Attachment H-5: Slope Stability and Reliability Calculations

Long-Term, Drained Conditions

Fargo Project ID: 5708, 10th St. N

Fargo Project ID: 5708
Location: 10th St. N
Top of Levee: 898.5
Elevation at Dryside Toe: 893.5
Height: 5
Top Width: 10
Riverside Slope: 3
Landside Slope: 3

Run	Levee Friction	Levee Cohesion	Sherack Friction	River Stage	FS	SLIDE ΔF	(ΔF/2)^0.5
Most Likely Values	27	250	27	898.5	2.135		
2	24	250	27	898.5	2.110		
3	30	250	27	898.5	2.160	-0.05	0.0006
4	27	175	27	898.5	1.934		
5	27	325	27	898.5	2.300	-0.37	0.0335
6	27	250	24	898.5	1.958		
7	27	250	30	898.5	2.307	-0.35	0.0305
8							
9					0.00		0
Standard Deviation	3	75	3		(sum)		0.254095
Coefficient of Variation	10.3%	30.0%	10.3%		Coeff. Of Var. of FS		11.90%

Probability of Failure (FS < 1)	1.18E-10	or	0.000%
	1.18	chance in	1.E+10
	Reliability Index		6.34

Run	Levee Friction	Levee Cohesion	PL Sherack Friction	River Stage	FS	SLIDE ΔF	(ΔF/2)^0.5
Most Likely Values	27	250	21	898.5	1.725		
2	24	250	21	898.5	1.707		
3	30	250	21	898.5	1.744	-0.04	0.0003
4	27	175	21	898.5	1.571		
5	27	325	21	898.5	1.825	-0.25	0.0161
6	27	250	18	898.5	1.547		
7	27	250	24	898.5	1.893	-0.35	0.0299
8							
9					0.00		0
Standard Deviation	3	75	3		(sum)		0.215407
Coefficient of Variation	10.3%	30.0%	13.7%		Coeff. Of Var. of FS		12.49%

Probability of Failure (FS < 1)	7.77E-06	or	0.001%
	1.00	chance in	1.3.E+05
	Reliability Index		4.32

Fargo Project ID: 4903, Cardinal Muench Seminary

Fargo Project ID: 4903
Location: Cardinal Muench Seminary
Top of Levee: 898
Elevation at Dryside Toe: 893
Height: 5
Top Width: 5
Riverside Slope: 6
Landside Slope: 6

Run	Levee Friction	Levee Cohesion	Sherack Friction	River Stage	FS	SLIDE ΔF	(ΔF/2)^0.5
Most Likely Values	27	250	27	898	2.010		
2	24	250	27	898	2.010		
3	30	250	27	898	2.010	0.00	0.0000
4	27	175	27	898	2.006		
5	27	325	27	898	2.014	-0.01	0.0000
6	27	250	24	898	1.758		
7	27	250	30	898	2.276	-0.52	0.0671
8							
9					0.00		0
Standard Deviation	3	75	3		(sum)		0.259030886
Coefficient of Variation	10.3%	30.0%	10.3%		Coeff. Of Var. of FS		12.89%

Probability of Failure (FS < 1)	3.82E-08	or	0.000%
	7636.00	chance in	2.0.E+11
	Reliability Index		5.38

Run	Levee Friction	Levee Cohesion	PL Sherack Friction	River Stage	FS	SLIDE ΔF	(ΔF/2)^0.5
Most Likely Values	27	250	21	898	1.439		
2	24	250	21	898	1.439		
3	30	250	21	898	1.439	0.00	0.0000
4	27	175	21	898	1.439		
5	27	325	21	898	1.439	0.00	0.0000
6	27	250	18	898	1.218		
7	27	250	24	898	1.670	-0.45	0.0511
8							
9					0.00		0
Standard Deviation	3	75	3		(sum)		0.226000
Coefficient of Variation	10.3%	30.0%	13.7%		Coeff. Of Var. of FS		15.71%

Probability of Failure (FS < 1)	1.21E-02	or	1.211%
	1.00	chance in	82.50
	Reliability Index		2.25

Fargo Project ID: 4579-3, 10th Ave S (Dike West)

Fargo Project ID: 4579-3
Location: 10th Ave S (Dike West)
Top of Levee: 905
Elevation at Dryside Toe: 890
Height: 15
Top Width: 10
Riverside Slope: 3
Landside Slope: 3

Run	Levee Friction	Levee Cohesion	Sherack Friction	River Stage	FS	SLIDE ΔF	(ΔF/2)^0.5
Most Likely Values	27	250	27	905	1.339		
2	24	250	27	905	1.331		
3	30	250	27	905	1.347	-0.02	0.0001
4	27	175	27	905	1.257		
5	27	325	27	905	1.415	-0.16	0.0062
6	27	250	24	905	1.208		
7	27	250	30	905	1.469	-0.26	0.0170
8							
9					0.00		0
Standard Deviation	3	75	3		(sum)		0.152758797
Coefficient of Variation	10.3%	30.0%	10.3%		Coeff. Of Var. of FS		11.41%

Probability of Failure (FS < 1)	6.03E-03	or	0.603%
	1.00	chance in	165
	Reliability Index		2.51

Run	Levee Friction	Levee Cohesion	Sherack Friction	River Stage	FS	SLIDE ΔF	(ΔF/2)^0.5
Most Likely Values	27	250	27	900	1.445		
2	24	250	27	900	1.427		
3	30	250	27	900	1.461	-0.03	0.0003
4	27	175	27	900	1.359		
5	27	325	27	900	1.462	-0.10	0.0027
6	27	250	24	900	1.259		
7	27	250	30	900	1.582	-0.32	0.0261
8							
9					0.00		0
Standard Deviation	3	75	3		(sum)		0.170362848
Coefficient of Variation	10.3%	30.0%	10.3%		Coeff. Of Var. of FS		11.79%

Probability of Failure (FS < 1)	1.05E-03	or	0.105%
	1.00	chance in	950
	Reliability Index		3.07

Run	Levee Friction	Levee Cohesion	Sherack Friction	River Stage	FS	SLIDE ΔF	(ΔF/2)^0.5
Most Likely Values	27	250	27	897.5	1.761		
2	24	250	27	897.5	1.751		
3	30	250	27	897.5	1.779	-0.03	0.0002
4	27	175	27	897.5	1.698		
5	27	325	27	897.5	1.832	-0.13	0.0045
6	27	250	24	897.5	1.586		
7	27	250	30	897.5	1.954	-0.37	0.0339
8							
9					0.00		0
Standard Deviation	3	75	3		(sum)		0.196318619
Coefficient of Variation	10.3%	30.0%	10.3%		Coeff. Of Var. of FS		11.15%

Probability of Failure (FS < 1)	2.37E-07	or	0.000%
	1.00	chance in	4,200,000
	Reliability Index		5.04

Run	Levee Friction	Levee Cohesion	Sherack Friction	River Stage	FS	SLIDE ΔF	(ΔF/2)^0.5
Most Likely Values	27	250	27	895	1.892		
2	24	250	27	895	1.869		
3	30	250	27	895	1.918	-0.05	0.0006
4	27	175	27	895	1.790		
5	27	325	27	895	1.999	-0.21	0.0109
6	27	250	24	895	1.719		
7	27	250	30	895	2.074	-0.36	0.0315
8							
9					0.00		0
Standard Deviation	3	75	3		(sum)		0.207428903
Coefficient of Variation	10.3%	30.0%	10.3%		Coeff. Of Var. of FS		10.96%

Probability of Failure (FS < 1)	3.76E-09	or	0.000%
	1.00	chance in	265,000,000
	Reliability Index		5.78

Fargo Project ID: 4579-3, 10th Ave S (Dike West)

Fargo Project ID: 4579-3
Location: 10th Ave S (Dike West)
Top of Levee: 905
Elevation at Dryside Toe: 890
Height: 15
Top Width: 10
Riverside Slope: 3
Landside Slope: 3
MSE Wall Height: 5
Toe of slope (ft): 890
Geogrid length (ft): 4

Run	Levee Friction	Levee Cohesion	PL Sherack Friction	River Stage	FS	SLIDE ΔF	(ΔF/2)^0.5
Most Likely Values	27	250	21	905	1.015		
2	24	250	21	905	1.012		
3	30	250	21	905	1.018	-0.01	0.0000
4	27	175	21	905	0.957		
5	27	325	21	905	0.970	-0.01	0.0000
6	27	250	18	905	0.809		
7	27	250	24	905	1.143	-0.33	0.0279
8							
9					0.00		0
Standard Deviation	3	75	3		(sum)		0.167153
Coefficient of Variation	10.3%	30.0%	13.7%		Coeff. Of Var. of FS		16.47%

Probability of Failure (FS < 1)	4.96E-01	or	49.632%
	1.00	chance in	2.02
	Reliability Index		0.01

Run	Levee Friction	Levee Cohesion	PL Sherack Friction	River Stage	FS	SLIDE ΔF	(ΔF/2)^0.5
Most Likely Values	27	250	21	900	1.047		
2	24	250	21	900	1.038		
3	30	250	21	900	1.055	-0.02	0.0001
4	27	175	21	900	0.997		
5	27	325	21	900	1.032	-0.04	0.0003
6	27	250	18	900	0.873		
7	27	250	24	900	1.175	-0.30	0.0228
8							
9					0.00		0
Standard Deviation	3	75	3		(sum)		0.152248
Coefficient of Variation	10.3%	30.0%	13.7%		Coeff. Of Var. of FS		14.54%

Probability of Failure (FS < 1)	4.03E-01	or	40.316%
	1.00	chance in	2.47
	Reliability Index		0.25

Run	Levee Friction	Levee Cohesion	PL Sherack Friction	River Stage	FS	SLIDE ΔF	(ΔF/2)^0.5
Most Likely Values	27	250	21	897.5	1.381		
2	24	250	21	897.5	1.371		
3	30	250	21	897.5	1.391	-0.02	0.0001
4	27	175	21	897.5	1.331		
5	27	325	21	897.5	1.377	-0.05	0.0005
6	27	250	18	897.5	1.161		
7	27	250	24	897.5	1.564	-0.40	0.0406
8							
9					0.00		0
Standard Deviation	3	75	3		(sum)		0.203055
Coefficient of Variation	10.3%	30.0%	13.7%		Coeff. Of Var. of FS		14.70%

Probability of Failure (FS < 1)	1.64E-02	or	1.642%
	1.00	chance in	61
	Reliability Index		2.13

Run	Levee Friction	Levee Cohesion	PL Sherack Friction	River Stage	FS	SLIDE ΔF	(ΔF/2)^0.5
Most Likely Values	27	250	21	895	1.545		
2	24	250	21	895	1.521		
3	30	250	21	895	1.569	-0.05	0.0006
4	27	175	21	895	1.441		
5	27	325	21	895	1.571	-0.13	0.0042
6	27	250	18	895	1.327		
7	27	250	24	895	1.705	-0.38	0.0357
8							
9					0.00		0
Standard Deviation	3	75	3		(sum)		0.201301
Coefficient of Variation	10.3%	30.0%	13.7%		Coeff. Of Var. of FS		13.03%

Probability of Failure (FS < 1)	5.04E-04	or	0.050%
	1.00	chance in	1985
	Reliability Index		3.29

FIle: FMMFS_Geo_C2EL_Prob_Failure_rev_2010-01.xls
Worksheet: P(F) Stability
Printed on 11/30/2009
Final Fargo-Moorhead Metro Feasibility Report and Environmental Impact Statement
July 2011

Attachment H-5, pg 1
Credit to Existing Levees

Long-Term, Drained Conditions

Fargo Project ID: 4908, Lindenwood Drive

Parameter	Value
Fargo Project ID	4908
Location	Lindenwood Drive
Top of Levee	905
Elevation at Dryside Toe	897
Height	8
Top Width	8
Riverside Slope	4
Landside Slope	4
MSE Wall Height	5
Geogrid length (ft)	4

Run	Levee Friction	Cohesion	Sherack Friction	River Stage	FS	SLIDE ΔF	(ΔF/2)^0.5
Most Likely Values	27	250	27	905	1.206		
2	24	250	27	905	1.203		
3	30	250	27	905	1.206	0.00	0.0000
4	27	175	27	905	1.101		
5	27	325	27	905	1.292	-0.19	0.0091
6	27	250	24	905	1.088		
7	27	250	30	905	1.314	-0.23	0.0128
8							
9					0.00	0	
Standard Deviation	3	75	3		(sum)	0.147957764	
Coefficient of Variation	10.3%	30.0%	10.3%		Coeff. Of Var. of FS	12.27%	

Probability of Failure (FS < 1): 7.06E-02 or 7.060%; 1.00 chance in 14.2; Reliability Index 1.47

Run	Levee Friction	Cohesion	Sherack Friction	River Stage	FS	SLIDE ΔF	(ΔF/2)^0.5
Most Likely Values	27	250	27	898	1.675		
2	24	250	27	898	1.650		
3	30	250	27	898	1.701	-0.05	0.0007
4	27	175	27	898	1.548		
5	27	325	27	898	1.795	-0.25	0.0153
6	27	250	24	898	1.539		
7	27	250	30	898	1.817	-0.28	0.0193
8							
9					0.00	0	
Standard Deviation	3	75	3		(sum)	0.187679248	
Coefficient of Variation	10.3%	30.0%	10.3%		Coeff. Of Var. of FS	11.20%	

Probability of Failure (FS < 1): 2.53E-06 or 0.000%; 1.00 chance in 395,000; Reliability Index 4.56

Run	Levee Friction	Cohesion	Sherack Friction	River Stage	FS	SLIDE ΔF	(ΔF/2)^0.5
Most Likely Values	27	250	27	901	1.516		
2	24	250	27	901	1.479		
3	30	250	27	901	1.538	-0.06	0.0009
4	27	175	27	901	1.373		
5	27	325	27	901	1.620	-0.25	0.0153
6	27	250	24	901	1.389		
7	27	250	30	901	1.617	-0.23	0.0130
8							
9					0.00	0	
Standard Deviation	3	75	3		(sum)	0.170641437	
Coefficient of Variation	10.3%	30.0%	10.3%		Coeff. Of Var. of FS	11.26%	

Probability of Failure (FS < 1): 1.30E-04 or 0.013%; 1.00 chance in 7,650; Reliability Index 3.65

