Appendix A

Groundwater Elevations from
Draft-Final Focused Site Inspection Report
(Bay West Inc., 2008)

Table 1

**USACE FSI Well and
Groundwater Elevation Summary
UMore Park
Rosemount, MN**

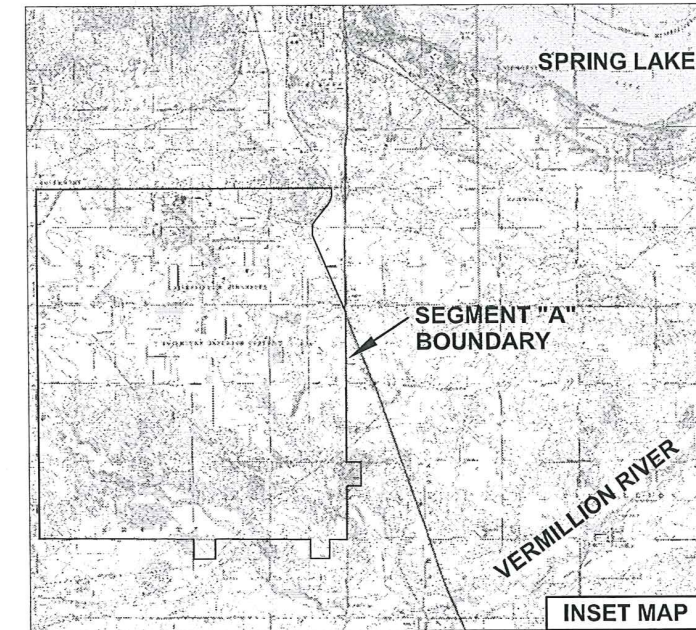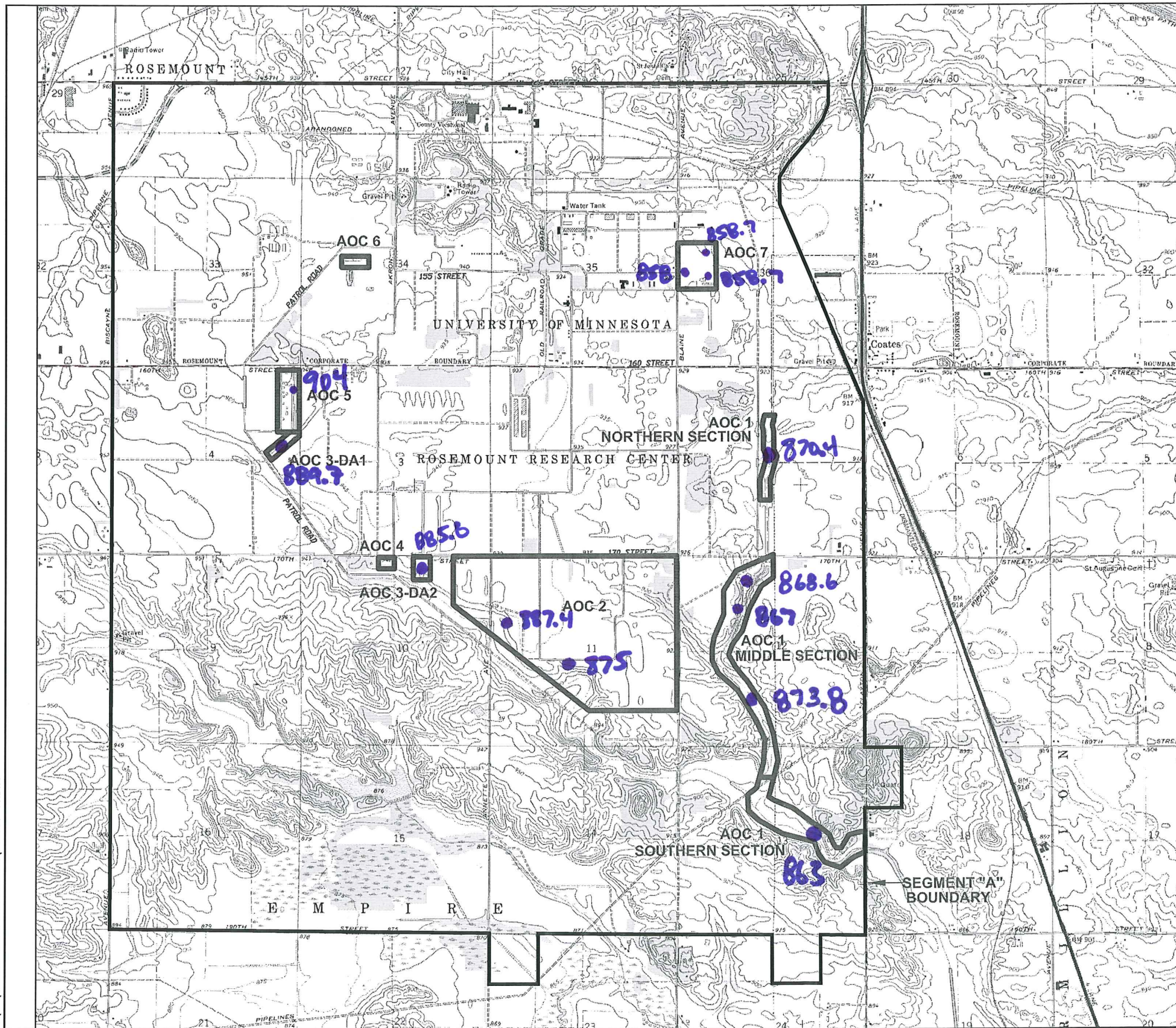| Location ID	Point Type	Estimated Reference Elevation * (ft MSL)	Depth to Water (feet)	Estimated Groundwater Elevation (ft MSL)	Northing	Easting	Comments
AOC1M-GP1	Temporary Well	900	31.40	868.6	496222.1	4949659.3	36.0 ft geoprobe borehole and temp well, drilled 9/17/07
AOC1M-GP2	Temporary Well	907	40.00	867	496187.4	4949486.4	44.0 ft geoprobe borehole and temp well, drilled 9/20/07
AOC1M-GP3	Temporary Well	888	14.20	873.8	496302.4	4948668.0	20.0 ft geoprobe borehole and temp well, drilled 9/23/07
AOC1N-GP1	Temporary Well	920	49.60	870.4	496442.2	4950776.1	52.0 ft geoprobe borehole and temp well, drilled 9/18/07
AOC1S-GP1	Temporary Well	869	5.40	863.6	496473.8	4947752.4	10.0 ft geoprobe borehole and temp well, drilled 9/24/07
AOC1S-GP2	Temporary Well	869	6.40	862.6	496890.4	4947407.5	10.0 ft geoprobe borehole and temp well, drilled 9/24/07
AOC2-GP1	Temporary Well	919	31.60	887.4	494152.0	4949412.5	36.0 ft geoprobe borehole and temp well, drilled 9/13/07
AOC2-GP2	Temporary Well	930	55.00	875	494717.1	4949078.4	56.0 ft geoprobe borehole and temp well, drilled 9/13/07
AOC3-DA1-GP1	Temporary Well	940	50.30	889.7	492272.6	4950909.1	52.0 ft geoprobe borehole and temp well, drilled 9/10/07
AOC3-DA2-GP1	Temporary Well	935	49.40	885.6	493439.5	4949850.1	52.0 ft geoprobe borehole and temp well, drilled 9/12/07
AOC5-GP7	Temporary Well	945	41.00	904	492358.9	4951424.7	44.0 ft geoprobe borehole and temp well, drilled 9/5/07
AOC7B-GP1	Temporary Well	925	66.25	858.75	495856.1	4952546.9	68.0 ft geoprobe borehole and temp well, drilled 8/17/07
AOC7B-GP2	Temporary Well	925	66.30	858.7	495919.4	4952555.0	68.0 ft geoprobe borehole and temp well, drilled 8/17/07
AOC7B-GP3	Temporary Well	921	63.30	857.7	495946.9	4952491.2	68.0 ft geoprobe borehole and temp well, drilled 8/20/07
AOC7C-GP3	Temporary Well	925	66.30	858.7	495859.4	4952418.6	68.0 ft geoprobe borehole and temp well, drilled 8/21/07
AOC7C-GP6	Temporary Well	921	60.20	860.8	495952.1	4952369.7	68.0 ft geoprobe borehole and temp well, drilled 8/22/07
AOC7C-GP7	Temporary Well	923	64.30	858.7	495902.4	4952321.6	65.0 ft geoprobe borehole and temp well, drilled 8/22/07
AOC7D-GP1	Temporary Well	922	61.30	860.7	495734.7	4952601.2	68.0 ft geoprobe borehole and temp well, drilled 8/27/07
AOC7D-GP2	Temporary Well	923	63.89	859.11	495750.7	4952599.8	68.0 ft geoprobe borehole and temp well, drilled 2/28/07
AOC7D-GP5	Temporary Well	922	63.25	858.75	495766.9	4952366.6	68.0 ft geoprobe borehole and temp well, drilled 8/30/07
AOC7D-GP8	Temporary Well	922	64.30	857.7	495705.7	4952341.5	68.0 ft geoprobe borehole and temp well, drilled 8/29/07
BG-GP8	Temporary Well	925	55.50	869.5	494353.3	4949041.7	52.0 ft geoprobe borehole and temp well, drilled 9/14/07
BG-GP14	Temporary Well	885	14.90	870.1	496239.5	4948234.1	20.0 ft geoprobe borehole and temp well, drilled 9/21/07

Notes:

ft = feet

MSL=Mean Sea Level

* indicates reference elevations are estimated from topographic maps

Source: BayWest, 2008 Focused Site Inspection Report, Former Gopher Ordnance Works, Rosemount, Minnesota.
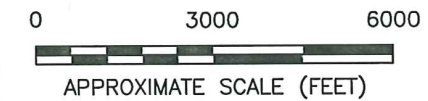
SPRING LAKE

SEGMENT "A"
BOUNDARY

VERMILLION RIVER

INSET MAP

NOTE:
AOC BOUNDARIES ARE APPROXIMATE.

MINN.

QUADRANGLE
LOCATION

SOURCE:
USGS 7.5 MINUTE
TOPOGRAPHIC MAP—
COATES & VERMILLION, MN
QUADRANGLES

0   3000   6000

APPROXIMATE SCALE (FEET)

N

ENGR'G	B.W.	DATE		BAY WEST Inc.
DRAWN	K.M.	2/26/07		ENVIRONMENTAL SERVICES
REV.	T.P.	6/2/08		ST. PAUL, MN

PROJECT NAME	GOPHER ORDNANCE
TITLE	SITE LOCATION MAP (SEGMENT "A")

| DWG. NO. | 060631-T1 | SCALE | 1:36,000 | FIGURE # | 1 |

Z:\06\060631-GOPHER ORDNANCE\060631-T1.DWG

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Appendix B

Soil Boring and Groundwater Data
(ProSource, 2008)

TABLE 1
SUMMARY OF GEOLOGIC ASSESSMENT DATA
UMore Park
Rosemount, Minnesota

Soil Boring ID	UTM Location East (meters)	UTM Location North (meters)	Ground Elevation (feet msl)	Total Depth (feet)	Depth to Water (feet)	Estimated Water Table Elevation (feet msl)
A0000	490849	4950000	947.2	65	54.5	892.7
A0200	490849	4950199	948.4	65	57	891.4
A0400	490850	4950400	949.1	65	56	893.1
A0600	490850	4950601	950.8	64	N.E.	N.E.
A0700	490904	4950693	949.9	52	N.E.	N.E.
A0800	490851	4950800	950.2	65	59	891.2
A1000	490851	4950999	946.8	65	57	889.8
A1200	490848	4951200	945.0	42	N.E.	N.E.
A1400	490850	4951399	947.8	45	N.E.	N.E.
A1600	490900	4951600	953.6	65	N.E.	N.E.
A1800	490900	4951800	953.7	65	N.E.	N.E.
A2000	490898	4952000	953.9	65	N.E.	N.E.
A2200	490901	4952199	953.8	65	N.E.	N.E.
A2300	490932	4952303	954.0	80	65	889.0
A2400	490900	4952401	954.6	65	N.E.	N.E.
A2600	490895	4952585	955.1	61	N.E.	N.E.
A2700	490898	4952701	955.7	120	73	882.7
A2800	490901	4952800	957.1	65	N.E.	N.E.
A3000	490901	4953000	954.2	65	N.E.	N.E.
AA0100	493501	4950100	938.7	65	58	880.7
AA0300	493503	4950298	940.3	65	59	881.3
AA0500	493500	4950505	939.6	65	58	881.6
AA0700	493500	4950701	938.9	65	57	881.9
AA0900	493500	4950865	939.4	60	N.E.	N.E.
AA1100	493501	4951101	942.0	55	N.E.	N.E.
AA1300	493498	4951302	940.5	65	61	879.5
AA1300A	493498	4951302	940.5	26	N.E.	N.E.
AA2500	493499	4952505	940.9	65	N.E.	N.E.
AA2700	493502	4952700	938.2	40	N.E.	N.E.
AA2900	493497	4952976	938.9	40	N.E.	N.E.
AA3100	493500	4953101	936.0	40	N.E.	N.E.
AA3300	493493	4953300	910.6	35	22	888.6
AAA1200	496115	4951191	904.3	45	N.E.	N.E.
AAA1400	496102	4951429	922.6	65	N.E.	N.E.
AAA1600	496099	4951599	919.3	65	N.E.	N.E.
AAA1800	496101	4951801	922.0	65	N.E.	N.E.
AAA2000	496101	4952023	922.5	65	N.E.	N.E.
AAA2200	496100	4952199	922.1	55	N.E.	N.E.
AAA2400	496100	4952402	919.3	65	N.E.	N.E.
AAA2600	496102	4952605	927.8	65	N.E.	N.E.
AAA2800	496110	4952801	929.0	65	N.E.	N.E.
AAA3000	496100	4953000	927.0	65	N.E.	N.E.
AAA3200	496100	4953202	926.7	65	N.E.	N.E.
B0350	491000	4950350	948.7	45	N.E.	N.E.
B0550	491001	4950554	948.9	65	58	890.9
B0750	491001	4950765	949.3	65	60	889.3
B0950	491017	4950950	949.0	100	65	884.0
B1150	491024	4951154	940.5	80	57	883.5
B1250	490999	4951250	944.0	37	N.E.	N.E.
B1450	491000	4951449	953.0	65	N.E.	N.E.

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Soil Boring ID	UTM Location East (meters)	UTM Location North (meters)	Ground Elevation (feet msl)	Total Depth (feet)	Depth to Water (feet)	Estimated Water Table Elevation (feet msl)
B1650	490999	4951650	953.9	65	N.E.	N.E.
B1750	491000	4951748	952.5	120	58	894.5
B1850	490999	4951850	953.3	65	N.E.	N.E.
B1950	490997	4951966	954.3	150	57	897.3
B2150	491000	4952150	954.4	120	58	896.4
B2250	491000	4952250	954.4	65	N.E.	N.E.
B2450	490999	4952451	951.3	53	N.E.	N.E.
B2650	491001	4952652	954.7	65	N.E.	N.E.
B2850	491000	4952850	953.9	65	N.E.	N.E.
B3050	491001	4953049	948.7	100	L.U.	L.U.
BB1150	493600	4951150	942.5	45	N.E.	N.E.
BB1350	493601	4951350	939.6	64	N.E.	N.E.
BB2450	493602	4952450	940.3	100	77	863.3
BBB3050	496199	4953049	925.7	92	67	858.7
C0100	491106	4950100	947.8	61	55.5	892.3
C0300	491106	4950300	947.9	50	50	897.9
C0500	491107	4950499	951.7	65	58	893.7
C0700	491106	4950700	947.2	55	N.E.	N.E.
C0900	491099	4950873	951.2	65	62	889.2
C1100	491100	4951099	942.2	52	N.E.	N.E.
C1300	491102	4951298	947.6	65	58	889.6
C1500	491098	4951536	952.3	65	N.E.	N.E.
C1700	491100	4951701	937.1	25	N.E.	N.E.
C1900	491101	4951900	930.0	65	44	886.0
C2100	491099	4952101	954.9	65	N.E.	N.E.
C2300	491100	4952300	953.1	65	N.E.	N.E.
C2500	491109	4952500	952.6	65	N.E.	N.E.
C2700	491099	4952700	953.5	65	N.E.	N.E.
C2900	491099	4952900	948.3	65	N.E.	N.E.
C3100	491100	4953100	947.1	65	64	883.1
C3300	491100	4953299	953.8	100	70	883.8
CC0000	493702	4950001	938.0	65	58.5	879.5
CC0200	493701	4950200	938.4	65	57	881.4
CC0400	493707	4950399	938.2	65	58	880.2
CC0600	493699	4950600	938.9	65	57	881.9
CC0800	493708	4950806	937.8	45	N.E.	N.E.
CC1000	493700	4951005	938.6	45	N.E.	N.E.
CC1200	493699	4951201	941.0	65	N.E.	N.E.
CC1400	493700	4951380	937.3	65	62	875.3
CC2400	493698	4952399	938.9	65	N.E.	N.E.
CC2600	493700	4952600	940.8	65	N.E.	N.E.
CC2800	493703	4952804	891.4	25	23	868.4
CC3000	493707	4953000	936.1	40	N.E.	N.E.
CC3400	493710	4953399	905.2	25	19	886.2
CCC1300	496305	4951296	920.1	65	64.5	855.6
CCC1500	496301	4951500	919.3	65	64.5	854.8
CCC1501	496343	4951499	918.3	90	77	841.3
CCC1700	496345	4951699	923.8	65	N.E.	N.E.
CCC1900	496344	4951900	920.0	58	N.E.	N.E.
CCC2100	496343	4952100	918.1	65	N.E.	N.E.

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TABLE 1
SUMMARY OF GEOLOGIC ASSESSMENT DATA
UMore Park
Rosemount, Minnesota

Soil Boring ID	UTM Location East (meters)	UTM Location North (meters)	Ground Elevation (feet msl)	Total Depth (feet)	Depth to Water (feet)	Estimated Water Table Elevation (feet msl)
CCC2200	496348	4952201	919.1	80	65	854.1
CCC2300	496345	4952301	924.6	65	N.E.	N.E.
CCC2500	496346	4952499	927.5	65	N.E.	N.E.
CCC2600	496326	4952597	926.5	94	77	849.5
CCC2700	496300	4952700	927.8	65	N.E.	N.E.
CCC2900	496299	4952900	922.1	65	N.E.	N.E.
CCC3100	496302	4953101	924.7	65	N.E.	N.E.
D0450	491200	4950450	952.6	53	N.E.	N.E.
D0550	491200	4950551	950.2	65	60.5	889.7
D0750	491198	4950764	949.0	65	61	888.0
D0950	491201	4950976	945.9	65	59	886.9
D1150	491200	4951150	943.9	65	58	885.9
D1350	491200	4951350	954.2	65	N.E.	N.E.
D1650	491201	4951648	911.4	65	26	885.4
D1750	491197	4951749	908.8	65	5	903.8
D1850	491194	4951850	917.9	65	32	885.9
D1950	491197	4951997	953.1	120	65	888.1
D2150	491202	4952146	954.6	140	65	889.6
D2350	491200	4952398	952.6	65	N.E.	N.E.
D2550	491200	4952550	952.5	65	N.E.	N.E.
D2750	491200	4952749	952.4	65	N.E.	N.E.
D2950	491200	4952950	946.1	65	62	884.1
D3150	491200	4953150	953.2	65	N.E.	N.E.
DD0850	493800	4950850	938.5	43	N.E.	N.E.
DD1050	493800	4951050	936.8	40	N.E.	N.E.
DD1250	493800	4951250	939.4	65	59	880.4
E0000	491300	4949974	947.0	48	N.E.	N.E.
E0200	491298	4950259	949.5	50	N.E.	N.E.
E0400	491301	4950406	951.2	55	N.E.	N.E.
E0600	491300	4950551	948.0	59	56.5	891.5
E0800	491300	4950764	948.8	65	61	887.8
E1000	491299	4950978	944.4	45	N.E.	N.E.
E1200	491301	4951200	947.5	65	60	887.5
E1400	491302	4951415	953.1	65	62	891.1
E1500	491305	4951498	936.3	65	60	876.3
E1600	491342	4951601	951.2	45	N.E.	N.E.
E1700	491326	4951699	950.7	140	65	885.7
E1800	491300	4951800	951.8	65	N.E.	N.E.
E1900	491301	4951898	953.0	162	65.5	887.5
E2000	491288	4952000	953.4	65	N.E.	N.E.
E2100	491327	4952096	953.3	100	57	896.3
E2200	491299	4952201	953.9	65	N.E.	N.E.
E2300	491329	4952299	954.3	100	74	880.3
E2400	491300	4952398	952.8	65	N.E.	N.E.
E2600	491304	4952600	952.2	65	N.E.	N.E.
E2800	491300	4952801	944.6	65	62	882.6
E3000	491300	4953000	949.0	65	N.E.	N.E.
E3200	491300	4953201	951.4	65	N.E.	N.E.
E3400	491300	4953400	956.8	65	N.E.	N.E.
E3600	491300	4953600	959.0	65	N.E.	N.E.

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TABLE 1
SUMMARY OF GEOLOGIC ASSESSMENT DATA
UMore Park
Rosemount, Minnesota

Soil Boring ID	UTM Location East (meters)	North (meters)	Ground Elevation (feet msl)	Total Depth (feet)	Depth to Water (feet)	Estimated Water Table Elevation (feet msl)
EE0100	493881	4950103	935.2	65	55	880.2
EE0300	493881	4950300	936.2	65	56	880.2
EE0500	493900	4950503	935.9	25	N.E.	N.E.
EE0700	493900	4950700	937.8	45	N.E.	N.E.
EE0900	493901	4950899	937.4	45	N.E.	N.E.
EE1100	493900	4951102	937.0	55	N.E.	N.E.
EE1300	493900	4951300	939.8	65	60	879.8
EE1400	493899	4951400	938.8	65	63	875.8
EE1500	493900	4951504	938.2	65	63	875.2
EE2500	493905	4952518	939.0	65	N.E.	N.E.
EE2600	493894	4952597	939.1	120	77	862.1
EE2700	493900	4952699	939.4	65	N.E.	N.E.
EE2900	494002	4952875	913.7	65	29	884.7
EE3100	493839	4953077	927.3	35	N.E.	N.E.
EE3300	493903	4953300	884.1	45	19	865.1
F0450	491402	4950450	948.9	44	N.E.	N.E.
F0650	491400	4950650	947.6	65	62	885.6
F0750	491400	4950767	949.1	92	L.U.	L.U.
F1150	491399	4951149	944.1	65	59	885.1
F1350	491410	4951347	940.1	65	55	885.1
F1550	491400	4951544	950.9	64	N.E.	N.E.
F1850	491402	4951848	952.4	140	60	892.4
F2150	491454	4952132	953.3	65	N.E.	N.E.
F2400	491401	4952390	952.8	120	65	887.8
F2650	491400	4952650	946.5	100	65	881.5
F2850	491399	4952850	940.8	100	65	875.8
F2950	491400	4952950	952.3	65	N.E.	N.E.
F3150	491399	4953150	950.9	65	N.E.	N.E.
F3350	491398	4953347	948.9	90	65	883.9
F3550	491400	4953549	957.2	100	85	872.2
F3750	491401	4953751	958.2	120	85	873.2
FF0150	494035	4950149	936.7	80	L.U.	L.U.
FF0550	494000	4950551	938.8	25	N.E.	N.E.
FF0850	494001	4950850	938.1	43	N.E.	N.E.
FF1050	494000	4951050	938.4	40	N.E.	N.E.
FF1250	494001	4951250	935.4	45	N.E.	N.E.
FF1450	494000	4951449	937.6	65	64	873.6
FF1650	493999	4951649	927.7	45	N.E.	N.E.
FF2450	493998	4952452	937.5	70	N.E.	N.E.
FF2750	493995	4952747	937.5	100	78	859.5
G0100	491501	4950113	948.6	39.5	N.E.	N.E.
G0300	491501	4950258	948.2	47	45	903.2
G0400	491501	4950404	947.5	41	N.E.	N.E.
G0500	491498	4950550	946.3	65	62	884.3
G0700	491500	4950690	945.6	55	N.E.	N.E.
G0900	491500	4950874	945.7	65	60	885.7
G1100	491500	4951101	944.0	65	58	886.0
G1300	491500	4951300	948.1	65	62	886.1
G1500	491500	4951494	952.5	65	N.E.	N.E.
G1700	491500	4951700	951.4	65	N.E.	N.E.

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TABLE 1
SUMMARY OF GEOLOGIC ASSESSMENT DATA
UMore Park
Rosemount, Minnesota

Soil Boring ID	UTM Location		Ground Elevation (feet msl)	Total Depth (feet)	Depth to Water (feet)	Estimated Water Table Elevation (feet msl)
	East (meters)	North (meters)				
G1900	491500	4951900	952.1	60	N.E.	N.E.
G2000	491499	4951972	953.3	65	N.E.	N.E.
G2100	491501	4952096	953.2	65	N.E.	N.E.
G2300	491500	4952299	951.7	65	N.E.	N.E.
G2500	491501	4952500	949.4	65	N.E.	N.E.
G2700	491501	4952701	941.8	65	61	880.8
G2900	491502	4952898	950.9	65	N.E.	N.E.
G3100	491499	4953100	949.7	65	N.E.	N.E.
G3100A	491499	4953100	949.7	20	N.E.	N.E.
G3300	491500	4953300	955.3	65	N.E.	N.E.
G3500	491500	4953499	955.8	65	N.E.	N.E.
G3700	491500	4953700	958.4	65	N.E.	N.E.
GG0000	494101	4950000	935.6	65	57	878.6
GG0200	494100	4950200	936.3	65	58	878.3
GG0400	494099	4950400	935.6	50	N.E.	N.E.
GG0500	494094	4950489	937.8	53	N.E.	N.E.
GG0600	494098	4950600	937.1	57	N.E.	N.E.
GG0700	494100	4950700	937.7	42	N.E.	N.E.
GG0800	494101	4950804	936.6	45	N.E.	N.E.
GG1000	494099	4951000	937.2	45	N.E.	N.E.
GG1200	494100	4951207	938.4	38	N.E.	N.E.
GG1400	494099	4951396	934.9	50	N.E.	N.E.
GG1600	494099	4951609	935.9	65	63	872.9
GG1700	494091	4951678	931.7	90	L.U.	L.U.
GG2200	494117	4952166	930.5	45	N.E.	N.E.
GG2400	494099	4952402	938.8	65	N.E.	N.E.
GG2600	494100	4952600	937.5	65	N.E.	N.E.
GG2800	494099	4952800	904.1	25	N.E.	N.E.
GG3000	494100	4953000	910.0	65	46	864.0
GG3200	494111	4953277	928.3	65	63	865.3
GG3400	494101	4953400	935.3	65	N.E.	N.E.
H0350	491601	4950348	947.5	45	N.E.	N.E.
H0650	491600	4950650	945.8	65	59	886.8
H0850	491601	4950872	945.4	65	60	885.4
H0950	491599	4950950	942.2	110	65	877.2
H1150	491598	4951148	948.7	142	65	883.7
H1350	491603	4951349	953.4	140	65	888.4
H1550	491601	4951536	952.2	160	L.U.	L.U.
H1750	491600	4951752	949.9	147	L.U.	L.U.
H1950	491628	4951962	951.7	140	L.U.	L.U.
H2250	491601	4952250	952.8	65	N.E.	N.E.
H3450	491605	4953447	952.9	100	78	874.9
H3650	491597	4953649	957.0	100	80	877.0
H3850	491599	4953850	957.2	120	85	872.2
HH0650	494199	4950650	937.4	38	N.E.	N.E.
HH0850	494202	4950856	935.8	38	N.E.	N.E.
HH1100	494199	4951102	936.9	45	N.E.	N.E.
HH1350	494177	4951350	936.3	45	N.E.	N.E.
HH2650	494187	4952645	925.9	100	65	860.9
I0000	491699	4950000	947.3	20	N.E.	N.E.

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Soil Boring ID	UTM Location		Ground Elevation (feet msl)	Total Depth (feet)	Depth to Water (feet)	Estimated Water Table Elevation (feet msl)
	East (meters)	North (meters)				
I0200	491701	4950201	947.4	45	44	903.4
I0400	491700	4950400	947.2	65	63	884.2
I0600	491699	4950603	947.2	65	63	884.2
I0800	491702	4950764	946.4	65	60.5	885.9
I1000	491700	4950976	938.5	50	N.E.	N.E.
I1200	491701	4951169	947.5	65	N.E.	N.E.
I1400	491775	4951401	951.8	65	N.E.	N.E.
I1600	491700	4951599	950.8	65	N.E.	N.E.
I1800	491700	4951799	949.7	65	N.E.	N.E.
I2000	491701	4952000	951.5	65	N.E.	N.E.
I2100	491699	4952099	951.3	59	N.E.	N.E.
I2200	491700	4952199	947.5	65	N.E.	N.E.
I2400	491699	4952400	948.9	65	N.E.	N.E.
I2600	491700	4952601	950.3	65	N.E.	N.E.
I2800	491699	4952801	949.7	65	N.E.	N.E.
I3000	491699	4953001	949.9	65	N.E.	N.E.
I3200	491699	4953200	952.7	65	N.E.	N.E.
I3400	491700	4953399	951.4	65	N.E.	N.E.
I3600	491700	4953599	955.4	65	N.E.	N.E.
I3800	491700	4953800	952.2	65	N.E.	N.E.
II0100	494284	4950100	934.3	65	60	874.3
II0300	494303	4950300	932.7	65	56	876.7
II0400	494303	4950400	933.3	40	N.E.	N.E.
II0500	494299	4950505	933.1	65	60	873.1
II0700	494300	4950697	936.1	65	N.E.	N.E.
II0900	494300	4950835	935.3	45	N.E.	N.E.
II1000	494296	4951002	934.6	40	N.E.	N.E.
II1100	494371	4951100	936.3	45	N.E.	N.E.
II1200	494291	4951200	934.3	45	N.E.	N.E.
II1300	494374	4951312	934.4	45	N.E.	N.E.
II1500	494336	4951500	935.3	32	N.E.	N.E.
II1700	494300	4951699	935.3	43	N.E.	N.E.
II1900	494322	4951903	932.8	65	64.5	868.3
II2100	494300	4952100	909.7	65	44	865.7
II2300	494281	4952306	929.1	65	N.E.	N.E.
II2400	494311	4952391	931.8	100	L.U.	L.U.
II2500	494300	4952500	935.7	55	N.E.	N.E.
II2700	494300	4952700	885.2	45	22	863.2
II2900	494303	4952892	895.3	45	33	862.3
II3100	494318	4953100	937.3	65	N.E.	N.E.
II3300	494301	4953299	929.7	65	N.E.	N.E.
J0050	491800	4950049	946.3	25	N.E.	N.E.
J0350	491801	4950351	946.0	65	63	883.0
J0750	491800	4950760	948.0	65	63	885.0
J1150	491774	4951147	947.9	65	62	885.9
J1650	491800	4951678	949.3	160	60	889.3
J1950	491799	4951951	948.6	65	64.5	884.1
J2450	491800	4952449	952.6	65	N.E.	N.E.
J2650	491800	4952648	951.4	64	60	891.4
J2850	491800	4952850	952.6	54	N.E.	N.E.

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TABLE 1
SUMMARY OF GEOLOGIC ASSESSMENT DATA
UMore Park
Rosemount, Minnesota

Soil Boring ID	UTM Location East (meters)	UTM Location North (meters)	Ground Elevation (feet msl)	Total Depth (feet)	Depth to Water (feet)	Estimated Water Table Elevation (feet msl)
J3350	491803	4953349	951.9	100	80	871.9
J3750	491800	4953750	946.7	45	N.E.	N.E.
JJ0050	494448	4950061	934.4	78	L.U.	L.U.
JJ0450	494400	4950443	930.5	45	N.E.	N.E.
JJ0650	494400	4950650	937.4	39	N.E.	N.E.
JJ0850	494399	4950846	936.1	38	N.E.	N.E.
JJ1650	494396	4951649	936.2	80	N.E.	N.E.
K0100	491899	4950109	945.6	35	32.5	913.1
K0200	491900	4950199	945.7	42	N.E.	N.E.
K0300	491900	4950257	946.0	47	N.E.	N.E.
K0500	491900	4950544	947.2	65	62	885.2
K0700	491900	4950739	948.5	65	63	885.5
K0900	491900	4950954	943.6	65	59	884.6
K1100	491926	4951099	948.8	50	N.E.	N.E.
K1200	491928	4951200	950.1	140	L.U.	L.U.
K1300	491927	4951298	950.7	65	N.E.	N.E.
K1500	491927	4951499	949.0	65	N.E.	N.E.
K1700	491900	4951699	949.9	65	N.E.	N.E.
K1800	491898	4951800	949.2	65	N.E.	N.E.
K1900	491900	4951900	948.7	65	N.E.	N.E.
K2100	491900	4952101	949.4	65	N.E.	N.E.
K2300	491900	4952301	951.7	65	N.E.	N.E.
K2500	491900	4952500	950.5	65	N.E.	N.E.
K2700	491901	4952699	951.2	55	N.E.	N.E.
K2900	491900	4952900	950.7	65	N.E.	N.E.
K3100	491900	4953099	949.7	65	N.E.	N.E.
K3300	491899	4953299	951.3	65	N.E.	N.E.
K3400	491898	4953399	950.3	65	N.E.	N.E.
K3500	491900	4953500	948.3	45	N.E.	N.E.
K3700	491874	4953701	942.8	45	N.E.	N.E.
KK0000	494486	4950000	933.0	45	N.E.	N.E.
KK0200	494488	4950198	933.2	65	55.5	877.7
KK0300	494499	4950300	929.9	55	N.E.	N.E.
KK0400	494490	4950400	927.3	45	N.E.	N.E.
KK0600	494500	4950599	935.9	40	N.E.	N.E.
KK0800	494496	4950804	934.8	40	N.E.	N.E.
KK0900	494490	4950900	937.0	45	N.E.	N.E.
KK1000	494489	4951001	935.5	40	N.E.	N.E.
KK1200	494489	4951200	934.6	60	N.E.	N.E.
KK1400	494489	4951401	934.3	55	N.E.	N.E.
KK1600	494507	4951649	936.6	48	N.E.	N.E.
KK1800	494480	4951800	932.8	35	N.E.	N.E.
KK2000	494480	4951999	930.0	65	N.E.	N.E.
KK2200	494474	4952200	923.8	65	63	860.8
KK2400	494500	4952380	934.1	65	N.E.	N.E.
KK2600	494510	4952599	932.7	65	N.E.	N.E.
KK2800	494516	4952790	933.1	65	N.E.	N.E.
KK3000	494502	4952999	938.1	65	N.E.	N.E.
KK3200	494510	4953199	933.7	65	N.E.	N.E.
KK3400	494488	4953411	931.7	60	N.E.	N.E.

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TABLE 1
SUMMARY OF GEOLOGIC ASSESSMENT DATA
UMore Park
Rosemount, Minnesota

Soil Boring ID	UTM Location East (meters)	North (meters)	Ground Elevation (feet msl)	Total Depth (feet)	Depth to Water (feet)	Estimated Water Table Elevation (feet msl)
KK3600	494500	4953604	936.7	65	N.E.	N.E.
KK3800	494505	4953774	938.4	65	N.E.	N.E.
L0150	492001	4950150	945.0	35	N.E.	N.E.
L0350	491997	4950349	945.4	65	60	885.4
L0450	491999	4950497	948.9	120	L.U.	L.U.
L0550	491993	4950544	947.3	65	62	885.3
L0750	492001	4950763	943.1	142	L.U.	L.U.
L0950	491983	4950949	948.7	140	60	888.7
L1050	492001	4951016	948.4	120	L.U.	L.U.
L1150	492000	4951149	947.5	65	63	884.5
L1350	492000	4951350	950.1	160	60	890.1
L3050	492000	4953051	949.1	100	65	884.1
LL0350	494601	4950350	928.4	40	N.E.	N.E.
LL0550	494600	4950550	936.7	45	N.E.	N.E.
LL0750	494601	4950751	935.2	37	N.E.	N.E.
LL1250	494601	4951250	933.6	45	N.E.	N.E.
LL1850	494601	4951844	933.9	100	76	857.9
LL2250	494604	4952244	933.5	135	85	848.5
M0000	492076	4950000	944.5	15	N.E.	N.E.
M0200	492101	4950194	945.8	45	N.E.	N.E.
M0400	492100	4950400	946.4	65	61.5	884.9
M0600	492100	4950600	942.2	65	57	885.2
M0800	492071	4950814	939.7	65	55	884.7
M1000	492093	4951010	947.3	65	N.E.	N.E.
M1200	492122	4951199	946.7	55	N.E.	N.E.
M1400	492122	4951398	947.4	65	62.5	884.9
M1500	492088	4951500	948.7	64	63	885.7
M1600	492147	4951629	950.2	45	N.E.	N.E.
M1800	492092	4951802	948.7	65	N.E.	N.E.
M2000	492099	4952000	947.3	65	N.E.	N.E.
M2200	492100	4952201	948.4	65	N.E.	N.E.
M2300	492100	4952297	949.1	65	N.E.	N.E.
M2400	492100	4952401	947.4	45	N.E.	N.E.
M2600	492108	4952596	949.1	50	N.E.	N.E.
M2800	492100	4952779	950.1	55	N.E.	N.E.
M3000	492099	4953000	948.0	65	N.E.	N.E.
M3200	492099	4953199	947.7	45	N.E.	N.E.
M3400	492099	4953400	950.3	45	N.E.	N.E.
M3600	492096	4953591	947.3	45	N.E.	N.E.
M3800	492100	4953801	917.1	40	N.E.	N.E.
MM0100	494701	4950100	934.0	65	59	875.0
MM0300	494700	4950300	929.8	45	N.E.	N.E.
MM0500	494699	4950500	933.2	45	N.E.	N.E.
MM0700	494708	4950685	935.0	34.5	N.E.	N.E.
MM0800	494723	4950805	934.9	28	N.E.	N.E.
MM0900	494708	4950900	933.9	25	N.E.	N.E.
MM1100	494700	4951101	935.1	45	N.E.	N.E.
MM1300	494700	4951301	933.8	65	58	875.8
MM1500	494698	4951500	933.6	65	44	889.6
MM1700	494700	4951699	933.2	60	N.E.	N.E.

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TABLE 1
SUMMARY OF GEOLOGIC ASSESSMENT DATA
UMore Park
Rosemount, Minnesota

Soil Boring ID	UTM Location East (meters)	UTM Location North (meters)	Ground Elevation (feet msl)	Total Depth (feet)	Depth to Water (feet)	Estimated Water Table Elevation (feet msl)
MM1900	494700	4951900	934.1	65	N.E.	N.E.
MM2100	494671	4952072	930.0	65	N.E.	N.E.
MM2120	494716	4952086	931.4	122	L.U.	L.U.
MM2300	494700	4952299	934.7	65	N.E.	N.E.
MM2500	494672	4952554	932.6	65	N.E.	N.E.
MM2700	494719	4952687	934.0	65	N.E.	N.E.
MM2900	494706	4952914	937.0	57	N.E.	N.E.
MM3100	494701	4953100	936.7	65	N.E.	N.E.
MM3300	494700	4953301	921.4	55	N.E.	N.E.
MM3500	494700	4953500	930.4	55	N.E.	N.E.
MM3700	494701	4953698	936.2	50	N.E.	N.E.
N0050	492207	4950066	943.7	25	N.E.	N.E.
N0250	492205	4950251	944.2	65	60	884.2
N0850	492203	4950839	946.8	65	62	884.8
N1250	492242	4951248	945.9	80	L.U.	L.U.
N2450	492200	4952451	944.6	45	N.E.	N.E.
N2850	492202	4952852	948.3	65	N.E.	N.E.
N3050	492200	4953050	948.1	65	N.E.	N.E.
NN0250	494799	4950250	930.9	50	N.E.	N.E.
NN0450	494800	4950449	931.5	45	N.E.	N.E.
NN0650	494799	4950650	934.6	35	N.E.	N.E.
NN1250	494800	4951249	934.3	45	N.E.	N.E.
NN1450	494800	4951450	935.3	52	N.E.	N.E.
NN1850	494805	4951864	932.3	80	L.U.	L.U.
O0100	492300	4950120	945.4	45	N.E.	N.E.
O0300	492298	4950335	945.1	65	60	885.1
O0450	492326	4950454	944.7	130	58	886.7
O0500	492300	4950503	940.1	65	57	883.1
O0500A	492300	4950503	940.1	17	N.E.	N.E.
O0700	492299	4950701	944.9	65	61	883.9
O0800	492300	4950799	947.4	65	63	884.4
O0900	492300	4950900	937.1	65	53	884.1
O1000	492304	4950998	944.4	100	L.U.	L.U.
O1100	492415	4951100	944.4	65	N.E.	N.E.
O1300	492410	4951305	948.1	65	N.E.	N.E.
O1500	492410	4951500	947.0	27	N.E.	N.E.
O1700	492300	4951699	948.1	15	N.E.	N.E.
O1900	492238	4951846	949.8	25	N.E.	N.E.
O2100	492300	4952101	947.6	65	N.E.	N.E.
O2300	492299	4952298	945.1	40	N.E.	N.E.
O2500	492299	4952500	944.5	45	N.E.	N.E.
O2700	492295	4952700	948.8	55	N.E.	N.E.
O2900	492300	4952901	945.5	65	N.E.	N.E.
O3100	492301	4953100	946.9	45	N.E.	N.E.
O3300	492299	4953299	943.9	45	N.E.	N.E.
O3500	492301	4953412	938.7	45	N.E.	N.E.
O3700	492299	4953697	935.1	65	N.E.	N.E.
OO0800	494894	4950799	933.7	35	N.E.	N.E.
OO1000	494921	4951000	942.2	25	N.E.	N.E.
OO1200	494916	4951200	934.2	65	N.E.	N.E.

