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Nicolet Minerals Company

Environmental Impact Report

Section 3.6

Groundwater

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3.6 Groundwater

The purpose of project groundwater and hydrogeologic investigations was to assess existing hydrogeologic conditions with respect to groundwater occurrence, hydrogeologic properties, groundwater flow; to assess groundwater interaction with surface water bodies such as lakes, streams and wetlands; and to establish data regarding background groundwater quality.

Since the late 1970s, numerous investigations have been conducted to characterize the groundwater regime within the project study area. These investigations were conducted in three main phases in the late 1970s and early 1980s by Dames & Moore (1982), Golder Associates (1981b, 1982), and STS Consultants, Ltd (1984a and b). Work included extensive drilling and the installation of groundwater monitoring wells and piezometers to characterize the groundwater regime within the primary hydrostratigraphic units within the study area. The study area is defined as the area bounded by Lake Metonga to the north; St. John's and Rolling Stone Lakes to the south; Pickerel Creek and Mole Lake to the west; and Ground Hemlock, Walsh, Clark and St. John's Lakes to the east. Figure 3.5-1 shows the approximate geographic boundaries of the groundwater study area.

In addition to the regional studies, focused investigations were conducted in the 1980s and 1994 by STS Consultants, Ltd.(1982, 1984c, 1986), Dames and Moore (1985), Foth & Van Dyke (1994a; CMC, 1994), and Subsurface Detections Investigations, Inc. (SDII, 1994) that assessed hydrogeologic characteristics that control the interaction between lakes and wetlands located in the immediate project vicinity with the regional groundwater system. Additional studies were conducted in the 1980s and 1994 by Camp, Dresser & McKee (CDM, 1982), Golder Associates (1982), Dames & Moore (1978), Exxon (Landers, 1981), STS Consultants, Ltd. (1984a and b), and Foth & Van Dyke (1995a and b) that assessed major hydraulic characteristics of the glacial overburden and bedrock. Numerous wells and piezometers have been installed in the project study area to characterize groundwater flow, and quality and to evaluate hydraulic parameters. The logs for these borings, soil testing results and some well construction and development data, are contained in appendices previously referenced in Section 3.5 of this report. Additional well construction and development data and in situ hydraulic conductivity testing data is provided in appendices relating to this section of the EIR.

Groundwater quality testing was performed as part of specific studies in the late 1970s and early 1980s. Groundwater quality validation sampling was conducted in 1994 by Foth & Van Dyke. A discussion of the field and laboratory methods employed in the work and results and interpretations follows.

3.6.1 Field and Laboratory Methods

Project groundwater and hydrogeologic studies have been designed to document and describe the hydrogeologic conditions within the study area. Initially, groundwater resources and hydrogeologic conditions were reviewed based on information available from the U.S. Geological Survey (USGS), topographic maps, and information available from the 1976

exploratory drilling program. Based on this initial review, subsequent detailed field investigations were designed for characterization of the regional hydrogeologic conditions and the location and design of the TMA. The remainder of this section contains a description of each investigation and the methods employed.

3.6.1.1 Historical Drilling & Monitoring Well Installation Programs

Well installations have been conducted in various stages that date back to 1977. The following is a description of the major historical well installation programs and the methods employed.

3.6.1.1.1 1977-1979 Dames & Moore Investigations

From 1977 to 1979, 78 monitoring wells were installed in three different phases for hydrogeologic characterization (Dames & Moore 1982). For the first phase, locations were selected for the installation of monitoring wells (DMA series wells) based on the review of available literature on groundwater resources in the vicinity of the project study area. This phase was designed to provide a basic understanding of the hydrogeologic system and groundwater resources within the project study area. Information obtained from this phase was then used to select locations for the next phase of well installations (DMB series wells). The third phase of well installations (DMC series wells) were conducted to obtain information on the hydrogeologic conditions and groundwater resources along the eastern edge of the study area. Additional borings and wells (DMI, DMP, DMS, DW, TW, and WW series) were completed to evaluate the feasibility of various design alternatives. The location of the wells are shown on Figures 3.6-1 and 3.6-2.

Wells constructed of two inch schedule 40 PVC casing fitted with a three to 15 foot section of slotted tubing with 0.01 inch slots were installed in the following manner. Once the borehole drilling was completed, one to two feet of sand and/or pea gravel was poured into the hole. The slotted section of the well was wrapped with a geofabric to discourage fouling of the slots with silts or sands. The screen was then lowered into position so that it rested on the sand and/or pea gravel. Once in position, sand and/or pea gravel was added to the annulus until the material was approximately two feet above the screened interval of the monitoring well. A layer of fine sand was then added to prevent the bentonite-cement slurry from migrating downward and possibly plugging the screen. A bentonite-cement slurry was added to fill the annulus to the ground surface. This material was used to prevent the downward migration of water from water-bearing strata located above the screened interval. Before the bentonite-cement slurry solidified, a protector pipe with a locking protective cap was installed over the top of the well. As each well was installed, construction data were recorded on preprepared forms. A summary of the construction details for each of the wells is contained in Table 3.6-1. Well construction information is provided on boring logs in Appendix 3.5-1.

Wells were not disturbed for a minimum of 24 hours after construction to allow the bentonite-cement slurry time to harden. The wells were then developed using a pitcher pump, bailer, or air lift to surge the water back and forth through the screened interval. This was done to remove the

Table 3.6-1
Summary of Well Completion Data

revision #2 11/09/98 welllist.wb2

Well ID	Date(s) Installed	State Plane Coordinates (ft)		Elevation (msl)		Condition	Construction Details												# of Wells per Boring	Formation Monitored	Well Type	Model Layer
		North	East	Ground	PVC		Total Boring Depth BGS (ft)	Screen Top BGS (ft)	Screen Top (msl) +	Screen Bottom BGS (ft)	Screen Bottom (msl) +	Gravel Pack Top BGS (ft)	Gravel Pack Top (msl) +	Gravel Pack Bottom BGS(ft)	Gravel Pack Bottom (msl) +	Well Diameter (in)	Annular Space Seal					
BE-211-1	3/3/81	116533.635	2276308.686	1647.53	1649.61	TA	200.50	158.00	1489.53	197.00	1450.53	143.00	1504.53	200.00	1447.53	2	Grout		1	SS/MS/EWT	P	4
BE-211-2L	2/19/81	116451.725	2276560.523	1660.92	1662.64	TA	188.50	180.00	1480.92	187.00	1473.92	173.00	1487.92	188.00	1472.92	3/4	Grout		2	SS/MS	P	
BE-211-2U	2/19/81	116451.725	2276560.523	1660.92	1662.72	TA	188.50	130.00	1530.92	150.00	1510.92	118.00	1542.92	160.00	1500.92	3/4	Grout		2	EWT	P	4
BE-211-3L	3/19/81	116476.081	2276300.595	1647.89	1650.70	TA	220.50	208.00	1439.89	218.00	1429.89	198.00	1449.89	221.00	1426.89	3/4	Grout		2	SS/MS	P	5
BE-211-3U	3/19/81	116476.081	2276300.595	1647.89	1650.70	TA	220.50	183.00	1464.89	193.00	1454.89	169.00	1478.89	193.00	1454.89	3/4	Grout		2	MS/EWT	P	
BE-213-1	2/13/81	116025.402	2278436.725	1618.92	1621.66	Ab	92.50	65.00	1553.92	90.00	1528.92	53.00	1565.92	93.00	1525.92	2	Grout		1	SS/MS/EWT/CO	P	3
BE-213-2	2/17/81	116063.997	2278664.481	1616.09	1619.35	Ab	95.00	65.00	1551.09	90.00	1526.09	54.00	1562.09	95.00	1521.09	2	Grout		1	SS/MS/EWT/CO	P	4
BE-213-3L	3/24/81	116112.337	2278467.363	1623.74	1625.60	Ab	115.00	103.00	1520.74	113.00	1510.74	97.00	1526.74	115.00	1508.74	3/4	Grout		2	SS	P	
BE-213-3U	3/24/81	116112.337	2278467.363	1623.74	1625.70	Ab	115.00	77.00	1546.74	87.00	1536.74	67.00	1556.74	89.00	1534.74	3/4	Grout		2	MS/EWT/CO	P	4
BE-216-1	3/10/81	116252.761	2277530.922	1657.45	1659.20	TA	151.50	129.00	1528.45	149.00	1508.45	119.00	1538.45	152.00	1505.45	2	Grout		1	MS/EWT/SS	P	4
BE-216-2	3/18/81	116327.310	2277744.023	1655.18	1657.11	TA	140.50	118.00	1537.18	138.00	1517.18	113.00	1542.18	141.00	1514.18	3/4	Grout		1	MS/EWT/SS	P	
BE-216-3L	4/14/81	116338.082	2277555.071	1661.98	1664.08	TA	178.50	160.00	1501.98	170.00	1491.98	156.00	1505.98	178.50	1483.48	3/4	Grout		2	SS	P	5
BE-216-3U	4/14/81	116338.082	2277555.071	1661.98	1664.08	TA	178.50	123.00	1538.98	149.00	1512.98	111.00	1550.98	150.00	1511.98	3/4	Grout		2	MS/EWT	P	4
CDM-4 ~	12/81	116533.290	2275382.320	1641.39	1644.04	TA	195.00	60.00	1581.39	90.00	1551.39	60.00	1581.39	90.00	1551.39	2	NR		1	CO	WT	
CDM-15	12/81	119587.670	2276543.210	1645.76	1646.44	TA	180.00	60.00	1585.76	90.00	1555.76	60.00	1585.76	90.00	1555.76	2	NR		1	CO	WT	
CDM-16	12/81	114360.100	2277074.010	1595.56	1597.01	A	180.00	50.00	1545.56	80.00	1515.56	NR	NR	NR	NR	2	NR		1	FO	P	
CDM-17	12/81	114387.870	2277034.440	1596.71	1598.37	TA	9.70	7.70	1589.01	9.70	1587.01	None	None	None	None	2 - SWP	None		1	FO	WT	
CDM-18	12/81	114345.430	2277078.070	1595.15	1596.81	A	29.10	27.10	1568.05	29.10	1566.05	None	None	None	None	2 - SWP	None		1	CO	P	
CDM-19	12/81	114345.430	2277078.070	1595.15	1596.67	A	8.00	6.00	1589.15	8.00	1587.15	None	None	None	None	2 - SWP	None		1	FO	WT	
CDM-20	12/81	114320.070	2277138.120	1594.50	1597.07	TA	8.00	6.00	1588.50	8.00	1586.50	None	None	None	None	2 - SWP	None		1	FO	WT	
DMA-1	3/14/77	113660.000	2272030.000	1637.96	1639.60	TA	55.00	51.00	1586.96	55.00	1582.96	45.00	1592.96	55.00	1582.96	2	Grout		1	CO	DRY	
DMA-10	3/15/77	110510.000	2275400.000	1593.58	1595.07	Ab	46.00	42.00	1551.58	46.00	1547.58	33.00	1560.58	46.00	1547.58	2	Grout		1	CO	WT	2
DMA-12	3/24/77	117887.267	2279966.309	1621.18	1622.92	A	45.00	41.00	1580.18	45.00	1576.18	35.00	1586.18	45.00	1576.18	2	Grout		1	CO	WT	2
DMA-13	5/14/77	110450.000	2265800.000	1554.66	1556.04	Ab	40.50	35.00	1519.66	39.00	1515.66	32.50	1522.16	39.00	1515.66	2	Bent/Grout		1	FO/LA	P	2
DMA-16	3/17/77	123792.874	2271254.081	1589.93	1591.28	Ab	60.30	56.00	1533.93	60.00	1529.93	52.00	1537.93	60.00	1529.93	2	Bent/Grout		1	CO/LWT	WT	2
DMA-17	4/6/77	106565.370	2275547.040	1563.95	1565.48	Ab	36.00	27.50	1536.45	31.50	1532.45	20.00	1543.95	34.00	1529.95	2	Bent/Grout		1	CO	P	
DMA-18	4/6/77	111757.520	2269883.645	1619.36	1621.09	A	70.50	66.00	1553.36	70.00	1549.36	55.00	1564.36	70.50	1548.86	2	Grout		1	CO	WT	2
DMA-19	3/21/77	115003.778	2279719.951	1597.24	1598.45	A	30.00	22.00	1575.24	26.00	1571.24	15.00	1582.24	26.00	1571.24	2	Grout		1	CO/LWT	WT	2
DMA-1N	5/77	113664.490	2272028.860	1637.96	1638.86	Ab	55.00	14.00	1623.96	18.00	1619.96	10.00	1627.96	18.00	1619.96	2	Grout		1	LWT	PERCHED	
DMA-1S	5/77	113661.403	2272029.866	1637.96	1638.88	Ab	55.00	51.00	1586.96	55.00	1582.96	45.50	1592.46	55.00	1582.96	2	Grout		1	LWT/CO	DRY	
DMA-20	3/28/77	119200.231	2272622.047	1591.97	1593.18	A	54.00	50.00	1541.97	54.00	1537.97	36.00	1555.97	54.00	1537.97	2	Grout		1	CO/LWT	WT	2
DMA-22B	11/8/79	113800.000	2297350.000	1629.19	1630.74	Ab	100.40	90.00	1539.19	100.00	1529.19	78.80	1550.39	100.40	1528.79	2	Bent/Grout		1	CO	P	2
DMA-29	3/26/77	101230.000	2251380.000	1537.11	1538.60	Ab	40.00	17.00	1520.11	21.00	1516.11	9.00	1528.11	40.00	1497.11	2	Grout		1	LA	WT	
DMA-29AL	5/12/77	101250.000	2251380.000	1536.69	1538.45	Ab	53.00	50.00	1486.69	53.00	1483.69	48.00	1488.69	53.00	1483.69	3/4	Bent		2	CO	P	
DMA-29AU	5/12/77	101250.000	2251380.000	1539.69	1538.46	Ab	53.00	42.00	1497.69	46.00	1493.69	38.50	1501.19	46.00	1493.69	2	Grout		2	LA	P	
DMA-3	3/11/77	115494.403	2273938.327	1647.51	1648.95	Ab	45.00	39.00	1608.51	43.00	1604.51	32.00	1615.51	45.00	1602.51	2	Grout		1	LWT	DRY	
DMA-31	4/18/77	120160.000	2281570.000	1592.09	1593.53	A	25.00	21.00	1571.09	24.00	1568.09	15.00	1577.09	24.00	1568.09	2	Bent/Grout		1	LWT	WT	1
DMA-32A	4/28/77	112050.000	2290580.000	1592.14	1593.55	Ab	175.00	33.00	1559.14	37.00	1555.14	30.00	1562.14	42.00	1550.14	2	Bent/Grout		1	CO	WT	2
DMA-34	4/15/77	114000.000	2248050.000	1535.92	1537.03	Ab	30.50	18.00	1517.92	22.00	1513.92	15.00	1520.92	22.00	1513.92	2	Bent/Grout		1	LWT/LA	WT	
DMA-35	5/14/77	111180.000	2245820.000	1570.39	1571.79	Ab	29.50	25.00	1545.39	29.00	1541.39	20.00	1550.39	29.50	1540.89	2	Grout		1	CO	WT	
DMA-38	5/3/77	141150.000	2249880.000	1772.00	1773.49	Ab	30.00	24.50	1747.50	28.50	1743.50	19.50	1752.50	30.00	1742.00	2	Grout		1	LWT/CO	DRY	
DMA-4	3/23/77	111424.715	2280846.947	1612.03	1613.55	TA	30.00	26.00	1586.03	30.00	1582.03	14.00	1598.03	30.00	1582.03	2	Grout		1	LWT	WT	1
DMA-43	3/25/77	137000.000	2272720.000	1624.70	1626.58	Ab	40.00	36.00	1588.70	40.00	1584.70	25.00	1599.70	40.00	1584.70	2	Grout		1	LWT	P	1
DMA-45	5/1/77	100630.000	2310200.000	1640.61	1641.98	Ab	49.20	44.00	1596.61	48.00	1592.61	33.00	1607.61	48.00	1592.61	2	Grout		1	CO	WT	
DMA-46	5/02/77	117420.000	2319400.000	1714.52	1715.75	Ab	72.50	68.50	1646.02	72.50	1642.02	45.00	1669.52	72.50	1642.02	2	Grout		1	CO	DR	
DMA-47	3/30/77	121392.614	2276057.949	1573.62	1574.71	Ab	31.00	23.00	1550.62	27.00	1546.62	17.50	1556.12	31.00	1542.62	2	Grout		1	LWT	WT	1
DMA-48	3/26/77	118981.495	2268708.522	1547.42	1548.71	A	29.50	24.00	1523.42	28.00	1519.42	20.00	1527.42	28.00	1519.42	2	Grout/Bent		1	CO	WT	2
DMB-1	5/11/78	114405.000	2282890.000	1627.30	N/A	TA	59.30	5.00	1622.30	15.00	1612.30	5.00	1622.30	15.00	1612.30	2	Grout		1	LWT	DRY	
DMB-10	6/23/78	117720.000	2271170.000	1619.11	1620.67	A	99.50	89.50	1529.61	99.50	1519.61	62.00	1557.11	99.50	1519.61	2	Bent/Grout		1	FO/LWT	P	2
DMB-11	6/27/78	109960.000	2273820.000	1656.85	1658.95	A	100.00	89.50	1567.35	99.50	1557.35	86.00	1570.85	99.50	1557.35	2	Bent/Grout		1	CO	WT	2
DMB-12	6/27/78	107390.000	2275205.000	1586.05	1587.59	Ab	81.90	70.00	1516.05	80.00	1506.05	70.00	1516.05	80.00	1506.05	2	Bent/Grout		1	LWT	P	2
DMB-13	6/29/78	107110.000	2269980.000	1609.39	1611.03	Ab	60.00	50.00	1559.39	60.00	1549.39	48.00	1561.39	60.00	1549.39	2	Bent/Grout		1	LWT	WT	2
DMB-14	6/29/78	110075.000	2270985.000	1638.69	N/A	Ab	100.90	90.00	1548.69	100.00	1538.69	87.00	1551.69	100.00	1538.69	2	Bent/Grout		1	CO	P	
DMB-15	6/7/78	113660.000	2272025.000	1637.52	1639.50	TA	79.50	69.50	1568.02	79.50	1558.02	60.00	1577.52	79.50	1558.02	2	Bent/Grout		1	CO	WT	
DMB-16	6/9/78	111880.000	2273475.000	1674.63	1675.44	TA	99.20	88.50	1586.13	98.50	1576.13	63.00	1611.63	98.50	1576.13	2	Grout		1	CO	DRY	
DMB-17	6/9/78	108960.000	2268755.000	1648.95	1650.43	Ab	80.50	70.00	1578.95	80.00	1568.95	70.00	1578.95	80.00	1568.95	2	Bent/Grout		1	CO	DRY	

Table 3.6-1 (Continued)

revision #2 11/09/98 welllist.wb2

Well ID	Date(s) Installed	State Plane Coordinates (ft) North	State Plane Coordinates (ft) East	Elevation (msl) Ground	Elevation (msl) PVC	Condition	Construction Details: Total Boring Depth BGS (ft)	Screen Top BGS (ft)	Screen Top (msl) +	Screen Bottom BGS (ft)	Screen Bottom (msl) +	Gravel Pack Top BGS (ft)	Gravel Pack Top (msl) +	Gravel Pack Bottom BGS(ft)	Gravel Pack Bottom (msl) +	Well Diameter (in)	Annular Space Seal	# of Wells per Boring	Formation Monitored	Well Type	Model Layer
DMB-18	6/10/78	110560.000	2268060.000	1601.40	1602.50	Ab	80.90	70.00	1531.40	80.00	1521.40	65.00	1536.40	80.00	1521.40	2	Bent/Grout	1	CO	WT	2
DMB-19	6/21/78	110450.000	2265815.000	1554.64	1554.29	Ab	160.70	76.50	1478.14	86.50	1468.14	65.00	1489.64	86.50	1468.14	2	Grout	1	CO	P	
DMB-1A	5/16/78	114405.000	2282900.000	1627.94	1629.60	A	79.40	69.00	1558.94	79.00	1548.94	30.00	1597.94	79.00	1548.94	2	Grout	1	CO/LWT	WT	1
DMB-2	5/17/78	114995.000	2285800.000	1706.28	1707.99	TA	100.30	90.20	1616.08	100.20	1606.08	68.20	1638.08	100.20	1606.08	2	Bent/Grout	1	CO/LWT	DRY	
DMB-20	6/10/78	115725.000	2270530.000	1605.80	1607.61	TA	40.00	29.20	1576.60	39.20	1566.60	25.50	1580.30	39.20	1566.60	2	Bent/Grout	1	CO/LA	PERCHED	
DMB-20A	11/27-28/78	115720.000	2270545.000	1606.20	1607.77	TA	84.80	79.50	1526.70	84.50	1521.70	75.00	1531.20	84.50	1521.70	2	Bent/Grout	1	CO	P	2
DMB-21	6/12/78	112820.000	2265775.000	1559.32	1561.25	Ab	49.50	38.90	1520.42	48.90	1510.42	30.00	1529.32	48.90	1510.42	2	Bent/Grout	1	CO	P	2
DMB-22	6/13/78	113240.000	2269090.000	1616.48	1618.13	Ab	79.00	68.60	1547.88	78.60	1537.88	70.00	1546.48	78.60	1537.88	2	Bent/Grout	1	CO	WT	2
DMB-23	6/21/78	115900.000	2268205.000	1563.30	1564.96	A	99.20	89.00	1474.30	99.00	1464.30	88.00	1475.30	99.20	1464.10	2	Bent/Grout	1	FO	P	3
DMB-24	12/18/78	102060.000	2271375.000	1565.43	1566.84	Ab	49.00	43.20	1522.23	48.20	1517.23	42.00	1523.43	48.20	1517.23	2	Bent/Grout	1	CO	P	2
DMB-25	12/15-18/78	105725.000	2268525.000	1644.66	1646.01	Ab	129.50	124.50	1520.16	129.50	1515.16	118.00	1526.66	129.50	1515.16	2	Bent/Grout	1	CO	WT	3
DMB-26	12/12-13/78	105520.000	2282250.000	1712.98	1714.29	Ab	134.10	124.00	1588.98	134.00	1578.98	120.00	1592.98	134.00	1578.98	2	Bent/Grout	1	CO	WT	2
DMB-27	12/6/78	108675.000	2283695.000	1649.04	1650.57	Ab	83.90	73.80	1575.24	83.80	1565.24	72.00	1577.04	83.80	1565.24	2	Bent/Grout	1	CO	WT	2
DMB-28	12/5/78	106840.000	2285425.000	1642.13	1643.70	Ab	70.00	64.50	1577.63	69.50	1572.63	63.00	1579.13	69.50	1572.63	2	Bent/Grout	1	CO	WT	2
DMB-29	11/29/78	104385.000	2288110.000	1629.98	1631.53	Ab	69.30	64.30	1565.68	69.30	1560.68	62.00	1567.98	69.30	1560.68	2	Bent/Grout	1	CO/LWT	WT	2
DMB-3	5/18/78	116895.000	2287465.000	1587.93	1590.31	Ab	61.50	55.00	1532.93	60.00	1527.93	50.00	1537.93	60.00	1527.93	2	Grout	1	CO	P	2
DMB-4	5/22-23/78	118405.000	2283785.000	1644.49	1645.93	A	80.30	69.50	1574.99	79.50	1564.99	69.50	1574.99	79.50	1564.99	2	Bent/Grout	1	LWT/CO	WT	1
DMB-5	5/24/78	112135.000	2285540.000	1688.77	1690.43	TA	98.50	88.40	1600.37	98.40	1590.37	68.00	1620.77	98.40	1590.37	2	Grout	1	CO/LWT	WT	1
DMB-5A	12/4/78	112130.000	2285545.000	1689.33	1690.68	TA	120.20	110.00	1579.33	120.00	1569.33	96.00	1593.33	120.00	1569.33	2	Bent/Grout	1	LWT/CO	P	1
DMB-6	5/26/78	112385.000	2283015.000	1666.47	1668.12	A	86.00	75.50	1590.97	85.50	1580.97	61.60	1604.87	85.50	1580.97	2	Bent/Grout	1	LWT	WT	1
DMB-7	6/6/78	106150.000	2287845.000	1653.67	1654.97	Ab	79.20	69.00	1584.67	79.00	1574.67	59.00	1594.67	79.00	1574.67	2	Bent/Grout	1	CO	WT	2
DMB-8	6/7/78	114595.000	2287840.000	1622.74	1624.58	Ab	50.70	45.00	1577.74	50.00	1572.74	40.00	1582.74	50.00	1572.74	2	Bent/Grout	1	LWT	WT	1
DMB-9A	6/24-26/78	110555.000	2287235.000	1661.61	1663.11	Ab	260.50	217.00	1444.61	227.00	1434.61	218.00	1443.61	243.00	1418.61	1	Bent	3	EWT/FO	P	3
DMB-9B	6/24-26/78	110555.000	2287325.000	1661.61	1663.11	Ab	260.50	190.00	1471.61	200.00	1461.61	183.00	1478.61	210.00	1451.61	1	Bent	3	FO	P	3
DMB-9C	6/24-26/78	110555.000	2287235.000	1661.61	1663.11	Ab	260.50	152.00	1509.61	162.00	1499.61	136.00	1525.61	168.00	1493.61	1	Grout	3	FO/CO	P	3
DMC-1	11/13/79	115120.000	2292330.000	1614.34	1615.99	Ab	47.50	37.00	1577.34	47.00	1567.34	34.00	1580.34	47.50	1566.84	2	Bent/Grout	1	CO/FO	WT	2
DMC-2	11/12/79	126510.000	2288740.000	1588.60	1590.02	Ab	51.50	39.00	1549.60	49.00	1539.60	36.00	1552.60	51.50	1537.10	2	Bent/Grout	1	CO	P	3
DMC-3	11/19/79	106940.000	2291715.000	1610.02	1611.94	Ab	46.50	35.00	1575.02	45.00	1565.02	29.00	1581.02	46.50	1563.52	2	Bent/Grout	1	FO	WT	2
DMI-1	6/14/77	116746.693	2278815.316	1636.74	1638.24	TA	109.00	106.00	1530.74	108.50	1528.24	52.00	1584.74	109.00	1527.74	1	Grout	1	UDB/SS/MS/EWT	P	4
DMI-2L	6/21/77	116608.916	2278750.054	1629.43	1630.61	TA	139.00	134.00	1495.43	139.00	1490.43	88.00	1541.43	139.00	1490.43	3/4	Grout	2	UDB	P	6
DMI-2U	6/21/77	116608.916	2278750.054	1629.43	1630.60	TA	139.00	50.00	1579.43	53.00	1576.43	40.00	1589.43	53.00	1576.43	1	Grout	2	EWT	WT	4
DMP-1	10/30/79	116675.000	2278480.000	1647.62	1649.33	TA	70.70	63.70	1583.92	70.70	1576.92	60.00	1587.62	70.70	1576.92	2	Grout	1	EWT/CO	WT	3
DMP-2	10/31/79	115135.000	2278685.000	1595.58	1596.88	TA	36.50	30.60	1564.98	35.60	1559.98	28.50	1567.08	36.50	1559.08	2	Grout	1	LWT	P	1
DMP-3	11/2/79	113665.000	2275625.000	1623.55	1625.19	TA	65.60	57.50	1566.05	65.50	1558.05	53.20	1570.35	65.60	1557.95	2	Bent/Grout	1	CO	P	2
DMS-1	9/16/77	117104.143	2278219.913	1661.65	1663.77	A	128.00	95.00	1566.65	105.00	1556.65	50.00	1611.65	105.00	1556.65	2	Grout	1	EWT	WT	
DMS-2	9/27/77	117926.677	2277889.698	1641.19	1643.33	TA	184.00	80.00	1561.19	90.00	1551.19	50.00	1591.19	90.00	1551.19	2	Grout	1	CO	WT	4
DW-1A	3/77	116334.871	2276266.441	1648.49	1649.43	A	71.00	58.00	1590.49	70.00	1578.49	53.00	1595.49	71.00	1577.49	1-1/4	Cement Grout	1	EWT	WT	4
DW-1L	3/77	116320.893	2276261.008	1648.32	1649.63	A	215.00	137.00	1511.32	147.00	1501.32	130.00	1518.32	147.00	1501.32	1	Cement Grout	2	EWT	P	4
DW-1U	3/77	116320.893	2276261.008	1648.42	1649.63	A	215.00	92.00	1556.42	97.00	1551.42	85.00	1563.42	105.00	1543.42	1	Cement Grout	2	EWT	P	4
DW-2L	3/77	116776.783	2279794.404	1600.74	1601.70	TA	95.00	85.00	1515.74	90.00	1510.74	77.00	1523.74	95.00	1505.74	3/4	Cement Grout	2	EWT	P	
DW-2U	3/77	116776.783	2279794.404	1600.74	1601.69	TA	95.00	55.00	1545.74	70.00	1530.74	47.00	1553.74	71.00	1529.74	1	Cement Grout	2	CO	P	4
DW-3L	3/77	116254.648	2274840.101	1657.07	1658.61	A	169.00	128.00	1529.07	133.00	1524.07	121.00	1536.07	136.00	1521.07	3/4	Cement Grout	2	EWT	P	4
DW-3U	3/77	116254.648	2274840.101	1657.07	1658.58	TA	169.00	88.00	1569.07	98.00	1559.07	63.00	1594.07	102.00	1555.07	1-1/4	Cement Grout	2	EWT	WT	3
EX-10AL	3/16/84	115111.000	2284239.000	1674.93	1678.17	A	256.00	245.00	1429.93	248.00	1426.93	243.00	1431.93	250.00	1424.93	2	Cem/Bent/Grout	2	LA	P	4
EX-10AU	3/16/84	115111.000	2284239.000	1674.93	1678.22	A	256.00	194.00	1480.93	197.00	1477.93	192.00	1482.93	201.00	1473.93	2	Cem/Bent/Grout	2	FO	P	3
EX-10BL	3/16/84	115109.000	2284216.000	1673.62	1677.18	TA	147.00	142.00	1531.62	145.00	1528.62	140.00	1533.62	147.00	1526.62	2	Cem/Bent/Grout	2	LWT	P	1
EX-10BU	3/16/84	115109.000	2284216.000	1673.62	1677.17	TA	147.00	80.00	1593.62	95.00	1578.62	65.00	1608.62	97.00	1576.62	2	Cem/Bent/Grout	2	LWT	WT	1
EX-11AL	3/24/84	113254.000	2283698.000	1682.05	1685.31	TA	285.00	267.00	1415.05	270.00	1412.05	261.00	1421.05	272.00	1410.05	2	Cem/Bent/Grout	2	LA/CO	P	3
EX-11AU	3/24/84	113254.000	2283698.000	1682.05	1685.34	TA	285.00	222.00	1460.05	225.00	1457.05	220.00	1462.05	227.00	1455.05	2	Cem/Bent/Grout	2	FO	P	3
EX-11BL	3/25/84	113260.000	2283714.000	1681.75	1684.54	TA	174.00	169.00	1512.75	172.00	1509.75	167.00	1514.75	174.00	1507.75	2	Cem/Bent/Grout	2	CO	P	2
EX-11BU	3/25/84	113260.000	2283714.000	1681.75	1684.54	TA	174.00	137.00	1544.75	140.00	1541.75	135.00	1546.75	142.00	1539.75	2	Cem/Bent/Grout	2	LWT	P	1
EX-11CL	3/27/84	113259.000	2283684.000	1681.98	1685.29	TA	102.00	85.00	1596.98	100.00	1581.98	75.00	1606.98	102.00	1579.98	2	Cem/Bent/Grout	1	LWT	WT	1
EX-12AL	3/2-7/84	113156.000	2284707.000	1687.76	1691.10	A	305.00	291.00	1396.76	294.00	1393.76	289.00	1398.76	296.00	1391.76	2	Cem/Bent/Grout	2	LA	P	4
EX-12AU	3/2-7/84	113156.000	2284707.000	1687.76	1691.08	A	305.00	232.00	1455.76	235.00	1452.76	227.00	1460.76	237.00	1450.76	2	Cem/Bent/Grout	2	EWT	P	4
EX-12BL	3/7/84	113163.000	2284692.000	1688.02	1691.24	A	186.07	181.00	1507.02	184.00	1504.02	179.00	1509.02	186.00	1502.02	2	Cem/Bent/Grout	2	CO	P	2
EX-12BU	3/7/84	113163.000	2284692.000	1688.02	1691.25	A	186.07	107.00	1581.02	122.00	1566.02	87.00	1601.02	124.00	1564.02	2	Cem/Bent/Grout	2	LWT	WT	1
EX-13AL	2/20/84	111555.000	2283499.000	1657.32	1659.70	TA	235.00	228.00	1429.32	231.00	1426.32	226.00	1431.32	235.00	1422.32	2	Cem/Bent/Grout	1	EWT	P	4
EX-13BL	2/21-22/84	111541.000	2283510.000	1657.71	1660.21	A	193.01	188.00	1469.71	191.00	1466.71	186.00	1471.71	193.00	1464.71	2	Cem/Bent/Grout	2	EWT/FO	P	3
EX-13BU	2/21-22/84	111541.000	2283510.000	1657.71	1660.24	A	193.01	141.00	1516.71	144.00	1513.71	135.00	1522.71	151.00	1506.71	2	Cem/Bent/Grout	2	CO	P	2
EX-13CL	2/27/84	111538.000	2283501.000	1657.56	1660.68	TA	108.00	104.00	1553.56	107.00	1550.56	101.00	1556.56	108.00	1549.56	2	Cem/Bent/Grout	1	LWT	P	1
EX-13DL	2/29/84	111534.000	2283508.000	1657.88	1661.13	TA	75.00	58.00	1599.88	73.00	1584.88	46.00	1611.88	75.00	1582.88	2	Cem/Bent/Grout	1	LWT/CO	WT	1

Table 3.6-1 (Continued)

