

Attachment I-13: Uplift Analysis



Fargo-Moorhead Metro Feasibility Study

Phase 3: Calculations for Uplift Factors of Safety NEAREST CENTERLINE only

Compiled By: KAH
Date: 8/20/2010

Revised By:
Date:

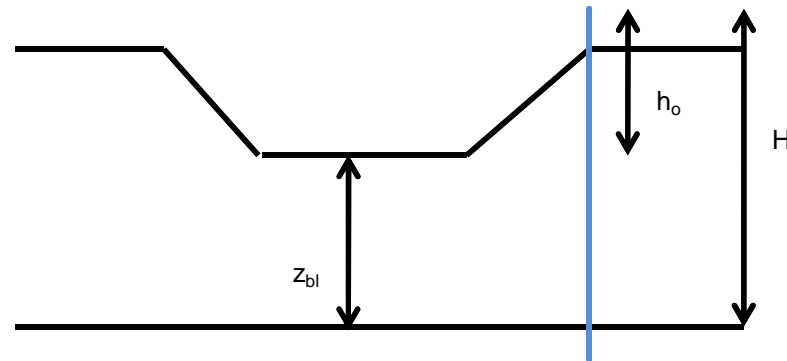
Piezometric Level Below Ground Surface 7.5 FT

	Area	STA	Offset	Boring	Ground Surface	Bottom of Diversion Channel	Depth of Channel	Piezometric Level in Aquifer	Depth to Aquifer	Elevation of Aquifer	Head in Aquifer	Impervious Blanket Thickness	Excess Head above Diversion	FS (gradient)	Z _T
3	70th Ave NW	~440+00	400 Right	10-87M	902	883	19	894.5	110	792	102.5	91	11.5	5.28	91.0
4	57th Ave N	~510+00	400 Left	10-82M	906	884	22	898.5	100	806	92.5	78	14.5	3.59	78.0
9	43rd Ave N	~585+00	900 Right	10-93M	911	884	27	903.5	128	783	120.5	101	19.5	2.07	60.5
13	28th Ave N	~636+00	400 Left	10-104M	913	885	28	905.5	87	826	79.5	59	20.5	1.74	53.6
16	15th Ave N	~688+00	50 Right	10-83M	913	885	28	905.5	91	822	83.5	63	20.5	1.87	57.6
21	HWY 10	~741+00	150 Right	10-103M	913	886	27	905.5	76	837	68.5	49	19.5	1.46	42.7
24	12th Ave S	~795+00	805 Left	10-102M	912	887	25	904.5	54	858	46.5	29	17.5	0.86	22.7
25			0											1.03	
26		~795+00	2800 Right	10-101M	913	887	26	905.5	77	836	69.5	51	18.5	1.61	44.7
27	I-94	~850+00	4300 Right	09-43C	913	888	25	905.5	94	819	86.5	69	17.5	2.63	69.0
28	40th Ave S	~-910+00	3100 Right	09-15M	915	889	26	907.5	102	813	94.5	76	18.5	2.74	76.0

$\gamma_{sat} = 104$ pcf
 $\gamma_b = 41.6$ pcf
 $\gamma_w = 62.4$ pcf

$$FS \text{ (gradient)} = \frac{(\gamma_{sat} - \gamma_w) * Z_t}{\gamma_w * h_o}$$

* Ground Surface elevations determined using LiDAR data; elevations similar to surveyed elevations



EM 1110-2-1914, Relief Wells
Allowable Heads
FS = 1.5, downstream areas
 $FS = i_o / i_c = \gamma' Z_t / \gamma_w h_a$

EM 1110-2-1913, Levee Design
Upward Gradient through berm:
if gradient through blanket is greater than 0.8 at gradient at landside toe of levee, berm should be built to reduce to 0.3

berm width based on allowable gradient of 0.8 through top stream landward of berm
 i_c based on 115 pcf sat. unit weight

EM 1110-2-1901, Seepage for Dams
FS - 1.5 to 15



Fargo-Moorhead I

Phase 3: Calculations for Upl

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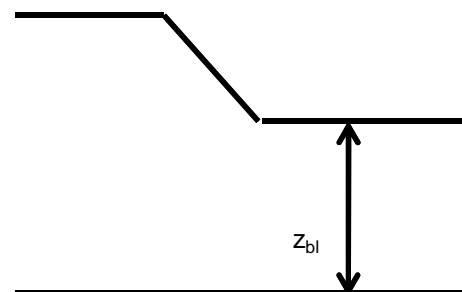
Piezometric Level Below Ground Surface 7.5 FT