Run	Levee Friction	Cohesion	Sherack Friction	River Stage	FS	SLIDE ΔF	(ΔF/2)^0.5
Most Likely Values	27	250	27	903	1.498		
2	24	250	27	903	1.471		
3	30	250	27	903	1.515	-0.04	0.0005
4	27	175	27	903	1.360		
5	27	325	27	903	1.602	-0.24	0.0146
6	27	250	24	903	1.368		
7	27	250	30	903	1.606	-0.24	0.0142
8							
9					0.00	0	
Standard Deviation	3	75	3		(sum)	0.171131528	
Coefficient of Variation	10.3%	30.0%	10.3%		Coeff. Of Var. of FS	11.42%	

Probability of Failure (FS < 1): 2.40E-04 or 0.024%; 1.00 chance in 4,175; Reliability Index 3.49

Fargo Project ID: 4908, Lindenwood Drive

Parameter	Value
Fargo Project ID	4908
Location	Lindenwood Drive
Top of Levee	905
Elevation at Dryside Toe	897
Height	8
Top Width	8
Riverside Slope	4
Landside Slope	4
MSE Wall Height	5
Geogrid length (ft)	4

Run	Levee Friction	Cohesion	PL Sherack Friction	River Stage	FS	SLIDE ΔF	(ΔF/2)^0.5
Most Likely Values	27	250	21	905	0.948		
2	24	250	21	905	0.952		
3	30	250	21	905	0.947	0.01	0.0000
4	27	175	21	905	0.879		
5	27	325	21	905	1.018	-0.14	0.0048
6	27	250	18	905	0.833		
7	27	250	24	905	1.067	-0.23	0.0137
8							
9					0.00	0	
(sum)						0.136108413	
Standard Deviation	3	75	3				
Coefficient of Variation	10.3%	30.0%	13.7%		Coeff. Of Var. of FS	14.36%	

Probability of Failure (FS < 1): 6.72E-01 or 67.194%; 1.01 chance in 1.5; Reliability Index -0.45

Run	Levee Friction	Cohesion	PL Sherack Friction	River Stage	FS	SLIDE ΔF	(ΔF/2)^0.5
Most Likely Values	27	250	21	898	1.393		
2	24	250	21	898	1.370		
3	30	250	21	898	1.419	-0.05	0.0006
4	27	175	21	898	1.273		
5	27	325	21	898	1.405	-0.13	0.0044
6	27	250	18	898	1.175		
7	27	250	24	898	1.486	-0.31	0.0242
8							
9					0.00	0	
(sum)						0.170694171	
Standard Deviation	3	75	3				
Coefficient of Variation	10.3%	30.0%	13.7%		Coeff. Of Var. of FS	12.25%	

Probability of Failure (FS < 1): 3.98E-03 or 0.398%; 1.00 chance in 251; Reliability Index 2.65

Run	Levee Friction	Cohesion	PL Sherack Friction	River Stage	FS	SLIDE ΔF	(ΔF/2)^0.5
Most Likely Values	27	250	21	901	1.152		
2	24	250	21	901	1.140		
3	30	250	21	901	1.164	-0.02	0.0001
4	27	175	21	901	1.083		
5	27	325	21	901	1.230	-0.15	0.0054
6	27	250	18	901	1.029		
7	27	250	24	901	1.287	-0.26	0.0166
8							
9					0.00	0	
(sum)						0.148953852	
Standard Deviation	3	75	3				
Coefficient of Variation	10.3%	30.0%	13.7%		Coeff. Of Var. of FS	12.93%	

Probability of Failure (FS < 1): 1.50E-01 or 15.045%; 1.00 chance in 7; Reliability Index 1.03

Run	Levee Friction	Cohesion	Sherack Friction	River Stage	FS	SLIDE ΔF	(ΔF/2)^0.5
Most Likely Values	27	250	21	903	1.130		
2	24	250	21	903	1.119		
3	30	250	21	903	1.147	-0.03	0.0002
4	27	175	21	903	1.068		
5	27	325	21	903	1.208	-0.14	0.0049
6	27	250	18	903	1.013		
7	27	250	24	903	1.264	-0.25	0.0158
8							
9					0.00	0	
(sum)						0.144382305	
Standard Deviation	3	75	3				
Coefficient of Variation	10.3%	30.0%	13.7%		Coeff. Of Var. of FS	12.78%	

Probability of Failure (FS < 1): 1.85E-04 or 18.492%; 1.00 chance in 5; Reliability Index 0.90

Fargo Project ID: 4980, Southwood Drive

Parameter	Value
Fargo Project ID	4980
Location	Southwood Drive
Top of Levee	905
Elevation at Dryside Toe	901
Height	4
Top Width	4
Riverside Slope	3
Landside Slope	3
Toe of slope (ft)	900
Height at toe of slope	5

Run	Levee Friction	Cohesion	Sherack Friction	River Stage	FS	SLIDE ΔF	(ΔF/2)^0.5
Most Likely Values	27	250	27	905	1.839		
2	24	250	27	905	1.833		
3	30	250	27	905	1.842	-0.01	0.0000
4	27	175	27	905	1.684		
5	27	325	27	905	1.972	-0.29	0.0207
6	27	250	24	905	1.672		
7	27	250	30	905	2.007	-0.34	0.0281
8							
9					0.00	0	
Standard Deviation	3	75	3		(sum)	0.220935511	
Coefficient of Variation	10.3%	30.0%	10.3%		Coeff. Of Var. of FS	12.01%	

Probability of Failure (FS < 1): 2.46E-07 or 0.000%; 1.00 chance in 4,050,000; Reliability Index 5.03

Run	Levee Friction	Cohesion	PL Sherack Friction	River Stage	FS	SLIDE ΔF	(ΔF/2)^0.5
Most Likely Values	27	250	21	905	1.395		
2	24	250	21	905	1.394		
3	30	250	21	905	1.395	0.00	0.0000
4	27	175	21	905	1.285		
5	27	325	21	905	1.483	-0.20	0.0098
6	27	250	18	905	1.223		
7	27	250	24	905	1.560	-0.34	0.0284
8							
9					0.00	0	
(sum)						0.195431574	
Coefficient of Variation	10.3%	30.0%	13.7%		Coeff. Of Var. of FS	14.01%	

Probability of Failure (FS < 1): 1.02E-02 or 1.022%; 1.00 chance in 98; Reliability Index 2.32

Fargo Project ID: 5093, Drain 27 / Rose Coulee

Parameter	Value
Fargo Project ID	5093
Location	Drain 27 / Rose Coulee
Top of Levee	909
Elevation at Dryside Toe	904
Height	5
Top Width	10
Riverside Slope	5
Landside Slope	5

Run	Levee Friction	Cohesion	Sherack Friction	River Stage	FS	SLIDE ΔF	(ΔF/2)^0.5
Most Likely Values	27	250	27	909	2.291		
2	24	250	27	909	2.278		
3	30	250	27	909	2.304	-0.03	0.0002
4	27	175	27	909	2.169		
5	27	325	27	909	2.400	-0.23	0.0133
6	27	250	24	909	2.059		
7	27	250	30	909	2.532	-0.47	0.0559
8							
9					0.00	0	
Standard Deviation	3	75	3		(sum)	0.263517552	
Coefficient of Variation	10.3%	30.0%	10.3%		Coeff. Of Var. of FS	11.50%	

Probability of Failure (FS < 1): 3.65E-13 or 0.000%; 1.00 chance in 2,750,000,000,000; Reliability Index 7.17

Run	Levee Friction	Cohesion	PL Sherack Friction	River Stage	FS	SLIDE ΔF	(ΔF/2)^0.5
Most Likely Values	27	250	21	905	1.692		
2	24	250	21	905	1.685		
3	30	250	21	905	1.699	-0.01	0.0000
4	27	175	21	905	1.619		
5	27	325	21	905	1.763	-0.14	0.0052
6	27	250	18	905	1.476		
7	27	250	24	905	1.914	-0.44	0.0480
8							
9					0.00	0	
(sum)						0.230638245	
Coefficient of Variation	10.3%	30.0%	13.7%		Coeff. Of Var. of FS	13.63%	

Probability of Failure (FS < 1): 7.00E-05 or 0.007%; 1.00 chance in 14,250; Reliability Index 3.81

File: FMMFS_Geo_C2EL_Prob_Failure_rev_2010-01.xls
Worksheet: P(F) Stability
Printed on 11/30/2009
Final Fargo-Moorhead Metro Feasibility Report and Environmental Impact Statement
July 2011
Attachment H-5, pg 2
Credit to Existing Levees

Project: FMMFS
Subject: Stability Analysis
Computed By: KAH
Date: 19-Dec-08
Revised By: KAH
Date: 13-Jan-09

Long-Term, Drained Conditions

Moorhead Project ID:	97-13-15
Location:	Woodlawn Park
Top of Levee	904
Elevation at Dryside Toe	894
Height	10
Top Width	10
Riverside Slope	3
Landside Slope	3

Moorhead Project ID: 97-13-15, Woodlawn Park

Run	Levee Friction	Cohesion	Sherack Friction	River Stage	FS	SLIDE ΔF	(ΔF/2)^0.5	Levee Friction	Cohesion	PL Sherack Friction	River Stage	FS	SLIDE ΔF	(ΔF/2)^0.5
Most Likely Values	27	250	27	904	1.617			27	250	21	904	1.303		
2	24	250	27	904	1.593			24	250	21	904	1.287		
3	30	250	27	904	1.640	-0.05	0.0006	30	250	21	904	1.319	-0.03	0.0003
4	27	175	27	904	1.498			27	175	21	904	1.212		
5	27	325	27	904	1.720	-0.22	0.0123	27	325	21	904	1.384	-0.17	0.0074
6	27	250	24	904	1.477			27	250	18	904	1.159		
7	27	250	30	904	1.756	-0.28	0.0195	27	250	24	904	1.442	-0.28	0.0200
8														
9					0.00	0						0.00	0	
Standard Deviation	3	75	3			(sum)	0.179815183	3	75	3			(sum)	0.166355793
Coefficient of Variation	10.3%	30.0%	10.3%		Coeff. Of Var. of FS		11.12%	10.3%	30.0%	13.7%		Coeff. Of Var. of FS		12.77%

Probability of Failure (FS < 1)	9.37E-06	or	0.001%			Probability of Failure (FS < 1)	2.18E-02	or	2.180%
	1.00	chance in	107,000				1.00	chance in	46.0
	Reliability Index		4.28				2.02		

Moorhead Project ID:	97-13-14
Location:	Horn Park
Top of Levee	905
Elevation at Dryside Toe	888
Height	17
Top Width	10
Riverside Slope	3
Landside Slope	3
Toe of slope (ft)	884
Height at toe of slope	21

Moorhead Project ID: 97-13-14, Horn Park

Run	Levee Friction	Cohesion	Sherack Friction	River Stage	FS	SLIDE ΔF	(ΔF/2)^0.5	Levee Friction	Cohesion	Sherack Friction	River Stage	FS	SLIDE ΔF	(ΔF/2)^0.5	Levee Friction	Cohesion	Sherack Friction	River Stage	FS	SLIDE ΔF	(ΔF/2)^0.5	Levee Friction	Cohesion	Sherack Friction	River Stage	FS	SLIDE ΔF	(ΔF/2)^0.5
Most Likely Values	27	250	27	905	1.278			27	250	27	901	1.520			27	250	27	898	1.625			27	250	27	894	1.718		
2	24	250	27	905	1.260			24	250	27	901	1.491			24	250	27	898	1.592			24	250	27	894	1.680		
3	30	250	27	905	1.297	-0.04	0.0003	30	250	27	901	1.547	-0.06	0.0008	30	250	27	898	1.658	-0.07	0.0011	30	250	27	894	1.753	-0.07	0.0013
4	27	175	27	905	1.210			27	175	27	901	1.452			27	175	27	898	1.562			27	175	27	894	1.655		
5	27	325	27	905	1.342	-0.13	0.0044	27	325	27	901	1.562	-0.11	0.0030	27	325	27	898	1.682	-0.12	0.0036	27	325	27	894	1.778	-0.12	0.0038
6	27	250	24	905	1.162			27	250	24	901	1.378			27	250	24	898	1.471			27	250	24	894	1.557		
7	27	250	30	905	1.398	-0.24	0.0139	27	250	30	901	1.660	-0.28	0.0199	27	250	30	898	1.779	-0.31	0.0237	27	250	30	894	1.881	-0.32	0.0262
8																												
9					0.00	0						0.00	0						0.00	0						0.00	0	
Standard Deviation	3	75	3			(sum)	0.136463365	3	75	3			(sum)	0.153915561	3	75	3			(sum)	0.16853783	3	75	3			(sum)	0.177083314
Coefficient of Variation	10.3%	30.0%	10.3%		Coeff. Of Var. of FS		10.68%	10.3%	30.0%	10.3%		Coeff. Of Var. of FS		10.13%	10.3%	30.0%	10.3%		Coeff. Of Var. of FS		10.37%	10.3%	30.0%	10.3%		Coeff. Of Var. of FS		10.31%

Probability of Failure (FS < 1)	1.22E-02	or	1.221%	Probability of Failure (FS < 1)	2.11E-05	or	0.002%	Probability of Failure (FS < 1)	1.73E-06	or	0.000%	Probability of Failure (FS < 1)	9.31E-08	or	0.000%
	1.00	chance in	82		1.00	chance in	47,500		1.00	chance in	580,000		1.00	chance in	10,750,000
	Reliability Index		2.25		Reliability Index		4.10		Reliability Index		4.64		Reliability Index		5.21

Moorhead Project ID:	97-13-14
Location:	Horn Park
Top of Levee	905
Elevation at Dryside Toe	888
Height	17
Top Width	10
Riverside Slope	3
Landside Slope	3
Toe of slope (ft)	884
Height at toe of slope	21