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Well ID	Date(s) Installed	State Plane Coordinates (ft) North	State Plane Coordinates (ft) East	Elevation (msl) Ground	Elevation (msl) PVC	Condition	Construction Details: Total Boring Depth BGS (ft)	Screen Top BGS (ft)	Screen Top (msl) +	Screen Bottom BGS (ft)	Screen Bottom (msl) +	Gravel Pack Top BGS (ft)	Gravel Pack Top (msl) +	Gravel Pack Bottom BGS(ft)	Gravel Pack Bottom (msl) +	Well Diameter (in)	Annular Space Seal	# of Wells per Boring	Formation Monitored	Well Type	Model Layer
EX-14AL	2/23/84	110251.000	2286304.000	1682.67	1685.32	A	283.00	265.00	1417.67	268.00	1414.67	263.00	1419.67	270.00	1412.67	2	Cem/Bent/Grout	2	LA	P	4
EX-14AU	2/23/84	110251.000	2286304.000	1682.67	1685.32	A	283.00	200.00	1482.67	203.00	1479.67	198.00	1484.67	205.00	1477.67	2	Cem/Bent/Grout	2	FO	P	3
EX-14BL	2/25/84	110257.000	2286282.000	1682.78	1685.01	A	167.00	162.00	1520.78	165.00	1517.78	160.00	1522.78	167.00	1515.78	2	Cem/Bent/Grout	2	LWT	P	3
EX-14BU	2/25/84	110257.000	2286282.000	1682.78	1685.01	A	167.00	100.00	1582.78	115.00	1567.78	67.00	1615.78	117.00	1565.78	2	Cem/Bent/Grout	2	CO	WT	2
EX-15AL	2/10-12/84	112443.000	2280005.000	1626.64	1629.24	TA	235.00	219.50	1407.14	222.50	1404.14	217.00	1409.64	226.00	1400.64	2	Cem/Bent/Grout	2	EWT	P	4
EX-15AU	2/10-12/84	112443.000	2280005.000	1626.64	1629.24	TA	235.00	117.00	1509.64	120.00	1506.64	115.00	1511.64	122.50	1504.14	2	Cem/Bent/Grout	2	CO	P	2
EX-15BL	2/11/84	112447.000	2280010.000	1626.10	1629.30	A	52.00	35.00	1591.10	50.00	1576.10	10.00	1616.10	52.00	1574.10	2	Cem/Bent/Grout	1	FO	WT	1
EX-16AL	2/13-14/84	113316.000	2282043.000	1614.70	1617.39	A	145.00	139.00	1475.70	142.00	1472.70	137.00	1477.70	145.00	1469.70	2	Cem/Bent/Grout	2	FO	P	3
EX-16AU	2/13-14/84	113316.000	2282043.000	1614.70	1617.43	A	145.00	104.00	1510.70	107.00	1507.70	102.00	1512.70	109.00	1505.70	2	Cem/Bent/Grout	2	CO	P	2
EX-16BL	3/1/84	113322.000	2282041.000	1614.62	1616.84	A	70.57	55.00	1559.62	70.00	1544.62	42.00	1572.62	70.00	1544.62	2	Cem/Bent/Grout	1	LWT/FO	WT	1
EX-1AL	2/29-3/1/84	104151.000	2273714.000	1555.48	1558.00	Ab	132.80	126.00	1429.48	129.00	1426.48	124.00	1431.48	132.50	1422.98	2	Cem/Bent/Grout	2	EWT	P	4
EX-1AU	2/29-3/1/84	104151.000	2273714.000	1555.48	1558.00	Ab	132.80	103.00	1452.48	106.00	1449.48	101.00	1454.48	108.00	1447.48	2	Cem/Bent/Grout	2	CO/EWT	P	3
EX-1BL	3/1/84	104144.000	2273710.000	1555.16	1557.56	Ab	47.00	42.00	1513.16	45.00	1510.16	40.00	1515.16	47.00	1508.16	2	Cem/Bent/Grout	2	CO	P	2
EX-1BU	3/1/84	104144.000	2273710.000	1555.16	1557.53	Ab	47.00	5.00	1550.16	20.00	1535.16	2.50	1552.66	22.00	1533.16	2	Cem/Bent/Grout	2	CO	WT	2
EX-2AL	3/27/84	110340.000	2262240.000	1592.11	1594.91	Ab	192.00	152.00	1440.11	155.00	1437.11	150.00	1442.11	157.00	1435.11	2	Cem/Bent/Grout	2	FO	P	
EX-2AU	3/27/84	110340.000	2262240.000	1592.11	1594.91	Ab	192.00	70.00	1522.11	73.00	1519.11	68.00	1524.11	75.00	1517.11	2	Cem/Bent/Grout	2	CO	P	
EX-2BL	3/27/84	110340.000	2262240.000	1591.99	1694.62	Ab	37.00	15.00	1576.99	35.00	1556.99	10.00	N/A	37.00	N/A	2	Bent. Seal	1	LWT	DRY	
EX-2CL	5/17/84	110340.000	2262240.000	1592.11	1594.60	Ab	47.00	30.00	1562.11	45.00	1547.11	27.00	1565.11	47.00	1545.11	2	Cem/Bent/Grout	1	LWT	WT	
EX-3AL	3/30/84	110285.000	2263941.000	1559.09	1562.05	Ab	162.00	144.00	1415.09	147.00	1412.09	142.00	1417.09	149.00	1410.09	2	Cem/Bent/Grout	2	EWT	P	
EX-3AU	3/30/84	110285.000	2263941.000	1559.09	1562.02	Ab	162.00	110.00	1449.09	113.00	1446.09	108.00	1451.09	115.00	1444.09	2	Cem/Bent/Grout	2	FO	P	
EX-3BL	3/30/84	110287.000	2263932.000	1559.38	1562.36	Ab	75.00	70.00	1489.38	73.00	1486.38	68.00	1491.38	75.00	1484.38	2	Cem/Bent/Grout	2	CO	P	
EX-3BU	3/30/84	110287.000	2263932.000	1559.38	1562.38	Ab	75.00	40.00	1519.38	43.00	1516.38	38.00	1521.38	45.00	1514.38	2	Cem/Bent/Grout	2	FO	P	
EX-3CL	3/31/84	110280.000	2263921.000	1560.09	1562.62	Ab	12.00	3.00	1557.09	11.00	1549.09	2.50	1557.59	12.00	1548.09	2	Bent. Powder	1	FO	WT	
EX-4AL	2/6-8/84	119912.000	2274288.000	1573.87	1577.06	TA	119.00	114.50	1459.37	117.50	1456.37	112.50	1461.37	119.00	1454.87	2	Cem/Bent/Grout	2	EWT	P	4
EX-4AU	2/6-8/84	119912.000	2274288.000	1573.87	1577.02	TA	119.00	91.50	1482.37	94.50	1479.37	89.00	1484.87	97.00	1476.87	2	Cem/Bent/Grout	2	FO	P	3
EX-4BL	2/6-8/84	119917.000	2274278.000	1573.68	1577.15	A	67.95	62.50	1511.18	65.50	1508.18	60.50	1513.18	66.50	1507.18	2	Cem/Bent/Grout	2	CO	P	3
EX-4BU	2/6/84	119917.000	2274278.000	1573.68	1577.08	A	67.95	37.00	1536.68	40.00	1533.68	35.00	1538.68	42.00	1531.68	2	Cem/Bent/Grout	2	LWT	P	2
EX-4CL	2/7/84	119929.000	2274283.000	1573.58	1577.03	TA	29.00	11.00	1562.58	26.00	1547.58	4.00	1569.58	29.00	1544.58	2	Concrete	1	CO	WT	2
EX-5AL	2/7-8/84	119857.000	2276790.000	1632.50	1635.39	TA	189.00	183.00	1449.50	186.00	1446.50	181.00	1451.50	189.00	1443.50	2	Cem/Bent/Grout	2	UDB	P	7
EX-5AU	2/7-8/84	119857.000	2276790.000	1632.50	1635.39	TA	189.00	160.00	1472.50	163.00	1469.50	158.00	1474.50	165.00	1467.50	2	Cem/Bent/Grout	2	UDB	P	5
EX-5BL	2/15-16/84	119858.000	2276781.000	1632.54	1635.83	TA	112.00	107.00	1525.54	110.00	1522.54	105.00	1527.54	112.00	1520.54	2	Cem/Bent/Grout	2	CO	P	2
EX-5BU	2/15-16/84	119858.000	2276781.000	1632.54	1635.83	TA	112.00	43.00	1589.54	58.00	1574.54	20.00	1612.54	60.00	1572.54	2	Cem/Bent/Grout	2	LWT	DRY	
EX-5CL	4/3/84	119851.000	2276781.000	1632.78	1635.75	A	75.88	58.00	1574.78	73.00	1559.78	48.00	1584.78	75.00	1557.78	2	Cement Grout	1	LWT	WT	1
EX-6AL	3/6-7/84	120340.000	2289928.000	1606.94	1609.63	Ab	196.00	175.00	1431.94	178.00	1428.94	173.00	1433.94	180.00	1426.94	2	Cement Grout	2	EWT	P	4
EX-6AU	3/6-7/84	120340.000	2289928.000	1606.94	1609.61	Ab	196.00	119.00	1487.94	122.00	1484.94	117.00	1489.94	124.00	1482.94	2	Cem/Bent/Grout	2	CO	P	3
EX-6BL	3/7/84	120341.000	2289919.000	1606.80	1609.78	Ab	87.00	82.00	1524.80	85.00	1521.80	80.00	1526.80	87.00	1519.80	2	Cem/Bent/Grout	2	FO	P	2
EX-6BU	3/7/84	120341.000	2289919.000	1606.80	1609.78	Ab	87.00	15.00	1591.80	30.00	1576.80	10.00	1596.80	32.00	1574.80	2	Cem/Bent/Grout	2	CO	WT	2
EX-7AL	3/8/84	117862.000	2286791.000	1580.35	1583.42	Ab	169.00	156.50	1423.85	159.50	1420.85	154.00	1426.35	161.00	1419.35	2	Bent. Slurry	1	EWT	P	4
EX-7BL	3/9/84	117856.000	2286783.000	1580.67	1583.91	Ab	112.00	107.00	1473.67	110.00	1470.67	105.00	1475.67	112.00	1468.67	2	Cem/Bent/Grout	2	EWT	P	4
EX-7BU	3/9/84	117856.000	2286783.000	1580.67	1583.92	Ab	112.00	67.00	1513.67	70.00	1510.67	66.50	1514.17	73.50	1507.17	2	Cem/Bent/Grout	2	CO	P	3
EX-7CL	3/8/84	117853.000	2286779.000	1581.15	1583.06	Ab	11.50	3.50	1577.65	9.50	1571.65	3.50	1577.65	11.50	1569.65	2	Bent/Grout	1	FO	WT	2
EX-8AL	3/14/84	116362.000	2287655.000	1586.46	1589.26	A	175.00	161.00	1425.46	164.00	1422.46	159.00	1427.46	166.00	1420.46	2	Cem/Bent/Grout	2	EWT	P	4
EX-8AU	3/14/84	116362.000	2287655.000	1586.46	1589.26	A	175.00	102.00	1484.46	105.00	1481.46	100.00	1486.46	107.00	1479.46	2	Cem/Bent/Grout	2	EWT	P	4
EX-8BL	3/12/84	116371.000	2287651.000	1586.62	1589.40	A	77.74	72.00	1514.62	75.00	1511.62	70.00	1516.62	77.00	1509.62	2	Cem/Bent/Grout	2	FO	P	3
EX-8BU	3/12/84	116371.000	2287651.000	1586.62	1589.40	A	77.74	5.00	1581.62	13.00	1573.62	4.00	1582.62	14.00	1572.62	2	Cem/Bent/Grout	2	CO	WT	2
EX-9AL	3/21/84	116461.000	2284725.000	1708.86	1712.34	A	280.00	275.00	1433.86	278.00	1430.86	273.00	1435.86	280.00	1428.86	2	Cem/Bent/Grout	2	UDB	P	5
EX-9AU	3/21/84	116461.000	2284725.000	1708.86	1712.33	A	280.00	243.00	1465.86	246.00	1462.86	241.00	1467.86	248.00	1460.86	2	Cem/Bent/Grout	2	FO	P	3
EX-9BL	3/30/84	116472.000	2284729.000	1708.64	1711.68	A	193.50	187.00	1521.64	190.00	1518.64	185.00	1523.64	192.00	1516.64	2	Cem/Bent/Grout	2	CO	P	2
EX-9BU	3/30/84	116472.000	2284729.000	1708.64	1711.71	A	193.50	115.00	1593.64	135.00	1573.64	105.00	1603.64	137.00	1571.64	2	Cem/Bent/Grout	2	CO/LWT	WT	1
G40-D24	12/20/79	108060.000	2266940.000	1629.93	1632.17	Ab	188.50	174.00	1455.93	184.00	1445.93	167.00	1462.93	188.50	1441.43	2	Bent/Grout	1	EWT	P	4
G40-H16	3/28/79	113260.000	2269110.000	1617.10	1619.33	Ab	268.00	145.00	1472.10	155.00	1462.10	110.00	1507.10	158.00	1459.10	2	Bent/Grout	1	EWT/FO	P	3
G40-H27	12/20/79	105930.000	2269650.000	1602.12	1603.78	Ab	250.00	171.00	1431.12	181.00	1421.12	157.00	1445.12	250.00	1352.12	2	Bent/Grout	1	EWT/UDB	P	
G40-J15	3/02/79	113810.000	2270150.000	1603.60	1605.52	TA	51.50	37.00	1566.60	47.00	1556.60	32.00	1571.60	51.50	1552.10	2	Bent/Grout	1	LWT	WT	2
G40-K13	3/01/79	115130.000	2270885.000	1600.90	1603.34	TA	50.25	34.00	1566.90	44.00	1556.90	25.00	1575.90	44.00	1556.90	2	Bent/Grout	1	CO/FO	WT	2
G40-L23	1/15/80	108920.000	2271065.000	1639.30	1641.06	Ab	90.90	77.00	1562.30	87.00	1552.30	74.00	1565.30	90.90	1548.40	2	Bent/Grout	1	LWT/CO	WT	2
G40-M15	4/11/79	113660.000	2271735.000	1637.60	1639.15	Ab	310.00	264.00	1373.60	274.00	1363.60	264.00	1373.60	310.00	1327.60	2	Bent/Grout	1	EWT	P	
G40-P10A	1/15/82	116745.000	2272895.000	1651.35	1655.05	Ab	160.00	86.00	1565.35	96.00	1555.35	80.00	1571.35	160.00	1491.35	2	Bent/Grout	1	CO/EWT/UDB	WT	3
G40-P20	1/3/80	111070.000	2273515.000	1641.09	1643.13	Ab	81.00	66.00	1575.09	76.00	1565.09	60.00	1581.09	81.00	1560.09	2	Bent/Grout	1	CO	WT	2
G40-Q7	1/17/80	119050.000	2274350.000	1608.07	1609.68	Ab	70.50	57.00	1551.07	67.00	1541.07	50.00	1558.07	70.50	1537.57	2	Bent/Grout	1	LWT	WT	2
G40-R23	1/8/80	108770.000	2274805.000	1620.30	1622.09	Ab	81.00	66.00	1554.30	76.00	1544.30	60.00	1560.30	81.00	1539.30	2	Bent/Grout	1	FO/LWT	WT	2
G40-S17	12/17/81	112295.000	2275770.000	1595.65	1598.14	A	150.76	116.00	1479.65	126.00	1469.65	111.00	1484.65	150.70	1444.95	2	Bent/Grout	1	EWT/FO	P	4

Table 3.6-1 (Continued)

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Well ID	Date(s) Installed	State Plane Coordinates (ft) North	State Plane Coordinates (ft) East	Elevation (msl) Ground	Elevation (msl) PVC	Condition	Construction Details: Total Boring Depth BGS (ft)	Screen Top BGS (ft)	Screen Top (msl) +	Screen Bottom BGS (ft)	Screen Bottom (msl) +	Gravel Pack Top BGS (ft)	Gravel Pack Top (msl) +	Gravel Pack Bottom BGS(ft)	Gravel Pack Bottom (msl) +	Well Diameter (in)	Annular Space Seal	# of Wells per Boring	Formation Monitored	Well Type	Model Layer
G40-S17A	12/18/81	112335.000	2275790.000	1595.90	1598.12	TA	30.00	21.00	1574.90	26.00	1569.90	16.00	1579.90	30.00	1565.90	2	Bent/Grout	1	LWT	WT	1
G40-T30	2/11/82	105765.000	2278410.000	1590.40	1592.66	Ab	162.00	105.00	1485.40	115.00	1475.40	100.00	1490.40	162.00	1428.40	2	Bent/Grout	1	CO/EWT	P	4
G40-X1	1/15/82	121515.000	2277990.000	1616.55	1618.85	TA	143.00	75.00	1541.55	85.00	1531.55	69.00	1547.55	143.00	1473.55	2	Bent/Grout	1	LWT/EWT/CO	P	3
G40-X1A	1/14/82	121930.000	2277830.000	1578.90	1581.22	Ab	75.00	50.00	1528.90	60.00	1518.90	41.00	1537.90	75.00	1503.90	2	Bent/Grout	1	EWT/CO/LWT	P	2
G40-Y15	12/17/81	113655.000	2279180.000	1593.40	1595.85	A	175.00	84.00	1509.40	94.00	1499.40	79.00	1514.40	175.00	1418.40	2	Bent/Grout	1	CO	P	3
G40-Y15A	12/17/81	113665.000	2279170.000	1593.70	1595.90	A	20.00	5.00	1588.70	10.00	1583.70	5.00	1588.70	20.00	1573.70	2	Bent/Grout	1	LA	WT	1
G40-Y21	12/28/81	110730.000	2278040.000	1592.80	1595.46	TA	20.00	12.00	1580.80	17.00	1575.80	11.00	1581.80	20.00	1572.80	2	Bent/Grout	1	CO	WT	2
G40-Y22	1/22/82	108880.000	2278310.000	1609.10	1611.42	Ab	196.00	162.00	1447.10	172.00	1437.10	154.00	1455.10	196.00	1413.10	2	Bent/Grout	1	CO/FO	P	3
G40-Y26	1/20/82	106680.000	2278800.000	1590.70	1592.77	Ab	128.00	93.00	1497.70	103.00	1487.70	88.00	1502.70	128.00	1462.70	2	Bent/Grout	1	CO/FO/EWT	P	3
G41-A23	1/18/82	108070.000	2280288.000	1608.00	1610.26	A	48.00	37.50	1570.50	43.00	1565.00	32.00	1576.00	48.00	1560.00	2	Bent/Grout	1	LWT	P	1
G41-A24	6/9/81	107060.000	2280500.000	1614.08	1616.64	Ab	180.00	100.00	1514.08	110.00	1504.08	85.00	1529.08	180.00	1434.08	2	Bent/Grout	1	CO/FO/EWT/UDB	P	3
G41-B12	12/31/81	116120.000	2280610.000	1610.65	1613.25	TA	126.00	75.00	1535.65	85.00	1525.65	68.00	1542.65	126.00	1484.65	2	Bent/Grout	1	CO/LWT/EWT/UDB	P	4
G41-C15	3/7/79	113350.000	2282075.000	1615.60	1617.12	TA	217.30	195.00	1420.60	205.00	1410.60	190.00	1425.60	217.30	1398.30	2	Bent/Grout	1	EWT/LA	P	4
G41-C15A	3/9/79	113365.000	2282080.000	1615.60	NR	Ab	145.00	130.80	1484.80	133.00	1482.60	None	None	None	None	2	None	1	FO	P	
G41-C15B	3/30-31/79	113265.000	2281850.000	1611.60	1613.81	A	26.50	21.50	1590.10	26.50	1585.10	19.00	1592.60	26.50	1585.10	2	Bent/Grout	1	FO	P	
G41-C15C	1/18/82	113160.000	2281790.000	1611.35	1613.88	TA	22.00	13.00	1598.35	18.00	1593.35	10.50	1600.85	22.00	1589.35	2	Bent/Grout	1	IM	PERCHED	
G41-C32	2/9/82	102500.000	2282115.000	1739.80	1742.89	Ab	262.00	213.00	1526.80	223.00	1516.80	200.00	1539.80	262.00	1477.80	2	Bent/Grout	1	FO/EWT/UDB	P	3
G41-E13	3/6/79	114395.000	2282889.000	1627.30	1629.34	A	250.50	227.00	1400.30	237.00	1390.30	225.00	1402.30	250.50	1376.80	2	Bent/Grout	1	UDB/FO	P	3
G41-E13A	3/27/79	114395.000	2282890.000	1626.70	1629.50	TA	191.00	188.83	1437.87	191.00	1435.70	None	None	None	None	2	None	1	FO	P	
G41-E17	4/2/79	112385.000	2283005.000	1666.40	1668.37	A	260.00	235.00	1431.40	245.00	1421.40	228.00	1438.40	260.00	1406.40	2	Bent/Grout	1	EWT/UDB	P	4
G41-E19A	5/15/81	110260.000	2283290.000	1645.59	1648.97	A	276.00	115.00	1530.59	125.00	1520.59	108.00	1537.59	126.00	1519.59	2	Bent/Grout	1	CO/FO	P	3
G41-E22	1/04/82	109970.000	2282570.000	1609.75	1611.93	A	224.00	115.00	1494.75	125.00	1484.75	110.00	1499.75	224.00	1385.75	2	Bent/Grout	1	FO	P	3
G41-E22A	1/06/82	109955.000	2282590.000	1609.50	1611.71	TA	42.10	33.00	1576.50	38.00	1571.50	28.00	1581.50	42.10	1567.40	2	Bent/Grout	1	LWT	WT	1
G41-F24	1/8/80	107255.000	2283465.000	1653.50	1656.18	Ab	243.00	83.00	1570.50	93.00	1560.50	75.00	1578.50	243.00	1410.50	2	Bent/Grout	1	CO/EWT/FO	WT	3
G41-G12	3/31/79	115825.000	2284430.000	1675.70	1678.57	TA	21.00	14.50	1661.20	19.50	1656.20	13.00	1662.70	21.00	1654.70	2	Bent/Grout	1	LWT	PERCHED	
G41-G13	6/4/81	115260.000	2284725.000	1709.58	1712.19	TA	319.00	247.00	1462.58	255.00	1454.58	225.00	1484.58	319.00	1390.58	2	Bent/Grout	1	CO/LWT	P	4
G41-G14A	11/16/79	114080.000	2284315.000	1706.91	1708.43	TA	241.00	221.00	1485.91	241.00	1465.91	190.00	1516.91	241.00	1465.91	2	Bent/Grout	1	LWT	P	3
G41-G14B	11/30/79	114055.000	2284315.000	1706.80	1708.71	TA	360.10	272.00	1434.80	292.00	1414.80	263.00	1443.80	360.10	1346.70	2	Bent/Grout	1	EWT	P	4
G41-G14C	12/4/79	114030.000	2284315.000	1706.33	1708.51	TA	160.00	131.00	1575.33	151.00	1555.33	124.00	1582.33	150.00	1556.33	2	Bent/Grout	1	LWT	WT	1
G41-G14D	12/11/79	113855.000	2284315.000	1705.56	1707.42	TA	257.00	222.00	1483.56	242.00	1463.56	215.00	1490.56	245.00	1460.56	2	Bent/Grout	1	FO/CO	P	3
G41-G14E	12/07/79	113830.000	2284315.000	1705.61	1707.81	TA	165.00	134.00	1571.61	154.00	1551.61	129.00	1576.61	154.00	1551.61	2	Bent/Grout	1	CO	P	1
G41-G14F	11/6/79	113805.000	2284315.000	1703.50	1706.73	TA	332.00	290.00	1413.50	310.00	1393.50	281.00	1422.50	310.00	1393.50	2	Bent/Grout	1	EWT	P	4
G41-G15	4/9/79	113415.000	2284420.000	1691.50	1694.19	TA	338.00	240.00	1451.50	250.00	1441.50	234.00	1457.50	338.00	1353.50	2	Bent/Grout	1	EWT/UDB/LA	P	4
G41-G15A	3/9/79	113480.000	2284390.000	1692.75	1695.61	TA	113.00	101.50	1591.25	111.50	1581.25	92.00	1600.75	113.00	1579.75	2	Bent/Grout	1	CO	WT	1
G41-G15B	3/13/79	113440.000	2284385.000	1692.10	NR	TA	170.00	158.00	1534.10	168.00	1524.10	146.00	1546.10	170.00	1522.10	2	Bent/Grout	1	LWT	P	1
G41-G21	12/5/79	109495.000	2284265.000	1664.83	1665.95	Ab	100.50	90.00	1574.83	99.00	1565.83	67.00	1597.83	100.50	1564.33	2	Bent/Grout	1	LWT	WT	2
G41-H17	2/28/79	112145.000	2284960.000	1684.50	1686.89	TA	74.30	22.50	1662.00	32.50	1652.00	20.00	1664.50	33.00	1651.50	2	Bent/Grout	1	CO/LWT	DRY	
G41-H18	3/9/79	111430.000	2285125.000	1684.30	1686.30	TA	75.30	17.00	1667.30	27.00	1657.30	12.00	1672.30	30.00	1654.30	2	Bent/Grout	1	LWT	DRY	
G41-H18A	3/30/79	111590.000	2285065.000	1680.40	1684.38	TA	21.50	17.00	1663.40	20.00	1660.40	16.00	1664.40	20.00	1660.40	2	Bent/Grout	1	LWT	PERCHED	
G41-H18B	6/3/81	110995.000	2285335.000	1683.80	1686.99	A	288.00	147.00	1536.80	157.00	1526.80	140.00	1543.80	288.00	1395.80	2	Bent/Grout	1	CO/LWT/EWT/FO/LA	P	4
G41-H9	5/26/81	117330.000	2285000.000	1702.04	1704.69	A	315.00	230.00	1472.04	240.00	1462.04	210.00	1492.04	315.00	1387.04	2	Bent/Grout	1	CO/LWT/FO/LA/EWT	P	3
G41-J18	3/13/79	111215.000	2285495.000	1679.70	1682.98	TA	70.50	23.00	1656.70	33.00	1646.70	18.00	1661.70	36.00	1643.70	2	Bent/Grout	1	CO/LWT	DRY	
G41-K13	4/9/79	114755.000	2285965.000	1699.70	1702.79	A	285.00	260.00	1439.70	270.00	1429.70	240.00	1459.70	285.00	1414.70	2	Bent/Grout	1	EWT/UDB	P	4
G41-K13A	3/31/79	114770.000	2285955.000	1699.90	1702.88	TA	122.20	109.30	1590.60	119.30	1580.60	105.50	1594.40	122.20	1577.70	2	Bent/Grout	1	LWT	WT	2
G41-K13B	3/28/79	114850.000	2286070.000	1696.80	1698.70	TA	20.00	15.00	1681.80	20.00	1676.80	10.00	1686.80	20.00	1676.80	2	Bent/Grout	1	LWT	DRY	
G41-K26	5/11/81	106260.000	2286445.000	1686.10	1688.14	Ab	330.00	157.00	1529.10	167.00	1519.10	137.00	1549.10	168.00	1518.10	2	Bent/Grout	1	FO/LA/CO/EWT/UDB	P	3
G41-M11	4/28/81	116270.000	2287725.000	1582.79	1585.61	Ab	160.50	50.00	1532.79	60.00	1522.79	42.00	1540.79	160.50	1422.29	2	Bent/Grout	1	FO	P	4
G41-M24	12/5/79	107900.000	2287176.000	1653.11	1655.30	Ab	30.80	21.50	1631.61	30.80	1622.31	8.00	1645.11	30.80	1622.31	2	Bent/Grout	1	CO/LWT	PERCHED	
G41-N21	12/1/79	109170.000	2288410.000	1727.36	1729.40	Ab	150.50	138.50	1588.86	148.40	1578.96	76.00	1651.36	150.50	1576.86	2	Bent. Grout	1	CO	WT	2
G41-P16	4/27/81	113755.000	2288760.000	1588.72	1592.33	Ab	181.00	44.00	1544.72	54.00	1534.72	39.00	1549.72	181.00	1407.72	2	Bent. Grout	1	LWT/CO/EWT	WT	3
G41-P18	3/27/79	111645.000	2288825.000	1588.90	1591.41	Ab	130.00	100.00	1488.90	110.00	1478.90	95.00	1493.90	125.00	1463.90	2	Bent. Grout	1	CO/LWT	P	3
G41-P18B	3/29/79	111390.000	2288820.000	1589.10	1591.24	Ab	44.50	35.00	1554.10	40.00	1549.10	33.00	1556.10	40.00	1549.10	2	Bent. Grout	1	LWT	WT	2
G41-P24	12/20/79	107550.000	2288660.000	1681.95	1684.21	Ab	345.00	103.00	1578.95	113.00	1568.95	95.00	1586.95	345.00	1336.95	2	Bent. Grout	1	CO/FO/LWT/EWT	WT	3
G41-Q22	5/8/81	108460.000	2289190.000	1612.30	1615.46	Ab	316.50	177.00	1435.30	187.00	1425.30	170.00	1442.30	316.50	1295.80	2	Bent. Grout	1	FO/LA/CO/EWT/UDB	P	3
STS-B1	1/25/80	116792.120	2278140.830	1655.70	1657.72	TA	110.30	NR	NR	84.70	1571.00	NR	NR	NR	NR	2	Bent. Grout	1	NR	NR	
STS-DHL-1	2/13/84	108983.000	2281442.000	1605.40	1606.50	Ab	43.00	38.80	1566.60	41.80	1563.60	38.00	1567.40	41.80	1563.60	1-1/2	Grout	1	LWT	P	
STS-DL-1	2/8/84	112581.000	2281760.000	1611.80	1613.70	Ab	60.00	56.70	1555.10	59.70	1552.10	55.70	1556.10	59.70	1552.10	1-1/2	Bent. Pellets	1	FO	P	
STS-DL-2 ~	10/25/85	113175.000	2281778.000	1611.70	1614.20	A	34.50	31.50	1580.20	34.50	1577.20	None	None	None	None	2 - Galv	Bent. Pellets	1	LWT/FO	P	
STS-DL-3 ~	10/25/85	113882.000	2281574.000	1612.50	1616.00	TA	19.50	17.00	1595.50	19.00	1593.50	None	None	None	None	2 - Galv	Bent. Pellets	1	FO	WT	
STS-DL-4 ~	10/25/85	113114.000	2281514.000	1612.60	1615.60	A	20.00	17.50	1595.10	19.50	1593.10	None	None	None	None	2 - Galv	Bent. Pellets	1	IM/LA/FO	P	
STS-DL-5 ~	10/25/85	112448.000	2280776.000	1612.60	1615.70	A	20.00	17.50	1595.10	19.50	1593.10	None	None	None	None	2 - Galv	Bent. Pellets	1	FO	WT	

Table 3.6-1 (Continued)