	Area	STA	Offset	Boring	Brenna				Argusville					Silts						
					Depth to Top	Depth to Bottom	Thickness	k_v	Depth to Top	Depth to Bottom	Thickness	k_v	F_t	Transformed Thickness	Depth to Top	Depth to Bottom	Thickness	k_v	F_t	Transformed Thickness
3	70th Ave NW	~440+00	400 Right	10-87M	19	85	66	0.00028	85	110	25	0.00028	1	25	110	110	0	0.00283	0.1	0
4	57th Ave N	~510+00	400 Left	10-82M	22	62	40	0.00028	62	100	38	0.00028	1	38	100	100	0	0.00283	0.1	0
9	43rd Ave N	~585+00	900 Right	10-93M	27	60	33	0.00028	60	83	23	0.00028	1	23	83	128	45	0.00283	0.1	4.5
13	28th Ave N	~636+00	400 Left	10-104M	28	60	32	0.00028	60	81	21	0.00028	1	21	81	87	6	0.00283	0.1	0.6
16	15th Ave N	~688+00	50 Right	10-83M	28	58	30	0.00028	58	85	27	0.00028	1	27	85	91	6	0.00283	0.1	0.6
21	HWY 10	~741+00	150 Right	10-103M	27	53	26	0.00028	53	69	16	0.00028	1	16	69	76	7	0.00283	0.1	0.7
24	12th Ave S	~795+00	805 Left	10-102M	25	47	22	0.00028	47	47	0	0.00028	1	0	47	54	7	0.00283	0.1	0.7
25		0																		
26		~795+00	2800 Right	10-101M	26	40	14	0.00028	40	70	30	0.00028	1	30	70	77	7	0.00283	0.1	0.7
27	I-94	~850+00	4300 Right	09-43C	25	50	25	0.00028	50	94	44	0.00028	1	44	94	94	0	0.00283	0.1	0
28	40th Ave S	~910+00	3100 Right	09-15M	26	61	35	0.00028	61	102	41	0.00028	1	41	102	102	0	0.00283	0.1	0

$\gamma_{sat} = 104$ pcf
 $\gamma_b = 41.6$ pcf
 $\gamma_w = 62.4$ pcf

Transformation: $F_t = k_b / k_n$

* Ground Surface elevations determined using LiDAR data; elevations sirr





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Phase 3: Calculations for Upl

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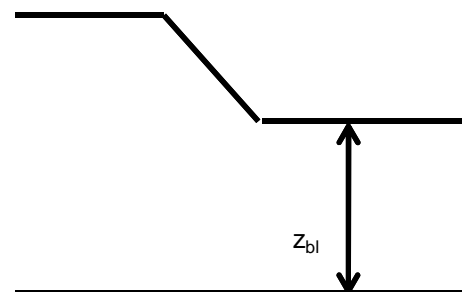
Piezometric Level Below Ground Surface 7.5 FT

Data Entry for calculations

	Area	STA	Offset	Boring	Ground Surface	Depth of Channel	Data Entry for calculations			Depth to Aquifer
							Brenna	Argusville	Silts	
3	70th Ave NW	~440+00	400 Right	10-87M	1000		85	110	110	110
4	57th Ave N	~510+00	400 Left	10-82M	1000		62	100	100	100
9	43rd Ave N	~585+00	900 Right	10-93M	1000		60	83	128	128
13	28th Ave N	~636+00	400 Left	10-104M			60	81	87	87
16	15th Ave N	~688+00	50 Right	10-83M	1000		58	85	91	91
21	HWY 10	~741+00	150 Right	10-103M	1000		53	69	76	76 85
24	12th Ave S	~795+00	805 Left	10-102M	1000		47	47	54	54 80
25			0							
26		~795+00	2800 Right	10-101M	1000		40	70	77	77 ????
27	I-94	~850+00	4300 Right	09-43C	1000		50	94	94	94
28	40th Ave S	~-910+00	3100 Right	09-15M	1000		61	102	102	102

$\gamma_{sat} = 104$ pcf
 $\gamma_b = 41.6$ pcf
 $\gamma_w = 62.4$ pcf

* Ground Surface elevations determined using LiDAR data; elevations sirr





Fargo-Moorhead Metro Feasibility Study

Phase 3: Calculations for ALL Uplift Factors of Safety

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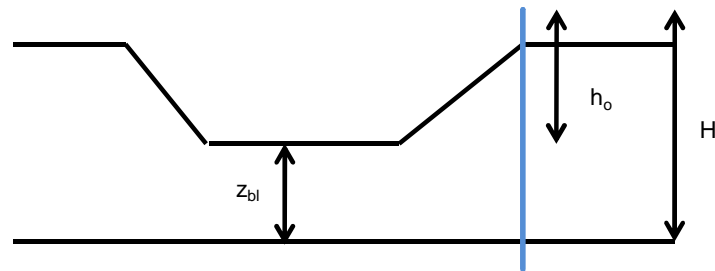
Revised By:
Date:

$\gamma_{sat} = 104$ pcf
 $\gamma_b = 41.6$ pcf
 $\gamma_w = 62.4$ pcf

Piezometric Level Below Ground Surface

	Area	STA	Offset	Boring	Ground Surface	Bottom of Diversion Channel	Depth of Channel	Piezometric Level in Aquifer	Depth to Aquifer	Elevation of Aquifer	Head in Aquifer	Impervious Blanket Thickness	Excess Head above Diversion	Piezometric Level Below Ground Surface				FS (heave)	Z_T
														7.5	5	7.5	10		
1	70th Ave NW	382+57	7000	Left	10-78M	896	13	888.5	110	786	102.5	97	5.5	11.76	8.08	11.76	21.56	1.58	97.0
2		406+30	2200	Left	10-79M	899	16	891.5	115	784	107.5	99	8.5	7.76	6.00	7.76	11.00	1.53	99.0
3		~440+00	400	Right	10-87M	902	19	894.5	110	792	102.5	91	11.5	5.28	4.33	5.28	6.74	1.48	91.0
4	57th Ave N	~510+00	400	Left	10-82M	906	22	898.5	100	806	92.5	78	14.5	3.59	3.06	3.59	4.33	1.41	78.0
5			1800	Right	10-90M	908	24	900.5	100	808	92.5	76	16.5	2.82	2.45	2.82	3.32	1.37	69.7
6			2400	Right	10-96M	908	24	900.5	90	818	82.5	66	16.5	2.67	2.32	2.67	3.14	1.33	66.0
7			4900	Right	10-84M	911	27	903.5	58	853	50.5	31	19.5	1.06	0.94	1.06	1.22	1.02	31.0
8	43rd Ave N	~585+00	2500	Left	10-89M	908	24	900.5	129	779	121.5	105	16.5	3.30	2.86	3.30	3.89	1.44	81.6
9		~585+00	900	Right	10-93M	911	27	903.5	128	783	120.5	101	19.5	2.07	1.83	2.07	2.37	1.40	60.5
10			1500	Right	10-88M	910	26	902.5	85	825	77.5	59	18.5	1.96	1.73	1.96	2.27	1.27	54.5
11			4400	Right	10-91M	916	32	908.5	35	881	27.5	3	24.5	0.01	0.01	0.01	0.01	0.18	0.3
12	28th Ave N	~636+00	3700	Left	10-92M	909	24	901.5	93	816	85.5	69	16.5	2.39	2.07	2.39	2.81	1.35	59.1
13			400	Left	10-104M	913	28	905.5	87	826	79.5	59	20.5	1.74	1.55	1.74	1.99	1.24	53.6
14		635+91	1500	Right	09-14M	913	28	905.5	70	843	62.5	42	20.5	1.22	1.09	1.22	1.39	1.12	37.5
15	60th St - 28th/15th Ave N		1600	Right	10-98M	913	28	905.5	75	838	67.5	47	20.5	0.97	0.87	0.97	1.11	1.16	29.9
16	15th Ave N	~688+00	50	Right	10-83M	913	28	905.5	91	822	83.5	63	20.5	1.87	1.67	1.87	2.13	1.26	57.6
17		~688+00	800	Right	10-100M	914	29	906.5	64	850	56.5	35	21.5	1.09	0.97	1.09	1.23	1.03	35.0
18			1500	Right	10-85M	916	31	908.5	40	876	32.5	9	23.5	0.03	0.02	0.03	0.03	0.46	0.9
19			4100	Right	10-86M	915	30	907.5	60	855	52.5	30	22.5	0.46	0.42	0.46	0.52	0.95	15.6
20	60th St - 15th Ave N / HWY 10		1800	Right	10-99M	915	29	907.5	56	859	48.5	27	21.5	0.45	0.40	0.45	0.51	0.93	14.4
21	HWY 10	~741+00	150	Right	10-103M	913	27	905.5	76	837	68.5	49	19.5	1.46	1.29	1.46	1.67	1.19	42.7
22			1100	Right	10-106M	913	27	905.5	70	843	62.5	43	19.5	1.32	1.17	1.32	1.51	1.15	38.5
23			2800	Right	09-40M	913	27	905.5	50	863	42.5	23	19.5	0.54	0.48	0.54	0.62	0.90	15.8
24	12th Ave S	~795+00	805	Left	10-102M	912	25	904.5	54	858	46.5	29	17.5	0.86	0.76	0.86	1.01	1.04	22.7
25		~795+00	0											1.03	0.90	1.03	1.20		
26		2800	Right	10-101M	913	26	905.5	77	836	69.5	51	18.5	1.61	1.42	1.61	1.86	1.22	44.7	
27	I-94		4300	Right	09-43C	913	25	905.5	94	819	86.5	69	17.5	2.63	2.30	2.63	3.07	1.33	69.0
28	40th Ave S		3100	Right	09-15M	915	26	907.5	102	813	94.5	76	18.5	2.74	2.41	2.74	3.17	1.34	76.0

Ground Surface elevations determined using LiDAR data; elevations similar to surveyed elevations



EM 1110-2-1914, Relief Wells

Allowable Heads

FS = 1.5, downstream areas

$$FS = i_o / i_c = \gamma' Z_t / \gamma_w h_a$$

EM 1110-2-1913, Levee Design

Upward Gradient through berm:

if gradient through blanket is greater than 0.8 at gradient at landside toe of levee, berm should be built to recede to 0.3

berm width based on allowable gradient of 0.8 through top stream landward of berm