Moorhead Project ID: 97-13-14, Horn Park

Run	Levee Friction	Cohesion	PL Sherack Friction	River Stage	FS	SLIDE ΔF	(ΔF/2)^0.5	Levee Friction	Cohesion	PL Sherack Friction	River Stage	FS	SLIDE ΔF	(ΔF/2)^0.5	Levee Friction	Cohesion	PL Sherack Friction	River Stage	FS	SLIDE ΔF	(ΔF/2)^0.5	Levee Friction	Cohesion	PL Sherack Friction	River Stage	FS	SLIDE ΔF	(ΔF/2)^0.5
Most Likely Values	27	250	21	905	1.012			27	250	21	901	1.187			27	250	21	898	1.272			27	250	21	894	1.352		
2	24	250	27	905	1.000			24	250	27	901	1.165			24	250	27	898	1.248			24	250	21	894	1.326		
3	30	250	27	905	1.023	-0.02	0.0001	30	250	21	901	1.206	-0.04	0.0004	30	250	21	898	1.294	-0.05	0.0005	30	250	21	894	1.376	-0.05	0.0006
4	27	175	27	905	0.961			27	175	27	901	1.139			27	175	21	898	1.227			27	175	21	894	1.302		
5	27	325	27	905	1.048	-0.09	0.0019	27	325	21	901	1.228	-0.09	0.0020	27	325	21	898	1.313	-0.09	0.0018	27	325	21	894	1.395	-0.09	0.0022
6	27	250	18	905	0.889			27	250	18	901	1.045			27	250	18	898	1.123			27	250	18	894	1.192		
7	27	250	24	905	1.130	-0.24	0.0145	27	250	24	901	1.324	-0.28	0.0195	27	250	24	898	1.422	-0.30	0.0224	27	250	24	894	1.510	-0.32	0.0253
8																												
9					0.00	0						0.00	0						0.00	0						0.00	0	
Standard Deviation	3	75	3			(sum)	0.128626397	3	75	3			(sum)	0.147853813	3	75	3			(sum)	0.157252186	3	75	3			(sum)	0.167535817
Coefficient of Variation	10.3%	30.0%	13.7%		Coeff. Of Var. of FS		12.71%	10.3%	30.0%	13.7%		Coeff. Of Var. of FS		12.46%	10.3%	30.0%	13.7%		Coeff. Of Var. of FS		12.36%	10.3%	30.0%	13.7%		Coeff. Of Var. of FS		12.39%

Probability of Failure (FS < 1)	4.88E-01	or	48.766%	Probability of Failure (FS < 1)	9.35E-02	or	9.349%	Probability of Failure (FS < 1)	2.92E-02	or	2.925%	Probability of Failure (FS < 1)	8.62E-03	or	0.862%
	1.00	chance in	2		1.00	chance in	11		1.00	chance in	34		1.00	chance in	116
	Reliability Index		0.03		Reliability Index		1.32		Reliability Index		1.89		Reliability Index		2.38

File: FMMFS_Geo_C2EL_Prob_Failure_rev_2010-01.xls
Worksheet: P(F) Stability
Printed on 11/30/2009

Final Fargo-Moorhead Metro Feasibility Report and Environmental Impact Statement
July 2011

Attachment H-5, pg 3
Credit to Existing Levees

Long-Term, Drained Conditions
Short-Term, Undrained Conditions

Moorhead Project ID:	97-13-14
Location:	Horn Park

Moorhead Project ID: 97-13-14, Horn Park

		Levee Cohesion	Sherack Cohesion		River Stage	FS	SLIDE ΔF	(ΔF/2)^0.5
Top of Levee	905							
Elevation at Dryside Toe	888	Run			Stage	FS	ΔF	(ΔF/2)^0.5
Height	17	Most Likely Values	1125	1125	905	2.138		
Top Width	10	2	950	1125	905	2.123		
Riverside Slope	3	3	1300	1125	905	2.141	-0.02	0.0001
Landside Slope	3	4	1125	950	905	1.971		
		5	1125	1300	905	2.311	-0.34	0.0289
Toe of slope (ft)	884	6						
Height at toe of slope	21	7					0.00	0.0000
		8						
		9					0.00	0
		Standard Deviation	175	175		(sum)		0.170238069
		Coefficient of Variation	-8.7%	15.6%	#DIV/0!	Coeff. Of Var. of FS		7.96%

Probability of Failure (FS < 1)	0.00E+00	or	0.000%
	0.00	chance in	10,000,000,000
		Reliability Index	9.52

Check of LongTerm, Drained Conditions using GeoStudio

Moorhead Project ID:	97-13-15
Location:	Woodlawn Park

Moorhead Project ID: 97-13-15, Woodlawn Park

			Levee Friction	Levee Cohesion	Sherack Friction	River Stage	FS	SLIDE ΔF	(ΔF/2)^0.5	Levee Friction	Levee Cohesion	Sherack Friction	River Stage	FS	Slope/W ΔF	(ΔF/2)^0.5
Top of Levee	904	Run														
Elevation at Dryside Toe	894	Most Likely Values	27	250	27	904	1.617			27	250	27	904	1.619		
Height	10	2	24	250	27	904	1.593			24	250	27	904	1.595		
Top Width	10	3	30	250	27	904	1.640	-0.05	0.0006	30	250	27	904	1.645	-0.05	0.0006
Riverside Slope	3	4	27	175	27	904	1.498			27	175	27	904	1.503		
Landside Slope	3	5	27	325	27	904	1.720	-0.22	0.0123	27	325	27	904	1.723	-0.22	0.0121
		6	27	250	24	904	1.477			27	250	24	904	1.482		
		7	27	250	30	904	1.756	-0.28	0.0195	27	250	30	904	1.760	-0.28	0.0193
		8						0.00	0						0.00	0
		9														
		Standard Deviation	3	75	3		(sum)		0.179815183	3	75	3		(sum)		0.179013966
		Coefficient of Variation	10.3%	30.0%	10.3%	Coeff. Of Var. of FS		11.12%	10.3%	30.0%	10.3%	Coeff. Of Var. of FS		11.06%

Probability of Failure (FS < 1)	9.37E-06	or	0.001%		Probability of Failure (FS < 1)	7.96E-06	or	0.001%
	1.00	chance in	107,000			1.00	chance in	125,500
		Reliability Index	4.28					4.32

Moorhead Project ID:	97-13-14
Location:	Horn Park

Moorhead Project ID: 97-13-14, Horn Park

			Levee Friction	Levee Cohesion	Sherack Friction	River Stage	FS	SLIDE ΔF	(ΔF/2)^0.5	Levee Friction	Levee Cohesion	PL Sherack Friction	River Stage	FS	Slope/W (Entry,Exit) ΔF	(ΔF/2)^0.5
Top of Levee	905	Run														
Elevation at Dryside Toe	888	Most Likely Values	27	250	27	905	1.278			27	250	27	905	1.281		
Height	17	2	24	250	27	905	1.260			24	250	27	905	1.261		
Top Width	10	3	30	250	27	905	1.297	-0.04	0.0003	30	250	27	905	1.299	-0.04	0.0004
Riverside Slope	3	4	27	175	27	905	1.210			27	175	27	905	1.211		
Landside Slope	3	5	27	325	27	905	1.342	-0.13	0.0044	27	325	27	905	1.342	-0.13	0.0043
Toe of slope (ft)	884	6	27	250	24	905	1.162			27	250	24	905	1.161		
Height at toe of slope	21	7	27	250	30	905	1.398	-0.24	0.0139	27	250	30	905	1.399	-0.24	0.0142
		8														
		9						0.00	0						0.00	0
		Standard Deviation	3	75	3		(sum)		0.136463365	3	75	3		(sum)		0.137157756
		Coefficient of Variation	10.3%	30.0%	10.3%	Coeff. Of Var. of FS		10.68%	10.3%	30.0%	10.3%	Coeff. Of Var. of FS		10.71%

Probability of Failure (FS < 1)	1.22E-02	or	1.221%		Probability of Failure (FS < 1)	1.17E-02	or	1.172%
	1.00	chance in	82			1.00	chance in	85
		Reliability Index	2.25					2.27

Moorhead Project ID:	97-13-14
Location:	Horn Park

Moorhead Project ID: 97-13-14, Horn Park

			Levee Friction	Levee Cohesion	PL Sherack Friction	River Stage	FS	SLIDE ΔF	(ΔF/2)^0.5	Levee Friction	Levee Cohesion	PL Sherack Friction	River Stage	FS	Slope/W (Entry,Exit) ΔF	(ΔF/2)^0.5
Top of Levee	905	Run														
Elevation at Dryside Toe	888	Most Likely Values	27	250	21	905	1.012			27	250	21	901	1.012		
Height	17	2	24	250	27	905	1.000			24	250	21	901	1.000		
Top Width	10	3	30	250	27	905	1.023	-0.02	0.0001	30	250	21	901	1.023	-0.02	0.0001
Riverside Slope	3	4	27	175	27	905	0.961			27	175	21	901	0.961		
Landside Slope	3	5	27	325	27	905	1.048	-0.09	0.0019	27	325	21	901	1.058	-0.10	0.0024
Toe of slope (ft)	884	6	27	250	18	905	0.889			27	250	18	901	0.891		
Height at toe of slope	21	7	27	250	24	905	1.130	-0.24	0.0145	27	250	24	901	1.131	-0.24	0.0144
		8														
		9						0.00	0						0.00	0
		Standard Deviation	3	75	3		(sum)		0.128626397	3	75	3		(sum)		0.129940371
		Coefficient of Variation	10.3%	30.0%	13.7%	Coeff. Of Var. of FS		12.71%	10.3%	30.0%	13.7%	Coeff. Of Var. of FS		12.84%

Probability of Failure (FS < 1)	4.88E-01	or	48.766%		Probability of Failure (FS < 1)	4.88E-01	or	48.829%
	1.00	chance in	2			1.00	chance in	2
		Reliability Index	0.03					0.03

FIle: FMMFS_Geo_C2EL_Prob_Failure_rev_2010-01.xls
Worksheet: P(F) Stability
Printed on 11/30/2009

Final Fargo-Moorhead Metro Feasibility Report and Environmental Impact Statement
July 2011

Attachment H-5, pg 4
Credit to Existing Levees

Project: FMMFS
Subject: Summary of Conditional Probability of Failure
Computed By: KAH
Date: 31-Dec-08
Revised By: KAH
Date: 8-Jan-09

Fargo Project ID: 5078-2, 10th St. N

Fargo Project ID:	5078-2
Location:	10th St. N
Top of Levee	898.5 ft
Elevation at Dryside Toe	893.5 ft
Height	5 ft

Top Width	10 ft
Riverside Slope	1V on 3H
Landside Slope	1V on 3H

Overall Expected Level of Performance: ABOVE AVERAGE

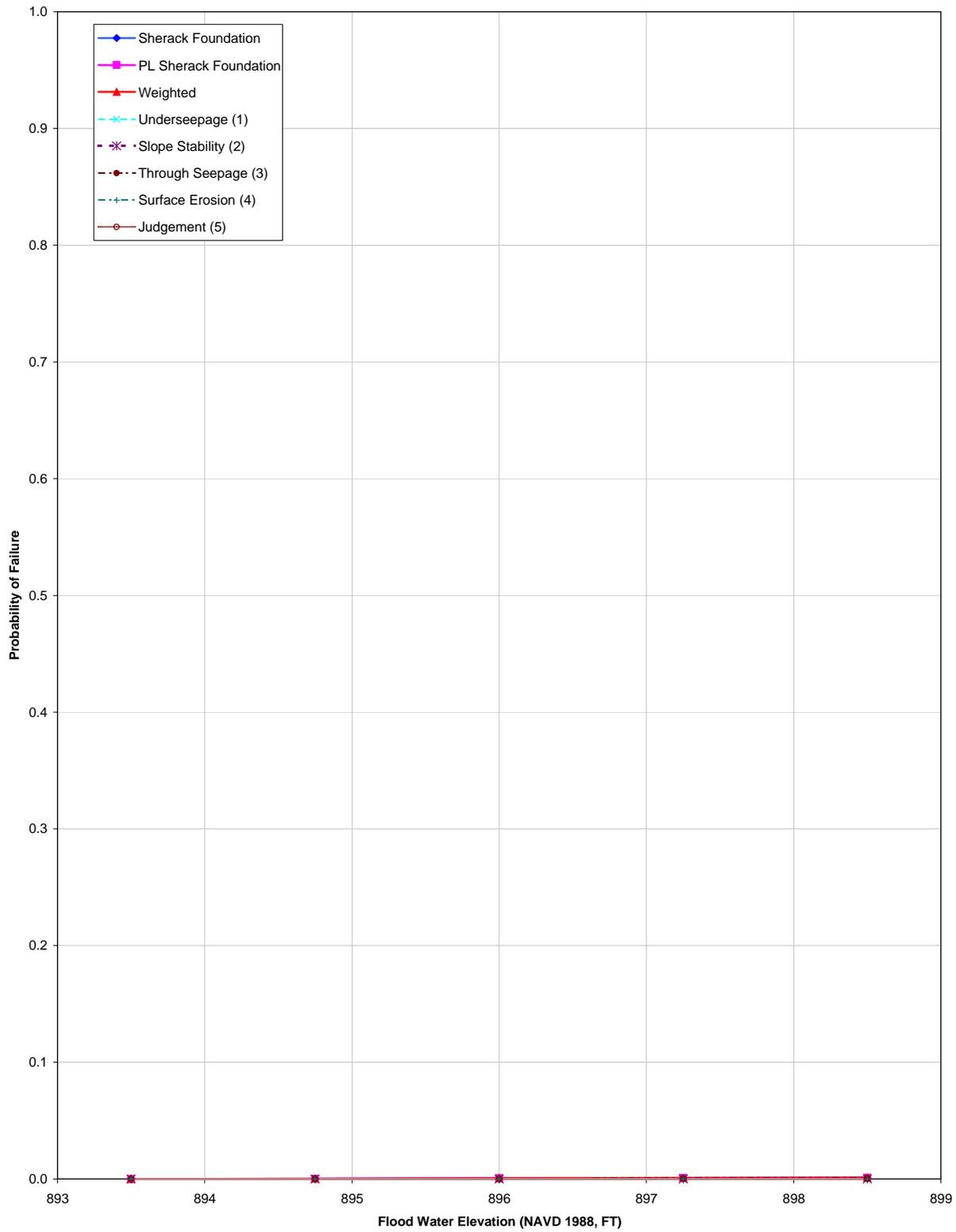|	Flood Water Elevation (NAVD 1988)	Height (ft)	Underseepage (1) P(f)	R	Slope Stability (2) P(f)	R	Through Seepage (3) P(f)	R	Surface Erosion (4) P(f)	R	Judgement (5) P(f)	R	Combined P(f)	R	Frequency of Failure 1 in X times
Sherack Foundation	893.5	0	0	1	0	1.00000	0	1	0	1	0	1	0	1	
	894.75	1.25	7.50E-06	1.0000	0.0000000	1.00000	2.50E-04	0.9998	3.18E-05	1.0000	7.50E-06	1.0000	0.00030	0.99970	3369
	896	2.5	1.50E-05	1.0000	0.0000000	1.00000	5.00E-04	0.9995	3.18E-05	1.0000	1.50E-05	1.0000	0.00056	0.99944	1780
	897.25	3.75	2.25E-05	0.9999775	0.0000000	1.00000	7.50E-04	0.9993	3.18E-05	1.0000	2.25E-05	1.0000	0.00083	0.99917	1210
	898.5	5	3.00E-05	0.99997	1.18E-10	1.00000	1.00E-03	0.999	3.18E-05	0.9999682	3.00E-05	0.99997	0.00109	0.99891	916
PL Sherack Foundation	893.5	0	0	1	0	1.00000	0	1	0	1	0	1	0	1	
	894.75	1.25	7.50E-06	1.0000	0.0000019	1.00000	2.50E-04	0.9998	3.18E-05	1.0000	7.50E-06	1.0000	0.00030	0.99970	3347
	896	2.5	1.50E-05	1.0000	0.0000039	1.00000	5.00E-04	0.9995	3.18E-05	1.0000	1.50E-05	1.0000	0.00057	0.99943	1768
	897.25	3.75	2.25E-05	0.9999775	0.0000058	0.99999	7.50E-04	0.9993	3.18E-05	1.0000	2.25E-05	1.0000	0.00083	0.99917	1201
	898.5	5	3.00E-05	0.99997	0.0000078	0.99999	1.00E-03	0.999	3.18E-05	0.9999682	3.00E-05	0.99997	0.00110	0.99890	910
Weighted	893.5	0	0	1	0	1.00000	0	1	0	1	0	1	0	1	
	894.75	1.25	7.50E-06	1.0000	9.71E-07	1.00000	2.50E-04	0.9998	3.18E-05	1.0000	7.50E-06	1.0000	0.00030	0.99970	3358
	896	2.5	1.50E-05	1.0000	1.94E-06	1.00000	5.00E-04	0.9995	3.18E-05	1.0000	1.50E-05	1.0000	0.00056	0.99944	1774
	897.25	3.75	2.25E-05	0.9999775	2.91E-06	1.00000	7.50E-04	0.9993	3.18E-05	1.0000	2.25E-05	1.0000	0.00083	0.99917	1205
	898.5	5	3.00E-05	0.99997	3.88E-06	1.00000	1.00E-03	0.999	3.18E-05	0.9999682	3.00E-05	0.99997	0.00110	0.99890	913

