MAPLE 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:	**Maple Aquaduct Structure - Retaining Walls**	**Date:**	**2/10/2011**
	Panel A	**Job #:**	**34091004**
File Path:	P:\Mpls\34 ND\09\34091004 Fargo Moorhead Metropolitan Feas. Study\WorkFiles_Phase4\070 Structural\Aqueducts\Maple\[34091004 PH4 Maple Retaining Walls Panel A.xlsx]Stem		
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)	895.99	895.99	896.38	902	881.5	**NA**
Diversion - Head Water El. (ft)	893.89	893.89	895.46	902	**NA**	**NA**
Diversion - Tail Water El. (ft)	892.57	892.57	893.66	902	**NA**	**NA**
Tributary - T.O. Wall El. (ft)	902					
Tributary - T.O. Deck L.P. El.(ft)	881.06					
Tributary - T.O. Deck H.P. El.(ft)	883.06					
Diversion - T.O. Mat El. (ft)	890.06					
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)	**14.93**	**14.93**	**15.32**	**20.94**	**0.44**	**NA**
Diversion - Head Water height (ft)	**3.83**	**3.83**	**5.4**	**11.94**	**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**	**895.99**	**NA**	**NA**	**881.5**	**NA**
Uplift @ HW (ft)	**7.83**	**7.83**	**9.4**	**15.94**	**NA**	**NA**
Uplift @ TW (ft)	**6.51**	**6.51**	**7.6**	**15.94**	**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**	**21**	**21**	**24**	**11.5**	**21**
Allowable Pile Capacity (tons) - Axial	**57.18**	**76.23**	**76.23**	**99.43**	**31.425**	**76.23**
Allowable Pile Capacity (tons) - Uplift	**33.88**	**45.17**	**45.17**	**58.91**	**4.625**	**45.17**

Pile Capacity	**Ultimate Axial Capacity (kips)**	**Allowable Lateral Capacity (kips)**		
		0.5" (Usual)	**0.67" (Unusual)**	**0.875" (Extreme)**
Undrained - Axial	228.7	36	42	48
Undrained - Uplift	135.5			
Drained - Axial	125.7	23	29	33
Drained - Uplift	18.5			

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

Monolith Structure

ITEM		UNIT	QUANITY	UNIT COST	TOTAL Cost
FURNISH HP14x73 WALL PILING		LF	1,065	0	$0
INSTALL HP14x73 WALL PILING		LF	1,065	0	$0
PILE TEST, 54.4 ft	Long	EA	4	0	$0
FOOTING CONCRETE		CY	128	0	$0
	Forming	SF	769		
STEM CONCRETE		CY	142	0	$0
	Forming	SF	2,060		
STEEL REINFORCEMENT		LB	28,888	0	$0
WALL RAILING		LF	81	0	$0
SHEET PILE CUT-OFF WALL		SF	805	0	$0
					$0

Structure Length = 80.5 ft

No. piles = 24 Each
Length = 44.38 ft

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

LENGTH
(FRONT FACE) 10 FT
Native Soil has low permeability assume cut-off
minimal to prevent scour

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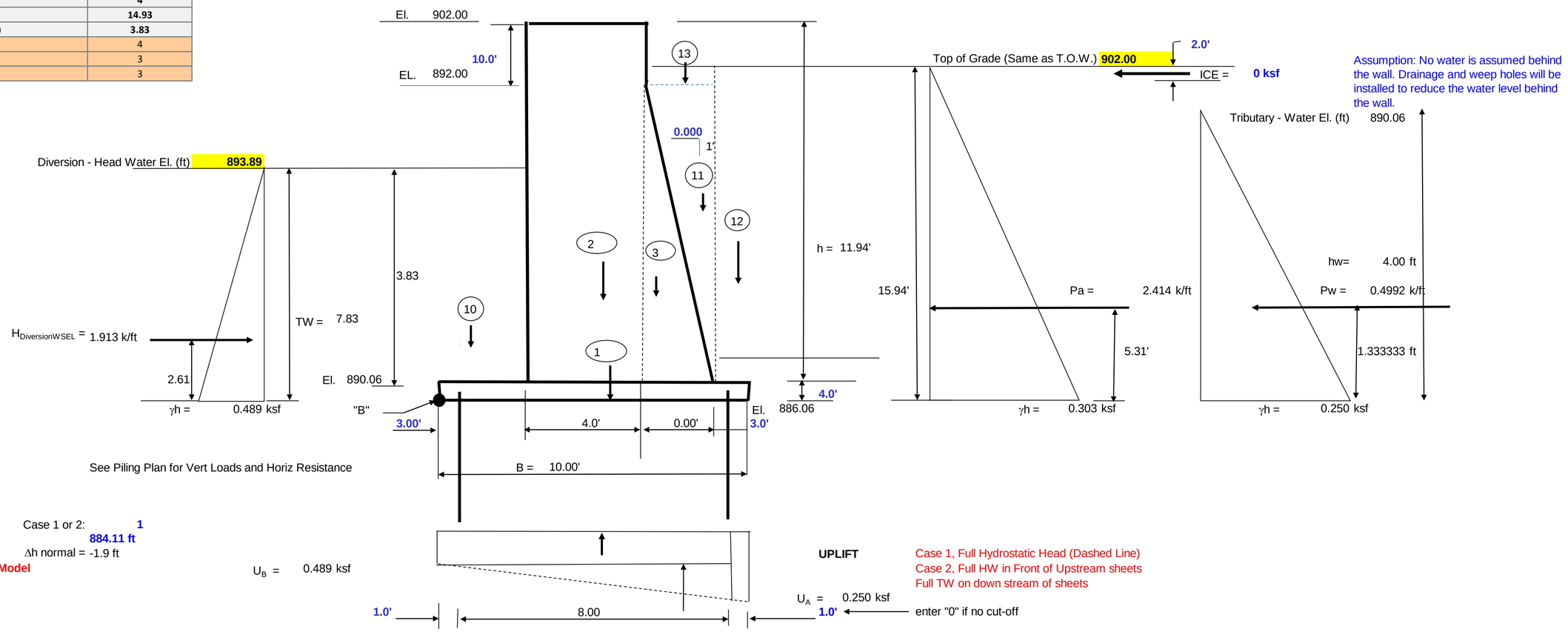
COMPUTED	CHECKED	SUBMITTED	PROJECT NUMBER	34091004	
MBI 2/11/11		MBI	SUBJECT	Maple Aquaduct Structure - Retaining Walls Load Cases: Case 1 100 yr. flood Panel A	

ID#	Case 1
Name	100 yr. flood
Load Category	Usual
Tributary - Water El. (ft)	895.99
Diversion - Head Water El. (ft)	893.89
Diversion - Tail Water El. (ft)	892.57
Tributary - T.O. Wall El. (ft)	902
Tributary - T.O. Deck L.P. El.(ft)	881.06
Tributary - T.O. Deck H.P. El.(ft)	883.06
Diversion - T.O. Mat El. (ft)	890.06
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)	14.93
Diversion - Head Water height (ft)	3.83
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. = **881.50 ft** DEC, JAN, FEB Mean Water Elevation

Non-Overflow Section **Length = 80.5 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 = -1.9 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	80.5	10.00	4.00	0.15	rec	483.0	5.00	2,415.0
Stem	2	80.5	4.00	11.94	0.15	rec	576.7	5.00	2,883.5
Batter	3	80.5	0.00	1.94	0.15	tri	0.0	7.00	0.0
					D.L. Concrete	ΣVc =	**1059.7**	ΣM_V =	**5,298.5**

