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 H	**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 H.xlsx]Piling		
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	903.5	881.5	**NA**
Diversion - Head Water El. (ft)	893.89	893.89	895.46	903.5	**NA**	**NA**
Diversion - Tail Water El. (ft)	892.57	892.57	893.66	903.5	**NA**	**NA**
Tributary - T.O. Wall El. (ft)	903.5					
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**	**22.44**	**0.44**	**NA**
Diversion - Head Water height (ft)	**3.83**	**3.83**	**5.4**	**13.44**	**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**	**17.44**	**NA**	**NA**
Uplift @ TW (ft)	**6.51**	**6.51**	**7.6**	**17.44**	**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		MBI	SUBJECT	Maple Aquaduct Structure - Retaining Walls	
2/11/11				Panel H	

Monolith Structure

ITEM		UNIT	QUANITY	UNIT COST	TOTAL Cost
FURNISH HP14x73 WALL PILING		LF	710	0	$0
INSTALL HP14x73 WALL PILING		LF	710	0	$0
PILE TEST, 54.4 ft	Long	EA	2	0	$0
FOOTING CONCRETE		CY	81	0	$0
	Forming	SF	510		
STEM CONCRETE		CY	100	0	$0
	Forming	SF	1,479		
STEEL REINFORCEMENT		LB	26,688	0	$0
WALL RAILING		LF	50	0	$0
SHEET PILE CUT-OFF WALL		SF	500	0	$0
					$0

Structure Length = 50 ft

No. piles = 16 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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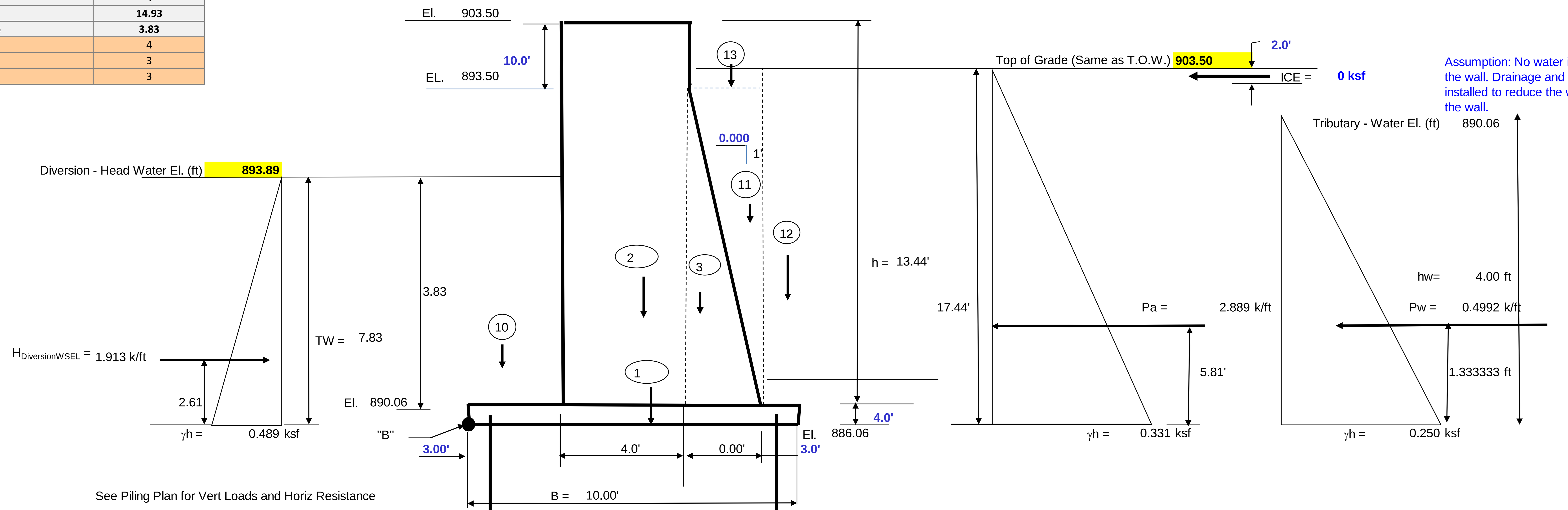
COMPUTED	CHECKED	SUBMITTED	PROJECT NUMBER	34091004	
MBI		MBI	SUBJECT	Maple Aquaduct Structure - Retaining Walls	
2/11/11				Load Cases: Case 1 100 yr. flood	Panel H

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)	903.5
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:

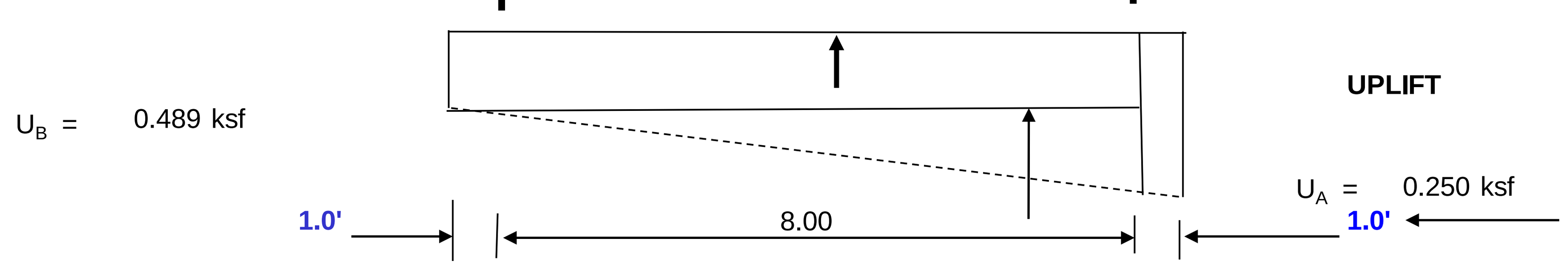
MN State Building Codes
Frost Depth = 5.0 ft — provide min frost ftg protection during Dec, Jan, Feb, March
Water El. = 881.50 ft — DEC, JAN, FEB Mean Water Elevation

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



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	13.44	0.15	rec	403.2	5.00	2,016.0
Batter	3	50	0.00	3.44	0.15	tri	0.0	7.00	0.0
					D.L. Concrete	ΣVc =	**703.2**	ΣM_V =	**3,516.0**

CONSTANT FOR ALL LOAD CASES

	Section	L	W	H	γ	shape	V	arm	Mv
T.W on ftg Stem	10	50	3.00	3.83	0.0624	rec	35.8	1.50	53.8
H.W. on Stem Slope	11	50	0.00	3.44	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	13.44	0.0626	rec	126.2	8.50	1,072.7
H.W. on Footing	12w	50	3.00	0.00	0.0624	rec	0.0	8.50	0.0
					D.L. Water	ΣVw =	**162.1**	ΣM_V =	**1,126.5**

Uplift Loads		L ft	W ft	Pressure ksf	shape	U K	arm ft	Mu ft-k
	U_B	50	10.00	0.489	rec	-244.3	5.00	-1,221
	U_A	50	10.00	-0.239	tri	59.7	6.67	398
					ΣU =	**-184.5**	ΣM_U =	**-823**