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Soil Boring ID	UTM Location		Ground Elevation (feet msl)	Total Depth (feet)	Depth to Water (feet)	Estimated Water Table Elevation (feet msl)
	East (meters)	North (meters)				
OO1400	494916	4951400	932.2	45	N.E.	N.E.
OO1600	494900	4951606	930.5	60	55	875.5
OO1800	494878	4951784	931.3	65	N.E.	N.E.
OO2000	494900	4951998	929.5	65	N.E.	N.E.
OO2200	494901	4952199	929.4	65	N.E.	N.E.
OO2700	494871	4952686	934.2	100	L.U.	L.U.
OO2800	494918	4952780	934.4	65	N.E.	N.E.
OO3000	494900	4952999	935.7	65	N.E.	N.E.
OO3200	494882	4953192	929.8	60	N.E.	N.E.
OO3400	494899	4953400	921.4	40	N.E.	N.E.
OO3600	494900	4953600	935.8	50	N.E.	N.E.
OO3800	494901	4953800	933.5	33	N.E.	N.E.
P0850	492403	4950851	947.8	100	60	887.8
P1150	492371	4951151	943.2	80	L.U.	L.U.
P2750	492399	4952750	948.3	55	N.E.	N.E.
P2950	492400	4952950	944.4	45	N.E.	N.E.
PP1250	495015	4951250	933.7	65	63	870.7
PP1450	495016	4951450	933.5	62	N.E.	N.E.
PP2950	494999	4952947	934.2	80	65	869.2
Q0800	492500	4950801	946.2	65	62	884.2
Q1000	492500	4951000	941.9	65	58	883.9
Q1200	492501	4951200	944.0	65	61	883.0
Q1400	492500	4951400	946.1	45	N.E.	N.E.
Q1500	492500	4951500	947.2	20	N.E.	N.E.
Q1600	492569	4951637	951.3	25	N.E.	N.E.
Q1800	492502	4951800	945.4	24	N.E.	N.E.
Q2000	492501	4952000	946.1	30	N.E.	N.E.
Q2200	492423	4952199	943.8	45	N.E.	N.E.
Q2400	492499	4952400	942.0	45	N.E.	N.E.
Q2600	492500	4952600	943.8	45	N.E.	N.E.
Q2800	492500	4952799	945.1	61	N.E.	N.E.
Q3000	492500	4953000	946.2	45	N.E.	N.E.
Q3200	492500	4953199	939.3	45	N.E.	N.E.
Q3400	492501	4953399	941.2	40	N.E.	N.E.
Q3600	492547	4953599	942.0	40	N.E.	N.E.
Q3800	492538	4953801	938.4	45	N.E.	N.E.
QQ0900	495103	4950901	933.2	25	N.E.	N.E.
QQ1100	495100	4951105	931.3	45	39	892.3
QQ1300	495099	4951303	930.5	60	N.E.	N.E.
QQ1500	495100	4951500	929.2	60	57	872.2
QQ1700	495168	4951681	927.9	65	N.E.	N.E.
QQ1900	495099	4951904	927.6	65	N.E.	N.E.
QQ2100	495100	4952101	928.4	65	N.E.	N.E.
QQ2300	495100	4952291	930.9	65	N.E.	N.E.
QQ2500	495129	4952500	932.8	65	N.E.	N.E.
QQ2700	495133	4952698	933.8	65	N.E.	N.E.
QQ2900	495097	4952910	935.5	65	N.E.	N.E.
QQ3100	495093	4953033	930.6	55	N.E.	N.E.
QQ3300	495101	4953300	931.0	45	40	891.0
QQ3500	495099	4953501	933.6	41	N.E.	N.E.

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Soil Boring ID	UTM Location		Ground Elevation (feet msl)	Total Depth (feet)	Depth to Water (feet)	Estimated Water Table Elevation (feet msl)
	East (meters)	North (meters)				
QQ3700	495100	4953700	935.7	35	N.E.	N.E.
R1350	492611	4951349	943.2	35	N.E.	N.E.
R2850	492600	4952850	944.0	45	N.E.	N.E.
RR1150	495199	4951150	931.8	45	N.E.	N.E.
RR1350	495200	4951351	930.0	60	N.E.	N.E.
RR1450	495200	4951450	928.9	65	N.E.	N.E.
RR1850	495203	4951867	929.3	102	L.U.	L.U.
RR2250	495214	4952216	930.6	100	L.U.	L.U.
S0900	492700	4950902	945.7	56.5	N.E.	N.E.
S1100	492700	4951100	943.7	60	N.E.	N.E.
S1300	492701	4951301	937.9	62	56	881.9
S1500	492700	4951499	940.4	40	N.E.	N.E.
S1700	492699	4951701	943.3	20	N.E.	N.E.
S1900	492700	4951900	943.7	25	N.E.	N.E.
S2100	492701	4952100	946.4	35	N.E.	N.E.
S2300	492699	4952299	945.2	45	N.E.	N.E.
S2500	492714	4952490	941.3	40	N.E.	N.E.
S2700	492700	4952699	944.3	45	N.E.	N.E.
S2900	492699	4952899	945.3	45	N.E.	N.E.
S3100	492700	4953016	943.9	45	N.E.	N.E.
S3300	492727	4953298	939.5	45	N.E.	N.E.
S3500	492700	4953499	945.6	45	N.E.	N.E.
S3700	492700	4953700	945.6	40	N.E.	N.E.
SS0800	495300	4950804	929.2	25	N.E.	N.E.
SS1000	495300	4951000	930.0	36	N.E.	N.E.
SS1200	495301	4951202	929.2	36	N.E.	N.E.
SS1400	495301	4951401	928.6	45	N.E.	N.E.
SS1600	495295	4951567	926.3	65	N.E.	N.E.
SS1800	495303	4951868	929.0	65	N.E.	N.E.
SS2000	495303	4952000	928.5	65	N.E.	N.E.
SS2200	495300	4952221	929.1	65	N.E.	N.E.
SS2400	495308	4952398	930.8	65	N.E.	N.E.
SS2600	495309	4952596	932.6	65	N.E.	N.E.
SS2800	495285	4952813	932.7	65	N.E.	N.E.
SS3000	495300	4953001	930.6	56	N.E.	N.E.
SS3200	495300	4953200	923.9	55	41	882.9
SS3400	495301	4953401	933.8	43	N.E.	N.E.
SS3600	495301	4953600	932.9	25	N.E.	N.E.
T1050	492800	4951042	942.9	65	60	882.9
T2650	492772	4952655	942.6	45	N.E.	N.E.
TT0850	495399	4950843	929.7	35	33	896.7
TT1050	495400	4951050	930.2	65	46	884.2
TT1250	495400	4951250	928.6	63	N.E.	N.E.
TT1450	495401	4951450	931.1	65	N.E.	N.E.
TT1850	495391	4951864	929.4	100	77	852.4
TT2950	495400	4952952	930.4	80	65	865.4
U0800	492899	4950801	942.7	65	60	882.7
U0900	492900	4950901	942.4	65	60	882.4
U1000	492901	4951001	941.7	65	60	881.7
U1200	492933	4951201	945.1	55	N.E.	N.E.

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TABLE 1
SUMMARY OF GEOLOGIC ASSESSMENT DATA
UMore Park
Rosemount, Minnesota

Soil Boring ID	UTM Location		Ground Elevation (feet msl)	Total Depth (feet)	Depth to Water (feet)	Estimated Water Table Elevation (feet msl)
	East (meters)	North (meters)				
U1400	492899	4951411	943.6	55	55	888.6
U1600	492893	4951627	946.8	20	N.E.	N.E.
U1800	492900	4951799	939.4	25	N.E.	N.E.
U2000	492869	4951980	942.9	25	N.E.	N.E.
U2200	492900	4952200	946.8	40	N.E.	N.E.
U2400	492886	4952390	943.2	45	N.E.	N.E.
U2500	492897	4952517	940.6	40	N.E.	N.E.
U2600	492900	4952601	939.9	35	N.E.	N.E.
U2800	492900	4952800	944.3	45	N.E.	N.E.
U3000	492900	4953000	938.8	45	N.E.	N.E.
U3200	492894	4953218	945.1	40	N.E.	N.E.
U3400	492900	4953399	941.7	45	N.E.	N.E.
U3600	492901	4953600	945.2	40	N.E.	N.E.
U3800	492900	4953800	944.3	40	N.E.	N.E.
UU0900	495501	4950900	928.1	40	N.E.	N.E.
UU1100	495498	4951100	928.7	45	N.E.	N.E.
UU1300	495500	4951298	926.5	65	N.E.	N.E.
UU1500	495499	4951500	930.5	65	N.E.	N.E.
UU1700	495500	4951688	929.4	65	N.E.	N.E.
UU1900	495502	4951865	929.1	65	N.E.	N.E.
UU2100	495536	4952096	928.8	65	N.E.	N.E.
UU2300	495523	4952296	926.8	65	N.E.	N.E.
UU2500	495476	4952482	929.8	65	N.E.	N.E.
UU2700	495501	4952705	931.9	65	N.E.	N.E.
UU2900	495500	4952907	932.5	65	N.E.	N.E.
UU3100	495511	4953091	929.5	65	N.E.	N.E.
UU3300	495499	4953305	926.4	40	N.E.	N.E.
UU3500	495500	4953499	928.8	25	N.E.	N.E.
V0950	492999	4950950	942.6	80	65	877.6
V1050	493001	4951040	941.9	55	N.E.	N.E.
V1250	493000	4951251	944.1	87	65	879.1
V2250	493001	4952251	943.9	41	N.E.	N.E.
VV2250	495606	4952220	928.0	62	N.E.	N.E.
W0900	493100	4950900	941.2	45	N.E.	N.E.
W1100	493101	4951100	942.4	56	53	889.4
W1300	493100	4951299	941.1	65	63	878.1
W1500	493067	4951500	942.1	45	N.E.	N.E.
W1700	493061	4951705	938.1	25	N.E.	N.E.
W1900	493101	4951900	935.2	30	24	911.2
W2100	493099	4952099	943.3	20	N.E.	N.E.
W2300	493100	4952300	943.2	37	N.E.	N.E.
W2400	493100	4952399	941.1	45	N.E.	N.E.
W2500	493099	4952499	940.1	45	N.E.	N.E.
W2700	493099	4952699	943.1	40	N.E.	N.E.
W2900	493099	4952900	940.2	65	N.E.	N.E.
W3100	493065	4953109	933.1	45	N.E.	N.E.
W3300	493101	4953300	940.3	40	N.E.	N.E.
W3500	493101	4953499	941.5	45	N.E.	N.E.
W3700	493101	4953701	942.7	45	N.E.	N.E.
WW1200	495707	4951225	927.1	60	N.E.	N.E.

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TABLE 1
SUMMARY OF GEOLOGIC ASSESSMENT DATA
UMore Park
Rosemount, Minnesota

Soil Boring ID	UTM Location		Ground Elevation (feet msl)	Total Depth (feet)	Depth to Water (feet)	Estimated Water Table Elevation (feet msl)
	East (meters)	North (meters)				
WW1400	495700	4951400	926.1	45	N.E.	N.E.
WW1600	495701	4951599	925.6	65	N.E.	N.E.
WW1800	495700	4951799	928.9	65	N.E.	N.E.
WW2000	495700	4952001	927.6	65	N.E.	N.E.
WW2200	495701	4952201	929.7	61	N.E.	N.E.
WW2600	495699	4952599	929.6	65	N.E.	N.E.
WW3000	495700	4953000	918.3	65	62	856.3
WW3100	495691	4953082	915.6	80	57	858.6
WW3200	495701	4953199	918.2	45	N.E.	N.E.
WW3400	495692	4953381	917.4	30	N.E.	N.E.
X1050	493200	4951050	942.3	55	N.E.	N.E.
Y0000	493299	4949999	940.3	65	59	881.3
Y0100	493222	4950076	941.4	92	L.U.	L.U.
Y0200	493300	4950200	942.5	65	58	884.5
Y0400	493301	4950400	942.5	65	60	882.5
Y0600	493299	4950600	942.3	65	60	882.3
Y0800	493299	4950801	939.8	65	N.E.	N.E.
Y1000	493304	4951011	940.2	45	N.E.	N.E.
Y1200	493300	4951202	941.4	36	N.E.	N.E.
Y1400	493301	4951376	937.6	65	58	879.6
Y2400	493300	4952398	937.8	50	N.E.	N.E.
Y2600	493300	4952600	939.7	45	40	899.7
Y2800	493314	4952800	932.3	45	N.E.	N.E.
Y3000	493388	4952976	940.2	45	N.E.	N.E.
Y3200	493303	4953209	938.5	45	N.E.	N.E.
Y3400	493312	4953401	939.2	40	N.E.	N.E.
YY1300	495901	4951325	920.4	45	N.E.	N.E.
YY1500	495900	4951501	925.4	45	N.E.	N.E.
YY1900	495931	4951900	928.5	65	N.E.	N.E.
YY2100	495905	4952100	929.4	65	N.E.	N.E.
YY2900	495901	4952918	928.1	65	N.E.	N.E.
YY3100	495896	4953082	913.2	65	57	856.2
YY3300	495900	4953300	904.7	45	44	860.7
YY3300A	495900	4953300	904.7	10	N.E.	N.E.
Z1050	493400	4951049	941.9	40	N.E.	N.E.
Z1250	493400	4951249	942.1	65	60	882.1

N.E. = Groundwater not encountered.

L.U. = Groundwater level uncertain.

Data Source: Geological Assessment, UMore Park, Rosemount and Empire
        Township, Minnesota by ProSource Technologies, Inc., 2008.

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data\Append B Geologic Assessment Data.xls

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Legend
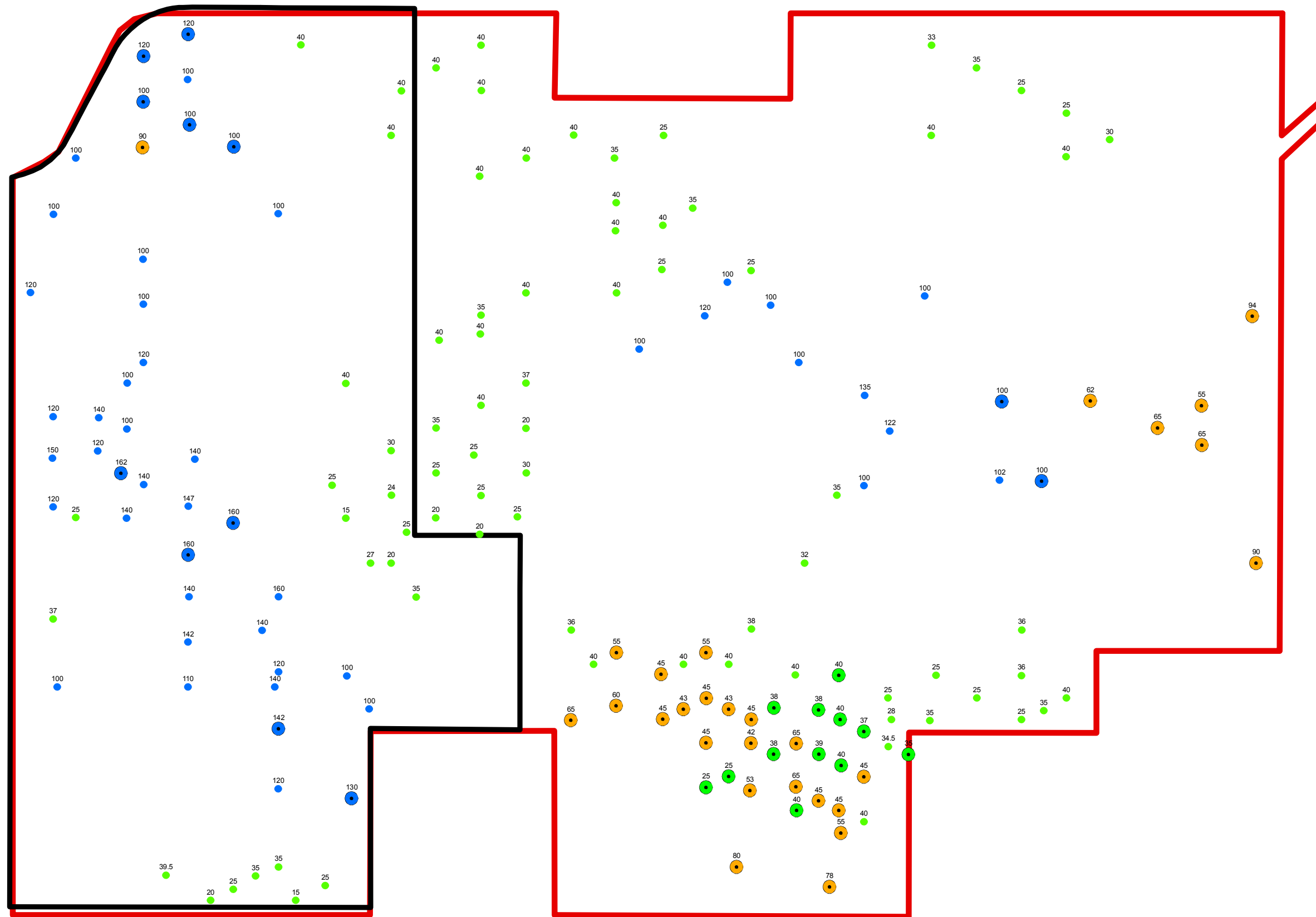
- Shallow (≤40') boring
- Shallow (≤40') boring terminating at bedrock
- Deep (41-99') boring terminating at bedrock
- Deep (≥100') boring
- Deep (≥100') boring terminating at bedrock
- Umore Park Boundary**
- EIS Study Area

Source: ProSource, SEH, Barr.

*Boring depths and material at bottom of deposit from ProSource, 2008.

**Property Boundary is Approximate - Users may not rely on infomation presented without verification of boundary survey performed on 12/14/2007 by Hakanson Anderson Associates Inc. and written permission of the University of Minnesota.

N

Feet

1,500   0   1,500

Appendix B

SOIL BORING DEPTHS
UMore EIS
Dakota County, MN

UMP003184
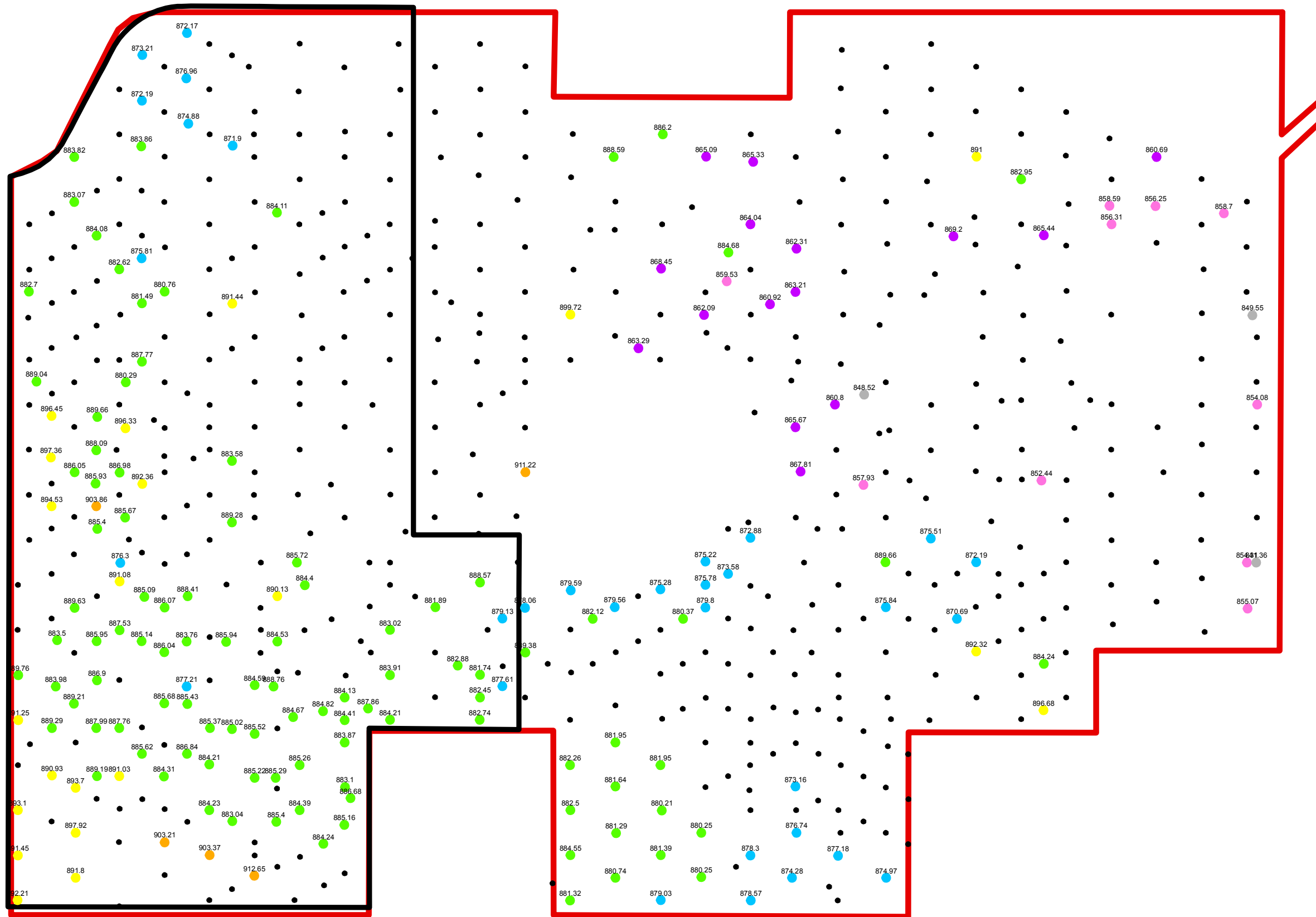
Boring Location
• (no groundwater elevation data)

Approximate Groundwater Elevation Range*
(feet)
● > 900
● 890 - 900
● 880 - 890
● 870 - 880
● 860 - 870
● 850 - 860
● < 850
▭ Umore Park Boundary**
▭ EIS Study Area

Source: ProSource, SEH, Barr.

*GE elevations derived from ProSource, 2008.
Ground Elevation - depth to water (in soil borings).

**Property Boundary is Approximate - Users may not rely
on information presented without verification of boundary
survey performed on 12/14/2007 by Hakanson Anderson
Associates Inc. and written permission of the University
of Minnesota.

N

Feet
1,500   0   1,500
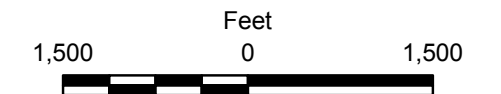
Appendix B

GW ELEVATIONS AT BORINGS
UMore EIS
Dakota County, MN

BARR

UMP003185

Appendix C

Metro Model Data

From: Evan G. Christianson
Sent: Monday, September 29, 2008 10:36 AM
To: Jim S. Aiken
Subject: Quat. Zone K Values

Jim,

Here are K values for the Quaternary zones around UMore. As you can see they cover several
orders of magnitude. One of the biggest flaws with the metro model is the wide range of K
values in the Quaternary with very little data to support the values. The highest K is zone 25
which clips to southwest corner of the UMore site. This may be the model telling us that there
is a lot of outwash with high K, or it could be a coincidence. The UMore site only covers zones
25 and 15, the others are surrounding.

Evan

Zone	K Value (m/day)
49	0.1
26	13.6
25	100
15	7.0
29	27.4

All major bedrock and glacial-drift aquifers and aquitards are included
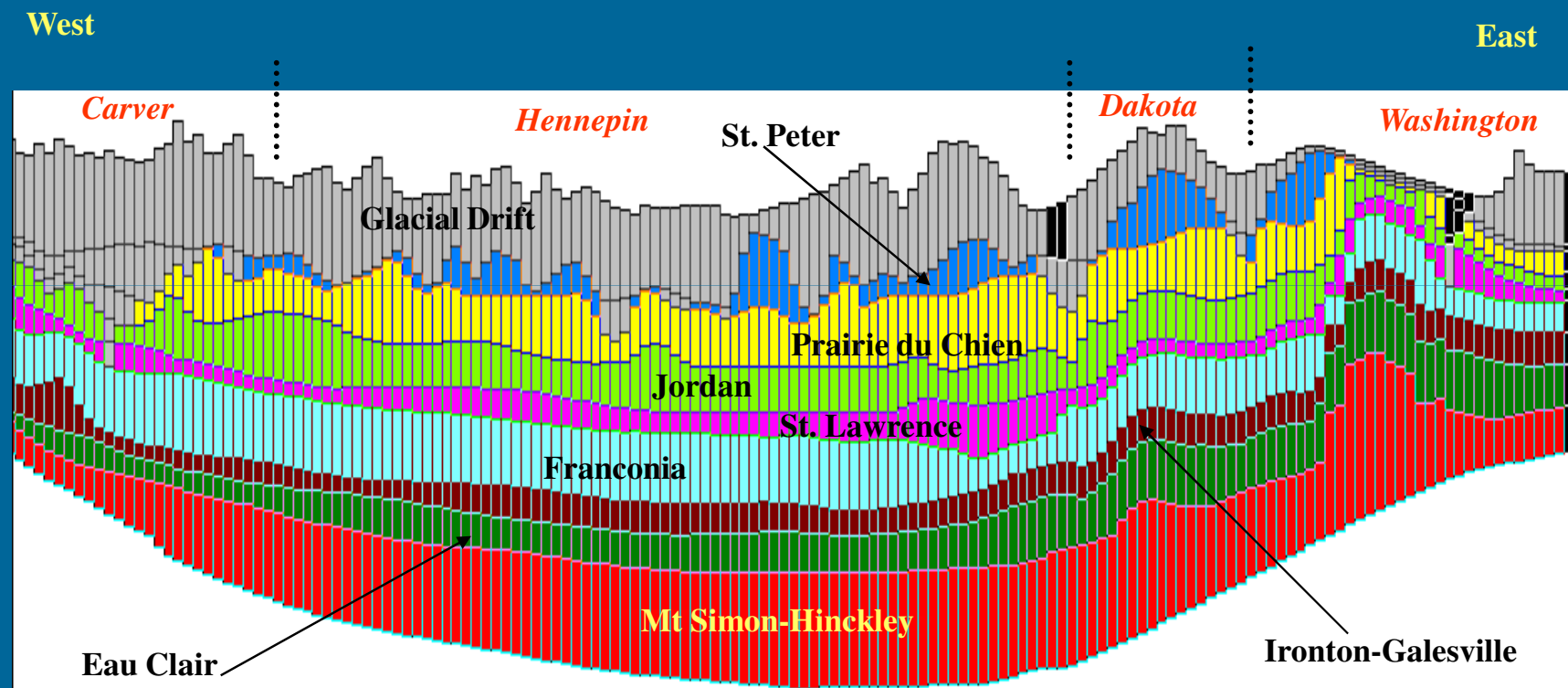
West-East Cross Section Through South Portion Of Model

UMP003188
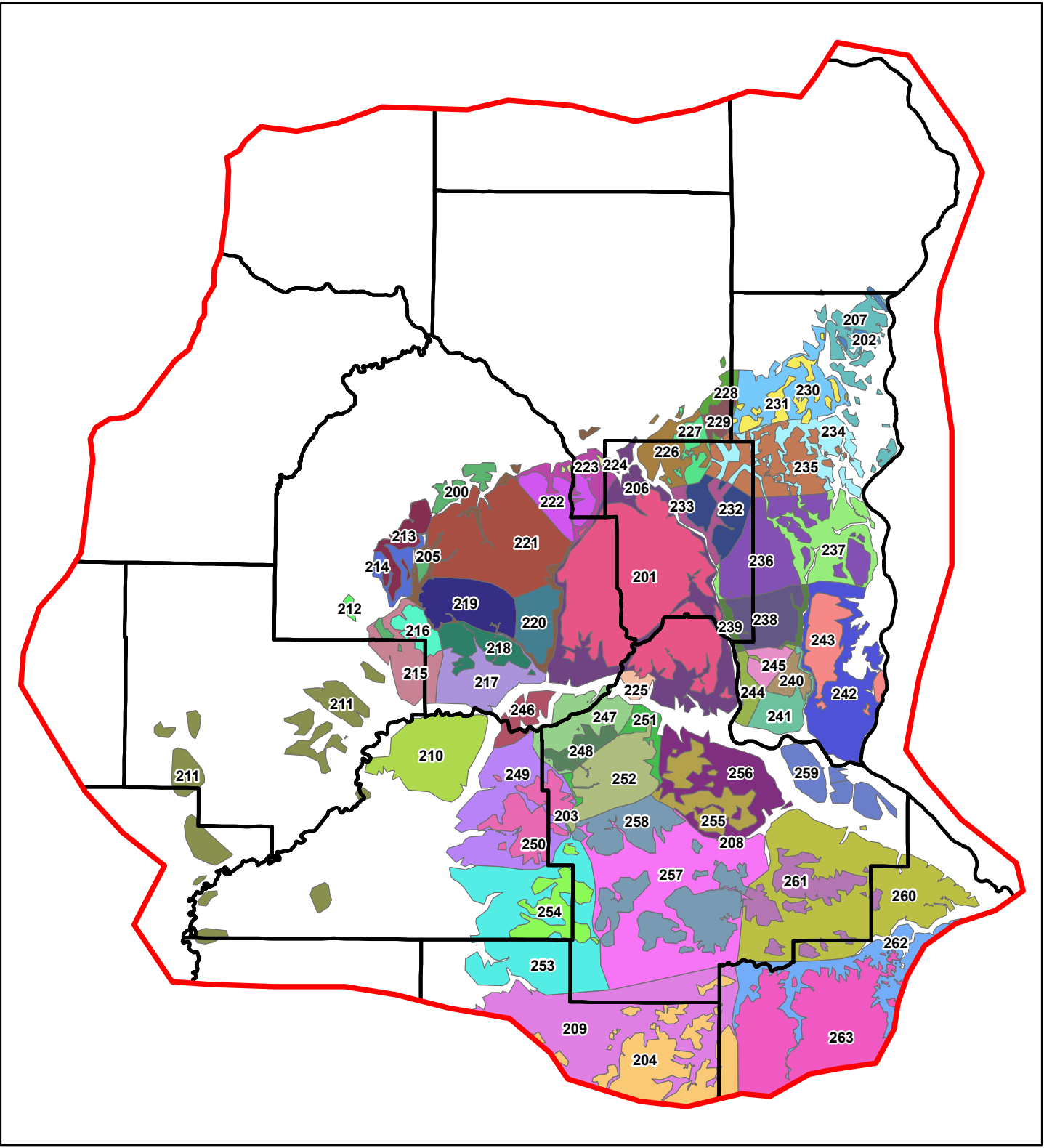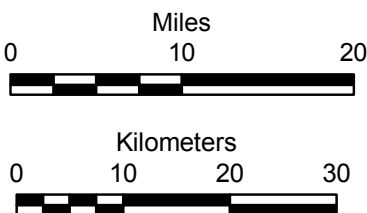
Figure X
Prairie Du Chien K Zones
Water Supply Availability Analysis
Metropolitan Council

Legend
— **Model Domain**
▭ **County Boundary**

Miles
0   10   20

Kilometers
0   10   20   30

N

Barr Footer: Date: 9/26/2008 11:08:19 AM   File: I:\Projects\23\62\954\GIS\MapsFor_Report\K_ZonesBy_Unit\OPDC_Zones.mxd User: egc

UMP003189

Legend

Model Domain
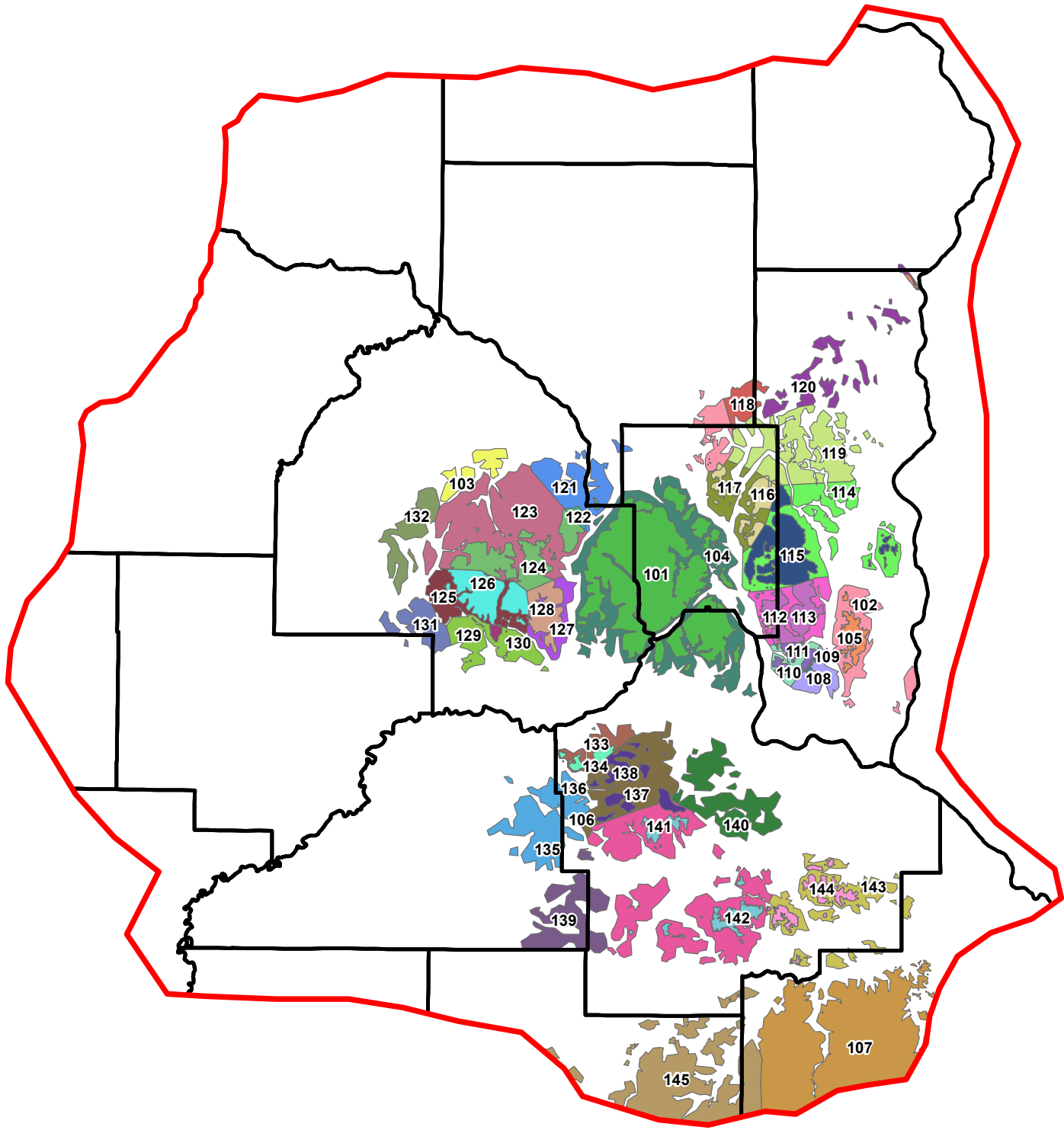
County Boundary

Miles
0   10   20

Kilometers
0   10   20   30
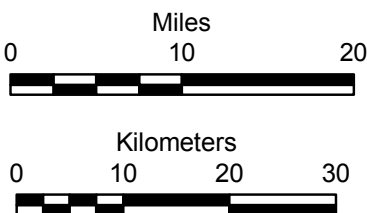
Figure X
St. Peter K Zones
Water Supply Availability Analysis
Metropolitan Council

UMP003190
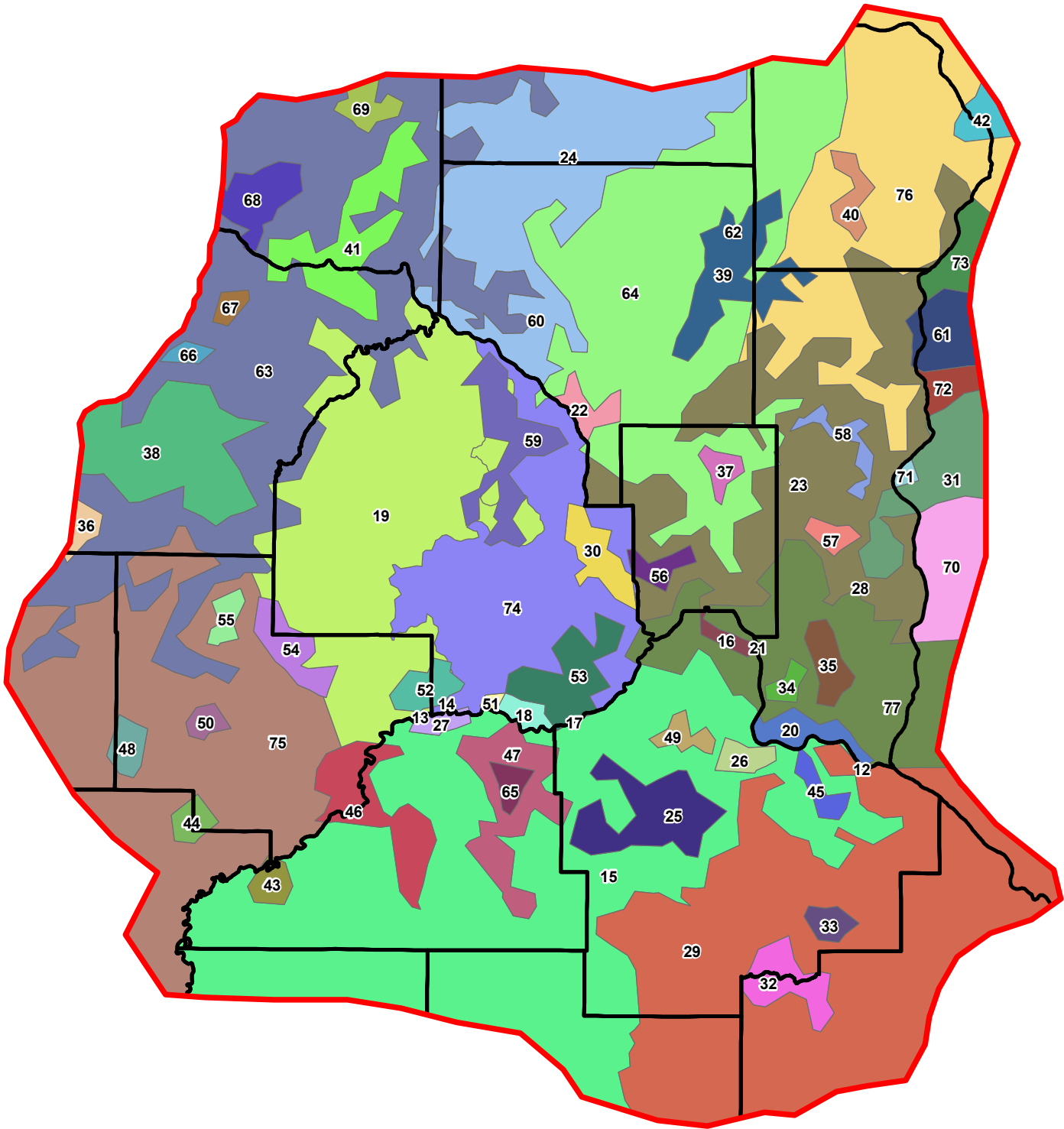
Legend

— **Model Domain**

☐ **County Boundary**

Miles

0   10   20

Kilometers

0   10   20   30

Figure X
Quaternary K Zones
Water Supply Availability Analysis
Metropolitan Council

UMP003191

Appendix D

Empire Township EIS

LEGEND
▨▨▨▨▨▨
MINING BOUNDARY

PROJECT AREA

ROSEMOUNT
POP. 14,619

COATES
POP. 163

FARMINGTON
POP. 12,365

Empire
EST. POP. 120

HAMPTON
POP. 434

EMPIRE

ROSEMOUNT RESEARCH CENTER

UNIVERSITY OF MINNESOTA
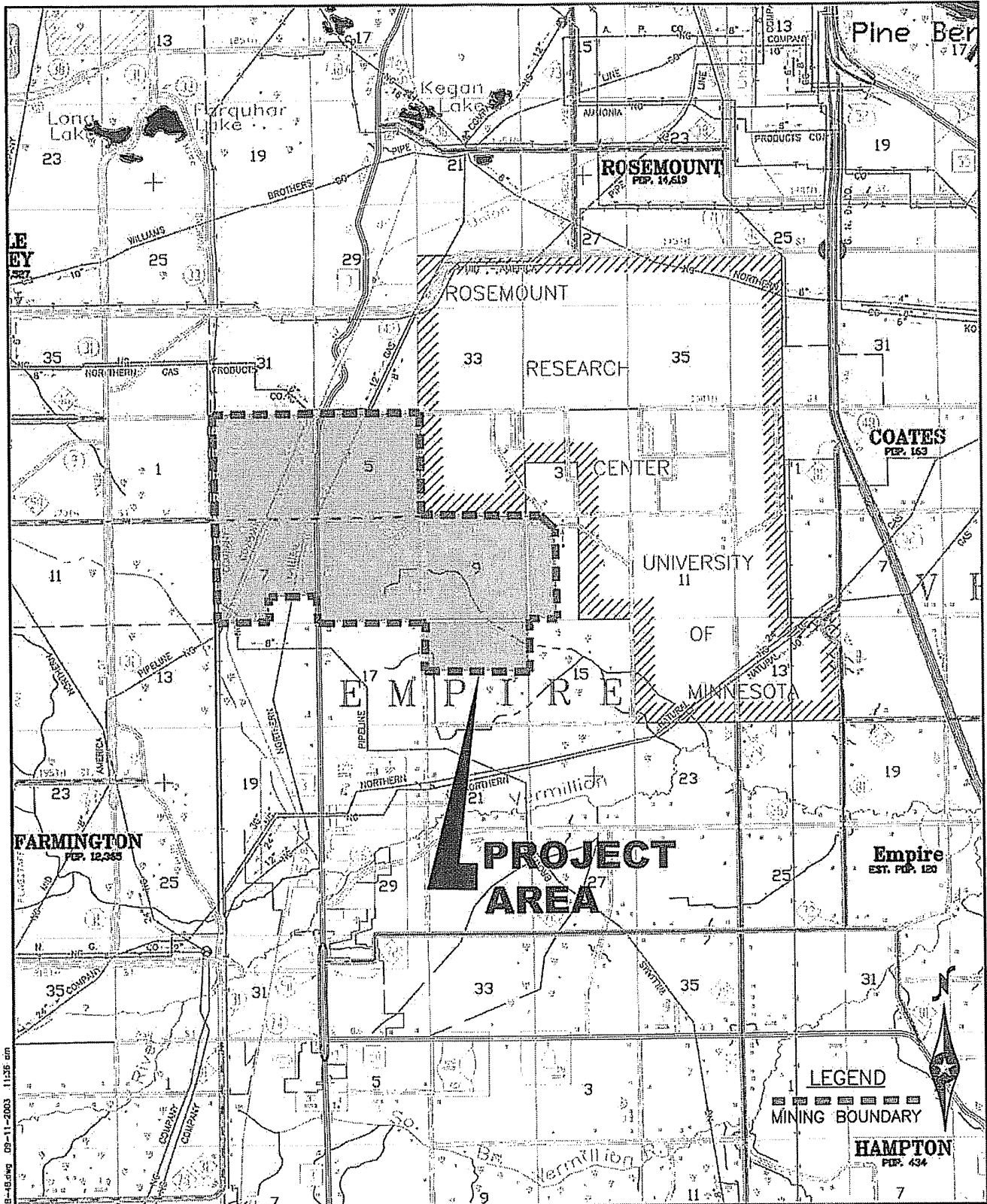
BOLTON & MENK, INC
CONSULTING ENGINEERS & SURVEYORS
MANKATO, MN   FAIRMONT, MN   SLEEPY EYE, MN   WILLMAR, MN
BURNSVILLE, MN   CHASKA, MN   AMES, IA   LIBERTY, MO

SAND & GRAVEL MINING AND ACCESSORY USES
EMPIRE TOWNSHIP, DAKOTA COUNTY
VICINITY MAP

JULY, 2003   EXHIBIT NO. 1B

UMP003193

Revised Groundwater Impact Study

Sand & Gravel Mining and Accessory Uses
Empire Township, Dakota County, MN

October 24, 2005

Prepared by

700 Third Street South, Suite 600
Minneapolis, MN 55415-1199

TABLE OF CONTENTS

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TABLES

FIGURES

UMP003198

1.0 INTRODUCTION

1.1 Project Description

A consortium of mine operators and landowners (Mining Consortium) propose to open new aggregate mines and expand existing aggregate Mining Areas to include a total area of approximately 3,600 acres in the northwest portion of Empire Township, Dakota County. Proposed mining will be consistent with Empire Township Ordinance Number 450 as amended and shall generally be consistent with ongoing practices at existing mines within and adjacent to the Mining Area. Routine functions as well as ancillary operations are described in detail below.