Sherack Foundation Weighting   0.5

Notes:

(1) P(f) due to "underseepage" is very small to neglible for clay embankments on clay foundations. During past flood fighting activities in the Red River Valley, no serious issues associated with piping have been observed. Therefore, judgement is used to estimate a P(f) due to "underseepage" based on an expected level of performance. Because this levee is similar to the Corp's typical section, the levee is expected to have the following level of performance:
Expected Level of Perfomance: **GOOD**   Beta: **4**   P(F):   **3.00E-05**

(2) P(f) due to "slope stability" was determined using the Taylor's Series procedure for reliability analysis as described in ETL 1110-2-556. The slope stability analyses was based on drained shear strengths and an assumed piezometeric surface similar to what would be expected to develop for steady-state seepage.

(3) P(f) due to "through seepage" (i.e. internal erosion) is very small for clay embankments on clay foundations. During past flood fighting activities in the Red River Valley, no serious issues associated with internal erosion have been observed. Therefore, judgment is used to estimate a P(f) due to "through seepage based on an expected level of performance. Because this levee is similar to the Corps' typical section, the levee is expected to have the following level of performance:
Expected Level of Perfomance: **ABOVE AVERAGE**   Beta: **3**   P(F):   **1.00E-03**

(4) P(f) due to "surface erosion" was determined using the procedure described in ETL 1110-2-556. The calculations are based on a maximum velocity of 2 feet per second occuring at the location of the levee. This velocity is assumed to occur for all flood elevations.

(5) Probability of failure based on "judgement" takes into account configuration of levee, features at or near the toe that could effect the stability of the levee, and observed conditions. Because this levee is similar to the Corps' typical section and 5 feet or less in height, the levee is expected to have the following level of performance:
Expected Level of Perfomance: **GOOD**   Beta: **4**   P(F):   **3.00E-05**

File: FMMFS_Geo_C2EL_Prob_Failure_rev_2010-01.xls
Worksheet: P(F) 10th St N
Printed on 11/30/2009

Final Fargo-Moorhead Metro Feasibility Report and Environmental Impact Statement
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Attachment H-5, pg 5
Credit to Existing Levees

FMMFS: Credit to Existing Levees
Probability of Failure vs Flood Water Elevation

Fargo Project ID: 5078-2, 10th St. N

Legend:
- Sherack Foundation
- PL Sherack Foundation
- Weighted
- Underseepage (1)
- Slope Stability (2)
- Through Seepage (3)
- Surface Erosion (4)
- Judgement (5)

Y-axis: **Probability of Failure**

X-axis: **Flood Water Elevation (NAVD 1988, FT)**

Fargo Project ID: 4903, Cardinal Muench Seminary

Fargo Project ID:	4903
Location:	Cardinal Muench Seminary
Top of Levee	898 ft
Elevation at Dryside Toe	893 ft
Height	5 ft

Top Width	5 ft
Riverside Slope	1V on 6H
Landside Slope	1V on 6H

Overall Expected Level of Performance: BELOW AVERAGE

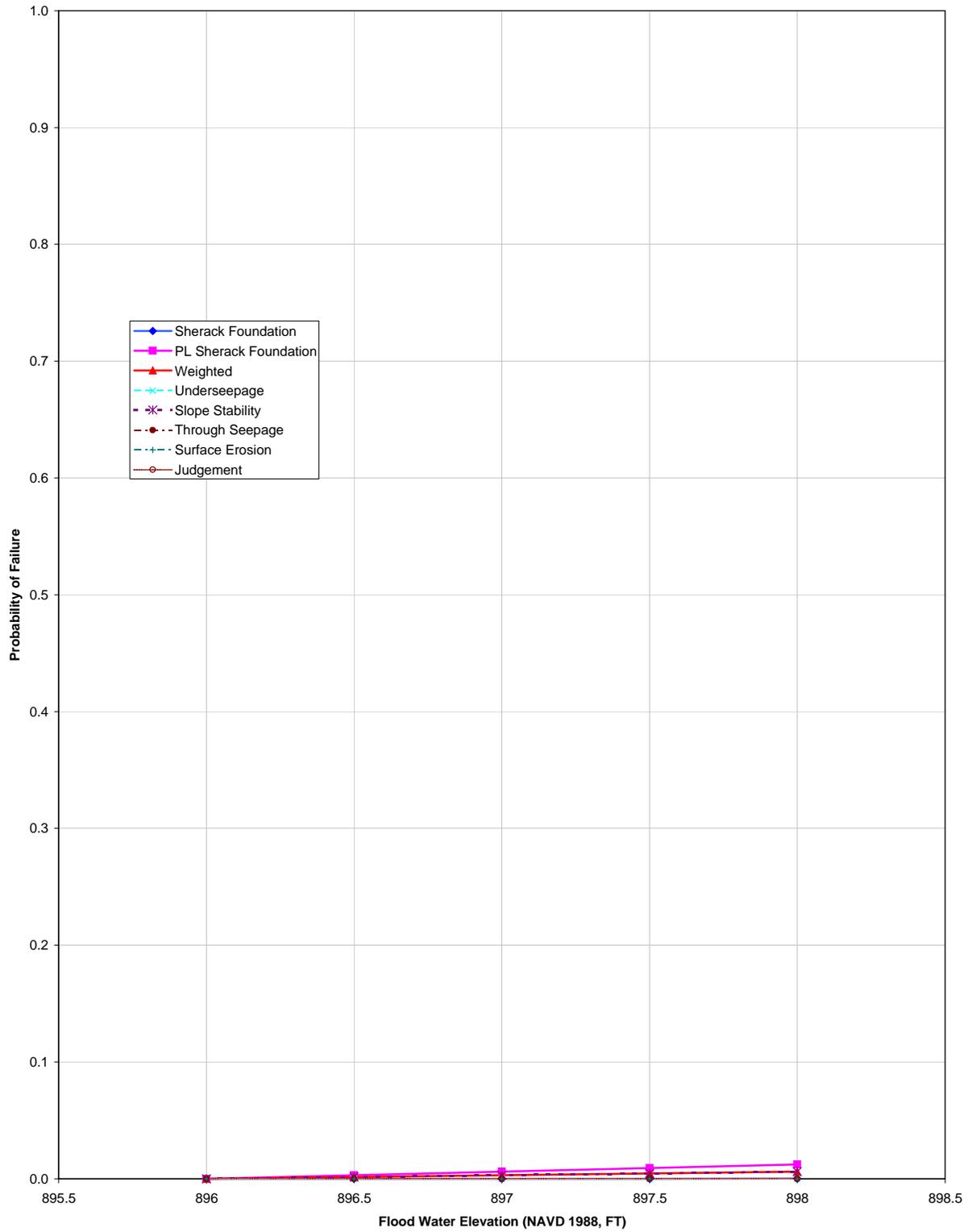|	Flood Water Elevation (NAVD 1988)	Height (ft)	Underseepage P(f)	R	Slope Stability P(f)	R	Through Seepage P(f)	R	Surface Erosion P(f)	R	Judgement P(f)	R	Combined P(f)	R	Frequency of Failure 1 in X times
Sherack Foundation	896	0	0	1	0	1	0	1	0	1	0	1	0	1	
	896.5	0.5	7.50E-06	1.0000	0.0000000	1.00000	7.50E-06	1.0000	3.18E-05	1.0000	7.50E-06	1.0000	0.00005	0.99995	18412
	897	1	1.50E-05	1.0000	0.0000000	1.00000	1.50E-05	1.0000	3.18E-05	1.0000	1.50E-05	1.0000	0.00008	0.99992	13018
	897.5	1.5	2.25E-05	0.9999775	0.0000000	1.00000	2.25E-05	1.0000	3.18E-05	1.0000	2.25E-05	1.0000	0.00010	0.99990	10068
	898	2	3.00E-05	0.99997	3.818E-08	1.00000	3.00E-05	0.99997	3.18E-05	0.9999682	3.00E-05	0.99997	0.00012	0.99988	8208
PL Sherack Foundation	896	0	0	1	0	1	0	1	0	1	0	1	0	1	
	896.5	0.5	7.50E-06	1.0000	0.0030285	0.99697	7.50E-06	1.0000	3.18E-05	1.0000	7.50E-06	1.0000	0.00308	0.99692	324
	897	1	1.50E-05	1.0000	0.0060570	0.99394	1.50E-05	1.0000	3.18E-05	1.0000	1.50E-05	1.0000	0.00613	0.99387	163
	897.5	1.5	2.25E-05	0.9999775	0.0090855	0.99091	2.25E-05	1.0000	3.18E-05	1.0000	2.25E-05	1.0000	0.00918	0.99082	109
	898	2	3.00E-05	0.99997	0.0121141	0.98789	3.00E-05	0.99997	3.18E-05	0.9999682	3.00E-05	0.99997	0.01223	0.98777	82
Weighted	896	0	0	1	0.00E+00	1	0	1	0	1	0	1	0	1	
	896.5	0.5	7.50E-06	1.0000	1.51E-03	0.99849	7.50E-06	1.0000	3.18E-05	1.0000	7.50E-06	1.0000	0.00157	0.99843	638
	897	1	1.50E-05	1.0000	3.03E-03	0.99697	1.50E-05	1.0000	3.18E-05	1.0000	1.50E-05	1.0000	0.00311	0.99689	322
	897.5	1.5	2.25E-05	0.9999775	4.54E-03	0.99546	2.25E-05	1.0000	3.18E-05	1.0000	2.25E-05	1.0000	0.00464	0.99536	215
	898	2	3.00E-05	0.99997	6.06E-03	0.99394	3.00E-05	0.99997	3.18E-05	0.9999682	3.00E-05	0.99997	0.00618	0.99382	162

Sherack Foundation Weighting   0.5

Notes:
(1) P(f) due to "underseepage" is very small to neglible for clay embankments on clay foundations. During past flood fighting activities in the Red River Valley, no serious issues associated with piping have been observed. Therefore, judgement is used to estimate a P(f) due to "underseepage" based on an expected level of performance. The levee only has a 5-foot top width but 1V on 6H side slopes and is 5 feet or less in height, therefore the levee is expected to have the following level of performance:

    Expected Level of Perfomance: **GOOD**   Beta: **4**   P(F): **3.00E-05**

(2) P(f) due to "slope stability" was determined using the Taylor's Series procedure for reliability analysis as described in ETL 1110-2-556. The slope stability analyses was based on drained shear strengths and an assumed piezometeric surface similar to what would be expected to develop for steady-state seepage.

(3) P(f) due to "through seepage" (i.e. internal erosion) is very small for clay embankments on clay foundations. During past flood fighting activities in the Red River Valley, no serious issues associated with internal erosion have been observed. Therefore, judgment is used to estimate a P(f) due to "through seepage based on an expected level of performance. The levee only has a 5-foot top width but 1V on 6H side slopes, the levee is expected to have the following level of performance:

    Expected Level of Perfomance: **GOOD**   Beta: **4**   P(F): **3.00E-05**

(4) P(f) due to "surface erosion" was determined using the procedure described in ETL 1110-2-556. The calculations are based on a maximum velocity of 2 feet per second occuring at the location of the levee. This velocity is assumed to occur for all flood elevations.