revision #2 11/09/98 welllist.wb2

Well ID	Date(s) Installed	State Plane Coordinates (ft) North	State Plane Coordinates (ft) East	Elevation (msl) Ground	Elevation (msl) PVC	Condition	Construction Details: Total Boring Depth BGS (ft)	Screen Top BGS (ft)	Screen Top (msl) +	Screen Bottom BGS (ft)	Screen Bottom (msl) +	Gravel Pack Top BGS (ft)	Gravel Pack Top (msl) +	Gravel Pack Bottom BGS(ft)	Gravel Pack Bottom (msl) +	Well Diameter (in)	Annular Space Seal	# of Wells per Boring	Formation Monitored	Well Type	Model Layer
STS-DL-6 ~	10/25/85	111630.000	2280917.000	1615.20	1615.20	A	20.00	17.50	1597.70	19.50	1595.70	None	None	None	None	2 - Galv	Bent. Pellets	1	LWT	WT	
STS-EVS	3/21/78	116340.800	2278955.800	1614.40	1616.50	TA	83.80	55.50	1558.90	65.50	1548.90	24.50	1589.90	74.20	1540.20	2	Cem Ben Grout	1	NR	P	
STS-OL-1	2/9-10/84	114464.000	2273195.000	1633.47	1635.20	Ab	53.00	47.00	1586.47	50.00	1583.47	46.30	1587.17	50.00	1583.47	1-1/2	Grout	1	CO/LA	DRY	
STS-SL-1	2/9/84	117588.000	2280516.700	1598.00	1599.70	Ab	17.40	14.40	1583.60	17.40	1580.60	12.30	1585.70	17.40	1580.60	1-1/2	Grout	1	CO	P	
STS-SL-3 ~	10/25/85	117765.800	2281033.500	1598.40	1600.30	A	6.00	4.00	1594.40	5.80	1592.60	None	None	None	None	2 - Galv	Bent. Pellets	1	IM/LA	WT	
STS-SL-4 ~	10/25/85	118074.100	2281309.100	1600.30	1602.70	TA	7.50	5.00	1595.30	7.00	1593.30	None	None	None	None	2 - Galv	Bent. Pellets	1	IM/LA	WT	
STS-SL-5 ~	10/25/85	117778.900	2281095.900	1598.70	1601.20	A	26.00	23.50	1575.20	25.50	1573.20	None	None	None	None	2 - Galv	Bent. Pellets	1	CO	P	
STS-LSL-1	3/18/82	114280.000	2278245.000	1591.90	NR	Ab	52.00	52.00	1539.90	54.00	1537.90	None	None	None	None	NR	NR	1	CO	P	
STS-LSL-2	3/22/82	113575.000	2277080.000	1591.90	NR	Ab	40.50	40.50	1551.40	42.50	1549.40	None	None	None	None	NR	NR	1	CO	P	
STS-LSL-4	3/20-21/82	112345.000	2276430.000	1591.90	NR	Ab	47.50	47.10	1544.80	49.10	1542.80	None	None	None	None	NR	NR	1	CO	P	
STS-LSL-6	3/20/82	110950.000	2276590.000	1591.90	NR	Ab	36.00	34.00	1557.90	36.00	1555.90	None	None	None	None	NR	NR	1	CO	P	
STS-WVS	3/22/78	116744.500	2274385.900	1683.40	1685.20	TA	189.50	135.00	1548.40	145.00	1538.40	28.00	1655.40	189.50	1493.90	2	Cem Ben Grout	1	NR	P	
TW-1	N/A	116883.850	2279723.300	1601.19	1602.57	A	55.00	40.00	1561.19	55.00	1546.19	30.00	1571.19	55.00	1546.19	8 - Steel	Bent. Slurry	1	EWT	PW	3
TW-2	N/A	116282.490	2274923.310	1654.40	1655.80	TA	96.00	86.00	1568.40	96.00	1558.40	70.00	1584.40	96.00	1558.40	8 - Steel	Bent. Slurry	1	EWT	PW	
TW-41	1/29/81	114130.000	2284315.000	1707.19	1708.68	TA	340.00	150.80	1556.39	316.00	1391.19	113.00	1594.19	340.00	1367.19	12 - Steel	Cement	1	MS/EWT/FO/CO	PW	
WP-1L	3/15/84	110547.000	2265406.000	1553.85	1556.04	Ab	33.00	30.00	1523.85	33.00	1520.85	None	None	None	None	2 - Galv.	Cement	1	FO	P	2
WP-1U	3/15/84	110540.000	2265404.000	1553.85	1556.09	Ab	6.00	2.00	1551.85	6.00	1547.85	None	None	None	None	2 - Galv.	Cement	1	FO	WT	2
WP-2L	3/30/84	119694.000	2267150.000	1536.12	1537.67	Ab	32.60	29.60	1506.52	32.60	1503.52	None	None	None	None	2 - Galv.	Cem Ben Slurry	1	CO	P	2
WP-2U	3/30/84	119698.000	2267150.000	1536.03	1538.48	Ab	6.00	2.00	1534.03	6.00	1530.03	None	None	None	None	2 - Galv.	Bent. Powder	1	PT/CO	WT	1
WP-3L	3/29/84	119269.000	2268045.000	1537.73	1539.67	Ab	33.00	30.00	1507.73	33.00	1504.73	None	None	None	None	2 - Galv.	Cem Ben Slurry	1	CO	P	2
WP-3U	3/29/84	119246.000	2268023.000	1540.89	1543.27	Ab	11.00	3.00	1537.89	11.00	1529.89	None	None	None	None	2 - Galv.	Cem Ben Slurry	1	CO	WT	2
WP-4L	3/29/84	121799.000	2274240.000	1541.18	1543.30	A	32.00	29.00	1512.18	32.00	1509.18	None	None	None	None	-" Galv.	Cem Ben Slurry	1	CO	P	2
WP-4U	3/29/84	121825.000	2274236.000	1545.29	1547.35	A	10.20	2.20	1543.09	10.20	1535.09	None	None	None	None	2 - Galv.	Cem Ben Slurry	1	CO	WT	2
WP-5L	4/2/84	120871.000	2274355.000	1548.02	1550.25	A	33.00	30.00	1518.02	33.00	1515.02	None	None	None	None	2 - Galv.	Cem Ben Slurry	1	LWT/CO	P/ART	
WP-5U	4/2/84	120865.000	2274352.000	1547.98	1550.12	A	5.00	2.00	1545.98	5.00	1542.98	None	None	None	None	2 - Galv.	Bent. Powder	1	CO	WT	2
WP-6L	3/30/84	118254.000	2287403.000	1579.60	1581.61	Ab	33.00	30.00	1549.60	33.00	1546.60	None	None	None	None	2 - Galv.	Cem Ben Slurry	1	CO	P	2
WP-6U	3/30/84	118247.000	2287407.000	1579.51	1581.66	Ab	6.50	2.50	1577.01	6.50	1573.01	None	None	None	None	2 - Galv.	Bent. Powder	1	PT/FO	WT	2
WP-7L	3/14/84	116486.000	2287958.000	1580.08	1583.94	Ab	33.00	30.00	1550.08	33.00	1547.08	None	None	None	None	2 - Galv.	Bent Cem Gt	1	LWT/CO	P	2
WP-7U	3/14/84	116494.000	2287958.000	1580.26	1582.53	Ab	6.00	2.00	1578.26	6.00	1574.26	None	None	None	None	2 - Galv.	Bent Cem Gt	1	LWT/CO	WT	1
WW-1	7/26-8/2/76	116903.198	2277828.575	1671.20	1671.50	TA	124.50	119.00	1552.20	124.00	1547.20	NR	NR	NR	NR	6 - Steel	NR	1	NR	PW	
WW-2	9/20-22/76	116442.007	2276157.379	1645.39	1645.89	TA	155.00	140.00	1505.39	155.00	1490.39	140.00	1505.39	155.00	1490.39	8 - Steel	NR	1	NR	PW	4
WW-3	3/28-30/76	NS	NS			TA	60.00	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	1	NR	PW	
WW-4	4/4-5/81	116170.970	2278391.910	1623.67	1625.30	TA	98.00	87.60	1536.07	97.80	1525.87	NR	NR	NR	NR	8 - Steel	NR	1	NR	PW	
CMC-03R	4/4/94	113563.600	2286751.700	1705.20	N/A	Ab	98.00	81.00	1624.20	96.00	1609.20	78.70	1626.50	98.00	1607.20	2	Chipped Bent.	1	LWT/CO	DRY	
CMC-01	3/31/94	116166.600	2282677.100	1650.20	1653.15	A	92.50	77.00	1573.20	92.00	1558.20	75.00	1575.20	92.50	1557.70	2	Chipped Bent.	1	CO/LWT	P	
CMC-01R	5/3/94	116156.500	2282675.100	1650.15	1653.07	A	68.00	48.00	1602.15	63.00	1587.15	46.00	1604.15	68.00	1582.15	2	Chipped Bent.	1	LWT	WT	
CMC-01P	3/25/94	116168.300	2282682.700	1650.15	1653.67	A	202.00	141.00	1509.15	146.00	1504.15	138.80	1511.35	149.80	1500.35	2	Chipped Bent.	1	CO	P	
CMC-02	3/28/94	115308.700	2286070.100	1697.90	NS	Ab	95.00	78.00	1619.90	93.00	1604.90	73.50	1624.40	95.00	1602.90	2	Chipped Bent.	1	CO	DRY	
CMC-02P	3/22/94	115306.800	2286077.300	1697.90	1700.96	A	191.10	185.00	1512.90	190.00	1507.90	183.00	1514.90	191.10	1506.80	2	Chipped Bent.	1	CO	P	
CMC-02R	9/8/94	115299.210	2286062.480	1697.66	1700.15	A	120.00	100.00	1597.66	115.00	1582.66	95.00	1602.66	117.00	1580.66	2	Chipped Bent./Grout	1	CO/LWT	WT	
CMC-03	3/24/94	113563.600	2286751.700	1705.20	NS	Ab	86.00	68.00	1637.20	83.00	1622.20	66.00	1639.20	86.00	1619.20	2	Chipped Bent.	1	LWT	DRY	
CMC-03RR	4/27/94	113563.600	2286751.700	1705.20	1707.90	A	128.00	108.00	1597.20	123.00	1582.20	106.00	1599.20	128.00	1577.20	2	Chipped Bent.	1	LWT/CO	WT	
CMC-03P	3/22/94	113560.100	2286745.300	1705.20	1708.61	A	201.00	190.00	1515.20	195.00	1510.20	188.00	1517.20	201.00	1504.20	2	Chipped Bent./Grout	1	CO	P	
CMC-04	3/10/94	111448.500	2285112.200	1683.90	1687.10	A	113.00	95.00	1588.90	110.00	1573.90	93.00	1590.90	113.00	1570.90	2	Chipped Bent.	1	CO	WT	
CMC-05	3/10/94	111541.200	2283490.000	1656.90	1660.17	A	79.00	63.00	1593.90	78.00	1578.90	61.00	1595.90	79.00	1577.90	2	Chipped Bent.	1	LWT	WT	
CMC-06P	3/10/94	112380.300	2283011.500	1666.50	1669.64	A	152.00	143.00	1523.50	148.00	1518.50	137.50	1529.00	152.00	1514.50	2	Chipped Bent.	1	CO	P	
CMC-07	3/28/94	114389.200	2282896.000	1626.90	1630.41	A	51.00	32.00	1594.90	47.00	1579.90	29.90	1597.00	51.00	1575.90	2	Chipped Bent.	1	CO	WT	
CMC-08	3/1/94	117115.900	2278213.600	1662.50	1665.76	A	75.00	59.00	1603.50	74.00	1588.50	57.00	1605.50	75.00	1587.50	2	Chipped Bent.	1	CO/EWT	WT	
CMC-08P	4/18/94	117107.100	2278200.200	1662.50	1665.60	A	113.50	90.00	1572.50	95.00	1567.50	88.00	1574.50	101.00	1561.50	2	Chipped Bent.	1	EWT	P	
CMC-09	3/30/94	116258.800	2274907.300	1653.50	1656.96	A	90.00	71.00	1582.50	86.00	1567.50	68.50	1585.00	90.00	1563.50	2	Chipped Bent.	1	CO	WT	
CMC-09P	4/15/94	116258.800	2274914.700	1653.30	1656.11	A	168.50	137.00	1516.30	142.00	1511.30	135.00	1518.30	148.50	1504.80	2	Chipped Bent.	1	EWT	P	
CMC-10	3/30/94	116056.600	2278575.400	1621.10	1624.34	A	50.00	33.00	1588.10	48.00	1573.10	31.00	1590.10	50.00	1571.10	2	Chipped Bent.	1	CO	WT	
CMC-10P	3/3/94	116046.900	2278514.200	1620.80	1624.02	A	101.50	80.00	1540.80	85.00	1535.80	78.00	1542.80	89.00	1531.80	2	Chipped Bent.	1	EWT	P	
CMC-B0-101A	2/7/94	117361.700	2283366.800	1637.30	1640.73	A	16.20	10.70	1626.60	15.70	1621.60	9.70	1627.60	15.90	1621.40	2	Chipped Bent.	1	LA	PERCHED	
CMC-BO-101B	2/1/94	117357.700	2283369.500	1637.30	1640.69	A	41.50	34.10	1603.20	39.10	1598.20	32.10	1605.20	41.10	1596.20	2	Chipped Bent.	1	CO	DRY	
CMC-SL-103A	2/7-8/94	117856.600	2281146.900	1599.20	1602.41	A	30.00	23.30	1575.90	28.30	1570.90	21.30	1577.90	29.30	1569.90	2	Chipped Bent.	1	IM	P	
CMC-SL-103B	2/8/94	117848.700	2281133.900	1599.20	1602.28	A	50.00	42.50	1556.70	47.50	1551.70	37.70	1561.50	48.50	1550.70	2	Chipped Bent.	1	CO	P	
CMC-DL-103A	2/11/94	113334.650	2281957.000	1613.60	1616.41	A	9.00	2.70	1610.90	7.70	1605.90	2.20	1611.40	7.80	1605.80	2	Chipped Bent.	1	LWT	PERCHED	
CMC-DL-103B	2/11/94	113333.300	2281954.300	1613.60	1616.49	A	36.50	16.70	1596.90	21.70	1591.90	14.70	1598.90	23.70	1589.90	2	Chipped Bent.	1	LWT/FO	WT	
CMC-LSL-102B	2/14/94	114284.900	2279010.600	1592.10	1595.00	Ab	34.00	31.30	1560.80	32.30	1559.80	30.80	1561.30	32.30	1559.80	2	Chipped Bent.	1	CO	P	
CMC-LSL-102A	2/15/94	114399.100	2278953.700	1592.10	1595.19	Ab	18.50	16.20	1575.90	18.20	1573.90	15.60	1576.50	18.20	1573.90	2	Chipped Bent.	1	LA	P	

Table 3.6-1 (Continued)

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Well ID	Date(s) Installed	State Plane Coordinates (ft) North	State Plane Coordinates (ft) East	Elevation (msl) Ground	Elevation (msl) PVC	Condition	Construction Details: Total Boring Depth BGS (ft)	Screen Top BGS (ft)	Screen Top (msl) +	Screen Bottom BGS (ft)	Screen Bottom (msl) +	Gravel Pack Top BGS (ft)	Gravel Pack Top (msl) +	Gravel Pack Bottom BGS(ft)	Gravel Pack Bottom (msl) +	Well Diameter (in)	Annular Space Seal	# of Wells per Boring	Formation Monitored	Well Type	Model Layer
CMC-LSL-104A	2/13/94	112076.200	2275945.000	1592.10	1594.72	Ab	18.00	14.70	1577.40	16.70	1575.40	13.20	1578.90	16.70	1575.40	2	Chipped Bent.	1	LA	P	
CMC-LSL-104B	2/13/94	112072.700	2275937.400	1592.10	1594.69	Ab	28.00	22.10	1570.00	25.10	1567.00	21.60	1570.50	25.10	1567.00	2	Chipped Bent.	1	CO	P	
CMC-SCC-102A	2/07/94	120038.800	2280679.900	1583.70	1587.41	A	11.00	4.70	1579.00	9.70	1574.00	4.20	1579.50	11.00	1572.70	2	Chipped Bent.	1	LWT	WT	
CMC-SCC-102B	2/7/94	120042.700	2280678.300	1583.70	1587.17	A	22.50	16.80	1566.90	21.80	1561.90	14.80	1568.90	22.50	1561.20	2	Chipped Bent.	1	CO	P	
CMC-OWA-5	10/15/94	115990.280	2277837.120	1648.60	1651.29	A	132.00	125.00	1523.60	130.00	1518.60	123.00	1525.60	132.00	1516.60	2	Bent/Bent. Slurry	1	EWT	P	
CMC-OWA-4	10/11/94	116367.710	2277607.170	1661.20	1663.85	A	126.00	120.00	1541.20	125.00	1536.20	118.00	1543.20	126.00	1535.20	2	Bent/Bent. Slurry	1	EWT	P	
CMC-OWA-3	10/18/94	116218.570	2277666.070	1657.80	1660.05	A	131.00	125.00	1532.80	130.00	1527.80	123.00	1534.80	131.00	1526.80	2	Bent/Bent. Slurry	1	EWT	P	
CMC-OWA-2	10/20/94	116283.020	2277645.760	1658.70	1661.07	A	191.00	185.00	1473.70	190.00	1468.70	183.00	1475.70	190.50	1468.20	2	Bent/Bent. Slurry	1	SS	P	
CMC-OWA-1	10/17/94	116229.250	227761.240	1657.60	1660.10	A	205.00	181.00	1476.60	186.00	1471.60	179.00	1478.60	190.00	1467.60	2	Bent/Bent. Slurry	1	SS	P	
CMC-14P	10/7/94	115996.510	2278987.850	1608.90	1611.31	A	110.00	93.00	1515.90	94.00	1514.90	91.00	1517.90	95.00	1513.90	2	Bent/Bent. Slurry	1	MS	P	
CMC-13P	10/3/94	116352.220	2276978.090	1684.40	1686.77	A	236.00	211.00	1473.40	212.00	1472.40	209.60	1474.80	213.00	1471.40	2	Bent/Bent. Slurry	1	MS	P	
CMC-12P	10/13/94	116478.660	2276322.760	1648.00	1650.44	A	205.00	194.00	1454.00	195.00	1453.00	192.00	1456.00	196.00	1452.00	2	Bent/Bent. Slurry	1	MS	P	
CMC-11P	10/15/94	116228.680	2275939.770	1643.50	1645.89	A	215.00	202.00	1441.50	203.00	1440.50	198.70	1444.80	205.00	1438.50	2	Bent/Bent. Slurry	1	MS	P	
CMC-10PP	10/18/94	116050.240	2278600.210	1619.70	1621.67	A	110.00	101.00	1518.70	102.00	1517.70	100.00	1519.70	103.00	1516.70	2	Bent/Bent. Slurry	1	MS	P	
CMC-PWA	9/25/94	116169.000	2277699.690	NS	NS	A	230.00	180.00	NR	230.00	NR	None	None	None	None	6 - Steel	Neat Cement	1	SS	PW	
CMC-PWB ~	10/9/94	116040.800	2278646.220	1616.50	NS	A	400.00	180.00	1436.50	400.00	1216.50	None	None	None	None	6 - Steel	Neat Cement	1	SS/UDB	PW	
CMC-PWAR ~	10/4/94	116183.060	2277679.090	1656.80	NS	A	270.00	219.00	1437.80	250.00	1406.80	None	None	None	None	6 - Steel	Neat Cement	1	SS	PW	
CMC-SP-01	12/2/94	114244.4	2279412.2	1595.15	1597.3	A	1589.5	2.65	1592.5	5.65	1589.5	None	None	None	None	1.25 SWP	None	1	LWT	WT	
CMC-SP-02	12/1/94	114181.3	2279306.4	1594.75	1596.95	A	1589.2	2.55	1592.2	5.55	1589.2	None	None	None	None	1.25 SWP	None	1	LWT	WT	
CMC-SP-03A	12/1/94	114628.8	2278974.6	1594.45	1597.2	A	1589.41	2.04	1592.41	5.04	1589.41	None	None	None	None	1.25 SWP	None	1	LWT	WT	
CMC-SP-03B	12/2/94	114627.6	2278975.8	1594.39	1596.04	A	1573.07	18.32	1576.07	21.32	1573.07	None	None	None	None	1.25 SWP	None	1	LA	P	
CMC-SP-04	12/1/94	114726.9	2279029.4	1593.49	1596.19	A	1588.46	2.03	1591.46	5.03	1588.46	None	None	None	None	1.25 SWP	None	1	LWT	WT	
CMC-SP-05A	12/1/94	114907.4	2278578.4	1592.63	1597.28	A	1589.51	0.12	1592.51	3.12	1589.51	None	None	None	None	1.25 SWP	None	1	LWT	WT	
CMC-SP-05B	12/1/94	114908.8	2278580.5	1593.79	1594.84	A	1572.35	18.44	1575.35	21.44	1572.35	None	None	None	None	1.25 SWP	None	1	LA	P	
CMC-SP-06	12/1/94	114977.8	2278619.2	1594.55	1597.55	A	1589.76	1.79	1592.76	6.79	1587.76	None	None	None	None	1.25 SWP	None	1	LWT	WT	
CMC-SP-07	12/1/94	115104.1	2278023.5	1594.52	1597.64	A	1584.89	1.63	1592.89	4.63	1589.89	None	None	None	None	1.25 SWP	None	1	LWT	WT	
CMC-SP-08	12/1/94	115222.1	2278024.2	1595.82	1596.92	A	1589.15	3.67	1592.15	6.67	1589.15	None	None	None	None	1.25 SWP	None	1	LWT	WT	
CMC-SP-09	12/1/94	115000.5	2279219.9	1596.7	1597.2	A	1590.17	3.53	1593.17	6.53	1590.17	None	None	None	None	1.25 SWP	None	1	LWT	WT	
CMC-SP-10	2/16/95	109595.2	2278780.3	1606.4	1608.46	A	1583.13	20.27	1586.13	23.27	1583.13	None	None	None	None	1.25 SWP	None	1	LWT	DRY	
CMC-SP-11A	2/27/95	113325.8	2278711.5	1593.16	1597.01	A	1589.26	0.9	1592.26	3.9	1589.26	None	None	None	None	1.25 SWP	None	1	LWT	WT	
CMC-SP-11B	2/27/95	113325.5	2278712.5	1593.28	1595.18	A	1572.13	18.15	1575.13	21.15	1572.13	None	None	None	None	1.25 SWP	None	1	LA	P	
SG-WP-1	1984	110564.3	2265584.1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	FO	SG	2
SG-WP-3	1984	119324.1	2267815.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	CO	SG	1
SG-WP-4	1984	121833.9	2274311.1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	CO	SG	2
SG-WP-6	1984	117798.5	2286975.1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	FO	SG	2
SG-WP-7	1984	116437.0	2287828.2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	CO	SG	1
NMC-101	4/10/98	116184.13	2277673.10	1657.03	1657.70	A	141.00	135.00	1522.03	140.30	1516.7	132.50	1524.5	141.00	1516.0	2	bent	1	EWT	P	
MWE-04	5/28/98	125469.01	2272880.45	1595.14	1597.62	A	35.0	24.2	1570.9	34.2	1560.9	20.0	1575.1	35.0	1560.1	2	bent	1	EWT	WT	
MWE-08	5/29/98	124080.03	2271394.51	1592.55	1595.02	A	45.0	34.0	1548.6	44.0	1548.6	32.0	1560.6	45.0	1547.6	2	bent	1	EWT	WT	
MWE-11	5/29/98	124103.03	2273398.74	1565.33	1568.06	A	19.0	8.0	1557.3	18.0	1547.3	6.0	1559.3	19.0	1546.3	2	bent	1	CO	WT	
MWE-14	7/8/98	123319.73	2271929.67	1557.78	1560.52	A	20.0	9.0	1548.8	19.0	1538.8	7.0	1550.8	20.0	1537.8	2	bent	1	CO	WT	
MWE-16	7/8/98	123987.77	2273950.86	1567.77	1570.22	A	20.5	10.0	1577.8	20.0	1547.8	8.0	1559.8	20.5	1547.3	2	bent	1	CO	WT	
MWE-18	7/9/98	124935.32	2274753.94	1574.47	1576.78	A	19.0	8.0	1566.5	18.0	1556.5	7.0	1567.5	19.0	1555.5	2	bent	1	CO	WT	
MWH-09	8/26/98	128822.63	2284111.34	1591.2	1594.34	A	15.0	4.0	1587.2	14.0	1577.2	3.5	1587.7	15.0	1576.2	2	bent	2	CO	WT	
MWH-09P	8/26/98	128827.77	2284111.79	1591.2	1594.44	A	35.0	29.0	1562.2	34.0	1557.2	27.0	1564.2	35.0	1556.2	2	bent	2	FO	P	
MWH-10	8/26/98	128524.62	2284996.76	1592.5	1595.62	A	18.0	7.0	1585.5	17.0	1575.2	6.0	1586.5	18.0	1574.5	2	bent	2	CO	WT	
MWH-10P	8/27/98	128534.44	2284996.57	1592.4	1595.48	A	38.0	32.0	1560.4	37.0	1555.4	30.0	1562.4	38.0	1554.4	2	bent	2	FO	P	
MWH-11	8/27/98	128234.40	2285323.43	1585.0	1588.16	A	15.0	4.0	1581.0	14.0	1571.0	3.5	1581.5	15.0	1570.0	2	bent	2	CO	WT	
MWH-11P	8/27/98	128240.76	2285325.07	1584.9	1588.02	A	35.0	29.0	1555.9	34.0	1550.9	27.0	1557.9	35.0	1549.9	2	bent	2	FO	P	
MWH-13	8/27/98	130355.72	2285041.29	1594.4	1597.54	A	16.0	5.0	1589.4	15.0	1579.4	4.5	1589.9	16.0	1578.4	2	bent	1	CO	WT	
MWH-14	8/26/98	127088.73	2285444.46	1588.7	1591.92	A	16.0	5.0	1583.7	15.0	1573.7	4.5	1584.2	16.0	1572.7	2	bent	1	CO	WT	
MWH-15	8/27/98	127542.29	2284156.78	1588.8	1591.73	A	16.0	5.0	1583.8	15.0	1573.8	4.5	1584.3	16.0	1572.8	2	bent	1	CO	WT	
MWH-16	8/27/98	129341.85	2284471.77	1592.9	1596.02	A	16.0	5.0	1587.9	15.0	1577.9	4.5	1588.4	16.0	1576.9	2	bent	1	CO	WT	
MWH-19	8/26/98	127614.65	2285679.80	1586.2	1589.38	A	16.0	5.0	1581.2	15.0	1571.2	4.5	1581.7	16.0	1570.2	2	bent	1	CO	WT	
SPH-01	9/16/98	127491	2284980	1581.52	1583.69(1)	A	NA	3.1	1578.4	6.1	1575.4	NA	NA	NA	NA	1.25	NA	NA	CO	WT	
SPH-01A	9/16/98	127495	2284981	1581.42	1585.95(1)	A	NA	11.1	1570.3	14.1	1567.3	NA	NA	NA	NA	1.25	NA	NA	CO	P	
SPH-02	9/16/98	128190	2285360	1581.95	1583.89(1)	A	NA	3.4	1578.6	6.4	1575.6	NA	NA	NA	NA	1.25	NA	NA	CO	WT	
SPH-02A	9/16/98	128191	2285357	1581.83	1584.36(1)	A	NA	13.3	1568.5	16.3	1565.5	NA	NA	NA	NA	1.25	NA	NA	CO	P	
SPH-03	9/16/98	129521	2284348	1591.08	1593.37(1)	A	NA	3.0	1588.2	6.0	1585.2	NA	NA	NA	NA	1.25	NA	NA	CO	WT	
SPH-03A	9/16/98	129524	2284350	1591.21	1594.49(1)	A	NA	12.7	1578.5	15.7	1575.5	NA	NA	NA	NA	1.25	NA	NA	CO	P	
SPH-04	9/16/98	128954	2284105	1590.76	1593.18(1)	A	NA	2.9	1587.9	5.9	1584.9	NA	NA	NA	NA	1.25	NA	NA	CO	WT	

Table 3.6-1 (Continued)

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Well ID	Date(s) Installed	State Plane Coordinates (ft) North	State Plane Coordinates (ft) East	Elevation (msl) Ground	Elevation (msl) PVC	Condition	Construction Details: Total Boring Depth BGS (ft)	Screen Top BGS (ft)	Screen Top (msl) +	Screen Bottom BGS (ft)	Screen Bottom (msl) +	Gravel Pack Top BGS (ft)	Gravel Pack Top (msl) +	Gravel Pack Bottom BGS(ft)	Gravel Pack Bottom (msl) +	Well Diameter (in)	Annular Space Seal	# of Wells per Boring	Formation Monitored	Well Type	Model Layer
SPH-04A	9/16/98	128960	2284105	1590.79	1594.88(1)	A	NA	11.6	1579.2	14.6	1576.2	NA	NA	NA	NA	1.25	NA	NA	CO	P	
SPH-05	9/16/98	129127	2285939	1580.45	1581.51(1)	A	NA	9.2	1571.2	12.2	1568.2	NA	NA	NA	NA	1.25	NA	NA	CO	WT	
SPH-06	9/16/98	129940	2285545	--	1587.51(1)	A	NA	--	1582.7	--	1579.7	NA	NA	NA	NA	1.25	NA	NA	CO	WT	
SGH-01	9/16/98	127913	2285254	1577.88	NA	A	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	CO	NA	
SGH-02	9/16/98	129132	2285942	1577.41	NA	A	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	CO	NA	

NS - Not Surveyed
NR - Not Reported or Recorded
BGS - Depth Below Ground Surface
msl - Mean Sea Level
TA - Temporarily Abandoned
A - Active
Ab - Abandoned
~ - Approximate Depth From Logs
NA - Not Applicable
(1) Top of 1-1/4 inch Galvanized Steel Pipe

LEGEND
SWP - Steel Well Point
Bent/Grout - Bentonite Seal With Grout Annular Space Seal
Note-Wells drilled through ice have the ice level for the ground elevation
Cem. Bent. Gt - Cement Bentonite Grout
SG-WP-1, -3, -4, -6, & -7 : Staff Gages in Creek

P=Piezometer
WT=Well used as water table well
PW=Pump Well
ART= Flowing Artesian Well
Perched=Well Monitoring Perched Zone
DRY= Dry Well
-- = Not Surveyed

FORMATION MONITORED
LWT - Late Wisconsinan Till
EWT - Pre-Early Wisconsinan Till
CO - Coarse Outwash
FO - Fine Outwash
LA - Lacustrine

IM - Ice Marginal
MS - Massive Saprolite
SS - Structured Saprolite
UDB - Undifferentiated Bedrock
UKN - Unknown

Prepared by: MLB (TLM)
Checked by: EAS (JJA)
Revised by: SVD1
Checked By: TH
Revised by: KJR1
Checked by: SVD1

Layer Number corresponds to groundwater model layer: Layer 1=Late Wisconsinan Till, Layers 2 and 3 = Outwash layers, Layer 4= Pre- to Early Wisconsinan Till.
Shaded cells = revised number.

[svd1]93c049\dbase\wllstr1.wb1

fine material resulting from boring and well installations, and was continued until a relatively clear water sample was obtained.

3.6.1.1.2 1979-1982 Golder Investigations

From 1979 to 1982, 110 borings were drilled and 64 monitoring wells were installed as part of the hydrogeologic and geotechnical investigations for the siting and design of the TMA (Golder 1981b). The investigations were completed in several phases and consisted of concurrent detailed characterization studies in two areas. The first site (Area 40, G40 series borings and wells) encompassed an area between Little Sand lake on the east, Mole Lake to the west, Rolling Stone Lake to the south and Swamp Creek to the north. The second site (Area 41, G41 series borings and wells) encompassed area between Ground Hemlock Lake on the east, Little Sand Lake to the west, Swamp Creek to the north and Walsh Lake to the south. The location of the wells are shown on Figure 3.6-1 and 3.6-2.

Drilling and soil sampling methods for these wells were described in Section 3.5.1.2.3. Wells for the observation of groundwater levels were placed at various depths over the prospective sites. The installation depths were varied to provide water quality samples from different levels and to observe the relationship between the hydrostatic head at these depths.

The observation wells consisted of five to 20 feet of machine slotted O.D. PVC pipe set at the desired depth with a gravel backfill. Solid two inch O.D. PVC pipe was then continued to the surface. Water was flushed through the assembly until the drilling mud and filter cake was washed from the hole. Gravel was then placed around the slotted and solid PVC pipe to the desired depth. A bentonite clay seal, a minimum of three feet thick, was placed over the gravel. The annulus around the solid pipe was then backfilled with cement grout to the surface. The PVC pipe was cut off two to three feet above the ground surface and capped with a steel protection pipe with hinged top and lock. Specific well installation details are presented with their respective boring logs in Appendix 3.5-2. Well construction is summarized in Table 3.6-1.

3.6.1.1.3 1981 Ore Body Pump Test Piezometer Installation Program

In 1981 a series of monitoring wells were installed in the vicinity of the ore body as part of an ore body pump test program (Section 3.6.1.6.3) to identify the hydraulic characteristics at the contact between the ore body and glacial overburden. The wells were installed under the direction of Camp, Dresser & McKee (CDM series monitoring wells) and Braun Engineering (BE series monitoring wells). The location of these monitoring wells are shown on Figures 3.6-1 and 3.6-2.

The drilling methods for installation of the CDM and BE series wells were described in Section 3.5.1.2.4. CDM wells CDM-15 and CDM-16, were constructed of two inch diameter PVC with 30 foot slotted screens. No information is available with regard to gravel pack dimensions or material used to seal the annular space. Given past well construction practices, it is assumed that the annular space above the screen of these two wells was sealed with a bentonite or cement grout. Boring logs are provided in Appendix 3.5-4. In addition to the two CDM

wells, Camp Dresser & McKee also installed several shallow sand points on the northwest side of Little Sand Lake, referred to as monitoring points CDM-17, 18, 19 and 20. These sand points consist of galvanized pipe with two foot long screens. The construction information for the CDM wells and sand points is presented in Table 3.6-1.

The BE series wells were installed in the vicinity of the ore body. These wells were constructed with two inch or ¾ inch diameter PVC equipped with screen lengths ranging from seven feet to 40 feet in length. The monitoring wells were screened in the bedrock, the glacial overburden, or across the glacial overburden bedrock contact. The gravel packs of the BE series wells typically extended from zero to ten feet below the screen bottom and extended from four to 15 feet above the top of the screen. The remainder of the annular space was sealed with grout. Table 3.6-1 summarizes construction details for these wells. Boring logs and well completion forms are contained in Appendices 3.5-3 and 3.6-1, respectively.

3.6.1.1.4 1984 Investigation

In 1984, STS Consultants, Ltd. (1984a and b) completed 16 borings that were converted to nested wells and installed seven nested well points along creeks, such as Hemlock, Swamp, and Pickerel, that act as groundwater discharge points. This investigation was designed to provide increased resolution of the hydrostratigraphic units and groundwater flow regime within the study area through the placement of nested wells and the completion of extensive grain size analyses.

The drilling program included sixteen soil borings and multiple well installations at the EX locations (EX-1 through EX-16). Details on drilling methods are described in Section 3.5.1.2.5.

Shallow well points were installed at seven locations (WP-1 through WP-7) by STS adjacent to groundwater discharge areas using either power augers or the wash boring technique. Two well points at different elevations were installed at each location. No drilling muds were used for the well point installations. The locations for the well points and EX borings are presented on Figures 3.6-1 and 3.6-2.

Three to five piezometers were installed at each EX location. Where possible, two piezometers were installed in a single borehole. The deepest borehole at each location was designated A, and the progressively shallower boreholes were designated B, C, and D. Within a single borehole, the lowest piezometer was designated "L", and the uppermost piezometer in the borehole was designated "U".

The specific construction details for each piezometer installation are shown on Field Well Installation Diagrams in Appendix 3.6-1. Each piezometer consisted of a two inch diameter, Schedule 40 PVC riser pipe with solvent-welded belled couplings. Prior to placing the well screen in the borehole, approximately two feet of pea gravel was placed. A three foot long well screen with No. 20 slot was then inserted in the borehole. Typically, Barafos was pumped into

the well screen area to help disperse the bentonite wall cake. Pea gravel was then placed around the well screen to approximately two feet above the well screen.

In the first few piezometer installations (EX-4,5,15 and 16), bentonite pellets were placed above the pea gravel to seal the piezometer tip into a particular soil stratum. Grout was then placed to fill the annulus to the next piezometer or the ground surface. The grout consisted of a mixture of seven gallons of water for each 94 pound bag of Type I Portland Cement with two pounds of bentonite powder. Two pounds of calcium chloride were also added to the grout to accelerate hardening. The grout was placed by using a tremie pipe. However, during initial installations problems developed with the grout displacing the bentonite pellet seal and entering the well screen. On the remaining installations, the cement grout and bentonite pellets were replaced with Benseal, a granulated bentonite. The Benseal was mixed with EZ Mud, a polymer, to retard swelling long enough to allow the driller to pump the mixture through a tremie pipe to the desired depth of the borehole. Benseal worked satisfactorily and reduced the waiting time between piezometer installations in a single borehole.

The shallowest piezometer at each multiple installation was designed as a water table observation well. It typically consisted of a two inch diameter PVC pipe with a 15 to 20 foot long well screen with No. 20 slot backfilled with pea gravel.

All the piezometers were developed after installation using compressed air for approximately 30 minutes. In addition, prior to conducting permeability tests, a plunger was used in each of the piezometers to surge the well screen at the request of the WDNR. After review of the field permeability test results, 17 piezometers were selected for further development. Most of these were located within fine sand layers. It appeared that the surging caused fine sand to enter the well screen and fill a portion of the riser pipe. These partially plugged wells were successfully redeveloped by using both water and compressed air to remove the fine sand.

STS installed 14 well points at seven locations (WP-1 through WP-7). Each location consisted of one shallow water table well and one deep piezometer. Well Installation Diagrams for these well points are presented in Appendix 3.6-1. The shallow well points typically ranged in depth from five to ten feet, and consisted of a four to eight foot length of PVC well screen with No. 10 slot. The shallow well points were installed within an auger hole and pea gravel was placed adjacent to the well screen. The PVC well screen was attached to a galvanized riser pipe and the annulus was sealed with a bentonite slurry. The lower well points were approximately 33 feet deep, and consisted to two inch diameter galvanized pipe with three foot long stainless steel well point with No. 10 slot. In general, the borehole was advanced to 30 feet, and then the well point was driven the final three feet. The borehole annulus was then sealed with grout. The well points were not developed.

3.6.1.2 Lake Bed and Wetland Drilling Studies

An extensive number of investigations have been completed to identify the hydrogeologic characteristics of lake beds and wetlands within the immediate study area. These investigations

were conducted in the early and mid 1980s. Subsequent investigations were conducted in 1994. Section 3.5.1.3 summarized the drilling programs that were completed to characterize the soil properties that comprise the lake bottoms. In addition to the borings described in Section 3.5.1.3, monitoring wells were completed within and below the lake bottoms to assess the hydraulic relationship between lakes and the regional groundwater system. Following is a summary of the wells installed for each investigation. Figure 3.6-3 shows the location of lake and wetland borings and piezometers. Table 3.6-1 summarizes piezometer construction information.

3.6.1.2.1 1982 Little Sand Lake Piezometer Installation Program

In 1982, STS Consultants, Inc. (1982) conducted a drilling program (STS-LSL series borings) on Little Sand Lake to characterize lake bed sediments with regard to thickness, physical characteristics and permeability. A total of six borings were completed on Little Sand Lake, of which four were used as piezometers to measure hydraulic head beneath the lake bed. The location of the borings and piezometers are presented in Figure 3.6-3, and consist of the STS-LSL series.

At four of the boring locations the boreholes were bailed, and water level observations were made in the casing over a period of five days until the water level in the casing had stabilized. Since the casing was advanced into the outwash deposits, the water level in the casing reflected the hydraulic head in the outwash deposits that form part of the regional aquifer. Boring logs for the STS-LSL wells are contained in Appendix 3.5-7.

