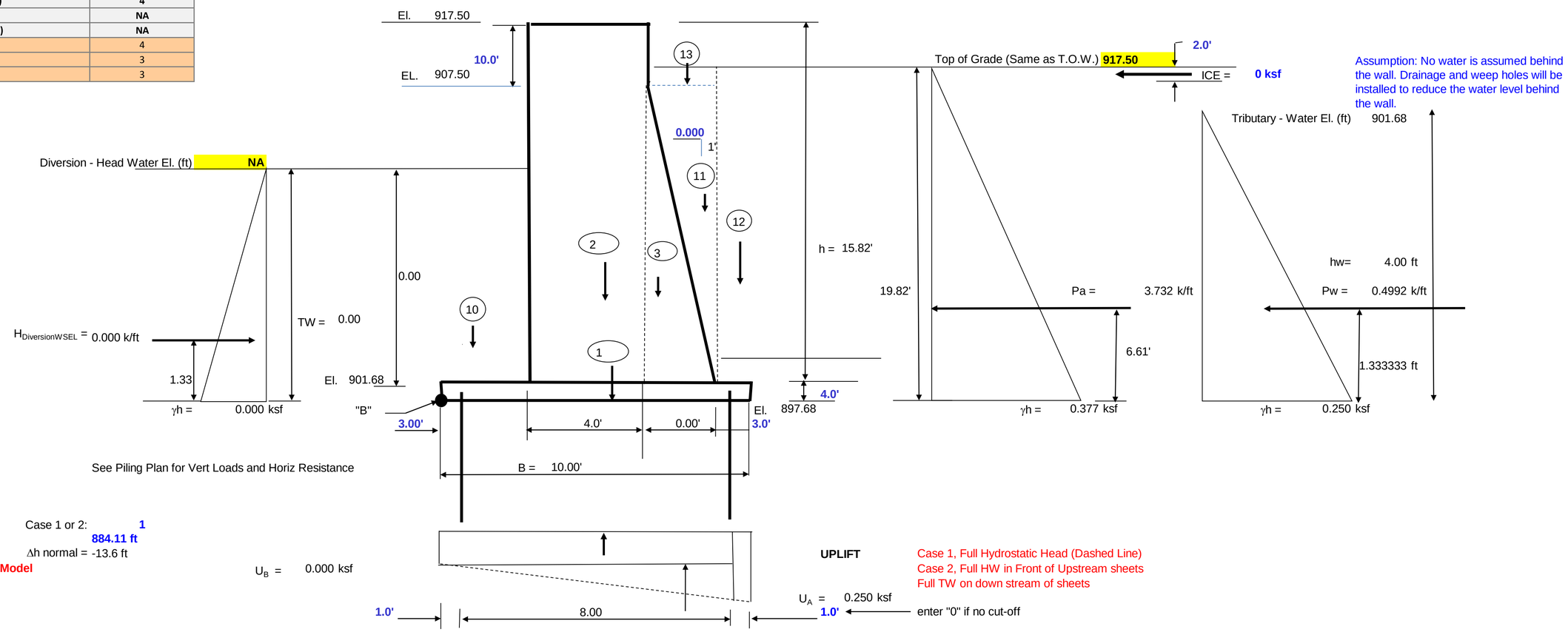
BARR ENGINEERING			DATE	2/11/2011	SHEET NO.
			PROJECT NAME	FARGO – MOORHEAD METRO FLOOD RISK MANAGEMENT PROJECT, FEASIBILITY STUDY, PHASE 4	
COMPUTED	CHECKED	SUBMITTED	PROJECT NUMBER	34091004	
MBI 2/11/11		MBI	SUBJECT	Sheyenne Aquaduct Structure - Retaining Walls	
				Load Cases: Case 6 Construction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

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)	901.68
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)	3
Heel (ft)	3

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 = 50.0 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 = -13.6 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	50	10.00	4.00	0.15	rec	300.0	5.00	1,500.0
Stem	2	50	4.00	15.82	0.15	rec	474.6	5.00	2,373.0
Batter	3	50	0.00	5.82	0.15	tri	0.0	7.00	0.0
					D.L. Concrete	ΣVc =	**774.6**	ΣM_V =	**3,873.0**
T.W on ftg Stem	10	50	3.00	0.00	0.0624	rec	0.0	1.50	0.0
H.W. on Stem Slope	11	50	0.00	5.82	0.12	tri	0.0	7.00	0.0
H.W. Above Slope	13	50	0.00	10.00	0.12	rec	0.0	7.00	0.0
Soil on Footing	12s	50	3.00	15.82	0.0626	rec	148.5	8.50	1,262.7
H.W. on Footing	12w	50	3.00	0.00	0.0624	rec	0.0	8.50	0.0
					D.L. Water	ΣVw =	**148.5**	ΣM_V =	**1,262.7**