(5) Probability of failure based on "judgement" takes into account configuration of levee, features at or near the toe that could effect the stability of the levee, and observed conditions. There is only a small segment of the levee that is 5 feet in height while the rest is two feet or less. Because of this the levee system is expected to have the following level of performance:

    Expected Level of Perfomance: **GOOD**   Beta: **4**   P(F): **3.00E-05**

File: FMMFS_Geo_C2EL_Prob_Failure_rev_2010-01.xls
Worksheet: P(F) Cardinal Muench Seminary
Printed on 11/30/2009

Final Fargo-Moorhead Metro Feasibility Report and Environmental Impact Statement   Attachment H-5, pg 7
July 2011   Credit to Existing Levees

FMMFS: Credit to Existing Levees
Probability of Failure vs Flood Water Elevation

Project: Fargo Project ID: 4903, Cardinal Muench Seminary

File: FMMFS_Geo_C2EL_Prob_Failure_rev_2010-01.xls
Worksheet: P(F) Cardinal Muench Seminary
Printed on 11/30/2009

Final Fargo-Moorhead Metro Feasibility Report and Environmental Impact Statement
July 2011

Attachment H-5, pg 8
Credit to Existing Levees

Project: FMMFS
Subject: Summary of Conditional Probability of Failure
Computed By: KAH
Date: 5-Jan-09
Revised By: KAH
Date: 9-Jan-09

Fargo Project ID: 4579-3, 10th Ave S (Dike West)

Fargo Project ID: 4579-3
Location: 10th Ave S (Dike West)

Overall Expected Level of Performance: HAZARDOUS

	Top of Levee	905 ft		Top Width	10 ft
	Elevation at Dryside Toe	890 ft		Riverside Slope	1V on 3H
	Height	15 ft		Landside Slope	1V on 3H

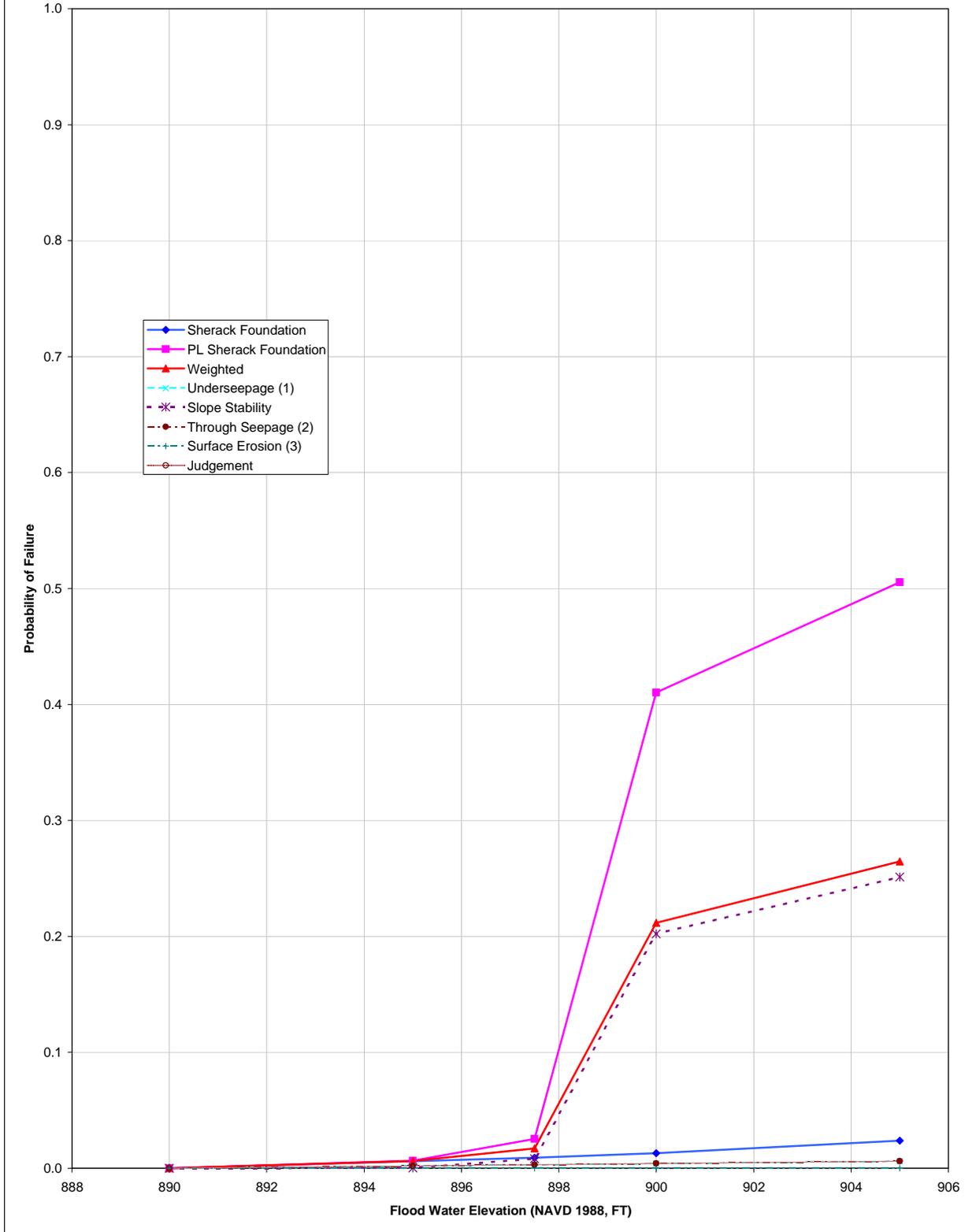|	Flood Water Elevation (NAVD 1988)	Height (ft)	Underseepage (1) P(f)	R	Slope Stability P(f)	R	Through Seepage (2) P(f)	R	Surface Erosion (3) P(f)	R	Judgement P(f)	R	Combined P(f)	R	Frequency of Failure 1 in X times
Sherack Foundation	890	0	0	1	0	1	0	1	0	1	0	1	0	1	
	895	5	2.00E-03	0.9980	0.0000000	1.00000	2.00E-03	0.9980	3.18E-05	1.0000	2.00E-03	0.9980	0.00602	0.99398	166
	897.5	7.5	3.00E-03	0.9970	0.0000002	1.00000	3.00E-03	0.9970	3.18E-05	1.0000	3.00E-03	0.9970	0.00900	0.99100	111
	900	10	4.00E-03	0.996	0.0010549	0.99895	4.00E-03	0.9960	3.18E-05	1.0000	4.00E-03	0.9960	0.01303	0.98697	77
	905	15	6.00E-03	0.994	6.032E-03	0.99397	6.00E-03	0.994	3.18E-05	0.9999682	6.00E-03	0.994	0.02385	0.97615	42
PL Sherack Foundation	890	0	0	1	0	1	0	1	0	1	0	1	0	1	
	895	5	2.00E-03	0.9980	0.0005044	0.99950	2.00E-03	0.9980	3.18E-05	1.0000	2.00E-03	0.9980	0.00652	0.99348	153
	897.5	7.5	3.00E-03	0.9970	0.0164164	0.98358	3.00E-03	0.9970	3.18E-05	1.0000	3.00E-03	0.9970	0.02527	0.97473	40
	900	10	4.00E-03	0.996	0.4031575	0.59684	4.00E-03	0.9960	3.18E-05	1.0000	4.00E-03	0.9960	0.41031	0.58969	2
	905	15	6.00E-03	0.994	0.4963200	0.50368	6.00E-03	0.994	3.18E-05	0.9999682	6.00E-03	0.994	0.50535	0.49465	2
Weighted	890	0	0	1	0.00E+00	1	0	1	0	1	0	1	0	1	
	895	5	2.00E-03	0.9980	2.52E-04	0.99975	2.00E-03	0.9980	3.18E-05	1.0000	2.00E-03	0.9980	0.00627	0.99373	159
	897.5	7.5	3.00E-03	0.9970	8.21E-03	0.99179	3.00E-03	0.9970	3.18E-05	1.0000	3.00E-03	0.9970	0.01714	0.98286	58
	900	10	4.00E-03	0.996	2.02E-01	0.79789	4.00E-03	0.9960	3.18E-05	1.0000	4.00E-03	0.9960	0.21167	0.78833	5
	905	15	6.00E-03	0.994	2.51E-01	0.74882	6.00E-03	0.994	3.18E-05	0.9999682	6.00E-03	0.994	0.26460	0.73540	4

Sherack Foundation Weighting   0.5

Notes:

(1) P(f) due to "underseepage" is very small to neglible for clay embankments on clay foundations. During past flood fighting activities in the Red River Valley, no serious issues associated with piping have been observed. Therefore, judgement is used to estimate a P(f) due to "underseepage" based on an expected level of performance. With a retaining wall in the dryside slope, which decreases the seepage path length, the levee is expected to have the following level of performance:

Expected Level of Perfomance: **BELOW AVERAGE**   Beta: **2.5**   P(F):   **6.00E-03**

(2) P(f) due to "slope stability" was determined using the Taylor's Series procedure for reliability analysis as described in ETL 1110-2-556. The slope stability analyses was based on drained shear strengths and an assumed piezometeric surface similar to what would be expected to develop for steady-state seepage.

(3) P(f) due to "through seepage" (i.e. internal erosion) is very small for clay embankments on clay foundations. During past flood fighting activities in the Red River Valley, no serious issues associated with internal erosion have been observed. Therefore, judgment is used to estimate a P(f) due to "through seepage based on an expected level of performance. With a retaining wall in the dryside slope, the levee is expected to have the following level of performance:

Expected Level of Perfomance: **BELOW AVERAGE**   Beta: **2.5**   P(F):   **6.00E-03**

(4) P(f) due to "surface erosion" was determined using the procedure described in ETL 1110-2-556. The calculations are based on a maximum velocity of 2 feet per second occuring at the location of the levee. This velocity is assumed to occur for all flood elevations.

(5) Probability of failure based on "judgement" takes into account configuration of levee, features at or near the toe that could effect the stability of the levee, and observed conditions. With a retaining wall in the dryside slope, the levee system is expected to have the following level of performance:

Expected Level of Perfomance: **BELOW AVERAGE**   Beta: **2.5**   P(F):   **6.00E-03**

File: FMMFS_Geo_C2EL_Prob_Failure_rev_2010-01.xls
Worksheet: P(F) 10th Ave S (Dike West)
Printed on 11/30/2009

Final Fargo-Moorhead Metro Feasibility Report and Environmental Impact Statement
July 2011

Attachment H-5, pg 9
Credit to Existing Levees

FMMFS: Credit to Existing Levees
Probability of Failure vs Flood Water Elevation

Fargo Project ID: 4579-3, 10th Ave S (Dike West)

Legend:
- Sherack Foundation
- PL Sherack Foundation
- Weighted
- Underseepage (1)
- Slope Stability
- Through Seepage (2)
- Surface Erosion (3)
- Judgement

Y-axis: Probability of Failure
X-axis: Flood Water Elevation (NAVD 1988, FT)

Fargo Project ID: 4908, Lindenwood Drive

Fargo Project ID:	4908
Location:	Lindenwood Drive

Overall Expected Level of Performance: HAZARDOUS

Top of Levee	905 ft	Top Width	8 ft
Elevation at Dryside Toe	897 ft	Riverside Slope	1V on 4H
Height	8 ft	Landside Slope	1V on 4H

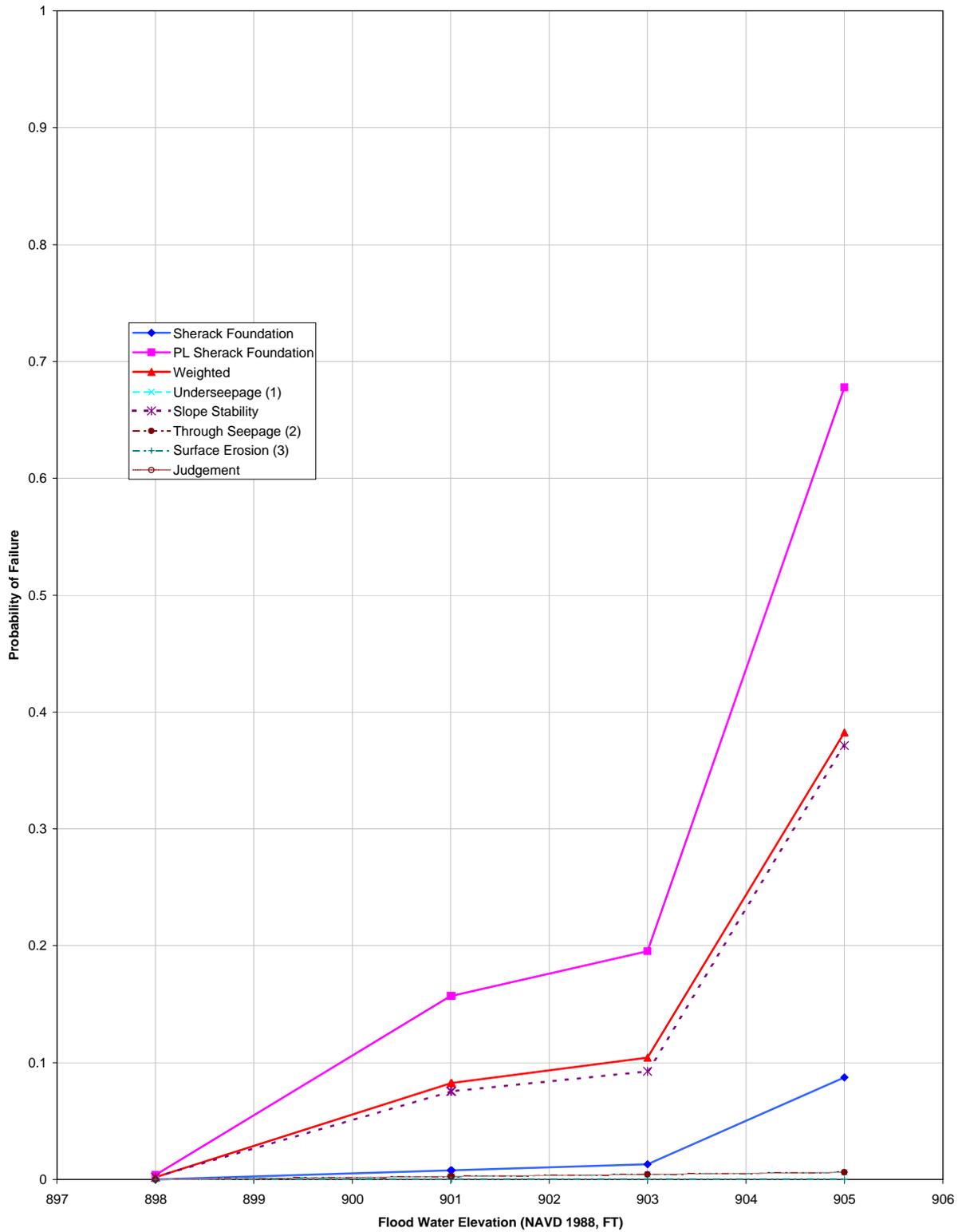|	Flood Water Elevation (NAVD 1988)	Height (ft)	Underseepage (1) P(f)	R	Slope Stability P(f)	R	Through Seepage (2) P(f)	R	Surface Erosion (3) P(f)	R	Judgement P(f)	R	Combined P(f)	R	Frequency of Failure 1 in X times
Sherack Foundation	898	1	0	1	0.0000025	1.00000	0	1	0	1	0	1	2.532E-06	0.9999975	394866.8518
	901	4	2.57E-03	0.9974	0.0001301	0.99987	2.57E-03	0.9974	3.18E-05	1.0000	2.57E-03	0.9974	0.00786	0.99214	127
	901.01	4.01	2.58E-03	0.9974	0.0001301	0.99987	2.58E-03	0.9974	3.18E-05	1.0000	2.58E-03	0.9974	0.00788	0.99212	127
	903	6	4.29E-03	0.9957143	0.0002396	0.99976	4.29E-03	0.9957	3.18E-05	1.0000	4.29E-03	0.9957	0.01307	0.98693	77
	905	8	6.00E-03	0.994	0.0705971	0.92940	6.00E-03	0.994	3.18E-05	0.9999682	6.00E-03	0.994	0.08726	0.91274	11
PL Sherack Foundation	898	1	0	1	0.0039767	0.99602	0	1	0	1	0	1	0.0039767	0.9960233	251.4663997
	901	4	2.57E-03	0.9974	0.1504469	0.84955	2.57E-03	0.9974	3.18E-05	1.0000	2.57E-03	0.9974	0.15701	0.84299	6
	901.01	4.01	2.58E-03	0.9974	0.1504469	0.84955	2.58E-03	0.9974	3.18E-05	1.0000	2.58E-03	0.9974	0.15703	0.84297	6
	903	6	4.29E-03	0.9957143	0.1849162	0.81508	4.29E-03	0.9957	3.18E-05	1.0000	4.29E-03	0.9957	0.19538	0.80462	5
	905	8	6.00E-03	0.994	0.6719359	0.32806	6.00E-03	0.994	3.18E-05	0.9999682	6.00E-03	0.994	0.67782	0.32218	1
Weighted	898	1	0	1	1.99E-03	0.99801	0	1	0	1	0	1	0.0019896	0.9980104	502.6127163
	901	4	2.57E-03	0.9974	7.53E-02	0.92471	2.57E-03	0.9974	3.18E-05	1.0000	2.57E-03	0.9974	0.08243	0.91757	12
	901.01	4.01	2.58E-03	0.9974	7.53E-02	0.92471	2.58E-03	0.9974	3.18E-05	1.0000	2.58E-03	0.9974	0.08246	0.91754	12
	903	6	4.29E-03	0.9957143	9.26E-02	0.90742	4.29E-03	0.9957	3.18E-05	1.0000	4.29E-03	0.9957	0.10422	0.89578	10
	905	8	6.00E-03	0.994	3.71E-01	0.62873	6.00E-03	0.994	3.18E-05	0.9999682	6.00E-03	0.994	0.38254	0.61746	3