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

Horizontal Loads

	L	H	Pressure / Force		ICE / H	arm	Mu / Mw
	ft	ft	ksf		K	ft	ft-k
ICE	50	2.00	0.00	rec	0.0	16.44	0.0
	L		Force		**H**	arm	**Mw**
	ft		k/ft		K	ft	ft-k
SOIL	50		-2.889		-144.47	5.81	-839.87
Water Loads							
H_{TW}	50		1.913	tri	95.64	2.61	249.63
H_{HW}	50		-0.499	tri	-24.96	1.33	-33.28
				ΣWater =	**70.68**	ΣM_W =	**-623.5**

Overturning Moments	$\Sigma M_{OT} = M_U + M_W + M_{ICE}$ =	-1447	kip-ft
Resisting Moments	$\Sigma M_R = M_V$ =	4642	kip-ft
Sum of Moments	$\Sigma Mnet = M_R + M_{OT}$ =	**3,196**	kip-ft
Sum of Vertical Forces	P = Conc + Water + Uplift =	**681**	kips
Sum of Horizontal Forces	H = Σhorizontal	**-74**	kips

Location of Resultant
Xr = ΣM / P = 4.69 ft from Toe
e = B/2 - Xr = 0.31 ft
B/6 = 1.667 ft

CONCRETE QUANTITIES

			forming	
Ftg conc:	77	cy (includes stepped)	510	sf
Stem Conc:	100	cy	1479	sf
Total =	177			

STEEL REINFORCEMENT: (assumed)

		Bar #	Spacing	LB /ft	Length	# of bars	Total wt		
	a) Footing		in		ft	ea	lb		
Top mat	Transverse:	9	6	3.40	9.5	104	3,359		
	Longitudinal:	9	6	3.40	51.5	20	3,502		
Bot mat	Transverse:	9	6	3.40	9.5	104	3,359		
	Longitudinal:	9	6	3.40	51.5	20	3,502		
								cy	**LB/cy**
							13,722	77	178.1273077
	b) Skin Reinf. On Monolith								
Vert Face	Vertical	9	12	3.40	12.94	50	2,200	4,399.60	
	Longitudinal:	9	12	3.40	49.5	13	2,188	4,375.80	
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	12.9	50	2,200		
	Vertical O.F.	9	12	3.40	12.9	50	2,200		
								cy	**LB/cy**
							10,056	100	101.0039063
						Σ =	**23,778**		
	Lap Splices (long. Bars)		9	3.40	8	107	2,910		
						Σ Bar Wt=	26,688	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 =		13.44	0.019	0.25536	1.716	4.480	7.687766
Tributary WSEL =		0.00	0.0624	0	0.000	0.000	0
	Sum				1.716		7.687766
	Net Forces				1.258		7.103474

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MBI		MBI	SUBJECT	Maple Aquaduct Structure - Retaining Walls	
2/11/11				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)	895.99
Diversion - Head Water El. (ft)	893.89
Diversion - Tail Water El. (ft)	892.57
Tributary - T.O. Wall El. (ft)	903.5
Tributary - T.O. Deck L.P. El.(ft)	881.06
Tributary - T.O. Deck H.P. El.(ft)	883.06
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Tributary - Deck Slab thickness @ L.P. (ft)	2
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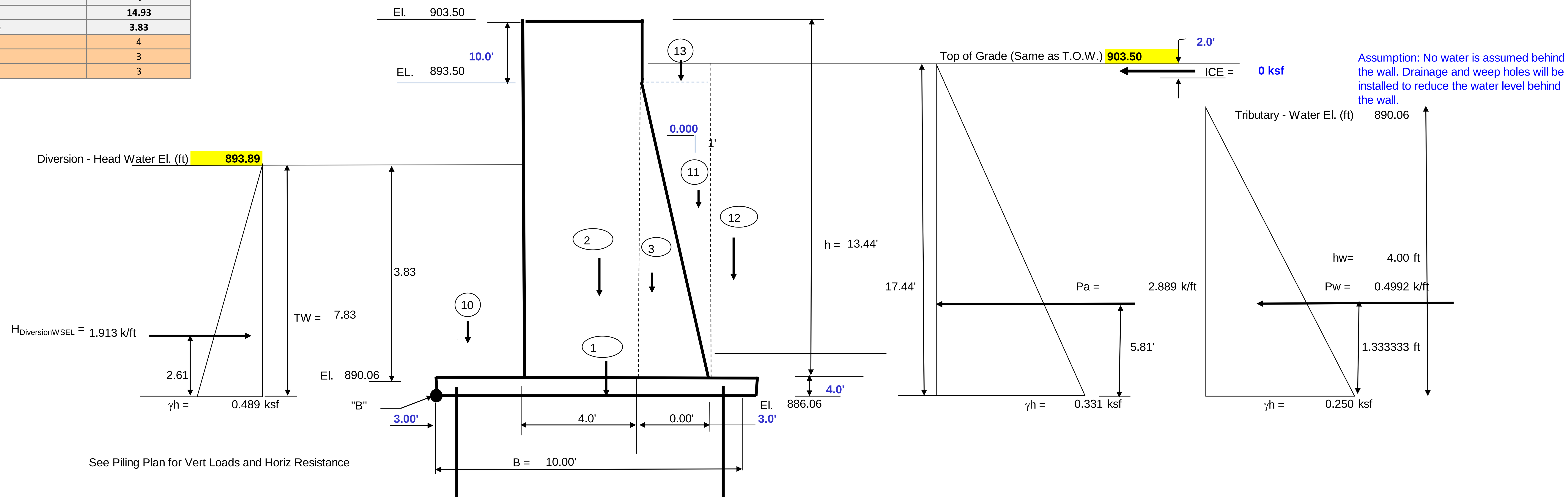
Tibutary - Water height (ft)	14.93
Diversion - Head Water height (ft)	3.83
Wall Thickness (ft)	4
Toe (Ft)	3
Heel (ft)	3

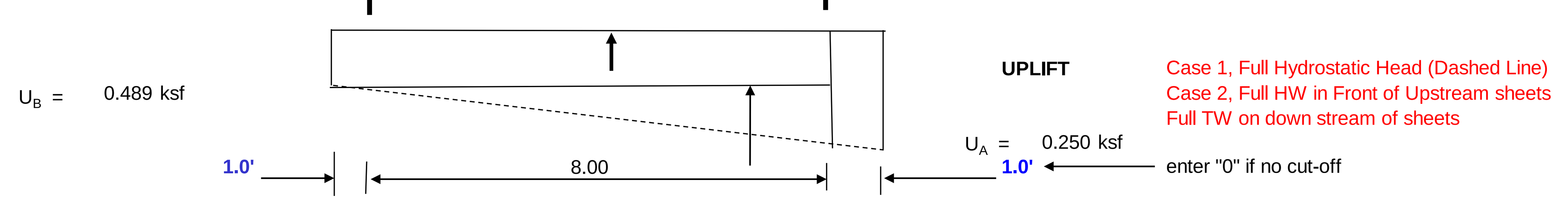
File:

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



Case 1 or 2: **1**
Normal Water Level, El. **884.11 ft**
Δh normal = -1.9 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	13.44	0.15	rec	403.2	5.00	2,016.0
Batter	3	50	0.00	3.44	0.15	tri	0.0	7.00	0.0
					D.L. Concrete	ΣVc =	**703.2**	ΣM_V =	**3,516.0**