← CONSTANT FOR ALL LOAD CASES

Uplift Loads		L ft	W ft	Pressure ksf		U K	arm ft	Mu ft-k
	U_B	50	10.00	0.000	rec	0.0	5.00	0
	U_A	50	10.00	0.250	tri	-62.4	6.67	-416
					ΣU =	**-62.4**	ΣM_U =	**-416**

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 H

ICE	50	2.00	0.00	rec	0.0	18.82	0.0
	L		Force		**H**	arm	**Mw**
	ft		k/ft		K	ft	ft-k
SOIL	50		-3.732		-186.60	6.61'	-1232.77
Water Loads							
H_{TW}	50		0.000	tri	0.00	1.33	0.00
H_{HW}	50		-0.499	tri	-24.96	1.33	-33.28
				ΣWater =	**-24.96**	ΣM_W =	**-1266.1**

Overturning Moments	$\Sigma M_{OT} = M_U + M_W + M_{ICE}$ =	-1682	kip-ft
Resisting Moments	$\Sigma M_R = M_V$ =	5136	kip-ft
Sum of Moments	$\Sigma Mnet = M_R + M_{OT}$ =	**3,454**	kip-ft
Sum of Vertical Forces	P = Conc + Water + Uplift =	**861**	kips
Sum of Horizontal Forces	H = Σhorizontal	**-212**	kips

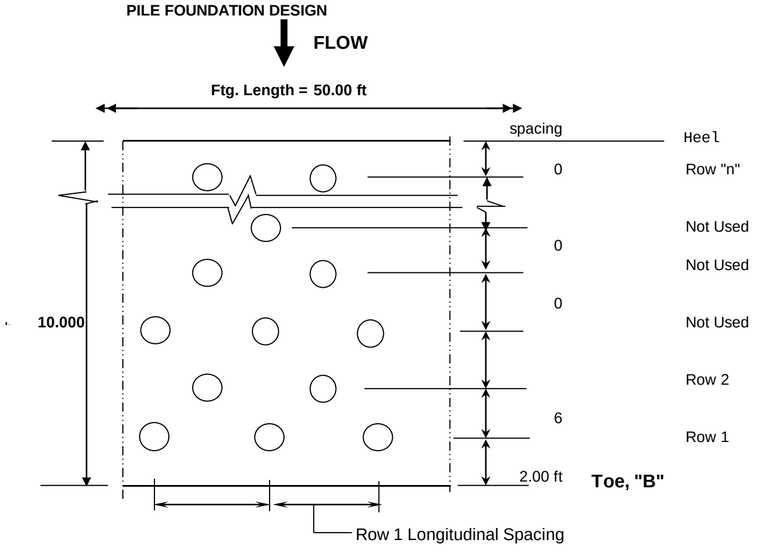
Location of Resultant	Xr = ΣM / P =	4.01	ft from Toe
	e = B/2 - Xr =	0.99	ft
	B/6 =	1.667	ft

FORCES AT THE BOTTOM OF THE STEM

	H	γ	Pbase	**V**	arm	**Mv**
	ft	kcf		K	ft	ft-k
Diversion Face						
Diversion WSEL	0.00	**0.0624**	0	0.000	0.000	0
Tributary SEL =	15.82	**0.019**	0.30058	2.378	5.273	12.53781
Tributary WSEL =	0.00	**0.0624**	0	0.000	0.000	0
Sum				2.378		12.53781
Net Forces				2.378		12.53781