← CONSTANT FOR ALL LOAD CASES

T.W on ftg Stem	10	80.5	3.00	3.83	0.0624	rec	57.7	1.50	86.6
H.W. on Stem Slope	11	80.5	0.00	1.94	0.12	tri	0.0	7.00	0.0
H.W. Above Slope	13	80.5	0.00	10.00	0.12	rec	0.0	7.00	0.0
Soil on Footing	12s	80.5	3.00	11.94	0.0626	rec	180.5	8.50	1,534.3
H.W. on Footing	12w	80.5	3.00	0.00	0.0624	rec	0.0	8.50	0.0
					D.L. Water	ΣVw =	**238.2**	ΣM_V =	**1,620.9**

Uplift Loads	L ft	W ft	Pressure ksf		**U** K	arm ft	**Mu** ft-k
U_B	80.5	10.00	0.489	rec	-393.3	5.00	-1,967
U_A	80.5	10.00	-0.239	tri	96.2	6.67	641
				ΣU =	**-297.1**	ΣM_U =	**-1,325**

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			PROJECT NAME	FARGO – MOORHEAD METRO FLOOD RISK MANAGEMENT PROJECT, FEASIBILITY STUDY, PHASE 4		
COMPUTED	CHECKED	SUBMITTED	PROJECT NUMBER	34091004		
MBI		MBI	SUBJECT	Maple Aquaduct Structure - Retaining Walls		
2/11/11				Load Cases: Case 1 100 yr. flood	Panel A	

Horizontal Loads

	L	H	Pressure		ICE	arm	Mu
	ft	ft	ksf		K	ft	ft-k
ICE	80.5	2.00	0.00	rec	0.0	14.94	0.0

	L	Force		H	arm	Mw
	ft	k/ft		K	ft	ft-k
SOIL	80.5	-2.414		-194.31	5.31	-1032.44
Water Loads						
H_{TW}	80.5	1.913	tri	153.98	2.61	401.90
H_{HW}	80.5	-0.499	tri	-40.19	1.33	-53.58
			ΣWater =	**113.80**	ΣM_W =	**-684.1**

Overturning Moments	$\Sigma M_{OT} = M_U + M_W + M_{ICE}$ =	-2009	kip-ft
Resisting Moments	$\Sigma M_R = M_V$ =	6919	kip-ft
Sum of Moments	$\Sigma Mnet = M_R + M_{OT}$ =	**4,910**	kip-ft
Sum of Vertical Forces	P = Conc + Water + Uplift =	**1,001**	kips
Sum of Horizontal Forces	H = Σhorizontal	**-81**	kips

Location of Resultant	Xr = ΣM / P =	4.91	ft from Toe
	e = B/2 - Xr =	0.09	ft
	B/6 =	1.667	ft

CONCRETE QUANTITIES

				forming	
Ftg conc:	122	cy (includes stepped)		769	sf
Stem Conc:	142	cy		2060	sf
Total =	265				

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	83	2,681		
	Longitudinal:	9	12	3.40	82	10	2,788		
Bot mat	Transverse:	9	12	3.40	9.5	83	2,681		
	Longitudinal:	9	12	3.40	82	10	2,788		
								cy	**LB/cy**
							10,938	122	89.49109091
b) Skin Reinf. On Monolith									
Vert Face	Vertical	9	12	3.40	11.44	81	3,151	6,301.15	
	Longitudinal:	9	12	3.40	80	12	3,264	6,528.00	
Top Face	Transverse:	9	12	3.40	3.5	81	964		
	Longitudinal:	9	12	3.40	80	4	1,088		
Dowels	Vertical I.F.	9	12	3.40	11.4	81	3,151		
	Vertical O.F.	9	12	3.40	11.4	81	3,151		
								cy	**LB/cy**
							14,768	142	103.7084897
						Σ =	**25,705**		
	Lap Splices (long. Bars)	9		3.40	8	117	3,182		
						Σ Bar Wt=	28,888	lb	

FORCES AT THE BOTTOM OF THE STEM

Diversion Face	H	γ	Pbase	V	arm	Mv
	ft	kcf		K	ft	ft-k
Diversion WSEL	3.83	0.0624	0.238992	0.458	1.277	0.584292
Tributary SEL =	11.94	0.019	0.22686	1.354	3.980	5.39033
Tributary WSEL =	0.00	0.0624	0	0.000	0.000	0
Sum				1.354		5.39033
Net Forces				0.897		4.806038

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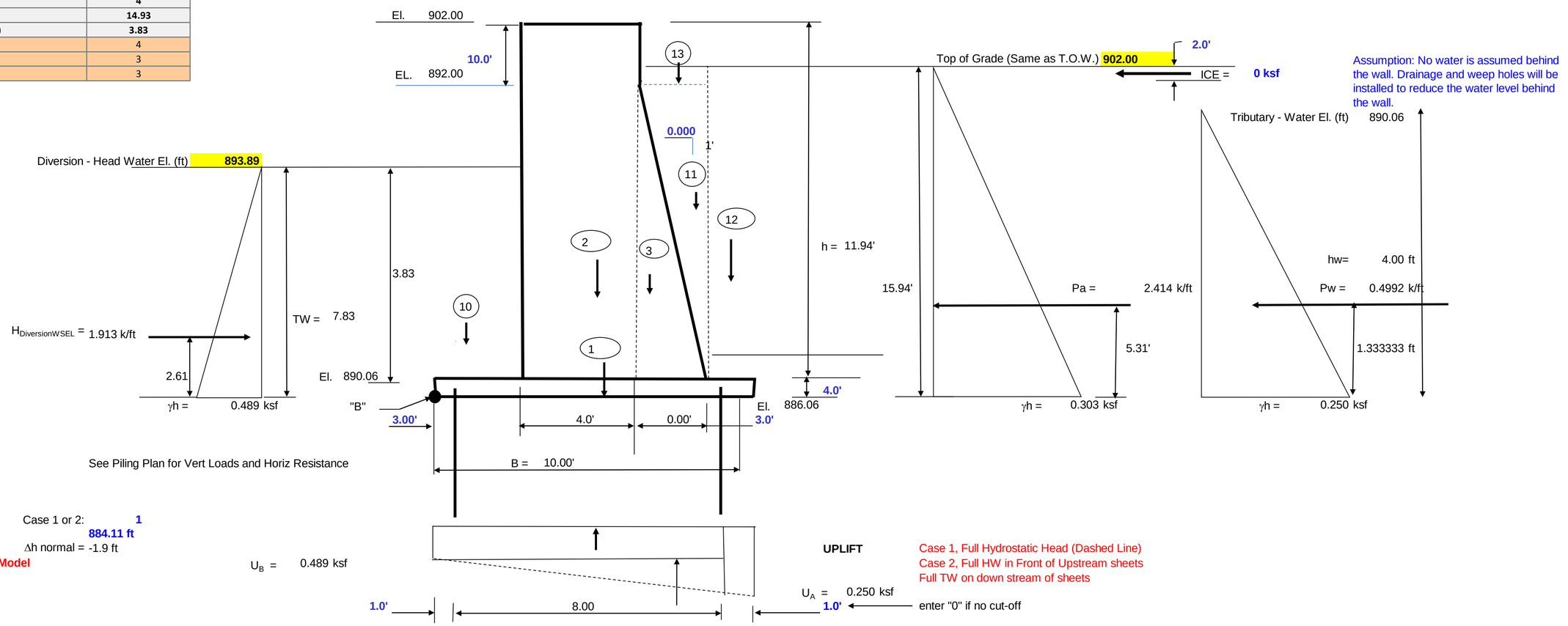
MBI 2/11/11		MBI	SUBJECT	Maple Aquaduct Structure - Retaining Walls Load Cases: Case 2 100 yr. flood + ice Panel A	