Mining and Aggregate Processing

- Clearing and grubbing the site of vegetation and structures, as necessary
- Relocation of infrastructure, as necessary
- Excavation and transport of the raw aggregate materials
- Excavation, stockpiling, and transporting of other soils materials, including clay and topsoil, which may be present within the Mining Area for shipment to sites out of the Mining Area or for use in reclamation
- Washing, grading and stockpiling aggregate materials for sale or later internal use
- Transporting and stockpiling waste "fines" for potential later use in reclamation
- Transporting finished aggregate materials internally for subsequent processing and to construction sites beyond the Mining Area
- Transporting, accepting, and stockpiling clean, compactable fill materials, typically referred to as "backhauled", for potential later use in reclamation
- Transporting, accepting, and stockpiling clean organic soil materials (i.e., peat) for potential later use in reclamation
- Eventual redistribution, compacting, grading of overburden and clean fill materials to reclaim the sites

Ancillary Manufacturing

- Manufacture and transport of asphalt products
- Manufacture, stockpiling, warehousing and transporting of ready-mixed concrete, bagged mortar products, concrete block, concrete pavers, concrete pipe, concrete plank, etc.
- Importing, grading, processing and stockpiling aggregates to be blended with local aggregates in the production of various products which will increase the effective use of the local aggregates and extend the life of the resource
- Transporting, accepting and recycling products returned from construction sites, including "come-back" asphalt, ready-mixed

concrete, bagged mortar products, concrete block, concrete pavers, concrete pipe, concrete plank, etc.

- Transporting, accepting, stockpiling and processing recycled construction materials for inclusion in new products

General Operations and Administrative
- Offices and sales areas
- Equipment maintenance areas
- Fuel storage and refueling areas

Currently, various companies included in the Mining Consortium either own, lease, or have purchase options on a majority of the Mining Area. Those properties not currently controlled by the mining companies are included in this study in recognition that future mining could occur. The mine operators with current and/or future interest or ownership in the Mining Area include:

- Aggregate Industries North Central Regional (Aggregate Industries)
- Cemstone Products Company (Cemstone)
- Dakota County Transportation Department (Dakota County)
- Fischer Sand and Aggregate Company (Fischer)
- Heikes Property (Heikes)
- McNamara Contracting, Inc. (McNamara)
- Tiller Corporation (Tiller)
- Don Peterson (Peterson)

1.2   Purpose of this Study

The various mine operators have investigated the potential for aggregate production in this area. In addition, the Minnesota Geologic Survey (MGS), Minnesota Department of Natural Resources (DNR), Metropolitan Council (METC) and local governments have conducted studies of available mineral aggregates in the metropolitan area. These studies, together with investigations conducted by mining companies, have revealed extensive reserves of mineral aggregates in portions of Empire Township. Over the next 30 to 40 years the Mining Consortium proposes to mine and process approximately 200 million tons of sand and gravel reserves within the Mining Area.

A Scoping Environmental Assessment Worksheet (Scoping EAW) was prepared for the proposed project in October 2003. Following review of this document, the Minnesota Environmental Quality Board (EQB) designated the review process as a "Related Actions Environmental Impact Statement (EIS)", since multiple companies and property owners are involved. A Scoping Decision Document was published in February 2004 declaring the need for an EIS and an outline of what it would address.

The Scoping Decision Document required that additional analysis be completed for the Mining Area, addressing a number of topics, including groundwater. The

original Groundwater Impact Study dated January 2005 was prepared to provide an analysis of reasonable worst-case groundwater impacts in the Mining Area, and to identify options for mitigating potential impacts. The findings of the original Impact Study were incorporated into Empire Township Draft EIS (March 2005) and Final EIS (June 2005). As a result of agency comments made on the EIS documents, revisions were made to the original impact study, and are incorporated into this Revised Groundwater Impact Study.

1.3   Project Location and Setting

The project is proposed for Empire Township, which lies in the central portion of Dakota County, MN (**Figure 1R**). The proposed Mining Area is in the northwest portion of the township, occurring in all or part of Township (T) 114N, Range (R) 19W Sections 5, 6, 7, 8, 9, 10 and 16.

1.4   Study Area

The Vermillion River is one of the primary discharge areas for groundwater. It is necessary to understand the relationship between the river and groundwater that discharges on both sides of the river to be able to understand surface water and groundwater interactions on and around the proposed Mining Area. Therefore, it is necessary that the Study Area cover a large area, as shown in **Figure 2R.**

The Study Area also includes Wellhead Protection Areas (WHPAs) and Drinking Water Supply Management Areas (DWSMAs) for the city of Rosemount, located immediately north of the Mining Area (**Figure 2R**). These are found in T115N, R19W, Sections 27, 29, 30, 31, 32, 34 and T114N, R19W, Section 6. Rosemount wells 3, 7, 8, and 9, in addition to rural wells 1 and 2 are currently utilized to provide the City's drinking water. Portions of the DWSMA and WHPA for Rosemount Well 8 extend approximately 3,000 feet into the northwestern portion of the proposed Mining Area, encompassing a majority of Section 6.

1.5   Previous Studies

The studies, reports and databases listed below were reviewed as a part of the Groundwater Impact Study. Unless specifically referenced in the text the information was reviewed by the author but not necessarily included in the report. As expected, there is a wealth of information concerning the Vermillion River Watershed and the aquifers that underlay Dakota County. The information available covers an extensive period of time and is of varying quality and completeness.   The author attempted to use the best available information in completing this report while avoiding the use of dated or incomplete information. The most recent information included in this report is from *A Soil Boring & Monitoring Well Installation Report, Empire Township, Minnesota* and *Scoping Environmental Assessment Worksheet, Sand & Gravel Mining & Accessory Uses,* which summarizes an extensive amount of site specific geological data collected to evaluate the mineral deposits. The author was able to make great use of the County Well Index and the Scott Dakota County MODFLOW Model.

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2.0 GROUNDWATER METHODS AND ASSUMPTIONS

A three-dimensional numerical groundwater flow model was developed to simulate the groundwater flow system in the Study Area. The model was developed using the USGS computer program MODFLOW (McDonald and Harbaugh 1988; 1996). MODFLOW is a standard, state of the practice, well-documented model code that simulates groundwater flow through three-dimensional, heterogeneous, anisotropic aquifer systems by iteratively solving the finite-difference approximation of the equation for groundwater flow. For this study, the model is designed as a steady-state flow model, because groundwater flow within the Study Area is generally stable. In addition, a simulated steady-state flow field is adequate for simulating the long-term fate and transport of potential impacting factors from the Mining Area.

For this study, the objective of this modeling is to evaluate and quantify the potential of the aggregate mining operations on local water resources. As a first step in the modeling process, potential impacts of Mining operations were identified. These potential impacts include changing of the groundwater flow regime in the Vermillion River Basin, possibly resulting in impact to local wetlands, municipal supply wells in wellhead protection areas, and local brown trout population of the Vermillion River. In addition, potential thermal impacts caused by excavation and aggregate washing were considered. After identifying these potential impacts, the numerical model was designed, set up, and calibrated to simulate the presently existing groundwater conditions. The model was then applied to simulate changes in the system resulting from mining (see Section 4).

2.1 Numerical Flow Model Design

The numerical flow model is a mathematical representation of the conceptual flow model. The design of a numerical model basically consists of three parts: (1) the configuration of the model, which represents the configuration of the aquifer; (2) boundary conditions, including sources and sinks, which represent the interactions of groundwater with internal and external water bodies; and (3) the parameters, which represent various properties of the aquifer.

2.1.1 Model Domain and Discretization

The domain is rectangular, encompassing the proposed Mining Area in addition to the surrounding areas they may be impacted by future mining operations. The rectangular model domain consists of a variable grid of model cells varying in dimension from 350 by 350 feet, refined to 100 by 100 feet in the project area to better simulate the hydrologic complexities of this area. The model domain consists of three layers, representing the three hydrostratigraphic units described in Section 3.2: (Layer 1) Glacial Drift-St. Peter Sandstone; (Layer 2) Prairie du Chien Group; and (Layer 3) Jordan Sandstone. Each layer contains 190 rows and 265 columns, and 151,050 active model cells. The numerical model domain and grid are shown on **Figure 3R**.

The groundwater mounds are interpreted to occur in a fictional model layer 0, which interacts with actual model layer 1 in a manner like rainfall infiltration (see **Figure 17R**). Water from layer 0 might cascade down at the edge of the Glennwood Formation, but the correct amount and location of water entering the top of layer 1 can probably be modeled adequately by using typical values of infiltration as if the Platteville-Glennwood is not there. Head values measured in or above the Platteville would not be part of the calibration target. Hydraulic conductivity values in model layer 1 below the Glenwood would reflect the full thickness of the St. Peter, and be on the upper end of reported values, rather than the lower end.

2.1.2 External Boundary Conditions

The model external boundary conditions represent the hydrologic interaction between the areas inside and outside of the model. The perimeters of each model layer were designated as specified head boundaries according to the interpreted groundwater potentiometric surface (surface that represents the level to which water will rise in tightly cased well; the water table is a particular potentiometric surface for an aquifer) shown in **Figure 4R**. The groundwater contour lines indicate that groundwater flows into the model domain from west and southwest and flows out of the model domain along the east and northeast margins. Along these boundaries, prescribed head boundary conditions were specified as the head values from the interpreted potentiometric surface. This allows groundwater flux (flow through a prescribed area over a given time)to enter or exit through the specified head boundaries as indicated by the interpreted potentiometric surface.

2.1.3 Groundwater Recharge

Groundwater recharge (net flux into aquifer system is positive) was specified for area recharge and floodplain recharge, and simulated as an areally distributed (spatially distributed) specified flux using the MODFLOW Recharge Package.

This recharge distribution is modified from the distribution delineated by Barr Engineering (1999) in the Scott-Dakota County model using sand-content maps provided by MPCA Metro Modeling Group. The distribution is generally the same given differences in scales between the two models and respective studies. In addition, the recharge distribution emphasizes the importance of recharge from the floodplains and wetlands. Areal groundwater recharge from precipitation in the proposed Mining Area is approximately 4.5 in/yr.

There is no direct information available to define floodplain and wetland recharge rate. Nonetheless, the modeled floodplain recharge zone is delineated based on the 100-year floodplain and wetland distribution delineated in **Figure 2R**. The rate of floodplain recharge is calibrated as 9 in/yr. This rate represents the upper limit of recharge available from precipitation after allowing for evapotranspiration (Schoenberg, 1990). The distribution of recharge simulated in the model is depicted in Figure 18R.

2.1.4 Vermillion River and Associated Tributaries

The perennial portions of the Vermillion River and associated tributaries are represented as a head-dependent boundary condition using the MODFLOW River Package. Specification of model river cells is shown in **Figure 3R**. The purpose of this package is to simulate flow of water between surface water features and groundwater systems. The rate and direction of flow is dependent upon the head gradient between the river and groundwater. Flow between the river and aquifer is assumed to occur in one-dimension.

Based on field observations and streamflow data from the USGS gauging station located southeast of the project area, the river stage was assigned as 3.0 feet above the topographic surface. However, field observations suggest the river stage is approximately 1.0 foot in depth upstream near the confluence of North Creek. Flow rates (described in Section 3.6.1) were used as targets for model calibration. The conductance of the river cells was calibrated with specified constraints during model calibration.

2.1.5 Wetlands

Groundwater also discharges (next flux of water into the aquifer system is negative, i.e. losing water) to wetlands where the groundwater table intersects the ground surface. Wetlands were simulated using the MODFLOW DRAIN package. Specification of model drain cells is shown in **Figure 3R**. The purpose of this package is to simulate groundwater flow discharging to the wetlands. The distribution of the wetlands simulated as groundwater discharge features is based on a map of delineated groundwater dependent natural resources provided by EOR (2004a). The bottom elevations of the drain cells were specified approximately according to the topographic surface at the appropriate locations.

Because information for the wetlands is limited, the conductance for these features was specified between 2,500 to 5,000 ft^2/day, accordingly, without model calibration.

2.1.6 Pumping Wells

In the model, pumping wells are represented as a specified flux boundary using the MODFLOW Well Package. Wells are assigned to the model layer based on the stratigraphic position of the pumping well screen. For example, wells screened and pumping from the Jordan Sandstone are assigned to layer three of the groundwater model. Pumping rates are assigned based on rates provided by the Minnesota Department of Health in the Scott-Dakota County regional groundwater modeling report (Barr Engineering, 1999).

2.1.7 Hydraulic Parameters

In the numerical flow model, hydraulic parameters, such as distribution of hydraulic conductivity (a coefficient of proportionality describing the rate at which water can move through a permeable medium), vertical anisotropy (exhibiting properties with different values when measured in different directions)

and conductance of model river cells were adjusted during model calibration. The final selected hydraulic parameters are discussed in Section 2.2.2.

2.2 Calibration Strategies

Model calibration is an important process to adjust various parameters, boundary conditions, and hydraulic stresses to make the model reflect actual site conditions. Parameter values are adjusted consistent with available data to match calibration targets to a reasonable degree. Model calibration is a process that allows examination and improvement of the conceptual model. Only a calibrated model is credible for use to perform model prediction simulations. The overall goal of model calibration was to make the model results match the observed flow conditions.

2.2.1 Calibration Targets

The flow model calibration targets include not only the measured hydraulic heads at monitoring wells, but also (1) the groundwater flow pattern, hydraulic gradients, and flow pathways; and (2) the measured or estimated flux. The flow model calibration targets included:

- Water levels from newly installed Empire monitoring wells and available water levels from the Minnesota County Well Index
- Estimated groundwater discharge rates to the Vermillion River between gauging stations BSC2 and USGS Station
- Estimated groundwater discharge rates to North Creek between gauging stations CHP3 and 801
- Estimated groundwater discharge rates to Center Creek between gauging stations PKN1 and 801
- General trend of vertical hydraulic gradients

2.2.2 Calibration Parameters

The flow model calibration parameters include:

- Horizontal hydraulic conductivity distribution in all three model layers
- Vertical anisotropy of horizontal hydraulic conductivity versus vertical hydraulic conductivity, (*i.e.*, Kx/Kz; Ky/Kz), assumed to be uniform over each layer
- Distributed conductance for all river cells
- Distributed conductance for all drain cells (wetlands)

During model calibration, the adjustment of these parameters is targeted to meet the various calibration targets (Section 3.2.1) and is bounded by specified upper and lower limits, which are chosen based on available information and understanding of the hydrogeologic system.

2.3 Flow Model Calibration Results

The model calibration results are evaluated from various aspects, including comparison to the observed hydraulic heads, groundwater potentiometric surface, horizontal and vertical hydraulic gradients, groundwater flow pathways, estimated flux, and overall mass balance.

2.3.1 Simulated Potentiometric Surface and Hydraulic Heads

Figure 5R presents the simulated groundwater contours in comparison with the interpreted contours from **Figure 4R**. The general flow patterns match reasonably well with flow converging from the west and southwest toward the Vermillion River and northeast toward the Mississippi River. The hydraulic gradient distributions generally match well also, with fairly consistent gradients away from the creeks and variable gradients near and along the floodplains. As expected, the model shows a relatively poor match at topographic highs (groundwater mounds) where data is unavailable, and the mounds represent perched conditions not sufficiently connected to the regional groundwater system. While the model simulated heads do not match the data exactly, the general flow pattern is well represented.

Comparison of measured hydraulic head values to those simulated by the model is the primary basis for judging the calibration results. The overall standard deviation versus the head range in the entire model domain is 0.047. The standard deviation versus the hydraulic head range of the model in Layer 1, where most of the wells are located, is 0.040; 0.057 in Layer 2; and 0.135 in Layer 3. Based on the rule of thumb that the standard deviation versus head range should be equal to or less than about 0.10, the calibration results are considered adequate.

The match of hydraulic heads in layers 2 and 3 is not as good as for Layer 1, however, the overall flow pattern to the northeast is well represented. The poorer fit in these layers is primarily due to the limited understanding of local heterogeneity in the deeper zones. In addition, there are a limited number of hydraulic head measurements in the deeper aquifers in this region. And those that do exist may be in question. For example, in an area where hydraulic heads should be approximately 820 ft based on average regional hydraulic gradients, two adjacent wells from the Minnesota County Well Index are located approximately 500 feet apart exhibit water levels of 795 feet and 915 feet – phenomenon that appears unrealistic given the general knowledge of the flow system. Consequently, the model predicted hydraulic head values for the lower model layers are subject to large uncertainties.

2.3.2 Simulated Vertical Hydraulic Gradients

The general spatial trend of vertical hydraulic gradients is important to migration of potential contaminants that may enter the groundwater system during mining operations; thus, it is necessary to be simulated in the model calibration. However, the local vertical hydraulic gradient is also controlled by the local

heterogeneity, which is not well understood and not possible to be simulated adequately at the scale of this model. Therefore, comparison of model simulated and observed vertical hydraulic gradients focused on the general spatial trend and the direction of vertical gradients rather than gradient values.

The regional vertical gradients are simulated reasonably well, upward gradients along the Vermillion River and adjacent floodplains and downward gradients away from the river. Discrepancies between measured and simulated vertical gradient may be due to local heterogeneity beyond current understanding of the hydrologic system, or model errors. It should be noted that even though a comparison of magnitude of vertical gradient is not presented, it was utilized in critical areas in the model calibration.

2.3.3 Model Mass Balance

Under steady-state, the inflow to the model and outflow from the model should be balanced. For the calibrated model, the overall simulated water budget is as follows:

Table 2-1: Model Mass Balance Summary

Sources and Sinks	Inflow to Model		Outflow from Model	
	(ft^3/day)	(%)	(ft^3/day)	(%)
Specified Head Boundaries	1,258,057	35.7	2,157,159	61.0
Recharge	1,943,686	55.2	0	-
River	318,727	9.1	613,512	17.3
Drains (Wetlands)	0	-	766,034	21.7
Total	**3,520,470**	**100**	**3,536705**	**100**

Note: Percent Error is –0.0046

According to this water budget, the primary source of water to the groundwater system is groundwater recharge, including areal recharge and floodplain recharge. The primary groundwater discharge component is discharge to the rivers and lateral flow out of the model domain to the northeast through the specified head boundaries.

2.3.4 Simulated Groundwater Discharge to Vermillion River and Tributaries

Simulated groundwater discharge to creeks depends on the specified river stage elevations, calibrated creek conductance, simulated groundwater levels, and calibrated hydraulic conductivity of the aquifer. In addition, estimated discharge includes discharge to the river channel in addition to wetlands located along the banks of the river drainages which are interpreted to contribute to the overall discharge. Table 2-2 presents a summary of simulated discharge to select portions of the Vermillion River and associated tributaries.

Table 2-2: Summary of Model Simulated Groundwater Discharge to the Vermillion River and Associated Tributaries

River Segment	Model Simulated Net Discharge (ft³/day)	Model Simulated Net Discharge (cfs)	Estimated Discharge[1] (cfs)	Estimated Discharge[2] (cfs)
Vermillion River, between BSC2 and USGS Station.[3]	621,947	7.2	3.6	10 - 25
North Creek, between CHP3 and 801	94,833	1.1	2.5	0.01 - 10
Middle Creek, between PKN1 and 801	184,228	2.1	2.3	25 –40

[1] Baseflow estimates based on average unit discharge of 1.20 cfs/mile obtained by the Minnesota Department of Health from the Metropolitan Council.
[2] Baseflow estimates from EOR (2004).
[3] Includes contribution from Unnamed Tributary 1.

As indicated in Table 3-3, North Creek discharge is within the range provided by EOR (2004) and comparable to the estimate of MDH. Simulated baseflow (flow solely attributed to groundwater flow) to Middle Creek is comparable to the estimate of MDH, but much lower than the estimate of EOR (2004). The baseflow estimate of 25 to 40 cfs for Middle Creek (EOR, 2004) may be unreliable. One of the gauging stations used for estimates was also used for an estimate of baseflow for a downstream section of the Vermillion that estimated a loss of 15 to 30 cfs. An unlikely scenario given that the majority of the upper reaches of the Vermillion River and its associated tributaries maintain a relatively uniform discharge rate of 0.01 to 10 cfs. Thus, the estimated discharge provided by MDH is considered a more reliable estimate at this time.

The baseflow estimate of the Vermillion of 7.2 cfs is lower than estimated range by EOR (2004), but is greater than the estimated discharge by MDH. To achieve discharge rates of 10 cfs or higher requires using river conductance values that are unrealistic. The discharge estimate of 7.2 cfs may be considered representative of very low baseflow conditions, which in turn, will add to the conservatism in estimates on the impacts to surface waters presented in Section 4.

The groundwater model only simulates a small portion of the Vermillion River. Total baseflow in the Vermilion River is the sum of the model-simulated discharge in addition to discharge to the river that is upgradient of the model domain. Estimates of discharge upgradient of the model domain using both information from EOR and MDH indicate approximately 30 cfs of baseflow in the Vermillion and its associated tributaries. This coupled with the 10.4 cfs of discharge in the model indicates a simulated baseflow of approximately 40 cfs observed at USGS gauging station 05345000. This is comparable to the 10-year average of 38 cfs (EOR, 2004).

Simulated baseflow to Butler Pond is approximately 0.18 cfs. However, this is primarily a man-made surface water feature and a net source of recharge. Simulated leakage to the aquifer is approximately 0.47 cfs.

2.3.5 Simulated Discharge to Wetlands

Simulated groundwater discharge to the wetland areas depends on the specified elevation, calibrated drain conductance, simulated groundwater levels, and calibrated hydraulic conductivity of the aquifer. Wetlands that are located along the banks of the perennial streams are interpreted to contribute to the overall baseflow in the river channels. This section is intended to evaluate the simulated flow rates to the wetlands located away from the major rivers.

The following are simulated discharge rates to select wetland locations within the model domain:

- Simulated discharge to wetlands north of Butler Pond is 1.80 cfs
- Simulated discharge to wetlands south of Butler Pond along the tributary is 0.75 cfs
- Simulated discharge to wetlands south of Butler Pond and west of the confluence of the Vermillion River and Unnamed Tributary 1 is 0.36 cfs
- Simulated discharge to wetlands south of Vermillion River is 0.15 cfs

No data are available regarding discharge rates to the local wetlands. Thus, the simulated flow rates cannot be verified. Therefore, assessment of potential impacts from the proposed mining operation presented in Section 4 should be considered in terms of a percent reduction in flow rates as opposed to changes in absolute flow rates.

2.3.6 Calibrated Hydraulic Conductivity Distribution

Model calibrated hydraulic conductivity distribution for Layer 1 is presented in Figure 7R. The range and general order of magnitude of calibrated hydraulic conductivity distributions is relatively consistent with the available hydraulic field test results. In general, the calibrated K-values for Layer 1 range from approximately 10 to 110 ft/day. As expected, higher hydraulic conductivities lie within in the floodplain alluvium and throughout the Superior Lobe tills. Lower conductivities correspond to areas of elevated topography and locations of "Old Gray" Till (discussed further in Section 3.1.2). Due to lack of sufficient data constraints, uniform values of 30 ft/day for Layer 2 and 40 ft/day for Layer 3 were used in the model. These are comparable to values used in previous modeling efforts accepted by The County (e.g. Barr Engineering, 1990) and are in agreement with mean values from aquifer tests conducted in Apple Valley, northwest of the proposed mining area (Barr Engineering, 2002).

The model calibrated hydraulic conductivities represent large-scale effective hydraulic conductivities. There is strong correlation between the interpreted potentiometric surface and the calibrated hydraulic conductivities. In the calibrated hydraulic conductivity of layer 1, as shown in **Figure 7R**, higher hydraulic conductivities are generally associated with flatter hydraulic gradients and lower hydraulic conductivities are associated with steeper hydraulic gradients.

A comparison of simulated versus observed hydraulic heads in all three model layers is presented in **Figure 6R**. The small-scale heterogeneity that affects contaminant migration cannot be simulated by the calibrated hydraulic conductivities, because the effects of such small changes cannot be seen in the hydraulic head distribution or interpreted potentiometric surface.

The calibrated hydraulic conductivity distribution is a function of the combined effect of hydraulic gradients represented in the potentiometric surface, applied groundwater recharge rate, and specified layer thickness. Any uncertainty or inconsistency between model setup and field conditions that are related to these components might introduce uncertainty or inconsistency to the calibrated hydraulic conductivity distribution.

2.3.7 Calibrated Anisotropy

The vertical anisotropy is expected to be significant based on observations of vertical hydraulic gradients throughout the Study Area and the depositional processes of the formation. The model calibrated vertical anisotropy ratios of Kx versus Kz for layers 1, 2, and 3 are 10, 100, and 50, respectively. These ratios are distributed uniformly over each of the layers. Ratio of 50 was used for Layer 1 where St. Peter aquitard is present – approximating the affects of the underlying aquitard. A ratio of 100 was used where both the Glenwood-Platteville Formations and St. Peter Sandstone are present to represent the combined effect of both units.   A ratio of 100 was used for Layer 2 owing to the horizontal, tabular nature of the dolomite in the Prairie du Chien Group. These ratios are within the upper ranges of anisotropy ratios estimated by Schoenberg (1994).

Sensitivity analyses were performed to assist with a calibration. When a ratio of 100 (200 for Layer 2) was used, the hydraulic head of Layer 1 can be matched well, but the simulated heads for layers 2 and 3 were unreasonably low. Likewise, when ratios of 1 to 5 were used (lower range of estimates by Schoenberg [1994]), the magnitudes of simulated vertical hydraulic gradients were smaller than observed vertical gradients.

2.4 Sensitivity Analysis

The calibrated model is predisposed by uncertainty owing to the inability to define the exact spatial distribution of parameter values within the model domain. A sensitivity analysis provides a mechanism to evaluate the model response to variations in model input data and establish the effect of uncertainty of the calibrated model. Parameters with a high sensitivity are indicative of conditions for which small changes in the value of the parameter can cause large changes in an observation (e.g. head, flow rates). Thus, parameters with high sensitivities have a small range of values for which a calibrated model is possible.

Since the surface water resources are integral to this study, and likewise, calibrated values of hydraulic conductivity in some areas of the model domain exhibit values lower than expected, a sensitivity analysis of flux rates to select surface water discharge points was evaluated with respect to variations in

hydraulic conductivity. Table 2-3 provides a summary of variations in discharge rates to select surface water locations due to order-of-magnitude variations in calibrated hydraulic conductivity.

Table 2-3: Sensitivity of Groundwater Discharge due to Variations in Hydraulic Conductivity

Surface Water Discharge Area	Simulated Discharge (cfs)		
	Calibrated Model	K x 0.1	K x 10
Vermillion River, between BSC2 and USGS Station	7.2	2.41	10.05
North Creek, between CHP3 and 801	1.1	0.74	1.45
Middle Creek, between PKN1 and 801	2.1	1.09	2.22
Wetlands North of Butler Pond	1.80	0.62	2.05
Butler Pond	0.18	0.06	0.42
Wetlands South of Butler Pond	0.75	0.41	0.81

Variations of hydraulic conductivity by and order-of-magnitude yield corresponding deviations in discharge rates that vary by a factor of 2 to 5. The amount of water discharging from the system cannot decrease or increase substantially as the primary source of water to the groundwater system in this area is infiltration from precipitation. As such, precipitation-based recharge is the most sensitive parameter within the numerical, a conclusion also reached in the Scott-Dakota County model developed by Barr Engineering (1999). However, this value was not varied from the assigned value in the model, as the recharge rates assigned in Section 2.1.3 represent the potential maximum amount of recharge to the groundwater system.

While flux rates to surface water bodies are comparable to observed ranges when using a hydraulic conductivity value of ten times the calibrated value, the lower flow rates are more indicative of very low baseflow conditions, which adds to the conservatism in estimates on impacts to surface waters as presented in Section 4.

2.5   Model Limitations
The following limitations of the model should be recognized in understanding the model results or before applying the model to future uses.

- The model simulated flow field represents average flow conditions that do not vary over time, and the simulated volumetric fluxes and contaminant migration represent long-term average conditions without consideration of seasonal fluctuation.
- The calibrated hydraulic conductivity distribution is a function of the combined effect of hydraulic gradients represented in the

potentiometric surface, applied groundwater recharge rate, and specified layer thickness. Any uncertainty or inconsistency between model setup and field conditions that are related to these components might introduce uncertainty or inconsistency to the calibrated hydraulic conductivity distribution.

- The model simulated aquifer heterogeneity is limited by two factors: the model grid size and the heterogeneity that can be reflected in the hydraulic head distribution or interpreted potentiometric surface. The level of detail of heterogeneity, if beyond the above factors, may not be simulated in the model, even though it may have significant influence on hydrologic impacts or contaminant migration.

- Hydraulic conductivity and variations in recharge of the rejected sand that is backfilled in the excavations are unknown. Assumptions were made based on the changes, but the absolute values of these parameters is unknown. If the actual values of these parameters differ significantly from those proposed here, the results of this model may not be directly applicable.

- The simulated TDS and temperature plumes are highly dependent upon the assumed TDS and temperature at the source locations. Thus, the simulated plumes are subject to the uncertainties associated with source conditions.

- The simulated extent of TDS and temperature plumes is based on assumed effective porosity as well as assumed dispersivities. Because these two parameters are assumed based on literature values instead of site-specific information, the simulated extent of these "plumes" is subject to uncertainties associated with these assumptions.

- The calculated mass loading of TDS and temperature to the surface water features depends on simulated fluxes. As there is some uncertainty in these simulated fluxes to Butler Pond and the neighboring wetland features, the model-simulated mass loading may be overestimated.

- The transport code MT3D used for this study does not explicitly simulate heat transfer. This process is approximated in this study using principles in the conservation of mass. This is intended to provide a baseline to analyze the effects of temperature. Any analysis of the effects of temperature with this model in further detail than that described herein may be unreliable.

3.0   EXISTING CONDITIONS

3.1   Geology
Geologic units in Dakota County in the vicinity of Empire Township can be classified into three major categories: (1) Precambrian volcanic and crystalline rocks; (2) Cambrian through Ordovician sedimentary rocks; and (3) Quaternary unconsolidated deposits which include glacial outwash, glacial till, and alluvial deposits.

3.1.1   Bedrock Geology
A stratigraphic column of the bedrock geology in Dakota County is shown on **Figure 9R** and the distribution of the bedrock geologic units is depicted in **Figure 10R**. The general characteristics of the bedrock units pertinent to this study which include Platteville-Glenwood Formations, St. Peter Sandstone, Prairie du Chien Group, and Jordan Sandstone are summarized below. The thickness and textural characteristics of these units can vary from place to place but, in a general sense, are relatively uniform.

Other bedrock units present in Dakota County include the Ordivician Decorah Shale, St. Lawrence Formation, Franconia Formation, Ironton-Galesville Sandstones, Eau Claire Formation, Cambrian Mt. Simon-Hinkley Sandstones, and Precambrian Solor Formation. These are not discussed herein as some units are not present within the immediate Study Area or they are not connected to the hydrogeologic system being studied (see Section 3.2).

Platteville and Glenwood Formations
The Ordovician Glenwood Formation is green, sandy shale that overlies the St. Peter Sandstone, where present. The Glenwood Formation ranges in thickness up to 15 feet. The Ordovician Platteville Formation is a fine-grained dolostone and limestone (Mossler, 1990). The Platteville Formation is reported to be approximately 10 feet thick. Both units are present as small isolated flat-topped mesas within the Study Area.

St. Peter Sandstone
The upper half to two-thirds of the Ordovician St. Peter Sandstone is fine- to medium-grained quartzose sandstone that generally is massive to very thick bedded. The lower part of the St. Peter Sandstone contains multicolored beds of sandstone, siltstone, and shale with interbeds of very coarse sandstone. The base is a major erosional contact (Mossler, 1990). Quaternary erosion by glaciers has removed much of the St. Peter Sandstone and younger Paleozoic rocks from central and southern Dakota County, leaving remains of the St. Peter Sandstone as isolated outcrops, typically capped by the Platteville-Glenwood Formations, which are more resistant to erosion.

Prairie du Chien Group

The Ordovician Prairie du Chien Group contains the Shakopee Formation (upper) and the Oneota Dolomite (lower). The Shakopee Formation is a dolostone that forms approximately half to two thirds of the Prairie du Chien Group and is commonly thin bedded and sandy or oolitic. The Shakopee Formation contains thin beds of sandstone and chert. The Oneota Dolomite forms approximately one third to one half of the Prairie du Chien Group and is commonly massive to thick bedded. Both formations are karsted and the upper contact may be rubbly. The Prairie du Chien Group is approximately 145-feet thick near St. Paul (Mossler, 1990).

Jordan Sandstone

The upper part of the Cambrian Jordan Sandstone is medium- to coarse-grained, friable, quartzose sandstone that is trough cross-bedded. The lower part is primarily massively bedded and bioturbated. The Jordan Sandstone is approximately 90 feet thick near the Minnesota River and thickens to over 200 feet in southern Dakota County (Mossler, 1990).

3.1.2 Quaternary Geology

The Quaternary geology surrounding the Mining Area is primarily outwash and till deposits related to the advance of the Superior and Des Moines glacial lobes. Superior till and outwash predominate the Mining Area, but there is also some Des Moines till/outwash near the southern portion of the Mining Area (**Figure 11R**). The Superior Lobe deposits are typically red in color, containing oxidized basalt cobbles and other mafic igneous rocks. The Superior Lobe sediments contain very little limestone and dolomite from marine deposits. Superior lobe tills are generally rich in sand with lesser portions of silt and clay. The Des Moines Lobe sediments are rich in shales, marine carbonates, and granitic rocks. Des Moines Lobe tills are very clay-rich. The area surrounding the Vermillion River channel is primarily filled with floodplain alluvium, but also contains till from the Superior and Des Moines lobes. In addition, there also exist some isolated exposures of pre-late Wisconsin deposits such as the "Old Gray" Till which is observed in isolated exposures on some of the topographic highs surrounding the Mining Area.

3.1.3 Structural Geology

The regional dip of the Paleozoic units is toward the north, reflecting the position of Dakota County on the southeastern margin of the Twin Cities basin. The Twin Cities basin developed in the Middle Ordovician, as a result of many small folds and faults in step-fashion. Individual folds have amplitudes of as much as approximately 100 feet and individual faults have displacements (throws) of 50 to 150 feet.

The two major structures are the Vermillion anticline and the Empire fault, both located north and parallel to the Vermillion River (Mossler, 1990). Maximum displacement (throw) of the Empire Fault is approximately 100 feet. A number of

smaller faults have axis that trend northwest-southeast. No faults are visible in outcrop in the Study Area.

3.2   Hydrogeologic Setting

3.2.1 Hydrostratigraphic Units

Hydrostratigraphic units comprise geologic formations of similar hydrogeologic properties. Several geologic units might be combined into a single hydrostratigraphic unit or a geologic formation may be subdivided into a number of aquifers and aquitards. The hydrostratigraphy forms the framework of the conceptual model of the groundwater flow system. The geologic units that have been selected for the aquifers and aquitards are shown on **Figure 9R**. The following discussion is a summary of rationale for their selection (Barr Engineering, 1999).

Prairie du Chien-Jordan Aquifer
In early hydrologic studies, the Prairie du Chien Group and the Jordan Sandstone are typically treated as a single aquifer system in the Twin Cities area; the Prairie du Chien-Jordan Aquifer. However, chemical and isotopic studies (Tipping, 1992), artificial recharge studies (Reeder, 1976), and aquifer testing (Barr Engineering, 1990) indicate that while hydraulic head measurements and hydraulic properties of these aquifers may be relatively similar, they are two distinct units that respond independent of one another. Groundwater flow in the Prairie du Chien Group is primarily through fractures, joints, and solution features. Groundwater flow in the Jordan is primarily intergranular but secondary permeabilities have developed due to fracturing (Schoenberg, 1990).

Jordan Sandstone
In Dakota County, many high-capacity wells are completed solely within this unit. The unit is approximately 100 feet thick but may thicken to the south. The degree of cementation of the Jordan Sandstone varies (Tipping, 1992). Hydraulic conductivity can vary, depending upon the degree of cementation.

The Jordan Sandstone sub-crops beneath glacial drift and alluvium in major river valleys, which are the primary discharge zones. In these areas, hydraulic head can be expected to be at or slightly above the elevation of the river. Discharge via high-capacity wells is also a significant discharge route. Recharge is primarily through leakage from the overlying Prairie du Chien Group.

Prairie du Chien Group
The areal extent of the Prairie du Chien Group is similar to that of the underlying Jordan Sandstone. Horizontal hydraulic conductivity values are in the same range as those of the Jordan Sandstone. Flow in the Prairie du Chien Group is heavily controlled by fracturing, jointing, and solution cavities. The top of the Prairie du Chien Group is an erosional surface.

Unlike deeper hydrostratigraphic units, the Prairie du Chien Group can be unconfined where the drift is thin or absent. Recharge is primarily through leakage from the overlying glacial drift. Discharge is to the glacial drift in the valleys of major rivers.