3.6.1.2.2 1984 Deep Hole, Duck, Skunk, and Oak Lake Drilling Program

In 1984, a second lake bed piezometer installation program was completed by STS Consultants, Ltd. (1984c) to characterize thickness, physical characteristics, and hydraulic conductivity of additional lakes within the project study area. The lakes that were investigated were Oak, Deep Hole, Duck and Skunk Lakes (STS-OL, STS-DHL, STS-DL and STS-SL series borings and wells). The borings were completed via conventional rotary wash methods with casing advanced through the lake bed down to the top of the underlying outwash/till deposits. Undisturbed soil samples were obtained of the lake bed for grain size analysis and permeability testing. After completion of the borings, wells were installed in the borings. After stabilized water level measurements were obtained from the wells, they were abandoned with a cement-bentonite grout. The boring and well locations are shown in Figure 3.6-3. Boring logs were provided in Appendix 3.5-8. Well construction forms are provided in Appendix 3.6-1.

3.6.1.2.3 1985 Duck and Skunk Lake Wetland Drilling Program

In 1985, a third investigation was conducted related to the lakes in the vicinity of the project site by STS Consultants, Ltd. (1986). The focus of this investigation was the wetlands in the vicinity of Duck and Skunk Lakes. This investigation consisted of four well installations in the Skunk Lake wetland and five well installations in the Duck Lake wetland. Figure 3.6-3 shows the location of the well installations (STS-DL-2, 3, 4, 5 and 6, and STS-SL-3, 4, 5 and 6) that were

completed. The wells were installed manually with a hand auger, and thus no undisturbed soil samples were obtained for permeability testing. Boring logs with referenced well completion information is contained in Appendix 3.5-9.

3.6.1.2.4 1994 Little Sand Lake and Wetland Drilling Program

In 1994, Foth & Van Dyke (1994a; CMC, 1994) completed a fourth lake bed and wetland piezometer installation program. The objectives of this program were to:

- further define the hydraulic relationships between lake/wetlands, and the regional groundwater system; and,
- to further define the hydraulic properties of lake beds and wetland soils through in situ hydraulic conductivity tests on piezometers and lab permeability tests performed on undisturbed soil samples.

The areas that were investigated as part of this program were:

- the littoral zone of Little Sand Lake (CMC-LSL series borings and wells);
- the Skunk and Duck Lake wetlands (CMC-DL, and CMC-SL series borings and wells); and,
- Bur Oak Swamp, the Swamp Creek Cedars Wetland and the Swamp Creek Wetland (CMC-BO, CMC-SCC, and CMC-SC series borings and wells, respectively).

Figure 3.6-3 shows the location of piezometer nests that were completed in 1994. Drilling procedures were described in Section 3.5.1.3.4. One piezometer nest was completed in each of the Swamp Creek Cedars, Bur Oak Swamp and Skunk Lake wetlands. One piezometer was installed immediately adjacent to the Duck Lake wetland since the wetland could not be accessed by any drilling equipment. Previous studies on Little Sand Lake focused on lacustrine clay thickness and hydraulic characteristics in the center of the lake. For the current study, in addition to the four borings described in Section 3.5.1.3.4, two piezometer nests were installed around the perimeter (littoral zone) of Little Sand Lake to assess the hydraulic characteristics of lacustrine clay in shoreline areas and the hydraulic relationship between the lake and underlying outwash.

All borings not used for piezometer installations were abandoned in accordance with NR 141 of the Wis. Admin. Code. Wells installed in Little Sand Lake were left in place for approximately three weeks. After water levels stabilized (approximately two weeks) slug tests were performed to assess the in situ hydraulic conductivity of the lacustrine clay lake bed. Slug tests were performed by instantaneously increasing the water level in the well by quickly inserting a solid PVC pipe and measuring the rate at which the water level returned to equilibrium. This data was analyzed according the method described by Bouwer and Rice (1976) and Bouwer (1989).

Several days after completion of the slug tests, the wells in Little Sand Lake were abandoned in accordance with NR 141 of the Wis. Admin. Code. All abandonment forms are provided in Appendix 3.5-10.

Lake bed and wetland piezometers were constructed in accordance with NR 141 of the Wis. Admin. Code and comments from the WDNR. Piezometers were constructed of two inch diameter Schedule 40 PVC or black pipe with a one to five foot long 10 slot PVC screen. The riser extended to three feet above the lake or wetland surface. All wells were developed in accordance with NR 141 of the Wis. Admin. Code. Well construction and development documentation is provided in Appendix 3.6-1.

3.6.1.3 1994 Groundwater Verification Monitoring Well Installation Program

Groundwater was sampled in 1994 and 1995 to validate the characterization of the groundwater quality work performed by Dames & Moore from 1978 to 1981. Described in this section is the rationale for selecting the monitoring well locations for this program and the well construction procedure used.

3.6.1.3.1 Selection of Well Locations for Monitoring

Forty-four wells were previously monitored by Dames & Moore (1982). Of these wells ten were sampled once, fourteen were sampled three to five times and 20 were sampled more than six times each. Additionally of these 44 wells, 24 had been abandoned in the mid-1980s, 13 were temporarily abandoned. Six were open and were being monitored quarterly for groundwater levels between the mid-1980s and 1994. Of the 20 wells that had been sampled more than six times, 12 have been abandoned, two wells have been temporarily abandoned, and five wells are active.

The purpose of the 1994 groundwater quality validation program was based on the following assumptions:

- The data collected by Dames & Moore was representative of the regional groundwater quality.
- Additional groundwater quality monitoring should concentrate on the locations identified as the areas of direct project impact (plant site and TMA) so that the data collected in 1994 could serve as baseline data for continued monitoring during the project after permits were obtained.

Planning for the groundwater quality validation program included reviewing the cumulative hydrogeological data collected by the various consultants in the 1970s and 1980s. Based on this review, a definitive groundwater quality validation program was developed. The first step in this program was to select the zones for monitoring. Like the 1970/1980 program, the 1994/1995

program focused on the overburden aquifer. The specific zones identified and the reasons for choosing them are:

- For the TMA, at the water table interface since this is the first contact that water recharging the aquifer has with groundwater, and within the outwash sand and gravel since this is the zone with the highest horizontal permeability.

- For the plant site, at the water table interface since the aquifer is thinner and the water table occurs in the outwash, and within the till immediately above the bedrock. These two zones would provide groundwater quality data for the groundwater that will flow into the mine.

Once the planned zones for monitoring were chosen, existing plant site and TMA area wells were evaluated to determine their applicability to the program. As part of this assessment, wells which were temporarily abandoned were opened so that a field evaluation could be conducted for well continuity. The evaluation also included wells which were being actively monitored for groundwater levels. Each well was assessed by visual inspection, measurement of the water level, measurement of total depth, and recording of the well size, condition and total depth. In addition, one or two photographs of each well were taken for documentation of existing conditions.

Based on the above the baseline groundwater validation program for the TMA was established to include two existing water table monitoring wells, four existing piezometers, the addition of six new water table wells and the addition of four new piezometers. Validation of groundwater quality at the plant site was established to include three new water table wells and three new piezometers. Table 3.6-2 lists the new and existing wells selected for the 1994 program. The location of the wells is shown on Figure 3.6-2a.

The original plan presented in the NOI/SOS (Foth & Van Dyke, 1994c) was to use an existing well (DMS-1) as a piezometer at the plant site. After well installation work began in the spring of 1994, it became apparent that DMS-1, which has a very long filter pack, would not serve well as a piezometer for the planned program. Therefore, CMC-08P was installed in its place. Also the plan presented in the NOI/SOS had referred to the use of existing well EX-9AL. The correct reference is to well EX-9BL. Well EX-9BL was the well used in the validation program.

3.6.1.3.2 Well Construction

To supplement historical groundwater quality data obtained in the study area, a series of new groundwater monitoring wells were installed in 1994. These wells are referred to as CMC-01R, -01P, -02R, -02P, -03RR, -03P, -04, -05, -06P, -07, -08, -08P, -09, -09P, -10 and -10P. The drilling methods for the installation of these wells was described previously in Section 3.5.1.4 of this report. The wells were constructed in accordance with NR 141 of the Wis. Admin. Code.

Table 3.6-2

Groundwater Quality Validation Wells

Well	Formation to be Monitored	Existing (E) or New (N)
TMA		
CMC-01R	water table	N
CMC-01P	outwash	N
EX-9BU	water table	E
EX-9BL	outwash	E
CMC-02R	water table	N
CMC-02P	outwash	N
CMC-03RR	water table	N
CMC-03P	outwash	N
CMC-04	water table	N
G41-H18B	outwash/Late Wisconsinan Till	E
CMC-05	water table	N
EX-13BU	outwash	E
DMB-6	water table	E
CMC-06P	outwash	N
CMC-07	water table	N
DMB-1A	outwash/Late Wisconsinan Till	E
Plant Site		
CMC-08	outwash	N
CMC-08P	till above bedrock	N
CMC-09	outwash	N
CMC-09P	till above bedrock	N
CMC-10	outwash	N
CMC-10P	till above bedrock	N

Prepared by: LLA
Checked by:SVD1

All wells were constructed of two-inch diameter Schedule 40 or Schedule 80 PVC. The annular space of the well was sealed with bentonite chips or slurry. Water table wells were constructed with 15-foot long slotted PVC screens. The filter pack was constructed of Red Flint Filter Sand. Approximately two feet of fine sand was placed between the gravel pack and the bottom of the annular space seal. After the well was set, a four-inch diameter locking steel casing was placed over the well. All wells were developed in accordance with NR 141. Well completion and development forms are provided in Appendix 3.6-1. Table 3.6-1 summarizes the construction information for these wells.

The existing wells used in the validation program were installed prior to the promulgation of NR 141. A comparison of the completion information for these wells to NR 141 requirements is shown on Table 3.6-3. As shown in the table the existing wells were installed with screens, filter packs and impermeable annular space seals and therefore, were deemed suitable for groundwater sampling as part of the 1994 program. Prior to using the existing wells for groundwater sampling, each well was redeveloped by surging and purging with a pump until the water was clear and readings for pH, temperature, and conductivity had stabilized.

3.6.1.4 1994 Saprolite Investigation Monitoring Well Installation Program

A component of the 1994 saprolite investigation was the installation of monitoring wells within the structured saprolite, bedrock, and overlying massive saprolite and glacial till. These wells were used for slug tests and observation points in a large scale pump test to characterize the hydraulic characteristics of a massive saprolite layer that resides over the ore body. The monitoring wells that were installed as part of this program include CMC-10PP, 11PP, 12P, 13P and 14P; and CMC-OWA1, 2, 3, 4 and 5. Table 3.6-1 summarizes the construction information for these wells. Figure 3.6-2 shows their geographic location.

The monitoring wells and pump test observation wells constructed as part of the saprolite investigation program were installed either in the Pre-to Early Wisconsinan Till, the massive saprolite, or structured saprolite. Five monitoring wells were installed and sealed within the massive saprolite (CMC-10PP, CMC-11P, CMC-12P, CMC-13P, CMC-14P). Two pump test observation wells were installed and sealed within structured saprolite (CMC-OWA1, CMC-OWA2). Three pump test observation wells were installed and sealed within the lower portion of the Pre-to Early Wisconsinan Till (CMC-OWA3, CMC-OWA4, CMC-OWA5).

The borings for the massive saprolite wells were cored a minimum of ten feet into structured saprolite for observation of the full thickness of the massive saprolite present at each location.

The lower portion of the borehole was backfilled with Holeplug™ up into the lower one to two feet of the massive saprolite. One to two feet of filter pack sand were then placed above the Holeplug™ below the bottom of the well screen. Schedule 80 PVC flush threaded well screen and casing were used for wells greater than 100 feet in depth. Schedule 40 PCV flush threaded well screen and casing were used for wells less than 100 feet in depth. A one-foot long well screen with a factory cut 0.006-inch slot was installed in each massive saprolite well.

Table 3.6-3

Comparison of Existing Wells to NR 141

NR 141	EX-9BU	EX-9BL	G41-H18B	EX-13BU	DMB-6	DMB-1A
Total Depth-Borehole (Ft)	193.5	193.5	288	193	86	79.4
Total Depth-Well (Ft)[D]	138	193	160	147	87	81
Borehole Diameter (In)	6.25	6.25	[B]	6.25	6	6
Well Casing (In)	2	2	2	2	2	2
Well Casting Material	Sch 40 PVC	Sch 40 PVC	PVC[A]	Sch 40 PVC	PVC[A]	PVC[A]
Well Screen Length (Ft)	20	3	10	3	10	10
Well Screen Material	PVC	PVC	PVC	PVC	PVC	PVC - 2 in
Screen Size	#20 Slot	#20 Slot	[C]	#20 Slot	[C]	[C]
Filter Pack	Pea Gravel 2 Ft Below Screen 10 ft above Screen	Pea Gravel 2 Ft Below Screen 2 Ft above Screen	Pea Gravel 131 Ft Below Screen 7 Ft above Screen	Pea Gravel 7 Ft Below Screen 6 Ft above Screen	Gravel Pack 23.9 Ft	Gravel Pack 49 Ft
Filter Pack Seal	17 Ft Bentonite Slurry	28 Ft Bentonite Slurry	3 Ft Bentonite Slurry	7 Ft Bentonite Slurry	7.8 Ft Sand 3.8 Ft Bentonite	6 Ft Sand

Table 3.6-3 *(Continued)*

NR 141	EX-9BU	EX-9BL	G41-H18B	EX-13BU	DMB-6	DMB-1A
Annular Space Seal	88 Ft Cement Bentonite Grout	32 Ft Pea Gravel 17 Ft Bentonite Slurry 88 Ft Cement/ Bentonite Grout	140 Ft Grout	128 Ft Cement/ Bentonite Grout	50 Ft Grout	24 Ft Grout
Ground Surface Seal	Cement/Bentonite Grout	Cement/Bentonite Grout	Grout	Cement/Bentonite Grout	Grout	Grout
Note	EX-9BU and EX-9BL are in common borehole	EX-9AU and EX-9AL are in common borehole.		EX-13BU and EX-13BL are in a common borehole.		

[A]Schedule of PVC not noted on borelog by installer.
[B]Borehole diameter not noted on drill log.
[C]Screen slot size not noted on drill log.
[D]Reported to nearest foot, reloaded from top of casing.

Prepared by: LLA
Checked by: SVD1

The filter pack, filter pack seal and bentonite seal lengths were field fit in accordance to the plan presented in the *Work Plan for Investigation and Identification of Saprolite Properties* (Foth & Van Dyke, 1994b). The thinner massive saprolite zones had filter packs which extended one-foot above the top of the screen and filter pack seals nine-inches thick so that the wells were sealed within the massive saprolite. Thicker massive saprolite zones had filter packs which extended two feet above the well screen and filter pack seals which extended two feet above the filter packs in conformance with Wisconsin Administrative Code NR 141. These wells were also sealed within the massive saprolite. Bentonite seals in the massive saprolite wells ranged in thickness from three to 17 feet thick. Thicker bentonite seals were the result of the driller placing more Holeplug™ before filling the remaining annular space with bentonite slurry. The remaining annular space was sealed with bentonite slurry ranging in weight from 10.5 to 12.2 pounds per gallon. The annular space seal was covered with native soils at the surface to prevent the bentonite from drying and cracking. The PVC wells were fitted with vented slip caps and four-inch steel protector pipes with locking covers.

Observation wells installed in the structured saprolite were constructed with schedule 80 PVC flush threaded well screen and casing. The well screens were five feet long and were factory cut 0.006-inch slots. The filter packs extended two feet above the well screens and the filter pack seals extended two feet above the filter packs. Bentonite seals in the structured saprolite wells ranged in thickness from four to six feet. The remaining annular space was sealed with bentonite slurry which weighed approximately 12 pounds per gallon. The annular space seal was covered with native soils at the surface to prevent the bentonite from drying and cracking. The PVC wells were fitted with vented slip caps and four-inch steel protector pipes with locking covers.

Observation wells installed in the Pre- to Early Wisconsinan Till were constructed with schedule 80 PVC flush threaded well screen and casing. The well screens were five feet long and were factory cut 0.006-inch slots. The filter packs extended two feet above the wells screen and the filter pack seals extended approximately two feet above the filter packs. Bentonite seals on the Pre- to Early Wisconsinan Till wells ranged in thickness from 11 to 22 feet. The remaining annular space was sealed with a high solids grout (per NR 141). The annular space seal was covered with native soils at the surface to prevent the bentonite from drying and cracking. The PVC wells were fitted with vented slip caps and four-inch steel protector pipes with locking covers.

All wells were developed prior to pump or slug testing. Well development consisted of bailing only for wells which could be purged dry and surging and bailing for wells which could not be purged dry. In all cases, because well recovery rates were slow, the development effort was performed on two consecutive days for each well. Well construction and development details are provided in Appendix 3.6-1. Boring logs are provided in Appendix 3.5-13.

Three pump test production wells were drilled. Because of caving conditions in the open production interval of CMC-PWA it was unusable. Well CMC-PWB did not produce enough water for a pump test. The third well, CMC-PWAR, was used in the pump test. Conditions encountered during drilling resulted in the modification of each well installation. The saprolite

work plan proposed wells that were drilled 20 feet into the structured saprolite and were steel cased and grouted. The production portion of the well was planned to be a 50-foot interval drilled below the bottom of the casing, with additional 50-foot drilled zones added if necessary to produce the required quantity of water. A high capacity well permit was granted by the WDNR on September 2, 1994.

Drilling of CMC-PWA was initiated on September 22, 1994. A ten-inch diameter borehole was drilled a depth of 180 feet by mud rotary drilling using Quick-Gel™, a Department-approved drilling mud with an additive. A 19.18 pound per foot new black steel Sawhill T&C A-53B casing was placed in the borehole and was held slightly off the bottom. The annular space was pressure grouted with neat cement grout. The grout was placed in the bottom of the casing and forced under the casing and up through the annular space. Grouting continued until fresh grout flowed out of the borehole between the casing and the borehole. The grout had a nominal mud weight of 16.6 pounds per gallon. After the grout was placed, but prior to setting, the casing was driven 27 inches into the bedrock with a casing driver that had been welded onto the lower end of the casing. The neat cement was allowed to cure for 72-hours prior to completion of the open portion of the well.

On September 27, 1994, the drilling of the open portion of the well was initiated. The drilling method for the lower portion of the well was completed by air rotary methods using a nominal six-inch down-hole hammer bit. High pressure air was used to lift cuttings and groundwater out of the borehole. Estimates of the amount of groundwater being produced can be made by this drilling method. The first twenty feet of drilling encountered soft friable structured saprolite. This material continued to cave into the hole even as the hole was advanced for an open interval of 50 feet to a total depth of 230 feet. The drill rods were removed and the well was allowed to equilibrate overnight. The next day the hole was found to have a total depth of 180 feet, which was the depth to the bottom of the casing, indicating that the hole had caved. Because of the variable nature of the ore body, a decision was made to install a replacement production well with a longer cased interval beyond this friable zone.

The second well, CMC-PWAR was located approximately 20 feet to the west of CMC-PWA. Drilling of CMC-PWAR was initiated on September 29, 1994 and was completed in a manner similar to CMC-PWA. The upper portion of the well was drilled by mud rotary methods to a total depth of 220 feet. The well was grouted as described above. The open portion of the well was started and completed on October 4, 1994 to total depth of 270 feet. Well construction reports, WDNR Form 3300-77A, for CMC-PWA and CMC-PWAR are included in Appendix 3.6-1. Boring logs are provided in Appendix 3.5-13.

Specific capacity testing of CMC-PWAR produced many fine-grained materials which increased in frequency as the well was pumped. A decision was made to place a four-inch Johnson channel pack screen in the well so that the production zone would stay open during the pump test. The well screen was a 30-foot long four-inch pipe size (5.25-inch O.D. by 4.0-inch I.D.), 8-slot

screen with a 40 by 60 filter pack which was factory installed between two screens. The screen was lowered into the well on a ten-foot length of blank casing and sealed in the bottom of the well by a K-packer. The lower 20 feet of CMC-PWAR had caved so the total depth of the well was only 250 feet at the time of installation of the well screen.

The drilling of CMC-PWB was initiated on October 5, 1994 and was completed in a manner similar to CMC-PWA. The upper portion of the well was drilled by mud rotary methods to a total depth of 220 feet. The casing was not grouted. Instead the casing was driven into the rock to refusal and the annular space remained filled with bentonite drilling mud. This procedure was implemented in case a sloughing zone was encountered and the casing needed to be driven deeper. Drilling of the open portion of the well was started on October 6, 1994 and completed on October 9, 1994. The first 50-feet of open zone drilled produced an estimated five gallons per minute of groundwater. An additional 130 feet of open hole was drilled in an attempt to intercept a water-bearing fracture zone. After this additional drilling CMC-PWB still would produce only an estimated five gallons per minute of groundwater. The well construction report, WDNR Form 3300-77A, for CMC-PWB is included in Appendix 3.6-1. The boring log for CMC-PWB is provided in Appendix 3.5-13.

Past drilling records in the area of CMC-PWB were again reviewed. The rock materials encountered in the drilling of CMC-PWB were consistent with rock cores obtained during exploratory drilling programs. Limited groundwater was encountered in the southern extent of the ore body and footwall during the previous drilling efforts. Therefore, it was concluded that additional drilling attempts along the southern extent of the ore body would not be expected to produce the quantity of water desired for an ore body-footwall pump test. If the production well moved northward, the well would produce water from the ore body-hanging wall contact instead of from the ore body-footwall contact. As a result, the CMC-PWB pump test was deleted from the saprolite investigation program.

3.6.1.5 1994 Little Sand Lake Sand Point Installation Program & Miscellaneous Well Installations

In December 1994 and February 1995 NMC installed 14 sand points in the vicinity of Little Sand Lake to further define the relationship between lake stage and shallow groundwater around Little Sand Lake and between Little Sand and Deep Hole Lakes. The sand points that were installed include the CMC-SP series wells shown on Figure 3.6-2. The sand points were constructed of 1¼ inch galvanized pipe with a three foot steel screen attached to the end of the pipe. The sand points were installed by manually driving the point into the soils with a weight. Table 3.6-1 summarizes the completion information for these sand points. Sand point installation information is provided in Appendix 3.6-1.

During the late 1970s several wells were installed in the vicinity of the plant site to evaluate various facility design alternatives. These wells include the DW Series, production wells TW-1 and TW-2 and the WW Series wells. Wells STS-EVS and STS-WVS, were installed as part of the evaluation and design of the east and west vent shafts. Well TW-41 was installed in the

vicinity of the TMA and used for the 24-day pump test discussed in Section 3.6.1.6.3 below. Available well construction reports are provided in Appendix 3.6-1. Note that well construction reports are not available for the WW Series wells.

3.6.1.6 Hydraulic Conductivity Testing

A number of programs have been conducted since the late 1970s to evaluate the hydraulic conductivity of major hydrogeologic units that control regional groundwater flow and the interaction of groundwater between the ore body/bedrock and the glacial overburden. These testing programs consisted of lab permeability tests, slug tests on monitoring wells, ore body pump tests in 1981 and 1994, packer tests in open bedrock exploration holes and a pump test in the glacial drift. A brief description of each testing program is presented below.

3.6.1.6.1 Soil Permeability Tests 1977-1979

Soil Permeability tests in the study area were completed as part of the regional hydrogeologic investigation during the installation of DMA, DMB, and DMC series borings and monitoring wells. Information on in situ permeability was collected by conducting falling and rising head slug tests on selected DM series wells.

Rising head and falling head tests were conducted on 36 monitoring wells (Dames & Moore 1982). These tests were conducted by changing the static water level in the well by adding or removing water. The subsequent return of the water level to the static condition is then recorded over time. Field data collected during the falling and rising head tests were analyzed using Hvorslev's relationship (1951), which is an exponential curve function that relates the change in head in a piezometer verses time to arrive at an estimate of in situ soil permeability. Figures 3.6-4 and 3.6-5 show the location of DM series wells that slugs were performed on. Slug test data is provided in Appendix 3.6-2.

3.6.1.6.2 Bedrock Packer and Slug Tests

In 1978, 1981, 1983 and 1984 a number of single well packer tests and slug tests were conducted on wells and exploration holes screened and sealed within the Precambrian bedrock. The purpose of these tests was to assess the water-producing ability and hydraulic conductivity of the ore body, host rock and regional bedrock.

In 1978, Dames & Moore (1978) conducted a series of packer tests in deep exploration holes 165, 155, 70, 66, 91 and 77. Within any given exploration hole, multiple zones were tested. The tests were performed with multiple packers used to isolate selected zones between the packers or with a single packer used to isolate a zone between the packer and the bottom of the hole. Recovery data was analyzed according to the methodology of Ferris, et al. (1962).

In 1981, Exxon (Landers, 1981) conducted a series of packer tests in exploration hole 213 to evaluate the change in hydraulic conductivity within a weathered zone along the contact between the hanging wall and ore body. Like the Dames & Moore tests, multiple zones were tested.

In 1983, Exxon (Rowe, 1984) conducted a number of single well slug tests of the upper regions of the ore body. The tests were conducted by instantaneously stressing the aquifer, through injection or removal of water, such that the resulting water level was above or below the pre-stressed potentiometric level and then measuring the rate of recovery of the water level in the well. The holes tested (253, 254, 255, 256 and 257) were cased through the glacial overburden and into the top of the bedrock. The test section of the wells were left as open holes with no screen or casing. The recovery data were analyzed according to the Jacob's straight line approximation method (Fetter, 1980).

In 1984, STS Consultants (1984a and b), as part of the regional hydrogeologic investigations, installed a number of wells in the regional bedrock that were used to conduct falling head permeability tests. The static water level in these wells was instantaneously increased by inserting a 15 foot long, one inch diameter PVC slug. The recovery of the water level in the well was then recorded over time. Recovery data was analyzed according to methodology developed by the Department of Navy (1971), which is equivalent to the Hvorslev method (1951) with the exception that the recovery data is not normalized. The location of the exploration holes and monitoring wells that were tested are shown on Figure 3.6-6. Bedrock permeability test data is provided in Appendix 3.6-3.

In 1995 Hydro-Geo Consultants, Inc. (Hydro-Geo, 1995) performed a series of additional packer permeability tests in open boreholes adjacent to the proposed mine. In addition, this new data and previously collected data were analyzed by Hydro-Geo Consultants, Inc. to characterize bedrock permeability at the project site. The results of this work are presented in *Hydrologic Investigation and Packer Permeability Testing of Bedrock at the Crandon Mine* which can be found in Appendix F of the report titled *Numerical Simulation of the Effect on Groundwater and Surface Water of the Proposed Zinc and Copper Mine Near Crandon, Wisconsin* (GeoTrans, 1996). The GeoTrans report is included in this EIR as Appendix 4.2-3.

3.6.1.6.3 1981 Bedrock Pump Test

In 1981, two pump tests were conducted by Camp Dresser & McKee (1982) in the Crandon Formation to evaluate the hydraulic connection between the ore body and the overlying glacial overburden.

The pumping wells used in the pump test were open exploration holes drilled through the overburden and the bedrock north (hanging wall) of the ore body. The tests were labeled according to the hole number that was pumped. The open holes were cased into bedrock and thus only pumped water from within the ore body and bedrock. The pump test in hole 211 was conducted for a total of 170 hours at a discharge rate of 225 gallons per minute (gpm). The pump test on well 213 was conducted for 170 hours at a pumping rate of 560 gpm.

During the pump test groundwater levels were measured in wells and exploration holes completed in both the overburden and the ore body (angled core holes or vertical wells placed in the top of the bedrock). Drawdown and recovery data from the pump tests were analyzed utilizing standard type curve methods described in Lohman (1972) and Reed (1980) to arrive at values for bedrock transmissivity, storage coefficient and boundary correlation. The ore body pump tests are described in detail in the Camp Dresser & McKee (1982) pump test report. The Camp Dresser & McKee pump test is discussed extensively in the Saprolite Report (FVD, 1995a) submitted to the WDNR in February, 1995. Wells that were installed for this program include the CDM and BE Series wells. No construction records are available for the CDM wells. BE Series well construction records are provided in Appendix 3.6-1.

3.6.1.6.4 1981 Glacial Overburden Pump Test

In 1981, Golder Associates performed a pump test in the vicinity of the TMA to assess major hydraulic parameters of the glacial till and outwash deposits. The pump test was comprised of a test well, 13 primary observation wells, and 17 secondary observation wells.

The test well was screened over the full depth of the saturated glacial deposits. Observation wells were completed at various distances from the test well and at various depths. The drawdown phase of the pump test lasted 24 days, from June 27 to July 21, 1981, and was conducted at an average pumping rate of 1,420 gpm. Pump test drawdown and recovery data was analyzed according to standard type curve analysis. Figure 3.6-7 shows the location of the test well and observation wells used in the pump test. The Golder Associates Pump Test Report is provided in Appendix 3.6-4.

3.6.1.6.5 1984 Slug Tests on Glacial Deposits

Field permeability or hydraulic conductivity tests were conducted by STS in 51 EX monitoring wells, seven well WP series points, and 27 older wells. Where possible, both rising and falling head tests were conducted in each well. Falling head tests were only conducted in wells sealed into very low permeability formations, such as bedrock. In the small diameter older BE series wells, rising head tests were conducted by using compressed air to remove the water column with the rate of water level recovery manually recorded. Except for the old small diameter wells, the field permeability tests were conducted using a pressure transducer and data logger.

The general procedures involved placing the 25 psi transducer approximately 20 feet below the static water level. The model PT-105V pressure transducer was connected to an Enviro Labs model DL120 data logger which has a microprocessor capable of being programmed to take and store transducer readings at any intervals from 10 seconds to 24 hours. Once the data logger was programmed to begin logging, a solid one inch diameter PVC slug approximately 15 feet long was dropped into the borehole to displace the column of water. Once the falling head test was completed, the slug was removed and a rising head test was conducted. After the test was completed, the data were printed out. Recovery data, which is provided in Appendix 3.6-5, was analyzed according to methodology developed by the Department of Navy (1971), known as the

DM-7 Method. The DM-7 formula does not take into consideration changes in screen length or drainage from unsaturated gravel packs so field permeability tests were not conducted in the shallow water table piezometers or upper well points. The DM-7 formula is as follows:

$$K = \frac{r^2}{2L}\left(ln\frac{L}{R}\right)\left(\frac{lnH1/H2}{t2-t1}\right)$$

K = permeability
r = standpipe radius
L = gravel pack length
R = gravel pack radius
H = head level
t = time

This formula is equivalent to formula developed by Hvorslev (1951), with the exception that recovery data is not normalized. This formula is applicable when the radius of the intake point of the monitoring well differs from the radius of the standpipe. For the EX monitoring wells, the radius of the intake point is the radius of the borehole or gravel pack which is 3.125 inches. The radius of the standpipe is only one inch. Also, in all the EX wells, the gravel pack length exceeds the screen length. Therefore, the gravel pack length was used in the formula since water entering the entire gravel pack is immediately reflected in head level changes in the standpipe.

Field permeability test data is provided in Appendix 3.6-5. The first sheet provides a summary of the well construction details and permeability results. The second sheet is the graphical plot of the head ratio versus time. The third sheet is a summary of the field data (transducer readings). Figures 3.6-4 and 3.6-5 show the location of the EX and WP series wells and DM series wells that slug tests were performed on.

3.6.1.6.6 1994 Lake Bed and Wetland Slug Tests

Slug tests were performed on selected wells that were installed as part of the 1994 lake bed and wetland investigations. The wells that were tested include CMC-LSL-102 A/B, CMC-LSL-104 A/B, CMC-SL-102 A/B, CMC-DL-102B and CMC-BO-101A.

Slug tests were performed by instantaneously increasing the water level in the well by quickly inserting a solid PVC pipe and measuring the rate at which the water level returns to equilibrium. In the case of water table wells, a bailer was used to quickly remove a volume of water after which the water level rise in the well was recorded. This data was analyzed according to the method described by Bouwer and Rice (1976) and Bouwer (1989). Slug test data is provided in Appendix 3.6-6.

3.6.1.6.7 1994 Saprolite Investigation & Ore Body Pump Tests

In 1994, Foth & Van Dyke (1995a) conducted a detailed investigation of the hydraulic connection between the ore body and the glacial overburden. The focus of this investigation was to evaluate the hydraulic characteristics of a highly weathered bedrock layer or massive saprolite layer. The investigation consisted of the installation of monitoring wells placed along the strike of the ore body which were screened within the massive saprolite. Additional wells were placed above and below the massive saprolite in the vicinity of a high capacity well installed into the weathered bedrock (structured saprolite) above the ore body. A pump test was conducted in which the monitoring wells were used to measure drawdown below, within and above the massive saprolite. Slug tests were conducted on all observation wells. Pump test data was analyzed via numerical methods. The details of this investigation are discussed in the Saprolite Report (Foth & Van Dyke, 1995a) submitted to WDNR in February 1995. Slug test data is provided in Appendix 3.6-7.

3.6.1.7 1998 Soil Absorption System Investigation

In 1998, Foth & Van Dyke conducted a series of subsurface investigations to evaluate potential soil absorption system sites. In addition to test pits and borings discussed in Section 3.5, the investigation included 14 water table monitoring wells, three piezometers, six shallow sand points, four deep sand points, and two staff gages. The locations of each are shown on Figure 3.6-7a.

Details on drilling methods for the borings, wells and piezometers are described in Section 3.5.1.10. The monitoring wells and piezometers were constructed of two inch diameter, PVC pipe. Prior to placing the well screen in the hole, approximately one foot of coarse sand was placed, then the well screen was placed and coarse sand was added to the annulus until the material was approximately 0.5 to 4 feet above the screened interval of the well. A layer of fine sand was then added to prevent bentonite from migrating downward and possibly plugging the screen. Bentonite chips were added above the fine sand to fill the annulus up to the ground surface. Protector pipes with protective caps were installed over the top of each well. Wells were developed in accordance with NR 141. A summary of well and piezometer construction details is provided in Table 3.6-1. Detailed well construction and development information is provided in Appendix 3.6-7a.

In addition to the 14 wells and three piezometers, six shallow well points (SPH-01 through SPH-06) and four deep sand points (SPH-01A through SPH-04A) were installed. The sand points consist of 1¼ inch galvanized pipe with three-foot long screens. The construction information for the wells is presented in Table 3.6-1.

Infield permeability tests were performed in Area E and Area H. The data sheets are provided in Appendix 3.6-7b.

3.6.1.8 1998 Grout Test Program

In 1998, TRC Hydro-Geo Consultants completed a grout testing program to evaluate the feasibility of constructing a grout blanket at the base of the crown pillar. The purpose of the grout blanket is to reduce groundwater seepage from the glacial overburden into the mine. The test program included constructing 12 cored bedrock holes and one piezometer, NMC-101. The location of NMC-101 is shown on Figure 3.5-10a in Section 3.5.

Drilling methods for NMC-101 were described in 3.5.1.9. The piezometer was constructed of two-inch diameter, Schedule 80 PVC with a six-foot slotted screen. Prior to placing the well screen, approximately ½ foot of coarse sand was placed. Then the well screen was placed and coarse sand was added to the annulus until the material was approximately 2½ feet above the screened interval of the monitoring well. A layer of fine sand was then added to prevent bentonite from migrating downward and possibly plugging the screen. Bentonite grout was then added to fill the annulus to approximately one foot below ground surface. Concrete was added to fill the annulus to the ground surface. Before the concrete was solidified, a protector pipe with a locking protective cap was installed over the top of the well. The well was developed in accordance with NR 141. A summary of the piezometer construction details is provided in Table 3.6-1. Detailed well construction and development information is provided in Appendix 3.6-7c.