← CONSTANT FOR ALL LOAD CASES

	Section	L	W	H	γ	shape	V	arm	Mv
T.W on ftg Stem	10	50	3.00	3.83	0.0624	rec	35.8	1.50	53.8
H.W. on Stem Slope	11	50	0.00	3.44	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	13.44	0.0626	rec	126.2	8.50	1,072.7
H.W. on Footing	12w	50	3.00	0.00	0.0624	rec	0.0	8.50	0.0
					D.L. Water	ΣVw =	**162.1**	ΣM_V =	**1,126.5**

Uplift Loads		L ft	W ft	Pressure ksf	shape	U K	arm ft	Mu ft-k
	U_B	50	10.00	0.489	rec	-244.3	5.00	-1,221
	U_A	50	10.00	-0.239	tri	59.7	6.67	398
					ΣU =	**-184.5**	ΣM_U =	**-823**

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

ICE	50	2.00	0.00	rec	0.0	16.44	0.0	
	L		Force		**H**	arm	**Mw**	
	ft		k/ft		K	ft	ft-k	
SOIL	50		-2.889		-144.47	5.81	-839.87	
Water Loads								
H_{TW}	50		1.913	tri	95.64	2.61	249.63	
H_{HW}	50		-0.499	tri	-24.96	1.33	-33.28	
				ΣWater =	**70.68**	ΣM_W =	**-623.5**	

Overturning Moments	$\Sigma M_{OT} = M_U + M_W + M_{ICE}$ =	-1447	kip-ft
Resisting Moments	$\Sigma M_R = M_V$ =	4642	kip-ft

Sum of Moments	$\Sigma Mnet = M_R + M_{OT}$ =	**3,196**	kip-ft
Sum of Vertical Forces	P = Conc + Water + Uplift =	**681**	kips
Sum of Horizontal Forces	H = Σhorizontal	**-74**	kips

Location of Resultant	Xr = ΣM / P =	4.69	ft from Toe
	e = B/2 - Xr =	0.31	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 =		13.44	**0.019**	0.25536	1.716	4.480	7.687766
Tributary WSEL =		0.00	**0.0624**	0	0.000	0.000	0
	Sum				1.716		7.687766
	Net Forces				1.258		7.103474

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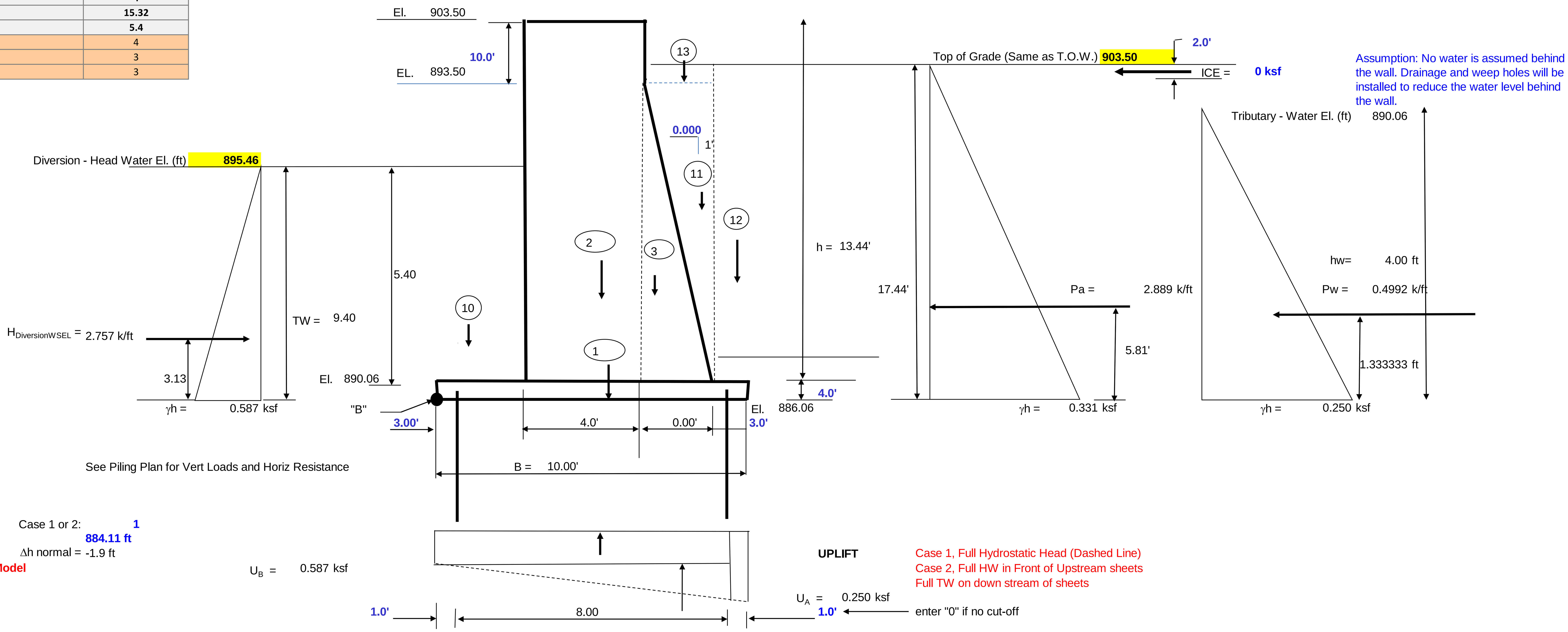
COMPUTED	CHECKED	SUBMITTED	PROJECT NUMBER	34091004	
MBI 2/11/11		MBI	SUBJECT	Maple Aquaduct Structure - Retaining Walls Load Cases: Case 3 500 yr. flood Panel H	

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)	903.5
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 = 50.0 ft
Stepped Ftg Ls = 2.0 ft overlap distance at stepped ftg



Case 1 or 2: 1
Normal Water Level, El. 884.11 ft
Δh normal = -1.9 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	13.44	0.15	rec	403.2	5.00	2,016.0
Batter	3	50	0.00	3.44	0.15	tri	0.0	7.00	0.0
					D.L. Concrete	ΣVc =	703.2	ΣM$_V$ =	3,516.0

CONSTANT FOR ALL LOAD CASES

	Section	L	W	H	γ	shape	V	arm	Mv
T.W on ftg Stem	10	50	3.00	5.40	0.0624	rec	50.5	1.50	75.8
H.W. on Stem Slope	11	50	0.00	3.44	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	13.44	0.0626	rec	126.2	8.50	1,072.7
H.W. on Footing	12w	50	3.00	0.00	0.0624	rec	0.0	8.50	0.0
					D.L. Water	ΣVw =	176.7	ΣM$_V$ =	1,148.5

Uplift Loads		L ft	W ft	Pressure ksf	shape	U K	arm ft	Mu ft-k
	U$_B$	50	10.00	0.587	rec	-293.3	5.00	-1,466
	U$_A$	50	10.00	-0.337	tri	84.2	6.67	562
					ΣU =	-209.0	ΣM$_U$ =	-905

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

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2/11/11				Load Cases: Case 3 500 yr. flood	Panel H