i_c based on 115 pcf sat. unit weight

EM 1110-2-1901, Seepage for Dams

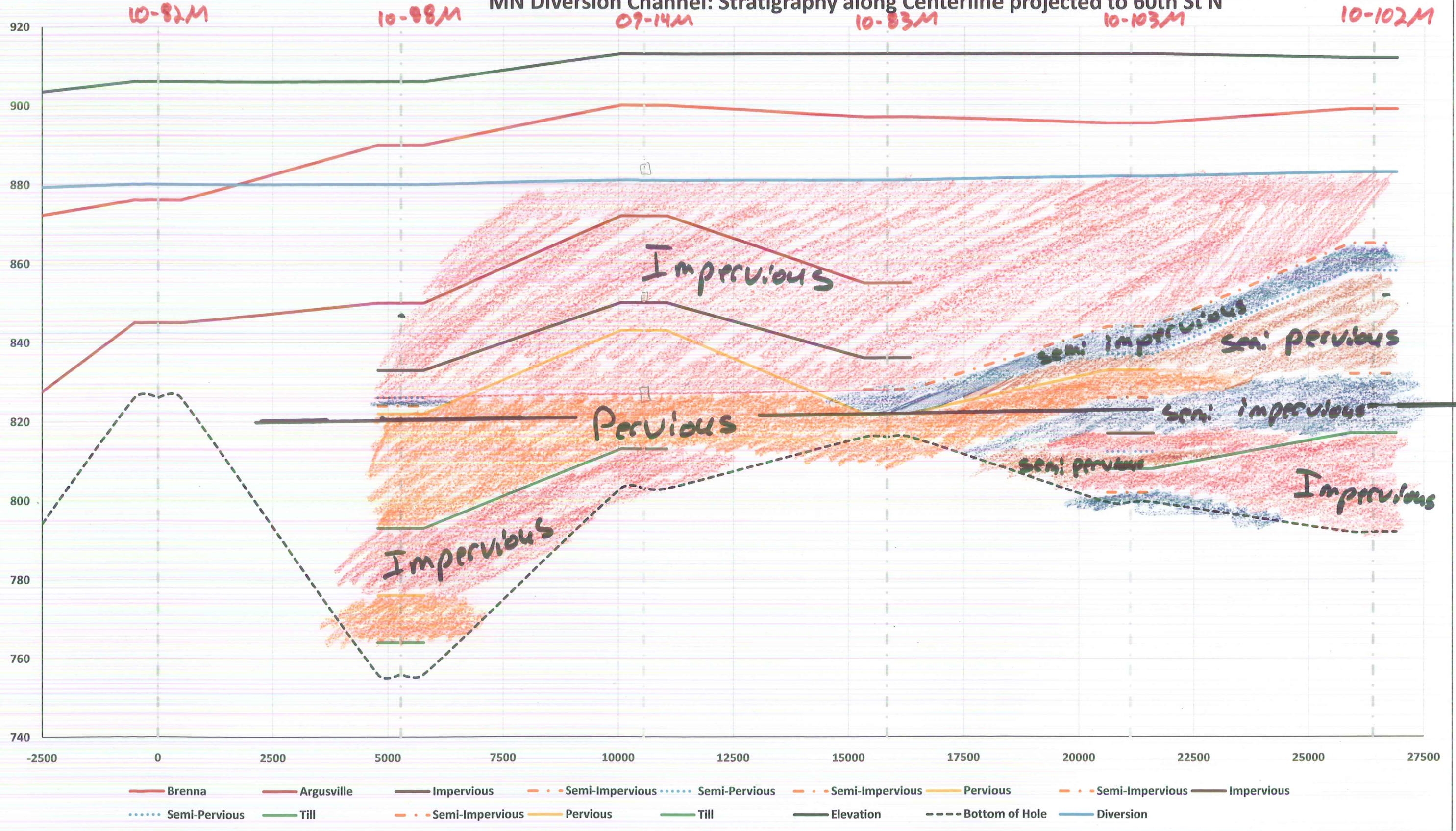
FS - 1.5 to 15

$$FS \text{ (gradient)} = \frac{(\gamma_{sat} - \gamma_w) * Z_t}{\gamma_w * h_o}$$