3.6.1.9 Groundwater Level Measurements

Water levels from the monitoring wells installed during the above referenced investigations have been monitored with different frequencies dating back to the late 1970s. Water levels measured for each well are summarized in a data base and on hydrographs contained in Appendix 3.6-8.

Prior to 1994 the depth to groundwater was recorded with an electronic water level indicator which measured groundwater to the nearest 0.05 foot, and estimated to the nearest 0.01 foot. This work was completed under the direction of NMC predecessor companies. From March 1994 through January 1995, groundwater elevations were measured monthly. The depth to groundwater was measured with a Well Wizard Model 6000 or Solinst Model 101 electronic water level indicator which measures to the nearest 0.01 foot.

All groundwater elevations were determined by subtracting the depth to water from the elevation of the measuring point (top of PVC casing). Each well was surveyed to establish vertical (ground surface and top of casing) and horizontal (coordinates) control. Vertical control was established to 0.01 feet. Horizontal control was established to 0.1 feet. The survey work was completed by Imman-Foltz and Associates, Inc. of Minocqua, Wisconsin and Foth & Van Dyke of Green Bay, Wisconsin. Survey work was completed under the direction of Wisconsin registered land surveyors.

3.6.1.10 Sample Collection, Analytical Procedures and Quality Control

Monthly sampling of 17 of the groundwater validation monitoring wells began in May of 1994. Monthly sampling of four additional wells began in June of 1994, while monthly sampling of CMC-02R began in October 1994. The June start-up related to the need to complete boring and well construction work. The October start related to the need to replace CMC-02 with CMC-02R, since the CMC-02 well screen as installed was not at the water table. In addition monitoring wells CMC-08, 08P, 09, 09P, 10 and 10P were not sampled in November of 1994 since they were included in water level monitoring programs for the saprolite pump test.

Collected samples were shipped under chain-of-custody procedures to the laboratory for analysis. Table 3.6-4 contains the list of parameters for the groundwater validation program. Analytical methods, target practical quantification limits, precision targets, etc. are outlined in the Project's Quality Assurance Plan (Foth & Van Dyke, 1995c) and in the updates to that plan contained in Appendix 3-1.

Sampling procedures were consistent with those outlined in Appendix E, Project Quality Assurance Plan of the project's NOI/SOS (Foth & Van Dyke, 1994c). A brief outline of the sampling procedures used follows.

Prior to purging, the depth to water was first determined by an electronic water level indicator. The well was then purged by removing four times the volume of water in the well or until the well was dewatered, whichever came first. Subsequent to purging, samples were be removed with either the dedicated PVC bailer or the Grundfos® submersible pump. Water samples were poured from the bailer, or from the pump tubing, into containers specifically prepared for the given parameter(s). Metal sample aliquots for dissolved metals analyses were filtered in the field prior to acidification. Documentation of purging and sampling activities was recorded on Groundwater Monitoring Field Forms. Upon collection, the temperature, specific conductivity and pH of each sample were measured.

WDNR personnel were notified of the dates for each round of sampling so that they could, if they chose, observe procedures and/or split samples. WDNR personnel were present during the June through November 1994 sampling events.

Table 3.6-4

Groundwater Quality Validation Parameter List

Field Measured Parameters	Laboratory Analyzed Parameters	
Specific Conductance	Total Alkalinity	Antimony
pH	Total Hardness	Aluminum
Temperature	COD	Arsenic
	Fluoride	Barium
	Kjeldahl (N)	Cadmium
	Nitrite & Nitrate	Calcium
	Chloride	Chromium
	Sulfate	Cobalt
	Cyanide (total)	Copper
	Total Dissolved Solids	Iron
		Lead
		Magnesium
		Manganese
		Mercury
		Molybdenum
		Nickel
		Selenium
		Silver
		Zinc

Prepared by: LLA
Checked by: JWS

3.6.2 Water Well Information

The following subsections discuss domestic water well inventory work completed in the area of the project and NMC plans for future water well installation relating to the project.

3.6.2.1 Domestic Water Well Inventory

NMC conducted an inventory of domestic water wells in the vicinity of the proposed mine in the summer of 1994. This inventory built upon two previous inventories of domestic water wells in the project vicinity. Dames and Moore conducted the first inventory in 1982 (Dames and Moore, 1982) and Northern Lake Services, Inc. (NLS) conducted a second inventory in 1984 (Northern Lake Service, 1984).

For the 1982 inventory, Dames & Moore developed a system of numbering plats. Each well that was identified was assigned a number corresponding to the number of the plat on which the well was located. The water well inventory resulted in the identification of 42 wells within the inventory area. The information on these wells was obtained from well logs or from personal communication with well owners.

In 1984 NLS conducted an inventory of a 36 square-mile area surrounding the proposed plant site. The numbering system of the Dames & Moore inventory was adopted and the region was divided into four zones. Zone I corresponded to that area which was estimated to experience greater than one meter (3.3 feet) of drawdown from mine dewatering, based on modeling done at the time. Zone I is the shaded region in Figure 3.6-8. Zones II, III, and IV represented three outer boundary zones. Within Zone I, scattered wells were assigned numbers 1-99, and wells clustered around Little Sand Lake were assigned numbers between 101-199. NLS supplemented the data collected by Dames & Moore with questionnaires to well owners. Owners that did not respond to the questionnaire were contacted by phone or in person. An effort was made to make on-site observations of all shallow-driven wells. Well driller reports provided by the Wisconsin Geologic and Natural History Survey (WGNHS) provided most of the information on drilled wells. Rigorous information collection was conducted only for Zone I. Of 54 estimated wells in Zone I, information was collected on 52 wells. In the entire 36-square mile inventory area, there were estimated to be 318 wells, and information was obtained on 211 of these wells.

In response to a request from the WDNR, additional inventory work related to domestic water wells in the vicinity of the proposed mine was completed in 1996. In 1998 an inventory of domestic water wells in the vicinity of the proposed soil absorption system site was also completed. Details regarding the surveys completed in 1996 and 1998 can be found in the project's *High Capacity Well Permit Application* (Foth & Van Dyke, 1995/1998a).

3.6.2.1.1 1994 Inventory

The domestic water well inventory conducted in the summer of 1994 retained the numbering system of previous inventories. The inventory also focused on Zone I (Figure 3.6-8) since

preliminary results from the regional groundwater model have indicated that the extent of drawdown from mine dewatering will be no greater than that predicted in the 1980s and likely will be less. Previously known wells were identified using the numbers they were assigned in the 1984 NLS inventory. Data from the NLS inventory was updated with a new survey of current landowners and with a new review of WGNHS files to identify new Well Construction Reports submitted since the last collection. Scattered new wells in Zone I were numbered following the 01-99 convention. New wells immediately surrounding Little Sand Lake were numbered using the 101-199 convention.

The inventory area included sections of both Forest County and Langlade County. The current Forest County Atlas and Plat Book and the current Langlade County Atlas and Plat Book were initially consulted to determine current land ownership. To further update the land ownership data from the plat books, the current Forest County treasury files and Langlade County treasury and real property lister files were consulted. From this information, the current property owners at that time were identified in the inventory area. These property owners are listed in Table 3.6-5.

Since the 1984 inventory, many changes in land ownership had occurred. Approximately 40 percent of the property in the inventory area is currently owned or under purchase option or easement to by NMC. This property includes about 75 percent of the Little Sand Lake area, and a section unit to the immediate east, immediate north, and immediate west of Little Sand Lake. Properties purchased by NMC were not included in the survey because NMC plans to abandon any wells on these plats should they be affected by the groundwater drawdown.

A questionnaire was prepared for mailing to all current landowners within the inventory area. Property owners were placed in one of three categories: existing property owners that participated in the 1984 survey (Original Owners), owners of property not previously surveyed in the area (New Owners), and new owners of property previously surveyed (Transferred Owners). A questionnaire was prepared for Original Owners, and a separate questionnaire was prepared for New Owners/Transferred Owners. A different cover letter was prepared for each of the three groups.

Original Owners were asked to describe any maintenance or changes to their well system since 1984. Maintenance changes referenced on the questionnaire included well replacement, relining the well, deepening the well, and pump replacement. New Owners and Transferred Owners were asked to provide general information about their well such as primary water use, method and date of well installation, pump type, well depth, well diameter, screen length, static water level, water level during pumping, and casing material. All owners were asked to give an opinion of the water quality of their wells in terms of taste, odor, and quantity.

On July 11, 1994, questionnaires and cover letters were mailed to area property owners. On August 1, 1994, all owners who failed to respond to the July 11 questionnaires were mailed a second questionnaire. An attempt was made to contact by telephone each landowner who did not respond to either questionnaire.

Table 3.6-5

Property Owners and Domestic Water Wells in Inventory Area

Property Owner	Well Number	Form of Contact	Comments
Becker, William J.	108	phone	private well on property
Betters, William	118	returned survey	private well on property
Bishop, Joseph	—	returned survey	survey response not clear but appears no well
Bradley, Alicia	—	reviewed property tax records	Property tax records indicated improvements but no sewer or well permits were on file, therefore, no well likely exists
Bradley, Scott	—	reviewed property tax records	no property improvements were noted, therefore, no well likely exists
Bradley, Wallace	—	reviewed property tax records	no property improvements were noted, therefore, no well likely exists
Buckley, Gerald	167	returned survey	private well on property
Campshure, James	—	returned survey	no well on property
Cheslock, Richard	—	returned survey	no well on property
Clark, Thomas	33	returned survey	private well on property
Connor, Richard M.	—	returned survey	no well on property
Consolidated Papers, Inc.	—	returned survey	no well on property
Cook, Ralph J.	—	returned survey	own well, but well appears to be outside Zone I
Dhuey, David J.	166	returned survey	private well on property
Dietzler, Ruth	115	returned survey	private well on property
Dilley, Lyon	—	reviewed property tax records	no property improvements were noted, therefore, no well likely exists
Dix, Beverly	114	returned survey	private well on property
Fishler, Grace	—	phone	well identified in 1984 NLS inventory but owner claims no well

Table 3.6-5 *(Continued)*

Property Owner	Well Number	Form of Contact	Comments
Forest County	—	reviewed property tax records	no property improvements were noted, therefore, no well likely exists
Freye, William	—	returned survey	own well, but well appears to be outside Zone I
Fritsche, Franklin J.	107	returned survey	private well on property
George, Lloyd E.	—	returned survey	no well on property
Haferman, Ralph W.	106	returned survey	private well on property
Hess, John	—	returned survey	no well on property
Hockers, C.J.	—	reviewed property tax records	no property improvements were noted, therefore, no well likely exists
Hoffman, Cynthia	—	returned survey	well identified in 1984 NLS inventory but owner claims no well
Hoffman, David	—	returned survey	abandoned well on property
Hoffman, Jerome	—	returned survey	no well on property
Hoffman, Joan	—	returned survey	no well on property
Hoffman, Raymond H.	90, 91	returned survey	two private wells on properties; second well identified in 1984 NLS inventory
Jameson, John G., Jr.	—	phone	no well on property
Jansen, Jeff	32	returned survey	private well on property
Johnson, Archie	—	returned survey	no well on property
Johnson, Gary	162	returned survey	private well on property
Kelchner, Robert M.	105, 105a	returned survey	two private wells on property; second well identified by Well Construction Report
Keppert, Gerald D.	—	returned survey	own well, but well appears to be outside Zone I
Kloehn, Gerald	168	returned survey	private well on property
Kriegel, Elmyra	89, 89a	returned survey	two private wells on property; second well identified in 1984 NLS inventory

Table 3.6-5 *(Continued)*

Property Owner	Well Number	Form of Contact	Comments
Langlade County, C.F.L.	—	not reached	no Well Construction Report on file, review of quadrangle revealed little probability of well
Lijewski, Edward	144	returned survey	private well on property
Mantey, James P.	121	not reached	well identified in 1984 NLS inventory
Mihalko Land and Logging	—	phone	no well on property
Mihalko, Thomas	—	phone	no well on property
Menominee Indian Tribe of Wisconsin	68	drive-by survey	private well likely on property, well Construction Report on file
Northern Woodlands, Inc.	—	not reached	no Well Construction Report on file, review of quadrangle revealed little probability of well
Noteboom, Maureen B.	—	returned survey	no well on property
Pallen, Herman	116	returned survey	private well on survey
Parker, R.W.	143	reviewed property tax records	Well Construction Report on file, well permit issued in 1977
Phalen, Patrick, Jr.	57	returned survey	private well on property
Pieritz, Richard	102	returned survey	private well on property
Pryor, Harold	—	reviewed property tax records	no property improvements were noted, therefore, no well likely exists
Schallock, Jerry L.	145	returned survey	private well on property
Schmidt, John	87, 87a	returned survey	two private wells on property
Schrading, Mark	—	returned survey	no well on property
Schultz, Delores	—	returned survey	no well on property
Seawell, Elizabeth	—	reviewed property tax records	no property improvements were noted, therefore, no well likely exists
Sokaogon Chippewa Community	—	reviewed property tax records	no property improvements were noted, therefore, no well likely exists

Table 3.6-5 *(Continued)*

Property Owner	Well Number	Form of Contact	Comments
Solper, Gerald K.	—	returned survey	own well, but well appears to be outside Zone I
State of Wisconsin	—	reviewed property tax records	no property improvements were noted, therefore, no well likely exists
Streur, William	—	reviewed property tax records	no property improvements were noted, therefore, no well likely exists
Tambellini, Thomas	—	returned survey	no well on property
Terzinski, Kathy	—	phone	no well on properties within Inventory Area
Thornton, Thomas J.	—	reviewed property tax records	no property improvements were noted, therefore, no well likely exists
Tomahawk and Timber	—	reviewed property tax records	no property improvements were noted, therefore, no well likely exists
Torgerson, Bernie	—	returned survey	own well, but well appears to be outside Zone I
Verlotta, Joseph	—	reviewed property tax records	no property improvements were noted, therefore, no well likely exists
Walentowski, Clement	84, 92, 93, 119	returned survey	four private wells on properties; survey mentioned one well; others identified in 1984 NLS inventory
Walentowski, Harold	—	phone	well identified in 1984 NLS inventory but owner claims no well
Webb, Richard	—	reviewed property tax records	owned well 102 but sold section to Pieritz
Wisconsin DNR	—	phone	no well on property
Wisconsin Timber Association	—	returned survey	no well on property
Yeager, Florence Ann	120	returned survey	private well on property
Younk, G.	—	returned survey	no well on property

— No well known to be located on property.

Prepared by: JJA1/SGL
Checked by: XXC/JWS

In addition to the questionnaires, a review of WGNHS files for Well Construction Reports on properties in the inventory area was requested. Only Well Construction Reports up to 1990 were available. More current reports were still being sorted by WGNHS at the time of request.

3.6.2.1.2 Summary of Inventory Results

Of the 73 non-NMC property owners in the inventory area, responses were received from 52 owners. Questionnaires were returned by 45 owners, and seven owners were reached by telephone. The remaining 21 landowners could not be reached.

Among those landowners reached, 30 wells were identified in the inventory area. Additionally, three wells were identified from Well Construction Reports or from the 1984 NLS inventory on properties belonging to owners who could not be reached. These wells were assumed to still be in operation. Thus, a total of 33 domestic wells were listed in the inventory. Some of the landowners own several pieces of property in the inventory area. Others own additional properties outside of the inventory area or own properties that extend off the inventory area. When these landowners answered the questionnaire, it was not always clear which specific property their well was located on or even if the well was located in the inventory area. Table 3.6-5 lists the response of each property owner to the survey, and any special notes or uncertainties related to their wells or property. Figure 3.6-8 shows well locations for the entire inventory area. Figure 3.6-9 shows well locations immediately surrounding Little Sand Lake. Information on those wells which have been identified is summarized in Table 3.6-6. Since the July of 1994 survey, NMC has acquired purchase options for a number of the properties containing wells listed in Table 3.6-6. These properties are associated with well numbers 102, 114, 115, 116, 118, 120, 162, 167, and 168.

In 1996, work was completed to gather additional information on properties included in the 1994 domestic water well survey for which a questionnaire was not returned. In order to determine whether groundwater wells exist on these properties a review of Forest County property tax records was performed. The property tax records review indicated that, with two exceptions, the questionnaires which were not returned in 1994 corresponded to properties with no improvements. Therefore, it is unlikely that groundwater wells exist on these properties. Two properties (Alicia Bradley and R.W. Parker), which did not have returned questionnaires, did list improvements based on the property tax records. The property of Alicia Bradley had no sewer or well permits on file and, therefore, likely has no groundwater well on site. The property of R.W. Parker had a well permit issued in 1977. Data was previously obtained on the Parker well from the 1980s well surveys and is included in the survey data base.

Generally, the wells in this area are shallow. The average well depth is approximately 35 feet. The deepest is 96 feet. In most cases the static depth to water is less than 30 feet, but in one well the static depth to water was 72 feet. The oldest well was installed in approximately 1948, with the newest installed in 1993. Most are driven wells, although some are drilled wells. Most use shallow well type pumps and nearly all are used for private domestic purposes. They draw from aquifers in either the undifferentiated Late Wisconsinan Till or the underlying outwash deposits.

Table 3.6-6

Description of Domestic Water Wells in Inventory Area

	Well Number	Location	Water Use	Year of Installation	Installation Method	Well Details			Depth to Water (ft)		Casing Material	Pump Type	Water Quality (Owner's Opinion)	Description of Well Repairs
						Depth (ft.)	Diam. (in.)	Screen (ft.)	Static	Pumping				
Jansen, Jeff	32	S4-T34N-R13E	Private	1993	Driven	12	1.75	3	—	—	Galv.	Hand Pump	Good taste, very clear	none
Clark, Thomas	33	S4-T34N-R13E	Private	1988	Driven	25	2	—	—	—	Galv.	Shallow Well	Excellent, almost no mineral taste, no odor, minimal staining	Pump replaced - 02/94
Phalen, Patrick	57	S35-T35N-R12E	Private	1991	Drilled	60	6	3	45	—	—	Submersible	Very clear	N/A
Menominee Indian Tribe of Wisconsin	68	S25-T35N-R12E	Private	1988	Drilled	83.5	6	3	72	75	Blk Steel	—	—	
Walentowski, Clement	84	S26-T35N-R12E	Private	—	Driven	26	1.25	—	14	—	Galv.	—	Good	
Schmidt, John	87	S26-T35N-R12E	Private	Unknown	Driven	28	1.25	—	—	—	Galv.	—	Taste OK, no odor, very little staining	New pump motor, point and pipe
Schmidt, John	87a	S25-T35N-R12E	Private	1993	Drilled	31	6	3	—	—	Steel	Submersible	Taste OK, no odor	
Kriegel, Elmyra	89	S26-T35N-R12E	Private	1960 (est)	Driven	20	1.25	3	20	—	Galv.	Shallow Well	Taste OK, no odor, hard	Well not in use
Kriegel, Elmyra	89a	S26-T35N-R12E	Private	—	Driven	20	1.25	3	—	—	Galv.	No Pump	Rusty, bacteriologically unsafe	Not in use
Hoffman, Raymond H.	90	S26-T35N-R12E	Private	1948 (est)	Driven	27	1.25	4	21	—	Galv.	Shallow Well	Good, slightly hard	Not repaired or re
Hoffman, Raymond H.	91	S26-T35N-R12E	Private	—	Driven	28	1.25	4	22	—	Galv.	Shallow Well	Excellent	Not repaired or re
Walentowski, Clement	92	S26-T35N-R12E	Private	—	Drilled	63	5	3	14	19	Blk Steel	Shallow Well	Good taste, no odor, some rust	
Walentowski, Clement	93	S26-T35N-R12E	Domestic Commer-cial	—	Driven	28	1.25	3	20	—	Galv.	Shallow Well	Iron taste and color	

Table 3.6-6 *(Continued)*

	Well Number	Location	Water Use	Year of Installation	Installation Method	Well Details: Depth (ft.)	Well Details: Diam. (in.)	Well Details: Screen (ft.)	Depth to Water (ft): Static	Depth to Water (ft): Pumping	Casing Material	Pump Type	Water Quality (Owner's Opinion)	Description of Well Repairs
Pieritz, Richard	102[1]	S36-T35N-R12E	Private	1959	Drilled	58	4	3	25	45	Std. Steel	Deep Well Jet	Good, some iron	None
Kelchner, Robert M.	105	S36-T35N-R12E	Private	1977	Drilled	54	6	3	21	26	ASTMA 53	Submersible	Excellent	No repairs
Kelchner, Robert M.	105a	S36-T35N-R12E	Private	1962	Driven	22	2	2	—	—	Galv.	Shallow Well	Good, clear, soft	
Haferman, Ralph W.	106	S36-T35N-R12E	Private	1956	Driven	17	1.25	—	5	—	Galv.	Shallow Well	Okay	None
Fritsche, Franklin J.	107	S36-T35N-R12E	Private	1961	Driven	20	1.25	4	14	—	Galv.	Shallow Well	Excellent quantity - good taste, no odor	Pump replaced - 06/89 new point 06/90
Becker, William J.	108	S36-T35N-R12E	Private	1965	Driven	25	1.25	—	—	—	Galv.	—	Good, clear	
Dix, Beverly	114[1]	S35-T35N-R12E	—	—	Driven	18	—	—	—	—	—	—	Good tasting and very clear	New pump
Dietzler, Ruth	115[1]	S36-T35N-R12E	Private	1968	Driven	20-30	1.25	—	—	—	—	Shallow Well	Good taste, no odor, no iron staining	None
Pallen, Herman	116[1]	S36-T35N-R12E	Private	—	Driven	23	1.25	3	6	—	Galv.	—	Water is clear, tastes excellent, no iron	
Betters, William	118[1]	S36-T35N-R12E	Private	1978	Driven	23	1.25	—	6	—	Galv.	Shallow Well	Good, no odor	None
Walentowski, Clement	119	S36-T35N-R12E	Private	—	Drilled	20-30	3	—	11	—	—	Shallow Well	Not the best taste	
Yeager, Florence Ann	120[1]	S36-T35N-R12E	Private	—	Driven	30	1.25	3	25	—	Galv.	Shallow Well	Pure water - not hard, good taste	Pump Replaced
Mantey, James P.	121	S31-T35N-R13E	Private	1970	Driven	24	1.25	4	—	—	Galv.	Shallow Well	Good, clear	
Parker, R.W.	143	S31-T35N-R13E	Private	1977	Drilled	64	5	3	23	—	Galv.	Submersible	Good	
Lijewski, Edward	144	S31-T35N-R13E	Private	1975	Drilled	58	5	2	23	50	Blk steel	Submersible	Excellent, clear water	None

Table 3.6-6 *(Continued)*

	Well Number	Location	Water Use	Year of Installation	Installation Method	Well Details: Depth (ft.)	Well Details: Diam. (in.)	Well Details: Screen (ft.)	Depth to Water (ft): Static	Depth to Water (ft): Pumping	Casing Material	Pump Type	Water Quality (Owner's Opinion)	Description of Well Repairs
Shallock, Jerry L.	145	S31-T35N-R13E	Private	1974	Drilled	96	0.5	—	20	—	—	Submersible	Good taste, some iron	No Repairs
Johnson, Gary	162[1]	S6-T34N-R13E	Private	—	—	—	—	—	—	—	—	—	No problem.	No Repairs.
Dhuey, David J.	166	S6-T34N-R13E	Private	—	Driven	32	2	—	25	—	Galv.	Deep Well Jet	Good, no problems	No repairs.
Buckley, Gerald	167[1]	S6-T34N-R13E	Private	1980	Drilled	57	5	2	26	50	Blk Steel	Submersible	Very good taste, no odor, little staining, sufficient quantity	None
Kloehn, Gerald	168[1]	S36-T35N-R12E	Private	—	Drilled	37.5	4	—	23	—	N/A	No Pump	—	No Repairs

[1]NMC land purchase option obtained since the 1994 well inventory.

Prepared by: CH/MLD2
Checked by: JJA1/JWS

3.6.2.2 New NMC Water Supplies

A new potable well will be constructed for the project approximately one-half mile south of the plant site, and approximately 1,200 feet northwest of Little Sand Lake. This well, as shown on Figure 3.6-8, will be located in a relatively undeveloped area in the SE¼ of the NE¼ of Section 36, T35N, R12E, Nashville Township. It will be the sole supplier of potable water to the project's various facilities.

A second non-potable well will be installed to provide construction water for the TMA. The TMA well location is also shown on Figure 3.6-8. The well will be located approximately 1,000 feet north of the TMA in the SE¼ of Section 29, T35N, R13E, of Lincoln Township. This well will be used for seasonal processing of site glacial material and for seasonal wash plant operations during the construction phases of the TMA, estimated to occur approximately every three years. A third non-potable well will be installed to provide mitigation water to groundwater fed creeks and springs. The well location is shown on Figure 3.6-8. The well will be located approximately 2,900 feet north of Swamp Creek within the proposed access road corridor in the NW¼ of Section 19, T35N, R13E, Lincoln Township. Details regarding all three wells can be found in the project's *High Capacity Well Permit Application* (Foth & Van Dyke, 1995/1998a).

3.6.3 Regional Hydrogeology/Groundwater Quality

The project area is located, as defined by Olcott (1968) in the Fox-Wolf River Hydrologic Basin. On a regional scale, the hydrogeologic conditions around the project area generally consist of saturated glacial till and outwash overlying Precambrian bedrock. According to NR 182.08(2)(c), the term regional is defined as "that area which may affect or be affected by a proposed site. In most cases this will be the proposed site and, the area within a radius of up to five miles from the site." Figure 3.6-10 illustrates the five mile radial area surrounding the project area. NR 182.08(2)(c)(4) states that the regional hydrogeology discussion should include discussions on depth to groundwater, groundwater flow characteristics, recharge and discharge areas, groundwater divides, aquifers and groundwater use. Each of these topics plus regional groundwater quality is discussed below.

3.6.3.1 Groundwater Aquifers

On a regional scale, groundwater in the vicinity of the project area occurs within two primary hydrostratigraphic units. These units consist of the Precambrian bedrock and the glacial overburden. The glacial overburden can be subdivided into glacial till and outwash. Regionally, the water table resides within the glacial deposits.

The bulk of the Precambrian bedrock, although locally fractured and showing secondary permeability features, typically yields only small amounts of water to wells. As such it does not fit any of the conventional definitions (Freeze and Cherry, 1979) of an aquifer. Figure 3.6-10a shows the location of known wells completed in the bedrock within a five mile radius of the site.

Appendix 3.6-15 contains constructor's reports or construction information for these wells. A review of the data provided in the appendix shows that the majority of the wells completed in the bedrock produce 5 gpm or less of water.

The glacial aquifer consists of saturated deposits of glacial till and glacial outwash. The glacial till typically has a low permeability and typically would not be used as an aquifer except where embedded lenses of sand and gravel exist. Based on the work of Simpkins, et al. (1987), the outwash deposits are relatively prolific on a regional scale. These outwash deposits are typically sand and gravel, and therefore are permeable enough to yield significant amounts of water. As such the outwash deposits form the primary regional aquifer for domestic and municipal water supplies. Section 3.6.2 contains information on the domestic water supply wells located in the vicinity of the project area.

The depth to groundwater within the glacial deposits is quite variable. This is attributed to the considerable topographic relief in the vicinity of the project area. Near groundwater discharge areas such as streams, lakes and wetlands, the depth to groundwater is on the order of several feet. In groundwater recharge areas located at topographic highs, or in upland areas, the depth to groundwater can be more than 100 feet.

3.6.3.2 Regional Groundwater Flow System

Groundwater flow occurs primarily within the glacial till and outwash deposits with the majority of flow occurring within the more permeable outwash deposits. Flow within the outwash can typically be characterized as occurring under unconfined conditions. However, semi-confined conditions may occur locally within the outwash due to the presence of lacustrine clay lake beds overlying the outwash or in instances where the outwash deposits are overlain by less permeable glacial till.

On a regional scale, groundwater flows from areas of high hydraulic head to areas of low hydraulic head or from potentiometric highs to potentiometric lows. The potentiometric surface is defined as the as the height to which water will rise in a well tapping a confined aquifer and is the water table under unconfined conditions. Thus under unconfined conditions, areas of high hydraulic head correspond to topographic highs in the regional water table. Similarly, areas of low hydraulic head correspond to topographic lows in the regional water table. Under unconfined conditions the potentiometric surface and water table are essentially the same except in areas where strong vertical gradients exists, such as would occur near discharge points and some lakes.

High water table elevations occur within upland areas and around upland lakes and wetlands. Low water table elevations occur in low land areas associated with streams, wetlands or lakes. Groundwater is replenished in recharge areas defined as an area where the net vertical component of flow is downward. Recharge areas are typically associated with upland areas, upland lakes and high water table elevations. Groundwater discharge areas are defined as areas where the net vertical component of flow is upwards. Groundwater discharge areas are typically restricted to a

narrow band around streams, wetlands and or lakes. Thus recharge to the glacial aquifer occurs over much of the regional study area.

In 1982 Golder Associates (1982) prepared a regional potentiometric surface map depicting the horizontal flow of groundwater within the glacial deposits. This potentiometric surface map, shown in Figure 3.6-11, was prepared from water levels taken in study area in February 1982, in addition to data on regional groundwater elevations available from the USGS. The map covers a large geographic area encompassing Lakes Metonga and Lucerne to the north; Roberts and Lost Lakes to the east; Pickerel, Crane, and Rolling Stone Lakes to the south; and Bishop Lake to the west.

The potentiometric surface map is roughly equivalent to the regional water table, depicting the change in the water table elevation and the horizontal hydraulic gradient on a regional scale. Areas where the potentiometric surface map would not be equivalent to the water table, would be in the vicinity of upland lakes, such as Little Sand Lake, that are hydraulically connected to the regional groundwater system. In these localized areas a mounded water table exists due to the occurrence of low permeability lacustrine clay and silt lake beds which create semi-confined conditions in the underlying glacial till and outwash. The large scale potentiometric surface map does not reflect these small localized mounded systems. Rather, in the vicinity of the upland lakes, the regional potentiometric surface map represents the potentiometric surface in the semi-confined underlying glacial till and outwash.

Figure 3.6-11 shows a well defined groundwater flow system constrained by a network of creeks and lakes. The near project area controlling surface water features, moving clockwise from the north, are Lake Metonga, Swamp Creek, Hemlock Creek, Ground Hemlock Lake, Crane Lake, Pickerel Lake, Rolling Stone Lake, Pickerel Creek, Mole Lake, Rice Lake and Gliske Creek. Groundwater flows from water table highs located in upland areas to discharge areas controlled by the above referenced surface water features.

The regional groundwater high of about 1,640 feet is located in the vicinity of Lake Lucerne. The groundwater divide for the hydrologic basin is located just to the north of Lake Metonga and to the east of Lake Lucerne (Olcott, 1968). South and east of this divide groundwater flows into Lake Metonga or Swamp Creek. South and west of Lake Metonga groundwater flows into Outlet Creek, Swamp Creek, Rice Lake or Gliske Creek. Outlet Creek, which drains Lake Metonga, is a tributary of Swamp Creek.

A second groundwater divide exists south of Swamp Creek in the vicinity of the proposed TMA. Flow north of this divide is to Swamp and Hemlock Creeks and Ground Hemlock Lake. South of this divide flow is southeasterly and southwesterly toward Crane, Pickerel, and Rolling Stone Lakes, and Pickerel Creek between Rolling Stone and Mole Lakes.

3.6.3.3 Regional Groundwater Quality

Information on the regional water quality was obtained from Olcott (1968). Within the glacial overburden, the groundwater typically has a dissolved solids content ranging from 200 to 300 mg/L. However the concentration of dissolved solids can be quite variable and locally can be as high as 400 mg/L. Water within the glacial till and outwash is of the calcium magnesium bicarbonate type. It is moderately hard with high iron concentrations, a common occurrence in much of the area.

3.6.4 Project Site Hydrogeology

As described in Sections 3.5.1 and 3.6.1, the hydrogeology of the study area has been thoroughly characterized through numerous investigations that included several hundred soil borings, the installation of several hundred monitoring wells, multiple pump tests, slug tests, packer tests, geophysical studies, and studies on groundwater/lake interactions. The result of these investigations is a thoroughly evaluated and well understood hydrogeologic system. The following narrative which presents the results of the groundwater investigations draws on data obtained from the studies described in Sections 3.5.1 and 3.6.1. The results of these investigations form the basis for predictions of impacts on the groundwater system due to mine activities which will be discussed later in this report.

Section 3.6.4.1 provides a detailed description of the principal hydrostratigraphic units, the hydrogeologic characteristics of which are presented in Section 3.6.4.2. Section 3.6.4.3 describes the groundwater flow system within the study area and addresses the interaction of groundwater with lakes and wetlands.

3.6.4.1 Study Area Hydrostratigraphic Units

The principal hydrostratigraphic units correspond to the major geologic formations depicted on the cross sections shown of Figures 3.5-26 through 3.5-32 in Section 3.5. Ascending the stratigraphic column the major hydrostratigraphic units across the study area consist of the Precambrian bedrock, the Pre to Early Wisconsinan Till, the coarse and fine grained outwash, and the Late Wisconsinan Till. Hydrostratigraphic units of a more local nature include lacustrine silts/clays that form the lake beds for many of the lakes within the study area such as Little Sand, Oak, Deep Hole, Duck and Skunk Lakes. The localized lacustrine deposits are also associated within the more extensive till and outwash deposits described above. In the vicinity of the ore body the bedrock has been differentiated into unweathered bedrock, structured saprolite and massive saprolite.

The Precambrian bedrock in the study area is part of the southern extension of the Canadian Shield referred to as the Southern Province. Within the study area, the Precambrian bedrock is composed of metavolcanic bedrock formed from the deposition of volcanic material just at and below the ocean floor. The deposition of the volcanic material, some of which constitutes the massive sulfide zinc and copper ore body, was followed by a period of lithification and metamorphism which hardened and solidified both the host rock and ore body over time. The

bedrock was later uplifted resulting in the near vertical orientation of the volcanic layers and ore body.

The metamorphic Precambrian bedrock that exists in the study area exhibits both primary and secondary permeability features and weathering, or tertiary, permeability features. Since the porosity of metamorphic rock is typically less that two percent and the voids that make up the porosity are minute and not interconnected, the primary permeability of the bedrock in the study area is less than 2.8E-6 ft/d (1E-9 cm/s), impermeable in the context of most groundwater studies (Freeze and Cherry, 1979). The ability of the Precambrian bedrock to transmit water is therefore governed by interconnected fractures that occur within the near surface regions of the bedrock. These fractures, or secondary permeability features act as the principal conduit for groundwater movement within the bedrock. The source of these secondary permeability features is attributed to changes in stress conditions (Freeze and Cherry, 1979) caused by events such as glaciation. Packer test studies on the bedrock, the results of which are described below, were performed to measure the permeability associated with these secondary permeability features. The secondary permeability features are the principal source of groundwater within the Precambrian bedrock.