Glacial Drift-St. Peter Aquifer
The hydrogeologic characteristics of glacially deposited sediment are very complex. At a given location, these sediments may contain several interfingering sand-gravel layers with till; however these discrete zones may not show any correlation, even in relatively small areas. Consequently, the modeling of discrete zones of saturation is typically not possible, given the limited amount of reliable data on stratigraphy, hydraulic characteristics, and hydraulic head. Thus, for this system, transmissive sediments are therefore considered to be one single heterogeneous aquifer system, which is assumed to be hydraulically connected.

Locations were the upper St. Peter Sandstone is present may be included as part of the Glacial Drift Aquifer (Barr Engineering, 1999). The upper part of the St. Peter Sandstone is poorly cemented, granular, and may be used to supply domestic wells. The lower portion of the St. Peter Sandstone is shaley and functions as an aquitard over the Prairie du Chien Group (Palen, 1990). The St. Peter Sandstone has been eroded away over much of Scott and Dakota Counties and is present in complete thickness only where overlain by the Glenwood and Platteville Formations. In those areas where the St. Peter Sandstone is not present, glacial drift overlies the Prairie du Chien Group. In these areas, the St. Peter-basal till aquitard is composed of glacial till or other glacial drift, which allow varying rates of leakage.

The Glacial Drift-St. Peter Aquifer is in relatively good hydraulic connection with local streams and lakes. Recharge is primarily by infiltrating precipitation. Discharge is to streams, lakes, and leakage to underlying aquifers.

3.2.2 Groundwater Flow
Groundwater generally moves from upland areas of recharge downgradient to lowland areas of discharge. In the Study Area, groundwater movement is generally from west-southwest to east-northeast in accordance with the hydraulic gradients defined by potentiometric surfaces. The interpreted potentiometric surfaces for the Glacial Drift-St. Peter, Prairie du Chien, and Jordan aquifers are depicted in **Figure 4R**.

The potentiometric contours for the shallow Glacial Drift-St. Peter aquifer were derived based on water level measurements from the Minnesota County Well Index, boreholes used to delineate the depth and extent of aggregate mining deposit, in addition to the five newly installed Empire Township monitoring wells (**Figure 2R**). In addition, groundwater contours are constrained by the surface topography of wetland areas that have been delineated as groundwater dependent resources and represent groundwater discharge areas (see Section 2.6).

Groundwater elevations in the shallow aquifer throughout Dakota County are generally stable, exhibiting fluctuations of less than three to four feet (EOR, 2004). Depth to groundwater in the Mining Area is generally in excess of 20 feet. In some localities, depth to groundwater may be more than 50 feet. In the vicinity of the Vermillion River and other groundwater discharge areas, depth to groundwater is essentially negligible with some areas exhibiting artesian conditions.

Usable data were not available for a majority of wells in the vicinity of the Mining Area. In addition, numerous wells have anomalously low water levels and exhibit evidence of pumping during water level measurement. Thus, depicted contours have been represented to illustrate the more regional flow pattern and do not emphasize the smaller, more local variations. Dates on which water levels were taken vary considerably, thus the potentiometric surface represented in **Figure 4R** is generalized from a non-synoptic data set.

The most obvious feature in the groundwater potentiometric map is a groundwater mound in the southern portion of the proposed Mining Area. While no shallow groundwater wells exist, this feature has been interpreted based on water levels in borings drilled to access the depth of the aggregate deposit which indicate a northeast gradient as opposed to the expected southward gradient directed toward the Vermillion River. In addition, in an unconfined hydrologic system, the groundwater table should, for the most part, represent a subdued replica of the topography (Freeze and Cherry, 1979). This groundwater mound forms a groundwater divide that is roughly coincident with the surface water divide forming the Mississippi and Vermillion River watershed boundaries (Almendinger and Mitton, 1995). Additional groundwater mounds have been interpreted in local topographic highs to the east of the Mining Area. While data supporting the inferences of these groundwater mounds may be adequate, it is likely that these mounds may represent perched water conditions due to the low permeability of the underlying geologic units. Thus, these mounds may not be sufficiently connected to the regional groundwater system, and will be treated as such.

Groundwater contours for the Prairie du Chien and Jordan aquifers shown in **Figure 4R** are similar to those presented by EOR (2004). These contours were developed from linear kriging (an interpolation technique for obtaining estimates of surface elevations from a set of control points) of well data from the Minnesota County Well Index and a DNR observation network.

Groundwater contours in all aquifers conform to general groundwater flow pattern delineated in a regional study by Palen (1990).

3.2.3 Hydraulic Gradients
As shown on the groundwater potentiometric surface of the Glacial Drift-St. Peter aquifer (**Figure 4R**), the horizontal hydraulic gradient is approximately 0.002

feet/feet and does not vary substantially throughout the Study Area. To the northeast, hydraulic gradients increase slightly to 0.003 feet/feet as groundwater approaches the discharge area of the Mississippi River. To the west of the Mining Area boundary, the hydraulic gradient is 0.001 feet/feet. This may be indicative of more permeable strata in the subsurface, but this is speculative as the available hydraulic head data west of the Mining Area is limited.

Vertical hydraulic gradients vary substantially throughout the Study Area and some spatial trends in vertical gradients have been observed. Generally, measured hydraulic head differences between shallow and deep aquifers at wells clustered together (**Figure 4R**) show downward gradients in upland areas away from the river and upwards gradient in the vicinity of the river. This suggests that groundwater recharge by direct infiltration of precipitation occurs in most of the areas away from the creeks, whereas groundwater discharge occurs at the creeks and along the floodplains. It also suggests that the convergence of groundwater flow toward the Vermillion River occurs horizontally as well as vertically. This is supported by strong upward hydraulic gradients, even artesian flow conditions, observed along the river. However, local vertical hydraulic gradients may vary significantly and not follow this spatial trend. Upward flow gradients have been observed in areas away from the creeks and vice versa, suggesting that local vertical gradients are influenced by local heterogeneities.

3.3 Groundwater Recharge

Groundwater recharge occurs throughout the Study Area as a result of surface water infiltration. Infiltration of direct precipitation is dependent upon the rate and duration of precipitation, the soil type and soil cover, land use, evapotranspiration, and topography. In a steady-state model, the resulting infiltration rate is typically estimated on an annual basis - although seasonal estimates are sometimes utilized. Groundwater recharge in the upland areas and lowland areas along the floodplains can be considered separately as areal recharge and floodplain recharge, respectively.

The predominant source of recharge for the deeper aquifers in Dakota County is regional flow from areas outside the County and downward leakage from the Glacial Drift/St. Peter aquifer.

3.3.1 Areal Recharge

Areal groundwater recharge occurs as a result of surface water infiltration primarily during early springtime. Precipitation in the Minneapolis-St. Paul metropolitan area averages between 26 and 32 inches per year, of which approximately 19 to 23 inches is returned to the atmosphere by evapotranspiration while about 7 to 9 inches per year are available for recharge and overland runoff (Schoenberg, 1994). Schoenberg (1990) estimated that the annual groundwater flow to streams is 1.60 to 4.30 inches of precipitation per year, with an average of 4.1 inches per year. Assuming that long-term groundwater recharge is approximately equal to long-term groundwater discharge to streams, annual

recharge from precipitation is approximately 1.5 to 4.5 inches per year. Thus, about 6 to 15 percent of precipitation infiltrates to groundwater.

3.3.2 Floodplain and Wetland Recharge

The occurrence and amount of groundwater recharge along the river and tributary floodplains are expected to be of greater magnitude than areal recharge. Infiltration occurs along the floodplains as a result of direct precipitation and flooding caused by surface water runoff. The distribution of the 100-year floodplains and wetlands within the Study Area is depicted in **Figure 2R**.

Infiltration along the floodplain and wetlands may occur frequently in response to surface water flooding events. Infiltrated water will partially be evaporated from the soil and transpired by the vegetation along the drainages, and partially percolate to groundwater. The rate of floodplain recharge is unknown, but it is expected to be greater than areal groundwater recharge.

3.4   Hydraulic Properties of Aquifer(s)

Hydraulic conductivity, specific yield (or storage coefficient), and effective porosity are commonly used to characterize the hydraulic properties of an aquifer. In this study, the flow conditions are considered relatively stable; thus, specific yield, which is related to temporal variation of groundwater, is not discussed. Site-specific data for effective porosity are not available.

3.4.1 Hydraulic Conductivity Distribution

Hydraulic Conductivity data for the hydrostratographic units in this region is limited, but sufficient data in these units has been gathered in the northern portion of Dakota County (Schoenberg, 1990; 1994). Hydraulic conductivity data for the aquifer units was obtained from several permeameter, slug, and aquifer tests.

The following table presents the range of values for various geologic units in the area:

Table 3-1: Summary of Hydraulic Conductivity Measurements

Aquifer Unit	Hydraulic Conductivity (ft/day)	Number of measurements
Alluvium	8 to 61	8
Glacial Till	4×10^{-5} to 26	12
St. Peter Sandstone	0.3 to 94	8
Prairie du Chien	50	1
Jordan Sandstone	19 to 107	3

Hydraulic conductivity of the geologic materials in the saturated zone above the St. Lawrence-Franconia aquitard varies in both the horizontal and vertical directions, reflecting the heterogeneity of the flow system.

3.4.2 Anisotropy

Hydraulic conductivity distribution in an aquifer is not only heterogeneous but may also be anisotropic. Vertical anisotropy is evidenced by vertical hydraulic head differences observed over the entire Study Area (**Figure 4R**), which suggests that the vertical hydraulic conductivity is smaller than the horizontal hydraulic conductivity, (*i.e.*, the vertical anisotropy is high). The vertical anisotropy is likely attributed to the physical layering of different geologic units. It is not uncommon for layered heterogeneity to lead to regional anisotropy on the order of 100:1 or even greater (Freeze and Cherry, 1979). The site-specific vertical anisotropy ratio for the Study Area is calibrated through modeling.

3.5   Surface Water

3.5.1 Vermillion River and Associated Tributaries

The Vermillion River is located approximately two miles south of the southern boundary of the proposed Mining Area. The Vermillion River begins in Scott County and flows into Dakota County, ultimately discharging into the Mississippi River near the city of Hastings, Minnesota. The drainage area to the Vermillion River at the gauging station is approximately 129 square miles. The Vermillion River is a zone of groundwater discharge in the Study Area and becomes a source of groundwater recharge downstream closer to the Mississippi (Palen, 1990; Almendinger and Mitton, 1995)

North Creek is located approximately one mile west of the west boundary of the proposed Mining Area. North Creek extends from the City of Lakeville into the City of Farmington and Empire Township, and acts as a major tributary to the Vermillion River. The total area of the North Creek watershed is approximately 15,774 acres, including drainage areas from Lakeville, Farmington, Apple Valley, Rosemount, Burnsville and Empire Township. This creek is perennial throughout much of its length, but has several ephemeral branches in its headwaters. Middle Creek is another perennial tributary to the Vermillion River that drains the highland area west of Flagstaff Avenue in southern Lakeville.

South of the Mining Area is an unnamed tributary to the Vermillion River, hereafter referred to Unnamed Tributary 1. This is a perennial tributary that drains the Butler Pond area. Butler Pond is a man-made surface water feature located just outside the southeast border of the proposed Mining Area. It is estimated to be approximately 10 feet deep. Local residents have indicated that this pond does not completely freeze during coldest winter months suggesting that it may be fed, in part, by groundwater flow. A small portion of Unnamed Tributary 1 north of Butler Pond is considered to be groundwater fed based on mapping of adjacent vegetation, but is ephemeral throughout most of the proposed Mining Area (EOR, 2004).

To the east of the Mining Area is an unnamed tributary to the Vermillion River that is ephemeral and typically dry (denoted as Unnamed Tributary 2 in Figure 1).

Detailed analysis was performed at Site 4 on this tributary by Almendinger and Mitton (1995). It was noted that more than 70 percent of the time, this stream was dry and more than 90 percent of the time, the groundwater table was below the stream level, indicating this tributary is a zone of recharge. Hydraulic gradient between nested wells in the vicinity of these drainages indicate downward gradients representative of a recharge area.

The following table presents a summary of stream flow data taken in mid-July of 2004 indicating representative flow rates observed at several of the gauging stations depicted in **Figure 2R** (EOR, 2004).

Table 3-2: **Summary of Stream Gauging Measurements in the Vicinity of the Proposed Mining Area**

Gauging Station	River Branch	Flow (cfs)
ANN1	Unnamed Tributary 1	1.30
CHP3	North Creek	6.49
CHP2	North Creek	7.81
BCS2	Vermillion River	69.04
801	Middle Creek	51.4
804	Vermillion River	31.0
807	Vermillion River	37.4
808	North Creek	10.7
USGS	Vermillion River	84.0

3.5.2 Wetlands

Wetlands within the Study Area as delineated by the Empire Township Wetland Inventory are depicted in **Figure 2R**. Two types of wetlands are typically present in Dakota County: those that are discharge areas, and those that are recharge, for at least part of the year (Palen, 1990). Discharge areas occur in the floodplains of the Minnesota and Mississippi Rivers, along the Vermillion River and its major tributaries, and in isolated areas along the Cannon River.

Wetlands surrounding the proposed Mining Area consist of both discharge and recharge wetlands. A study using field investigation and GIS analysis is currently underway by Emmons and Olivier Resources, Inc. (EOR) to delineate the extent of groundwater dependent resources in Scott-Dakota County. This includes determining the quantity and extent of wetlands discharging groundwater. A preliminary map of these wetlands was provided to aid in this evaluation. The wetlands delineated as probable groundwater discharge areas are located along the banks of the Vermillion River and North Creek in addition to several flatland areas in the vicinity of Butler Pond. These consist of mixed hardwood swamp, willow swamp, wet prairie, and wet meadow. Each of these plant communities was analyzed with relation to the water table, Vermillion River, and other groundwater dependent resources to determine their likelihood of being groundwater dependent.

The wetlands not delineated in the EOR study are considered to be wetlands that recharge the groundwater system. Recharge to the shallow aquifer occurs when the wetland collects rain or spring snowmelt. Although the bottom of the wetland may restrict infiltration because of accumulations of organic matter, higher rates of recharge occur around its edges where sand or sandy till is temporarily inundated. Slow, steady leakage may also occur though the organic sediments as well, even though they are not very permeable (Palen, 1990).

3.6   Summary of Conceptual Model

The conceptual model utilized in this study is consistent with conceptual models developed in previous studies (Barr Engineering, 1999) and is depicted in **Figure 12R**. For this study, the groundwater flow system includes three discrete aquifers: the Glacial Drift/St. Peter Sandstone; the Prairie du Chien Group; and the Jordan Sandstone. The St. Lawrence-Franconia aquitard forms the lower bounds of the uppermost groundwater flow system. Deeper aquifers such as the Ironton-Galesville and Mt. Simon-Hinkley are not included, as interaction with these aquifer units is considered negligible. In this conceptual model, there is a leaky aquitard between each aquifer unit. Between the glacial drift/St. Peter aquifer and the underlying Prairie du Chien Group, the aquitard consists of the basal portion of the St. Peter Sandstone and glacial till. Between the Prairie du Chien Group and the Jordan Sandstone, an aquitard layer is present in the basal portion of the Oneota Formation (Prairie du Chien Group).

The primary source of recharge to the Glacial Drift/St. Peter Sandstone aquifer is infiltrating precipitation. The primary source of recharge for the Prairie du Chien Group and Jordan Sandstone aquifers is leakage from adjoining aquifer. Lakes and ponded water in wetlands are generally perched above the water table and leak water down into the aquifer as a function of the resistance of the lake's bottom sediment and the unsaturated drift material below the lakes.

Discharge of groundwater occurs at the Vermillion and Mississippi Rivers and their adjacent wetlands. Pumping wells also remove water from the aquifer units.

4.0   MINING IMPACT ANALYSIS

4.1   Mining and Production Operations

Mining of sand and aggregate is proposed to begin in 2006 and finish in approximately 2040. For each mining year, project operations include those outlined in Section 1.1. Approximately five production plant facilities will be located across the proposed Mining Area. Each plant site will require an industrial groundwater supply well, supplying water for production operations. Required flow rates will vary based on specific plant operations. Specifically, water may be used for sand and aggregate washing, concrete product production, equipment maintenance, concrete truck washout and site dust control. Water from the groundwater supply wells will be used initially to fill wash ponds. Once the ponds are filled, the supply wells will only supplement recycled site stormwater and wash water, as necessary. Generally, aggregate washwater will be pumped from on-site, shallow sump pits, not traditional deep production wells.

Site stormwater, sand/aggregate wash water and concrete truck wash water will typically be detained in a triple stage series of on-site detention ponds at each plant location. Water for the production facilities will be pumped from the third detention pond for reuse. The detention ponds will typically be constructed above the groundwater and will essentially function as sedimentation and infiltration ponds, removing the majority of the suspended solids. Pond depths will typically range between 10 feet and 20 feet with pond areas ranging between approximately one and three acres. Stormwater and wash water will enter the on-site detention ponds via overland flow, pressure or gravity piping.

Upon completion of mining operations, the excavations will be backfilled with unused materials, back-hauled fill, overburden materials and topsoil. The preliminary end use grading plan (**Figure 13R**) identifies approximate final grading elevations, location and sizes of the proposed end use ponds. Rejected sand from the production operations will typically be placed on the bottom of the mining excavation, facilitating groundwater infiltration and subsurface flow. In areas where mining excavations extend below the groundwater table, except at end use pond locations, the excavations will be backfilled with rejected sand then overburden and topsoil to the end use grades. During reclamation, the proposed Mining Area will be restored to the proposed end use grades and returned to agricultural land.

Rejected sand from production areas typically consists of 15 percent to 30 percent of the total sand/gravel excavation volume. Based on a total estimated sand/gravel excavation of 200 million tons and an assumed unit weight of 115 pounds per cubic foot (lb/ft^3), an estimated total sand/gravel volume of approximately 130 million cubic yards is anticipated. Based on a typical value of rejected sand that is 15 percent to 30 percent of the total excavated volume, approximately 19 million to 39 million cubic yards of rejected sand is anticipated. If spread uniformly

across the proposed 3,590 acre Mining Area, the depth of reject sand would range from approximately three to seven feet.

Eleven end use ponds, with surface areas totaling approximately 240 acres, are proposed across the Mining Area (**Figure 13R**). The ponds sizes vary from approximately 6 acres to 90 acres, with depths ranging between approximately 1 foot and 42 feet. The ponds, developed from mining excavations below the groundwater, will consist mainly of groundwater. In areas where end use ponds are proposed, the excavations will not be backfilled and the ponds will fill with groundwater. Typically, the bottom of the groundwater ponds will correspond to the bottom of sand/aggregate deposit with some exceptions. This is of particular interest for Ponds 1 and 2, which are located within the southern extent of the DWSMA and WHPAs for the city of Rosemount. As indicated in Figure 13, Pond 1 is to be excavated to a depth of 42 feet, with a base elevation of 860 feet amsl, while Pond 2 is to be excavated to a depth of 18, with a base elevation of 908 feet amsl. The depths of the excavated pounds will be limited to the Glacial-St. Peters aquifer and no excavation of material from the Prairie du Chien or Jordan aquifers is expected.

Separate stormwater ditches, constructed outside of the groundwater end-use ponds and separated by berms, will provide stormwater diversion and prevent direct mixing of stormwater and groundwater, reducing the potential for groundwater contamination. In areas where stormwater drains directly to protected surface waters, perimeter stormwater ponds will function as flow-through, non retention-based swales, diverting stormwater flows around the groundwater ponds to prevent stormwater/groundwater mixing and minimize flow impacts to the surface waters. Depending on the soil infiltration and atmospheric evaporation rates, these ponds will essentially function as a combination of infiltration and sedimentation basins, removing the majority of the suspended solids during settling and groundwater infiltration. The summer months will expose the pond water to warm air temperatures and extended hours of solar radiation. This has the potential of increasing the ambient temperature of the water and increasing the total dissolved solid (TDS) concentration through evaporation.

The greatest potential for impacts exists during the end use plan as the ponds alter the groundwater flow field, which may increase flow to local surface water features, potential trout habitats, and wetlands. Additionally, infiltration of water with elevated TDS and temperature may impact the groundwater resource. Infiltration of water thus impaired could potentially have adverse impacts on the surface water and wetland features. Conceivably, similar water quality impacts may even affect WHPAs as delineated to the north of the Mining Area. Therefore, the reasonable worst-case modeling for evaluating the end use plan assumes that the stormwater ponds shown in Figure 12 capture and retain all of the stormwater

4.2   Simulation of Hydrologic Impacts of End Use Ponds

The end-use ponds are modeled as a groundwater fed surface water bodies and in turn, act as a source and sink for the groundwater system. Groundwater enters the ponds from the upgradient side of the pond, for the most part from the south-southwest. While in the pond, the water is then affected by meteoric processes such as possible increased TDS concentration due to evaporation, and increased overall temperature due to heating by ambient temperatures. This water then re-enters the groundwater system on the downgradient side of the pond, to the north-northeast. Using the calibrated flow model developed for this study, the groundwater ponds were simulated as head dependent flux boundaries using the General Head Boundary Package. Interaction between these ponds is dependent on the relative hydraulic head relationships between the General Head cells and the surrounding groundwater system. Conductance for the general head boundaries representing the groundwater ponds were specified to be relatively higher values (on the order of 100 ft/day) compared to the calibrated hydraulic conductivity surrounding the boundary cells. Values were assigned in this manner because groundwater discharge to and from the ponds is controlled by the surrounding lithologies and the general head conductance should not limit flux. The water level elevation of these ponds was estimated based on the interpreted groundwater contour map (**Figure 4R**). These estimated elevations are depicted in **Figure 13R**.

The stormwater ponds surrounding the end-use ponds are intended to act as swales and prevent surface water runoff from entering the larger ponds. Thus, the only source of water to the ponds is groundwater discharge and direct precipitation into the pond itself. Precipitation in the metro area ranges from 26 to 32 inches and evapotranspiration is on average 23 inches (Allmendinger and Mitton, 1995). This suggests for the most part that during dry years, precipitation and evaporation to the ponds will essentially be balanced (i.e. minimum precipitation and maximum evaporation). But, during wet years, when precipitation is at a maximum and evaporation is at a minimum, this could be an increase of water to the ponds of just less than one foot. To maintain conservatism in the study, two feet were added to the water elevation in the ponds as noted above to facilitate increased leakage of "affected" water to the groundwater system. It should be noted, that this may be overly conservative as this is representing "wet" conditions, whereas the simulated flow to surface water features (i.e. rivers, wetlands) in the model are intended to represent dry or low flow conditions.

The elevation of water in the ponds should be approximately that of the groundwater elevation prior to excavation of the pond.   Expected elevations of the ponds denoted in **Figure 13R** are based on the potentiometric surface map depicted in **Figure 4R**. However, these values represent elevations expected to occur in the field. As expected, simulated heads in the proposed mining area of the calibrated model may differ from actual, in some cases by a few feet. Elevations assigned to the boundary conditions representing the end-use ponds were adjusted to account for the differences in model-simulated and actual heads

expected as indicated in **Figure 13R**. Assigning a head value in the ponds above the water table ensures continued leakage of the end-use pond water into the groundwater system. This approach was taken because it will likely add more than actual affected water to the system, adding even more conservatism to the model prediction for hydraulic impacts and contaminant migration.

Potential leakage from the surface water/stormwater ponds was simulated using the River Package with a constant stage and the base of the water body as the base of the respective pond. As these ponds are located above the groundwater table, downward flux to the groundwater is controlled by the depth of the pond and the hydraulic conductivity of the base of the pond. The water elevation and base of the stormwater ponds in the model were assigned based on the estimated elevations depicted in **Figure 13R**. A hydraulic conductivity of 0.1 ft/day (equates to a conductance value of approximately 250 ft^2/day) was assumed for the base of the ponds. While this is intended to represent silts and other fine material that will eventually settle and line the base of the ponds limiting leakage to the groundwater, this value of hydraulic conductivity is probably higher than the actual value, and thus provides a conservative scenario for assessing impacts to the groundwater system.

For model simulations, the rejected sand was assumed to have hydraulic conductivity of 30 ft/day, a typical value for loosely consolidated sands, with the inclusion of some fine materials (Freeze and Cherry, 1979). Likewise, it is assumed that this sand will be loosely consolidated following initial backfill and may facilitate additional recharge to the groundwater system in the immediate vicinity. Thus, the average recharge rate was assumed to increase from approximately 4.5 inches/yr to 6 inches per year in the area of the reject sand.

The model simulations indicate a slight rise in elevation in areas directly beneath and adjacent to proposed end use ponds that is generally on the order of 2.0 to 3.0 feet (see **Figure 14R**). For the most part, water level increases are less than one foot as distance increases away from these ponds. **Table 4-1** summarizes the changes in flux to select surface water localities following the implementation of the end use plan.

Table 4-1: Summary of Changes in Groundwater Discharge at Select Surface Water Localities after Implementation of the Mining End Use Plan

Surface Water Feature	Original Flux (cfs)	New Flux (cfs)	Difference	Percent Change
North Creek[1]	1.10	1.18	0.08	6.8
Wetlands North of Butler Pond	1.80	1.85	0.05	2.7
Butler Pond	0.15	0.19	0.02	21.1
Wetlands South of Butler Pond	0.75	0.79	0.04	5.0

[1] Flow from gauging station CHP3 to 801

Using the conservative, worst-case changes produces minimal impacts to the estimated groundwater fluxes to select surface water features surrounding the proposed mining area. Groundwater flow rates to Butler Pond and the surrounding wetlands are estimated to increase between 0.02 and 0.05 cfs, resulting in a 2.7 to 21.1 percent change in flow. Groundwater flow to North Creek is estimated to increase 0.08 cfs, reflecting a 6.8 percent increase in flow. These changes in the simulated long-term, average estimated flow rates are less than the observed seasonal and yearly fluctuations. Given the conservative, worst-case assumptions, hydraulic impacts to these surface water features are estimated to be negligible.

4.3 Simulation of Potential TDS and Temperature Impacts

The computer code MT3DMS, a modular three-dimensional multi-species transport model (Zheng and Wang, 1998), was used to simulate fate and transport of water introduced to the groundwater system from the stormwater ponds in the end use plan. MT3DMS does not simulate heat transport. However, the governing equations work on the underlying principle in which mass/energy is conserved. Therefore, it may be used to approximate the fate and transport of solar-heated stormwater infiltration mixing with ambient groundwater. The model does not simulate conductive cooling of the recharge water as it flows within the relatively cooler aquifer matrix. Thus, the results provided in this study are considered to be very conservative, illustrating a worst-case scenario for evaluating the effects of temperature and TDS.

4.3.1 Input Parameters Transport Simulations

The following sections describe the rationale for selecting the input parameter values for the transport model.

Transport Parameters

To use the MT3DMS transport model, some additional parameters are necessary, which include porosity and dispersivity. Porosities of 0.3, 0.09, and 0.21 were used for Layers 1,2, and 3 of the model, respectively. These values are based on recommendations of the Minnesota Department of Health and are similar to porosities used by Barr Engineering (1999) to evaluate well capture zones in the Scott-Dakota County regions flow model. No field data was available for dispersivities in the Scott-Dakota County area. Therefore, literature values were taken from regional-scale studies in similar rock types and aquifer thicknesses (Gelhar *et al*., 1992). Longitudinal, transverse, and vertical dispersivities assigned to Layers 1 and 3 were 100 feet, 30 feet, and 0.1. Similarly, dispersivities assigned to Layer 2 were 60 feet, 12 feet, and 0.1 feet, respectively.

Groundwater

Sampling of the newly installed Empire Township wells, in addition to data from Almendinger and Mitton (1995), indicate that average groundwater TDS is approximately 500 mg/L. The average groundwater temperature from these wells is approximately 11°C.

Surface Water

The median TDS in the Vermillion is also approximately 500 mg/L, the same as the surrounding shallow groundwater (Almendinger and Mitton, 1995). However, ambient temperatures are variable through the year with temperatures as low as 2°C during winter months to average temperatures as high as 19.5°C during July.

Analogue for End Use Ponds

Shanahan Pond is a mining-related surface water body, located approximately 10 miles from the proposed Mining Area at Latitude 44°51'15", Longitude 93°06'21". It is interpreted to be fed, at least in part, by groundwater, and therefore should prove as an adequate analogue as to how the end-use ponds will react to temperature and TDS increases attributed to solar radiation and evapo-concentration. The pond is about 7 feet deep and chemical properties were sampled at this pond at a depth of three feet.

Average TDS based on specific conductance data indicates that the average TDS of Shanahan Pond is 80 mg/L. This is more than five times lower than average TDS in groundwater and local surface water. Thus, the pond is likely being recycled with fresh stormwater and has limited time to be affected by evapo-concentration effects. To maintain conservatism in this analysis, a TDS concentration of 1,000 mg/L was assigned to represent pond water heavily impacted by evapo-concentration. Note that the TDS concentration of the ponds (~1,000 mg/L) is more than ten times the summer TDS of the analogue pond (80 mg/L) and twice the ambient groundwater TDS (~500 mg/L). Figure 15R illustrates the distribution of iso-concentration contours of the net increase in TDS in the local groundwater during the 40 years following implementation of the end use plan, assuming the end-use ponds have a TDS concentration of 1,000 mg/L.

As expected, Shanahan Pond exhibits temperature fluctuations similar to those of the Vermillion River. During winter months, water temperature is approximately 2°C, identical to that of the Vermillion River. However, during July, temperatures rise as high as 26.5°C. To evaluate the worst-case scenario, the end-use ponds were assumed to have an elevated temperature 26.5°C throughout the year. **Figure 16R** illustrates the distribution of isotherms of the net increase in temperature in the local groundwater during the 40 years following implementation of the end use plan.

Note that while the surface water ponds/swales may allow infiltration of moderate amounts of surface water, it is expected that this water may not have enough residence time to experience significant increases in temperature or TDS prior to infiltration. Thus, these surface water bodies are modeled solely as a hydraulic source to the groundwater system but with no appreciable amount of temperature or TDS added to the system.

4.3.2 Simulated Impacts to Surface Water and Wetlands

Surface water TDS concentrations and temperature increases were calculated simply by dividing the mass flux of TDS (or temperature) by the groundwater flux to the surface water feature, both estimated by the model, at selected time intervals. The basic assumptions for calculations of TDS (or temperature increases) in the surface water features were that flow was presumed to be solely attributed to groundwater discharge, thus, overland flow and surface water runoff to the creeks was not accounted for in the calculations. These assumptions provide a very conservative, "worst-case" scenario in which to estimate the concentration of TDS or temperature increase in the surface water.

The following tables summarize the simulated TDS and temperature increases at select localities after implementation of the mining end use plan.

Table 4-2: Summary of Simulated TDS Increases at Select Surface Water Localities after Implementation of the Mining End Use Plan

Surface Water Locality	Simulated Discharge (ft³/day)	Simulated Cumulative Mass Loading (mg/L)*(ft³/day)	TDS Concentration Increase (mg/L)
North Creek[1]	102,734	26,384	3.9
Wetlands North of Butler Pond	159,893	5,756,112	36
Butler Pond	16,416	85,363	5.2
Wetlands South of Butler Pond	68,246	245,049	3.6

[1] Includes the entire perennial section of North Creek north of gauging station CHP3

Table 4-3: Summary of Simulated Temperature Increases at Select Surface Water Localities after Implementation of the Mining End Use Plan

Surface Water Locality	Simulated Discharge (ft³/day)	Simulated Cumulative Mass Loading (°C)*(ft³/day)	Temperature Increase (°C)
North Creek[1]	102,734	7,385	0.07
Wetlands North of Butler Pond	159,893	180,872	1.13
Butler Pond	16,416	1,806	0.11
Wetlands South of Butler Pond	68,246	6,852	0.10

[1] Includes the entire perennial section of North Creek north of gauging station CHP3

Assuming a very conservative scenario in which the end-use ponds have an elevated TDS of 1,000 mg/L, ten times the TDS concentration of a local analogue pond and twice the average concentration of local groundwater and surface water concentrations. Likewise, thermal impacts were simulated using conservative, worst-case assumption in which there is no conductive heat loss to the aquifer. Model results indicate TDS concentration increases ranging between 3.6 to 36 mg/L and temperature increases ranging between 0.07 and 1.13 °C to the local surface water and wetland features (as shown in Tables 4-2 and 4-3). These

estimated changes in TDS and temperature are well below the range of seasonal fluctuations and within the range of variability related to sampling error. Therefore, given the conservative, worst-case assumptions, impacts related to temperature and TDS to these surface water features are deemed to be negligible.

4.3.3 Wellhead Protection and Drinking Water Supply Management Areas

The WHPAs and DWMAs for Rosemount Wells 3, 7, 8, and 9, in addition to Rural Wells 1 and 2 are depicted on **Figure 2R**. These wells pump from the Jordan Aquifer (Layer 3 of the model). **Figure 19R** depicts the extent of simulated TDS and temperature increase in the Jordan aquifer. After 40 years, there is evidence of leakage of the potentially affected end-use pond water down to the Jordan aquifer. The model estimates that TDS will increase approximately 5 to 85 mg/L and will increase in temperature approximately 0.2 to 2.0 °C within the WHPAs and DWMAs delineated for the Rosemount wells. However, for the most, maximum increases are localized in a small portion of the WHPA and DWMA with increases in TDS and temperature primarily on the order of 30 to 50 mg/L and less than 1.0 °C, respectively. The greatest increase in TDS and temperature are localized in the center of the proposed mining area (see **Figure 19R**) where the end-use ponds are clustered. Impacts are lesser toward the edges of the proposed mining area.

The model-predicted TDS increase is likely overestimated due to the conservative initial concentration for the ponds. Likewise, the simulated temperature increase is unlikely as the model does not account for conductive heat loss that will occur as the water migrates through a few hundred feet of aquifer material. This is also compounded by the vertical discretization of the model domain. The relative thickness of the model layers is set up to represent the relative aquifer thickness, which may be subject to numerical dispersion. This in turn, will facilitate an increase in simulated downward leakage of the affected water the lower aquifer. This adds to the conservatism of the contaminant transport model. Therefore, given the conservative, worst-case assumptions related to simulating the end use plan, impacts to the WHPAs are likely to be minimal.

4.3.4 Wash Ponds

Gravel washing and detention ponds created during production operations will not remain in place upon final site reclamation. Only the end use ponds shown in **Figure 13R** will remain. Potential groundwater TDS and temperature impacts from production detention ponds exist; however, the potential impacts are reduced since the detention pond water will be continuously recycled. Furthermore, impact of these ponds is expected to be less than that of the end use ponds due to the much smaller numbers, size, and areal extent in which they cover. Any mitigation measures taken to minimize impacts resulting from the end use ponds should be sufficient to mitigate potential impacts incurred, if any, from the wash ponds. After 40 years, the simulated effects of TDS and temperature have

minimally impacted the surface water, wetlands, and the WHPAs with eleven larger ponds in the end use plan. Therefore, the potential impact from the smaller wash ponds is considered to be negligible in comparison. Also, the wash ponds tend to form a very tight silt/clay liner after a short period of time, further minimizing potential impacts (Hansen, 1999).

4.4 Dewatering

Based on the interpreted groundwater contour map of the shallow aquifer (**Figure 4R**) and the interpreted depth and extent of the aggregate deposit, portions of the aggregate deposit will be subject to underwater mining.

Localized dewatering used to facilitate excavation of sand and gravel below groundwater was considered. Should localized dewatering occur, it would likely be accomplished utilizing shallow well points or sump pits. The methodology of dewatering is assumed to be similar to that previously evaluated for the Lauer property within the proposed Mining Area (SEH, 2003). It consists of a pumping scenario that utilizes between 12 and 18 wells equally spaced around a circle with a diameter of approximately 1,000 feet. The total pumping rate to dewater this area is estimated to range between 600 and 1,200 gallons per minute (gpm). Dewatering discharge would be pumped to on-site infiltration basins with no direct off-site discharge to North Creek, the Vermillion River or other protected surface waters.

There are two main areas of concern when dewatering during future mining operations. Dewatering the southwest corner of the proposed Mining Area near the future location of End Use Pond 10 (**Figure 13R**) may impact flows to North Creek, and the southeast corner of the Mining Area near the future location of Pond 11 may impact flows to Butler Pond and the neighboring wetlands.

Simulations were conducted using 15 wells equally spaced around a circle with a diameter of approximately 1,000 feet. Pumping rates of 600 gpm and 1,200 gpm equally distributed between the wells were evaluated. **Table 4-4** summarizes the hydraulic impacts to select surface water localities.

Table 4-4: Summary of Changes in Groundwater Discharge at Select Localities During Select Dewatering Scenarios

Surface Water Locality	Initial Flux (ft^3/day)	Flux during Dewatering at 600 gpm (ft^3/day)	Percent Change	Flux during Dewatering at 1,200 gpm (ft^3/day)	Percent Change
North Creek[1]	102,734	96,189	6.3	93,693	8.8
Wetland North of Butler Pond	159,893	129,033	19.3	125,953	21.2
Butler Pond	16,416	8,513	48.1	7,822	52.4
Wetland South of Butler Pond	68,246	41,046	39.9	38,029	44.3

[1] Includes the entire perennial section of North Creek north of gauging station CHP3

Modeling estimates that fluxes to the local surface water and wetlands near the southern boundary of the proposed mining area will experience reduction in flux rates ranging from 6.3 to 52.4 percent (see Table 4-4). These results suggest that dewatering may be feasible in the northern portion of the proposed Mining Area with minimal impacts on surface water features. Dewatering in other portions of the Mining Area has potential for impacts to surface waters and should only be permitted after further study and monitoring to ensure minimal impacts.

As indicated at the Lauer Property by SEH (2003), if pumping cannot occur in the lower aquifer, it will only be feasible to partially dewater the deposit, as it is not feasible to drawdown the aquifer to the impervious boundary. Therefore, it may be necessary to terminate mining of the deposit short of the bottom or excavate a portion of the aggregate deposit in wet conditions. It is recommended to focus dewatering efforts where the bottom of the deposit is the lowest (e.g. location of future end use ponds), as this will have the most beneficial impact and will likely reduce dewatering efforts in the surrounding areas.

5.0 MITIGATION OPTIONS

Sand and gravel operators utilize substantial quantities of groundwater in the processing of aggregate, production of concrete and asphalt products and for dust suppression. Use of groundwater resources by mine operators must be balanced with existing and future uses of the groundwater resource including base flow to the Vermilion River watershed, agriculture irrigation and potable well usage. Sand and gravel mining frequently occurs in areas where the targeted sand and gravel deposits provide a shallow, productive aquifer. In many cases, mining may remove overburden and near surface layers of soils and aggregate deposits that would otherwise act as a level of protection to the underlying groundwater. In addition, many sites from which aggregate is extracted are later used as landfills, industrial plants sites or for unrestricted residential development. Changes can occur in groundwater chemistry, water elevation, flow direction, gradient and groundwater temperature ultimately upsetting the delicate balance in both the local and regional environmental setting. Services provided by groundwater can thus be adversely impacted by sand and gravel mining and the final end use conditions after mine reclamation. In order to minimize potential impacts and ensure that mining and ancillary processes can proceed under desirable cost-benefit conditions, the following Mitigation Options are suggested as components of the mining operations plan and end use plan.

5.1 Mitigation Measures

5.1.1. Permitting
Mining operators shall obtain all applicable permits concerning the design, drilling, installation, use and abandonment of groundwater production and dewatering wells per Dakota County Ordinance Number 114. Production wells, dewatering wells and sumps shall comply with all Dakota County Rules and Regulations and Minnesota Department of Health Rules and regulations. Mine Operators shall obtain Minnesota Department of Natural Resources groundwater use allocations for all production wells. Production and end use ponds shall comply with all appropriate and or applicable requirements including Dakota County Ordinance Number 50 concerning Shoreline and Floodplain Management.

5.1.2. Unsaturated Zone
Mine operators shall comply with Empire Township Ordinance Number 450 and 450a, "An Ordinance Establishing Regulations and Standards for Mineral Extraction" or the amended versions thereof. The mining permits and the reclamation plans will specifically address and control the amount of acreage that can be exposed to extraction and the amount of total acreage that can be utilized by an operator at any one time. This portion of the ordinance is an important component of the protection of groundwater because it limits the amount of exposed surface area where the underlying saturated zone containing groundwater is at greatest vulnerability. The ordinance further requires operators return overburden and topsoil in adequate quantities to protect the underlying groundwater as a part of the site reclamation.

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5.1.3. End Use Planning

The current 2020 comprehensive plan identifies the proposed Mining Area as Agriculture. During the mining period the Township will periodically update the future land use plan. Non-agriculture land uses will require careful analysis because of the shallow depth to the water table. The Township will be required to perform new environmental review of certain proposed developments according to Minnesota Environmental Rules. It is recommended that the Township consider an Alternative Urban Areawide Review for future non-agriculture land uses of larger mined tracks as the mining activities begin to cease operations. The End Use Plan should ensure the presevation of surface water drainage as identified in Figure 12, "Sand and Gravel Mining and Accessory Uses" or as the abovementioned plan may be modified. Any future land uses must carefully consider that in many cases groundwater will be less than 10 feet below the surface making the site vulnerable to contamination. Future end uses shall include consideration of the importance of the Rosemount Wellhead Protection Program and the Vermillion River Watershed.