ICE	50	2.00	0.00	**rec**	0.0	16.44	0.0	
	L		Force		**H**	arm	**Mw**	
	ft		k/ft		K	ft	ft-k	
SOIL	50		-2.889		-144.47	5.81'	-839.87	
Water Loads								
H_{TW}	50		2.757	**tri**	137.84	3.13	431.90	
H_{HW}	50		-0.499	**tri**	-24.96	1.33	-33.28	
				ΣWater =	**112.88**	ΣM_W =	**-441.2**	

Overturning Moments	$\Sigma M_{OT} = M_U + M_W + M_{ICE}$ =	-1346	kip-ft
Resisting Moments	$\Sigma M_R = M_V$ =	4665	kip-ft
Sum of Moments	$\Sigma Mnet = M_R + M_{OT}$ =	**3,318**	kip-ft
Sum of Vertical Forces	P = Conc + Water + Uplift =	**671**	kips
Sum of Horizontal Forces	H = Σhorizontal	**-32**	kips

Location of Resultant	Xr = ΣM / P =	4.95	ft from Toe
	e = B/2 - Xr =	0.05	ft
	B/6 =	1.667	ft

FORCES AT THE BOTTOM OF THE STEM

	H	γ	Pbase	**V**	arm	**Mv**
Diversion Face	ft	kcf		K	ft	ft-k
Diversion WSEL	5.40	**0.0624**	0.33696	0.910	1.800	1.637626
Tributary SEL =	13.44	**0.019**	0.25536	1.716	4.480	7.687766
Tributary WSEL =	0.00	**0.0624**	0	0.000	0.000	0
Sum				1.716		7.687766
Net Forces				0.806		6.05014

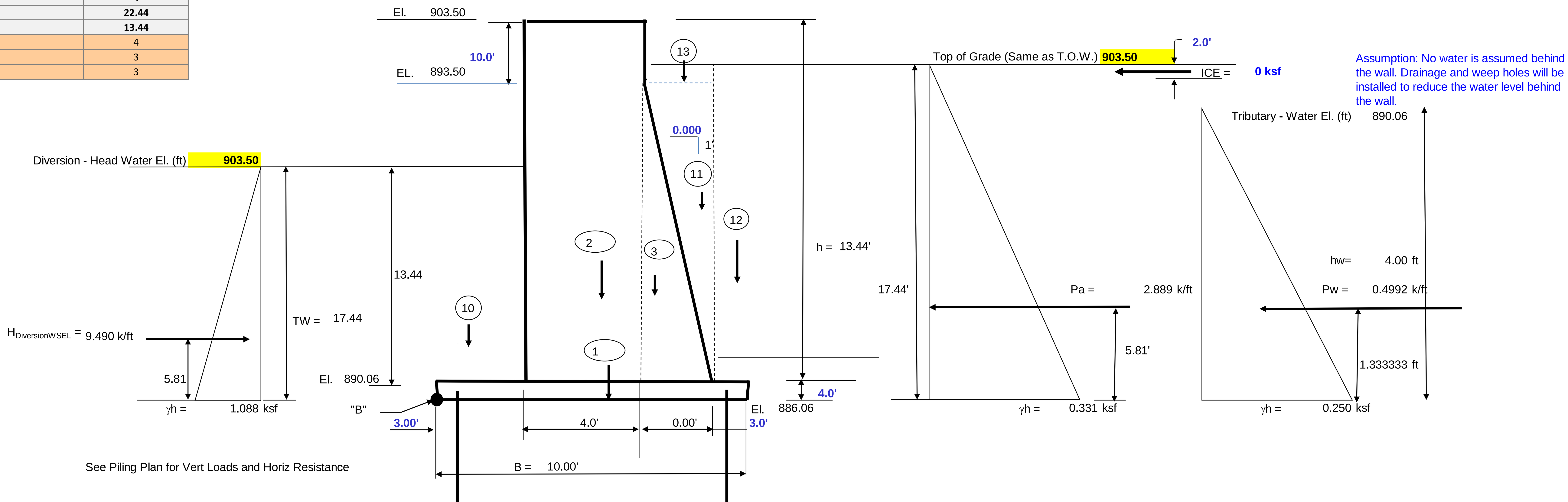
BARR ENGINEERING			DATE	2/11/2011	SHEET NO.
			PROJECT NAME	FARGO – MOORHEAD METRO FLOOD RISK MANAGEMENT PROJECT, FEASIBILITY STUDY, PHASE 4	
COMPUTED	CHECKED	SUBMITTED	PROJECT NUMBER	34091004	
MBI 2/11/11		MBI	SUBJECT	Maple Aquaduct Structure - Retaining Walls Load Cases: Case 4 T.O. Levee Panel H	

ID#	Case 4
Name	T.O. Levee
Load Category	Extreme
Tributary - Water El. (ft)	NA
Diversion - Head Water El. (ft)	903.5
Diversion - Tail Water El. (ft)	903.5
Tributary - T.O. Wall El. (ft)	903.5
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)	22.44
Diversion - Head Water height (ft)	13.44
Wall Thickness (ft)	4
Toe (Ft)	3
Heel (ft)	3

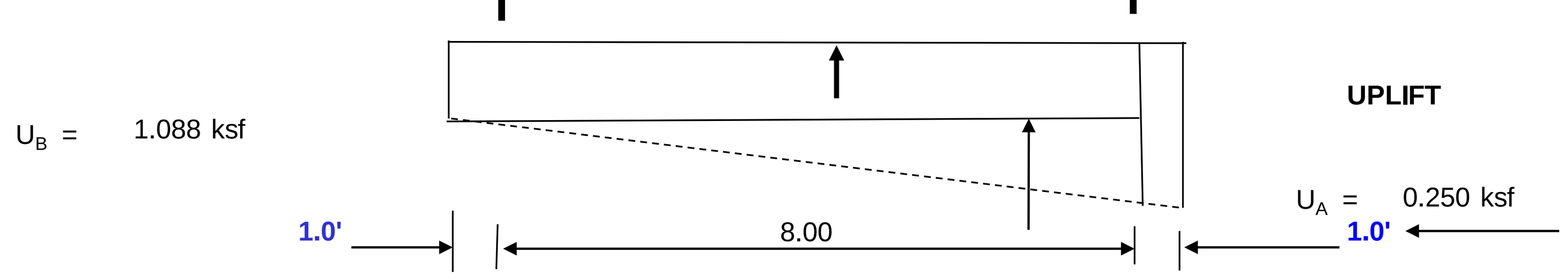
File:

MN State Building Codes
Frost Depth = 5.0 ft provide min frost ftg protection during Dec, Jan, Feb, March
Water El. = 881.50 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 or 2: 1
Normal Water Level, El. 884.11 ft
Δh normal = -1.9 ft
See Geotechnical seepage Model



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	13.44	0.15	rec	403.2	5.00	2,016.0
Batter	3	50	0.00	3.44	0.15	tri	0.0	7.00	0.0
					D.L. Concrete	ΣVc =	**703.2**	ΣM_V =	**3,516.0**