Associated with the Precambrian bedrock surface is a structured and massive saprolite layer developed from intense weathering of the Precambrian bedrock. The massive saprolite is a clay to sandy clay, thoroughly decomposed bedrock material formed in place by chemical weathering of the metavolcanic bedrock. Since the primary and secondary permeability features of the original bedrock have been destroyed during the weathering process, the massive saprolite functions hydraulically like a conventional porous medium. Below the massive saprolite is the structured saprolite, rock which has been weathered to mostly clays and iron oxides, but still retains the rock structure. Since the original rock structure of the structured saprolite has not been completely altered by weathering processes, the structured saprolite retains primary, secondary and weathering, or tertiary, modified permeability features. Below the structured saprolite is progressively less weathered bedrock.

The massive saprolite and structured saprolite are comparatively thin hydrostratigraphic units. Given the fact that these layers reside on top of the bedrock in the vicinity of the ore body subcrop, they are an important localized feature that will control, along with the overlying glacial till, the inflow of groundwater from the glacial overburden to the mine. Thus, the massive and structured saprolite have been differentiated primarily in the vicinity of the ore body. On the scale of the study area, the massive saprolite and structured saprolite do exist in localized areas depending on rock type but have not been differentiated since groundwater flow on the scale of the study area will be governed by the more predominant and transmissive glacial deposits.

The Pre- to Early Wisconsinan Till resides on top of the Precambrian bedrock. In the vicinity of the ore body, the Pre- to Early Wisconsinan Till resides stratigraphically on top of the massive saprolite. Deposited more than 40,000 years $\pm$ 2,000 years before present (BP), the Pre- to Early Wisconsinan Till is nearly continuous across the entire study area and is composed of dark brown, brown or yellowish red calcareous to non-calcareous till of the Marathon and Lincoln Formations. Ice advances from the northwest and north during Pre and Early Wisconsinan time deposited this material. The Pre- to Early Wisconsinan Till formation contains a higher content

of expandable clay minerals, less sand and a higher silt and clay content than the outwash deposits, and younger overlying Late Wisconsinan age tills of the Horicon and Copper Falls Formations (Simpkins, et al. 1987). Although this unit is thick in some areas and nearly always saturated, the suitability of the Pre- to Early Wisconsinan Till as an aquifer is marginal at best. Occasional thin sand lenses may provide sufficient water for domestic uses. Across the study area the only known area where parts of the Pre- to Early Wisconsinan Till is unsaturated is over the middle of the ore body where the water table resides within the till.

The Pre- to Early Wisconsinan Till is typically separated from the younger and overlying Late Wisconsinan age till formations by undifferentiated deposits of coarse and fine grained outwash sands and gravel. Deposited by glacial meltwater streams during advances and retreat of the glaciers during the Wisconsinan glaciation period, the outwash deposits are ubiquitous across the study area. The outwash deposits tend to thin to the north in the vicinity of Swamp Creek and constitute the predominant glacial material south of Little Sand Lake. Extensive in nature, the outwash deposits comprise the principal aquifer across the study area. Swamp, Hemlock, Outlet, and Pickerel Creek and Creek 12-9 commonly incise the outwash and act as the principal sinks for groundwater discharge. Far field lakes such as Rolling Stone, Crane, Pickerel, Ground Hemlock and Mole also incise the outwash deposits and act as additional sinks for the discharge of groundwater from the outwash. Near the Plant Site, smaller lakes such as Little Sand, Oak, Duck and Skunk reside on top of the outwash, separated from the outwash by a layer of lacustrine silt and clay. Across much of the study area the water table resides within the outwash deposits.

The Late Wisconsinan Till is the upper most hydrostratigraphic unit, residing at the surface across upland areas. Deposited between 19,000 and 11,000 years BP this till is composed of the Horicon Formation and Copper Falls Formation till deposited by the advance of the Green Bay and Langlade Lobes, respectively. The Late Wisconsin till typically has a higher sand content than the older Pre- to Early Wisconsinan Till, is reddish brown to yellowish red and has non-expandable illite as its predominant clay mineral (Simpkins et al., 1987). The late Wisconsinan Till is less extensive in nature than the other glacial formations, residing primarily in upland areas around the TMA and plant site. In areas where the Late Wisconsinan Till is absent the outwash resides at the surface. As such, much of the recharge to the groundwater occurs through the till in upland areas. Where the till is absent, recharge occurs through the outwash sands and gravels. In the vicinity of the TMA, the water table resides in the Late Wisconsinan Till. Elsewhere in the study area this unit is frequently unsaturated and thus is a marginal aquifer.

Localized deposits of lacustrine silt and clay in upland areas form the last recognized hydrostratigraphic unit in the study area. The lacustrine deposits are typically associated with and derived from the Late Wisconsinan Till. Since the Late Wisconsinan Till contains illite as its principal clay mineral, the clay fraction of the lacustrine deposits is primarily illite, a non-expandable clay. Being local in nature, these deposits play a minor role in governing the overall regional flow of groundwater across the study area. However, locally they play a dominant role in controlling the hydrologic interaction between the groundwater system and lakes and wetlands.

3.6.4.2 Hydrogeologic Characteristics

The hydrogeologic characteristics of the Precambrian bedrock, structured saprolite, massive saprolite, glacial overburden and lake beds have been extensively characterized via pump tests, slug tests, permeability tests and packer tests. Sections 3.6.4.2.1 through 3.6.4.2.4 present the results of these studies.

3.6.4.2.1 Bedrock

The hydrogeologic characteristics of the bedrock in the vicinity of the ore body have been extensively reviewed in the report Bedrock Hydrogeology at the Crandon Site (Foth & Van Dyke, 1995b) which is contained in its entirety in Appendix 3.5-15. This report was submitted to relevant regulatory agencies and others in February 1995. A brief summary of this report is provided below followed by the principal conclusions regarding the transmissive properties of the bedrock and the conceptual model for groundwater inflow to the mine.

Given the low primary permeability of metavolcanic bedrock as described above, secondary and tertiary permeability features, such as fractures and weathered bedrock, will control the transmissive characteristics of the bedrock in the vicinity of the ore body. These secondary and tertiary hydrogeologic characteristics of the bedrock were evaluated based on exploration delineation and drilling, fracture characterization studies, bedrock weathering studies, packer tests, down hole temperature logging, bedrock water chemistry data and vertical gradients between the bedrock and glacial overburden.

Data to support the characterization of the Crandon deposit and surrounding bedrock has included six separate bedrock drilling programs totaling approximately 320,000 feet (60 miles) in over 200 angle holes in the immediate vicinity of the ore body. Figure 3.6-12 presents a plan map showing the traces of the bedrock drill holes. The six drilling campaigns were conducted over a 20 year period. Early drilling programs provided factual data on both near surface and deep structure and stratigraphy, particularly the location, trend and continuity of the Crandon Formation hanging wall and footwall contacts, and contained ore zones. Later drilling programs intersected contacts and ore zones at their interpreted locations. This means that there has been no significant north-south fault offsets, to the interpreted east-west stratigraphic trends, that could provide a means for transmission of water into the mine from the regional bedrock.

Fracture studies described in the bedrock hydrogeology report in Appendix 3.5-15 show that interconnected fractures that could give rise to flow within the bedrock, and ultimately from the bedrock to the mine, are limited to the near surface bedrock in the hanging wall and footwall rocks surrounding the Crandon Formation. Within the Crandon Formation, interconnected fractures exist to a depth of about 1,000 feet. Within the hanging wall and foot wall, fractures are most prominent along east-west trending trajectories that nearly parallel the strike of bedding planes and are least common along north-south trending trajectories. At depth there is little evidence of water movement through the fractures suggesting water movement in the bedrock is restricted to the upper few hundred feet of the bedrock.

Weathering studies described in the bedrock hydrogeology report show that the maximum vertical extent of weathered bedrock occurs within the Crandon Formation to a depth of about 1,100 feet. Figure 3.6-12 shows the location of several longitudinal weathering profiles within and north and south of the Crandon Formation. These weathering profiles are displayed in Figures 3.6-13 through 3.6-16. Weathering decreases in depth and intensity as one moves north into the hanging wall away from the Crandon Formation. At 400 feet north of the ore body, strong to moderate weathering is limited to near surface bedrock regions extending to a depth of about 250 feet. The depth of weathering is less in the foot wall rocks to the south of the Crandon Formation. Two hundred feet south of the ore body, strong to moderate weathering extends to a depth of about 250 feet. Table 3.6-7 provides a summary of weathering and bedrock permeability data for the footwall, Crandon formation and hanging wall.

Exploration drilling programs have delineated a fresh unweathered, post-mineralization gabbro dike south of the ore body. Locally named the Duck Lake gabbro dike, this unit, located immediately south of the ore body, as depicted in Figures 3.6-12 and 3.6-17, is likely to function as a low permeability barrier to potential lateral flow from the bedrock into the mine. The only potential for lateral flow across this formation into the mine would be the upper 200 to 300 feet where there is some evidence of water movement.

In the 1970s and 1980s, packer and slug tests were performed on 12 core holes open to the bedrock and three piezometers screened within the bedrock. The location of these core holes and piezometers are shown in Figure 3.6-18. The 1970s and 1980s packer and slug test data, summarized in Table 3.6-8, shows that the bulk hydraulic conductivity of the bedrock outside the area of influence of the Crandon Formation is likely to be in the range of 2.8E-2 ft/d (1E-5 cm/s) to 2.8 E-3 ft/d (1E-6 cm/s). Higher permeability bedrock is typically associated with weathered regions of the Crandon Formation and weathered zones along the Crandon Formation hanging wall contact. Given that fractures are oriented preferentially in an east west direction, it is likely that the bedrock is anisotropic with the east-west trending permeability being greater than the north-south permeability.

Two pump tests were also conducted on hole 214. The first test was conducted over an interval from 107 feet to 360 feet, and was able to produce water at a rate of only 0.36 gpm, perhaps derived from a fracture zone at 325 to 345 feet. When a larger interval was tested, 107 feet to 750 feet, water was produced at a slightly higher rate of two gpm indicating that other fracture zones were likely intersected. The low water yielding capacity of the rock in hole 214 suggests restricted water movement within the region tested.

Downhole temperature measurements in the boreholes shown on Figure 3.6-19 and summarized in Tables 3.6-9 and 3.6-10 show a smooth regional thermal gradient of 0.81 °F per 100 vertical feet. With the exception of several small temperature fluctuations of less than 0.5 °F in holes

Table 3.6-7

Crandon Deposit Weathering and Permeability Data

		Footwall				Crandon Formation				Hanging Wall			
Weathering Intensity Rating	Destructive Agent	Rock Chemistry	General Pattern	Comments	Permeability	Rock Chemistry	General Pattern	Comments	Permeability	Rock Chemistry	General Pattern	Comments	Permeability
Strong: Strong development of two or more of the destructive processes, (oxidation, leaching, argillization, or fracturing. Rock will have low compressive strengths and workings would have to be supported at all times.	Acid water due to the breakdown of varying amounts of sulfides during oxidation (i.e., weathering).	Overall siliceous composition in large part due to silicification. Fine pyrite dusting and multi thin quartz, calcite, sulfide veinlets.	Uniform relatively horizontal zone with root like penetrations into underlying moderate zone.	Leaching breaks down sulfides, silicates, and carbonates, alters come to clay. May or may not increase permeability.	Similar throughout strong, moderate, and low zones. Gradual decrease with depth. Argillization tends to plug up porosity developed in leaching and reduces permeability.	Variable with high to low sulfide content, siliceous alteration, tuffs, and argillite units.	Irregular with several deeper spikes, and local isolated areas.	Varied internal stratigraphy controls irregular pattern and types of weathering. High sulfide, strong acid generation. Interbedded units, clay development from silicates. Fracturing. Solutions channel down beds.	Varied but commonly porous with higher permeability. More chlorite rich areas alter to clay with lower permeability. 255: 8.9x10-4 256: 2.5x10-4	Relatively homogeneous chlorotic tuff with local more siliceous material.	Broad gently undulating. Becomes less pronounced as move north from deposit.	Argillization due to chlorite tends to be pervasive. Little sulfide. Zone becomes deeper as approach Crandon Formation from north due to weathering of Crandon Deposit sulfides.	Near surface weathering and fractures. Clays plug up. 255: 1.7x10-5
Moderate: Strong development of one of the destructive processes (or moderate development of two) and weak to moderate development of at least one more. Rocks may or may not be strong enough to hold a back, depending upon which destructive processes have been active. Strong development of argillization or fracturing would make the rock very weak or unstable, whereas strong development of oxidation or leaching may not seriously affect its ability to hold a back.	Acid water due to the breakdown of varying amounts of sulfides during oxidation (i.e., weathering).	Overall siliceous composition in large part due to silicification. Fine pyrite dusting and multi thin quartz, calcite, sulfide veinlets.	Uniform relatively horizontal zone with root like penetrations less abundant into lower zones.	More limited leaching and development of clay. Similar but less intense than above.	Similar throughout strong, moderate, and low zones. Gradual decrease with depth. Argillization tends to plug up porosity developed in leaching and reduces permeability. 254: 3.4x10-6	Variable with high to low sulfide content, siliceous alteration, tuffs, and argillite units.	Irregular broad zone along strike with wider deeper protrusions to depth associated with stronger intensity spikes from above.	As above, with moderate zone adjacent to and surrounds strong weathered areas. Can follow along strike nearer surface.	Varied, moderate to high depending on horizon. 66: 1.8x10-5 213: 3.4x10-3 213: 3.4x10-4 213: 2.4x10-3 256: 9.8x10-5	Relatively homogeneous chlorotic tuff with local more siliceous material.	road gently undulating. Becomes less pronounced as move north from deposit.	Argillization due to chlorite tends to be pervasive. Little sulfide. Zone becomes deeper as approach Crandon Fm from north due to weathering of Crandon Deposit sulfides.	Permeability decreases, fewer fractures, some plugging due to clay. 66: 1.8x10-5 5AL: 1.0x10-7 253: 6.4x10-6 213: 2.7x10-5

Table 3.6-7 *(Continued)*

Weathering Intensity Rating	Destructive Agent	Footwall				Crandon Formation				Hanging Wall			
		Rock Chemistry	General Pattern	Comments	Permeability	Rock Chemistry	General Pattern	Comments	Permeability	Rock Chemistry	General Pattern	Comments	Permeability
Low: Moderate leaching with only minor other effects. The compressive strength of the rock is not seriously reduced.	Acid water due to the breakdown of varying amounts of sulfides during oxidation (i.e., weathering).	Overall siliceous composition in large part due to silicification. Fine pyrite dusting and multi thin quartz, calcite, sulfide veinlets.	Broad open poorly defined areas.	Very limited leaching and alteration effects.	Decreases due to depth and lack of weathering effects. 66: 9.0x10-6 70: 1.2x10-5 70: 8.6x10-6 254: 7.0x10-6 257: 7.6x10-6	Variable with high to low sulfide content, siliceous alteration, tuffs, and argillite units.	Broad smooth zone below moderate intensity zone.	Not significant at depth below moderate zone.	Moderate to locally lower permeability. 66: 9.0x10-6 70: 1.2x10-5 70: 8.6x10-6 213: 1.0x10-4	Relatively homogeneous chlorotic tuff with local more siliceous material.	Broad gentle, not significant zone below moderate zone.	Broad not significant.	Few fractures. 66: 9.0x10-6 70: 1.2x10-5 70: 8.6x10-6 213: 5.0x10-6 213: 2.0x10-5 213: 2.2x10-5 213: 3.8x10-5
Weak: Weak development of leaching and/or oxidation. Rock strengths are not affected.	Acid water due to the breakdown of varying amounts of sulfides during oxidation (i.e., weathering).	Overall siliceous composition in large part due to silicification. Fine pyrite dusting and multi thin quartz, calcite, sulfide veinlets.	Broad open poorly defined areas.	Very limited leaching and alteration effects.	Decreases due to depth and lack of weathering effects. 91: 1.3x10-5 91: 1.9x10-5 165: 1.2x10-7	Variable with high to low sulfide content, siliceous alteration, tuffs, and argillite units.	Broad smooth zone below low intensity zone.	Not significant at depth below low zone.	91: 1.3x10-5 91: 1.9x10-5 77: 5.7x10-6 165: 5.8x10-7	Relatively homogeneous chlorotic tuff with local more siliceous material. (a) Leakage reported	Broad not significant.	Broad not significant.	9AL: 2x10-8 F 91: 1.3x10-5 e 5AU: 2x10-6 w 77: 5.7x10-6 253: 1.7x10-6 f 155: 5.8x10-7 r 155: 4.9x10-7 a 155: 4.4x10-7 c 155: 4.7x10-7 t 155: 3.9x10-7 u 155: 4.8x10-7 r 155: 5.4x10-7 e 155: 7.9x10-7 s 155: 3.8x10-5 155: 6.0x10-5a 155: 6.3x10-5a 165: 1.4x10-6

All permeability values reported in cm/s, multiply by 2834.6 to arrive at value in units of ft/d.

Prepared by: AJE
Checked by: SVD1

Table 3.6-8

Summary Bedrock Permeability Tests

		Core Interval Tests										
			Drill Depth (ft)			Vertical Depth (ft)		Horz to CrHW (ft)		Permeability		
	Hole #	Collar Dip	From	To	Thick	From	To	From	To	ft/d	cm/sec	Tests(c)	Formations(d)
1	EX-9AL	—	276.4	283.4	7	276.4	283.4	+1000	+1000	$5.7x10^{-5}$	$2x10^{-8}$	HW	Regional PC Bedrock
2	EX-5AL	—	183.9	191.9	8	183.9	191.9	+1000	+1000	$2.8x10^{-4}$	$1x10^{-7}$	HW	Regional PC Bedrock
3	EX-5AU	—	160.9	167.9	7	160.9	167.9	+1000	+1000	$5.7x10^{-3}$	$2x10^{-6}$	HW	Regional PC Bedrock
4	257	-90	246	360	114	246	360	833	833	$2.1x10^{-2}$	$7.6x10^{-6}$	FW	SL
5	254	-90	217	315	98	217	315	833	833	$9.6x10^{-3}$	$3.4x10^{-6}$	FW	SL
6	254	-90	315	435	120	315	435	98	115	$2.0x10^{-2}$	$7.0x10^{-6}$	FW	SL
7	256	-90	167	282	115	167	282	0	0	0.71	$2.5x10^{-4}$	CR	CR
8	256	-90	282	394	112	282	394	0	0	$2.8x10^{-1}$	$9.8x10^{-5}$	CR	CR
9	213	-75	144	231	87	139	223	278	223	$7.7x10^{-2}$	$2.7x10^{-5}$	HW	UML
10	—	—	231	312	81	223	301	223	177	$1.4x10^{-2}$	$5.0x10^{-6}$	HW	UML
11	—	—	312	392	80	301	379	177	128	$5.7x10^{-2}$	$2.0x10^{-5}$	HW	UML
12	—	—	392	472	77	379	453	128	79	$6.2x10^{-2}$	$2.2x10^{-5}$	HW	LML
13	—	—	472	552	83	453	533	79	30	$1.1x10^{-1}$	$3.8x10^{-5}$	HW	LML
14	—	—	552	631	79	533	609	30	26	9.6	$3.4x10^{-3}$	CR	CR
15	—	—	631	724	93	609	699	26	69	9.6	$3.4x10^{-3}$	CR	CR
16	—	—	724	808	83	699	780	69	118	6.8	$2.4x10^{-3}$	CR	CR
17	—	—	808	879	72	780	849	118	141	$2.8x10^{-1}$	$1.0x10^{-4}$	CR	CR

Table 3.6-8 *(Continued)*

Hole #		Collar Dip	Core Interval Tests: Drill Depth (ft) From	To	Thick	Vertical Depth (ft) From	To	Horz to CrHW (ft) From	To	Permeability ft/d	cm/sec	Tests(c)	Formations(d)
18	91	-75	179	1415	1236	175	1025	635	400	$3.7x10^{-2(b)}$	$1.3x10^{-5(b)}$	HW/CR/FW	SK/RL/UML/LML/CR/SL
19	—	—	852	1415	563	735	1025	145	400	$5.4x10^{-2(b)}$	$1.9x10^{-5(b)}$	HW/CR/FW	LML/CR/SL
20	155	-90	161	3050	2889	161	3050	836	295	$1.6x10^{-3}$	$5.8x10^{-7}$	HW	SK/RL/UML
21	—	—	362	3050	2688	362	3050	771	295	$1.4x10^{-3}$	$4.9x10^{-7}$	HW	SK/RL/UML
22	—	—	562	3050	2488	562	3050	715	295	$1.2x10^{-3}$	$4.3x10^{-7}$	HW	SK/RL/UML
23	—	—	842	3050	2208	842	3050	656	295	$1.3x10^{-3}$	$4.7x10^{-7}$	HW	RL/UML
24	—	—	942	3050	2108	942	3050	633	295	$1.1x10^{-3}$	$3.9x10^{-7}$	HW	RL/UML
25	—	—	1042	3050	2008	1042	3050	623	295	$1.4x10^{-3}$	$4.8x10^{-7}$	HW	RL/UML
26	—	—	1372	3050	1678	1372	3050	561	295	$1.5x10^{-3}$	$5.4x10^{-7}$	HW	RL/UML
27	—	—	2102	3050	948	2102	3050	462	295	$2.2x10^{-3}$	$7.9x10^{-7}$	HW	UML
28	—	—	2202	2215	13	2202	2215	442	295	$1.1x10^{-1}$	$3.8x10^{-5}$	HW	RL/UML
29	—	—	2710	2723	13	2710	2723	360	295	$1.8x10^{-1(a)}$	$6.0x10^{-5(a)}$	HW	UML
30	—	—	2712	2725	13	2712	2725	360	295	$1.9x10-^{1(a)}$	$6.3x10^{-5(a)}$	HW	UML
31	70	-65	302	1334	1037	275	960	400	480	$3.4x10^{-2}$	$1.2x10^{-5}$	HW/CR/FW	RL/ML/CR/SL
32	—	—	552	1334	782	490	960	200	480	$2.4x10^{-2}$	$8.6x10^{-6}$	HW/CR/FW	UML/LML/CR/SL
33	255	-55	252	300	48	183	217	46	0	$4.8x10^{-2}$	$1.7x10^{-5}$	HW	LML

Table 3.6-8 *(Continued)*

Hole #	Collar Dip	Core Interval Tests: Drill Depth (ft) From	To	Thick	Vertical Depth (ft) From	To	Horz to CrHW (ft) From	To	Permeability ft/d	cm/sec	Tests(c)	Formations(d)
34	—	—	300	426	126	217	308	0	92	2.5	$8.9x10^{-4}$	HW/FW /CR	LML/CR
35	165	-70	1600	2971	1371	1560	2585	400	590	$4.0x10^{-3}$	$1.4x10^{-6}$	HW/FW /CR	UML/LML/CR/SL
36	—	—	2297	2971	674	2150	2585	23	590	$1.6x10^{-3}$	$5.8x10^{-7}$	HW/FW /CR	LML/CR/SL
37	—	—	2920	2971	51	2575	2585	560	590	$3.4x10^{-4}$	$1.2x10^{-7}$	HW/FW /CR	LML/CR/SL
38	66	-65	228	1078	850	205	750	340	350	$5.1x10^{-2(b)}$	$1.8x10^{-5(b)}$	HW/FW /CR	UML/LML/CR/SL
39	—	—	402	1078	676	351	750	230	350	$2.6x10^{-2(b)}$	$9.0x10^{-6}$	HW/FW /CR	UML/LML/CR/SL
40	253	-90	167	258	91	167	258	62	43	$1.8x10^{-2}$	$6.4x10^{-6}$	HW	LML
41	—	—	258	375	117	258	375	43	16	$4.8x10^{-3}$	$1.7x10^{-6}$	CR	LML/CR
42	77	-70	602	1049	447	575	930	130	160	$1.6x10^{-2}$	$5.7x10^{-6}$	HW	LML/SL

(a) Some leakage around packers on these tests because of open fractures. D&M 4/19/1978, Table 1.
(b) Possible leakage around uncemented casing from overlying glacial material. D&M 4/19/1978, p.7.
(c) HW = Hanging Wall, FW = Footwall, CR = Crandon Formation
(d) SL = Sand Lake Formation, CR = Crandon Formation, UML = Upper Mole Lake Formation, LML = Lower Mole Lake Formation, RL = Rice Lake Formation
Shaded values representative of regional bedrock unaffected by weathering of Crandon Formation.

Prepared by: AJE
Checked by: SVD1

Table 3.6-9

Crandon Deposit Down Hole Bedrock Temperature Data (EDCON-1978)
Holes 11, 15, 19, 22, 38 and 42

	Hole No. 11			Hole No. 15			Hole No. 19			Hole No. 22			Hole No. 38			Hole No. 42		
	Drill Ft	Vertical Ft	°F	Drill Ft	Vertical Ft	°F	Drill Ft	Vertical Ft	°F	Drill Ft	Vertical Ft	°F	Drill Ft	Vertical Ft	°F	Drill Ft	Vertical Ft	°F
1	250	240	52.5	200	200	51.1	250	260	52.1	250	240	52.2	250	245	52.2	200	200	51.6
2	300	289	52.9	250	250	51.5	300	305	52.5	300	271	52.5	300	290	52.6	250	249	52.0
3	350	338	53.2	300	301	52.0	350	350	52.9	350	320	52.9	350	338	53	300	300	52.4
4	400	380	53.6	350	350	52.5	400	395	53.3	400	362	53.2	400	390	53.4	350	345	52.7
5	450	430	53.9	400	395	52.9	450	445	53.7	450	410	53.6	450	430	53.8	400	395	53.1
6	500	476	54.3	450	450	53.3	500	495	54.1	500	451	53.9	500	470	54.3	450	445	53.5
7	550	521	54.7	500	498	53.8	550	538	54.5	550	500	54.2	550	530	54.7	500	500	53.8
8	600	565	55.1	550	545	54.2	600	585	54.9	600	550	54.5	600	575	55.1	550	550	54.2
9	650	602	55.4	600	595	54.7	650	630	55.3	650	570	54.9	650	626	55.5	600	595	54.4
10	700	649	55.8	650	645	55.1	700	685	55.7	700	620	55.3	700	671	55.9	650	648	54.6
11	750	696	56.2	700	695	55.5	750	720	56.0	750	661	55.6	750	721	56.2	700	700	54.8
12	800	745	56.5	750	740	55.9	800	780	56.4	800	695	56.0	800	769	56.6	750	745	55.0
13	850	775	56.9	800	790	56.3	850	820	56.7	850	722	56.3	850	810	57.0	800	795	55.3
14	900	811	57.2	850	844	56.7	900	870	57.1	900	759	56.6	900	859	57.3	850	849	55.6
15	950	854	57.5	900	991	57.1	950	910	57.5	950	799	56.9	950	900	57.7	900	895	55.9
16	1000	890	57.8	950	945	57.5	1000	945	57.8	1000	830	57.2	1000	945	58.1	950	945	56.3
17	1050	921	58.1	1000	991	57.9	1050	980	58.1	1050	859	57.5	1050	985	58.4	1000	995	56.7
18	1100	956	58.4	1050	1040	58.3	1100	1020	58.4	1100	888	57.7	1100	1025	58.7	1050	1045	57.0
19	1150	991	58.7	1100	1090	58.8	1150	1060	58.7	1150	915	57.9	1150	1058	59	1100	1095	57.4
20	1200	1020	58.9	1150	1140	59.3	1200	1090	59.1	1200	945	58.2	1200	1100	59.3	1150	1140	57.7
21	1250	1050	59.1	1200	1183	59.8	1250	1120	59.4	1250	974	58.4	1250	1129	59.6	1200	1190	58.1
22	1300	1069	59.3	1250	1235	60.2	1300	1155	59.7	1300	1000	58.8	1300	1160	59.8	1250	1237	58.4
23	1350	1110	59.6	1300	1285	60.7	1350	1190	59.9				1350	1190	60.0	1300	1285	58.7
24				1350	1340	61.1	1400	1220	60.2				1400	1218	60.3	1350	1332	59.1
25				1400	1481	61.5	1450	1245	60.4				1450	1245	60.5	1400	1381	59.4
26				1450	1436	61.9	1500	1275	60.7				1500	1258	60.7	1450	1430	59.7

Table 3.6-9 *(Continued)*

	Hole No. 11			Hole No. 15			Hole No. 19			Hole No. 22			Hole No. 38			Hole No. 42		
	Drill Ft	Vertical Ft	°F	Drill Ft	Vertical Ft	°F	Drill Ft	Vertical Ft	°F	Drill Ft	Vertical Ft	°F	Drill Ft	Vertical Ft	°F	Drill Ft	Vertical Ft	°F
27				1500	1481	62.3	1550	1300	60.9				1550	1289	60.9	1500	1476	60.0
28				1550	1530	62.6	1600	1330	61.1				1600	1306	61.1	1550	1521	60.4
29				1600	1579	63.0	1650	1350	61.3				1650	1325	61.2	1600	1570	60.7
30				1650	1625	63.3	1700	1370	61.5				1700	1340	61.4	1650	1618	61.0
31				1700	1672	63.6	1750	1390	61.6							1700	1661	61.4
32				1750	1715	63.9	1800	1410	61.8							1750	1709	61.7
33				1800	1759	64.2	1850	1430	62.0							1800	1756	62.1
34				1850	1800	64.4	1900	1445	62.2							1850	1800	62.6
35				1900	1834	64.7										1900	1845	62.9
36				1950	1870	64.9										1950	1890	63.2
37				2000	1900	65.1										2000	1935	63.5
38				2050	1930	65.3										2050	1980	63.9
39				2100	1950	65.5										2100	2018	64.1
40				2150	1978	65.7										2150	2055	64.2
41				2200	2000	65.8										2200	2098	64.4
42				2550	2028	66.0										2250	2137	64.5
43				2300	2045	66.1										2300	2175	64.8
44				2350	2066	66.3										2350	2210	65.0
45				2400	2082	66.4										2400	2244	65.3
46				2450	2100	66.6										2450	2279	65.5
47																2500	2314	65.7
48																2550	2341	66.0
49																2600	2372	66.2
50																2650	2400	66.3
51																2700	2430	66.6
52																2750	2455	66.8
53																2800	2470	67.1

Prepared by: AJE
Checked by: JCP

Table 3.6-10

Crandon Deposit Down Hole Bedrock Temperature Data (EDCON-1978)
Holes 60, 80, 91, 139 and 155

	Hole No. 60			Hole No. 80			Hole No. 91			Hole No. 139			Hole No. 155		
	Drill Ft	Vertical Ft	°F	Drill Ft	Vertical Ft	°F	Drill Ft	Vertical Ft	°F	Drill Ft	Vertical Ft	°F	Drill Ft	Vertical Ft	°F
1	150	152	51.5	300	210	52.6	150	145	51.1				150	150	51.6
2	200	205	51.9	350	245	52.9	200	195	51.3				200	200	52.0
3	250	251	52.2	400	275	53.3	250	240	51.6				250	250	52.5
4	300	307	52.6	450	305	53.5	300	290	52.0		Frozen Pen Problems Top 500'		300	300	53.0
5	350	359	53.1	500	345	53.7	350	340	52.3				350	350	53.4
6	400	410	53.5	550	376	54.0	400	385	52.7				400	400	54.0
7	450	455	53.9	600	414	54.2	450	425	53.0				450	450	54.4
8	500	510	54.4	650	445	54.5	500	470	53.3				500	500	54.9
9	550	560	54.8				550	515	53.7	550	565	54.9	550	550	55.3
10	600	610	55.3				600	565	54.1	600	619	55.2	600	600	55.5
11	650	661	55.7				650	595	54.5	650	665	55.7	650	650	55.8
12	700	711	56.1				700	640	54.9	700	716	56.2	700	700	56.2
13	750	760	56.6				750	675	55.2	750	770	56.6	750	750	56.6
14	800	810	57.0				800	710	55.7	800	820	57.0	800	800	57.0
15	850	858	57.4				850	748	55.9	850	873	57.4	850	850	57.5
16	900	910	57.8				900	780	56.2	900	926	57.8	900	900	57.9
17	950	960	58.2				950	815	56.6	950	975	58.2	950	950	58.4
18	1000	1010	58.6				1000	845	56.9	1000	1029	58.6	1000	1000	58.8
19	1050	1056	59.1				1050	879	57.2	1050	1075	59.0	1050	1050	59.3
20	1100	1115	59.5				1100	900	57.4	1100	1130	59.3	1100	1100	59.7
21	1150	1160	59.9				1150	929	57.7	1150	1180	59.6	1150	1150	60.0
22	1200	1215	60.4				1200	950	57.9	1200	1230	60.1	1200	1200	60.4
23	1250	1265	60.8				1250	974	58.2	1250	1276	60.5	1250	1250	61.0

Table 3.6-10 *(Continued)*

	Hole No. 60			Hole No. 80			Hole No. 91			Hole No. 139			Hole No. 155		
	Drill Ft	Vertical Ft	°F	Drill Ft	Vertical Ft	°F	Drill Ft	Vertical Ft	°F	Drill Ft	Vertical Ft	°F	Drill Ft	Vertical Ft	°F
24	1300	1315	61.2				1300	995	58.4	1300	1330	60.9	1300	1300	61.4
25	1350	1358	61.6				1350	1016	58.6	1350	1381	61.3	1350	1350	61.8
26	1400	1419	62.1				1400	1038	58.8	1400	1430	61.7	1400	1400	62.1
27	1450	1470	62.4							1450	1480	62.1	1450	1450	62.5
28	1500	1521	62.8							1500	1530	62.5	1500	1500	62.9
29	1550	15571	63.2							1550	1580	62.9	1550	1550	63.2
30	1600	1625	63.6							1600	1629	63.3	1600	1600	63.5
31	1650	1674	63.9							1650	1681	63.7	1650	1650	63.8
32	1700	1727	64.3							1700	1735	64.0	1700	1700	64.2
33	1750	1778	64.6							1750	1785	64.3	1750	1750	64.5
34	1800	1820	64.9							1800	1832	64.6	1800	1800	64.9
35	1850	1876	65.3							1850	1884	64.9	1850	1850	65.3
36	1900	1920	65.6							1900	1934	65.2	1900	1900	65.7
37	1950	1965	66.0							1950	1980	65.6	1950	1950	66.1
38	2000	2012	66.4							2000	2031	65.9	2000	2000	66.5
39	2050	2055	66.7							2050	2080	66.3	2050	2050	66.9
40	2100	2105	67.0							2100	2130	66.5	2100	2100	67.3
41	2150	2149	67.4							2150	2175	66.9	2150	2150	67.7
42	2200	2190	67.7							2200	2212	67.1	2200	2200	68.0
43	2250	2235	68.0							2250	2269	67.7	2250	2250	68.3
44	2300	2275	68.3							2300	2321	68.1	2300	2300	68.5
45	2350	2320	68.7							2350	2369	68.3	2350	2350	68.9
46	2400	2360	69.0							2400	2416	68.6	2400	2400	69.3
47	2450	2400	69.2							2450	2460	68.8	2450	2450	69.6
48	2500	2440	69.5							2500	2503	69.0	2500	2500	69.9

Table 3.6-10 *(Continued)*

	Hole No. 60			Hole No. 80			Hole No. 91			Hole No. 139			Hole No. 155		
	Drill Ft	Vertical Ft	°F	Drill Ft	Vertical Ft	°F	Drill Ft	Vertical Ft	°F	Drill Ft	Vertical Ft	°F	Drill Ft	Vertical Ft	°F
49										2550	2550	69.1	2550	2550	70.2
50										2600	2590	69.6	2600	2600	70.5
51										2650	2640	69.8	2650	2650	71.0
52										2700	2690	70.1	2700	2700	71.5
53										2750	2731	70.4	2750	2750	71.8
54										2800	2774	70.8	2800	2800	72.0
55										2850	2810	71.0	2850	2850	72.2
56										2900	2850	71.0	2900	2900	72.5
57										2950	2886	71.3			
58										3000	2919	71.6			
59										3050	2957	71.8			
60										3100	2990	71.9			
61										3150	3020	72.1			
62										3200	3051	72.4			
63										3250	3085	72.6			
64										3300	3115	72.8			
65										3350	3145	72.9			
66										3400	3171	73.1			

Prepared by: AJE
Checked by: JCP

139 and 155, there were no temperature deflections encountered in the boreholes that would indicate significant circulation of fresh water. Circulation of fresh water through the fractured bedrock should create widespread temperature fluctuations within the hole and destroy the thermal gradient trends. Alternatively, restricted circulation of water through infrequent fractures would tend to produce small deflections in down hole temperatures, which is what was recorded.