ID#	Case 2
Name	100 yr. flood + ice
Load Category	Unusual
Tributary - Water El. (ft)	895.99
Diversion - Head Water El. (ft)	893.89
Diversion - Tail Water El. (ft)	892.57
Tributary - T.O. Wall El. (ft)	902
Tributary - T.O. Deck L.P. El.(ft)	881.06
Tributary - T.O. Deck H.P. El.(ft)	883.06
Diversion - T.O. Mat El. (ft)	890.06
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)	14.93
Diversion - Head Water height (ft)	3.83
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. = 881.50 ft DEC, JAN, FEB Mean Water Elevation

Non-Overflow Section **Length = 80.5 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 = -1.9 ft
See Geotechnical seepage Model

U_B = 0.489 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
1.0' ← 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	80.5	10.00	4.00	0.15	rec	483.0	5.00	2,415.0
Stem	2	80.5	4.00	11.94	0.15	rec	576.7	5.00	2,883.5
Batter	3	80.5	0.00	1.94	0.15	tri	0.0	7.00	0.0
					D.L. Concrete	ΣVc =	**1059.7**	ΣM_V =	**5,298.5**

← CONSTANT FOR ALL LOAD CASES

T.W on ftg Stem	10	80.5	3.00	3.83	0.0624	rec	57.7	1.50	86.6
H.W. on Stem Slope	11	80.5	0.00	1.94	0.12	tri	0.0	7.00	0.0
H.W. Above Slope	13	80.5	0.00	10.00	0.12	rec	0.0	7.00	0.0
Soil on Footing	12s	80.5	3.00	11.94	0.0626	rec	180.5	8.50	1,534.3
H.W. on Footing	12w	80.5	3.00	0.00	0.0624	rec	0.0	8.50	0.0
					D.L. Water	ΣVw =	**238.2**	ΣM_V =	**1,620.9**

Uplift Loads		L ft	W ft	Pressure ksf		U K	arm ft	Mu ft-k
	U_B	80.5	10.00	0.489	rec	-393.3	5.00	-1,967
	U_A	80.5	10.00	-0.239	tri	96.2	6.67	641
					ΣU =	**-297.1**	ΣM_U =	**-1,325**

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	Maple Aquaduct Structure - Retaining Walls	
2/11/11				Load Cases: Case 2 100 yr. flood + ice	Panel A

ICE	80.5	2.00	0.00	rec	0.0	14.94	0.0	
	L		Force		**H**	arm	**Mw**	
	ft		k/ft		K	ft	ft-k	
SOIL	80.5		-2.414		-194.31	5.31	-1032.44	
Water Loads								
H_{TW}	80.5		1.913	tri	153.98	2.61	401.90	
H_{HW}	80.5		-0.499	tri	-40.19	1.33	-53.58	
				ΣWater =	**113.80**	ΣM_W =	**-684.1**	

Overturning Moments	$\Sigma M_{OT} = M_U + M_W + M_{ICE}$ =	-2009	kip-ft
Resisting Moments	$\Sigma M_R = M_V$ =	6919	kip-ft
Sum of Moments	$\Sigma Mnet = M_R + M_{OT}$ =	**4,910**	kip-ft
Sum of Vertical Forces	P = Conc + Water + Uplift =	**1,001**	kips
Sum of Horizontal Forces	H = Σhorizontal	**-81**	kips

Location of Resultant	Xr = ΣM / P =	4.91	ft from Toe
	e = B/2 - Xr =	0.09	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	3.83	**0.0624**	0.238992	0.458	1.277	0.584292
Tributary SEL =	11.94	**0.019**	0.22686	1.354	3.980	5.39033
Tributary WSEL =	0.00	**0.0624**	0	0.000	0.000	0
Sum				1.354		5.39033
Net Forces				0.897		4.806038

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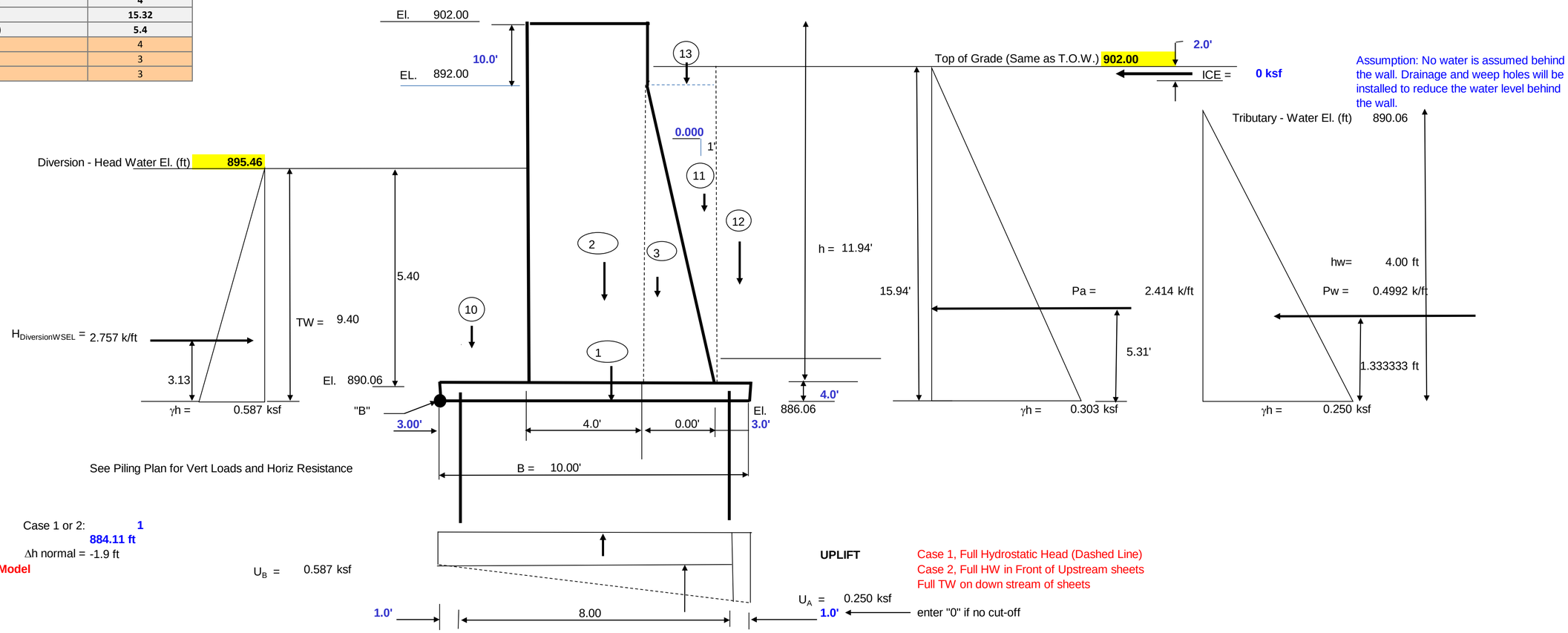
COMPUTED	CHECKED	SUBMITTED	PROJECT NUMBER	34091004	
MBI 2/11/11		MBI	SUBJECT	Maple Aquaduct Structure - Retaining Walls Load Cases: Case 3 500 yr. flood Panel A	

ID#	Case 3
Name	500 yr. flood
Load Category	Unusual
Tributary - Water El. (ft)	896.38
Diversion - Head Water El. (ft)	895.46
Diversion - Tail Water El. (ft)	893.66
Tributary - T.O. Wall El. (ft)	902
Tributary - T.O. Deck L.P. El.(ft)	881.06
Tributary - T.O. Deck H.P. El.(ft)	883.06
Diversion - T.O. Mat El. (ft)	890.06
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)	15.32
Diversion - Head Water height (ft)	5.4
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. = **881.50 ft** DEC, JAN, FEB Mean Water Elevation