CONSTANT FOR ALL LOAD CASES

	Section	L	W	H	γ	shape	V	arm	Mv
T.W on ftg Stem	10	50	3.00	13.44	0.0624	rec	125.8	1.50	188.7
H.W. on Stem Slope	11	50	0.00	3.44	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	13.44	0.0626	rec	126.2	8.50	1,072.7
H.W. on Footing	12w	50	3.00	0.00	0.0624	rec	0.0	8.50	0.0
					D.L. Water	ΣVw =	**252.0**	ΣM_V =	**1,261.4**

Uplift Loads		L ft	W ft	Pressure ksf		U K	arm ft	Mu ft-k
	U_B	50	10.00	1.088	rec	-544.1	5.00	-2,721
	U_A	50	10.00	-0.839	tri	209.7	6.67	1,398
					ΣU =	**-334.5**	ΣM_U =	**-1,323**

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 H

	L				H	arm	Mw
ICE	50	2.00	0.00	rec	0.0	16.44	0.0
	L		Force		**H**	arm	**Mw**
	ft		k/ft		K	ft	ft-k
SOIL	50		-2.889		-144.47	5.81'	-839.87
Water Loads							
H_{TW}	50		9.490	tri	474.48	5.81	2758.31
H_{HW}	50		-0.499	tri	-24.96	1.33	-33.28
				ΣWater =	**449.52**	ΣM_W =	**1885.2**

Overturning Moments	$\Sigma M_{OT} = M_U + M_W + M_{ICE}$ =	562	kip-ft
Resisting Moments	$\Sigma M_R = M_V$ =	4777	kip-ft
Sum of Moments	$\Sigma Mnet = M_R + M_{OT}$ =	**5,340**	kip-ft
Sum of Vertical Forces	P = Conc + Water + Uplift =	**621**	kips
Sum of Horizontal Forces	H = Σhorizontal	**305**	kips

Location of Resultant	Xr = ΣM / P =	8.60	ft from Toe
	e = B/2 - Xr =	(3.60)	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	13.44	**0.0624**	0.838656	5.636	4.480	25.24824
Tributary SEL =	13.44	**0.019**	0.25536	1.716	4.480	7.687766
Tributary WSEL =	0.00	**0.0624**	0	0.000	0.000	0
Sum				1.716		7.687766
Net Forces				-3.920		-17.5605

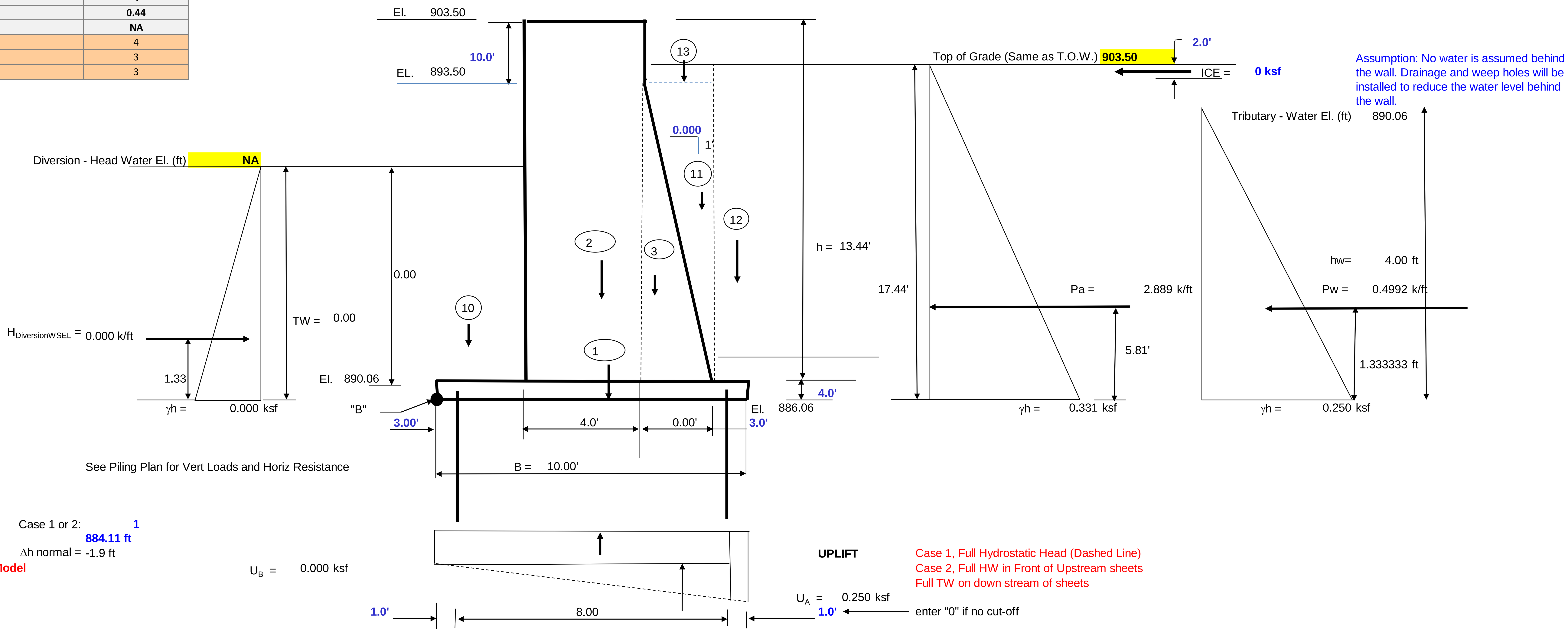
BARR ENGINEERING			DATE	2/11/2011	SHEET NO.
			PROJECT NAME	FARGO – MOORHEAD METRO FLOOD RISK MANAGEMENT PROJECT, FEASIBILITY STUDY, PHASE 4	
COMPUTED	CHECKED	SUBMITTED	PROJECT NUMBER	34091004	
MBI 2/11/11		MBI	SUBJECT	Maple Aquaduct Structure - Retaining Walls Load Cases: Case 5 Normal flow + ice Panel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

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)	903.5
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 = 50.0 ft
Stepped Ftg Ls = 2.0 ft — overlap distance at stepped ftg



Case 1 or 2: 1
Normal Water Level, El. 884.11 ft
Δh normal = -1.9 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	13.44	0.15	rec	403.2	5.00	2,016.0
Batter	3	50	0.00	3.44	0.15	tri	0.0	7.00	0.0
					D.L. Concrete	ΣVc =	703.2	ΣM_V =	3,516.0

← CONSTANT FOR ALL LOAD CASES

	Section	L	W	H	γ	shape	V	arm	Mv
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	3.44	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	13.44	0.0626	rec	126.2	8.50	1,072.7
H.W. on Footing	12w	50	3.00	0.00	0.0624	rec	0.0	8.50	0.0
					D.L. Water	ΣVw =	126.2	ΣM_V =	1,072.7

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	Maple 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	16.44	0.0	
	L		Force		**H**	arm	**Mw**	
	ft		k/ft		K	ft	ft-k	
SOIL	50		-2.889		-144.47	5.81'	-839.87	
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 =	**-839.9**	