5.1.4. Environmental Monitoring and Contingency Plan

Mine operators shall draft a surface and groundwater monitoring program for each separate mine operation and for each separate location. At a minimum it is anticipated that the monitoring plan shall include the monitoring of all surface water bodies including stormwater retention ponds, wash ponds and make-up water sumps. At a minimum, the plan shall include the installation and monitoring of both up-gradient and down-gradient monitoring wells capable of evaluating changes in groundwater elevation, temperature and dissolved solids. The operating plan shall be approvable by all local government authorities including Empire Township, the Rosemount Wellhead and Source Water Protection Plan Administrator, Dakota County Environmental Management and the Vermillion River Watershed Joint Powers Organization (JPO). The plan shall list contingencies that the mine operator will implement based on observed groundwater impacts.

The mine operators shall fund a separate long-term monitoring program that includes long-term monitoring and reporting of:

- The existing Empire groundwater monitoring wells
- Vermillion River and tributaries of the Vermillion River within Empire Township, which include, but are not limited to North Creek, Unnamed Tributaries 1 and Butler Pond
- Adjacent wetlands.

Information shall be used by the operators to validate the numerical model simulations and ensure that unanticipated changes in site conditions are promptly addressed. The Environmental Monitoring and Contingency Plan is intended to

address the inherent uncertainties associated with trying to simulate future conditions using a numerical groundwater model.

5.1.5. Improve Current Understanding of Layer 2 and Layer 3

The understanding of current site conditions for the underlying deeper aquifers could be improved by installing several nested pairs of groundwater monitoring wells at the site. The wells could be used to verify current assumptions concerning hydraulic conductivity, gradient and water quality in the Prairie du Chien and the Jordan aquifers. The additional wells would certainly add an additional level of confidence in the current understanding of the localized groundwater flow system. The wells could also serve as an early warning system or sentry network for changes at the site. These wells would be included in the long-term monitoring program for the Empire Aggregate Mine Sites described above.

5.1.6. Stormwater Treatment

This topic is covered in the Surface Water Impact Study. In addition to the traditional best management plans (BMPs) for addressing suspended solids entrained in stormwater it is suggested that the mine operators investigate the use BMPs that can address dissolved solids in process water and stormwater. Dissolved solids are typically generated by the dissolution of stored aggregate by rain events or in the aggregate washing process. Stormwater rich in dissolved minerals (hardness) can adversely impact services provided by surficial groundwater. Based on the model simulations it is not anticipated that dissolved solids will present a problem but the operators should have a contingent remedy available in case modeling simulations under predict future conditions.

5.1.7. End Use Stormwater Ponds

The mine operators can significantly mitigate or eliminate groundwater elevation increases, thermal impacts and total dissolved solids increases attributed to the reclamation end use plan by changing the configuration of the proposed end use stormwater ponds to diversion swales. The diversion swales will divert stormwater and minimize infiltration as opposed to enhance infiltration of high TDS laden stormwater.   Lower infiltration rates will minimize groundwater elevation increases, mitigate thermal impacts and eliminate any increases in TDS. This is a simple and cost effective mitigation effort that should be included in the Reclamation End Use Plan.

5.1.8. Vegetative Cover

The mine operators can minimize thermal inputs to the groundwater by installing and maintaining trees and tall bushes near end use ponds. This is a traditional method for managing summertime increases in pond water by implementing a shade management plan.

5.1.9. Security

Mine operators shall ensure, per Empire Township Ordinance 405, that areas where aggregate has been mined are adequately secured until reclamation is complete. This is particularly important in areas that are included in the Rosemount Wellhead Protection Program. The End Use Plan shall include provisions for protecting groundwater resources from potential releases of chemicals by direct infiltration or contamination of the end use ponds followed by infiltration into the groundwater resource.

6.0 EXECUTIVE SUMMARY

The following section provides a general summary of the Groundwater Impact Study prepared for Empire Township. The contents of each chapter are briefly summarized. However, a significant amount of the information provided in the study is not discussed in this chapter. It is recommended that the reader review the document in its entirety to understand the methodology, results and conclusions made in preparing the groundwater analysis.

6.1 Project Description and Purpose

A consortium of mine operators and landowners propose to open new mines and expand existing aggregate mining areas to include a total area of approximately 3,600 acres in the northwest portion of Empire Township, Dakota County. Mining would be conducted in a similar manner to the current practices at existing mines within and adjacent to the Mining Area.

The various mine operators have investigated the potential for aggregate production in this area. In addition, the Minnesota Geologic Survey (MGS), Minnesota Department of Natural Resources (DNR), Metropolitan Council (METC) and local governments have conducted studies of available mineral aggregates in the metropolitan area. These studies, together with investigations conducted by mining companies, have revealed extensive reserves of mineral aggregates in portions of Empire Township. Over the next 30 to 40+ years the Mining Consortium will remove and process approximately 200 million tons of sand and gravel reserves within the Mining Area.

A Scoping Environmental Assessment Worksheet (Scoping EAW) was prepared for the proposed project in October 2003. Following review of this document, the Minnesota Environmental Quality Board (EQB) designated the review process as a "Related Actions Environmental Impact Statement (EIS)", since multiple companies and property owners are involved. A Scoping Decision Document was published in February 2004 declaring the need for an EIS and an outline of what it would address.

The Scoping Decision Document required that additional analysis be completed for the Mining Area, addressing a number of topics, including surface water. This Impact Study has been prepared to provide an analysis of potential surface water and wetland impacts in the Mining Area, and to identify options for mitigating these potential impacts. The findings of this Impact Study will be incorporated into the EIS.

6.2 Project Methodology and Assumptions

A three-dimensional numerical groundwater flow model was developed to simulate the groundwater flow system in the Study Area. The model was developed using the USGS computer program MODFLOW (McDonald and Harbaugh 1988; 1996). For this study, the model is designed as a steady-state flow model, because groundwater flow within the Study Area is reasonably

stable. In addition, a simulated steady-state flow field is adequate for simulating the long-term fate and transport of potential impacting factors from the Mining Area.

For this study, the objective of this modeling is to evaluate and quantify the potential adverse impacts of the aggregate mining operations on local water resources. Steps in the modeling process included:

- The numerical model was designed, set up, and calibrated to simulate existing groundwater conditions.
- The model was then applied to simulate changes in the system resulting from mining
- Evaluation of potential impacts of mining operations were identified, including changing of the groundwater flow regime in the Vermillion River Basin, possible impact to local wetlands, municipal supply wells in wellhead protection areas, and local brown trout population of the Vermillion River
- Evaluation of potential thermal impacts caused by excavation and aggregate washing were considered

6.2.1 Numerical Flow Model Design

The numerical flow model is a mathematical representation of the conceptual flow model. The design of a numerical model basically consists of three parts: (1) the configuration of the model, which represents the configuration of the aquifer; (2) boundary conditions, including sources and sinks, which represent the interactions of groundwater with internal and external water bodies; and (3) the input parameters, which represent various properties of the aquifer. The aquifer configuration, boundary conditions and input parameters included in the numerical flow model included:

- Model domain and discretization – impact area and geologic layers included in the model
- External boundary conditions – representing hydrologic interaction between areas inside and outside of the model
- Groundwater recharge – recharge distribution, including areal and floodplain recharge
- Vermillion River and associated tributaries – consideration of the rate and direction of flow and the head gradient between the river and groundwater
- Wetlands - distribution of wetlands simulated as groundwater discharge features
- Pumping wells - represented as a specified flux boundary
- Hydraulic parameters – adjustment of factors such as distribution of hydraulic conductivity, vertical anisotropy and conductance of model river and drain (wetland) cells

6.2.2 Calibration Strategies

Model calibration is an important process to adjust various parameters, boundary conditions, and hydraulic stresses to make the model reflect actual site conditions. Parameter values are adjusted consistent with available data to match calibration targets to a reasonable degree. Model calibration is a process that allows examination and improvement the conceptual model. Only a calibrated model is credible for use to perform model prediction simulations. The overall goal of model calibration was to make the model results match the observed flow conditions.

To calibrate the model, a set of calibration targets was first established. The flow model calibration targets include not only the measured hydraulic heads at monitoring wells, but also (1) the groundwater flow pattern, hydraulic gradients, and flow pathways; and (2) the measured or estimated flux. The flow model calibration targets included:

- Water levels from newly installed Empire monitoring wells and available water levels from the Minnesota County Well Index
- Estimated groundwater discharge rates to the Vermillion River between gauging stations BSC2 and USGS Station
- Estimated groundwater discharge rates to North Creek between gauging stations CHP3 and 801
- Estimated groundwater discharge rates to Center Creek between gauging stations PKN1 and 801
- General trend of vertical hydraulic gradients

During model calibration, the adjustment of hydraulic parameters is targeted to meet the various calibration targets and is bounded by specified upper and lower limits, which are chosen based on available information and understanding of the hydrogeologic system.

The model calibration results are evaluated from various aspects, including comparison to the observed hydraulic heads, groundwater potentiometric surface, horizontal and vertical hydraulic gradients, groundwater flow pathways, estimated flux, and overall mass balance. For a detailed discussion of calibration results, see Section 2.3.1.

6.2.3 Model Limitations

The following limitations of the model should be recognized in understanding the model results or before applying the model to future uses.

- The model simulated flow field represents average flow conditions that do not vary over time, and the simulated volumetric fluxes and contaminant migration represent long-term average conditions without consideration of annual variation or seasonal fluctuation.

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- The calibrated hydraulic conductivity distribution is a function of the combined effect of hydraulic gradients represented in the potentiometric surface, applied groundwater recharge rate, and specified layer thickness. Any uncertainty or inconsistency between model setup and field conditions that are related to these components might introduce uncertainty or inconsistency to the calibrated hydraulic conductivity distribution.

- The model simulated aquifer heterogeneity is limited by two factors: the model grid size and the heterogeneity that can be reflected in the hydraulic head distribution or interpreted potentiometric surface. The level of detail of heterogeneity, if beyond the above factors, may not be simulated in the model, even though it may have significant influence on hydrologic impacts or contaminant migration.

- Hydraulic conductivity and variations in recharge of the rejected sand that is backfilled in the excavations are unknown. Assumptions were made based on the changes, but the absolute values of these parameters is unknown. If the actual values of these parameters differ significantly from those proposed here, the results of this model may not be directly applicable.

- The simulated TDS and temperature plumes are highly dependent upon the assumed TDS and temperature at the source locations. Thus, the simulated plumes are subject to the uncertainties associated with source conditions. Initial TDS and temperature inputs were worst-case.

- The simulated extent of TDS and temperature plumes is based on assumed effective porosity as well as assumed dispersivities. Because these two parameters are assumed based on literature values instead of site-specific information, the simulated extent of these "plumes" is subject to uncertainties associated with these assumptions.

- The calculated mass loading of TDS and temperature to the surface water features depends on simulated fluxes. As there is some uncertainty in this simulated fluxes to Butler Pond and the neighboring wetland features, the model simulated mass loading may be over estimated.

- The transport code MT3D used for this study does not explicitly simulate heat transfer. This process is approximated in this study using principles in the conservation of mass. This is intended to provide a baseline worst-case to analyze the effects of temperature. Any further analysis or refinement of the effects of temperature with this model in further detail than that described herein may be unreliable.

6.3   Existing Conditions

6.3.1 Geology

Geologic units in Dakota County in the vicinity of Empire Township can be classified into three major categories: (1) Precambrian volcanic and crystalline

rocks; (2) Cambrian through Ordovician sedimentary rocks; and (3) Quaternary unconsolidated deposits which include glacial outwash, glacial till, and alluvial deposits.

Bedrock Geology
The general characteristics of the bedrock units pertinent to this study include Platteville-Glenwood Formations, St. Peter Sandstone, Prairie du Chien Group, and Jordan Sandstone. The thickness and textural characteristics of these units can vary from place to place but, in a general sense, are relatively uniform.

Platteville and Glenwood Formations
The Ordovician Glenwood Formation is green, sandy shale that overlies the St. Peter Sandstone, where present. The Glenwood Formation ranges in thickness up to 15 feet. The Ordovician Platteville Formation is a fine-grained dolostone and limestone (Mossler, 1990). The Platteville Formation is reported to be approximately 10 feet thick. Both units are present as small isolated flat-topped mesas within the Study Area.

St. Peter Sandstone
The upper half to two-thirds of the Ordovician St. Peter Sandstone is fine- to medium-grained quartzose sandstone. Quaternary erosion by glaciers has removed much of the St. Peter Sandstone and younger Paleozoic rocks from central and southern Dakota County, leaving remains of the St. Peter Sandstone as isolated outcrops, typically capped by the Platteville-Glenwood Formations, which are more resistant to erosion.

Prairie du Chien Group
The Ordovician Prairie du Chien Group contains the Shakopee Formation (upper) and the Oneota Dolomite (lower). The Prairie du Chien Group is approximately 145-feet thick near St. Paul (Mossler, 1990).

Jordan Sandstone
The upper part of the Cambrian Jordan Sandstone is medium- to coarse-grained, friable, quartzose sandstone that is trough cross-bedded. The Jordan Sandstone is approximately 90 feet thick near the Minnesota River and thickens to over 200 feet in southern Dakota County (Mossler, 1990).

Quaternary Geology
The Quaternary geology surrounding the Mining Area is primarily outwash and till deposits related to the advance of the Superior and Des Moines glacial lobes. Superior till and outwash predominate the Mining Area, but there is also some Des Moines till/outwash near the southern portion of the Mining Area (**Figure 10R**). Superior lobe tills are generally rich in sand with lesser portions of silt and clay. Des Moines Lobe tills are very clay-rich. The area surrounding the Vermillion River channel is primarily filled with floodplain alluvium, but also contains till from the Superior and Des Moines lobes. In addition, there also exist

some isolated exposures of pre-late Wisconsin deposits such as the "Old Gray" Till which is observed in isolated exposures on some of the topographic highs surrounding the Mining Area.

6.3.2 Hydrogeologic Setting

Hydrostratigraphic Units
Hydrostratigraphic units comprise geologic formations of similar hydrogeologic properties, which are combined or divided into aquifers or aquitards. These hydrostratigraphic units include:

- Prairie du Chien-Jordan Aquifer – treated as a single aquifer system in early studies, but more recently identified as two distinct units
    - Jordan Sandstone - sub-crops beneath glacial drift and alluvium in major river valleys, which are the primary discharge zones
    - Prairie du Chien Group - groundwater flow primarily through fractures, joints, and solution features
- Glacial Drift-St. Peter Aquifer – relatively good hydraulic connection with local streams and lakes; recharge primarily by infiltrating precipitation; discharge to streams, lakes and leakage to underlying aquifers

Groundwater Flow
Groundwater generally moves from upland areas of recharge downgradient to lowland areas of discharge. In the Study Area, groundwater movement is generally from west-southwest to east-northeast.

The contours for the shallow Glacial Drift-St. Peter aquifer were derived based on water level measurements from the Minnesota County Well Index, boreholes used to delineate the depth and extent of aggregate mining deposit, in addition to the five newly installed Empire Township monitoring wells (**Figure 2R**). In addition, groundwater contours are constrained by the surface topography of wetland areas that have been delineated as groundwater dependent resources and represent groundwater discharge areas (see Section 2.6). Groundwater elevations in the shallow aquifer throughout Dakota County are generally stable, exhibiting fluctuations of less than three to four feet (EOR, 2004). Depth to groundwater in the Mining Area is generally in excess of 20 feet. In some localities, depth to groundwater may be more than 50 feet. In the vicinity of the Vermillion River and other groundwater discharge areas, depth to groundwater is essentially negligible with some areas exhibiting artesian conditions.

Hydraulic Gradients
The horizontal hydraulic gradient is approximately 0.002 feet/feet and does not vary substantially throughout the Study Area. To the northeast, hydraulic gradients increase slightly to 0.003 feet/feet as groundwater approaches the discharge area of the Mississippi River. To the west of the Mining Area boundary, the hydraulic gradient is 0.001 feet/feet. This may be indicative of

more permeable strata in the subsurface, but this is speculative as the available hydraulic head data west of the Mining Area is limited.

Vertical hydraulic gradients vary substantially throughout the Study Area and some spatial trends in vertical gradients have been observed. Generally, measured hydraulic head differences between shallow and deep aquifers at wells clustered together (**Figure 4R**) show downward gradients in upland areas away from the river and upwards gradient in the vicinity of the river. This suggests that groundwater recharge by direct infiltration of precipitation occurs in most of the areas away from the creeks, whereas groundwater discharge occurs at the creeks and along the floodplains. It also suggests that the convergence of groundwater flow toward the Vermillion River occurs horizontally as well as vertically. This is supported by strong upward hydraulic gradients, even artesian flow conditions, observed along the river. However, local vertical hydraulic gradients may vary significantly and not follow this spatial trend. Upward flow gradients have been observed in areas away from the creeks and vice versa, suggesting that local vertical gradients are influenced by local heterogeneities.

6.3.3 Groundwater Recharge

Groundwater recharge occurs throughout the Study Area as a result of surface water infiltration. Infiltration of direct precipitation is dependent upon the rate and duration of precipitation, the soil type and soil cover, land use, evapotranspiration, and topography. In a steady-state model, the resulting infiltration rate is typically estimated on an annual basis - although seasonal estimates are sometimes utilized. Groundwater recharge in the upland areas and lowland areas along the floodplains can be considered separately as areal recharge and floodplain recharge, respectively.

The predominant source of recharge for the deeper aquifers in Dakota County is regional flow from areas outside the County and downward leakage from the Glacial Drift/St. Peter aquifer.

Areal Recharge
Areal groundwater recharge occurs as a result of surface water infiltration primarily during early springtime. Assuming that long-term groundwater recharge is approximately equal to long-term groundwater discharge to streams, annual recharge from precipitation is approximately 1.5 to 4.5 inches per year. Thus, about 6 to 15 percent of precipitation infiltrates to groundwater.

Floodplain and Wetland Recharge
The occurrence and amount of groundwater recharge along the river and tributary floodplains are expected to be of greater magnitude than areal recharge. Infiltration occurs along the floodplains as a result of direct precipitation and flooding caused by surface water runoff. The rate of floodplain recharge is unknown, but it is expected to be greater than areal groundwater recharge.

6.3.4 Hydraulic Properties of Aquifer(s)

Hydraulic conductivity, specific yield (or storage coefficient), and effective porosity are commonly used to characterize the hydraulic properties of an aquifer. In this study, the flow conditions are considered relatively stable; thus, specific yield, which is related to temporal variation of groundwater, is not discussed. Site-specific data for effective porosity are not available.

6.3.5 Surface Water

Vermillion River and Associated Tributaries

The Vermillion River is located approximately two miles south of the southern boundary of the proposed Mining Area. The Vermillion River begins in Scott County and flows into Dakota County, ultimately discharging into the Mississippi River near the city of Hastings, Minnesota. The drainage area to the Vermillion River at the gauging station is approximately 129 square miles. The Vermillion River is a zone of groundwater discharge in the Study Area and becomes a source of groundwater recharge downstream closer to the Mississippi (Palen, 1990; Almendinger and Mitton, 1995)

North Creek is located approximately one mile west of the west boundary of the proposed Mining Area. North Creek extends from the City of Lakeville into the City of Farmington and Empire Township, and acts as a major tributary to the Vermillion River. The total area of the North Creek watershed is approximately 15,774 acres, including drainage areas from Lakeville, Farmington, Apple Valley, Rosemount, Burnsville and Empire Township. This creek is perennial throughout much of its length, but has several ephemeral branches in its headwaters. Middle Creek is another perennial tributary to the Vermillion River that drains the highland area west of Flagstaff Avenue in southern Lakeville.

There are two unnamed tributaries to the Vermillion River in vicinity of the Mining Area. Unnamed Tributary 1 lies south of the Mining Area. This is a perennial tributary that drains the Butler Pond area. Local residents have indicated that this pond does not completely freeze during coldest winter months suggesting that it may be fed, in part, by groundwater flow. Small portion of Unnamed Tributary 1 north of Butler Pond is considered to be groundwater fed based on mapping of adjacent vegetation, but is ephemeral throughout most of the proposed Mining Area (EOR, 2004).

Unnamed Tributary 2 lies to the east of the Mining Area is ephemeral and typically dry. Detailed analysis indicates this tributary is a zone of recharge. Hydraulic gradients between nested wells in the vicinity of these drainages indicate downward gradients representative of a recharge area.

The following table presents a summary of stream flow data taken in mid-July of 2004 indicating representative flow rates observed at several of the gauging stations depicted in **Figure 2R** (EOR, 2004).

Table 6-1: **Summary of Stream Gauging Measurements in the Vicinity of the Proposed Mining Area**

Gauging Station	River Branch	Flow (cfs)
ANN1	Unnamed Tributary 1	1.30
CHP3	North Creek	6.49
CHP2	North Creek	7.81
BCS2	Vermillion River	69.04
801	Middle Creek	51.4
804	Vermillion River	31.0
807	Vermillion River	37.4
808	North Creek	10.7
USGS	Vermillion River	84.0

6.3.6 Wetlands

Wetlands within the Study Area were identified by the Empire TownshipWetlands Inventory (EWI). Wetlands surrounding the proposed Mining Area consist of both discharge and recharge wetlands. A study using field investigation and GIS analysis is currently underway by Emmons and Olivier Resources, Inc. (EOR) to delineate the extent of groundwater dependent resources in Scott-Dakota County. The wetlands identified as probable groundwater discharge areas are located along the banks of the Vermillion River and North Creek in addition to several flatland areas in the vicinity of Butler Pond. These consist of mixed hardwood swamp, willow swamp, wet prairie, and wet meadow.

The wetlands not delineated in the EOR study are considered to be wetlands that recharge the groundwater system. Recharge to the shallow aquifer occurs when the wetland collects rain or spring snowmelt, and water infiltrates downward.

6.3.7 Summary of Conceptual Model

The primary source of recharge to the Glacial Drift/St. Peter Sandstone aquifer is infiltrating precipitation. The primary source of recharge for the Prairie du Chien Group and Jordan Sandstone aquifers is leakage from adjoining aquifer. Lakes and ponded water in wetlands are generally perched above the water table and leak water down into the aquifer as a function of the resistance of the lake's bottom sediment and the unsaturated drift material below the lakes.

Discharge of groundwater occurs at the Vermillion and Mississippi Rivers and their adjacent wetlands. Pumping wells also remove water from the aquifer units.

6.4 Mining Impact Analysis

The following section summarizes the results of the numerical modeling effort to assess potential impacts related to proposed mining operations.

6.4.1   Hydrologic Impacts Related to the End Use Plan

The model estimates that groundwater levels may raise between 2.0 and 3.0 feet with water table increases of 0.1 and 0.5 near the boundaries of the proposed Mining Area. This change in the groundwater elevations is interpreted to be the maximum potential impacts due to hydraulic impacts of the end use plan and considered to be a very worst-case scenario. These results are based on the use of a comparatively high hydraulic conductivity for the material lining the base of the stormwater ponds in addition to the assumption that these ponds will be used entirely as detention ponds as opposed to their primary intended use as stormwater diversion structures. Use of these as diversion structures will limit the amount of hydraulic head that will drive infiltration downward to the aquifer and will minimize the amount of groundwater level rise.

Using the conservative, worst-case assumptions, mining changes produce minimal impacts to the estimated groundwater fluxes to select surface water features surrounding the proposed mining area. Groundwater flow rates to Butler Pond and the surrounding wetlands are estimated to increase between 0.02 and 0.05 cfs, resulting in a 2.7 to 21.1 percent change in flow. Groundwater flow to North Creek is estimated to increase 0.08 cfs, reflecting a 6.8 percent increase in flow. These changes in the simulated long-term, average estimated flow rates are less than the observed seasonal fluctuations. Given the conservative, worst-case assumptions, hydraulic impacts to these surface water features are estimated to be negligible.

6.4.2   Impacts related to TDS and Temperature

The numerical model was used to evaluate potential TDS and temperature impacts to local surface water and wetlands features. A conservative scenario was used in which the stormwater ponds have an elevated TDS of 1,000 mg/L, ten times the TDS concentration of a local analogue pond and twice the average concentration of local groundwater and surface water concentrations. Likewise, thermal impacts were simulated using conservative, worst-case assumption in which there is no conductive heat loss to the aquifer. Model results indicate TDS concentration increases ranging between 3.6 to 36 mg/L and temperature increases ranging between 0.07 and 1.13 ℃ to the local surface water and wetland features (see tables 4-2 and 4-3). These estimated changes in TDS and temperature are well below the range of seasonal fluctuations and within the range of variability related to sampling error. Therefore, given the conservative, worst-case assumptions, impacts related to temperature and TDS to these surface water features are deemed to be negligible.

6.4.3   Impacts Related to Potential Dewatering

The methodology of dewatering is assumed to be similar to that exhibited at the Lauer property in Empire Township (SEH, 2003). Simulations were conducted using 15 wells equally spaced around a circle of diameter of approximately 1,000 feet. Pumping rates of 600 gpm and 1200 gpm equally distributed between the wells were evaluated. Modeling estimates that fluxes to the local surface water

and wetlands near the southern boundary of the proposed mining area will experience reduction is flux rates ranging from 6.3 to 52.4 percent (see Table 4-4). These impacts to the local surface water features are considered to be minimal to moderate. It is therefore recommended that dewatering during mining be limited to areas in the northern portion of the proposed Mining Area where impacts to the local surface water and wetlands are deemed to be negligible.

6.4.4   Impacts to the Wellhead Protection Area

The model estimates that the TDS will increase approximately 5 to 85 mg/L and will increase in temperature approximately 0.2 to 2.0 °C within the WHPAs and DWMAs delineated for the Rosemount wells. However, for the most, maximum increases are localized in a small portion of the WHPA and DWMA with increases in TDS and temperature primarily on the order of 30 to 50 mg/L and less than 1.0 °C, respectively. However, given the conservative, worst-case assumptions related to simulating the end use plan, impacts to the WHPAs are likely to be minimal.

6.4.5 Mining Impact Conclusions

Numerical modeling was performed to evaluate potential hydraulic, chemical (e.g. TDS), and thermal impacts on local wetlands, surface waters that may act as trout habitat, and wellhead protection areas. As indicated in the previous section, input parameters to evaluate these impacts have been selected using conservative assumptions to arrive at the worst-case scenario. While the worst-case assumption is assumed, model predications indicate that the potential adverse impacts to the aforementioned resources are negligible.

6.5   Mitigation Options

In order to minimize potential impacts and ensure that mining and ancillary processes can proceed under desirable cost-benefit conditions, the following Mitigation Options are suggested as components of the mining operations plan and end use plan.

- Permitting - Mining operators shall obtain all applicable permits concerning the design, drilling, installation, use and abandonment of groundwater production and dewatering wells per MDNR, MDH and Dakota County Ordinance Number 114.
- Unsaturated Zone - Mine operators shall comply with Empire Township Ordinance Number 450 and 450a, "An Ordinance Establishing Regulations and Standards for Mineral Extraction" or the amended version thereof.
- The current 2020 comprehensive plan identifies this area as Agriculture. During the 35-year mining period, the Township may periodically update the future land use plan. Any non-agriculture land uses identified within the Mining Area will require careful analysis because of the shallow depth to the water table. The Township will be required to perform new environmental review of non-agriculture

developments according to Minnesota Environmental Rules. It is recommended that the Township consider an Alternative Urban Areawide Review for future non-agriculture land uses of larger mined tracks as the mining activities begin to cease operations. The End Use Plan should ensure the preservation of surface water drainage as identified in Figure 12. The ultimate end use drainage features shall be preserved in the post mining land plan by enforcement of the then current planning and zoning ordinances and building codes. Any future land uses must carefully take into consideration that in many cases groundwater will be less than 10 feet below the surface making the site vulnerable to contamination. Future end uses shall include consideration of the importance of the Rosemount Wellhead Protection Program and the Vermillion River Watershed.

- Environmental Monitoring and Contingency Plan - mine operators shall draft a surface and groundwater monitoring program for each separate mine operation and for each separate location. At a minimum it is anticipated that the monitoring plan shall include the monitoring of all surface water bodies including stormwater retention ponds, wash ponds and make-up water sumps. At a minimum, the plan shall include the installation and monitoring of both up-gradient and down-gradient monitoring wells capable of evaluating changes in groundwater elevation, temperature and dissolved solids.

- The mine operators shall fund a separate long-term monitoring program that includes long-term monitoring and reporting of:
    - The existing Empire groundwater monitoring wells
    - Vermillion River and tributaries of the Vermillion River within Empire Township
    - Adjacent wetlands

- Improve the current understanding of Layer 2 and Layer 3 - install several nested pairs of groundwater monitoring wells at the site. The wells could also serve as an early warning system or sentry network for changes at the site. These wells would also be included in the long-term monitoring program described above.

- Stormwater treatment – Best Management Practices (BMPs) as described in the Surface Water Impact Study.

- End use ponds - mine operators can significantly mitigate or eliminate groundwater elevation increases, thermal impacts and total dissolved solids increases attributed to the reclamation end use plan by changing the configuration of the proposed end use ponds from retention ponds to diversion swales.

- Vegetative cover - mine operators can minimize thermal inputs to the groundwater by installing and maintaining trees and tall bushes near end use ponds.

- Security - Mine operators shall ensure, per Empire Township Ordinance 405, that areas where aggregate has been mined are adequately secured until reclamation is complete. This will protect

groundwater resources from potential releases of chemicals that could infiltrate and contaminate the resources. This is particularly important in areas that are included in the Rosemount Wellhead Protection Program.

6.6   Definitions

Anisotropy   exhibiting properties with different values when measured in different directions

Areally   spatially distributed

Baseflow   flow in a stream, river or creek solely attributed to groundwater discharge

Discharge   a condition in which the net flux of water into the aquifer system is negative, hence water is leaving the aquifer system

Discretization   how the model domain is divided up into space and time

Flux   flow of a volumetric quantity of a liquid through a prescribed area over a given time

Hydraulic Conductivity   a coefficient of proportionality describing the rate at which water can move through a permeable medium

Potentiometric Surface   a surface that represents the level to which water will rise in tightly cased wells

7.0   REFERENCES

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UMP003252

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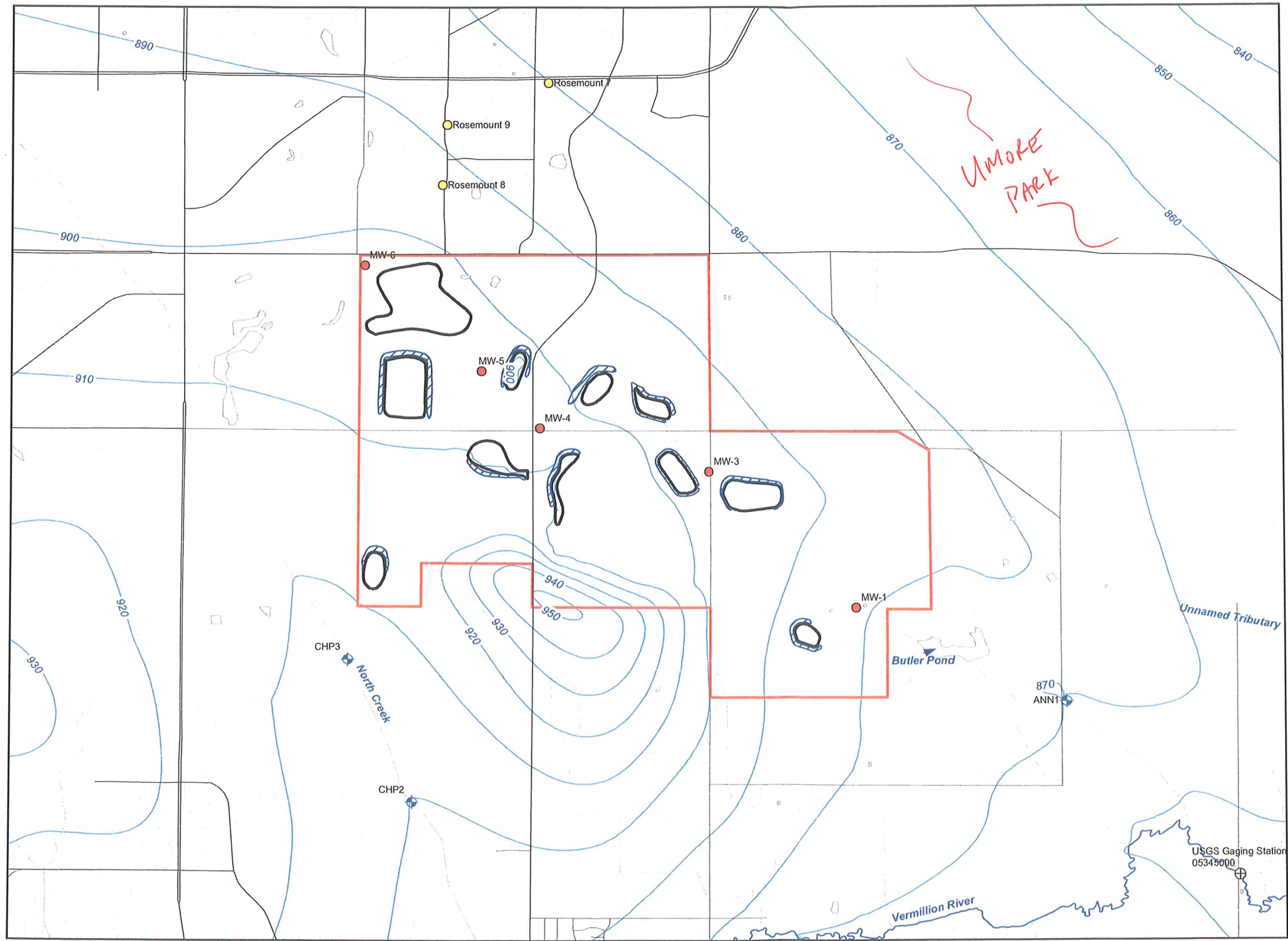
Explanation

⊕ USGS Gaging Station
● Gaging stations depicted in Almendinger and Mitton (1995)
◆ SWCD In-river piezometer and gaging station
○ Rosemount Wells
● Township Monitoring Well
— Perennial Stream
— Ephemeral Stream

Simulated Groundwater Contours (with ponds)
— Index Groundwater Contour
— Intermediate Groundwater Contour
▭ Proposed Mining Area
▭ Open Water

Proposed Ponds
▭ Groundwater Pond
▨ Stormwater Pond

UMORE PARK

From: Final Related Actions Environmental Impact Statement by Bolton + Menk, Inc., June 2005

Page 9

Sand & Gravel Mining and Accessory Uses

Figure 14
Simulated Reasonable Water Levels
After End-Use Plan Implementation

URS   Empire Township

0 750 1,500   3,000 Feet

UMP003254
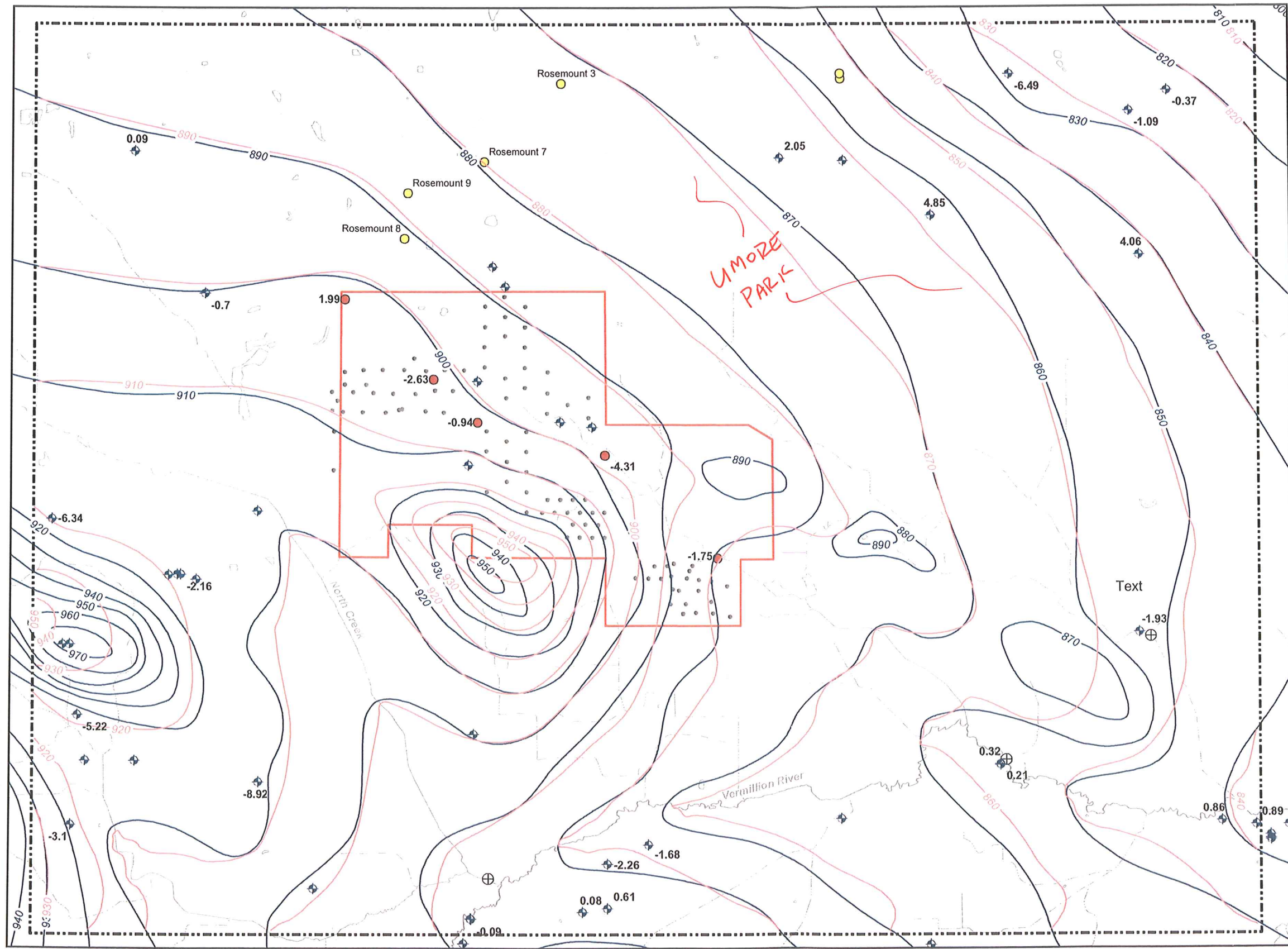
Explanation

⬩ Shallow Wells (screened in glacial outwash/till and/or St. Peter Sandstone)

🔴 DNR Monitoring Well

· Aggregate Boring Locations

🟡 Rosemount Wells

⊕ USGS Gauging Station

—— Simulated Groundwater Contours (ft)

—— Interpreted Groundwater Contours (ft)

⌐·⌐· Model Domain

▭ Proposed Mining Area

Open Water

-2.63   Model Residual (Observed – Simulated)

UMORE PARK

From: Final Related Actions Environmental Impact Statement by Bolton + Menk, June 2005

Sand & Gravel Mining and Accessory Uses

URS   Empire Township

N

0   2,000   4,000   8,000 Feet

Figure 5 Revised   Page 6
Interpreted vs. Simulated Groundwater
Contours for Model Layer 1

UMP003255
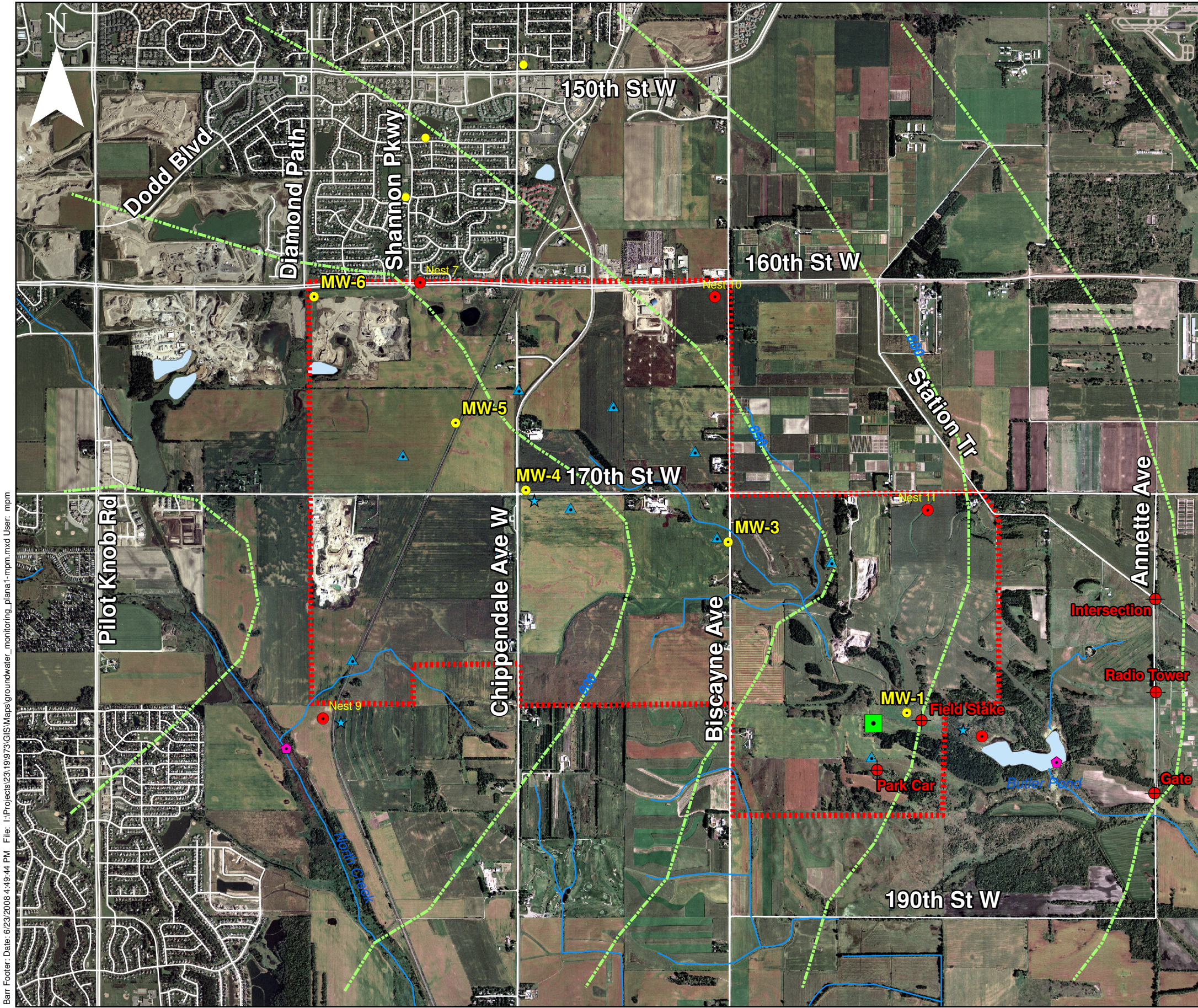
Legend

- ⊕ Landmarks
- ⊙ Existing_mon_wells_June_2008
- ★ Rain/Tipping Buckets
- ⬠ Surface-Water Level/Temp Monitoring Stations
- ▣ Runoff Monitoring Station
- ▲ Pond Shallow Wells (20 ft and 50 ft from Pond) (location is approximate)
- ● Proposed Well Nests
- ⎯⎯ Predicted Water-Table Contours (feet, MSL) at Year 40
- ● City of Rosemount Water Supply Wells
- ⬚ Proposed Mining Area Boundary (tentative location, site conditions permitting)

Notes: Proposed well locations, surface-water level monitoring locations, and tipping-bucket locations are approximate

Miles

0   0.45   0.9

Feet

0   3,200   6,400
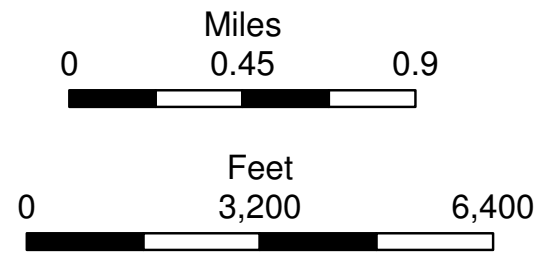
Figure 2-1-MPM

WELL LOCATIONS
MW-1 THROUGH MW-5

(Groundwater and Surface Water
Monitoring Plan: Proposed Location
of Wells and Tentative Location of
Runoff Monitoring Station)

UMP003256

Appendix E

Other Groundwater Information Sources

Technical Memorandum

To: File
From: Jim Eidem
Subject: Well Search, UMore Park
Date: October 1, 2008
Project: 23/19-0B05.03

This technical memorandum has been prepared to document the methods by which the well search for the above referenced project was conducted.