Non-Overflow Section **Length = 80.5 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 = -1.9 ft
See Geotechnical seepage Model

U_B = 0.587 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
1.0' ← 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	80.5	10.00	4.00	0.15	rec	483.0	5.00	2,415.0
Stem	2	80.5	4.00	11.94	0.15	rec	576.7	5.00	2,883.5
Batter	3	80.5	0.00	1.94	0.15	tri	0.0	7.00	0.0
					D.L. Concrete	ΣVc =	**1059.7**	ΣM_V =	**5,298.5**

← CONSTANT FOR ALL LOAD CASES

T.W on ftg Stem	10	80.5	3.00	5.40	0.0624	rec	81.4	1.50	122.1
H.W. on Stem Slope	11	80.5	0.00	1.94	0.12	tri	0.0	7.00	0.0
H.W. Above Slope	13	80.5	0.00	10.00	0.12	rec	0.0	7.00	0.0
Soil on Footing	12s	80.5	3.00	11.94	0.0626	rec	180.5	8.50	1,534.3
H.W. on Footing	12w	80.5	3.00	0.00	0.0624	rec	0.0	8.50	0.0
					D.L. Water	ΣVw =	**261.9**	ΣM_V =	**1,656.4**

Uplift Loads		L ft	W ft	Pressure ksf		U K	arm ft	Mu ft-k
	U_B	80.5	10.00	0.587	rec	-472.2	5.00	-2,361
	U_A	80.5	10.00	-0.337	tri	135.6	6.67	904
					ΣU =	**-336.6**	ΣM_U =	**-1,457**

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

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

ICE	80.5	2.00	0.00	rec	0.0	14.94	0.0	
	L		Force		**H**	arm	**Mw**	
	ft		k/ft		K	ft	ft-k	
SOIL	80.5		-2.414		-194.31	5.31'	-1032.44	
Water Loads								
H_{TW}	80.5		2.757	tri	221.92	3.13	695.36	
H_{HW}	80.5		-0.499	tri	-40.19	1.33	-53.58	
				ΣWater =	**181.74**	ΣM_W =	**-390.7**	

Overturning Moments	$\Sigma M_{OT} = M_U + M_W + M_{ICE}$ =	-1847	kip-ft
Resisting Moments	$\Sigma M_R = M_V$ =	6955	kip-ft
Sum of Moments	$\Sigma Mnet = M_R + M_{OT}$ =	**5,108**	kip-ft
Sum of Vertical Forces	P = Conc + Water + Uplift =	**985**	kips
Sum of Horizontal Forces	H = Σhorizontal	**-13**	kips

Location of Resultant	Xr = ΣM / P =	5.19	ft from Toe
	e = B/2 - Xr =	(0.19)	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	5.40	**0.0624**	0.33696	0.910	1.800	1.637626
Tributary SEL =	11.94	**0.019**	0.22686	1.354	3.980	5.39033
Tributary WSEL =	0.00	**0.0624**	0	0.000	0.000	0
Sum				1.354		5.39033
Net Forces				0.445		3.752704

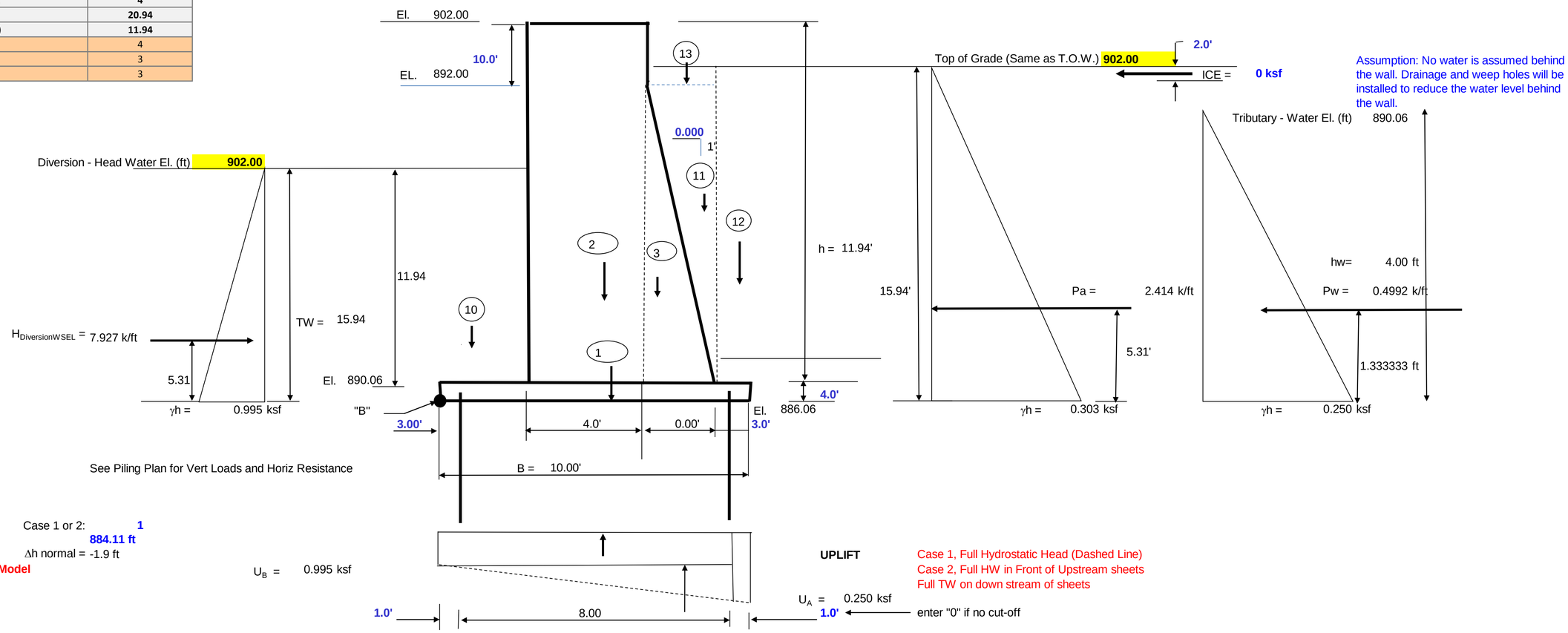
BARR ENGINEERING			DATE	2/11/2011	SHEET NO.
			PROJECT NAME	FARGO – MOORHEAD METRO FLOOD RISK MANAGEMENT PROJECT, FEASIBILITY STUDY, PHASE 4	
COMPUTED	CHECKED	SUBMITTED	PROJECT NUMBER	34091004	
MBI 2/11/11		MBI	SUBJECT	Maple Aquaduct Structure - Retaining Walls	
				Load Cases: Case 4 T.O. Levee Panel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

ID#	Case 4
Name	T.O. Levee
Load Category	Extreme
Tributary - Water El. (ft)	NA
Diversion - Head Water El. (ft)	902
Diversion - Tail Water El. (ft)	902
Tributary - T.O. Wall El. (ft)	902
Tributary - T.O. Deck L.P. El.(ft)	881.06
Tributary - T.O. Deck H.P. El.(ft)	883.06
Diversion - T.O. Mat El. (ft)	890.06
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)	20.94
Diversion - Head Water height (ft)	11.94
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. = **881.50 ft** DEC, JAN, FEB Mean Water Elevation

Non-Overflow Section **Length = 80.5 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 = -1.9 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	80.5	10.00	4.00	0.15	rec	483.0	5.00	2,415.0
Stem	2	80.5	4.00	11.94	0.15	rec	576.7	5.00	2,883.5
Batter	3	80.5	0.00	1.94	0.15	tri	0.0	7.00	0.0
					D.L. Concrete	ΣVc =	**1059.7**	$ΣM_V$ =	**5,298.5**