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 H	

PILE FOUNDATION DESIGN



L = 50.00 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"	8	16.25	1	21
Row 1 to Row 2	6.00 ft	8.0 ft	5.00 ft	0 "/12"	6	12.50	2	11
Row 2 to Row 3	0.00 ft	0.0 ft	0.00 ft	0 "/12"	0	25.00	0	0
Row 3 to Row 4	0.00 ft	0.0 ft	0.00 ft	0 "/12"	0	25.00	0	0
Row 4 to Row 5	0.00 ft	0.0 ft	0.00 ft	0 "/12"	0	25.00	0	0
Row 5 to Row 6	0.00 ft	0.0 ft	0.00 ft	0 "/12"	0	25.00	0	0
Row 6 to Row 7	0.00 ft	0.0 ft	0.00 ft	0 "/12"	0	25.00	0	0
Row 7 to Row 8	0.00 ft	0.0 ft	0.00 ft	0 "/12"	0	25.00	0	0
Row 8 to Row 9	0.00 ft	0.0 ft	0.00 ft	0 "/12"	0	25.00	0	0
Row 9 to Row 10	0.00 ft	0.0 ft	0.00 ft	0 "/12"	0	25.00	0	0
Row 10 to Row 11	0.00 ft	0.0 ft	0.00 ft	0 "/12"	0	25.00	0	0
Row 11 to Row 12	0.00 ft	0.0 ft	0.00 ft	0 "/12"	0	25.00	0	0
Row 12 to Row 13	0.00 ft	0.0 ft	0.00 ft	0 "/12"	0	25.00	0	0
Row 13 to Row 14	0.00 ft	0.0 ft	0.00 ft	0 "/12"	0	25.00	0	0
Row 14 to Row 15	0.00 ft	0.0 ft	0.00 ft	0 "/12"	0	25.00	0	0
Last Row to Heel	2.00 ft							
	10.00 ft				ΣN =	14		32

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

Pile Properties: Pile Type: **HP** (C.I.P or HP) Pile Length = **56.0 ft**

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

Wt. per ft, plf **73**

Ftg EL. 897.68

Pile Tip El. 842.68

Pile Cap Embed = **1.00 ft**

Total pile Length = **784** **LF**

Pile Group Properties

N.A. of Pile Group to Toe

$X_{NA} = (\Sigma N * d_{toe}) / \Sigma N =$ **4.57 ft**

	Dist. From N.A. to Pile Row	d	N	$I = N * d^2$
1	Dist. To Row 1	2.57 ft	8	52.9
2	Dist. To Row 2	-3.43 ft	6	70.5
0	Row 3 (not used)	0.00 ft	0	0.0
0	Row 4 (not used)	0.00 ft	0	0.0
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
			14	$\Sigma I =$ **123.4**

ALLOWABLE LOADS (from Geotechnical)

Service 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**	32.2	23.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	32.2	504	**OK**
Case 2	**82.6 tons**	32.2	23.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	32.2	574	**OK**
Case 3	**82.6 tons**	31.5	23.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	31.5	574	**OK**
Case 4	**107.7 tons**	-11.4	73.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	73.5	672	**OK**
Case 5	**36.5 tons**	35.4	24.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	35.4	322	**OK**
Case 6	**82.6 tons**	35.8	24.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	35.8	322	**OK**

Max Service : P = **73.5**

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

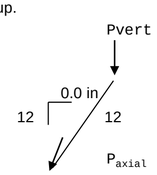
$$e_{NA} = X_{NA} - e_{toe}$$

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**	796	181	3,274	4.12	0.46	363
Case 2	**100 yr. flood + ice**	**Unusual**	796	181	3,274	4.12	0.46	363
Case 3	**500 yr. flood**	**Unusual**	788	162	3,277	4.16	0.41	326
Case 4	**T.O. Levee**	**Extreme**	700	-401	6,694	9.57	-5.00	-3495
Case 5	**Normal flow + ice**	**Usual**	861	212	3,487	4.05	0.52	448
Case 6	**Construction**	**Unusual**	861	212	3,454	4.01	0.56	481

SERVICE

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

Vertical Load, P = 796 kips
Horizontal Load, H = 181 kips
M_{NA} = 363 kip-ft

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	Vertical Pile Loading	P / N	+	M_{NA}* d / Σ I	= Pile Loads			**Axial Pile Load**
1	Row 1	56.8		7.6	64.4 kips/pile	32.2 tons/pile		32.2 tons/pile
2	Row 2	56.8		-10.1	46.8 kips/pile	23.4 tons/pile		23.4 tons/pile
3	Row 3	0.0		0.0	0.0 kips/pile	0.0 tons/pile		0.0 tons/pile
4	Row 4	0.0		0.0	0.0 kips/pile	0.0 tons/pile		0.0 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:	**max:**	**32.2 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	8	0.0	288	1.000	288 kips
2	Row 2	0	6	0.0	216	1.000	216 kips
3	Row 3	0	0	0.0	0	1.000	0 kips
4	Row 4	0	0	0.0	0	1.000	0 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
			14		504		**504 kips**