Sherack Foundation Weighting   0.5

Notes:

(1) P(f) due to "underseepage" is very small to neglible for clay embankments on clay foundations. During past flood fighting activities in the Red River Valley, no serious issues associated with piping have been observed. Therefore, judgement is used to estimate a P(f) due to "underseepage" based on an expected level of performance. With a retaining wall in the dryside slope, which decreases the seepage path length, the levee is expected to have the following level of performance:
    Expected Level of Perfomance: **BELOW AVERAGE**   Beta: **2.5**   P(F):   **6.00E-03**

(2) P(f) due to "slope stability" was determined using the Taylor's Series procedure for reliability analysis as described in ETL 1110-2-556. The slope stability analyses was based on drained shear strengths and an assumed piezometeric surface similar to what would be expected to develop for steady-state seepage.

(3) P(f) due to "through seepage" (i.e. internal erosion) is very small for clay embankments on clay foundations. During past flood fighting activities in the Red River Valley, no serious issues associated with internal erosion have been observed. Therefore, judgment is used to estimate a P(f) due to "through seepage based on an expected level of performance. With a retaining wall in the dryside slope, the levee is expected to have the following level of performance:
    Expected Level of Perfomance: **BELOW AVERAGE**   Beta: **2.5**   P(F):   **6.00E-03**

(4) P(f) due to "surface erosion" was determined using the procedure described in ETL 1110-2-556. The calculations are based on a maximum velocity of 2 feet per second occuring at the location of the levee. This velocity is assumed to occur for all flood elevations.

(5) Probability of failure based on "judgement" takes into account configuration of levee, features at or near the toe that could effect the stability of the levee, and observed conditions. With a retaining wall in the dryside slope, the levee system is expected to have the following level of performance:
    Expected Level of Perfomance: **BELOW AVERAGE**   Beta: **2.5**   P(F):   **6.00E-03**

File: FMMFS_Geo_C2EL_Prob_Failure_rev_2010-01.xls
Worksheet: P(F) Lindenwood Drive
Printed on 11/30/2009

Final Fargo-Moorhead Metro Feasibility Report and Environmental Impact Statement
July 2011

Attachment H-5, pg 11
Credit to Existing Levees

FMMFS: Credit to Existing Levees
Probability of Failure vs Flood Water Elevation

Fargo Project ID: 4908, Lindenwood Drive

Legend:
- Sherack Foundation
- PL Sherack Foundation
- Weighted
- Underseepage (1)
- Slope Stability
- Through Seepage (2)
- Surface Erosion (3)
- Judgement

Y-axis: Probability of Failure
X-axis: Flood Water Elevation (NAVD 1988, FT)

Project: FMMFS
Subject: Summary of Conditional Probability of Failure
Computed By: KAH
Date: 31-Dec-08
Revised By: KAH
Date: 9-Jan-09

Fargo Project ID: 4980, Southwood Drive

Fargo Project ID:	4980	
Location:	Southwood Drive	

Overall Expected Level of Performance: BELOW AVERAGE

Top of Levee	905 ft	Top Width	4 ft	
Elevation at Dryside Toe	901 ft	Riverside Slope	1V on 3H	
Height	4 ft	Landside Slope	1V on 3H	

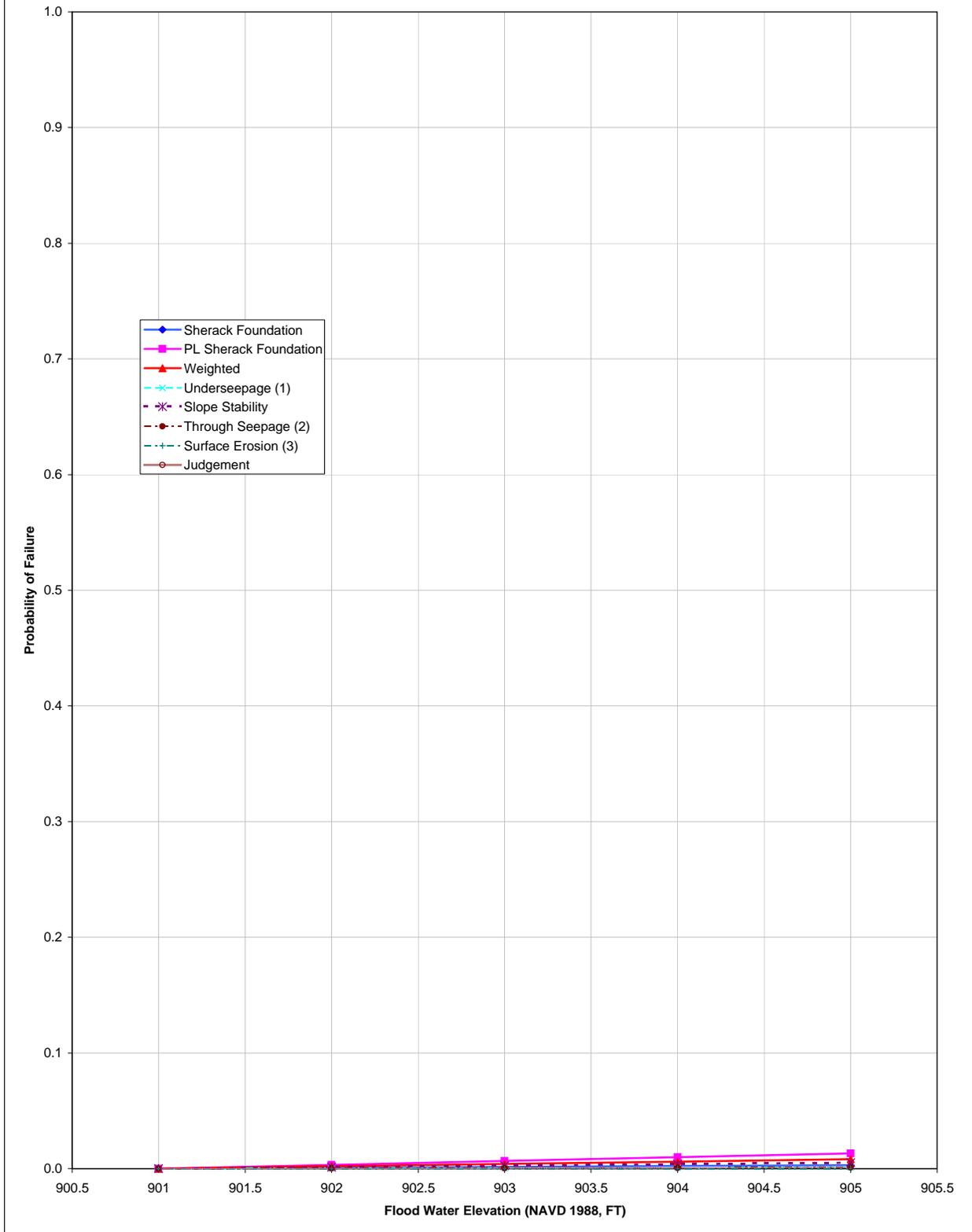|	Flood Water Elevation (NAVD 1988)	Height (ft)	Underseepage (1) P(f)	R	Slope Stability P(f)	R	Through Seepage (2) P(f)	R	Surface Erosion (3) P(f)	R	Judgement P(f)	R	Combined P(f)	R	Frequency of Failure 1 in X times
Sherack Foundation	901	0	0	1	0.00E+00	1.00000	0	1	0	1	0	1	0	1	
	902	1	2.50E-04	0.9998	6.15E-08	1.00000	2.50E-04	0.9998	3.18E-05	1.0000	2.50E-04	0.9998	0.00078	0.99922	1279
	903	2	5.00E-04	0.9995	1.23E-07	1.00000	5.00E-04	0.9995	3.18E-05	1.0000	5.00E-04	0.9995	0.00153	0.99847	653
	904	3	7.50E-04	0.99925	1.85E-07	1.00000	7.50E-04	0.9993	3.18E-05	1.0000	7.50E-04	0.9993	0.00228	0.99772	439
	905	4	1.00E-03	0.999	2.46E-07	1.00000	1.00E-03	0.999	3.18E-05	0.9999682	1.00E-03	0.999	0.00303	0.99697	330
PL Sherack Foundation	901	0	0	1	0	1.00000	0	1	0	1	0	1	0	1	
	902	1	2.50E-04	0.9998	0.0025555	0.99744	2.50E-04	0.9998	3.18E-05	1.0000	2.50E-04	0.9998	0.00334	0.99666	300
	903	2	5.00E-04	0.9995	0.0051109	0.99489	5.00E-04	0.9995	3.18E-05	1.0000	5.00E-04	0.9995	0.00663	0.99337	151
	904	3	7.50E-04	0.99925	0.0076664	0.99233	7.50E-04	0.9993	3.18E-05	1.0000	7.50E-04	0.9993	0.00993	0.99007	101
	905	4	1.00E-03	0.999	0.0102219	0.98978	1.00E-03	0.999	3.18E-05	0.9999682	1.00E-03	0.999	0.01322	0.98678	76
Weighted	901	0	0	1	0.00E+00	1	0	1	0	1	0	1	0	1	
	902	1	2.50E-04	0.9998	1.28E-03	0.99872	2.50E-04	0.9998	3.18E-05	1.0000	2.50E-04	0.9998	0.00206	0.99794	486
	903	2	5.00E-04	0.9995	2.56E-03	0.99744	5.00E-04	0.9995	3.18E-05	1.0000	5.00E-04	0.9995	0.00408	0.99592	245
	904	3	7.50E-04	0.99925	3.83E-03	0.99617	7.50E-04	0.9993	3.18E-05	1.0000	7.50E-04	0.9993	0.00610	0.99390	164
	905	4	1.00E-03	0.999	5.11E-03	0.99489	1.00E-03	0.999	3.18E-05	0.9999682	1.00E-03	0.999	0.00812	0.99188	123

Sherack Foundation Weighting   0.5

Notes:
(1) P(f) due to "underseepage" is very small to neglible for clay embankments on clay foundations. During past flood fighting activities in the Red River Valley, no serious issues associated with piping have been observed. Therefore, judgement is used to estimate a P(f) due to "underseepage" based on an expected level of performance. With only a 4-foot top width, decreasing the seepage path length, the levee is expected to have the following level of performance:
Expected Level of Perfomance: **ABOVE AVERAGE**   Beta: **3**   P(F):   **1.00E-03**

(2) P(f) due to "slope stability" was determined using the Taylor's Series procedure for reliability analysis as described in ETL 1110-2-556. The slope stability analyses was based on drained shear strengths and an assumed piezometeric surface similar to what would be expected to develop for steady-state seepage.

(3) P(f) due to "through seepage" (i.e. internal erosion) is very small for clay embankments on clay foundations. During past flood fighting activities in the Red River Valley, no serious issues associated with internal erosion have been observed. Therefore, judgment is used to estimate a P(f) due to "through seepage based on an expected level of performance. With 1V on 3H side slopes but only a 4-foot top width, the levee is expected to have the following level of performance:
Expected Level of Perfomance: **ABOVE AVERAGE**   Beta: **3**   P(F):   **1.00E-03**

(4) P(f) due to "surface erosion" was determined using the procedure described in ETL 1110-2-556. The calculations are based on a maximum velocity of 2 feet per second occuring at the location of the levee. This velocity is assumed to occur for all flood elevations.