← CONSTANT FOR ALL LOAD CASES

T.W on ftg Stem	10	80.5	3.00	11.94	0.0624	rec	179.9	1.50	269.9
H.W. on Stem Slope	11	80.5	0.00	1.94	0.12	tri	0.0	7.00	0.0
H.W. Above Slope	13	80.5	0.00	10.00	0.12	rec	0.0	7.00	0.0
Soil on Footing	12s	80.5	3.00	11.94	0.0626	rec	180.5	8.50	1,534.3
H.W. on Footing	12w	80.5	3.00	0.00	0.0624	rec	0.0	8.50	0.0
					D.L. Water	ΣVw =	**360.4**	$ΣM_V$ =	**1,804.2**

Uplift Loads		L ft	W ft	Pressure ksf		U K	arm ft	Mu ft-k
	U_B	80.5	10.00	0.995	rec	-800.7	5.00	-4,003
	U_A	80.5	10.00	-0.745	tri	299.9	6.67	1,999
					ΣU =	**-500.8**	$ΣM_U$ =	**-2,004**

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	Maple Aquaduct Structure - Retaining Walls	
2/11/11			Load Cases:	Case 4 T.O. Levee	Panel A

ICE	80.5	2.00	0.00	rec	0.0	14.94	0.0	
	L		Force		**H**	arm	**Mw**	
	ft		k/ft		K	ft	ft-k	
SOIL	80.5		-2.414		-194.31	5.31'	-1032.44	
Water Loads								
H_{TW}	80.5		7.927	tri	638.16	5.31	3390.74	
H_{HW}	80.5		-0.499	tri	-40.19	1.33	-53.58	
				ΣWater =	**597.97**	ΣM_W =	**2304.7**	

Overturning Moments	$\Sigma M_{OT} = M_U + M_W + M_{ICE}$ =	300	kip-ft
Resisting Moments	$\Sigma M_R = M_V$ =	7103	kip-ft
Sum of Moments	$\Sigma Mnet = M_R + M_{OT}$ =	**7,403**	kip-ft
Sum of Vertical Forces	P = Conc + Water + Uplift =	**919**	kips
Sum of Horizontal Forces	H = Σhorizontal	**404**	kips

Location of Resultant	Xr = ΣM / P =	8.05	ft from Toe
	e = B/2 - Xr =	(3.05)	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	11.94	**0.0624**	0.745056	4.448	3.980	17.70298
Tributary SEL =	11.94	**0.019**	0.22686	1.354	3.980	5.39033
Tributary WSEL =	0.00	**0.0624**	0	0.000	0.000	0
Sum				1.354		5.39033
Net Forces				-3.094		-12.3126

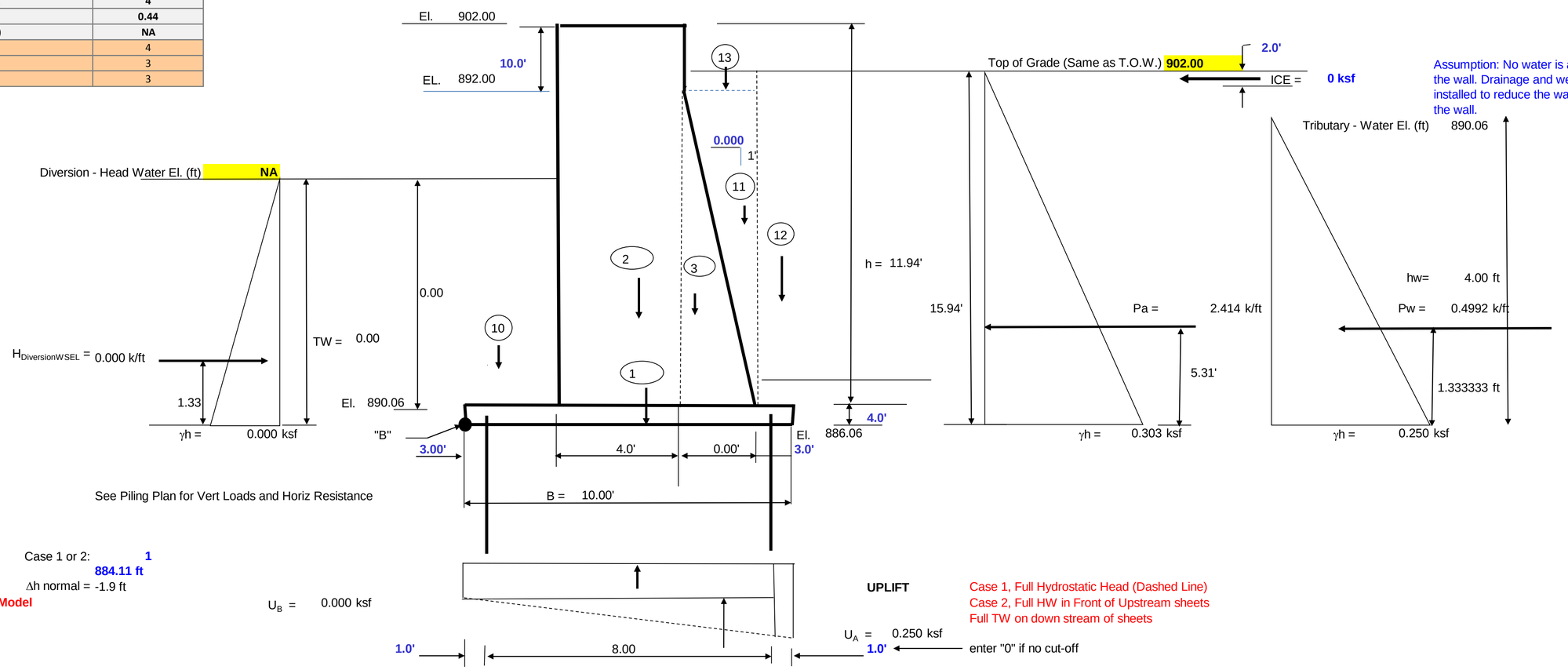
BARR ENGINEERING			DATE	2/11/2011	SHEET NO.
			PROJECT NAME	FARGO – MOORHEAD METRO FLOOD RISK MANAGEMENT PROJECT, FEASIBILITY STUDY, PHASE 4	
COMPUTED	CHECKED	SUBMITTED	PROJECT NUMBER	34091004	
MBI 2/11/11		MBI	SUBJECT	Maple Aquaduct Structure - Retaining Walls Load Cases: Case 5 Normal flow + ice Panel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

ID#	Case 5
Name	Normal flow + ice
Load Category	Usual
Tributary - Water El. (ft)	881.5
Diversion - Head Water El. (ft)	NA
Diversion - Tail Water El. (ft)	NA
Tributary - T.O. Wall El. (ft)	902
Tributary - T.O. Deck L.P. El.(ft)	881.06
Tributary - T.O. Deck H.P. El.(ft)	883.06
Diversion - T.O. Mat El. (ft)	890.06
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)	0.44
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. = **881.50 ft** DEC, JAN, FEB Mean Water Elevation

Non-Overflow Section **Length = 80.5 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 = -1.9 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	80.5	10.00	4.00	0.15	rec	483.0	5.00	2,415.0
Stem	2	80.5	4.00	11.94	0.15	rec	576.7	5.00	2,883.5
Batter	3	80.5	0.00	1.94	0.15	tri	0.0	7.00	0.0
					D.L. Concrete	ΣVc =	**1059.7**	$ΣM_V$ =	**5,298.5**