County Well Index Search

The well search was conducted with the use of the web-based County Well Index (CWI) data system which is maintained by the Minnesota Department of Health. The data system is available to public users for the storage and retrieval of water-well information. Output from the CWI includes a well logs with descriptions of the geologic units encountered, well construction information and approximate depth to water measurements and a map illustrating approximate well locations.

The CWI search area included the property within UMore Park and neighboring PLS sections. The search area was by Township/Range/Section and the returned well logs were catalogued. Table 1 provides a summary of the CWI records.

Additional Well Search

In addition to the CWI search, well logs and information were gathered from additional sources. These additional sources included the University of Minnesota, Dakota County, and information published from the Environmental Impact Statement prepared for the Empire Sand and Gravel Mining District located southwest of UMore Park. Data from these sources are also included in Table 1.

Technical Memorandum
To: File
From: JME
Subject: Well Search, UMore Park
Date: October 1, 2008
Page: 2

Data Review and Well Selection

The resultant well logs were reviewed to determine which existing wells may provide data useful for the hydrogeologic assessment. The following screening criteria were applied to the wells identified during the well search and specific wells were not considered useable if the well was:

- sealed;

- completed across multiple aquifers;

- completed in the Jordan aquifer (or deeper);

- located greater than ½ mile off-site (with a few exceptions);

- located off-site and used for domestic water supply; or

- the well log was incomplete (e.g. missing well construction or aquifer information).

After the initial screening with the criteria above, a site reconnaissance visit was conducted to locate wells that passed the screening. A number of wells that passed the screening criteria were not located during the site visit and thus were not considered for future use. Additional wells were removed from the list (rejected as 'not needed' in Table 1) if a nearby well that was selected for future use provided comparable data (i.e., if two Prairie du Chien wells were located within a ½ mile for each other, only one would be used for monitoring).

The final screening results are summarized in Table 1. The wells that were rejected based on the screening criteria are displayed as shaded records and wells that passed are included in non-shaded records. With permission from well/property owners and pending accessibility for a water level indicator probe, the wells that passed the screening criteria will be used to collect groundwater elevation data to supplement the hydrogeologic assessment data set.

TABLE 1 - APPENDIX E
WELL SEARCH RESULTS
UMore Park
Dakota County, Minnesota

MN Unique Well ID Number	Alternate ID Number	Location			PLLS Location				Listed Well Use	Ground Surface Elev (ft MSL)	Well Depth (ft bgs)	Aquifer	Data Source	Rejection Criteria	Comments
		On-Site	Off-Site	unknown	Townshp (north)	Range (west)	Sec	subSec							
100962			x		114	19	5	DDDAAB	Domestic	955	155	PDC	CWI	OS,DW	
101068			x		115	19	25	ADCBCD	Domestic	980	152	PDC	CWI	OS,DW	
101119			x		115	19	32	DADAAC	Domestic	954	200	PDC	CWI	OS,DW	
101181			x		115	19	32	ADAAAA	Domestic	951	220	PDC	CWI	OS,DW	
121082			x		115	19	36	DDDDCC	Domestic	910	365	Jordan	CWI	OS,TD	
124315			x		114	19	10	BAABAC	Domestic	937	135	PDC	CWI	OS,DW	
136548			x		115	19	32	BCCCDC	Sealed	941	200	PDC	CWI	SL	
145827			x		115	19	36	ADDCDC	Domestic	920	320	Jordan	CWI	OS,TD	
170826			x		115	19	36	DDDACA	Domestic	912	290	Jordan	CWI	OS,TD	
174675	2		x		115	19	27	DBCCCC	Domestic	941	178	PDC	CWI	OS,DW	Across 145th St from site, E of City Hall
179702			x		114	19	5	DCDCDC	Domestic	942	145	SP	CWI	OS,DW	
185278	Well #2	x			114	19	4	BCDCBC	Irrigation	951	310	PDC	CWI		UofM ownership, well #2
198269			x		115	19	32	CCACBB	Domestic	949	200	SP-PDC	CWI	MA	
207604			x		114	19	3	CCDBDD	Domestic	935	935		CWI	TD	
207605		x			114	19	3	BBAAAD	Domestic	943	206	PDC	CWI		Ag Eng.
207606	19	x			114	19	4	BBACBB	Sealed	954	429		CWI	SL	
207607		x			114	19	4	AAACBC	Domestic	945	170	PDC	CWI	NN	Use 208402
207608		x			114	19	4	DACADD	Public	948	415	Jordan	CWI	TD	
207611					115	19	26		Com supply	937	411		CWI	TD, ID	didn't show in intial CWI search; DNR
207612			x		115	19	26	AADADB	Domestic	895	177	PDC	CWI	OS,DW	
207613			x		115	19	26	BDDDBD	Domestic	938	178		CWI	OS,DW,ID	
207614			x	x	115	19	27	ADCDDD	Domestic	935	155	PDC	CWI	NF	
207615	4	x			115	19	33	ADBACC	Domestic	955	432		CWI	TD,ID	
207616	5	x			115	19	33	ABBBBC	Irrigation	954	221	SPPDC	CWI	MA	
207617	6	x			115	19	33	CDBBAA	Domestic	950	434		CWI	TD,ID	
207618		x			115	19	35	BADBAB	Com supply	935	390	Jor/StL	CWI	MA	
207619			x		115	19	25	BDCCCC	Domestic	965	380	Jordan	CWI	TD	
208400	1	x			115	19	28	DCCCBB	Unknown	950	153	SPPDC	CWI	MA	
208402		x			115	19	33	DDDCC	Domestic	950	166	PDC	CWI		UofM Admin bld
208403		x			115	19	34	AABBC	Unknown	940	188	QBAA	CWI		owner: US Naval Facility
208404		x			115	19	34	BABBDB	Domestic	940	115	QBAA	CWI		UofM ownership - north beef farm
208405		x			115	19	34	CCCCD	Domestic	953	236	PDC	CWI	NN	Use 208402
216240			x		114	19	9	ABBCAD	Domestic	955	182	PDC	CWI	OS,DW	
216473			x		115	19	25	BCCBAC	Domestic	950	169	QU	CWI	OS,DW	North of site on Blaine Ave (CR 71)
224320		X		x	115	19	34	BAA	Domestic	940	134	QBAA	CWI	NN	Use 208404
224364				x	115	19	35	CCCA	Domestic		73		CWI	NF	UofM ownership
224365				x	115	19	35	CACC	Domestic		50		CWI	NF	UofM ownership
224376				x	115	19	35	CBCD	Domestic		73		CWI	NF	UofM ownership
227460	T00019, MW21D	x			115	19	36	BCCDCC	Unknown	922	88	SPPDC ?			
232246				x	115	19	32	CDCCCB	Unknown	952	325	PDC	CWI	NF	
235758	23	x			114	19	1	BACDCA	Unknown	915			CWI	ID	boring?
239823			x		115	19	28			960	207		CWI	OS,ID	Far north of Site
243747		x		x	115	19	26	DCD	Unknown	930	156	PDC	CWI	NF	DNR Observ Well 19016
243767	T00006	x			115	19	35	CCC	Sealed	921	102	QWTA		SL	MW-9D, DNR obs well 19042
249104			x		115	19	25	DADACB	Domestic	921	560	Multiple	CWI	MA	
249519		x		x	115	19	34	AABB		938			CWI	NF	
249520		x		x	115	19	34	AABC		941			CWI	NF	
255137				x	114	19	4	CCCCCD	Scientific	954	80	Q	CWI	NF	detailed log by AET; boring?
255138				x	114	19	4	0	Scientific	958	85		CWI	NF	detailed log by AET; boring?
255139	22	x			114	19	2	CCCCCB	Sealed	941	78		CWI	SL	

UMP003260

TABLE 1 - APPENDIX E
WELL SEARCH RESULTS
UMore Park
Dakota County, Minnesota

MN Unique Well ID Number	Alternate ID Number	Location			PLLS Location				Listed Well Use	Ground Surface Elev (ft MSL)	Well Depth (ft bgs)	Aquifer	Data Source	Rejection Criteria	Comments
		On-Site	Off-Site	unknown	Townshp (north)	Range (west)	Sec	subSec							
255140				x	114	19	1	CBCB	Scientific	928	50		CWI	ID	boring?
328874		x			114	19	4	AAC	Sealed		59		CWI	SL	
407103			x		114	19	5	CBCBDD	Domestic	950	218	SP-PDC	CWI	MA	
412400			x		115	19	27	ADCCDB	Domestic	936	380	Jordan	CWI	TD	
425291	MW28	x			115	19	36	BCBCCC	Test well	930	230	PDC	CWI		10yr GW elevation data
425292	MW29	x			115	19	36	CBCBCB	Test well	926	230	PDC	CWI		10yr GW elevation data
425293	17	x			115	19	36	CBBCCC	Sealed	926	291	Jordan	CWI	SL	
429488	MW1		x	x	114	19	10		Monitor		52	SP	UofM		
429489		x			115	19	34		Sealed		68		CWI	SL	
434005	12	x			115	19	35	ACBCCB	Sealed	934	107	PDC	CWI	SL	
434006	13	x			115	19	35	BDDDBB	Sealed	934	84	QBUA	CWI	SL	
441909	3	x			115	19	27	DCDDBB	Domestic	940	380	Jordan	CWI	TD	
441911	11	x			115	19	34	BABBAD	Domestic	935	420	Jordan	CWI	TD	
441912		x			115	19	34	BA	Domestic		120?		CWI	SL	
441915			x		114	19	8	AAABBD	Domestic	938	150	SP	CWI	OS,DW	
450888				x	115	19	25		Sealed		60		CWI	SL	
450889				x	115	19	25		Sealed		94		CWI	SL	
450890				x	115	19	25		Sealed		84		CWI	SL	
457126			x	x	115	19	27	ADC	Monitor		245		CWI		
457167			x		115	19	27		Com supply	940	400	Jordan	CWI	TD	didn't show in intial CWI search; DNR
506638			x		115	19	32	DCCDBB	Domestic	952	198	PDC	CWI	OS,DW	
507991	MP1E		x		115	19	25		Monitor		78		CWI	NF	UofM ownership, WT well
507992	T00020, MW22		x		115	19	25		Sealed?		63		UofM		UofM Data available
513925	MW1		x		114	19	12	BAA	Monitor		50	Q-sp/cl	UofM	NN	Use 539518
513927	MW3		x		114	19	12	BAA	Monitor		68	Q-cl	UofM	NN	Use 539518
513928	MW4		x		114	19	12	BAA	Monitor		47	Q-cl	UofM	NN	Use 539518
539514	MW6		x		114	19	12	BAA	Monitor		68	Q-sp/ml	UofM	NN	Use 539518
539515	MW8		x		114	19	12	BAA	Monitor		68	Q-cl/sl	UofM	NN	Use 539518
539516	MW7		x		114	19	12	BAA	Monitor		51	Q	UofM	NN	Use 539518
539517	MW9		x		114	19	12	BAA	Monitor		50	Q	UofM	NN	Use 539518
539518	MW2		x		114	19	1	DCD	Monitor		68	Q	CWI		
539519	MW10		x		114	19	12	DCD	Monitor		51	Q	UofM	NN	Use 539518
540395	MW13		x		114	19	1	DCD	Monitor		99	PDC	CWI		
540396	MW12		x		114	19	12	BAA	Monitor		110	PDC	UofM	NN	Use 540395
543862	MW1	x			114	19	3	BBD	Sealed		65	Q	CWI	SL	PEER study of MPCA Leak #2529
543863	MW2	x			114	19	3	BBD	Sealed		65	Q	CWI	SL	PEER study of MPCA Leak #2529
543864	MW3	x			114	19	3	BBD	Sealed		65	Q	CWI	SL	PEER study of MPCA Leak #2529
575906	MW1	x		x	114	19	4	ADA	Monitor				Delta	NF	
585110					115	18	33	BBBCBD	Domestic	895	360	JOR-STL		TD	
585147					115	18	33	BCCABB	Domestic	899	360	JOR-STL		TD	
585160			x		115	19	36		Domestic		320		CWI	OS,DW	
590636				x	114	19	1		Industrial		320		CWI	TD	SKB well
629447			x		114	19	9	AABACB	Domestic	957	177	PDC	CWI	OS,DW	
635497	MW2	x			114	19	4	DAA	Sealed		50		CWI	SL	
635498	MW3	x			114	19	4	DAA	Sealed		50		CWI	SL	
635499	MW4	x			114	19	4	DAA	Sealed		59		CWI	SL	
642485		x			115	19	35	DCB	Domestic		340	Jordan	CWI	TD	UofM ownership
651999			x		114	19	3	CDB	Irrigation		320		CWI	TD,ID	
658488			x		114	19	5	DAA	Domestic		180		CWI	OS,DW	
672575			x		115	19	32	ACD	Irrigation		330		CWI	OS,ID	

TABLE 1 - APPENDIX E
WELL SEARCH RESULTS
UMore Park
Dakota County, Minnesota

MN Unique Well ID Number	Alternate ID Number	Location			PLLS Location				Listed Well Use	Ground Surface Elev (ft MSL)	Well Depth (ft bgs)	Aquifer	Data Source	Rejection Criteria	Comments
		On-Site	Off-Site	unknown	Townshp (north)	Range (west)	Sec	subSec							
678244			x		115	19	32	ABCDDB	Test well	965	467	Jordan	CWI	TD,OS	
683049			x		114	19	1	DDC	Domestic		275		CWI	OS,DW	
698456			x		114	19	16	AAA	Monitor		19	Q	CWI		Empire S&G MW
698459			x		114	19	8	AAD	Monitor		50.5	Q	CWI		Empire S&G MW
698460			x		114	19	6	DBD	Monitor		80.5	Q	CWI		Empire S&G MW
698461			x		114	19	6	BBB	Monitor		56	Q	CWI		Empire S&G MW
698462	MW4			x	114	19	5	CCC	Monitor		64.4		CWI		Empire S&G MW
706804			x		115	19	32	ABCDAD	Com supply	965	475	Jordan	CWI	TD,OS	
712760			x		115	19	36	DDD	Domestic		320		CWI	OS,DW	
745851		x			115	19	26	DAA	Domestic		420		CWI	TD, ID	
19W0000043			x		115	19	36	DA	Domestic	928	130		CWI	OS,DW	
19W0000103			x		115	19	27	AC	Domestic				CWI	OS,DW,ID	
19W0000282			x		115	19	36	DD	Domestic				CWI	OS,DW	
19W0000424			x		115	19	26	A	Domestic				CWI	OS,DW,ID	
19W0000641			x		114	19	5	CB	Domestic				CWI	OS,DW	
19W0000842	T00022, MW23D		x		115	19	25	DA	Monitor				UofM		UofM Data available
19W0020005				x	114	19	1	DCDCCD	Unknown	928			CWI	NF	
	T000023, MW5		x		115	19	13		Monitor				Delta	OS,ID	UofM monitoring well

Notes:
 Shading indicates well is not considered for data collection
 Domestic - indicates well is used for domestic water supply
 Sealed - indicates well has been sealed/decomissioned
 Irrigation - well used for crop irrigation water supply
 Com supply - well used for community water supply
 Monitor - well used for monitoring purposes
 SP - St. Peter Formation
 PDC - Prairie du Chien Group
 Jordan - Jordan Formation
 STL - St. Lawrence Formation
 Q - quaternary deposits
 CWI - County Well Index
 UofM - University of Minnesota

Rejection Criteria
 OS - Off-site to far to be of use
 SL - Decommissioned (sealed)
 DW - Domestic well
 TD - Total depth, well is constructed too deep to be of use
 NF - Not found
 NN - not needed
 MA - Mulitiple aquifers intercepted

UMP003262
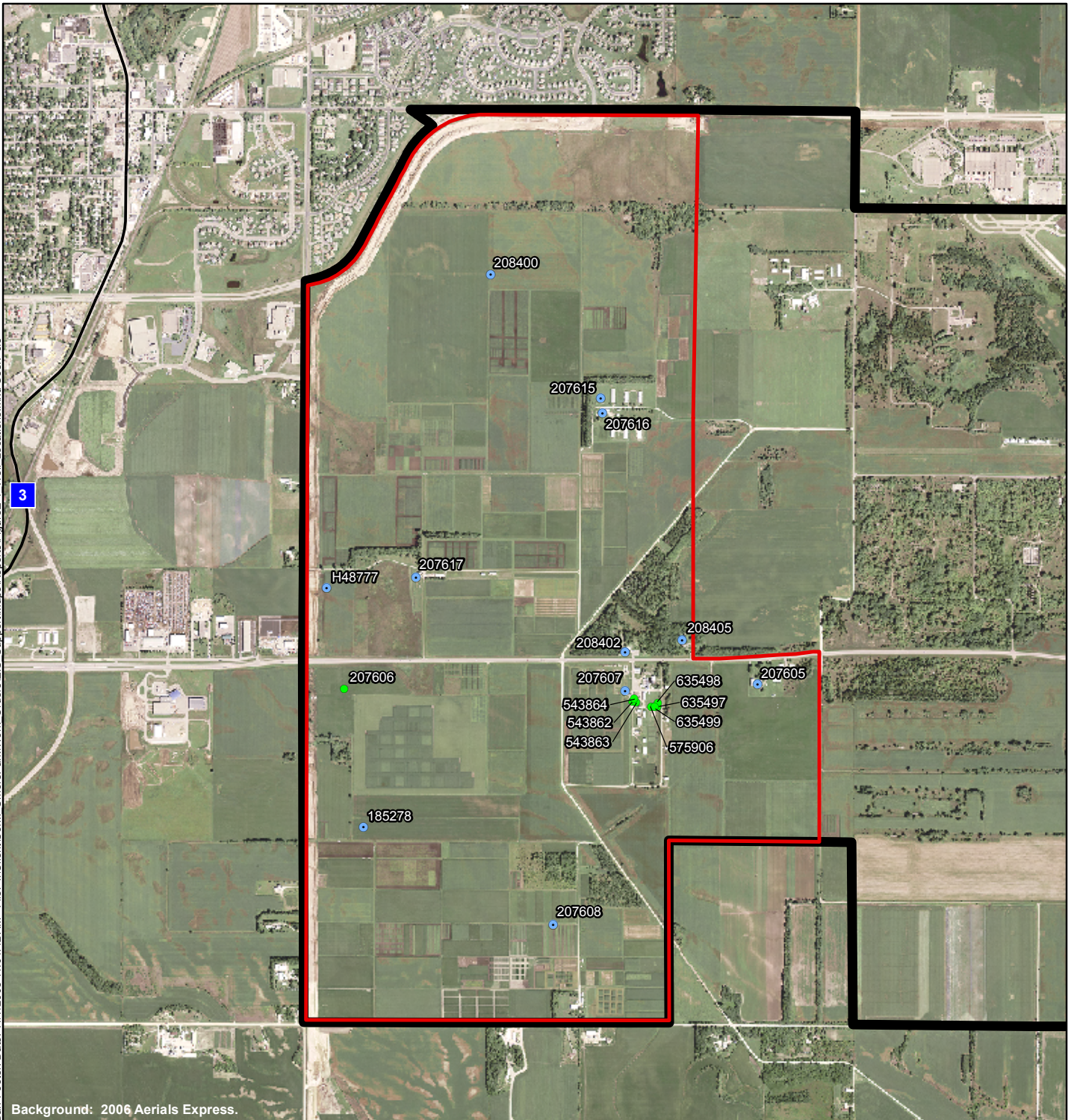
Background: 2006 Aerials Express.

3

208400

207615

207616

207617

H48777

208402

208405

207606

207607   635498

543864   635497

543862   635499

543863   575906

207605

185278

207608

- Active Well
- Sealed Well

UMore Mining Area (UMA)

UMore Park Boundary

N

Feet

2,000   0   2,000

Figure E-1

EXISTING AND SEALED WELLS

UMore Mining Area
Groundwater Assessment
Dakota County, MN

Source: Dakota County, SEH, Barr, HKGi.
Well data is from the Dakota County Well and Water
Management System (WELLMAN)

BARR

UMP003263

GROUNDWATER ELEVATIONS IN UNIVERSITY OF MINNESOTA MONITORING WELLS
UMore Park
Rosemount, Minnesota

Unique No.	Unique Well ID	Well Depth	Casing Depth	Static	Aquifer	Date Drilled	Riser Elevation	GW ELEV 6/18/2004	7/17/2006	9/27/2006	5/14/2007	3/18/2008	General Location Description
425291	MW28	230	95	80	OPDC	1986	927.38	864.57	881.36		859.28	857.46	Former pumping well; east of intersection of
425292	MW29	230	105	85	OPDC	1986	930.16	866.01	861.7		860.56	858.8	In clump of trees, E of Blaine Rd & ~1000' S
559530*	MW3	19	9	7	Q	1995	UK	12.42*		14.76*	14.6*		In brush west of Clayton Road and next to
559531*	MW1	16.5	6.5	7	Q	1995	UK	12.56*		14.44*	14.28*	14.60*	former Practice Pistol Range and tributary to
559532*	MW2	16.5	6.5	9	Q	1995	UK	12.85*		12.75*	12.9*	12.72*	Vermillion River.
T00006	MW9d	142			OPDC		932.98	869.7		866.4	865.49	863.67	East of old rail grade and south of 155th St.
T00019	MW21d	161			OSTP		931.9	865.53	865.15		860.2	858.2	East of intersection of 156th St and Blaine
T00020	MW22	135			OPDC		925.37	847.95	843.19		842.16	839.67	Next to farm road and US 52; about 50 feet
T00022	MW23d	137			OPDC		965.46	835.31		831.18	830.55	927.88	West of exit ramp in NW quadrant of
T00023	MW25	166			OPDC		849.51	811.58		806.41	806.05	802.79	West of power lines near turn on Ehlers Rd

* Well elvevation is actually depth to water from TOC

Legend:
- Dakota County Wells (green dot)
- Umore Park Boundary (black line)
- Umore Mining Area (UMA) (red line)

Source: SEH, Barr, HKGi, Dakota County.

Well labels on map:
- T00023 (802.79')
- T00022 (927.88')
- T00020 (839.67')
- 425291 (857.46')
- T00006 (863.67')
- T00019 (858.2')
- 425292 (858.8')
- 559532
- 559531
- 559530

Feet
1,000 0 1,000 2,000

Appendix E

GW ELEVATIONS AT UNIVERSITY
OF MINNESOTA WELLS

UMore Mining Area
Groundwater Assessment
Dakota County, MN

BARR

Barr Footer: Date: 10/23/2008 9:52:17 AM File: I:\Client\UofM_UmorePark\Work_Orders\EIS_Support\Maps\Reports\AppendixE_EIS_GW_Elevations_in_U_of_M_Wells.mxd User: ds

UMP003265

April 25, 2000

Mr. Dave Douglas
Minnesota Pollution Control Agency
520 Lafayette Road North
St. Paul, MN 55155

Subject: 2000 Ground Water Monitoring Results and
             Monitoring Well Abandonment
             University of Minnesota Rosemount Research Center
             Rosemount, Minnesota
             Delta Project No. A086-054

Dear Dave:

The purpose of this letter is to present, on behalf of the University of Minnesota (University), the results of the 2000 ground water monitoring activities at the above-referenced site. The monitoring activities were performed in accordance with a request by the Minnesota Pollution Control Agency (MPCA) in a February 6, 1998, letter to the University. In addition, documentation of the monitoring well abandonment is included.

Ground Water Monitoring
On March 23, 2000, five monitoring wells were gauged by Delta Environmental Consultants, Inc. (Delta). The well locations are depicted on Figure 1. Ground water elevation data are summarized in Table 1. Ground water elevation as measured in these wells has decreased less than a foot since May 1999. A ground water contour map (Figure 2) was constructed using ground water elevation data collected during the 2000 sampling event. Ground water flow is toward the northeast, which is similar to historical ground water flow patterns observed at the site.

Monitoring well MW-28 is located approximately 1 mile downgradient from the source area. This area has historically exhibited the highest level of impacts to ground water. MW-28 was sampled by Matrix Technologies, Inc. on March 21, 2000. The ground water sample was analyzed by Pace Analytical Services, Inc. for volatile organic compounds (VOCs) using Minnesota Department of Health (MDH) method 465E. The laboratory report is contained in Appendix A. The results of the analysis indicate that chloroform (6.7 micrograms per liter {μg/l}) and carbon tetrachloride (2.3 μg/l) were detected in MW-28. Methylene chloride was also detected in the sample; however, a footnote on the laboratory report identifies this compound as a common laboratory contaminant.

The additivity factor, Cumulative Hazard Index (CHI), was calculated using the recent analytical data obtained from MW-28 and compared to historical CHI results (Table 2). MW-28 currently has a CHI of 0.878. This represents a slight increase from the 1999 CHI result (0.810), but is still less than 1, the level indicating an excessive cancer risk due to multiple VOCs.

Mr. Dave Douglas
April 21, 2000
Page 2

Monitoring Well Abandonment

Abandonment activities in 1998 and early 1999 resulted in the sealing of 33 monitoring wells. In December 1999, five additional monitoring wells (429489, 429490, MW-6, MW-8, and MW-17) and two farmstead wells were abandoned (Table 1).

Eleven wells remain active, including five wells (4252291 {MW-28}, T00019 {MW-21D}, T00020 {MW-22}, T00022 {MW-23D} and T00023 {MW-25}) used by the University to monitor this investigation, four wells (559530, 559531, 559532, and 575906) used for monitoring a separate investigation, and two wells (425292 and T00006) which will likely be abandoned in the future. Two additional wells (MW-24 and MW-26) are buried and Delta is in the process of locating, uncovering, and sealing them.

If you have any questions or comments, please contact Mr. Paul Lucas of Delta at (651) 697-5192, or me at (651) 697-5203.
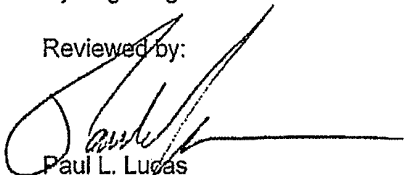
Sincerely,

DELTA ENVIRONMENTAL CONSULTANTS, INC.

Tina Overacker

for / Karen J. Thole
Hydrogeologist

Reviewed by:

Paul L. Lucas
Industrial Unit Manager

KJT/gdo

cc: Dr. Fay Thompson - University of Minnesota
City Administrator - City of Rosemount
Mr. Steve Scott - Dakota County

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UMP003267

TABLE 1

Ground Water Elevation Data
University of Minnesota Rosemount Research Center
Rosemount, Minnesota
Delta Project No. A086-054

Well ID	Date	Casing Elevation	Depth to Ground Water	Ground Water Elevation
MW-21D	10/26/95	931.90	68.62	863.28
	05/06/99	931.90	64.23	867.67
	03/23/00	931.90	64.51	867.39
MW-22	10/25/95	925.37	80.20	845.17
	05/06/99	925.37	75.35	850.02
	03/23/00	925.37	75.83	849.54
MW-23D	10/25/95	865.46	32.67	832.79
	05/06/99	865.46	28.49	836.97
	03/23/00	865.46	29.24	836.22
MW-25	10/24/95	849.51	40.84	808.67
	05/06/99	849.51	36.04	813.47
	03/23/00	849.51	36.68	812.83
MW-28	10/26/95	927.38	121.53	805.85
	05/06/99	927.38	60.68	866.70
	03/23/00	927.38	60.99	866.39

All elevations expressed in feet.

TABLE 2

Additivity Evaluation for Ground Water Chemistry - MW-28
University of Minnesota Rosemount Research Center
Rosemount, Minnesota
Delta Project No. A086-054

MW-28 (1990)

Organic Chemical	Drinking Water Criteria	Basis	Well Concentration (ug/L)	Ratio
Carbon Tetrachloride	3	HRL	1.4	0.467
Chloroform	60	HRL	29.0	0.483
1,2-Dichloroethane	4	HRL	ND	0.000
1,1,1-Trichloroethane (TCA)	600	HRL	0.6	0.001
1,1,2 Trichloroethylene (TCE)	30	HRL	2.0	0.067

Cumulative Hazard Index =   1.018

MW-28 (1992)

Organic Chemical	Drinking Water Criteria	Basis	Well Concentration (ug/L)	Ratio
Carbon Tetrachloride	3	HRL	1.2	0.400
Chloroform	60	HRL	31.0	0.517
1,2-Dichloroethane	4	HRL	1.8	0.450
1,1,1-Trichloroethane (TCA)	600	HRL	ND	0.000
1,1,2 Trichloroethylene (TCE)	30	HRL	0.7	0.023

Cumulative Hazard Index =   1.390

MW-28 (1993)

Organic Chemical	Drinking Water Criteria	Basis	Well Concentration (ug/L)	Ratio
Carbon Tetrachloride	3	HRL	1.7	0.567
Chloroform	60	HRL	36.0	0.600
1,2-Dichloroethane	4	HRL	1.6	0.400
1,1,1-Trichloroethane (TCA)	600	HRL	0.9	0.002
1,1,2 Trichloroethylene (TCE)	30	HRL	2.1	0.070

Cumulative Hazard Index =   1.638

TABLE 2

Additivity Evaluation for Ground Water Chemistry - MW-28
University of Minnesota Rosemount Research Center
Rosemount, Minnesota
Delta Project No. A086-054

MW-28 (1995)

Organic Chemical	Drinking Water Criteria	Basis	Well Concentration (ug/L)	Ratio
Carbon Tetrachloride	3	HRL	1.4	0.467
Chloroform	60	HRL	23.0	0.383
1,2-Dichloroethane	4	HRL	1.2	0.300
1,1,1-Trichloroethane (TCA)	600	HRL	0.9	0.002
1,1,2 Trichloroethylene (TCE)	30	HRL	2.4	0.080

Cumulative Hazard Index =   1.232

MW-28 (1999)

Organic Chemical	Drinking Water Criteria	Basis	Well Concentration (ug/L)	Ratio
Carbon Tetrachloride	3	HRL	1.1	0.367
Chloroform	60	HRL	23.0	0.383
1,2-Dichloroethane	4	HRL	ND	0.000
1,1,1-Trichloroethane (TCA)	600	HRL	ND	0.000
1,1,2 Trichloroethylene (TCE)	30	HRL	1.8	0.060

Cumulative Hazard Index =   0.810

MW-28 (2000)

Organic Chemical	Drinking Water Criteria	Basis	Well Concentration (ug/L)	Ratio
Carbon Tetrachloride	3	HRL	2.3	0.767
Chloroform	60	HRL	6.7	0.112
1,2-Dichloroethane	4	HRL	ND	0.000
1,1,1-Trichloroethane (TCA)	600	HRL	ND	0.000
1,1,2 Trichloroethylene (TCE)	30	HRL	ND	0.000

Cumulative Hazard Index =   0.878

TABLE 3

Monitoring Well Abandonment Summary
University of Minnesota Rosemount Research Center
Rosemount, Minnesota
Delta Project No. A086-054

Sealing No.	Unique No.	Local ID	Location	Depth	Diameter
H-146279	429489	MW-2	115/19/34-NWNWSW	67	2
H-146277	429490	MW-3	115/19/36-SWNWNW	72	2
H-146281		MW-6	115/19/35-SWSWSW	82	6
H-146282	243767	MW-8	115/19/35-SWSWSW	60	1¼
H-146280		MW-17	114/19/12-NENENW	74	2
H-146299		Old Well #1	114/19/10-NENENE	64	6
H-146300		Old Well #2	114/19/12-NWNWSW	72	6
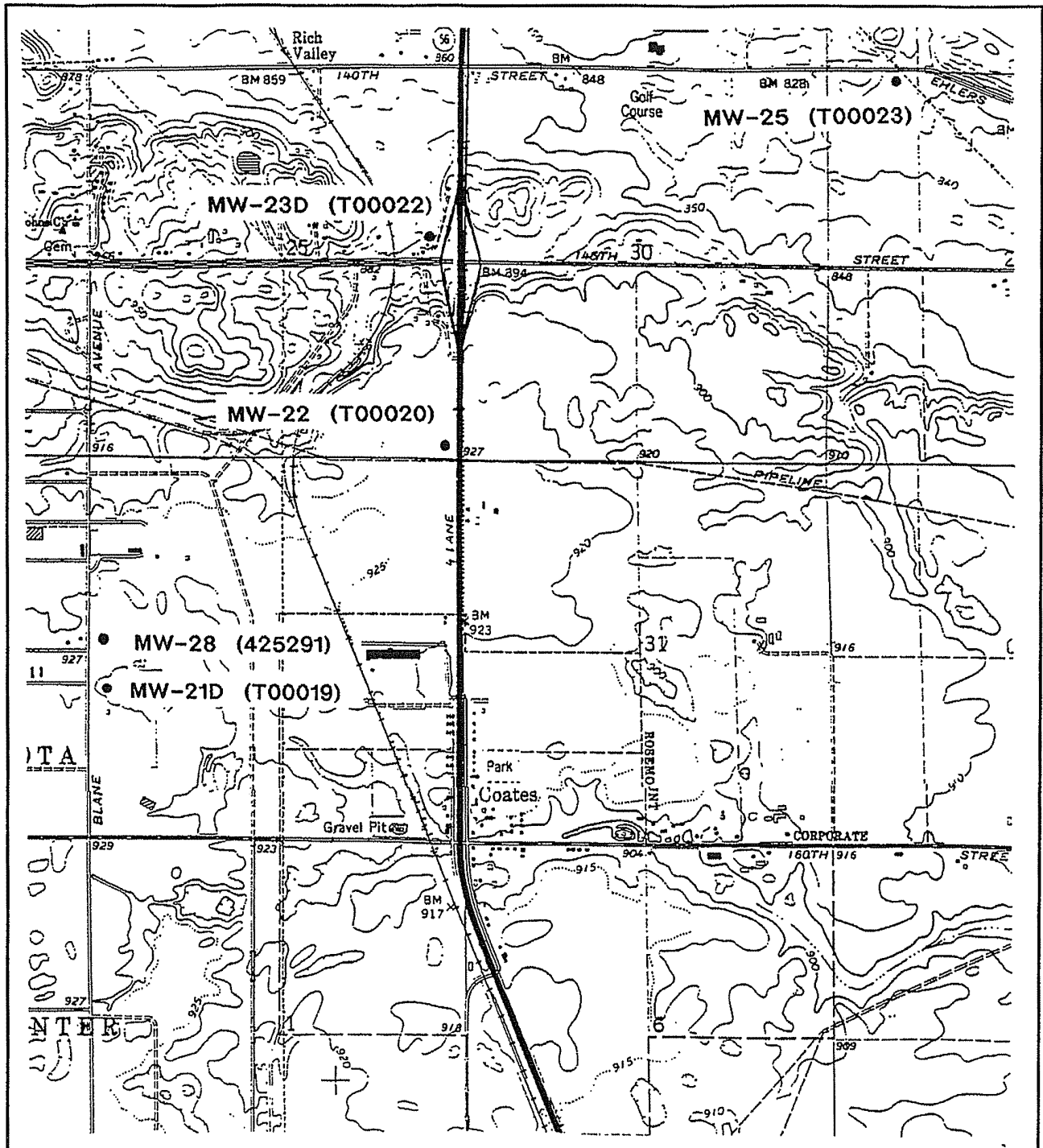
FIGURE 1
MONITORING WELL LOCATION MAP
UNIVERSITY OF MINNESOTA
ROSEMOUNT RESEARCH CENTER
ROSEMOUNT, MINNESOTA
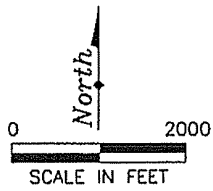
PROJECT NO.	PREPARED BY	
A085-054	KJT	**Delta** Environmental Consultants, Inc.
DATE	REVIEWED BY	
6/15/99		

UMP003272

MW-25 (T00023)
(812.83)

MW-23D (T00022)
(836.22)

MW-22 (T00020)
(849.54)

(866.39)
MW-28 (425291)

MW-21D (T00019)
(867.39)

Rich Valley
Golf Course
Park
Coates
Gravel Pit
CORPORATE STREET
160TH
140TH STREET
145TH STREET
ROSEMOUNT

820
830
840
850
860
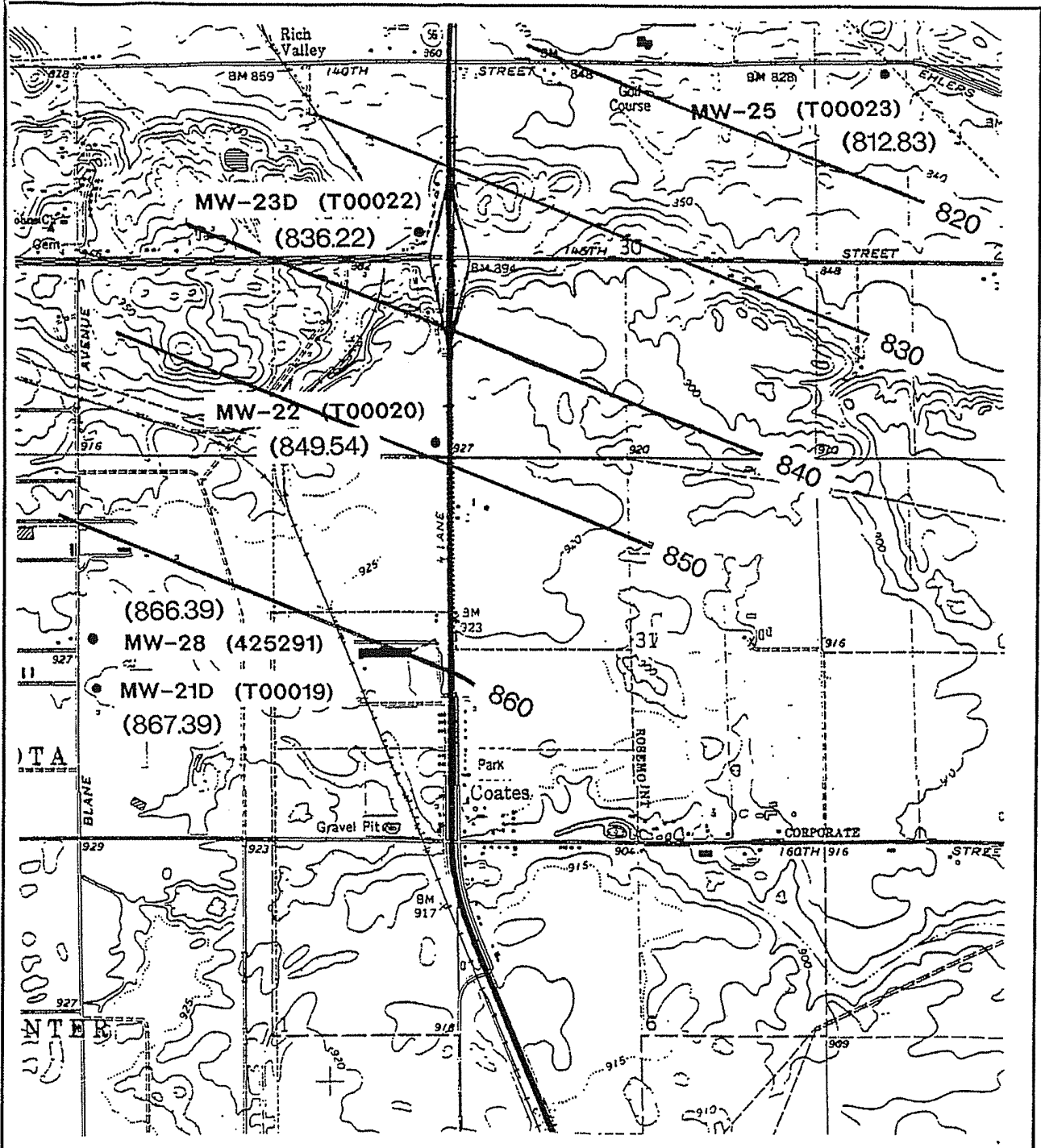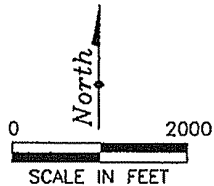
FIGURE 2
GROUND WATER FLOW MAP
March 23, 2000
UNIVERSITY OF MINNESOTA
ROSEMOUNT RESEARCH CENTER
ROSEMOUNT, MINNESOTA

PROJECT NO.	PREPARED BY
A085-054	KJT
DATE	REVIEWED BY

Delta
Environmental
Consultants, Inc.