(5) Probability of failure based on "judgement" takes into account configuration of levee, features at or near the toe that could effect the stability of the levee, and observed conditions. With being a short levee with 1V on 3H side slopes, the levee is expected to have the following level of performance:
Expected Level of Perfomance: **ABOVE AVERAGE**   Beta: **3**   P(F):   **1.00E-03**

File: FMMFS_Geo_C2EL_Prob_Failure_rev_2010-01.xls
Worksheet: P(F) Southwood Drive
Printed on 11/30/2009

Final Fargo-Moorhead Metro Feasibility Report and Environmental Impact Statement
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Attachment H-5, pg 13
Credit to Existing Levees

FMMFS: Credit to Existing Levees
Probability of Failure vs Flood Water Elevation

Fargo Project ID: 4980, Southwood Drive

File: FMMFS_Geo_C2EL_Prob_Failure_rev_2010-01.xls
Worksheet: P(F) Southwood Drive
Printed on 11/30/2009

Final Fargo-Moorhead Metro Feasibility Report and Environmental Impact Statement
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Attachment H-5, pg 14
Credit to Existing Levees

Fargo Project ID: 5093, Drain 27 / Rose Coulee

Fargo Project ID:	5093
Location:	Drain 27 / Rose Coulee

Overall Expected Level of Performance: AVERAGE

Top of Levee	909 ft	Top Width	10 ft
Elevation at Dryside Toe	904 ft	Riverside Slope	1V on 5H
Height	5 ft	Landside Slope	1V on 5H

	Flood Water Elevation (NAVD 1988)	Height (ft)	Underseepage (1) P(f)	R	Slope Stability P(f)	R	Through Seepage (2) P(f)	R	Surface Erosion (3) P(f)	R	Judgement P(f)	R	Combined P(f)	R	Frequency of Failure 1 in X times
Sherack Foundation	904	0	0	1	0	1.00000	0	1	0	1	0	1	0	1	
	905.25	1.25	2.50E-04	0.9998	0.0000000	1.00000	2.50E-04	0.9998	3.18E-05	1.0000	7.50E-06	1.0000	0.00054	0.99946	1855
	906.5	2.5	5.00E-04	0.9995	0.0000000	1.00000	5.00E-04	0.9995	3.18E-05	1.0000	1.50E-05	1.0000	0.00105	0.99895	956
	907.75	3.75	7.50E-04	0.99925	0.0000000	1.00000	7.50E-04	0.9993	3.18E-05	1.0000	2.25E-05	1.0000	0.00155	0.99845	644
	909	5	1.00E-03	0.999	0.0000000	1.00000	1.00E-03	0.999	3.18E-05	0.9999682	3.00E-05	0.99997	0.00206	0.99794	485
PL Sherack Foundation	904	0	0	1	0	1.00000	0	1	0	1	0	1	0	1	
	905.25	1.25	2.50E-04	0.9998	0.0000175	0.99998	2.50E-04	0.9998	3.18E-05	1.0000	7.50E-06	1.0000	0.00056	0.99944	1796
	906.5	2.5	5.00E-04	0.9995	0.0000350	0.99996	5.00E-04	0.9995	3.18E-05	1.0000	1.50E-05	1.0000	0.00108	0.99892	925
	907.75	3.75	7.50E-04	0.99925	0.0000525	0.99995	7.50E-04	0.9993	3.18E-05	1.0000	2.25E-05	1.0000	0.00161	0.99839	623
	909	5	1.00E-03	0.999	0.0000700	0.99993	1.00E-03	0.999	3.18E-05	0.9999682	3.00E-05	0.99997	0.00213	0.99787	469
Weighted	904	0	0	1	0.00E+00	1	0	1	0	1	0	1	0	1	
	905.25	1.25	2.50E-04	0.9998	8.75E-06	0.99999	2.50E-04	0.9998	3.18E-05	1.0000	7.50E-06	1.0000	0.00055	0.99945	1825
	906.5	2.5	5.00E-04	0.9995	1.75E-05	0.99998	5.00E-04	0.9995	3.18E-05	1.0000	1.50E-05	1.0000	0.00106	0.99894	940
	907.75	3.75	7.50E-04	0.99925	2.63E-05	0.99997	7.50E-04	0.9993	3.18E-05	1.0000	2.25E-05	1.0000	0.00158	0.99842	633
	909	5	1.00E-03	0.999	3.50E-05	0.99996	1.00E-03	0.999	3.18E-05	0.9999682	3.00E-05	0.99997	0.00210	0.99790	477

Sherack Foundation Weighting 0.5

Notes:

(1) P(f) due to "underseepage" is very small to neglible for clay embankments on clay foundations. During past flood fighting activities in the Red River Valley, no serious issues associated with piping have been observed. Therefore, judgement is used to estimate a P(f) due to "underseepage" based on an expected level of performance. With the levee section being more substaintial than the Corps' typical section (1V on 5H slopes), the levee is expected to have the following level of performance:

Expected Level of Perfomance: **ABOVE AVERAGE**   Beta: **3**   P(F):   **1.00E-03**

(2) P(f) due to "slope stability" was determined using the Taylor's Series procedure for reliability analysis as described in ETL 1110-2-556. The slope stability analyses was based on drained shear strengths and an assumed piezometeric surface similar to what would be expected to develop for steady-state seepage.

(3) P(f) due to "through seepage" (i.e. internal erosion) is very small for clay embankments on clay foundations. During past flood fighting activities in the Red River Valley, no serious issues associated with internal erosion have been observed. Therefore, judgment is used to estimate a P(f) due to "through seepage based on an expected level of performance. With the levee section being more substaintial than the Corps' typical section (1V on 5H slopes), the levee is expected to have the following level of performance:

Expected Level of Perfomance: **ABOVE AVERAGE**   Beta: **3**   P(F):   **1.00E-03**

(4) P(f) due to "surface erosion" was determined using the procedure described in ETL 1110-2-556. The calculations are based on a maximum velocity of 2 feet per second occuring at the location of the levee. This velocity is assumed to occur for all flood elevations.

(5) Probability of failure based on "judgement" takes into account configuration of levee, features at or near the toe that could effect the stability of the levee, and observed conditions. With the levee section being more substaintial than the Corps' typical section (1V on 5H slopes), the levee is expected to have the following level of performance:

Expected Level of Perfomance: **GOOD**   Beta: **4**   P(F):   **3.00E-05**

File: FMMFS_Geo_C2EL_Prob_Failure_rev_2010-01.xls
Worksheet: P(F) Drain 27, Rose Coulee
Printed on 11/30/2009

Final Fargo-Moorhead Metro Feasibility Report and Environmental Impact Statement
July 2011

Attachment H-5, pg 15
Credit to Existing Levees

FMMFS: Credit to Existing Levees
Probability of Failure vs Flood Water Elevation

Fargo Project ID: 5093, Drain 27 / Rose Coulee

File: FMMFS_Geo_C2EL_Prob_Failure_rev_2010-01.xls
Worksheet: P(F) Drain 27, Rose Coulee
Printed on 11/30/2009

Final Fargo-Moorhead Metro Feasibility Report and Environmental Impact Statement   Attachment H-5, pg 16
July 2011   Credit to Existing Levees

Moorhead Project ID: 97-13-15, Woodlawn Park

Moorhead Project ID:	97-13-15
Location:	Woodlawn Park
Top of Levee	904 ft
Elevation at Dryside Toe	894 ft
Height	10 ft

Top Width	10 ft
Riverside Slope	1V on 3H
Landside Slope	1V on 3H

Overall Expected Level of Performance: POOR

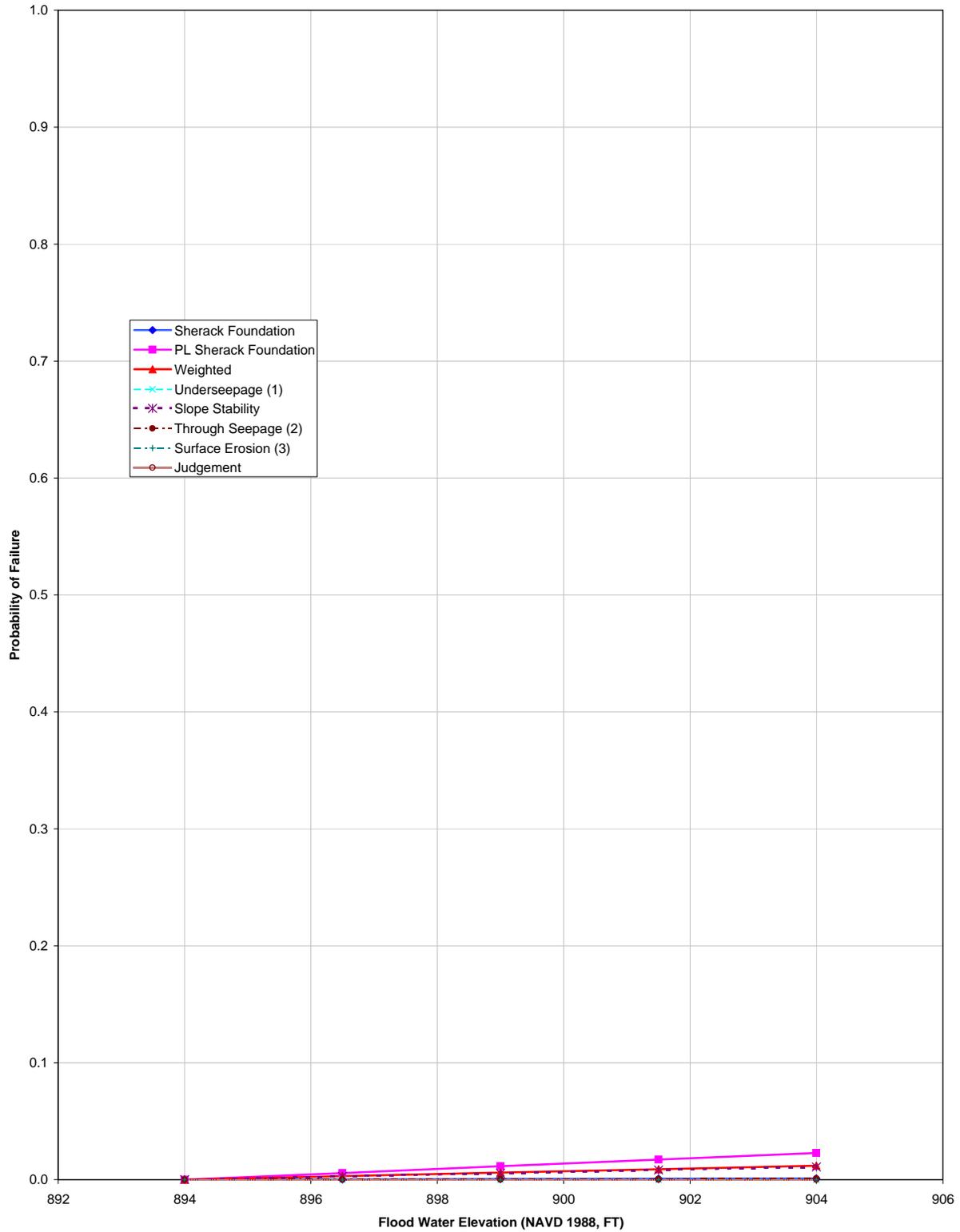|	Flood Water Elevation (NAVD 1988)	Height (ft)	Underseepage (1) P(f)	R	Slope Stability P(f)	R	Through Seepage (2) P(f)	R	Surface Erosion (3) P(f)	R	Judgement P(f)	R	Combined P(f)	R	Frequency of Failure 1 in X times
Sherack Foundation	894	0	0	1	0.00E+00	1.00000	0	1	0	1	0	1	0	1	
	896.5	2.5	7.50E-06	1.0000	2.34E-06	1.00000	2.50E-04	0.9998	3.18E-05	1.0000	7.50E-06	1.0000	0.00030	0.99970	3343
	899	5	1.50E-05	1.0000	4.68E-06	1.00000	5.00E-04	0.9995	3.18E-05	1.0000	1.50E-05	1.0000	0.00057	0.99943	1765
	901.5	7.5	2.25E-05	0.9999775	7.03E-06	0.99999	7.50E-04	0.9993	3.18E-05	1.0000	2.25E-05	1.0000	0.00083	0.99917	1199
	904	10	3.00E-05	0.99997	9.37E-06	0.99999	1.00E-03	0.999	3.18E-05	0.9999682	3.00E-05	0.99997	0.00110	0.99890	908
PL Sherack Foundation	894	0	0	1	0	1	0	1	0	1	0	1	0	1	
	896.5	2.5	7.50E-06	1.0000	0.0054505	0.99455	2.50E-04	0.9998	3.18E-05	1.0000	7.50E-06	1.0000	0.00575	0.99425	174
	899	5	1.50E-05	1.0000	0.0109009	0.98910	5.00E-04	0.9995	3.18E-05	1.0000	1.50E-05	1.0000	0.01146	0.98854	87
	901.5	7.5	2.25E-05	0.9999775	0.0163514	0.98365	7.50E-04	0.9993	3.18E-05	1.0000	2.25E-05	1.0000	0.01716	0.98284	58
	904	10	3.00E-05	0.99997	0.0218018	0.97820	1.00E-03	0.999	3.18E-05	0.9999682	3.00E-05	0.99997	0.02287	0.97713	44
Weighted	894	0	0	1	0.00E+00	1	0	1	0	1	0	1	0	1	
	896.5	2.5	7.50E-06	1.0000	2.73E-03	0.99727	2.50E-04	0.9998	3.18E-05	1.0000	7.50E-06	1.0000	0.00302	0.99698	331
	899	5	1.50E-05	1.0000	5.45E-03	0.99455	5.00E-04	0.9995	3.18E-05	1.0000	1.50E-05	1.0000	0.00601	0.99399	166
	901.5	7.5	2.25E-05	0.9999775	8.18E-03	0.99182	7.50E-04	0.9993	3.18E-05	1.0000	2.25E-05	1.0000	0.00900	0.99100	111
	904	10	3.00E-05	0.99997	1.09E-02	0.98909	1.00E-03	0.999	3.18E-05	0.9999682	3.00E-05	0.99997	0.01199	0.98801	83

Sherack Foundation Weighting   0.5

Notes:

(1) P(f) due to "underseepage" is very small to neglible for clay embankments on clay foundations. During past flood fighting activities in the Red River Valley, no serious issues associated with piping have been observed. Therefore, judgement is used to estimate a P(f) due to "underseepage" based on an expected level of performance. With the levee section similar to the Corps' typical section, the levee is expected to have the following level of performance:
   Expected Level of Perfomance: **GOOD**   Beta: **4**   P(F): **3.00E-05**

(2) P(f) due to "slope stability" was determined using the Taylor's Series procedure for reliability analysis as described in ETL 1110-2-556. The slope stability analyses was based on drained shear strengths and an assumed piezometeric surface similar to what would be expected to develop for steady-state seepage.

(3) P(f) due to "through seepage" (i.e. internal erosion) is very small for clay embankments on clay foundations. During past flood fighting activities in the Red River Valley, no serious issues associated with internal erosion have been observed. Therefore, judgment is used to estimate a P(f) due to "through seepage based on an expected level of performance. With the levee section similar to the Corps' typical section, the levee is expected to have the following level of performance:
   Expected Level of Perfomance: **ABOVE AVERAGE**   Beta: **3**   P(F): **1.00E-03**

(4) P(f) due to "surface erosion" was determined using the procedure described in ETL 1110-2-556. The calculations are based on a maximum velocity of 2 feet per second occuring at the location of the levee. This velocity is assumed to occur for all flood elevations.