Overturning Moments	$\Sigma M_{OT} = M_U + M_W + M_{ICE}$ =	-1256	kip-ft
Resisting Moments	$\Sigma M_R = M_V$ =	4589	kip-ft
Sum of Moments	$\Sigma Mnet = M_R + M_{OT}$ =	**3,333**	kip-ft
Sum of Vertical Forces	P = Conc + Water + Uplift =	**767**	kips
Sum of Horizontal Forces	H = Σhorizontal	**-169**	kips
Location of Resultant	Xr = ΣM / P =	4.35	ft from Toe
	e = B/2 - Xr =	0.65	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		0.00	**0.0624**	0	0.000	0.000	0
Tributary SEL =		13.44	**0.019**	0.25536	1.716	4.480	7.687766
Tributary WSEL =		0.00	**0.0624**	0	0.000	0.000	0
	Sum				1.716		7.687766
	Net Forces				1.716		7.687766

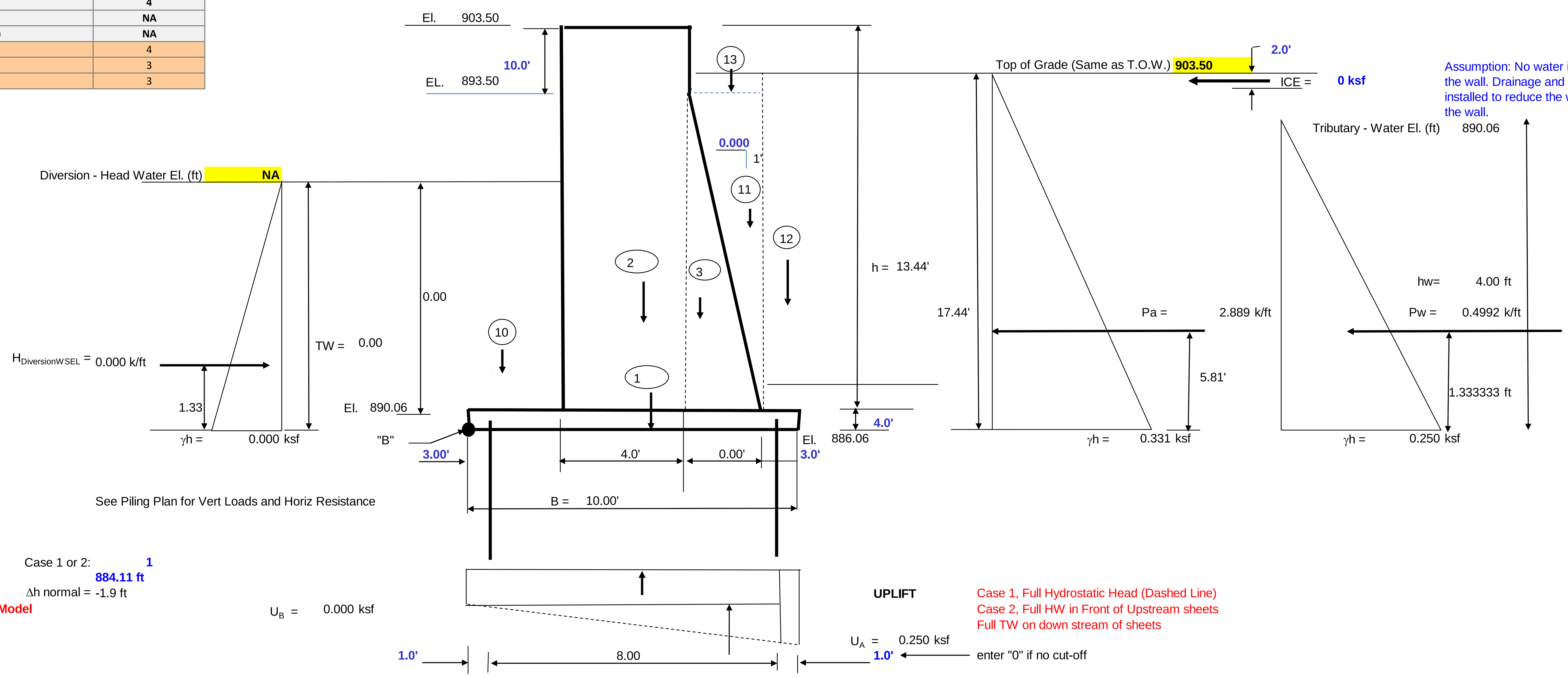
BARR ENGINEERING			DATE	2/11/2011	SHEET NO.
			PROJECT NAME	FARGO – MOORHEAD METRO FLOOD RISK MANAGEMENT PROJECT, FEASIBILITY STUDY, PHASE 4	
COMPUTED	CHECKED	SUBMITTED	PROJECT NUMBER	34091004	
MBI 2/11/11		MBI	SUBJECT	Maple Aquaduct Structure - Retaining Walls Load Cases: Case 6 Construction Panel H	

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)	903.5
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 =** 50.0 ft
Stepped Ftg Ls = 2.0 ft overlap distance at stepped ftg



Assumption: No water is assumed behind the wall. Drainage and weep holes will be installed to reduce the water level behind the wall.

Normal Water Level, El. 884.11 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	13.44	0.15	rec	403.2	5.00	2,016.0
Batter	3	50	0.00	3.44	0.15	tri	0.0	7.00	0.0
				D.L. Concrete		ΣVc =	**703.2**	ΣM_V =	**3,516.0**

← CONSTANT FOR ALL LOAD CASES

	Section	L	W	H	γ	shape	V	arm	Mv
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	3.44	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	13.44	0.0626	rec	126.2	8.50	1,072.7
H.W. on Footing	12w	50	3.00	0.00	0.0624	rec	0.0	8.50	0.0
				D.L. Water		ΣVw =	**126.2**	ΣM_V =	**1,072.7**

Uplift Loads		L ft	W ft	Pressure ksf	shape	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	Maple Aquaduct Structure - Retaining Walls	
2/11/11				Load Cases: Case 6 Construction	Panel H

ICE	50	2.00	0.00	rec	0.0	16.44	0.0
	L		Force		H	arm	Mw
	ft		k/ft		K	ft	ft-k
SOIL	50		-2.889		-144.47	5.81'	-839.87
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 =	-873.1

Overturning Moments	$\Sigma M_{OT} = M_U + M_W + M_{ICE}$ =	-1289	kip-ft
Resisting Moments	$\Sigma M_R = M_V$ =	4589	kip-ft
Sum of Moments	$\Sigma Mnet = M_R + M_{OT}$ =	3,300	kip-ft
Sum of Vertical Forces	P = Conc + Water + Uplift =	767	kips
Sum of Horizontal Forces	H = Σhorizontal	-169	kips

Location of Resultant	Xr = ΣM / P =	4.30	ft from Toe
	e = B/2 - Xr =	0.70	ft
	B/6 =	1.667	ft