The fracture characterization studies discussed in the bedrock hydrogeology report (Appendix 3.5-15), indicate that limited circulation of water may take place in the upper 1,000 feet of the bedrock due to higher fracture frequency and more interconnected fractures. The temperature measurements indicate that this circulation, if present, is minor since no alteration of the thermal gradient or large water movement is evident. Below the upper 1,000 feet of bedrock, the fracture studies discussed above suggest that circulation of water is not likely taking place, except perhaps over geologic time scales. The temperature logs support this interpretation since there is no significant alteration in the thermal gradient.

Bedrock water chemistry data supports the above interpretation of restricted water movement within the upper reaches of the bedrock. Bedrock water samples from nine angled core holes that intersected the Crandon Formation and one vertical core hole in the hanging wall were sampled over discrete intervals. The location of the tested core holes are shown in Figure 3.6-20. The data is summarized in Table 3.6-11.

In core holes that intersected the Crandon Formation, the chloride concentration was less than 50 mg/L for those samples collected above 1,800 feet. Water samples collected from below 1,800 feet contained chloride concentrations ranging from about 2,000-5,000 mg/L. Similarly, the common alkalies and alkaline earths (sodium, potassium, calcium, and magnesium) increased significantly below 1,800 feet. Collectively this data indicates that meteoric water may circulate in the weathered zones of the Crandon Formation to a depth of about 1,800 feet.

Within the hanging wall, samples were collected from 10 intervals within vertical core hole 155. The chloride concentration in all the samples was consistently above 2,000 mg/L from a depth of 362 feet to a depth of 3,050 feet. The high chloride concentrations indicate that meteoric water is not readily circulating below a depth of 362 feet in the hanging wall.

The fact that saline water was encountered in the hanging wall at shallow depths in hole 155 and that meteoric water was encountered at shallow depths in the Crandon Formation indicates that lateral movement of water between the hanging wall and Crandon Formation is likely restricted. Water chemistry data also suggests that water seeping into the mine workings from deep fractures within the hanging wall and footwall will likely be from pockets of saline water contained in, as identified by fractures studies, discontinuous fractures that do not extend to the bedrock surface, and therefore, would not, when drained, induce additional drawdown in the near bedrock surface. This general conclusion is consistent with work reported by Kelly, et al. (1986), who performed an extensive analysis of saline waters at Precambrian mine sites in the Keweenaw Peninsula of Northern Michigan. Kelly, et al. (1986) concludes that saline waters in the Precambrian rock are likely to be large fluid inclusions derived from Paleozoic brines that

Table 3.6-11

Bedrock Water Chemistry Data

Core Hole	Downhole Interval (ft)	Depth[a] (ft)	Chloride (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Sodium (mg/L)	Potassium (mg/L)
155	362-3050	362-3050	3,700	NA	NA	NA	NA
	562-3050	562-3050	4,200	NA	NA	NA	NA
	842-3050	842-3050	4,000	NA	NA	NA	NA
	942-3050	942-3050	3,600	404	127	1,670	25.8
	1042-3050	1042-3050	3,300	NA	NA	NA	NA
	1370-3050	1370-3050	2,900	NA	NA	NA	NA
	2102-3050	2102-3050	2,550	NA	NA	NA	NA
	2710-3050	2710-3050	2,100	NA	NA	NA	NA
	2202-2215	2202-2215	2,200	261	75.0	1,060	18.8
	2712-2725	2712-2725	2,250	NA	NA	NA	NA
66	402-1078	250-710	2	38.6	19.3	NA	NA
70	302-1334	235-935	6	39.5	22.8	NA	NA
	552-1334	470-935	8	39.1	23.4	NA	NA
77	602-1049	540-895	20	34.6	20.5	NA	NA
91	852-1415	730-1040	12	42.2	22.0	NA	NA
165	2300-2971	2120-2455	1,900	NA	NA	NA	NA
	2920-2971	2435-2455	2,650	468	185	1,090	18.8
181	1900-3405	1835-3110	4,850	850	221	1,810	3.5
190[b]	1700-2244	1340-1795	30	36.2	22.4	15.7	3.1
192[b]	2300-3219	2210-2960	5,100	1,060	298	2,450	50.5
194	800-1584	735-1335	46	34.2	20.1	21.4	3.3

NA = Not Analyzed

[a]Vertical depth below ground surface.

[b]Intervals for Holes 190 and 192 were reversed on original laboratory report.

Prepared by: JET
Checked by: SVD1

were sealed in the Precambrian rock under relatively high temperatures. Kelly, et al. (1986) notes that when encountered these saline waters emerge as seeps or flows that cease after periods ranging from days to years. These types of seeps are consistent with water derived from fractures of limited continuity at depth.

Vertical head differences between bedrock and the Pre- to Early Wisconsinan Till were measured at the eight locations shown on Figure 3.6-21. Hydrographs of the nested wells at the eight locations are shown in Figures 3.6-22 through 3.6-24. The hydrographs were developed using data from the Crandon Project hydrologic data base (Appendix 3.6-8). The hydrographs depicted in the figures are for wells screened completely within the upper bedrock or overlying Pre- to Early Wisconsinan Till.

With the exception of several well nests over the ore body (BE-211-2U/2L and CMC-OWA1, 2, 3, and PWAR), the hydrographs show that over time there is very little head difference between the glacial overburden and the bedrock, indicating that there is very little flow between the bedrock and the glacial overburden outside of the ore body. Therefore, it is unlikely that the bedrock is acting as a sink or source of groundwater to the glacial overburden. This is consistent with the conceptual model of limited flow in the bedrock, in which case the water encountered in fractures at shallow bedrock depths would be in hydrostatic equilibrium with the glacial overburden, which is hydraulically connected to the bedrock.

Based on bedrock hydrogeologic conditions, the conceptual model for mine inflow for the Crandon Project consists of three components: 1) stored water within the ore body and surrounding bedrock, 2) vertical leakage from the glacial deposits into the bedrock consisting of and surrounding the ore body; and 3) lateral flow of water within the bedrock to the mine workings, with the greatest majority of inflow emanating from the first two components. No single piece of data provides irrefutable information to confirm with certainty with this conceptual model is correct, however the data presented here and in Appendix 3.5-15 provides check after check that supports and is consistent with a conceptual model of limited lateral flow of water within the bedrock to the mine and limited drawdown within the bedrock. This conclusion is based on the following:

- Extensive drilling programs totaling approximately 320,000 feet (60 miles) of core have shown that major structural offsets that would give rise to significant lateral flow are not present at the Crandon mine site.

- Fracture and rock mechanics studies show a clear pattern of reduced fracture frequency with depth and an increase in RQD. Fracture orientation is preferential to east-west orientation. These parameters are consistent with decreased water flow in the bedrock with depth, with higher east-west than north-south permeabilities.

- Two bedrock pump tests on hole 214 from depths of 107 to 360 feet and 107 to 750 feet yielded low flow from the intersected hanging wall rocks.

- Weathering studies indicate that strong and moderate weathering is most pronounced in the Crandon Formation and is less in the hanging wall and footwall. The weathering is preferentially developed along the east-west trend of the bedrock formations.

- An east-west trending gabbro dike in the footwall will tend to limit the south to north water flow in the bedrock toward the mine.

- Packer test data is consistent with the conceptual model of bedrock water flow being primarily in the weathered zones.

- Temperature logs and geothermal gradients at the site are consistent with limited flow of water in the bedrock.

- Bedrock water chemistry changes with depth suggesting limited flow at depth.

- Vertical gradients indicate little head difference between the glacial overburden and bedrock.

Collectively, this information provides strong support for the conceptual model of water movement in the bedrock at the Crandon Project site.

To verify the conceptual model of water movement in the bedrock and to further quantify the permeability of the bedrock, NMC completed additional bedrock packer tests in 1995 on core holes 254, 257, 155, and 246. The intent of the 1995 packer test program was to supplement historical bedrock permeability data with packer test data that targeted the strongly, moderately, and weakly weathered bedrock in the hanging wall, footwall, and Crandon Formation. The results of the 1995 packer tests are presented in Table 3.6-11a. The 1995 data shows a general pattern of decreasing permeability with depth and degree of weathering. In addition, the data shows that the Crandon Formation is more permeable than the surrounding hanging wall and footwall rock.

The 1995 packer test program is discussed in detail in a report prepared by Hydro-Geo Consultants, Inc. (Hydro-Geo, 1995). This report can be found in Appendix F of the report titled *Numerical Simulation of the Effect on Groundwater and Surface Water of the Proposed Zinc and Copper Mine Near Crandon, Wisconsin* (GeoTrans, 1996). The GeoTrans report is included in this EIR as Appendix 4.2-3.

As part of the 1995 packer test program, Hydro-Geo Consultants, Inc. also evaluated all site bedrock permeability data to determine representative values and reasonable ranges of permeability for the various bedrock hydrostratigraphic units at the Crandon site. The summary of representative values and reasonable ranges of permeability for the bedrock is provided in Table 3.6-11b and confirms a trend of decreasing permeability with depth and degree of weathering that is consistent with the conceptual model described above.

Table 3.6-11a

Summary of 1995 Bedrock Permeability Tests

Hole	Test Interval (feet)	Test Length (feet)	Hydraulic Conductivity (cm/sec)	Hydrostratigraphic Unit	Comments
254	377 - 400	23	8.25×10^{-7}	Footwall weakly weathered	—
	354 - 377	23	2.57×10^{-5}	Footwall weakly weathered	—
	330 - 353	23	2.24×10^{-4}	Footwall weakly weathered	—
	307 - 330	23	1.85×10^{-7}	Footwall weakly weathered	—
	295 - 306	11	3.88×10^{-5}	Footwall moderately weathered	—
	284 - 295	11	4.66×10^{-6}	Footwall moderately weathered	—
	273 - 284	11	3.41×10^{-5}	Footwall moderately weathered	—
	262 - 273	11	1.68×10^{-5}	Footwall moderately weathered	—
	251 - 262	11	3.30×10^{-6}	Footwall moderately weathered	—
	241 - 247.5	6.5	3.23×10^{-5}	Footwall moderately weathered	Leakage around packer
	235.5 - 242	6.5	4.23×10^{-4}	Footwall moderately weathered	Leakage around packer
	230.5 - 237	6.5	4.22×10^{-4}	Footwall moderately weathered	Leakage around packer
	225.5 - 232	6.5	3.57×10^{-4}	Footwall moderately weathered	Leakage around packer
257	337 - 360	23	7.96×10^{-6}	Footwall weakly weathered	—
	314 - 337	23	7.46×10^{-5}	Footwall weakly weathered	—

Table 3.6-11a *(Continued)*

Hole	Test Interval (feet)	Test Length (feet)	Hydraulic Conductivity (cm/sec)	Hydrostratigraphic Unit	Comments
	291 - 314	23	$4.17x10^{-6}$	Footwall weakly weathered	—
	268 - 291	23	$3.74x10^{-5}$	Footwall weakly weathered	—
	283.5 - 290	6.5	$8.31x10^{-5}$	Footwall moderately weathered	Overlaps test 3
	278.5 - 285	6.5	$9.29x10^{-5}$	Footwall moderately weathered	Overlaps test 3
	273.5 - 280	6.5	$8.29x10^{-5}$	Footwall moderately weathered	Overlaps test 3
	265.5 - 272	6.5	$1.53x10^{-5}$	Footwall moderately weathered	Overlaps test 3
	259 - 265.5	6.5	$7.15x10^{-6}$	Footwall weakly weathered	—
	252.5 - 259	6.5	$1.06x10^{-5}$	Footwall moderately weathered	—
155	1,975 - 1,997	22	$5.35x10^{-7}$	Hangingwall weakly weathered	—
	1,854 - 1,876	22	$3.18x10^{-7}$	Hangingwall weakly weathered	—
	1,575 - 1,597	22	$1.98x10^{-7}$	Hangingwall weakly weathered	—
	1,210 - 1,232	22	$1.49x10^{-7}$	Hangingwall weakly weathered	—
	1,000 - 1,022	22	$1.27x10^{-7}$	Hangingwall weakly weathered	—
	760 - 782	22	$2.13x10^{-6}$	Hangingwall weakly weathered	—
	550 - 572	22	$7.44x10^{-7}$	Hangingwall weakly weathered	—
	250 - 272	22	$8.56x10^{-8}$	Hangingwall weakly weathered	—

Table 3.6-11a *(Continued)*

Hole	Test Interval (feet)	Test Length (feet)	Hydraulic Conductivity (cm/sec)	Hydrostratigraphic Unit	Comments
	140 - 162	22	$1.09x10^{-7}$	Hangingwall moderately weathered	—
	120 - 142	22	$3.04x10^{-8}$	Hangingwall moderately weathered	—
246[1]	1,035 - 1,052	22	$1.86x10^{-7}$	Footwall weakly weathered	—
	981 - 998	22	$2.49x10^{-7}$	Footwall weakly weathered	—
	928 - 945	22	$1.86x10^{-7}$	Footwall weakly weathered	—
	897 - 914	22	$1.80x10^{-7}$	Crandon weakly weathered	—
	851 - 868	22	$2.99x10^{-5}$	Crandon moderately weathered	—
	821 - 837	22	$9.51x10^{-6}$	Crandon strongly weathered	—
	790 - 807	22	$9.97x10^{-6}$	Footwall moderately weathered	—
	779 - 792	22	$2.66x10^{-5}$	Footwall weakly weathered	—

[1]Test interval is listed as true depth, borehole is inclined at 50°.

Source: Hydro-Geo, 1995.

Checked by: JWS

Table 3.6-11b

Representative Hydraulic Conductivities for Bedrock Hydrostratigraphic Units

Hydrostratigraphic Unit	Representative Value (cm/sec)	Estimated Range of Variability (cm/sec)	Method of Estimation (Rep. Value / Range)
Hanging Wall strongly weathered	1.7×10^{-5}	3.4×10^{-6} - 8.5×10^{-5}	1 Test / Estimated
Hanging Wall moderately weathered	5.0×10^{-6}	7.7×10^{-7} - 3.2×10^{-5}	Geom. Mean / Confidence Interval
Hanging Wall weakly weathered	3.3×10^{-7}	9.1×10^{-8} - 1.2×10^{-6}	Geom. Mean / Confidence Interval
Footwall strongly weathered	8.0×10^{-5}	1.6×10^{-5} - 4.0×10^{-4}	Estimated / Estimated
Footwall moderately weathered	1.0×10^{-5}	3.2×10^{-6} - 3.3×10^{-5}	Geom. Mean / Confidence Interval
Footwall weakly weathered	4.2×10^{-6}	1.2×10^{-6} - 1.4×10^{-5}	Geom. Mean / Confidence Interval
Crandon strongly weathered	1.6×10^{-4}	2.9×10^{-5} - 9.2×10^{-4}	Geom. Mean / Confidence Interval
Crandon moderately weathered	6.1×10^{-4}	1.2×10^{-4} - 3.0×10^{-3}	Geom. Mean / Estimated
Crandon weakly weathered	4.2×10^{-6}	8.4×10^{-7} - 2.1×10^{-5}	Estimated / Estimated

Source: Hydro-Geo, 1995.

Checked by: JWS

3.6.4.2.2 Structured & Massive Saprolite

In 1981 Camp Dresser & McKee conducted two pump tests from angled core holes 211 and 213 that intersected the Crandon Formation. The purpose of the pump tests were to evaluate, the relative degree of hydraulic connection between the ore body and glacial overburden. Figures 3.6-25 and 3.6-26 show the location of observation wells and angle core holes used to monitor the drawdown from these two pump tests. The results of the two pump tests are summarized in Tables 3.6-12 and 3.6-13. Based on the results of the pump test it was inferred that a low permeability layer resided over the ore body, since very little drawdown was observed in the wells screened in the glacial overburden. The exception was the drawdown observed in wells BE-216-1, BE-216-2, and BE-211-1. Based on the drawdown observed at these three wells, it was inferred that a direct hydraulic connection between the ore body and glacial overburden occurred in these areas.

In 1994 the hydraulic and geologic characteristics of the contact between the ore body and glacial overburden was further evaluated. Upon review of archived core and soil samples in the NMC Rhinelander core shed, it was concluded that a massive saprolite and glacial till layer at the interface of the bedrock and glacial overburden was the low permeability layer that will control vertical seepage of groundwater from the glacial overburden into the mine. Section 3.5.3.1.5 described the results of an investigation to characterize the thickness and extent of the structured and massive saprolite in the vicinity of the ore body. As part of the saprolite investigation, a pump test and numerous slug tests were performed to evaluate the hydraulic conductivity of the structured saprolite, massive saprolite, and Pre- to Early Wisconsinan Till. A description of the work performed and a discussion of the results were included in a February 23, 1995 report (Foth & Van Dyke, 1995a) submitted to the WDNR and USCOE. The report titled, *Investigation and Evaluation: Saprolite at the Crandon Site*. As described in the saprolite report, a specific objective of the investigation was to evaluate the hydraulic characteristics of the massive saprolite where, based on the 1981 ore body pump test, a direct hydraulic connection between the ore body and glacial overburden was inferred.

Results of the slug tests performed during the saprolite investigation are summarized in Table 3.6-14. Results of the 16 day pump test were principally analyzed through a numerical model that was calibrated to the pump test results. Calibrated hydraulic parameters from the pump test model are summarized in Table 3.6-15. The hydraulic conductivity of the massive saprolite was calibrated to 0.04 ft/d (1.4E-5 cm/s). As measured by slug tests (Table 3.16-14), the hydraulic conductivity of the massive saprolite ranged from 0.03 ft/d (1.3-5 cm/s) to 1.1 ft/d (3.8E-4 cm/s) and provides a reasonable estimate of the spacial variability for hydraulic conductivity of the massive saprolite.

Table 3.6-12

211 Pump Test Well Data and Drawdowns

Well	Maximum Drawdown (ft)	Screen Length (ft)	Location of Screen
211-1	15	39	1.5' above bedrock
211-2U	2.2	20	130'-150' below land surface
211-2L	2.4	7	in overburden on top of bedrock
211-3U	1.2	10	183'-193' below land surface
211-3L	.44	10	18' below overburden/bedrock interface
213-1	0	25	in overburden just above bedrock
213-2	0	25	in overburden just above bedrock
213-3U	0	10	in overburden just above bedrock
213-3L	0.1	10	14' below overburden/ bedrock interface
216-1	2.8	20	in overburden just above bedrock
216-2	0.5	20	in overburden just above bedrock
WW-2	7.3	15	160 ft. below land surface
WW-4	0	10 ft. 4 in.	97 ft. 10 in. below land surface
DW-2L	0	5	top of screen 85' below land surface
DW-3	0.2	5	top of screen 28' below land surface
DMI-1	0	2.5	gravel pack from 52-109 ft., top of screen 106 ft. below land surface
DMS-1	0	10	sand pack from 50 ft. to 105 ft., top of screen at 95 ft.
DMS-2	0	10	top of screen 80' below land surface
STSB-1	0	10	top of screen 84.7 ft. below land surface
TW-1	0	15	55 ft. below land surface
195E	0.2	unknown	unknown

Table 3.6-12 *(Continued)*

Well	Maximum Drawdown (ft)	Screen Length (ft)	Location of Screen
195W	NM	none	approximately 450' deep
209	0.9	180	25° off vertical-top of screen 1065' down hole, screened across hanging wall contact w/ore body
210	0.7	180	30° off vertical-top of screen 910' down hole, screened across hanging wall contact w/ore body
211 Pumping Well	308	none	980' open hole-from surface at 30° off vertical
213	0.5	none	880' open hole-from surface at 25° off vertical
216	1.5	none	1169' open hole-from surface at 25° off vertical
217	0.8	80	25° off vertical-top of screen 470' down hole, screened across hanging wall contact w/ore body
218	NM	60	15° off vertical-top of screen 840' down hole, screened across hanging wall contact w/ore body
219	258	105	25° off vertical-top of screen 390' down hole, screened across hanging wall contact w/ore body
220	223	160	25° off vertical-top of screen 390' down hole, screened across hanging wall contact w/ore body
221	0.8	211	25° off vertical-top of screen 489' down hole, screened across hanging wall contact w/ore body
222	0.8	232	25° off vertical-top of screen 442' down hole, screened across hanging wall contact w/ore body

Table 3.6-12 *(Continued)*

Well	Maximum Drawdown (ft)	Screen Length (ft)	Location of Screen
223	0.9	200	25° off vertical-top of screen 324' down hole, screened across hanging wall contact w/ore body
224	0.8	80	25° off vertical-top of screen 374' down hole, screened across hanging wall contact w/ore body
226	2.1	106	25° off vertical-top of screen 689' down hole, screened across hanging wall contact w/ore body
227	1.9	127	25° off vertical-top of screen 503' down hole, screened across hanging wall contact w/ore body
228	3.2	100	25° off vertical-top of screen 595' down hole, screened across hanging wall contact w/ore body
229	2.2	100	25° off vertical-top of screen 384' down hole, screened across hanging wall contact w/ore body
230	229	127	25° off vertical-top of screen 537' down hole, screened across hanging wall contact w/ore body
232	1.1	200	40° off vertical-top of screen 480' down hole, screened across hanging wall contact w/ore body

NM = Not Measured

Prepared by: JCP
Checked by: LLA

Table 3.6-13

213 Pump Test Well Data and Drawdowns

Well	Maximum Drawdown (ft)	Screen Length (ft)	Location of Screen
211-1	0.8	39	1.5' above bedrock
211-2U	0.2	20	130'-150' below land surface
211-2L	2.3	7	in overburden on top of bedrock
211-3U	0.2	10	183'-193' below land surface
211-3L	4.2	10	18' below overburden/bedrock interface
213-1	3.1	25	in overburden just above bedrock
213-2	3.4	25	in overburden just above bedrock
213-3U	3.4	10	in overburden just above bedrock
213-3L	6.4	10	14' below overburden/ bedrock interface
216-1	49	20	in overburden just above bedrock
216-2	14	20	in overburden just above bedrock
WW-2	0.4	15	160 ft. below land surface
WW-4	3.9	10 ft. 4 in.	97 ft. 10 in. below land surface
DW-2L	0	5	top of screen 85' below land surface
DW-3	0	5	top of screen 28' below land surface
DMI-1	1.2	2.5	gravel pack from 52-109 ft., top of screen 106 ft. below land surface
DMS-1	0	10	sand pack from 50 ft. to 105 ft., top of screen at 95 ft.
DMS-2	0	10	top of screen 80' below land surface
STSB-1	4	10	boring terminated in bedrock at 103 ft., well set at 84.7 ft. below land surface
195E	3.3	unknown	unknown

Table 3.6-13 *(Continued)*

Well	Maximum Drawdown (ft)	Screen Length (ft)	Location of Screen
195W	1.9	none	approximately 450' deep
209	124	180	25° off vertical-top of screen 1065' down hole, screened across hanging wall contact w/ore body
210	122	180	30° off vertical-top of screen 910' down hole, screened across hanging wall contact w/ore body
211	3.6	none	980' open hole-from surface at 30° off vertical
213 Pumping Well	221	none	880' open hole-from surface at 25° off vertical
216	28	none	1169' open hole-from surface at 25° off vertical
217	120	80	25° off vertical-top of screen 470' down hole, screened across hanging wall contact w/ore body
218	1.6	60	15° off vertical-top of screen 840' down hole, screened across hanging wall contact w/ore body
219	3.6	105	25° off vertical-top of screen 390' down hole, screened across hanging wall contact w/ore body
220	3.7	160	25° off vertical-top of screen 390' down hole, screened across hanging wall contact w/ore body
221	NM	211	25° off vertical-top of screen 489' down hole, screened across hanging wall contact w/ore body
222	94	232	25° off vertical-top of screen 442' down hole, screened across hanging wall contact w/ore body

Table 3.6-13 *(Continued)*

Well	Maximum Drawdown (ft)	Screen Length (ft)	Location of Screen
223	92	200	25° off vertical-top of screen 324' down hole, screened across hanging wall contact w/ore body
224	91	80	25° off vertical-top of screen 374' down hole, screened across hanging wall contact w/ore body
226	70	106	25° off vertical-top of screen 689' down hole, screened across hanging wall contact w/ore body
227	71	127	25° off vertical-top of screen 503' down hole, screened across hanging wall contact w/ore body
228	60	100	25° off vertical-top of screen 595' down hole, screened across hanging wall contact w/ore body
229	67	100	25° off vertical-top of screen 384' down hole, screened across hanging wall contact w/ore body
230	4.2	127	25° off vertical-top of screen 537' down hole, screened across hanging wall contact w/ore body
232	8.8	200	40° off vertical-top of screen 480' down hole, screened across hanging wall contact w/ore body
TW-1	0	15 ft.	55 ft. below land surface

NM = Not Measured

Prepared by: JCP
Checked by: LLA

Table 3.6-14

Saprolite Investigation Slug Test Permeability Data Summary

Well	Bouwer & Rice, 1976 Hydraulic Conductivity		Cooper, et al. (1967) Transmissivity		Cooper, et al. (1967) Hydraulic Conductivity		Formation
	ft/d	cm/s	ft^2/d	cm^2/s	ft/d	cm/s	
CMC-OWA1	0.01	4.2E-6	0.015	1.7E-4	1.3E-3	4.6E-7	Structured Saprolite
CMC-OWA2	0.15	5.2E-5	2.9	3.1E-2	0.24	8.5E-5	Structured Saprolite
CMC-OWA3	0.054	1.9E-5	1.3	1.4E-2	0.022	7.8E-6	Pre- to Early Wisconsinan Till
CMC-OWA4	0.048	1.7E-5	1.4	1.5E-2	0.028	9.8E-6	Pre- to Early Wisconsinan Till
CMC-OWA5	0.40	1.4E-4	8.1	8.7E-2	0.16	5.7E-5	Pre- to Early Wisconsinan Till
CMC-08	1.4	5.0E-4	—	—	—	—	Outwash
CMC-08P	0.028	1.0E-5	0.25	2.7E-3	7.8E-3	2.8E-6	Pre- to Early Wisconsinan Till
CMC-09	1.7	6.2E-4	—	—	—	—	Outwash

Table 3.6-14 *(Continued)*

Well	Bouwer & Rice, 1976 Hydraulic Conductivity		Cooper, et al. (1967) Transmissivity		Cooper, et al. (1967) Hydraulic Conductivity		Formation
	ft/d	cm/s	ft^2/d	cm^2/s	ft/d	cm/s	
CMC-09P	0.021	7.5E-6	0.22	2.4E-3	3.4E-3	1.2E-6	Pre- to Early Wisconsinan Till
CMC-10	14.2	5E-3	—	—	—	—	Outwash/ Pre- to Early Wisconsinan Till
CMC-10P	0.77	2.7E-4	15.8	0.17	0.49	1.7E-4	Pre- to Early Wisconsinan Till
CMC-10PP	0.40	1.4E-4	3.7	0.040	0.57	2.0E-4	Massive Saprolite
CMC-11P	0.082	2.9E-5	1.86	0.020	0.12	4.2E-5	Massive Saprolite
CMC-12P	0.06	2.1E-5	1.5	1.6E-2	0.12	4.3E-5	Massive Saprolite
CMC-13P	0.07	2.5E-5	0.51	5.5E-3	0.03	1.29E-5	Massive Saprolite
CMC-14P	1.1	3.8E-4	13.0	0.14	0.88	3.1E-4	Massive Saprolite

— Analysis by this method not used for wells screened in outwash.

Prepared by: SVD1
Checked by: JET

Table 3.6-15

Saprolite Investigation Calibrated Hydraulic Parameters

Layer #	Geologic Unit	Kx (ft/day)	Ky (ft/day)	Kz (ft/day)	Specific Yield (Sy) (d)	Specific Storage (Ss) (1/ft.)	Thickness (ft)
Layer 1	Outwash	33.3*	33.3*	2.72*	0.1	N/A	34*
Layer 2	Upper Till	0.8	0.8	0.16	.01	1.00E-6	29*
Layer 3	Lower Till	0.8	0.8	0.16	N/A	1.00E-6	29*
Layer 4	Massive Saprolite	0.04	0.04	0.04	N/A	1.00E-6	11*
Layer 5	Structured Saprolite	16	1.6	16	N/A	5.00E-5	19*
Layer 6	Bedrock**	3.5/0.05/ 0.005	0.35/0.00 5/0.0005	3.5/0.05/ 0.005	N/A	1.00E-6	400

Notes:

* Average value of a variable parameter
** Three conductivity zones are ore body/hanging wall/footwall
(d) dimensionless
N/A Not Applicable

Prepared by: PFA
Checked by: SVD1

The calibrated hydraulic conductivity of the structured saprolite ranged from 16 ft/d (5.6E-3 cm/s) along the strike of the ore body to 1.6 ft/d (5.6E-4 cm/s) perpendicular to the strike of the ore body. This anisotropy is likely attributed to east-west trending fractures that parallel bedding and foliation planes within the rock. The calibrated hydraulic conductivity of the structured saprolite from the pump test is reflective of the secondary permeability fracture features. In contrast, the slug tests, test a smaller zone of the structured saprolite measuring the primary permeability of the bedrock. Given that the pump test created a stress that was transmitted along nearly two-thirds of the ore body, the calibrated hydraulic conductivity from the pump test should provide a more representative estimate of the bulk hydraulic conductivity that will control flow within the structured saprolite.

Based on model calibration to drawdown in the Pre- to Early Wisconsinan Till, the horizontal hydraulic conductivity of the till was estimated to be 0.8 ft/d (2.8E-4 cm/s), with an estimated vertical hydraulic conductivity of 0.16 ft/d (5.6E-5 cm/s). As measured by slug tests, the Pre- to Early Wisconsinan Till over the ore body ranged from 3.4E-3 ft/d (1.2E-6 cm/s) to 0.77 ft/d (2.7E-4 cm/s).

Three principal observations resulted from the saprolite investigation/pump test work. The first was that no evidence was found to support the inferred direct hydraulic connection between the ore body and the higher permeable glacial outwash materials. In fact borings placed in areas where such contacts were postulated actually showed that the materials overlying the ore body are massive saprolite and Pre- to Early Wisconsinan Till. In addition, the pump test did not show any evidence of areas of direct connection. The second observation is that the calibrated hydraulic conductivities of the massive saprolite and Pre- to Early Wisconsinan Till were found to be of the same order of magnitude with the massive saprolite being slightly lower, indicating that the two formations likely will act as a unit under stressed conditions. Third, the response of water levels to the pumping showed that vertical leakage will likely be the predominant source of mine inflow.

3.6.4.2.3 Glacial Till & Outwash

The hydraulic conductivity of the Pre- to Early Wisconsinan Till, outwash sands and gravel and Late Wisconsinan Till was evaluated by studies conducted by Dames & Moore (1982), Golder Associates (1981a) and STS Consultants Ltd. (1984b).

Dames & Moore performed slug tests on 36 monitoring wells screened in the glacial overburden the results of which are summarized in Table 3.6-16. Based on these results, the hydraulic conductivity of the Pre- to Early Wisconsinan and Late Wisconsinan Till ranged from 3.1E-3 ft/d (1.1E-6 cm/s) to 1.13 ft/d (4.0E-4 cm/s). The outwash exhibited a higher permeability than both the Pre- to Early Wisconsinan Till and Late Wisconsinan Till ranging from 0.019 ft/d (6.7E-6 cm/s) to 16.44 ft/d (5.8E-3 cm/s). The data and supporting calculations are provided in Appendix 3.6-2.

Table 3.6-16

Slug Test Results for DM Series Wells

Boring Series	Number	Lithology	Permeability ft/d	Permeability cm/sec	Type of Test*
DMA	1-N	LWT	0.014	$5.1x10^{-6}$	FH
	1-S	LWT/CO	0.060	$2.1x10^{-5}$	FH
	3	LWT	0.028	$1.0x10^{-5}$	FH
	4	LWT	0.12	$4.3x10^{-5}$	FH
	19	CO/LWT	0.24	$8.3x10^{-5}$	FH
	43	LWT	0.019	$6.6x10^{-6}$	FH
DMB	1A	CO/LWT	1.73	$6.1x10^{-4}$	FH
	2	CO/LWT	0.016	$5.8x10^{-6}$	FH
	3	CO	0.54	$1.9x10^{-4}$	RH
	3	CO	1.67	$5.9x10^{-4}$	FH
	4	LWT/CO	0.34	$1.2x10^{-4}$	FH
	5	CO/LWT	0.0031	$1.1x10^{-6}$	FH
	5A	LWT/CO	0.057	$2.0x10^{-5}$	FH
	6	LWT	0.0031	$1.1x10^{-6}$	FH
	7	CO	1.62	$5.7x10^{-4}$	FH
	8	LWT	0.074	$2.6x10^{-5}$	FH
	9A	EWT/FO	1.08	$3.8x10^{-4}$	FH
	9B	FO	0.060	$2.1x10^{-5}$	FH
	9C	FO/CO	0.43	$1.5x10^{-4}$	FH
	10	LWT/FO	0.45	$1.6x10^{-4}$	FH
	10	LWT/FO	0.10	$3.7x10^{-5}$	RH
	12	LWT	1.13	$4.0x10^{-4}$	RH
	13	LWT	0.45	$1.6x10^{-4}$	FH
	14	CO	3.12	$1.1x10^{-3}$	FH
	15	CO	3.97	$1.4x10^{-3}$	FH
	15	CO	3.12	$1.1x10^{-3}$	FH

Table 3.6-16 *(Continued)*

Boring Series	Number	Lithology	Permeability ft/d	Permeability cm/sec	Type of Test*
DMB	15	CO	3.69	$1.3x10^{-3}$	FH
	18	CO	0.51	$1.8x10^{-4}$	FH
	18	CO	1.19	$4.2x10^{-4}$	RH
	19	CO	3.40	$1.2x10^{-3}$	FH
	19	CO	0.12	$4.2x10^{-5}$	RH
	20	CO	1.50	$5.3x10^{-4}$	FH
	20	CO	0.11	$3.8x10^{-5}$	RH
	20A	CO	2.81	$9.9x10^{-4}$	FH
	21	CO	8.50	$3.0x10^{-3}$	FH
	21	CO	7.37	$2.6x10^{-3}$	FH
	22	CO	5.95	$2.1x10^{-3}$	FH
	23	FO	2.04	$7.2x10^{-4}$	RH
	23	FO	1.39	$4.9x10^{-4}$	FH
	23	FO	0.85	$3.0x10^{-4}$	FH
	24	CO	2.47	$8.7x10^{-4}$	FH
	25	CO	0.019	$6.7x10^{-6}$	FH
	26	CO	0.031	$1.1x10^{-5}$	FH
	27	CO	0.021	$7.4x10^{-6}$	FH
	28	CO	16.44	$5.8x10^{-3}$	FH
	29	LWT/CO	0.10	$3.5x10^{-5}$	FH

FH = Falling Head Slug Test
RH = Rising Head Slug Test
LWT = Late Wisconsinan Till
EWT = Pre- to Early Wisconsinan Till
CO = Coarse Outwash
FO = Fine Outwash
= Raw data not available

Prepared by: SVD1
Checked by: XXC

Golder Associates (1981a) conducted a 24 day pump test from test well TW41 to evaluate the hydraulic characteristics of the glacial till and outwash deposits. The test was conducted at an average pumping rate of 1,420 gallons per minute using 13 primary observation wells and 16 secondary observation wells. Specific details on the pump test and analytical calculations for parameter estimates can be found in Golder Associates (1981a) which is provided in Appendix 3.6-4. The results of this pump test area summarized in Table 3.6-17. The measured horizontal hydraulic conductivity of the Pre- to Early Wisconsinan Till was 0.8 ft/d with a vertical hydraulic conductivity of 0.3 ft/d. The non differentiated outwash horizontal hydraulic conductivity was 37.2 ft/d with a vertical hydraulic conductivity of 3.7 ft/d. The estimated hydraulic conductivity for the Late Wisconsinan Till was equivalent to that of the Pre- to Early Wisconsinan Till. The measured hydraulic conductivity of the tills compare favorable to the calibrated values derived from the saprolite pump test described above, indicating a strong degree of confidence in the estimated hydraulic characteristics of the glacial deposits.