(5) Probability of failure based on "judgement" takes into account configuration of levee, features at or near the toe that could effect the stability of the levee, and observed conditions. With the levee section similar to the Corps' typical section but having a larger height, the levee is expected to have the following level of performance:
   Expected Level of Perfomance: **GOOD**   Beta: **4**   P(F): **3.00E-05**

File: FMMFS_Geo_C2EL_Prob_Failure_rev_2010-01.xls
Worksheet: P(F) Woodlawn Park
Printed on 11/30/2009

Final Fargo-Moorhead Metro Feasibility Report and Environmental Impact Statement
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Attachment H-5, pg 17
Credit to Existing Levees

FMMFS: Credit to Existing Levees
Probability of Failure vs Flood Water Elevation

Moorhead Project ID: 97-13-15, Woodlawn Park

Legend:
- Sherack Foundation
- PL Sherack Foundation
- Weighted
- Underseepage (1)
- Slope Stability
- Through Seepage (2)
- Surface Erosion (3)
- Judgement

Y-axis: Probability of Failure (0.0 to 1.0)
X-axis: Flood Water Elevation (NAVD 1988, FT) (892 to 906)

File: FMMFS_Geo_C2EL_Prob_Failure_rev_2010-01.xls
Worksheet: P(F) Woodlawn Park
Printed on 11/30/2009

Final Fargo-Moorhead Metro Feasibility Report and Environmental Impact Statement   Attachment H-5, pg 18
July 2011   Credit to Existing Levees

Project: FMMFS
Subject: Summary of Conditional Probability of Failure
Computed By: KAH
Date: 31-Dec-08
Revised By: KAH
Date: 9-Jan-09

Moorhead Project ID: 97-13-14, Horn Park

Moorhead Project ID:	97-13-14
Location:	Horn Park
Top of Levee	905 ft
Elevation at Dryside Toe	888 ft
Height	17 ft

Overall Expected Level of Performance: HAZARDOUS

Top Width	10 ft
Riverside Slope	1V on 3H
Landside Slope	1V on 3H

	Flood Water Elevation (NAVD 1988)	Height (ft)	Underseepage (1) P(f)	R	Slope Stability P(f)	R	Through Seepage (2) P(f)	R	Surface Erosion (3) P(f)	R	Judgement P(f)	R	Combined P(f)	R	Frequency of Failure 1 in X times
Sherack Foundation	888	0	0	1	0	1	0	1	0	1	0	1	0	1	
	894	6	1.06E-05	0.9999894	0.0000001	1.00000	1.06E-05	0.9999894	3.18E-05	0.9999682	3.53E-04	0.9996471	0	0.999594	2463
	898	10	1.76E-05	0.999982	0.0000017	1.00000	1.76E-05	0.9999824	3.18E-05	0.9999682	5.88E-04	0.9994118	0.00066	0.99934	1522
	901	13	2.29E-05	0.999977	0.0000211	0.99998	2.29E-05	0.9999771	3.18E-05	0.9999682	7.65E-04	0.9992353	0.00086	0.99914	1158
	901.01	13.01	2.30E-05	0.999977	0.0000211	0.99998	2.30E-05	0.9999770	3.18E-05	1.0000	7.65E-04	0.9992347	0.00086	0.99914	1157
	905	17	3.00E-05	0.999970	0.0122078	0.98779	3.00E-05	0.99997	3.18E-05	0.9999682	1.00E-03	0.9990	0.01329	0.98671	75

	Flood Water Elevation	Height	Underseepage (1) P(f)	R	Slope Stability P(f)	R	Through Seepage (2) P(f)	R	Surface Erosion (3) P(f)	R	Judgement P(f)	R	Combined P(f)	R	Frequency of Failure
PL Sherack Foundation	888	0	0	1	0	1	0	1	0	1	0	1	0	1	
	894	6	0	0.9999894	0.0086248	1	0	0.9999894	0	0.9999682	0	0.9996471	0	0.990973	111
	898	10	1.76E-05	0.9999824	0.0292494	0.97075	1.76E-05	0.9999824	3.18E-05	0.9999682	5.88E-04	0.9994118	0.02989	0.97011	33
	901	13	2.29E-05	0.9999771	0.0934942	0.90651	2.29E-05	0.9999771	3.18E-05	0.9999682	7.65E-04	0.9992353	0.09426	0.90574	11
	901.01	13.01	2.30E-05	0.999977	0.0934942	0.90651	2.30E-05	0.9999770	3.18E-05	0.9999682	7.65E-04	0.9992347	0.09426	0.90574	11
	905	17	3.00E-05	0.999970	0.4876618	0.51234	3.00E-05	0.99997	3.18E-05	0.999968	1.00E-03	0.9990	0.48822	0.51178	2

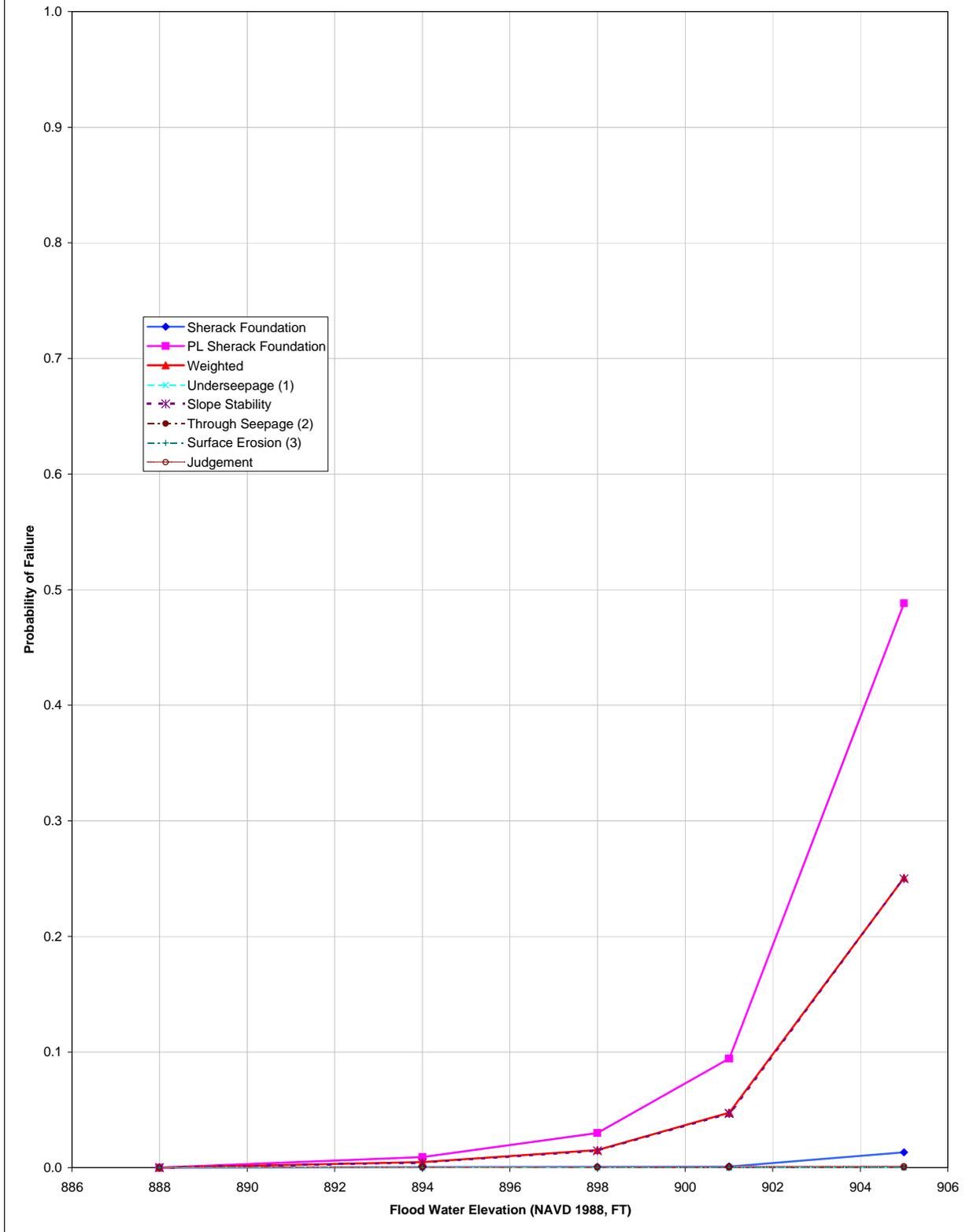|	Flood Water Elevation	Height	Underseepage (1) P(f)	R	Slope Stability P(f)	R	Through Seepage (2) P(f)	R	Surface Erosion (3) P(f)	R	Judgement P(f)	R	Combined P(f)	R	Frequency of Failure
Weighted	888	0	0	1	0	1	0	1	0	1	0	1	0	1	
	894	6	1.06E-05	0.9999894	4.31E-03	1	1.06E-05	0.9999894	3.18E-05	0.9999682	3.53E-04	0.9996471	0	0.995283	212
	898	10	1.76E-05	0.9999824	1.46E-02	0.98537	1.76E-05	0.9999824	3.18E-05	0.999968	5.88E-04	0.9994118	0.01527	0.98473	65
	901	13	2.29E-05	0.9999771	4.68E-02	0.95324	2.29E-05	0.9999771	3.18E-05	0.999968	7.65E-04	0.9992353	0.04756	0.95244	21
	901.01	13.01	2.30E-05	0.999977	4.68E-02	0.95324	2.30E-05	0.9999770	3.18E-05	0.999968	7.65E-04	0.9992347	0.04756	0.95244	21
	905	17	3.00E-05	0.999970	2.50E-01	0.75007	3.00E-05	0.999970	3.18E-05	0.999968	1.00E-03	0.999	0.25075	0.74925	4

Sherack Foundation Weighting   0.5

Notes:
(1) P(f) due to "underseepage" is very small to neglible for clay embankments on clay foundations. During past flood fighting activities in the Red River Valley, no serious issues associated with piping have been observed. Therefore, judgement is used to estimate a P(f) due to "underseepage" based on an expected level of performance. With the levee section similar to the Corps' typical section, the levee is expected to have the following level of performance:
Expected Level of Perfomance: **ABOVE AVERAGE**   Beta: **3**   P(F):   **1.00E-03**
(2) P(f) due to "slope stability" was determined using the Taylor's Series procedure for reliability analysis as described in ETL 1110-2-556. The slope stability analyses was based on drained shear strengths and an assumed piezometeric surface similar to what would be expected to develop for steady-state seepage.
(3) P(f) due to "through seepage" (i.e. internal erosion) is very small for clay embankments on clay foundations. During past flood fighting activities in the Red River Valley, no serious issues associated with internal erosion have been observed. Therefore, judgment is used to estimate a P(f) due to "through seepage based on an expected level of performance. With the levee section similar to the Corps' typical section, the levee is expected to have the following level of performance:
Expected Level of Perfomance: **ABOVE AVERAGE**   Beta: **3**   P(F):   **1.00E-03**
(4) P(f) due to "surface erosion" was determined using the procedure described in ETL 1110-2-556. The calculations are based on a maximum velocity of 2 feet per second occuring at the location of the levee. This velocity is assumed to occur for all flood elevations.
(5) Probability of failure based on "judgement" takes into account configuration of levee, features at or near the toe that could effect the stability of the levee, and observed conditions. With the levee section similar to the Corps' typical section but with having a larger height, the levee is expected to have the following level of performance:
Expected Level of Perfomance: **AVERAGE**   Beta: **2.75**   P(F):   **2.50E-03**

File: FMMFS_Geo_C2EL_Prob_Failure_rev_2010-01.xls
Worksheet: P(F) Horn Park
Printed on 11/30/2009

Final Fargo-Moorhead Metro Feasibility Report and Environmental Impact Statement   Attachment H-5, pg 19
July 2011   Credit to Existing Levees

FMMFS: Credit to Existing Levees
Probability of Failure vs Flood Water Elevation

Moorhead Project ID: 97-13-14, Horn Park

Legend:
- Sherack Foundation
- PL Sherack Foundation
- Weighted
- Underseepage (1)
- Slope Stability
- Through Seepage (2)
- Surface Erosion (3)
- Judgement

Y-axis: **Probability of Failure**

X-axis: **Flood Water Elevation (NAVD 1988, FT)**

File: FMMFS_Geo_C2EL_Prob_Failure_rev_2010-01.xls
Worksheet: P(F) Horn Park
Printed on 11/30/2009

Final Fargo-Moorhead Metro Feasibility Report and Environmental Impact Statement
July 2011

Attachment H-5, pg 20
Credit to Existing Levees

Project: FMMFS
Subject: ETL 1110-2-556 Example for Probability of Failure due to Erosion
Computed By: KAH
Date: 7-Jan-09
Revised By:
Date:

Project ID	Location	Water Surface Elevation				Velocity near Levee		$\ln(E[V_{crit}]/E[V])$		Beta		P(F)	
		10-year	50-year	100-yr	500-yr	100-yr	500-yr	100-yr	500-yr	100-yr	500-yr	100-yr	500-yr
4902	Riverwood 2nd Addition	887.38	893.16	894.86	897.76	2.00	2.00	0.92	0.92	4.00	4.00	3.1803E-05	3.1803E-05
5078-2	10th St. N	887.62	893.52	895.31	898.24	2.00	2.00	0.92	0.92	4.00	4.00	3.1803E-05	3.1803E-05
4903	Cardinal Muench Seminary	888.42	894.34	896.25	899.03	2.00	2.00	0.92	0.92	4.00	4.00	3.1803E-05	3.1803E-05
5036	Oak Grove Floodwall	890.48	897.10	899.49	902.90	1.00	2.00	1.61	0.92	7.02	4.00	1.0768E-12	3.1803E-05
144-115-07	1st Ave to 2nd Ave	890.88	897.57	900.00	903.51	2.00	2.00	0.92	0.92	4.00	4.00	3.1803E-05	3.1803E-05
97-13-14	Horn Park	891.85	898.87	901.55	905.58	2.00	2.00	0.92	0.92	4.00	4.00	3.1803E-05	3.1803E-05
4579-3	Dike West (10th Ave S)	892.16	899.27	902.01	906.13	2.00	2.00	0.92	0.92	4.00	4.00	3.1803E-05	3.1803E-05
4908	Lindenwood Drive	892.40	899.56	902.33	906.54	2.00	2.00	0.92	0.92	4.00	4.00	3.1803E-05	3.1803E-05
97-13-15	Woodlawn Park	893.36	900.59	903.35	907.65	1.00	1.00	1.61	1.61	7.02	7.02	1.0768E-12	1.0768E-12
4980	Southwood Drive	894.07	901.41	904.20	908.39	1.00	1.00	1.61	1.61	7.02	7.02	1.0768E-12	1.0768E-12
	General					2.00	2.00	0.92	0.92	4.00	4.00	3.1803E-05	3.1803E-05

Scouring velocity, V_{crit} = 5 $V(V_{crit})$ 0.2
$V(S)$ 0.1
$V(n)$ 0.1
$V(V)$ 0.1118
$\mathrm{sqrt}(V^2{}_{vcrit}+V^2{}_v)$ 0.22913