FORCES AT THE BOTTOM OF THE STEM

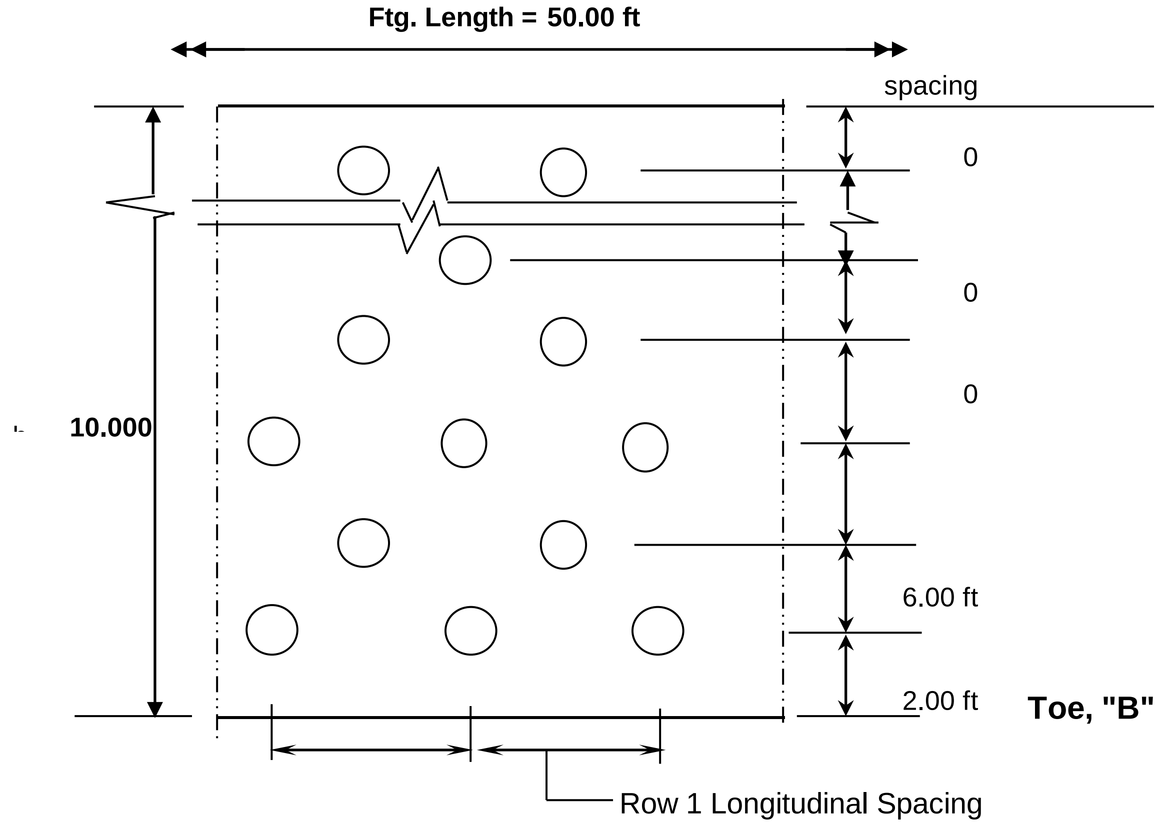
		H	γ	Pbase	V	arm	Mv
Diversion Face		ft	kcf		K	ft	ft-k
Diversion WSEL		0.00	0.0624	0	0.000	0.000	0
Tributary SEL =		13.44	0.019	0.25536	1.716	4.480	7.687766
Tributary WSEL =		0.00	0.0624	0	0.000	0.000	0
	Sum				1.716		7.687766
	Net Forces				1.716		7.687766

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				Panel H	

PILE FOUNDATION DESIGN

FLOW

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"	8	7.50	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		Note: Enter 0 for Longitudinal Spacing for Rows Not Used)		ΣN = 16			32

Pile Properties:			
Pile Type: HP	(C.I.P or HP)	Pile Length = 44.4 ft	Ftg EL. 886.06
HP Nominal Depth, h = 14.0 in			Pile Tip El. 842.68
Wt. per ft, plf 73		Total pile Length = 710 LF	Pile Cap Embed = 1.00 ft

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	3.00 ft	8	72.0
2	Dist. To Row 2	-3.00 ft	8	72.0
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
			16	Σ I = 144.0

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**	23.4	19.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	23.4	576	**OK**
Case 2	**76.2 tons**	23.4	19.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	23.4	672	**OK**
Case 3	**76.2 tons**	21.3	20.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	21.3	672	**OK**
Case 4	**99.4 tons**	-3.9	42.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	42.7	768	**OK**
Case 5	**31.4 tons**	29.2	18.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	29.2	368	**OK**
Case 6	**76.2 tons**	29.5	18.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	29.5	368	**OK**
														Max Service : P =	**42.7**	

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.

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

Pvert

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

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

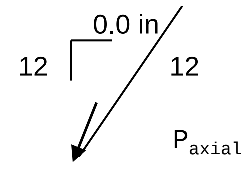
BARR ENGINEERING			DATE	2/11/2011	SHEET NO.
			PROJECT NAME	FARGO – MOORHEAD METRO FLOOD RISK MANAGEMENT PROJECT, FEASIBILITY STUDY, PHASE 4	
COMPUTED	CHECKED	SUBMITTED	PROJECT NUMBER	34091004	
MBI		MBI	SUBJECT	Maple Aquaduct Structure - Retaining Walls	
2/11/11				Panel H	

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**	681	74	3,196	4.69	0.31	208
Case 2	**100 yr. flood + ice**	**Unusual**	681	74	3,196	4.69	0.31	208
Case 3	**500 yr. flood**	**Unusual**	671	32	3,318	4.95	0.05	36
Case 4	**T.O. Levee**	**Extreme**	621	-305	5,340	8.60	-3.60	-2236
Case 5	**Normal flow + ice**	**Usual**	767	169	3,333	4.35	0.65	502
Case 6	**Construction**	**Unusual**	767	169	3,300	4.30	0.70	535

SERVICE

Case **Case 1**

Flood Event **100 yr. flood**

Usual

Vertical Load, P = 681 kips

Horizontal Load, H = 74 kips

M_{NA} = 208 kip-ft 16

	Vertical Pile Loading	P / N +	M_{NA}* d / Σ I	= Pile Loads		Axial Pile Load
1	Row 1	42.5	4.3	46.9 kips/pile	23.4 tons/pile	23.4 tons/pile
2	Row 2	42.5	-4.3	38.2 kips/pile	19.1 tons/pile	19.1 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
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:	**23.4 tons/pile**	**max: 23.4 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	8	0.0	288	1.000	288 kips	
2	Row 2	0	8	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	
			16		576		**576 kips**	**OK**

Case **Case 2**

Flood Event **100 yr. flood + ice**

Unusual

Vertical Load, P = 681 kips

Horizontal Load, H = 74 kips

M_{NA} = 208 kip-ft 16

	Vertical Pile Loading	P / N +	M_{NA}* d / Σ I	= Pile Loads		Axial Pile Load
1	Row 1	42.5	4.3	46.9 kips/pile	23.4 tons/pile	23.4 tons/pile
2	Row 2	42.5	-4.3	38.2 kips/pile	19.1 tons/pile	19.1 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
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:	**23.4 tons/pile**	**max: 23.4 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	8	0.0	336	1.000	336 kips	
2	Row 2	0	8	0.0	336	1.000	336 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	
			16		672		**672 kips**	**OK**

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

Vertical Load, P = 671 kips
Horizontal Load, H = 32 kips
M_{NA} = 36 kip-ft

	Vertical Pile Loading	P / N +	M_{NA}* d / Σ I	= Pile Loads			Axial Pile Load
1	Row 1	41.9	0.8	42.7 kips/pile		21.3 tons/pile	21.3 tons/pile
2	Row 2	41.9	-0.8	41.2 kips/pile		20.6 tons/pile	20.6 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:	**21.3 tons/pile**	**max: 21.3 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	8	0.0	336	1.000	336 kips	
2	Row 2	0	8	0.0	336	1.000	336 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	
			16		672		**672 kips**	**OK**