$$FS \text{ (heave)} = \frac{\gamma_{sat} * Z_{bl}}{\gamma_w * H}$$

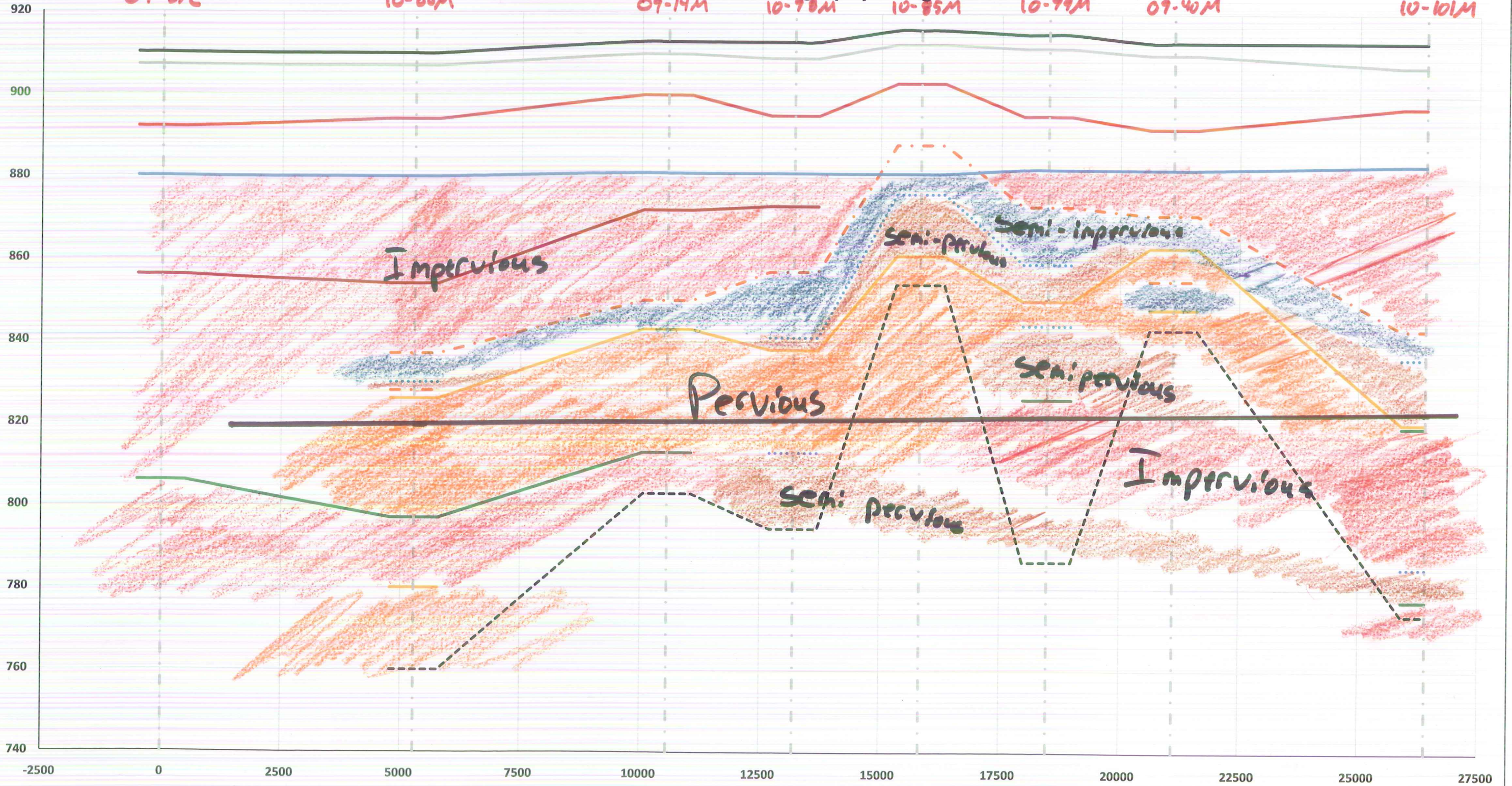
FMMFS

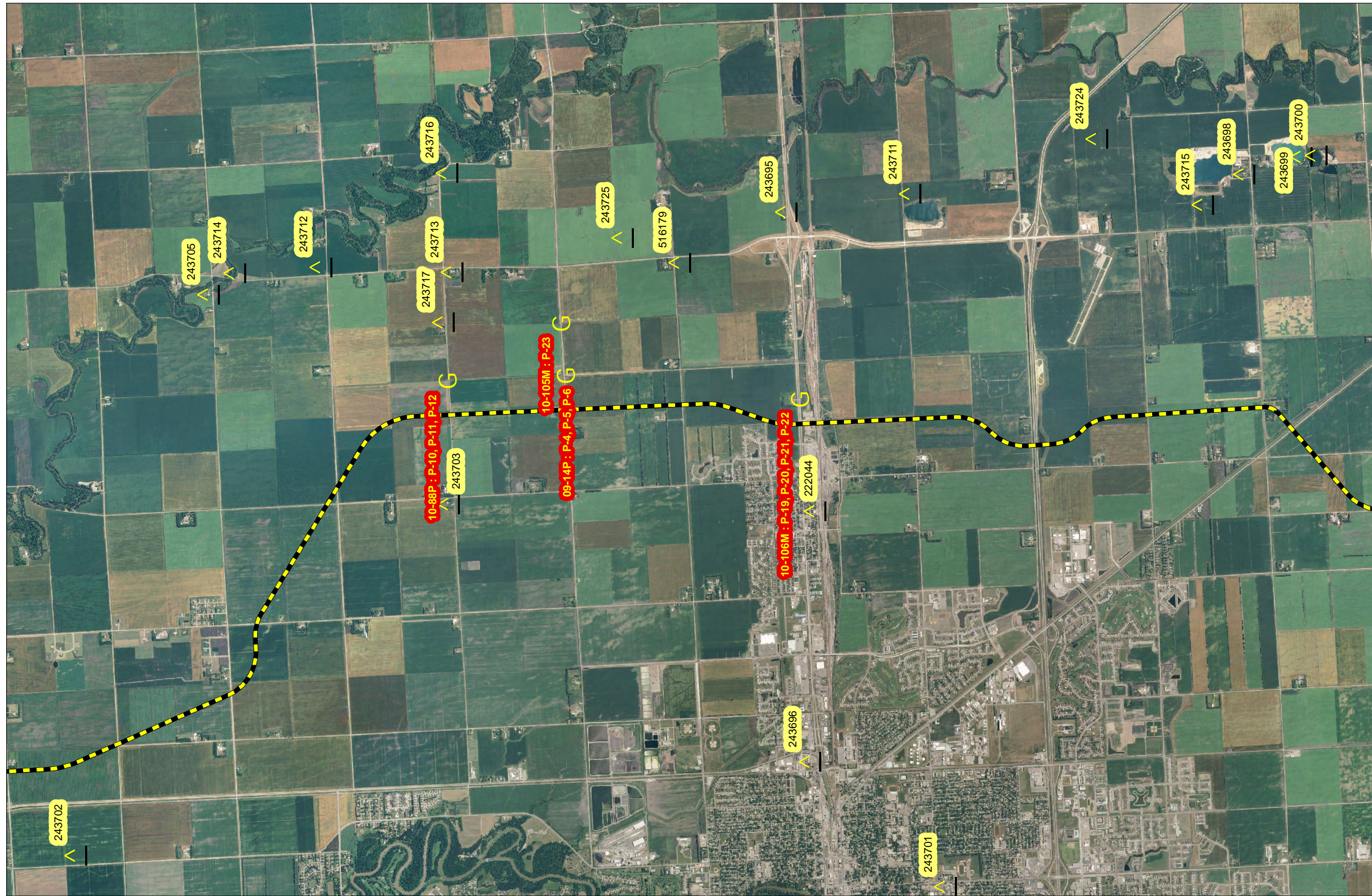
MN Diversion Channel: Stratigraphy along Centerline projected to 60th St N