← CONSTANT FOR ALL LOAD CASES

T.W on ftg Stem	10	80.5	3.00	0.00	0.0624	rec	0.0	1.50	0.0
H.W. on Stem Slope	11	80.5	0.00	1.94	0.12	tri	0.0	7.00	0.0
H.W. Above Slope	13	80.5	0.00	10.00	0.12	rec	0.0	7.00	0.0
Soil on Footing	12s	80.5	3.00	11.94	0.0626	rec	180.5	8.50	1,534.3
H.W. on Footing	12w	80.5	3.00	0.00	0.0624	rec	0.0	8.50	0.0
					D.L. Water	ΣVw =	**180.5**	$ΣM_V$ =	**1,534.3**

Uplift Loads		L ft	W ft	Pressure ksf		U K	arm ft	Mu ft-k
	U_B	80.5	10.00	0.000	rec	0.0	5.00	0
	U_A	80.5	10.00	0.250	tri	-100.5	6.67	-670
					ΣU =	**-100.5**	$ΣM_U$ =	**-670**

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	Maple Aquaduct Structure - Retaining Walls	
2/11/11				Load Cases: Case 5 Normal flow + ice Panel A	

ICE	80.5	2.00	0.00	rec	0.0	14.94	0.0	
	L		Force		**H**	arm	**Mw**	
	ft		k/ft		K	ft	ft-k	
SOIL	80.5		-2.414		-194.31	5.31'	-1032.44	
Water Loads								
H_{TW}	80.5		0.000	tri	0.00	1.33	0.00	
H_{HW}	80.5		-0.499	tri	-40.19	0.00	0.00	
				ΣWater =	**-40.19**	ΣM_W =	**-1032.4**	

Overturning Moments	$\Sigma M_{OT} = M_U + M_W + M_{ICE}$ =	-1702	kip-ft
Resisting Moments	$\Sigma M_R = M_V$ =	6833	kip-ft
Sum of Moments	$\Sigma Mnet = M_R + M_{OT}$ =	**5,131**	kip-ft
Sum of Vertical Forces	P = Conc + Water + Uplift =	**1,140**	kips
Sum of Horizontal Forces	H = Σhorizontal	**-234**	kips

Location of Resultant	Xr = ΣM / P =	4.50	ft from Toe
	e = B/2 - Xr =	0.50	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 =	11.94	**0.019**	0.22686	1.354	3.980	5.39033
Tributary WSEL =	0.00	**0.0624**	0	0.000	0.000	0
Sum				1.354		5.39033
Net Forces				1.354		5.39033

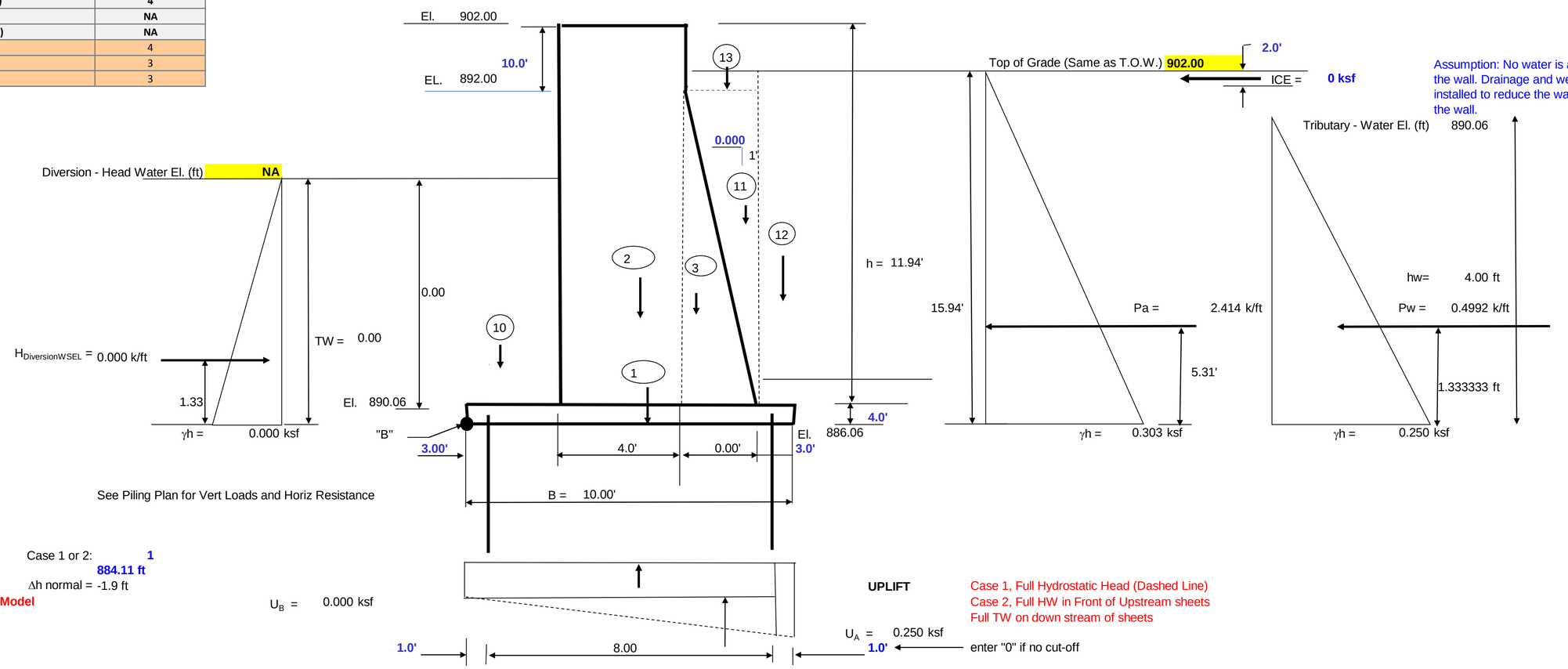
BARR ENGINEERING			DATE	2/11/2011	SHEET NO.
			PROJECT NAME	FARGO – MOORHEAD METRO FLOOD RISK MANAGEMENT PROJECT, FEASIBILITY STUDY, PHASE 4	
COMPUTED	CHECKED	SUBMITTED	PROJECT NUMBER	34091004	
MBI 2/11/11		MBI	SUBJECT	Maple Aquaduct Structure - Retaining Walls	
				Load Cases: Case 6 Construction Panel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

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)	902
Tributary - T.O. Deck L.P. El.(ft)	881.06
Tributary - T.O. Deck H.P. El.(ft)	883.06
Diversion - T.O. Mat El. (ft)	890.06
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. = **881.50 ft** DEC, JAN, FEB Mean Water Elevation

Non-Overflow Section **Length = 80.5 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 = -1.9 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
1.0' ← 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	80.5	10.00	4.00	0.15	rec	483.0	5.00	2,415.0
Stem	2	80.5	4.00	11.94	0.15	rec	576.7	5.00	2,883.5
Batter	3	80.5	0.00	1.94	0.15	tri	0.0	7.00	0.0
					D.L. Concrete	ΣVc =	**1059.7**	$ΣM_V$ =	**5,298.5**

← CONSTANT FOR ALL LOAD CASES

T.W on ftg Stem	10	80.5	3.00	0.00	0.0624	rec	0.0	1.50	0.0
H.W. on Stem Slope	11	80.5	0.00	1.94	0.12	tri	0.0	7.00	0.0
H.W. Above Slope	13	80.5	0.00	10.00	0.12	rec	0.0	7.00	0.0
Soil on Footing	12s	80.5	3.00	11.94	0.0626	rec	180.5	8.50	1,534.3
H.W. on Footing	12w	80.5	3.00	0.00	0.0624	rec	0.0	8.50	0.0
					D.L. Water	ΣVw =	**180.5**	$ΣM_V$ =	**1,534.3**