UMP003273

Your Vermillion River Watershed
Communities Connected by Water
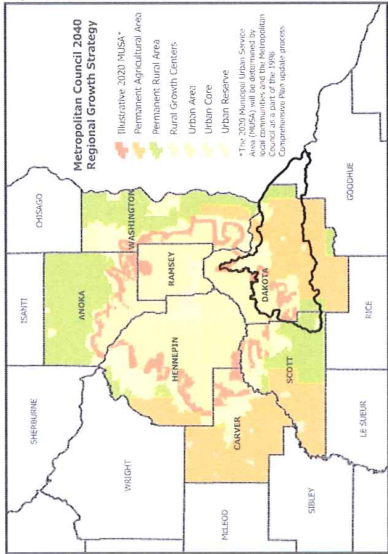
Legend

- Interstates
- U.S. Highways
- Minnesota Highways
- County State Aid Highways
- County Roads
- Vermillion River and Tributaries
- Intermittent Streams and Other Drainage
- Geographic Watershed Boundary (Differs from Watershed Management Boundary)
- Major Wetlands
- Lakes
- County Boundaries
- Wastewater Treatment Plants
- Trout Waters
- Water Quality/Quantity Monitoring Site
- Biological Monitoring Site

Water Quality Issues Affecting the Vermillion River

- High Fecal Coliform Bacteria
- High River Water Nitrates
- High Turbidity (Cloudiness)

Major Minnesota River Basins

Drainage Patterns of the Vermillion River Watershed

Metropolitan Council 2040 Regional Growth Strategy

- Illustrative 2020 MUSA*
- Permanent Agricultural Area
- Permanent Rural Area
- Rural Growth Centers
- Urban Area
- Urban Core
- Urban Reserve

*The 2020 Municipal Urban Service Area (MUSA) will be determined by local communities and the Metropolitan Council as a part of the 1998 Comprehensive Plan update process.

Miles
1 0.5 0 1 2 3 4 5

Map created by the Dakota County Survey and Land Information Department

Vermillion River Monitoring Network 2007 Report

Prepared for:
Vermillion River Watershed Joint Powers Organization

April 2008

Prepared by:
Dakota County Soil and Water Conservation District

Acknowledgments:

Overview:

The Vermillion River Watershed is the largest watershed located within the Minneapolis/St. Paul metropolitan area. More importantly, the Vermillion River watershed is home to a robust and thriving trout population. As a result, numerous water quality monitoring programs are actively assessing the health of this watershed. The purpose of this report it to concisely summarize the results of the surface water quality monitoring activities sponsored by the Vermillion River Watershed Joint Powers Organization (VRWJPO) and completed by the Dakota County Soil and Water Conservation District (DCSWCD) and the Scott Soil and Water Conservation District (SSWCD).

In addition to describing results from 2007, this report includes historical water quality monitoring results from as early as 2000. The historical results presented here are intended to describe preliminary long-term water quality trends apparent in the watershed. The level of statistical analysis completed here is limited due to a relatively brief water quality record, and results should be considered preliminary.

Vermillion River Monitoring Network:

The Vermillion River Monitoring Network (VRMN) was created in the early 1990's to a obtain water quality data from the Vermillion River Watershed and initially consisted of six monitoring stations located in Dakota County. Since then, the network has grown to include a total of eight permanent monitoring stations (Figure 1).
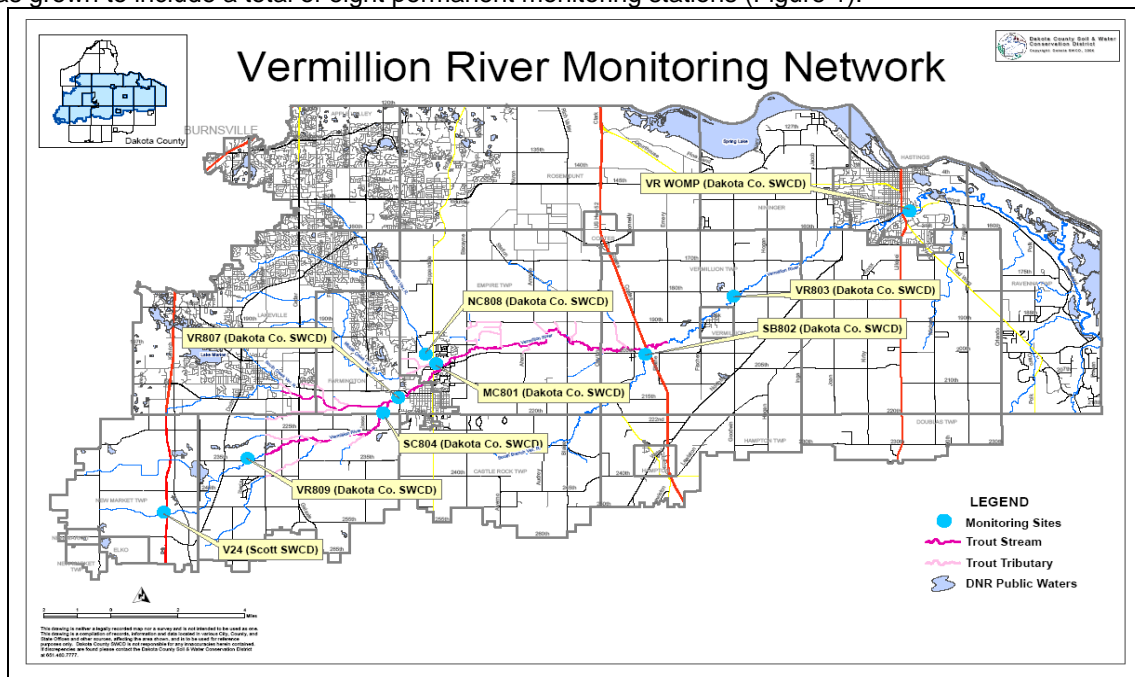
Figure 1. Vermillion River Monitoring Network and WOMP Station Locations

Several improvements were made to the Vermillion River Monitoring Network in 2007. The monitoring network was expanded to include an automated weather station, located near the center of the watershed. This station was added to the network to assist with water quality analysis in the Vermillion River Watershed (Figure 2).

The Vermillion River Joint Powers Board also contracted with the Department of Natural Resources in 2007 to assist in refining flow measurements and the data analysis necessary to convert 15-minute stage data into 15-min flow data, which is used by various water resource management organizations throughout the watershed.

Figure 2. Vermillion River Monitoring Network Weather Station

Methods:

Monthly base flow and event flow samples were collected from the Vermillion River Monitoring Network utilizing standardized procedures outlined by the Metropolitan Council Environmental Services (Metropolitan Council, 2003). At each station, automated equipment records stage every fifteen minutes, which is then converted to flow values through the use of MNDNR developed rating tables.

In addition to results from the Vermillion River Monitoring Network, data from the Metropolitan Council's Watershed Outlet Monitoring Program (WOMP) site, located on the Vermillion River in Hastings, are included to provide water quality data from the extreme eastern portion of the watershed. This site is labeled as VR WOMP in Figure 1. DCSWCD staff collect monthly low flow samples, event grab samples, and event composite samples from this location.

All samples are transported to the Metropolitan Council's Water Quality Lab and are analyzed according to EPA specified protocols for various endpoints. These endpoints include standard bacterial and chemical parameters. At the end of every sampling season, these data are entered into the MPCA's Environmental Data Access system and the EPA's STORET database.

Results and Discussion:

Results presented in the following graphs extend from the western-most site, located in Scott County, to the Metropolitan Council's Watershed Outlet Monitoring Program site, located in Hastings. Results include flow, precipitation, nutrient, turbidity, temperature, and *E. coli* (bacteria) data.

Results are typically presented as an arithmetic or geometric mean and are compared against mean values for minimally impacted streams of the Western Corn Belt Plains ecoregion, published by the Minnesota Pollution Control Agency (MPCA) (McCollor and Heiskary, 1993). The Western Corn Belt Plains ecoregion was selected since most of the Vermillion River Watershed is located within this ecoregion. Results are also compared against State Water Quality Standards (Minnesota Statute 7050) where appropriate. Stream temperature data are compared against optimal temperatures for adult brown trout (Bell, 2006).

Comparisons with ecoregion mean data and state standards are simple and are only intended to be used as a method to identify water quality exceedances. These analyses are not intended to be a definitive determination of water quality impairment. Assessment of impairment is completed bi-annually by the MPCA using a more comprehensive process and assessment methods.

3

Flow and Precipitation

Mean daily flows and precipitation data for the 2007 sampling season are presented in Figure 3.
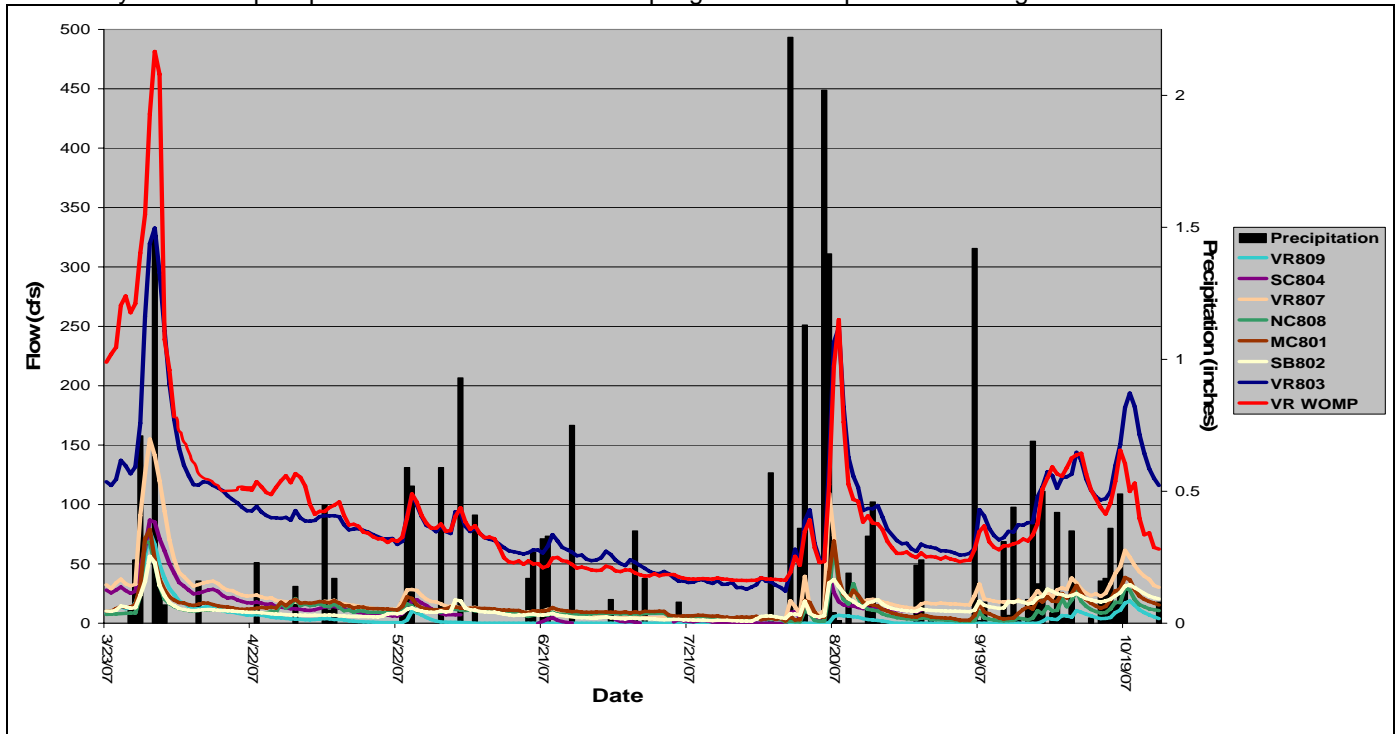

Figure 3. 2007 Vermillion River Monitoring Network and WOMP Flow and Precipitation Results

Total Phosphorus

Total phosphorus concentrations in 2007 were generally below the Western Corn Belt plains minimally impacted stream eco-region mean. Site V24 is located just downstream from the Elko/New Market Wastewater Treatment Plant, which likely accounts for the elevated event flow total phosphorus concentrations at this site. The VR WOMP site is located downstream from predominately agricultural lands which may be releasing a considerable amount of phosphorus rich agricultural runoff. In addition, sites VR803 and VR WOMP are downstream from several wastewater treatment facilities, which are possible sources of additional phosphorus.
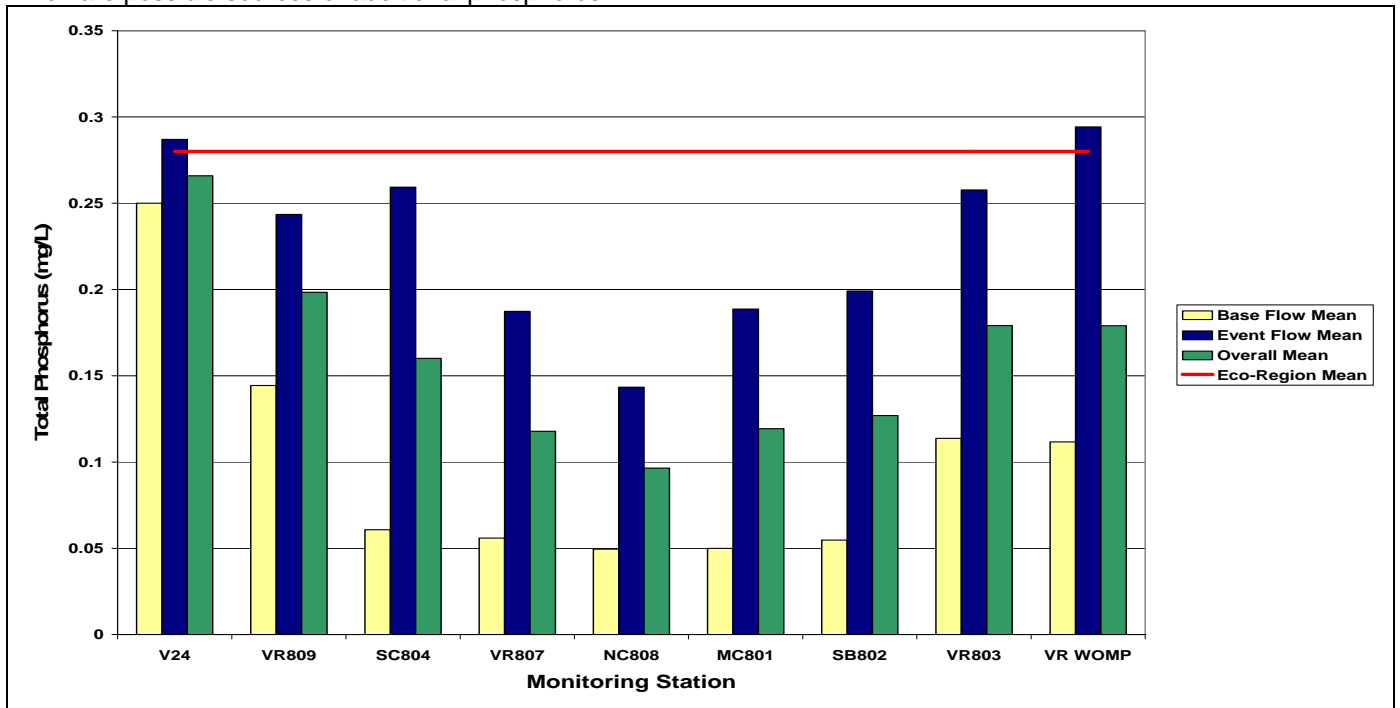
Figure 4. 2007 Mean Total Phosphorus Concentrations

4

Historical total phosphorus results are presented in Figure 5. Lower total phosphorus concentrations in 2006-2007 are likely the result of reduced rainfall over this period. Total phosphorus loading rates are often driven by precipitation. With fewer large rain events in 2006-2007, it is not surprising that total phosphorus concentrations appear to have decreased. In addition, the Metropolitan Council upgraded the Empire wastewater treatment plant in early 2006, which may account for a portion of the apparent decrease in phosphorus concentrations observed in recent years.
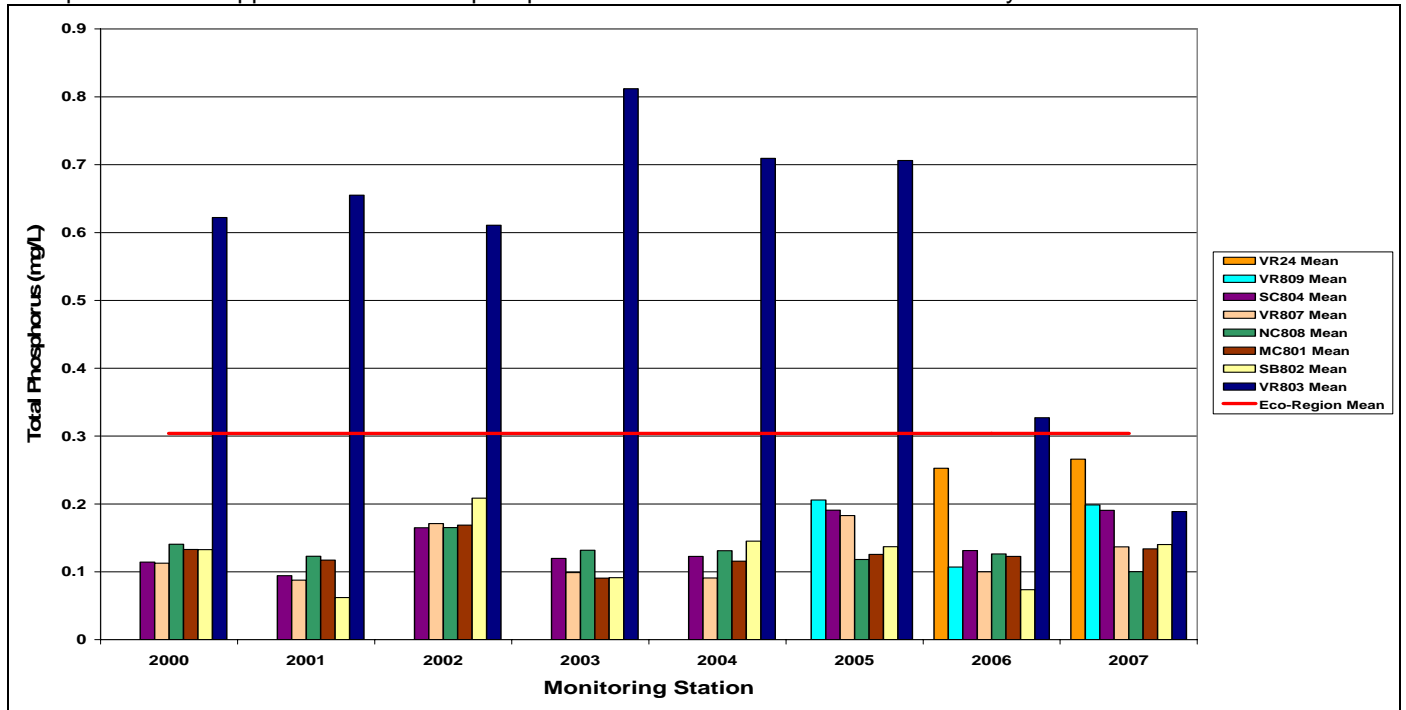
Figure 5. Annual Mean Total Phosphorus Concentrations

Nitrates

Nitrate concentrations were also below the minimally impacted stream eco-region mean, with the exception of sites SB802, VR803, and VR WOMP (Figure 6). This may be the result of a combination of nitrate sources including agricultural runoff, groundwater inputs, and discharge from the Empire and Vermillion wastewater treatment plants. However, it should be noted that nitrate concentrations at site SB802 were the highest in the watershed, and the source of these elevated results remains unknown.
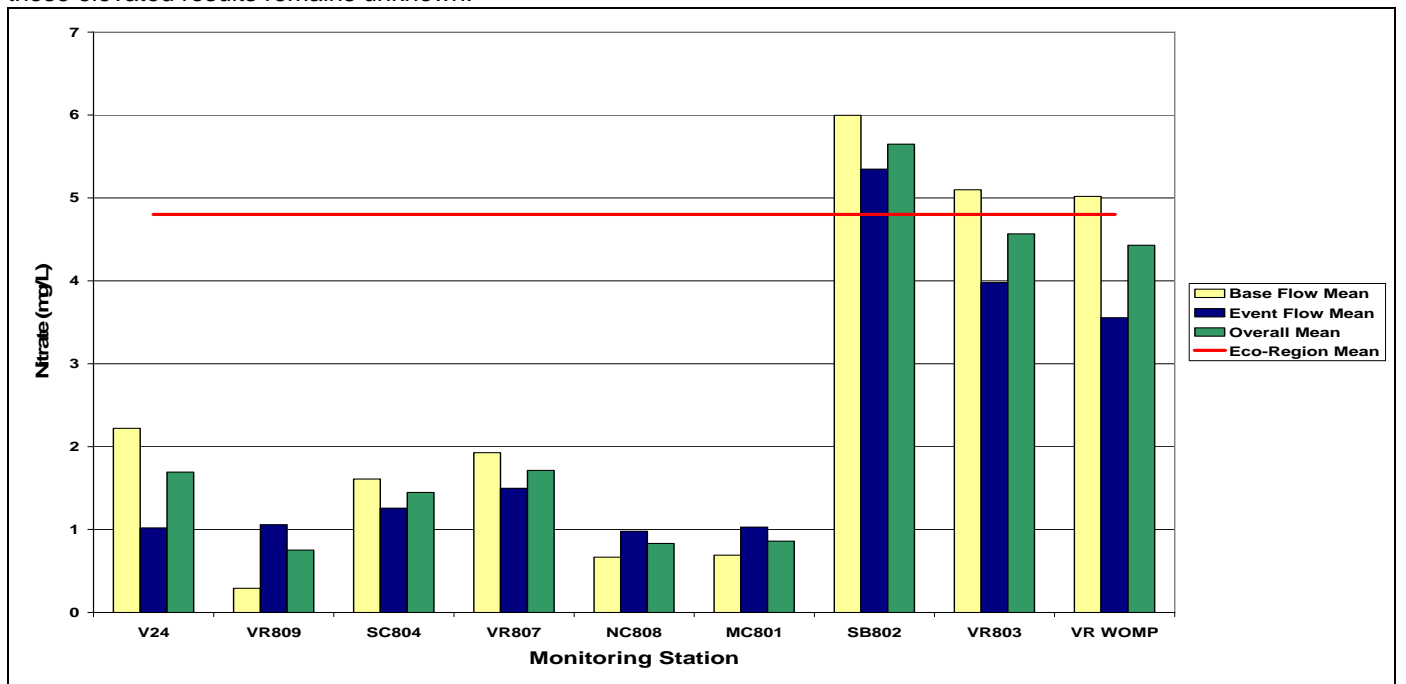
Figure 6. 2007 Mean Nitrate (NO_3) Concentrations

5

When 2007 nitrate concentrations are plotted against historical annual means, there appears little difference among the various years, despite lower 2007 precipitation results (Figure 7). However, for the second consecutive year, nitrate concentrations at the SB802 site continue to exceed those of the downstream VR803 site.
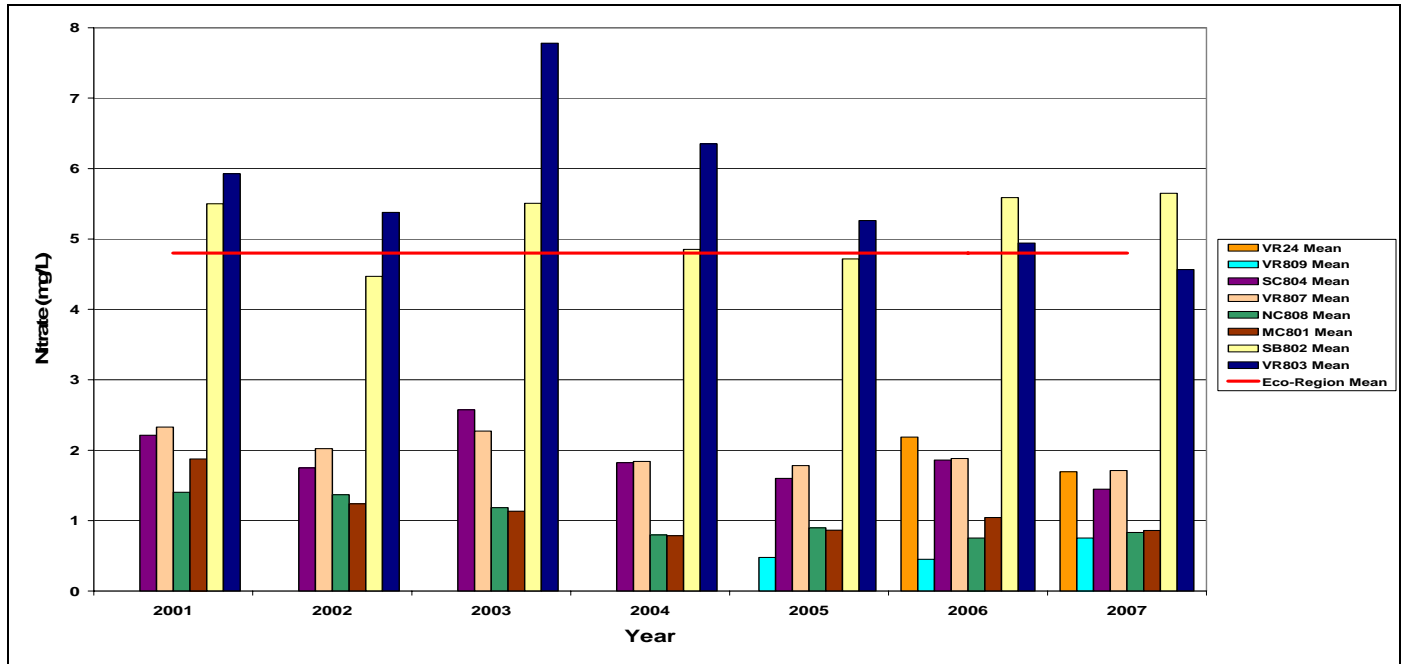
Figure 7. Annual Mean Nitrate (NO3) Concentrations

Pollutant Loads

Pollutant loads for 2007 were calculated using the FLUX stream load computation tool (Walker, 1988). A pollutant load is the mass of a particular pollutant that flows through a monitoring station over a given period of time. This is a new analysis applied to VRMN results and can be useful when comparing pollutant contributions to the Vermillion River among sub-watersheds. Calculated loads were divided by the area of the associated sub-watershed for each monitoring station (Figure 8). Loads for some tributaries were estimated by subtraction.
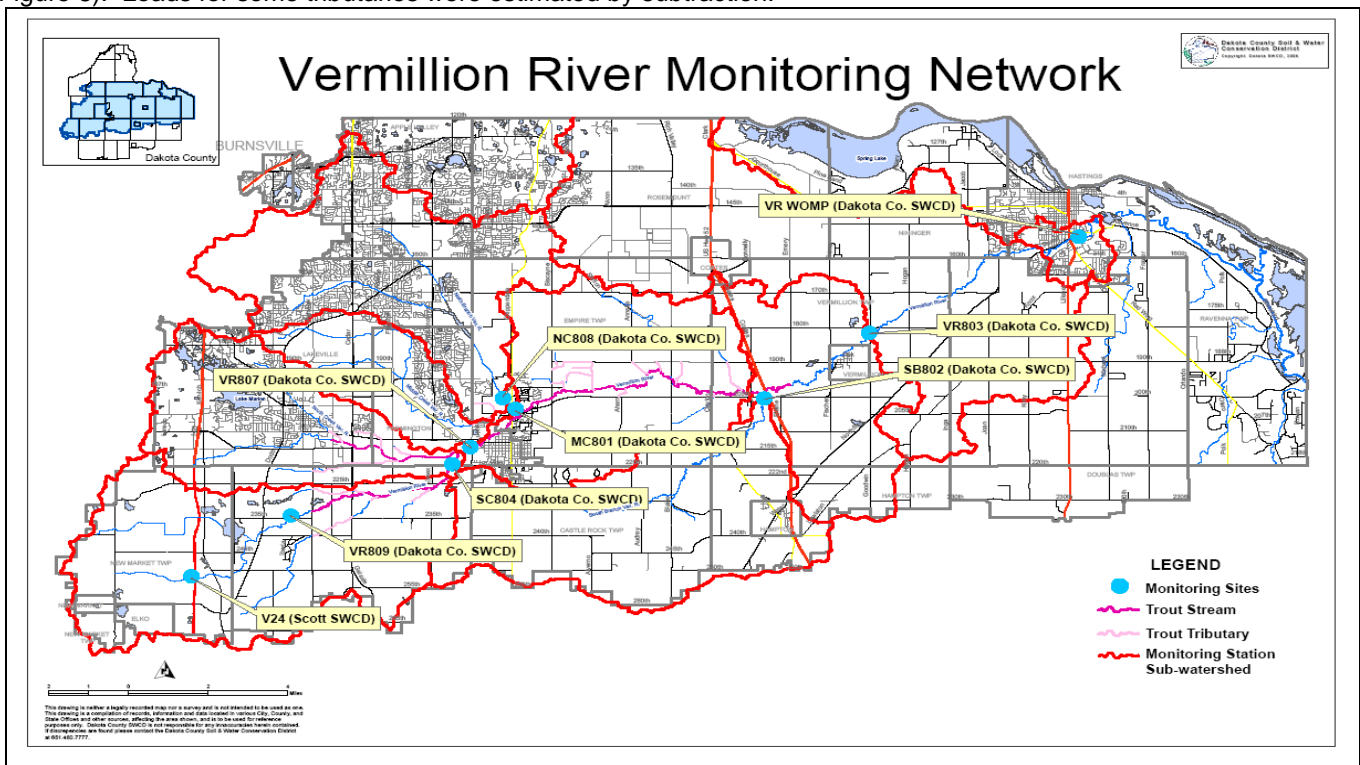
Figure 8. Monitoring Station Sub-watersheds

6

Total phosphorus loads per acre were relatively similar among monitoring stations and tributaries, with the exception of Goodwin Ave. sub-watershed (Figure 9). This watershed drains lands that include two wastewater treatment plants, which are likely major contributors to total phosphorus loads within this watershed.
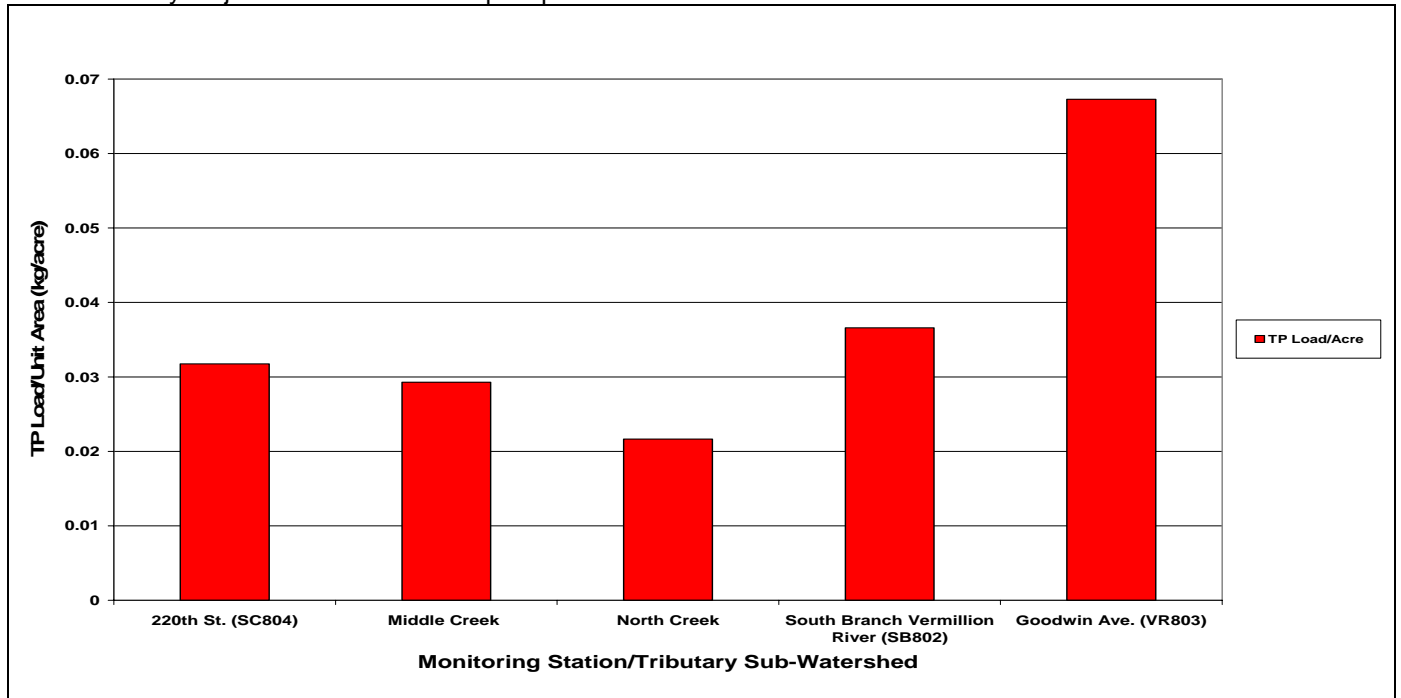
Figure 9. 2007 Total Phosphorus Load/Acre

Nitrate loads per acre were highest for the South Branch Vermillion River sub-watershed (Figure 10). The nitrate loads even exceeded the Goodwin Ave. watershed, which is downstream from several wastewater treatment plants. Additional monitoring may be needed to aid in determining the source of nitrates in the South Branch watershed.

The nitrate loads per acre for South Creek sub-watershed were also surprisingly high, considering that a similar, adjacent watershed (North Creek) had much lower nitrate loads.
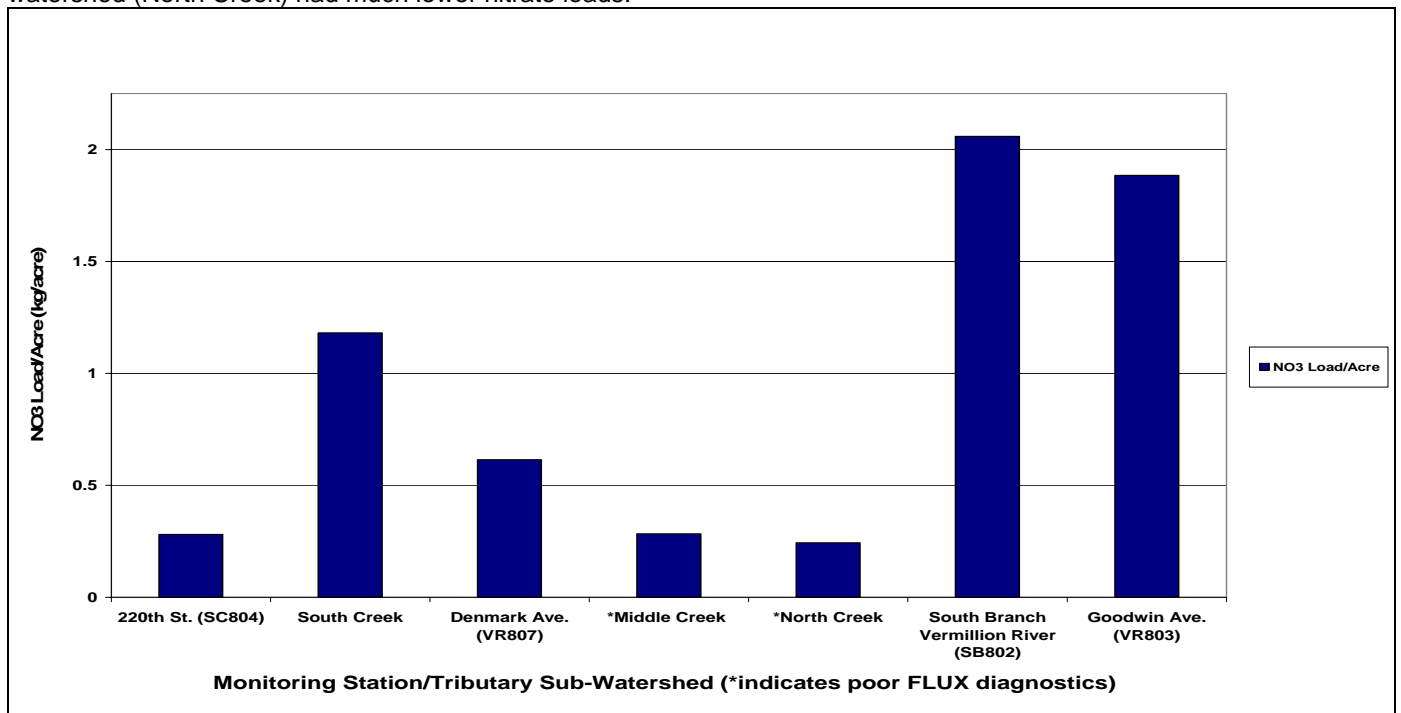
Figure 10. 2007 Nitrate Load/Acre Results

7

Turbidity

Turbidity results for 2007 were mixed (Figure 11). Turbidity during base flow conditions remained well below the state standards for all sites. However, during larger precipitation events turbidity was substantially elevated, often exceeding the state standard. The dramatic increase observed at the SC804 site is a consequence of a single, elevated May storm event sample.
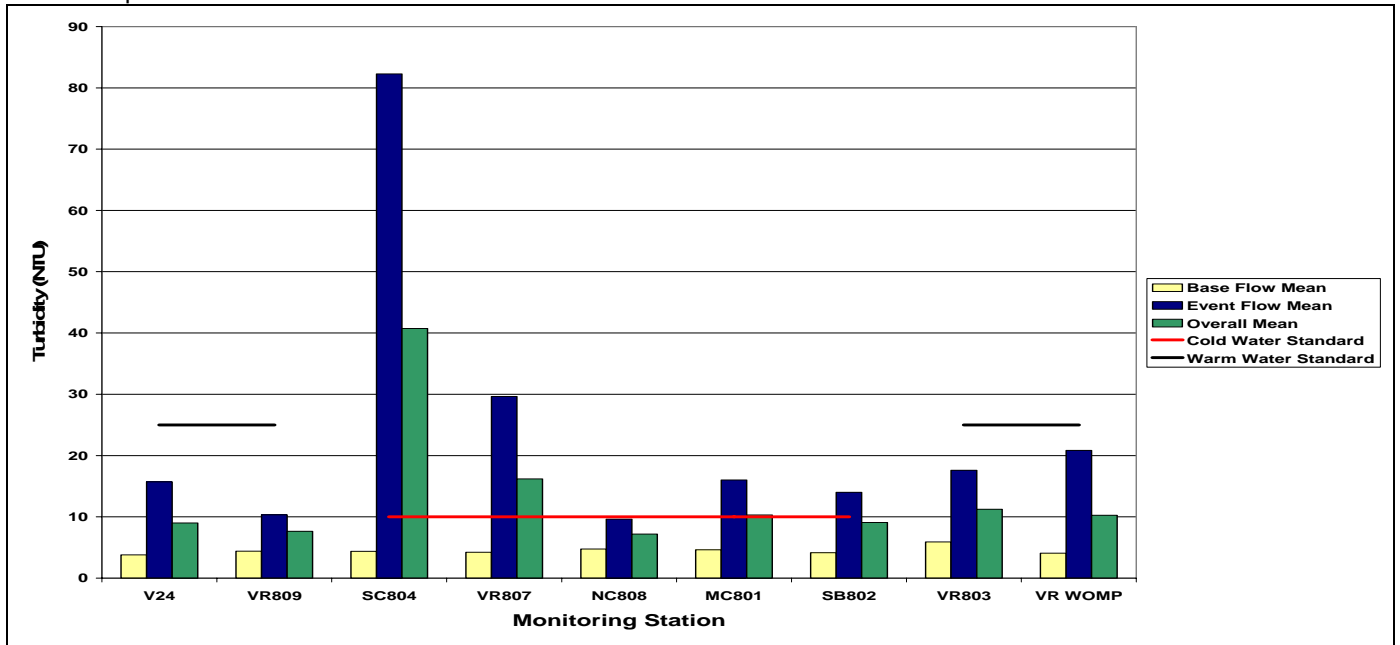
Figure 11. 2007 Mean Turbidity Results

Turbidity results are highly variable over the period of record (Figure 12). Results from 2007 are within the range of previous years, with the exception of the SC804 monitoring station. Again, the elevated concentration at this station is the result of a single sample collected during a storm event. It should also be mentioned that the MPCA has proposed including a reach of the Vermillion River near monitoring stations SC804 and VR807 for a turbidity impairment in the draft 2008 303d list. The most recent historical data for these sites appears to corroborate the proposed listing.
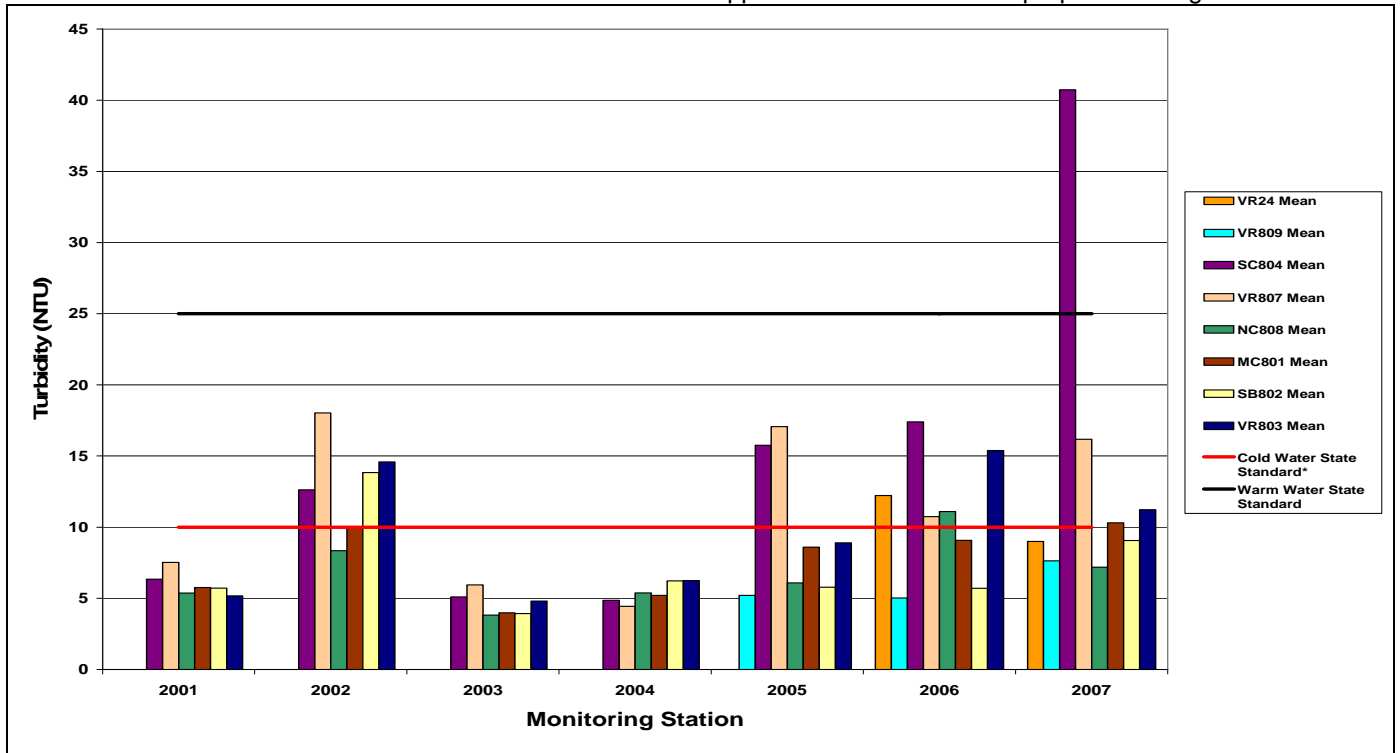
Figure 12. Annual Mean Turbidity Results
* Cold water standards apply only to trout stream portion of the Vermillion River (SC804, VR807, NC808, MC801, SB802).