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

Vertical Load, P = 621 kips
Horizontal Load, H = -305 kips
M_{NA} = -2236 kip-ft

	Vertical Pile Loading	P / N +	M_{NA}* d / Σ I	= Pile Loads		Axial Pile Load
1	Row 1	38.8	-46.6	-7.8 kips/pile	-3.9 tons/pile	-3.9 tons/pile
2	Row 2	38.8	46.6	85.4 kips/pile	42.7 tons/pile	42.7 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:	**42.7 tons/pile**	**max: 42.7 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	8	0.0	384	1.000	384 kips	
2	Row 2	0	8	0.0	384	1.000	384 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	
			16		768		**768 kips**	**OK**

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

Vertical Load, P = 767 kips
Horizontal Load, H = 169 kips
M_{NA} = 502 kip-ft

	Vertical Pile Loading	P / N +	M_{NA}* d / Σ I	= Pile Loads		Axial Pile Load
1	Row 1	47.9	10.5	58.4 kips/pile	29.2 tons/pile	29.2 tons/pile
2	Row 2	47.9	-10.5	37.5 kips/pile	18.7 tons/pile	18.7 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:	**29.2 tons/pile**	**max: 29.2 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	8	0.0	184	1.000	184 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	
			16		368		**368 kips**	**OK**

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

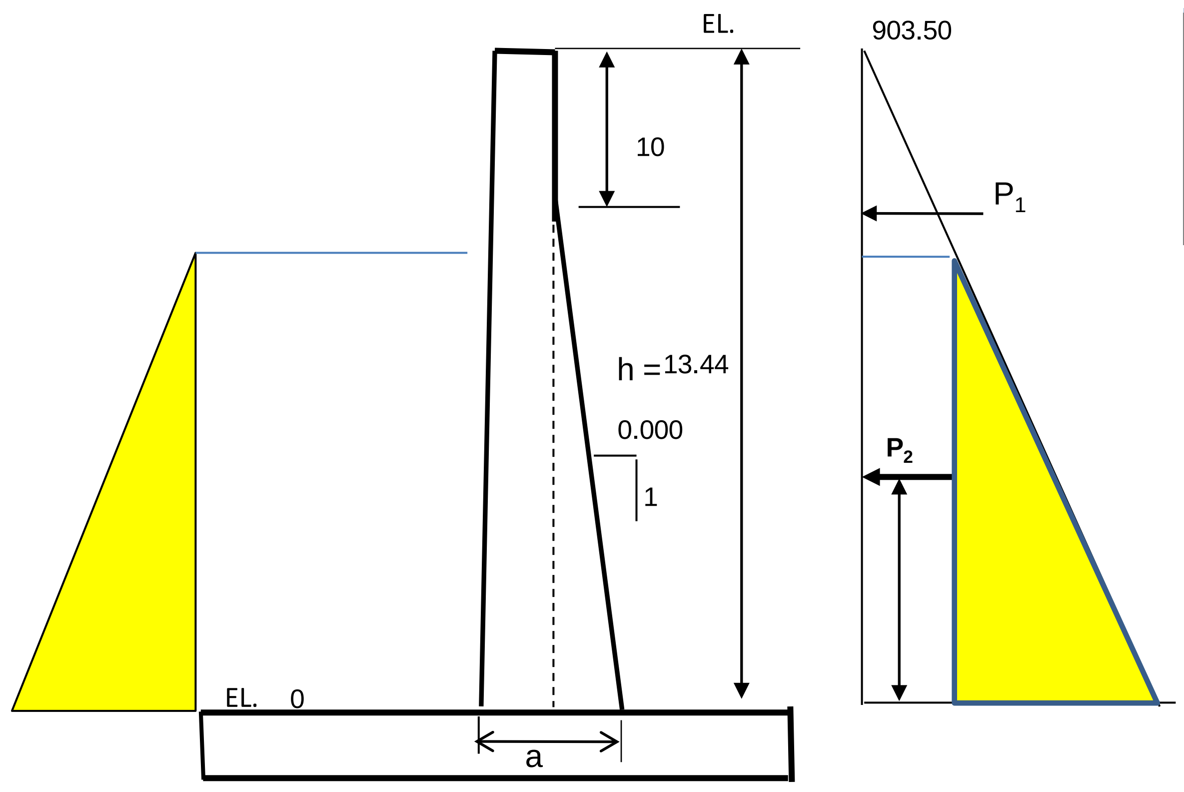
Vertical Load, P = 767 kips
Horizontal Load, H = 169 kips
M_{NA} = 535 kip-ft

	Vertical Pile Loading	P / N +	M_{NA}* d / Σ I	= Pile Loads			Axial Pile Load
1	Row 1	47.9	11.2	59.1 kips/pile	29.5 tons/pile		29.5 tons/pile
2	Row 2	47.9	-11.2	36.8 kips/pile	18.4 tons/pile		18.4 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:	**29.5 tons/pile**	**max:**	**29.5 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	8	0.0	184	1.000	184 kips	
2	Row 2	0	8	0.0	184	1.000	184 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	
			16		368		**368 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		MBI	SUBJECT	Maple Aquaduct Structure - Retaining Walls	
2/11/11				Panel H 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	903.500	903.50	0.00	903.50
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	1.26	7.103	2.78	15.70
Case 2	100 yr. flood + ice	Unusual	0.75	1.26	7.103	2.09	11.77
Case 3	500 yr. flood	Unusual	0.75	0.81	6.050	1.34	10.03
Case 4	T.O. Levee	Extreme	0.75	-3.92	-17.560	6.50	29.11
Case 5	Normal flow + ice	Usual	1	1.72	7.688	3.79	16.99
Case 6	Construction	Unusual	0.75	1.72	7.688	2.84	12.74

STEM DESIGN VALUES

MU, k-ft/ft	29.11	k-ft/ft
VU, k/ft	6.50	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 = 29 k-ft /ft **Includes: hf = 1.3**
Vuh= 6.50 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

$Ru=Mn/bd^2$ = 17.091 **ACI 10.5.1** **ACI 10.5.3**
REQ'D p= 0.0003 **O.K.** p(min)= 3*SQRT(Fc')/fy 200* / fy 4/3*p
p= 0.0004 0.00316 0.00333 0.0004

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

As (REQ'D)= 0.81 in^2 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**

a) For singly reinforced flexural members
1) p = **0.25** pb Recommended limit
2) p = **0.375** pb Max. permitted upper limit not requiring special study
3) p = **0.5** pb Max. permitted upper limit when excessive deflections are not predicted In ACI 318
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

T= As*fy = 60.0 k
C= B1*Fc' *b*a = 99.0 **a**
a= T/C = 0.606 in
Mn= T(d - a/2)/12 = 215.5 ft-k
ϕ Mn= 194.0 ft-k **> Mu O.K.**

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

Vuh = 6.5 k **NO SHEAR REINF. REQUIRED**
Vn = Vuh / ϕ = 8.7 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