OK

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

Vertical Load, P = 796 kips
Horizontal Load, H = 181 kips
M_{NA} = 363 kip-ft

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	Vertical Pile Loading	P / N	+	M_{NA}* d / Σ I	= Pile Loads			**Axial Pile Load**
1	Row 1	56.8		7.6	64.4 kips/pile	32.2 tons/pile		32.2 tons/pile
2	Row 2	56.8		-10.1	46.8 kips/pile	23.4 tons/pile		23.4 tons/pile
3	Row 3	0.0		0.0	0.0 kips/pile	0.0 tons/pile		0.0 tons/pile
4	Row 4	0.0		0.0	0.0 kips/pile	0.0 tons/pile		0.0 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:	**max:**	**32.2 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	8	0.0	328	1.000	328 kips
2	Row 2	0	6	0.0	246	1.000	246 kips
3	Row 3	0	0	0.0	0	1.000	0 kips

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4	Row 4	0	0	0.0	0	1.000	0 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	
			14		574		**574 kips**	**OK**

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

Vertical Load, P = 788 kips
Horizontal Load, H = 162 kips
M_{NA} = 326 kip-ft

	Vertical Pile Loading	P / N	+	M_{NA}* d / Σ I	= Pile Loads		**Axial Pile Load**
1	Row 1	56.3		6.8	63.1 kips/pile	31.5 tons/pile	31.5 tons/pile
2	Row 2	56.3		-9.1	47.2 kips/pile	23.6 tons/pile	23.6 tons/pile
3	Row 3	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
4	Row 4	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 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: **31.5 tons/pile**	**max:** **31.5 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	8	0.0	328	1.000	328 kips	
2	Row 2	0	6	0.0	246	1.000	246 kips	
3	Row 3	0	0	0.0	0	1.000	0 kips	
4	Row 4	0	0	0.0	0	1.000	0 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	
			14		574		**574 kips**	**OK**

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

Vertical Load, P = 700 kips
Horizontal Load, H = -401 kips
M_{NA} = -3495 kip-ft

	Vertical Pile Loading	P / N	+	M_{NA}* d / Σ I	= Pile Loads		**Axial Pile Load**
1	Row 1	50.0		-72.8	-22.8 kips/pile	-11.4 tons/pile	-11.4 tons/pile
2	Row 2	50.0		97.1	147.1 kips/pile	73.5 tons/pile	73.5 tons/pile
3	Row 3	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
4	Row 4	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 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: **73.5 tons/pile**	**max:** **73.5 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	8	0.0	384	1.000	384 kips	
2	Row 2	0	6	0.0	288	1.000	288 kips	
3	Row 3	0	0	0.0	0	1.000	0 kips	
4	Row 4	0	0	0.0	0	1.000	0 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	
			14		672		**672 kips**	**OK**

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

Vertical Load, P = 861 kips
Horizontal Load, H = 212 kips
M_{NA} = 448 kip-ft

	Vertical Pile Loading	P / N	+	M_{NA}* d / Σ I	= Pile Loads		Axial Pile Load
1	Row 1	61.5		9.3	70.8 kips/pile	35.4 tons/pile	35.4 tons/pile
2	Row 2	61.5		-12.4	49.0 kips/pile	24.5 tons/pile	24.5 tons/pile
3	Row 3	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
4	Row 4	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 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:	**35.4 tons/pile**	**max: 35.4 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	8	0.0	184	1.000	184 kips	
2	Row 2	0	6	0.0	138	1.000	138 kips	
3	Row 3	0	0	0.0	0	1.000	0 kips	
4	Row 4	0	0	0.0	0	1.000	0 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	
			14		322		**322 kips**	**OK**

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

Vertical Load, P = 861 kips
Horizontal Load, H = 212 kips
M_{NA} = 481 kip-ft

	Vertical Pile Loading	P / N	+	M_{NA}* d / Σ I	= Pile Loads		Axial Pile Load
1	Row 1	61.5		10.0	71.5 kips/pile	35.8 tons/pile	35.8 tons/pile
2	Row 2	61.5		-13.4	48.1 kips/pile	24.1 tons/pile	24.1 tons/pile
3	Row 3	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 tons/pile
4	Row 4	0.0		0.0	0.0 kips/pile	0.0 tons/pile	0.0 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