Uplift Loads		L ft	W ft	Pressure ksf		U K	arm ft	Mu ft-k
	U_B	80.5	10.00	0.000	rec	0.0	5.00	0
	U_A	80.5	10.00	0.250	tri	-100.5	6.67	-670
					ΣU =	**-100.5**	$ΣM_U$ =	**-670**

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	Maple Aquaduct Structure - Retaining Walls	
				Load Cases: Case 6 Construction	Panel A

ICE	80.5	2.00	0.00		rec	0.0	14.94	0.0
	L		Force			**H**	arm	**Mw**
	ft		k/ft			K	ft	ft-k
SOIL	80.5		-2.414			-194.31	5.31'	-1032.44
Water Loads								
H_{TW}	80.5		0.000		tri	0.00	1.33	0.00
H_{HW}	80.5		-0.499		tri	-40.19	1.33	-53.58
					ΣWater =	**-40.19**	ΣM_W =	**-1086.0**

Overturning Moments	$\Sigma M_{OT} = M_U + M_W + M_{ICE}$ =	-1756	kip-ft
Resisting Moments	$\Sigma M_R = M_V$ =	6833	kip-ft
Sum of Moments	$\Sigma Mnet = M_R + M_{OT}$ =	**5,077**	kip-ft
Sum of Vertical Forces	P = Conc + Water + Uplift =	**1,140**	kips
Sum of Horizontal Forces	H = Σhorizontal	**-234**	kips

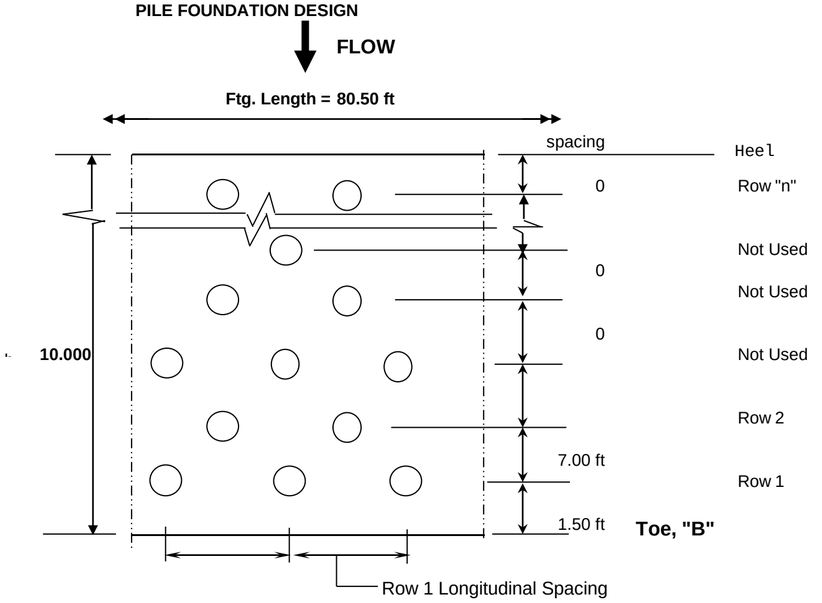
Location of Resultant	Xr = ΣM / P =	4.45	ft from Toe
	e = B/2 - Xr =	0.55	ft
	B/6 =	1.667	ft

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 =	11.94	**0.019**	0.22686	1.354	3.980	5.39033
Tributary WSEL =	0.00	**0.0624**	0	0.000	0.000	0
Sum				1.354		5.39033
Net Forces				1.354		5.39033

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	Maple Aquaduct Structure - Retaining Walls Panel A	

PILE FOUNDATION DESIGN



L = 80.50 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	1.50 ft	1.5 ft	2.50 ft	0	"/12"	12	26.50	1	33
Row 1 to Row 2	7.00 ft	8.5 ft	5.00 ft	0	"/12"	12	12.75	2	17
Row 2 to Row 3	0.00 ft	0.0 ft	0.00 ft	0	"/12"	0	40.25	0	0
Row 3 to Row 4	0.00 ft	0.0 ft	0.00 ft	0	"/12"	0	40.25	0	0
Row 4 to Row 5	0.00 ft	0.0 ft	0.00 ft	0	"/12"	0	40.25	0	0
Row 5 to Row 6	0.00 ft	0.0 ft	0.00 ft	0	"/12"	0	40.25	0	0
Row 6 to Row 7	0.00 ft	0.0 ft	0.00 ft	0	"/12"	0	40.25	0	0
Row 7 to Row 8	0.00 ft	0.0 ft	0.00 ft	0	"/12"	0	40.25	0	0
Row 8 to Row 9	0.00 ft	0.0 ft	0.00 ft	0	"/12"	0	40.25	0	0
Row 9 to Row 10	0.00 ft	0.0 ft	0.00 ft	0	"/12"	0	40.25	0	0
Row 10 to Row 11	0.00 ft	0.0 ft	0.00 ft	0	"/12"	0	40.25	0	0
Row 11 to Row 12	0.00 ft	0.0 ft	0.00 ft	0	"/12"	0	40.25	0	0
Row 12 to Row 13	0.00 ft	0.0 ft	0.00 ft	0	"/12"	0	40.25	0	0
Row 13 to Row 14	0.00 ft	0.0 ft	0.00 ft	0	"/12"	0	40.25	0	0
Row 14 to Row 15	0.00 ft	0.0 ft	0.00 ft	0	"/12"	0	40.25	0	0
Last Row to Heel	1.50 ft								
	10.00 ft					ΣN =	24		50

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

Pile Properties: Pile Type: **HP** (C.I.P or HP) Pile Length = **44.4 ft**
HP Nominal Depth, h = **14.0 in**
Wt. per ft, plf **73**
Ftg EL. 886.06
Pile Tip El. 842.68
Pile Cap Embed = **1.00 ft**
Total pile Length = 1,065 LF

Pile Group Properties

N.A. of Pile Group to Toe

$X_{NA} = (\Sigma N * d_{toe}) / \Sigma N =$ **5.00 ft**

	Dist. From N.A. to Pile Row	d	N	$I = N * d^2$
1	Dist. To Row 1	3.50 ft	12	147.0
2	Dist. To Row 2	-3.50 ft	12	147.0
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
			24	$\Sigma I =$ **294.0**

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	21.0 tons	21.0 tons	24.0 tons	11.5 tons	21.0 tons	
Allowable Pile Capacity (tons) - Axial	57.2 tons	76.2 tons	76.2 tons	99.4 tons	31.4 tons	76.2 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	**57.2 tons**	21.4	20.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	21.4	864	**OK**
Case 2	**76.2 tons**	21.4	20.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	21.4	1,008	**OK**
Case 3	**76.2 tons**	19.4	21.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	21.6	1,008	**OK**
Case 4	**99.4 tons**	2.4	35.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	35.9	1,152	**OK**
Case 5	**31.4 tons**	27.1	20.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	27.1	552	**OK**
Case 6	**76.2 tons**	27.4	20.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	27.4	552	**OK**

Max Service : P = **35.9**

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

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

Pvert

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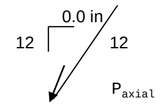
The moment about the neutral axis of the pile group becomes

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

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
Case 1	**100 yr. flood**	**Usual**	1,001	81	4,910	4.91	0.09	94
Case 2	**100 yr. flood + ice**	**Unusual**	1,001	81	4,910	4.91	0.09	94
Case 3	**500 yr. flood**	**Unusual**	985	13	5,108	5.19	-0.19	-182
Case 4	**T.O. Levee**	**Extreme**	919	-404	7,403	8.05	-3.05	-2807
Case 5	**Normal flow + ice**	**Usual**	1,140	234	5,131	4.50	0.50	568
Case 6	**Construction**	**Unusual**	1,140	234	5,077	4.45	0.55	622