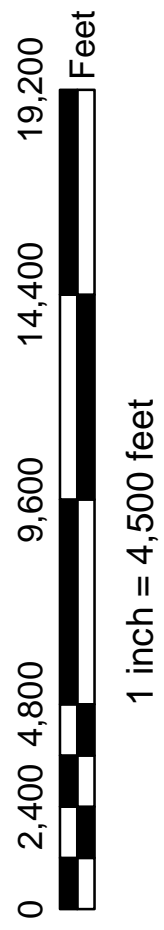
FMMFS

MN Diversion Channel: Stratigraphy along 60th St



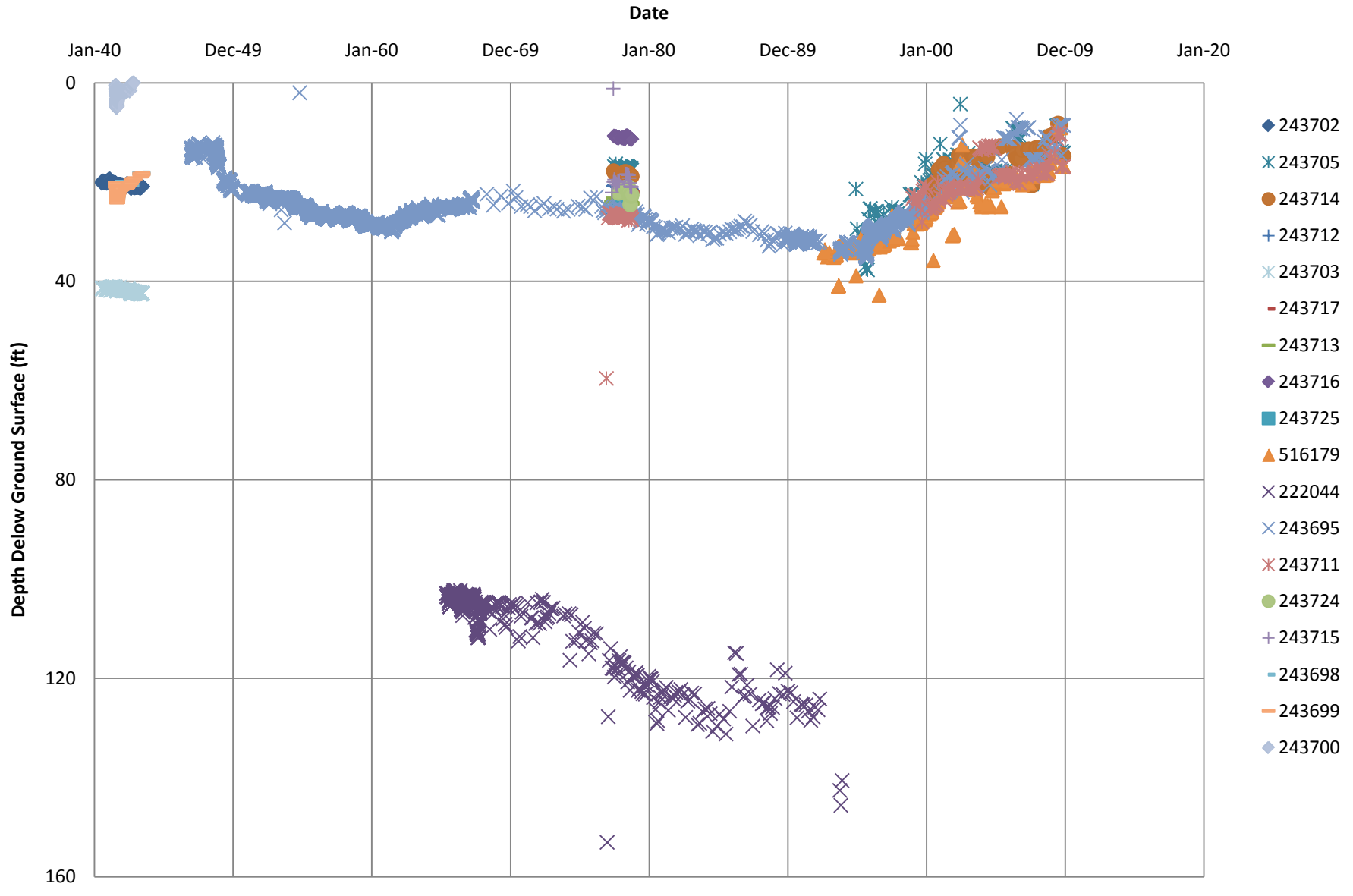


Fargo - Moorhead Metro Feasibility Study
 MN DNR Observation Well Locations

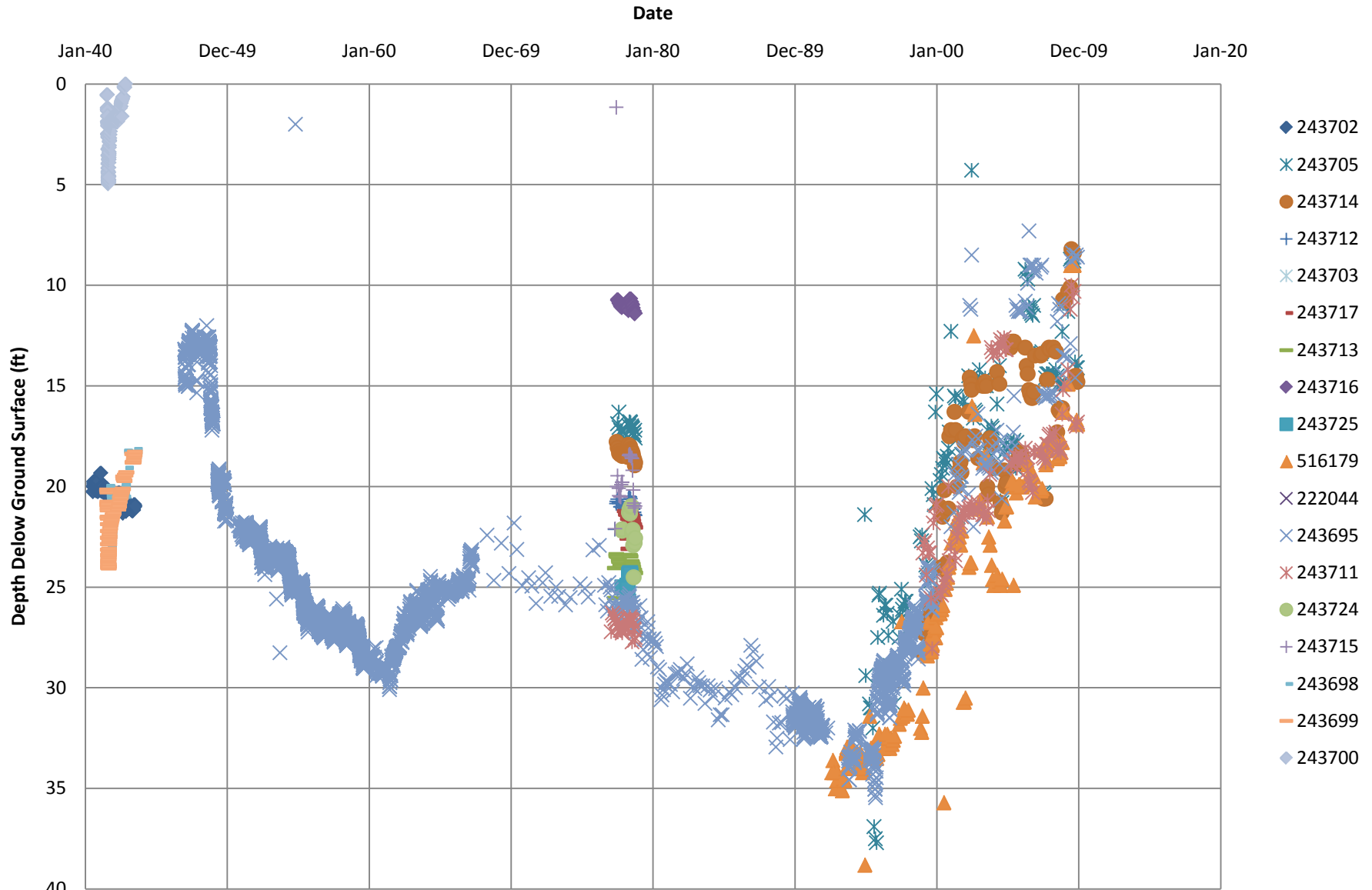


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 Printed 21 AUG 2010

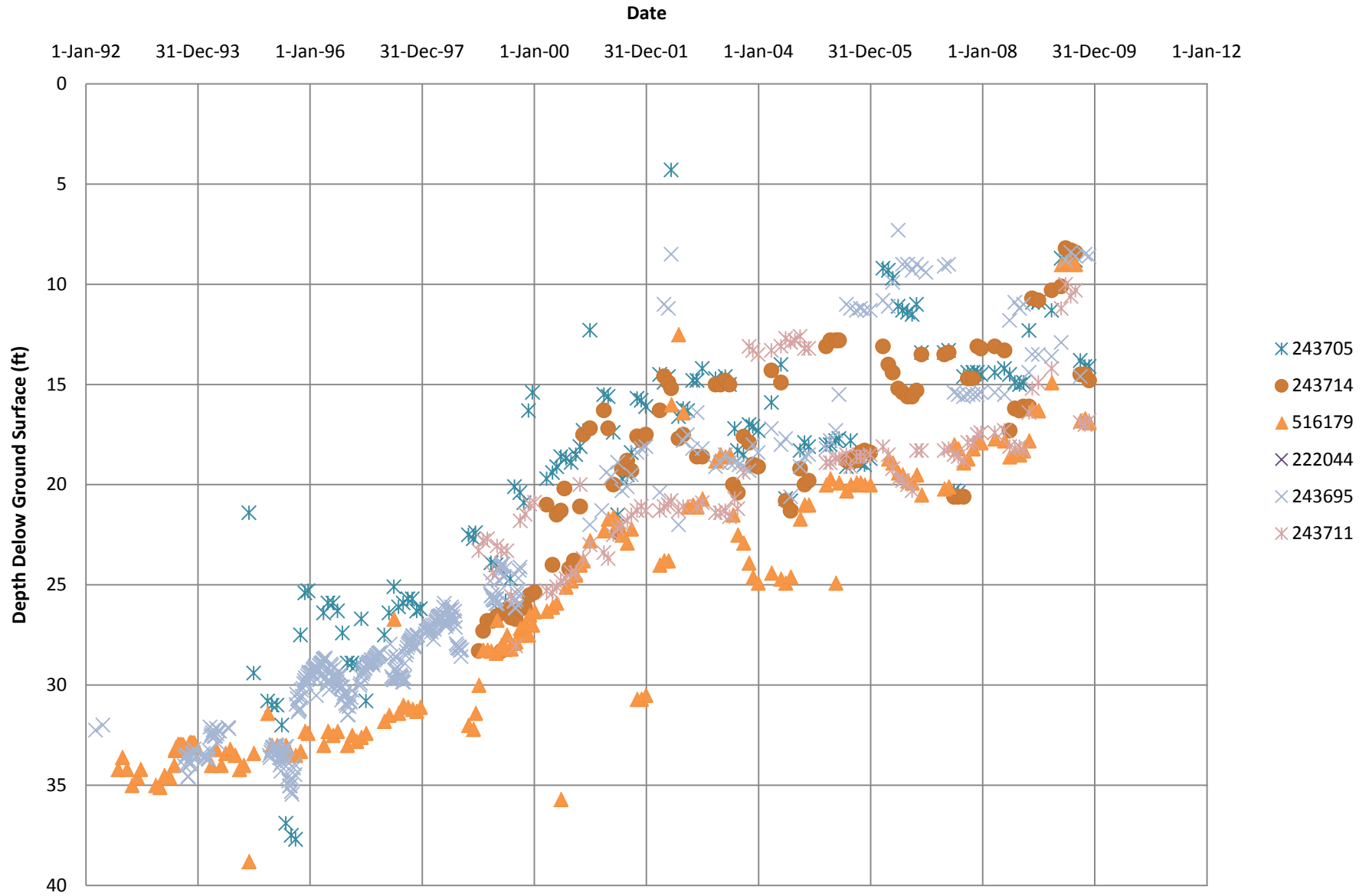
Fargo-Moorhead Metro Feasibility Study MN DNR Observation Well Readings



Fargo-Moorhead Metro Feasibility Study MN DNR Observation Well Readings



Fargo-Moorhead Metro Feasibility Study MN DNR Observation Well Readings





US Army Corps