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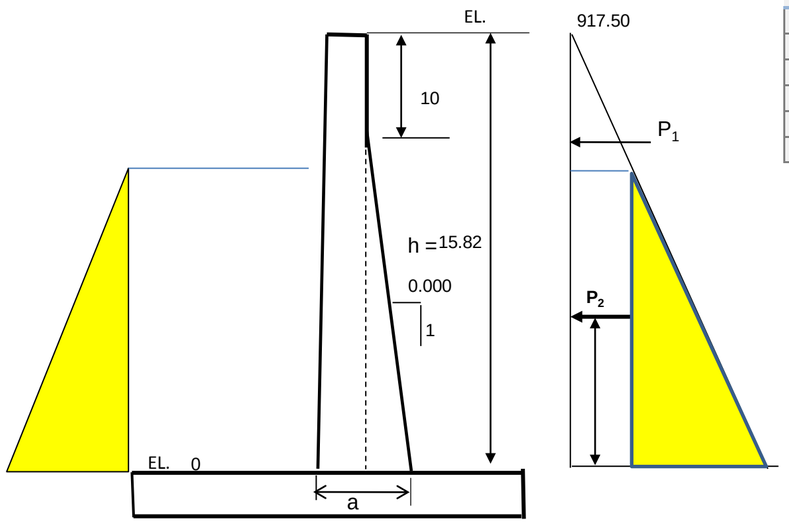
11	Row 11	0.0	0.0	0.0 kips/pile		0.0 tons/pile		0.0 tons/pile	
12	Row 12	0.0	0.0	0.0 kips/pile		0.0 tons/pile		0.0 tons/pile	
13	Row 13	0.0	0.0	0.0 kips/pile		0.0 tons/pile		0.0 tons/pile	
14	Row 14	0.0	0.0	0.0 kips/pile		0.0 tons/pile		0.0 tons/pile	
15	Row 15	0.0	0.0	0.0 kips/pile		0.0 tons/pile		0.0 tons/pile	
					max:	**35.8 tons/pile**	**max:**	**35.8 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	8	0.0	184	1.000	184 kips	
2	Row 2	0	6	0.0	138	1.000	138 kips	
3	Row 3	0	0	0.0	0	1.000	0 kips	
4	Row 4	0	0	0.0	0	1.000	0 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	
			14		322		**322 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 H 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	2.37	12.537	5.24	27.71
Case 2	100 yr. flood + ice	Unusual	0.75	2.37	12.537	3.93	20.78
Case 3	500 yr. flood	Unusual	0.75	2.29	12.492	3.80	20.71
Case 4	T.O. Levee	Extreme	0.75	-5.43	-28.639	9.00	47.47
Case 5	Normal flow + ice	Usual	1	2.38	12.538	5.25	27.71
Case 6	Construction	Unusual	0.75	2.38	12.538	3.94	20.78

STEM DESIGN VALUES

MU, k-ft/ft	47.47	k-ft/ft
VU, k/ft	9.00	k/ft

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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 =	47	k-ft /ft	**Includes: hf = 1.3**
Vuh=	9.00	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 =	27.873		**ACI 10.5.1** p(min)= 3*SQRT(Fc')/fy = 0.00316; 200* / fy = 0.00333; **ACI 10.5.3** 4/3*p = 0.0006
REQ'D p=	0.0005	**O.K.**	
p=	0.0006		
As (REQ'D)=	0.81	in^2	**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=	12	in	
# OF BAR=	1	(ENTER 1 IF PER FT, b=12")	a
As=	0.999	in^2	
d=	43.4375	in	
p = As/bd =	0.0019	**O.K. < 0.375pb**	**EM 110-2-2104**
p =	**0.067**	**pb**	**MAXIMUM TENSILE REINFORCEMENT**
T= As*fy =	60.0	k	a) For singly reinforced flexural members
C= B1*Fc' *b*a =	161.4	**a**	1) p = **0.25** pb Recommended limit
a= T/C =	0.372	in	2) p = **0.375** pb Max. permitted upper limit not requiring special study
Mn= T(d - a/2)/12 =	216.1	ft-k	3) p = **0.5** pb Max. permitted upper limit when excessive deflections are not predicted In ACI 318
ϕ Mn=	194.5	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 =	9.0	k	**NO SHEAR REINF. REQUIRED**
Vn = Vuh / ϕ =	12.0	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 =	0.25	* s
but not less than 50bw*s/ fy =	8.333333333	* 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