8

Temperature

The Minnesota Department of Natural Resources (MNDNR) has been very active in monitoring stream temperatures in the Vermillion River Watershed. Since 2005, the DCSWCD has been assisting the MNDNR with temperature monitoring. In addition, the VRWJPO was awarded an EPA Targeted Watershed Grant in 2005. Identifying and describing the way in which groundwater inputs are influencing the temperatures of the Vermillion River, was among one of several goals specified in this grant. Stream temperature results presented here are a compilation of data resulting from both MNDNR and the EPA Targeted Watershed Grant efforts.

Automated temperature loggers were placed at each of the Vermillion River Monitoring Network stations, and water temperature was recorded at 15-minute intervals. Mean temperatures for the period of 6/2-9/2 were then plotted and are shown in Figure 13. Results from 2007 were also plotted adjacent to 2005, 2006 temperatures for the same reference period. According to a recent literature review, the adult brown trout chronic (long-term) exposure temperature limit is approximately 64° F (Bell, 2006). Average temperatures at most monitoring stations, especially those in the trout stream portion of the Vermillion River (SC804, VR807, NC808, MC801, SB802) were near the 64° F threshold.

It appears that temperatures were generally higher in 2006 than in 2005 or 2007. Possible explanations include slightly higher ambient air temperatures and large construction de-watering projects in the Middle and North Creek area in 2005 and 2007. De-watering projects remove cool groundwater and discharge those waters to area streams. It should also be noted that the temperature logger at site VR809 was out of the water for much of the 2006-2007 summer months, and as a result the reported mean temperature is based on a smaller record than other sites.
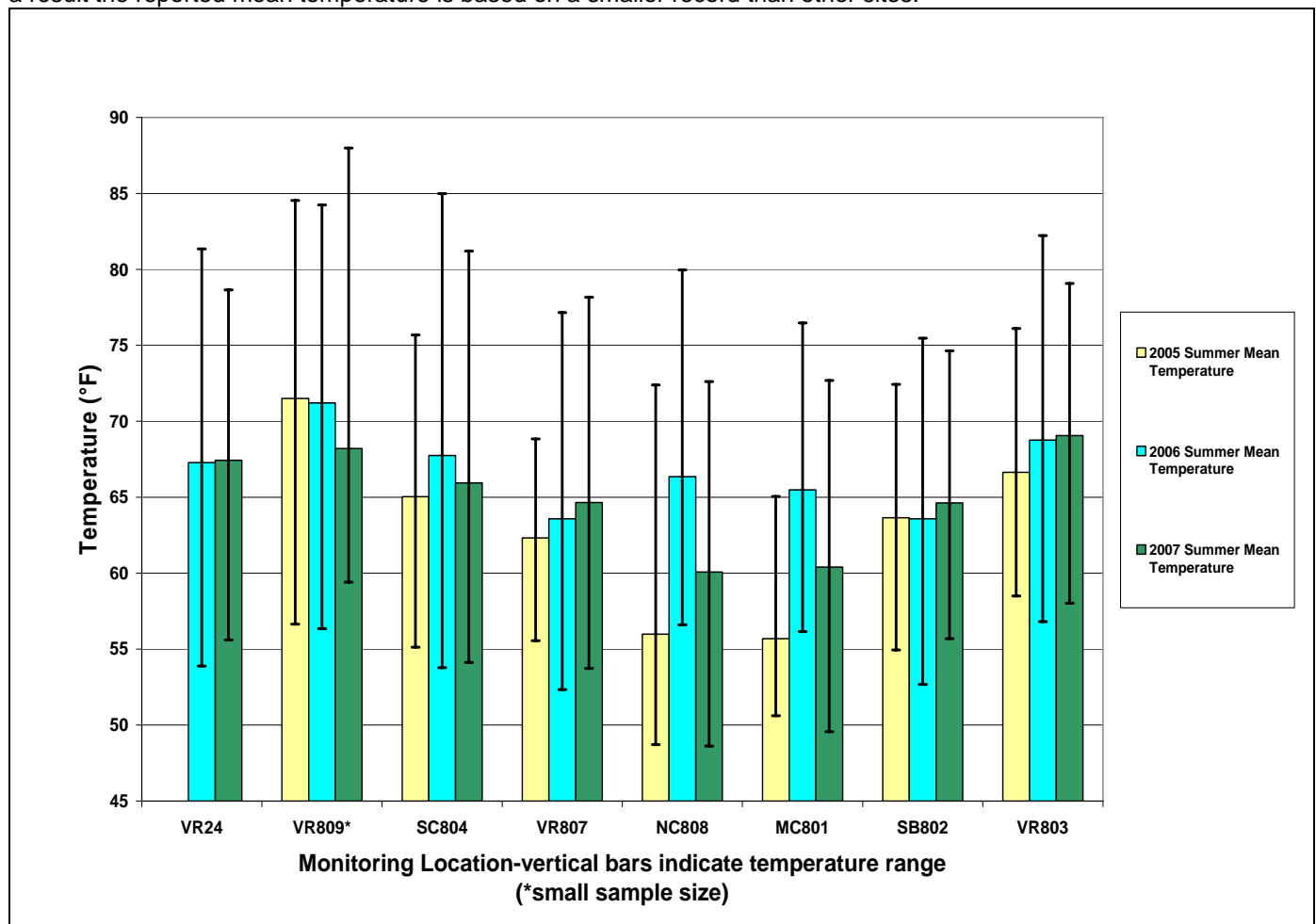

Figure 13. 2005-2007 Mean Temperature Results

9

Escherichia coli

E. coli concentrations within the Vermillion River continue to exceed the proposed state standard (Figure 14). Precipitation event samples produced the most elevated results. Possible explanations for base flow results include septic system discharge, agricultural runoff, livestock in streams, urban runoff, and re-suspension of sediment bacteria.

In 2007, the MPCA recommended that DCSWCD/SSWCD staff discontinue using fecal coliform as a bacterial endpoint. This was suggested in anticipation of a change in Minnesota water quality Rules 7050. Since no fecal coliform samples were collected in 2007, no historical comparison is possible.
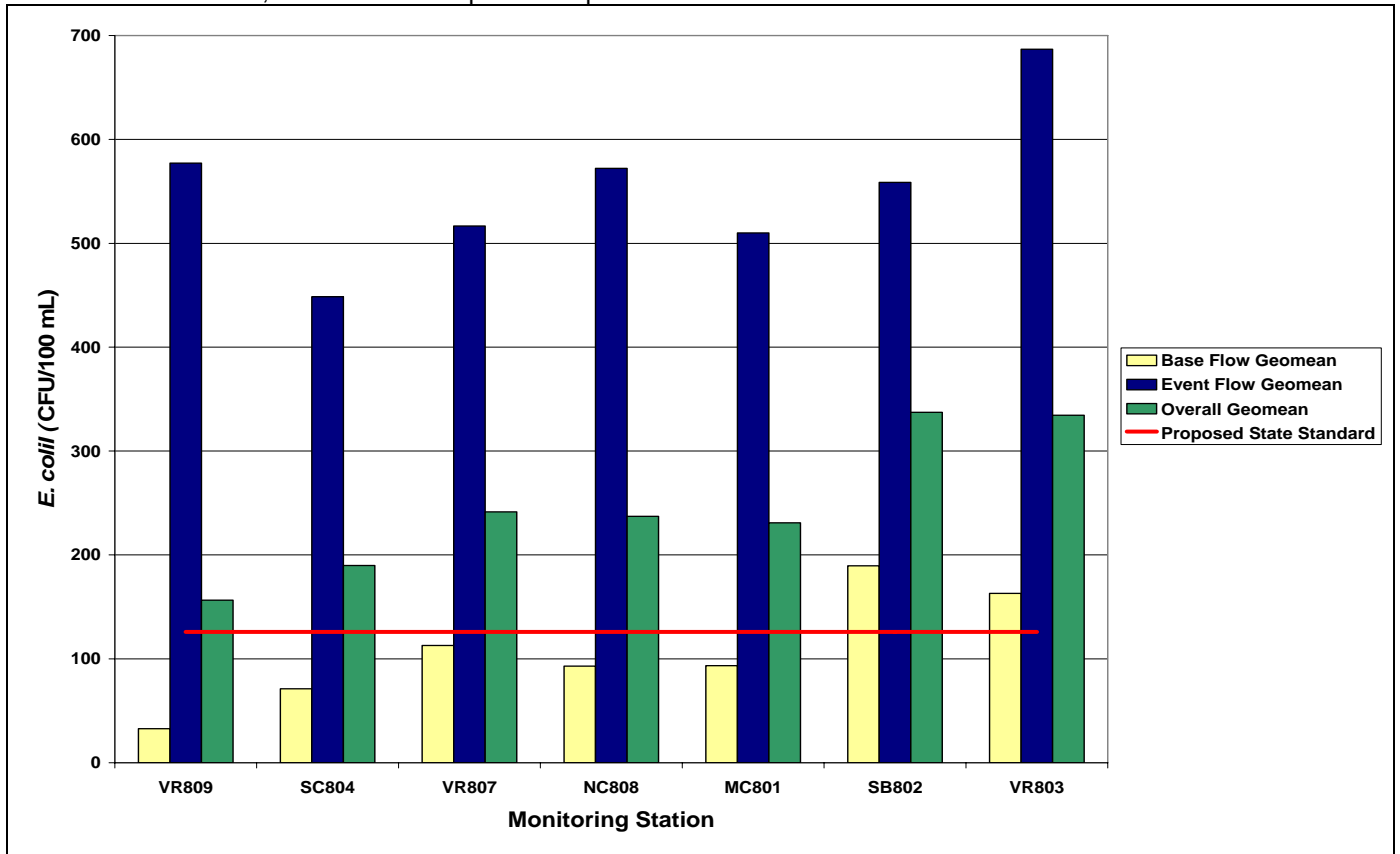
Figure 14. 2007 *Escherichia coli* Geometric Means

10

2007 Middle and North Creek Bacteria Study:

The Vermillion River was officially listed on the Federal Clean Water Act 303 (d) list in 1998 for elevated fecal coliform concentrations. In response to region wide fecal coliform impairments, the MPCA has developed and finalized a Lower Mississippi River Basin TMDL project, which includes the Vermillion River. An additional study was completed in 2004 to supplement the region wide TMDL, focusing specifically on the Vermillion River fecal coliform impairment. This study identified two sub-watersheds, Middle Creek and North Creek, as contributing unusually high levels of bacteria to the Vermillion. In 2006, the Middle and North Creek Bacteria Study was initiated to further identify sources in these sub-watersheds.

Thirteen bacteria monitoring sites were selected throughout the Middle and North Creek sub-watersheds (Figure 15). Samples were collected five times a month, from April to October. Samples were immediately placed on ice and transported to Minnesota Valley Testing Laboratories, Inc. for analysis. Approximately 10% of all samples were collected as QA/QC samples, which included blanks and field duplicates. Fecal coliform and *E. coli* analyses were completed using EPA approved methodology.
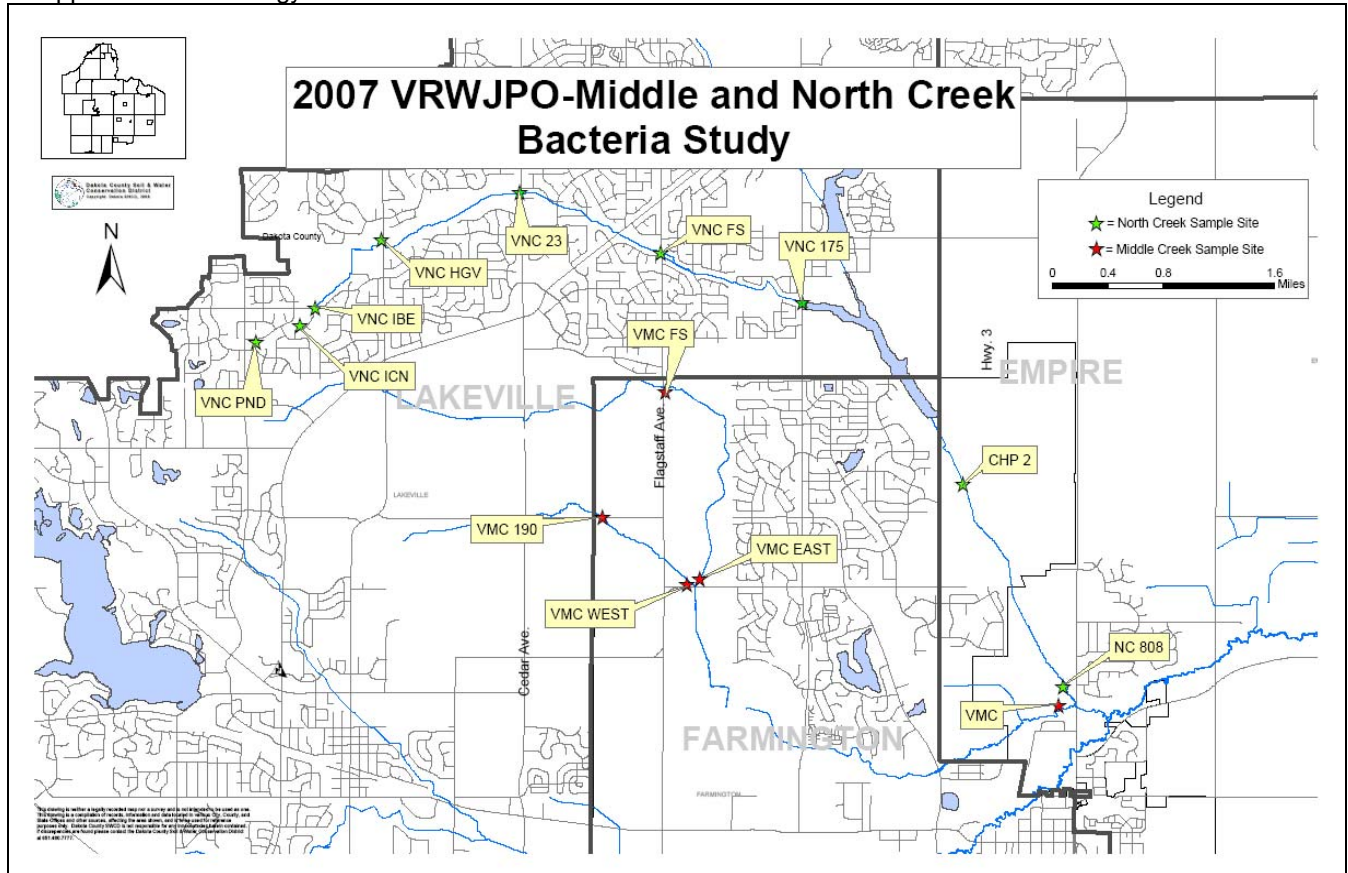

Figure 15. 2007 Middle and North Creek Bacteria Monitoring Locations

Results and Discussion:

In 2006, the MPCA recommended that the VRWJPO discontinue collecting fecal coliform samples in anticipation of the state bacteria standard changing from fecal coliform to *Escherichia coli*. In 2007, the VRWJPO funded water quality monitoring programs discontinued using the fecal coliform endpoint in exchange for the E. coli endpoint, including those samples collected for the Middle and North Creek Bacteria Study.

Escherichia coli concentrations were well in excess of the state standard throughout the sampling season, across all sites, and under nearly all flow conditions (Figure 16). Sampling locations in 2007 were expanded to include several sites very near to the headwaters of North Creek, within the Andersons Century Farms/Dakota Heights Eight Addition neighborhoods in northern Lakeville. Bacteria concentrations in these areas were well above the proposed state standard, even though very few potential sources could be identified. The 2007 *E. coli* results were similar to those observed in 2006, where fecal coliform was the endpoint utilized.

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The source of these bacteria in the Middle and North Creek Watersheds continues to remain elusive. No obvious source was identified, in either watershed, during the course of the study. Possible sources may include wildlife, domesticated animals, and impervious surface, as supported by recent research (Whitlock 2002, Young 1999). Bacteria, including *E. coli*, have been shown to survive and grow within soils and sediment, which may be yet another source within the Middle and North Creek Watersheds (Whitman 2003, Anderson 2005). Finally, in the highly urbanized setting of North Creek, septic sewer and storm sewer cross connections may exist between the two sewer systems in this area, possibly leading to the observed bacteria concentrations in this area.
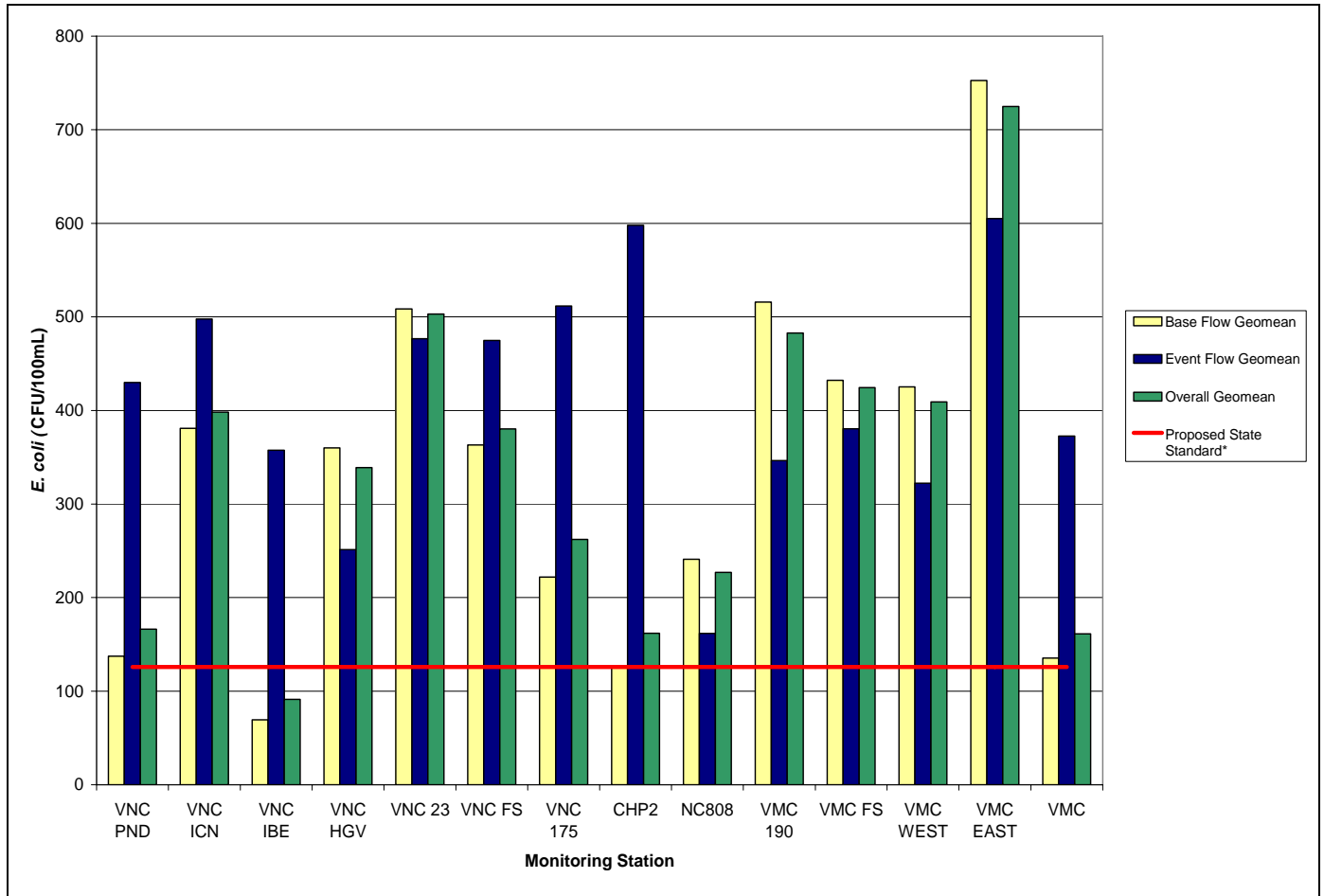

Figure 16. 2007 Middle and North Creek *E. coli* Geometric Means
*The proposed state standard applies to the monthly geometric mean of at least five samples. It should be noted that data presented in Figure 16 are annual (2007) rather than monthly geometric means.

12

References:

Andersen K.L., Whitlock J.E., Harwood V.J., 2005. Persistence and Differential Survival of Fecal Indicator Bacteria in Subtropical Waters and Sediments. Applied and Environmental Microbiology. 71, 3041-3048.

Bell J.M., 2006. The Assessment of Thermal Impacts on Habitat Selection, Growth, Reproduction, and Mortality in Brown Trout (*Salm trutta* L): A Review of the Literature. Prepared for the Vermillion River EPA Grant #WS 97512701-0 and the Vermillion River Joint Powers Board. Applied Ecological Services, Inc.

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Metropolitan Council Environmental Services-Quality Assurance Program Plan: Stream Monitoring (2003). Metropolitan Council. 5 Feb. 2007
<http://www.metrocouncil.org/Environment/RiversLakes/Streams/Stream%20Monitoring%20QAPP_Final.pdf>

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Whitlock J.E., Jones D.T., Harwood V.J., 2002. Identification of the Sources of Fecal Coliforms in an Urban Watershed Using Antibiotic Resistance Analysis. Water Research. 36, 4273-4282.

Whitman R.L., and Meredith B. Nevers, 2203. Foreshore Sand as a Source of *Escherichia coli* in Nearshore Waters of a Lake Michigan Beach. Applied and Environmental Microbiology. 69, 5555-5562.

Young K.D., and Edward L. Thackston, 1999. Housing Density and Bacterial Loading in Urban Streams. Journal of Environmental Engineering. 125, 1177-1180.

Vermillion River Monitoring Network
2007 Report: Executive Summary

Prepared for:
Vermillion River Watershed Joint Powers Organization

The Vermillion River Monitoring Network (Figure 1) was created to collect water quality and quantity data throughout the Vermillion River Watershed. Samples are analyzed for a variety of parameters including nutrients, bacteria, and sediment. These results are used to establish long-term water quality and quantity data, provide trend analysis and pollutant loading values.
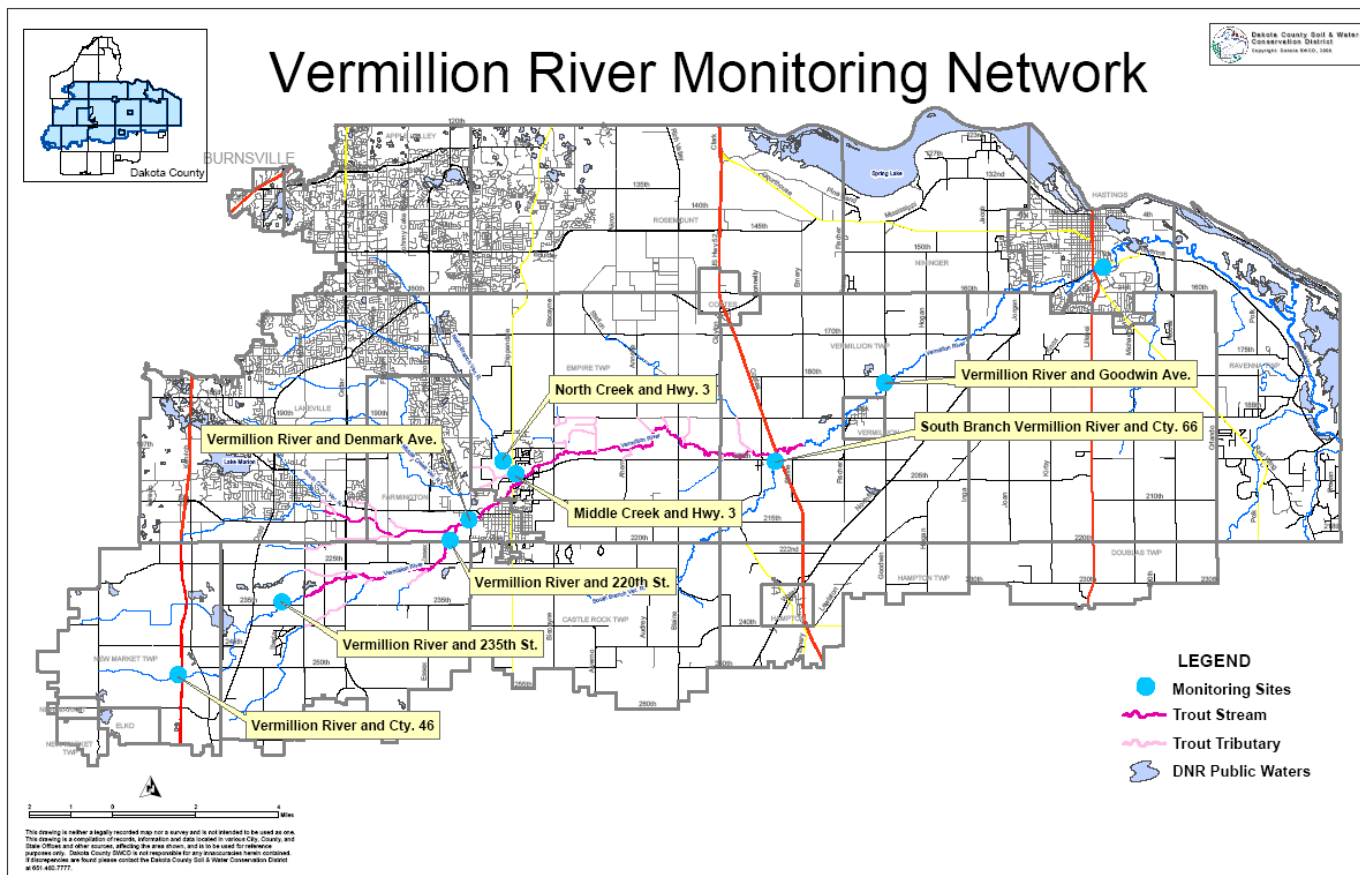

Figure 1. Vermillion River Monitoring Network and WOMP Station Locations

Results for the 2007 monitoring season are listed below and are compared against state water quality standards or minimally impacted stream eco-region means, developed by the Minnesota Pollution Control Agency. Results in red text are exceeding state water quality standards or eco-region means.

Wastewater treatment plant discharge can contribute to elevated conductivity levels which may explain the conductivity results for those sites downstream from nearby wastewater treatment plants (Elko/New Market and Empire/Vermillion). Since the Vermillion River has been listed as impaired for bacteria, it is not surprising that 2007 *E. coli* results exceeded the state standard at all locations. A region-wide effort is currently underway to address elevated bacteria concentrations. Nitrate results were unusually high at the South Branch site, and may warrant further investigation in view of nitrate groundwater contamination in the eastern portion of the watershed. The turbidity (cloudiness) results at sites located in the center of the watershed confirm concerns that turbidity in these locations frequently exceeds the state standard. The Minnesota Pollution Control Agency has proposed listing this reach as impaired for turbidity in 2008.

1

				Monitoring Sites					
		Vermillion River and Cty. 46 (Scott Co.)	Vermillion River and 235th St.	Vermillion River and 220th St.	Vermillion River and Denmark Ave.	Middle Creek and Hwy. 3	North Creek and Hwy. 3	South Branch Vermillion River and Cty. 66	Vermillion River and Goodwin Ave.	2007 Notes
Parameters	Alkalinity	271 mg/L	222 mg/L	211 mg/L	207 mg/L	195 mg/L	188 mg/L	173 mg/L	207 mg/L	Typical for freshwater
	Chloride	199 mg/L	79 mg/L	34 mg/L	41 mg/L	51 mg/L	52 mg/L	18 mg/L	90 mg/L	In compliance with state standard
	Conductivity (field)	1051 mMHOs	727 mMHOs	563 mMHOs	589 mMHOs	648 mMHOs	669 mMHOs	524 mMHOs	816 mMHOs	Above eco-region mean downstream from wastewater treatment plants
	Dissolved Oxygen	8.72 mg/L	8.38 mg/L	9.03 mg/L	8.33 mg/L	7.62 mg/L	8.16 mg/L	8.77 mg/L	9.15 mg/L	Adequate for trout fishery
	E. coli	na	156 CFU/100mL	190 CFU/100mL	242 CFU/100mL	231 CFU/100mL	237 CFU/100mL	337 CFU/100mL	335 CFU/100mL	Exceeding state standard at all sites
	Nitrate (NO_3)	1.70 mg/L	0.75 mg/L	1.45 mg/L	1.71 mg/L	0.86 mg/L	0.83 mg/L	5.65 mg/L	4.57 mg/L	Exceeding eco-region mean at S. Branch and Cty. 66
	Nitrogen Ammonia	0.09 ug/L	0.27 ug/L	0.08 ug/L	0.08 ug/L	0.22 ug/L	0.18 ug/L	0.15 ug/L	0.10 ug/L	Below eco-region mean
	Total Phosphorus	0.27 mg/L	0.20 mg/L	0.16 mg/L	0.12 mg/L	0.12 mg/L	0.10 mg/L	0.13 mg/L	0.18 mg/L	Below eco-region mean
	pH (field)	8.11	7.86	7.94	7.90	7.77	7.72	7.95	8.08	In compliance with state standard
	Suspended Solids	17.3 mg/L	10.2 mg/L	33.6 mg/L	23.0 mg/L	13.2 mg/L	15.1 mg/L	13.6 mg/L	25.9 mg/L	Below eco-region mean
	Average Summer Temperature	67.4 °F	68.2 °F	65.9 °F	64.7 °F	60.4 °F	60.1 °F	64.6 °F	69.1 °F	Slightly elevated for trout fishery at 220th St.
	Turbidity	9.0 NTU	7.6 NTU	40.7 NTU	16.2 NTU	10.3 NTU	7.2 NTU	9.1 NTU	11.2 NTU	Exceeding state standard near center of watershed

mg/L = milligrams per liter or parts per million (ppm) CFU = colony forming units
ug/L = micrograms per liter or parts per billion (ppb) NTU = nephelometric turbidity units
mMHO = micromhos or microseimens °F = degrees Fahrenheit

Recommendations for 2008 monitoring:
- Continue water quality/quantity monitoring utilizing the Vermillion River Monitoring Network
- Continue collaborating with MNDNR to further refine flow measurements and subsequent data analysis
- Further investigate turbidity issues in the center of the watershed

Summary of Wellhead and Source Water Protection Plan
City of Rosemount, Minnesota

The City of Rosemount has developed a Wellhead and Source Water Protection Plan (the Plan) for their municipal water supply wells. At the time the Plan was prepared the Rosemount municipal water supply system consisted of six wells: Wells 3, 7, 8, 9, RR-1, and RR-2. The source water aquifer for these wells is the Jordan Sandstone. The Plan was prepared in accordance with the applicable portions of the State of Minnesota Wellhead Protection Rules (Minnesota Rules 4720.5100 through 4720.5590).

In Part 1 of the Plan (Barr, 2002), Wellhead Protection Areas (WHPAs) and Drinking Water Supply Management Areas (DWSMAs) were delineated. In accordance with Minnesota Rules 4720.5550, the municipal wells were identified as vulnerable due to the presence of tritium in groundwater samples previously collected from the City's municipal wells by the Minnesota Department of Health. In the Part 1 report, the source water aquifer within the DWSMAs was also identified as vulnerable to contamination. The delineated WHPAs and DWSMAs as well as the source water aquifer vulnerability within the DWSMAs are shown on the attached Figure.

In Part 2 of the Plan (Barr, 2003), management strategies for protecting the source water aquifer are presented. Per the Wellhead Protection Rules, the Plan will need to be amended as new municipal water supply wells are put into service and updated at least every 10 years regardless of wells being added to the water supply system.

References:

Barr Engineering Company (Barr), 2002. *Wellhead Protection Area Delineations for the City of Rosemount, Minnesota, prepared for the City of Rosemount*, April 2002.

Barr Engineering Company (Barr), 2003. *Wellhead and Source Water Protection – Part 2: Wellhead Protection Plan, prepared for the City of Rosemount*, October 2003.

R 20 W | R 19 W

City of Rosemount

Drinking Water Supply Management Area (DWSMA) 20 year Time of Travel

ROSEMOUNT

H

H

H

T 115 N
T 114 N
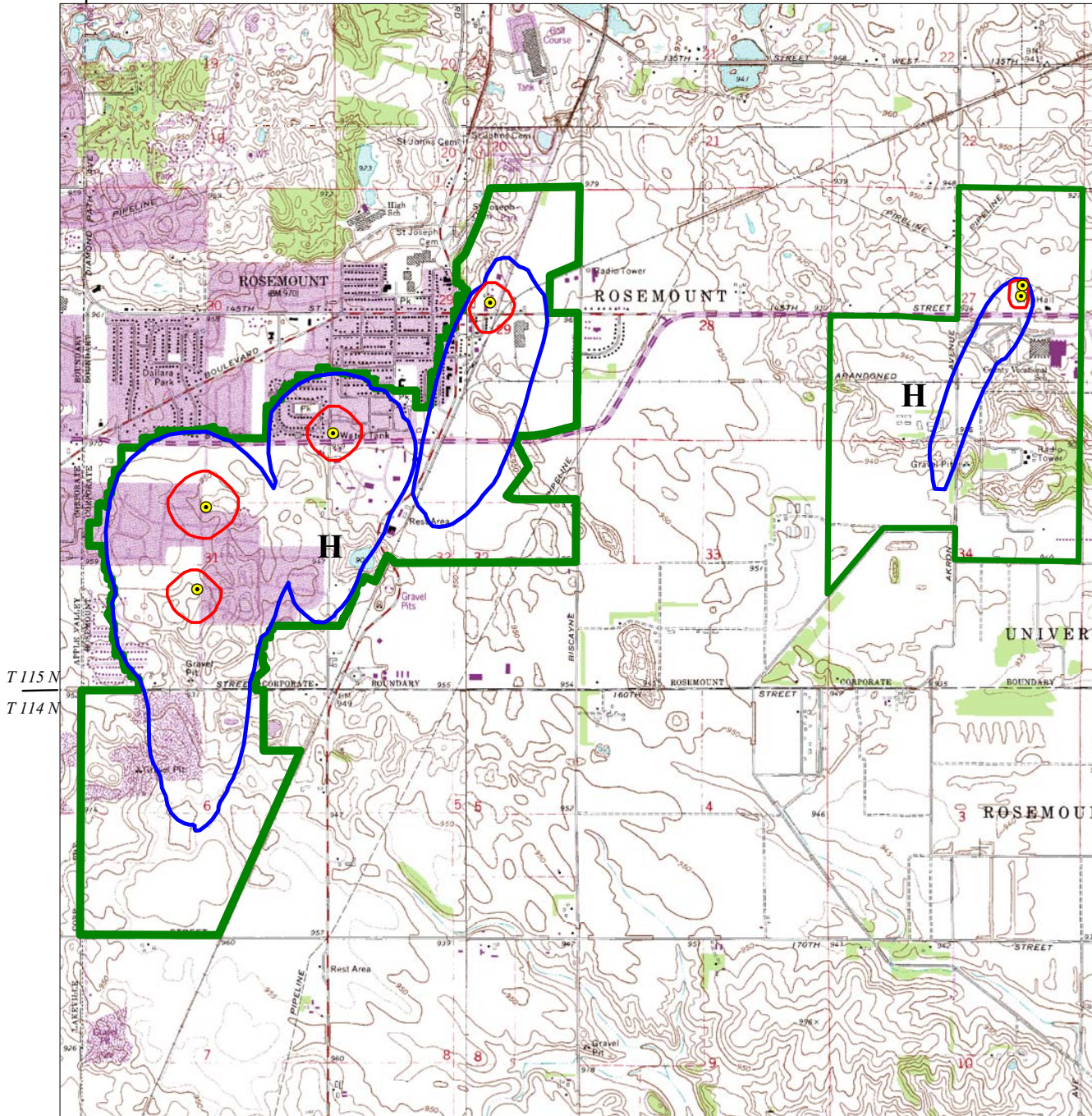
T 115 N
T 114 N

Legend:
- ⊙ **Public Water Supply Well**
- ▭ **Emergency Management Zone** (red)
- ▭ **Wellhead Protection Area (WHPA)** (blue)
- ▭ **DWSMA** (green)

H = High Vulnerability

0.5   0   0.5   Miles

Dakota

SWP
source water protection

MINNESOTA
MDH
DEPARTMENT of HEALTH

Approved June 20, 2002

UMP003291

R 20 W | R 19 W