of Engineers
St. Paul District

PROJECT TITLE:

Fargo - Moorhead Metro Feasibility Study

COMPUTED BY:

KAH

DATE:

2 SEP 09

SHEET:

1

SUBJECT TITLE:

Seepage: Piping & Uplift

CHECKED BY:

DATE:

CONTRACT NO.:

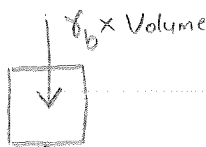
Piping: Factor of Safety for Escape Gradient

EM 1110-2-1901

$$i_{cr} = \frac{\gamma'_m}{\gamma_w} = \frac{\gamma_b}{\gamma_w}$$

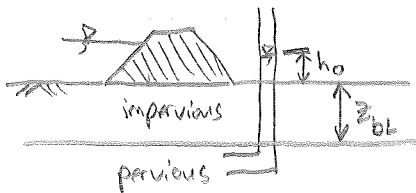
$$FS_G = \frac{i_{cr}}{i_e} = \frac{\gamma_b}{i_e \gamma_w} = \frac{\gamma_{sat} - \gamma_w}{i_e \gamma_w}$$

Proof: Look at element at surface



$$FS = \frac{\text{Resistance}}{\text{Applied}} = \frac{\gamma_b \times \text{Volume}}{i_0 \gamma_w \times \text{Volume}} = \frac{\gamma_b}{i_0 \gamma_w}$$

Uplift: Factor of Safety Against Uplift or Heaving



EM 1110-2-1701

$$h_c = \frac{z_{bl} \gamma_{sub}}{\gamma_w}$$

$$i = \frac{\Delta h}{z}$$

Long Term:
(Effective Stress)

$$FS_h = \frac{h_c}{h_0} = \frac{z_{bl} \gamma_{sub}}{\gamma_w h_0} = \frac{\gamma_{sub}}{\gamma_w i}$$

Also look at Short Term, Total Stress

$$FS_h = \frac{\text{Force Down}}{\text{Force Up}} = \frac{\gamma_{sat} z_{bl}}{\gamma_w (z_{bl} + h_0)}$$

(taken from CEE 5554 - Soil & Site Improvement,
Martin and Olgun, Spring 2007)