SERVICE

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

Vertical Load, P = 1001 kips
Horizontal Load, H = 81 kips
M_{NA} = 94 kip-ft

24

	Vertical Pile Loading	P / N	+	M_{NA}* d / Σ I	= Pile Loads		**Axial Pile Load**
1	Row 1	41.7		1.1	42.8 kips/pile	21.4 tons/pile	21.4 tons/pile
2	Row 2	41.7		-1.1	40.6 kips/pile	20.3 tons/pile	20.3 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:	**21.4 tons/pile**	**max:** **21.4 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	12	0.0	432	1.000	432 kips	
2	Row 2	0	12	0.0	432	1.000	432 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	
			24		864		**864 kips**	**OK**

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

Vertical Load, P = 1001 kips
Horizontal Load, H = 81 kips
M_{NA} = 94 kip-ft

24

	Vertical Pile Loading	P / N	+	M_{NA}* d / Σ I	= Pile Loads		**Axial Pile Load**
1	Row 1	41.7		1.1	42.8 kips/pile	21.4 tons/pile	21.4 tons/pile
2	Row 2	41.7		-1.1	40.6 kips/pile	20.3 tons/pile	20.3 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

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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:	**21.4 tons/pile**	**max:**	**21.4 tons/pile**

Assumed lateral Capacity: 42.0 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	12	0.0	504	1.000	504 kips	
2	Row 2	0	12	0.0	504	1.000	504 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	
			24		1008		**1008 kips**	**OK**

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

Vertical Load, P = 985 kips
Horizontal Load, H = 13 kips
M_{NA} = -182 kip-ft

	Vertical Pile Loading	P / N +	M_{NA}* d / Σ I	= Pile Loads				**Axial Pile Load**
1	Row 1	41.0	-2.2	38.9 kips/pile		19.4 tons/pile		19.4 tons/pile
2	Row 2	41.0	2.2	43.2 kips/pile		21.6 tons/pile		21.6 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:	**21.6 tons/pile**	**max:**	**21.6 tons/pile**

Assumed lateral Capacity: 42.0 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	12	0.0	504	1.000	504 kips	
2	Row 2	0	12	0.0	504	1.000	504 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	
			24		1008		**1008 kips**	**OK**

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

Vertical Load, P = 919 kips
Horizontal Load, H = -404 kips
M_{NA} = -2807 kip-ft

	Vertical Pile Loading	P / N	+	M_{NA}* d / Σ I	= Pile Loads			**Axial Pile Load**
1	Row 1	38.3		-33.4	4.9 kips/pile	2.4 tons/pile		2.4 tons/pile
2	Row 2	38.3		33.4	71.7 kips/pile	35.9 tons/pile		35.9 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:	**35.9 tons/pile**	**max:**	**35.9 tons/pile**

Assumed lateral Capacity: 48.0 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	12	0.0	576	1.000	576 kips	
2	Row 2	0	12	0.0	576	1.000	576 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	
			24		1152		**1152 kips**	**OK**

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

Vertical Load, P = 1140 kips
Horizontal Load, H = 234 kips
M_{NA} = 568 kip-ft

	Vertical Pile Loading	P / N	+	M_{NA}* d / Σ I	= Pile Loads			**Axial Pile Load**
1	Row 1	47.5		6.8	54.3 kips/pile	27.1 tons/pile		27.1 tons/pile
2	Row 2	47.5		-6.8	40.7 kips/pile	20.4 tons/pile		20.4 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:	**27.1 tons/pile**	**max:**	**27.1 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	12	0.0	276	1.000	276 kips
2	Row 2	0	12	0.0	276	1.000	276 kips

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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	
			24		552		**552 kips**	**OK**

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

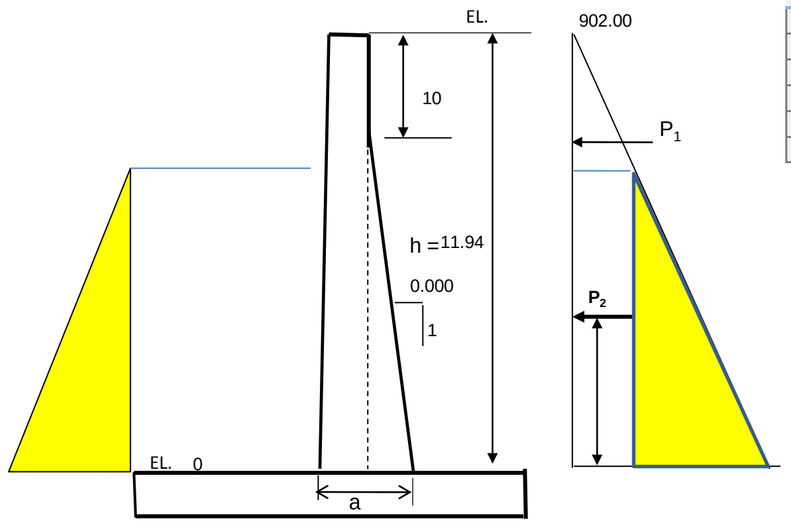
Vertical Load, P = 1140 kips
Horizontal Load, H = 234 kips
M_{NA} = 622 kip-ft

	Vertical Pile Loading	P / N	+	M_{NA}* d / Σ I	= Pile Loads		**Axial Pile Load**
1	Row 1	47.5		7.4	54.9 kips/pile	27.4 tons/pile	27.4 tons/pile
2	Row 2	47.5		-7.4	40.1 kips/pile	20.0 tons/pile	20.0 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:	**27.4 tons/pile**	**max:** **27.4 tons/pile**

Assumed lateral Capacity: 42.0 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	12	0.0	276	1.000	276 kips	
2	Row 2	0	12	0.0	276	1.000	276 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	
			24		552		**552 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	Maple Aquaduct Structure - Retaining Walls	
				Panel A 0	



CASE	Event		HW	TW	Dh	TW -ftg
Case 1	100 yr. flood	Usual	893.89	892.57	1.32	892.57
Case 2	100 yr. flood + ice	Unusual	893.89	892.57	1.32	892.57
Case 3	500 yr. flood	Unusual	896.380	893.66	2.72	893.66
Case 4	T.O. Levee	Extreme	902.000	902.00	0.00	902.00
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	0.90	4.806	1.98	10.62
Case 2	100 yr. flood + ice	Unusual	0.75	0.90	4.806	1.49	7.97
Case 3	500 yr. flood	Unusual	0.75	0.44	3.753	0.74	6.22
Case 4	T.O. Levee	Extreme	0.75	-3.09	-12.313	5.13	20.41
Case 5	Normal flow + ice	Usual	1	1.35	5.390	2.99	11.91
Case 6	Construction	Unusual	0.75	1.35	5.390	2.24	8.93

STEM DESIGN VALUES

MU, k-ft/ft	20.41	k-ft/ft
VU, k/ft	5.13	k/ft

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 =	20	k-ft /ft	**Includes: hf = 1.3**
Vuh=	5.13	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 =	11.984		**ACI 10.5.1**
REQ'D p=	0.0002	**O.K.**	p(min)= 3*SQRT(Fc')/fy 200* / fy **ACI 10.5.3** 4/3*p
p=	0.0003		0.00316 0.00333 0.0003
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 =	69.4	**a**	1) p = **0.25** pb Recommended limit
a= T/C =	0.864	in	2) p = **0.375** pb Max. permitted upper limit not requiring special study
Mn= T(d - a/2)/12 =	214.9	ft-k	3) p = **0.5** pb Max. permitted upper limit when excessive deflections are not predicted In ACI 318
ϕ Mn=	193.4	ft-k	4) p = >**0.5** pb but $\leq$ 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 =	5.1	k	**NO SHEAR REINF. REQUIRED**
Vn = Vuh / ϕ =	6.8	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) $\leq$ 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