STS Consultants Ltd. (1984) performed slug tests on EX-series wells and WP-series well points in addition to several wells installed by Golder Associates (1981b), Dames & Moore (1982) and Braun Engineering (CDM, 1982). The results of these tests are summarized in Table 3.6-18. Supporting data and calculations are provided in Appendix 3.6-5. The data is generally consistent with values measured by Dames & Moore (1978) and Golder Associates (1981a).

In all there were multiple tests conducted to evaluate the hydraulic characteristics of the glacial overburden. The results of the various investigations are generally in agreement indicating a high degree of confidence in the measured values.

3.6.4.2.4 Lake Bed and Wetland Deposits

The hydraulic conductivity of the lake beds of Little Sand, Oak, Deep Hole, Duck and Skunk Lakes and selected wetlands were evaluated based on laboratory permeability tests and in situ field permeability tests. Table 3.6-19 summarizes the lake bed and wetland data which can be found in Appendices 3.5-26, 3.5-27 and 3.5-28. The hydraulic conductivity of the lake beds as measured during three different drilling programs was consistently on the order of 2.8E-4 ft/d (1E-7 cm/s). The consistency of the measured permeability for the lake beds is likely attributed to the uniform nature of the lake bed deposits.

Wetlands in upland areas such as the Bur Oak, Duck Lake and Skunk Lake wetlands, exhibit consistently low permeability values due to the lacustrine clay and silt that underlies the wetland. In contrast, wetlands associated with discharge areas such as the wetlands around Swamp Creek are consistently of a sandy nature and thus would be expected to yield moderate to fairly high permeabilities as were measured from slug tests conducted on the WP-series well points summarized above in Table 3.6-18.

Table 3.6-17

Hydraulic Parameter Summary From 1981 Glacial Overburden 24 Day Pump Test[a]

Geologic Unit	Horizontal Hydraulic Conductivity Kh		Vertical Hydraulic Conductivity Kh		Specific Storage Ss	Specific Yield Sy
	ft/d	cm/s	ft/d	cm/s	ft^{-1}	%
Late Wisconsinan Till	0.8	$2.8x10^{-4}$	0.27	$9.4x10^{-5}$	$4.6x10^{-6}$	5.4
Outwash	37.2	$1.3x10^{-2}$	3.7	$1.3x10^{-3}$	$4.6x10^{-6}$	7.0
Pre- to Early Wisconsinan Till	0.8	$2.8x10^{-4}$	0.27	$9.4x10^{-5}$	$4.6x10^{-6}$	5.4

[a]Obtained from Golder, 1981.

Prepared by: SDV1
Checked by: XXC

Table 3.6-18

1984 Slug Test Results

Well	Test Type	Geologic Unit	Permeability	
			ft/d	cm/sec
EX 1AL	Fall	EWT	0.3	$9x10^{-5}$
	Rise		0.1	$4x10^{-5}$
EX 1AU	Fall	CO/EWT	17	$6x10^{-3}$
	Rise		11	$4x10^{-3}$
EX 1BL	Fall	CO	17	$6x10^{-3}$
	Rise		17	$6x10^{-3}$
EX 2AL	Fall	FO	2.0	$7x10^{-4}$
	Rise		1.7	$6x10^{-4}$
EX 2AU	Fall	CO	11	$4x10^{-3}$
	Rise		14	$5x10^{-3}$
EX 3AL	Fall	EWT	0.9	$3x10^{-4}$
EX 3AU	Fall	FO	2.8	$1x10^{-3}$
	Rise		2.3	$8x10^{-4}$
EX 3BL	Fall	CO	2.8	$1x10^{-3}$
	Rise		2.8	$1x10^{-3}$
EX 3BU	Fall	FO	5.7	$2x10^{-3}$
	Rise		2.8	$1x10^{-3}$
EX 4AL	Fall	EWT	2.0	$7x10^{-4}$
	Rise		1.7	$6x10^{-4}$
EX 4AU	Fall	FO	2.8	$1x10^{-3}$
EX 4BL	Fall	CO	2.8	$1x10^{-3}$
	Rise		2.8	$1x10^{-3}$
EX 4BU	Fall	LWT	2.0	$7x10^{-4}$
	Rise		0.9	$3x10^{-4}$
EX 5BL	Fall	CO	28	$1x10^{-2}$
EX 6AL	Fall	EWT	0.9	$3x10^{-4}$
	Rise		0.3	$1x10^{-4}$
EX 6AU	Fall	CO	8.5	$3x10^{-3}$
	Rise		11	$4x10^{-3}$

Table 3.6-18 *(Continued)*

Well	Test Type	Geologic Unit	Permeability ft/d	Permeability cm/sec
EX 6BL	Fall	FO	5.7	$2x10^{-3}$
	Rise		2.8	$1x10^{-3}$
EX 7AL	Fall	EWT	2.6	$9x10^{-4}$
	Rise		2.0	$7x10^{-4}$
EX 7BL	Fall	EWT	2.8	$1x10^{-3}$
	Rise		2.8	$1x10^{-3}$
EX 7BU	Fall	CO	2.8	$1x10^{-3}$
	Rise		2.8	$1x10^{-3}$
EX 8AL	Fall	EWT	0.3	$1x10^{-4}$
	Rise		0.2	$7x10^{-5}$
EX 8AU	Fall	EWT	0.6	$2x10^{-4}$
	Rise		0.6	$2x10^{-4}$
EX 8BL	Fall	FO	5.7	$2x10^{-3}$
	Rise		2.8	$1x10^{-3}$
EX 8BU	Fall	CO	2.8	$1x10^{-3}$
EX 9AU	Fall	FO	17	$6x10^{-3}$
	Rise		8.5	$3x10^{-3}$
EX 9BL	Fall	CO	0.3	$1x10^{-4}$
	Rise		5.7	$2x10^{-3}$
EX 10AL	Fall	LA	0.006	$2x10^{-6}$
	Rise		0.3	$1x10^{-5}$
EX 10AU	Fall	FO	2.8	$1x10^{-3}$
EX 10BL	Fall	LWT	0.06	$2x10^{-5}$
	Rise		0.06	$2x10^{-5}$
EX 11AL	Fall	LA/CO	5.7	$2x10^{-3}$
	Rise		2.8	$1x10^{-3}$
EX 11AU	Fall	FO	2.8	$1x10^{-3}$
	Rise		0.6	$2x10^{-4}$
EX 11BL	Fall	CO	14	$5x10^{-3}$
	Rise		17	$6x10^{-3}$
EX 11BU	Fall	LWT	0.3	$1x10^{-4}$
	Rise		0.09	$3x10^{-5}$

Table 3.6-18 *(Continued)*

Well	Test Type	Geologic Unit	Permeability ft/d	Permeability cm/sec
EX 12AL	Fall	LA	0.2	$7x10^{-5}$
	Rise		0.6	$2x10^{-4}$
EX 12AU	Fall	EWT	2.8	$1x10^{-3}$
	Rise		8.5	$3x10^{-3}$
EX 12BL	Fall	CO	0.03	$1x10^{-5}$**
	Rise		0.2	$6x10^{-5}$
EX 13AL	Fall	EWT	1.1	$4x10^{-4}$
	Rise		1.4	$5x10^{-4}$
EX 13BL	Fall	EWT/FO	0.6	$2x10^{-4}$
	Rise		2.3	$8x10^{-4}$*
EX 13BU	Fall	CO	2.6	$9x10^{-4}$
	Rise		8.5	$3x10^{-3}$
EX 13CL	Fall	LWT	0.2	$6x10^{-5}$
	Rise		0.09	$3x10^{-5}$
EX 14AL	Fall	LA	0.09	$3x10^{-5}$
	Rise		0.2	$7x10^{-5}$
EX 14AU	Fall	FO	5.7	$2x10^{-3}$
	Rise		5.7	$2x10^{-3}$
EX 14BL	Fall	LWT	0.14	$5x10^{-5}$
	Rise		0.057	$2x10^{-5}$
EX 15AL	Fall	EWT	0.6	$2x10^{-4}$
	Rise		0.6	$2x10^{-4}$
EX 15AU	Fall	CO	11	$4x10^{-3}$
	Rise		11	$4x10^{-3}$
EX 16AL	Fall	FO	2.8	$1x10^{-3}$
	Rise		2.8	$1x10^{-3}$
EX 16AU	Fall	CO	11	$4x10^{-3}$
	Rise		17	$6x10^{-3}$
EX 16BL	Fall	LWT/FO	0.03	$9x10^{-6}$
	Rise		0.0028	$1x10^{-6}$
WP-1L	Fall	FO***	5.7	$2x10^{-3}$
	Rise		11	$4x10^{-3}$

Table 3.6-18 *(Continued)*

Well	Test Type	Geologic Unit	Permeability ft/d	Permeability cm/sec
WP-2L	Fall	CO***	0.014	$5x10^{-6}$
	Rise		0.6	$2x10^{-4}$
WP-3L	Fall	CO***	20	$7x10^{-3}$
	Rise		26	$9x10^{-3}$
WP-4L	Fall	CO***	0.017	$6x10^{-6}$
WP-5L	Flowing well	Coarse drift		
WP-6L	Fall	CO***	11	$4x10^{-3}$
WP-7L	Fall	CO***	0.014	$5x10^{-6}$
	Rise		0.11	$4x10^{-5}$
G40-M15	Fall	EWT	0.3	$1x10^{-4}$
	Rise		0.2	$8x10^{-5}$
G40-S17	Fall	EWT/FO	1.1	$4x10^{-4}$
	Rise		2.3	$8x10^{-4}$
G41-E17	Fall	EWT/UDB	2.8	$1x10^{-3}$
	Rise		2.8	$1x10^{-3}$
G41-E19A	Fall	CO/FO	1.7	$6x10^{-4}$
	Rise		5.7	$2x10^{-3}$
G41-E22A	Fall	LWT	1.7	$6x10^{-4}$
	Rise		2.6	$9x10^{-4}$
G41-M11	Fall	FO	5.7	$2x10^{-3}$
	Rise		2.8	$1x10^{-3}$
G41-P16	Fall	LWT/CO/EWT	0.11	$4x10^{-5}$
	Rise		0.14	$5x10^{-5}$
G41-P18	Fall	LWT/CO	$6x10^{-4}$	$2x10^{-7}$
DMS-1	Fall	EWT	0.14	$5x10^{-5}$
	Rise		0.06	$2x10^{-5}$
DMI-2L	Fall	UDB	0.3	$1x10^{-4}$
DW-1L	Rise	EWT	$3x10^{-4}$	$1x10^{-7}$
DW-1U	Rise	EWT	$9x10^{-4}$	$3x10^{-7}$
DW-1A	Fall	EWT	$9x10^{-3}$	$3x10^{-6}$
DW-3U	Fall	EWT	2.3	$8x10^{-4}$

Table 3.6-18 *(Continued)*

Well	Test Type	Geologic Unit	Permeability ft/d	Permeability cm/sec
DW-3L	Rise	EWT	0.03	$1x10^{-5}$
BE 211-1	Rise	SS/MS/EWT	0.06	$2x10^{-5}$
BE 211-1 (Test #2)	Rise	SS/MS/EWT	0.09	$3x10^{-5}$
BE 211-2L	Rise	SS/MS	0.006	$2x10^{-6}$
BE 211-3U	Rise	MS/EWT	0.03	$1x10^{-5}$
BE 211-3L	Rise	SS/MS	0.06	$2x10^{-5}$
BE 213-1	Rise	SS/MS/EWT/CO	0.14	$5x10^{-5}$
BE 213-2	Rise	SS/MS/EWT/CO	0.3	$1x10^{-4}$
BE 213-3L	Rise	SS	0.20	$7x10^{-5}$
BE 216-1	Rise	MS/EWT/SS	0.06	$2x10^{-5}$
BE 216-2	Rise	MS/EWT/SS	0.011	$4x10^{-6}$
BE 216-3U	Rise	MS/EWT	0.02	$7x10^{-6}$
BE 216-3L	Rise	SS	0.03	$1x10^{-5}$

LWT = Late Wisconsinan Till
LA = Lacustrine
CO = Coarse Outwash
FO = Fine Outwash
EWT = Pre- to Early Wisconsinan Till
MS = Massive Saprolite
SS = Structural Saprolite
UDB = Undifferentiated Bedrock

Prepared by: SVD1
Checked by: XXC

* (EX Wells) Well not stabilized at time of report.
** Did not use data in statistical analysis - well plugged.
*** (WP Wells) No split-spoon samples taken. Geologic unit estimated from drill cuttings and adjacent stratigraphy.

Table 3.6-19

Lake Bed and Wetland Soil Testing and Permeability Data

Boring Location	Date	Boring No.	Soil Type (USCS)	Depth	% Gravel	% Sand	% Silt	% Clay	P-200	Hydraulic Conductivity Kv (cm/s)	Hydraulic Conductivity Kv (ft/d)	Groundwater Elevation (ft) MSL [b]	Field Measured Hydraulic Conductivity Kh ft/d	Field Measured Hydraulic Conductivity Kh cm/s
Little Sand Lake	1982	STS-LSL-1	Dark gray silty clay (CL)	30 - 32	—	—	—	14	99.2	$1.4x10^{-7}$	$4.0x10^{-4}$	1583.37		
			Dark gray silty clay (CL)	44.5 - 47	—	—	—	19	94.4	$1.7x10^{-7}$	$4.8x10^{-4}$			
	1982	STS-LSL-2	Dark gray silty clay (CL)	24.5 - 26.5	—	—	—	11.5	97.7	$7.3x10^{-7}$	$2.1x10^{-3}$	1584.68		
			Brown medium sand (SP)[c]	39 - 40.5	—	—	—		4.6	—	—			
	1982	STS-LSL-3	Dark gray silty clay (CL)	28 - 30	—	—	—	19	99	$3.7x10^{-7}$	$1.0x10^{-3}$	—		
			Dark gray silty clay (CL)	37 - 39	—	—	—	15	99.5	$1.5x10^{-7}$	$4.3x10^{-4}$			
			Brown to medium sand (SP)[c]	43.5 - 45	—	—	—	—	4.2	—	—			
	1982	STS-LSL-4	Dark gray silty clay (CL)	30.5 - 32.5	—	—	—	15	96.8	$1.1x10^{-7}$	$3.1x10^{-4}$	1583.63		
			Brown to medium sand (SP)[c]	45.5 - 47	—	—	—	—	18.7	—	—			
	1982	STS-LSL-5	Dark gray silty clay (CL)	20 - 22	—	—	—	17	98.4	$1.6x10^{-4}$[a]	0.45	—		
			Dark gray silty clay (CL)	28 - 30	—	—	—	19	96.8	$1.5x10^{-7}$	$4.3x10^{-4}$			

Table 3.6-19 *(Continued)*

Boring Location	Date	Boring No.	Soil Type (USCS)	Depth	% Gravel	% Sand	% Silt	% Clay	P-200	Hydraulic Conductivity Kv (cm/s)	Hydraulic Conductivity Kv (ft/d)	Groundwater Elevation (ft) MSL [b]	Field Measured Hydraulic Conductivity Kh ft/d	Field Measured Hydraulic Conductivity Kh cm/s
Little Sand Lake	1982	STS-LSL-6	Dark gray silty clay (CL)	16 - 18	—	—	—	8	93.3	$3.7x10^{-7}$	$1.0x10^{-3}$	1584.28		
			Dark gray silty clay (CL)	28 - 30	—	—	—	9	98.3	$1.6x10^{-6}$	$4.5x10^{-3}$			
	1994	CMC-LSL-101	Dark gray silty clay (CL)	14 - 16	0	4	70.6	25.4	96	$1.8x10^{-7}$	$5.1x10^{-4}$	—		
			Dark gray silty clay (CL)	20 - 22	0	4.9	75.3	19.8	95.1	—				
	1994	CMC-LSL-102	Dark gray silty clay (CL)	11 - 13	0	18.5	57.1	24.4	81.5	$2.5x10^{-7}$	$7.1x10^{-4}$	—		
	1994	CMC-LSL-102A	Dark gray silty clay (CL-ML)	16 - 18	0	12.8	67.6	19.6	87.2	—	—	1590.65	$2.3x10^{-3}$	$8.1x10^{-7}$
	1994	CMC-LSL-102B	Dark gray silty clay (CL)	12 - 14	0	10.9	63.1	26	89.1	$3.0x10^{-7}$	$8.5x10^{-4}$	1587.83	0.12	$4.2x10^{-5}$
			Dark gray silty clay (CL)	16 - 18	0	5.8	67.0	27.2	94.2	$1.8x10^{-7}$	$5.1x10^{-4}$			
			Dark gray silty clay (CL)	24 - 26	0	17.7	56.1	26.2	82.3	$2.3x10^{-7}$	$6.5x10^{-4}$			
			Brown silty clay (CL)	28 - 30	0	2.2	58.0	39.8	97.8	$4.5x10^{-7}$	$1.3x10^{-3}$			
			Brown clayey sand (SC)[c]	32 - 34	17.7	58.8	11.6	11.9	23.5	—	—			
Little Sand Lake	1994	CMC-LSL-103	Dark gray silty clay (CL-ML)	30 - 33	0	10.4	72.8	16.8	89.6	$1.2x10^{-7}$	$3.4x10^{-4}$	—		
			Dark gray silty clay (CL)	33 - 35	0	6.6	72.3	21.1	93.4	$8.8x10^{-8}$	$2.5x10^{-4}$			
	1994	CMC-LSL-103	Dark gray silty clay (CL)	18 - 19.6	0	27.6	55.8	16.6	72.4	—	—			

Table 3.6-19 *(Continued)*

Boring Location	Date	Boring No.	Soil Type (USCS)	Depth	% Gravel	% Sand	% Silt	% Clay	P-200	Hydraulic Conductivity Kv (cm/s)	Hydraulic Conductivity Kv (ft/d)	Groundwater Elevation (ft) MSL [b]	Field Measured Hydraulic Conductivity Kh ft/d	Field Measured Hydraulic Conductivity Kh cm/s
	1994	CMC-LSL-104A	Dark gray silty clay (CL)	15.4 - 17.4	0	6.6	70.4	23.0	93.4	$2.3x10^{-7}$	$6.5x10^{-4}$	1589.07	$2.3x10^{-3}$	$8.0x10^{-7}$
	1994	CMC-LSL-104B	Dark gray silty clay (CL)	17 - 19	0	7.7	65.2	27.1	92.3	$2.4x10^{-7}$	$6.8x10^{-4}$	1579.96	0.20	$7.1x10^{-5}$
			Dark gray silty clay (CL)	12 - 14	0	2.5	70.0	27.5	97.5	—	—			
			Brown sand (SP-SM)[c]	24 - 26	29.1	62.0		8.9	8.9	—	—			
	1994	CMC-LSL-105	Dark gray silty clay (CL)	6 - 8	0	10.2	65.2	24.6	89.8	$2.1x10^{-7}$	$6.0x10^{-4}$	—		
			Dark gray silty clay (CL)	8 - 10	0	4.9	64.7	30.4	95.1	—	—			
			Dark gray silty clay (CL)	12 - 14	0	19.7	55.2	25.1	80.3	$2.4x10^{-7}$	$6.8x10^{-4}$			
Duck Lake	1984	STS-DL-1	Dark gray silty clay (CL)	25.5 - 28	—	—	—	—	78	$1.3x10^{-6}$	$3.7x10^{-3}$	1594.75		
			Dark gray silty clay (CL)	38 - 40	—	—	—	—	93	$1.0x10^{-7}$	$2.8x10^{-4}$			
Skunk Lake	1984	STS-SL-½	Dark gray silty clay (CL)	9.1 - 10	—	—	—	—	93	$4.3x10^{-8}$	$1.2x10^{-4}$	1594.19		
Oak Lake	1984	STS-OL-1	Dark gray silty clay (CL)	37.5 - 39.5	—	—	—	—	88	$2.3x10^{-6}$	$6.5x10^{-3}$	Dry		
			Dark gray silty clay (CL)	42.5 - 44.5	—	—	—	—	93	$3.5x10^{-7}$	$9.9x10^{-4}$			
Deep Hole Lake	1984	STS-DHL-1	Dark gray silt (ML)	21 - 23	—	—	—	—	95	$6.8x10^{-7}$	$1.9x10^{-3}$	1587.93		
			Dark gray silt (ML)	33.5 - 35.2	—	—	—	—	88	$6.8x10^{-8}$	$1.9x10^{-4}$			

Table 3.6-19 *(Continued)*

Boring Location	Date	Boring No.	Soil Type (USCS)	Depth	% Gravel	% Sand	% Silt	% Clay	P-200	Hydraulic Conductivity Kv (cm/s)	Hydraulic Conductivity Kv (ft/d)	Groundwater Elevation (ft) MSL [b]	Field Measured Hydraulic Conductivity Kh ft/d	Field Measured Hydraulic Conductivity Kh cm/s
Bur Oak Swamp	1994	CMC-BO-101B	Sand (SC-SM)	4 - 6	0	53.7	32.5 Brown	13.8 Silty Clayey		$1.1x10^{-6}$	$3.1x10^{-3}$			
			Brown Clay (CL)	12 - 14	0	4.4	73.3	22.3		$2.9x10^{-6}$	$8.2x10^{-3}$			
			Brown Coarse Sand (SP)	36 - 38	1.8	95.6	2.6			—	—			
		CMC-BO-101A	Brown Clay (CL)	14 - 16	0.4	23.3	53.6	22.7		—	—		0.20	$7.1x10^{-5}$
		CMC-BO-102	Brown Clayey Sand (SC)	16 - 18	17.6	62.4	20			—	—			
			Brown Silty Sand (SM)	35 - 37	0	82.9	17.1			—	—			
Skunk Lake Wetland	1994	CMC-SL-103A	Gray Silty Clayey Sand (SC-SM)	6 - 8.5	0.1	57.4	19.6	22.9		$4.2x10^{-7}$	$1.2x10^{-3}$		1.7	6.1 X 10^{-4}
		CMC-SL-103B	Gray Clay (CL)	26 - 28	0	14.8	61.1	24.1		$3.5x10^{-6}$	$9.9x10^{-3}$			
			Brown Sand (SP)	38 - 40	25.5	70.1	4.4			—	—		2.3	$8.1x10^{-4}$
Skunk Lake Wetland, Continued		CMC-SL-104	Brown Silty Clayey Sand (SC-SM)	4 - 6	0	69.7	15.6	14.7		$1.8x10^{-6}$	$5.1x10^{-3}$			
			Gray Sandy Silty Clay (CL-ML)	16 - 19	0	30.5	56.0	13.5		$6.4x10^{-7}$*	$1.8x10^{-3}$			
			Brown Sand (SW-SM)	34 - 36	16.3	74.7	9			—	—			
Duck Lake Wetland	1994	CMC-DL-103A	Brown Silty Clayey Sand (SC-SM)	4 - 6	11.8	53.5	21.0	13.7		$9.3x10^{-8}$	$2.6x10^{-4}$			

Table 3.6-19 *(Continued)*

Boring Location	Date	Boring No.	Soil Type (USCS)	Depth	% Gravel	% Sand	% Silt	% Clay	P-200	Hydraulic Conductivity Kv (cm/s)	Hydraulic Conductivity Kv (ft/d)	Groundwater Elevation (ft) MSL [b]	Field Measured Hydraulic Conductivity Kh ft/d	Field Measured Hydraulic Conductivity Kh cm/s
		CMC-DL-103B	Brown Sand (SM)	20 - 22	0	67.4	27.6	5		—	—		2.2	$7.6x10^{-4}$
Swamp Creek Cedars Wetland	1994	CMC-SCC-101	Brown Clayey Sand (SC)	6 - 8	21.2	58.7	8.9	11.2		—	—			
		CMC-SCC-102A	Brown Silty Clayey Sand (SC-SM)	2 - 4	5.9	53.3	24.4	16.4		$3.3x10^{-7}$	$9.3x10^{-4}$			
			Gray Clayey Sand (SC)	8 - 10	14.6	57.7	27.7			—	—			
		CMC-SCC-102B	Brown Silty Fine Sand (SM)	16 - 18	13.2	67.9	11.6	7.3		—	—			
Swamp Creek Wetland	1994	CMC-SC-101	Gray Coarse Sand (SP)	12.5 - 14.5	0	98.6	1.4			—	—			
		CMC-SC-102	Gray Coarse Sand (SP)	10 - 12	6.5	90.5	3.0							

[a] Probable side channeling was noted in this test.
[b] Represents hydraulic head within the outwash/till deposits below the lake bed of the Lake. Note that the ordinary high water marks (feet MSL) of Little Sand Lake = 1591.96, Oak Lake = 1633.17, Deep Hole Lake = 1605.83, Duck Lake = 1611.09 and Skunk Lake = 1598.09.
[c] Outwash/till soil sample from beneath lake bed.
* Note sample was jarred when tube was removed from the hole.
— Not Tested

Prepared by: SVD1
Checked by: XXC

3.6.4.3 Study Area Groundwater Flow System

The groundwater flow system within the glacial overburden has been evaluated based on groundwater level measurements dating back to the late 1970s from monitoring wells shown in Figures 3.6-1 and 3.6-2. Hydrographs for these wells are presented and contained in Appendix 3.6-8.

Figures 3.6-27, 3.6-28, and 3.6-28a show water table contour maps for October 1984, August 1986, and June 1995 respectively. The October 1984 water table map depicts the water table configuration during a period of relatively normal precipitation and thus is considered to represent an average water table elevation and configuration. The August 1986 water table map represents the record high water table during which groundwater inflow to Little Sand Lake could occur. The June 1995 water table map displays current water table conditions. Cross-sections shown in Figures 3.5-26 through 3.5-32 show the elevation of the water table based primarily on the October 1984 data.

The water table is defined as the surface at which fluid pressure in the pores of a porous medium is equal to the atmospheric pressure and is indicated by the level at which water stands in a shallow well that penetrates just deep enough to encounter standing water. A well that extends deeper than the water table will have a static water level that represents an integrated average of hydraulic heads within the screened interval, and that is weighted by differences in transmissivity in the interval. Such a well would best represent the true water table when the vertical hydraulic gradient and permeability differences are minimal.

The first step in preparing the water table maps was to select site wells that are reasonably open to the shallowest groundwater. Although some wells have screens that span the water table, others do not. Therefore, it was necessary to set acceptance criteria for depths of screened intervals below the static water table. Because of the variability of well construction, it was assumed that the portion of the well open to the groundwater was the filter-packed interval. The wells were then evaluated to determine the distances between the tops of the filter packs and the October 1984 static water level in each well. Maximum distances of 20 feet and 40 feet, respectively, were used to accept wells as being representative of water table conditions. These criteria are considered reasonable considering the very low vertical gradients observed at the site (STS, 1984b). Vertical gradients at the 16 EX series well nests are minimal as indicated on the geologic cross sections shown in Figures 3.5-26 to 3.5-32. Vertical gradients are higher immediately around lakes that discharge to the groundwater. Therefore, acceptance criteria were shortened to 10 feet and 20 feet within 500 feet of these lakes. The shallow WP-series wells were used in water table wells and meet the above criteria. If available, the same wells were used to construct the 1986 water table map.

On a macro basis the water table maps compare favorably with the regional potentiometric surface map shown in Figure 3.6-11. The regional potentiometric surface map displays a generalized horizontal distribution of head within the glacial overburden, depicting the unconfined distribution of head within upland areas and the confined distribution of head beneath

the lake beds in upland areas (the lake beds function as a semi-confining layer). The connection of the upland lakes to the water table is not apparent in the potentiometric surface map, whereas the water table maps show the connection of the lakes to the groundwater system. The water table maps reflect the condition in which the surface elevation of the upland lakes are held above the surrounding groundwater due to the low permeability of the lake beds. This results in the lakes acting as sources of recharge to the groundwater system.

Figures 3.6-28b and 3.6-28c display potentiometric surface maps of the glacial outwash and Pre- to Early Wisconsinan Till, respectively, based on October 31, 1984 data. October 1984 was selected based on available data and to provide a comparison to the October 1984 water table map shown in Figure 3.6-27. The outwash potentiometric surface is based on wells screened in the outwash deposits and in some instances both the outwash and the Pre- to Early Wisconsinan Till or lacustrine deposits. The Pre- to Early Wisconsinan Till potentiometric surface is based on wells screened in the Pre- to Early Wisconsinan Till and in some instances both the Pre- to Early Wisconsinan Till and bedrock. The potentiometric surface maps are similar to the water table maps except in the vicinity of the lakes where the potentiometric surface maps reflect the distribution of head within the outwash and till beneath the lake beds. It should be noted that in many areas the potentiometric surface map of the outwash and water table maps are synonymous since the water table frequently resides within the outwash.

In general, the water table and potentiometric surface maps are a reflection of the surface topography. The water table and potentiometric high of about 1,595 occurs at the groundwater divide centered in the vicinity of the TMA. From this groundwater high, groundwater flows radially. Groundwater flow to the north and northwest eventually discharges to Swamp Creek. Groundwater flowing east and northeast discharges to Hemlock Creek and Ground Hemlock Lake. Groundwater flowing to the south is inferred, based on the regional water table map and regional potentiometric surface map, to discharge to Crane and Pickerel Lakes. Groundwater flow to the southwest and west eventually discharges to Pickerel Creek and Rolling Stone Lake. Other known discharge areas include Hoffman Springs which feeds into Swamp Creek, and Martin Springs which feeds into Rolling Stone Lake.

Horizontal gradients are typically moderate across most of the study area. The exception to this is in the vicinity of the lakes and near Hemlock Creek and the confluence of Swamp and Hemlock Creeks where steep horizontal gradients are observed. The cross sections shown in Figures 3.5-26 through 3.5-32 also display the groundwater flow system from a vertical perspective. In general vertical gradients are minimal as summarized in Appendix 3.6-8. However, in the vicinity of the TMA, downward vertical gradients exist as groundwater enters the system as recharge in this area and migrates down into the glacial deposits. The steepest downward gradients exist in the vicinity of the lakes and are attributed to the permeability contrast between the silty clay lake beds and underlying outwash/till. In the vicinity of the creeks, upward gradients exist as groundwater flows toward and discharges to the creeks that function as sinks to the system. Based on the vertical gradients on either side of Hemlock, Swamp, and Pickerel Creeks, the creeks appear to be fully penetrating in the sense that significant underflow beneath the creeks is not likely to take place.

Cross-sections show that across the study area the water table resides within various geologic formations. In the vicinity of the TMA and north of the plant site, the water table typically resides in the Late Wisconsinan Till. Whereas in the southern part of the study area, the water table typically resides within the outwash deposits. In the immediate vicinity of the plant site, the water table resides within the Pre- to Early Wisconsinan Till over the center part of the ore body. Along the eastern and western sides of the ore body, the water table resides within the overlying outwash deposits. The study area water table is a topic of ongoing discussions with the WDNR and USCOE. Upon completion of these discussions, a current water table map will be developed.

Golder Associates (1982) performed a water budget analysis to estimate net recharge to the groundwater system. The analysis was based on precipitation data from Laona and Swamp Creek base flow measurements. Golder Associates estimated that out of the 7.56E-3 ft/d (33.1 in/yr) of precipitation, 2.19E-10 ft/d (9.6 in/yr) or 29 percent of the total precipitation entered the groundwater system as recharge. Sensitivity analysis identified that the net annual recharge could vary between 1.96E-3 ft/d (8.58 in/yr) and 2.42E-3 ft/d (10.59 in/yr).

In the vicinity of the plant site, Swamp Creek and Hemlock Creek function as the principle groundwater discharge area that could be impacted by mine dewatering. A component of the groundwater modeling studies is to evaluate the potential reduction in groundwater discharge to these streams. To aid in this evaluation, the stream bed material which will influence the rate of groundwater discharge to the streams was evaluated. Figure 3.6-29 shows the results of the 1994 stream bed survey for Hemlock or Swamp Creeks. The survey was conducted visually, either on foot or by canoe. The stream bed of Hemlock Creek is predominantly silt and muck overlying sand. The stream bed of Swamp Creek ranges from predominantly sand to a mixture of sand, gravel, boulders and cobbles. The sandy stream beds reflect regions where the streams incise outwash deposits of sand. Whereas the mixture of sand, gravel, boulders and cobbles reflect regions where the streams incise deposits of glacial till in which the flowing stream has washed away the silt and clay component of the till.

Perched groundwater has been encountered at several locations across the study as identified in Figure 3.6-29a. In addition, many of the wetlands in upland areas are due to shallow perched water tables as discussed in Section 3.6.4.3.2. Perched groundwater occurs either near the land surface or deeper within the glacial deposits. The shallow perched groundwater is an integral part of wetlands and is created by low permeability fine grained soils and runoff. The deeper perched groundwater systems are also due to fine grained soils that intercept and retard percolating water.

The perched groundwater systems were identified based on an examination of boring logs and surrounding groundwater levels. In most instances the screened intervals of wells monitoring perched groundwater intersect fine grained deposits. In addition, nested or nearby water table wells that are deeper measure a phreatic surface substantially below the shallow groundwater which is indicative of perched conditions.

3.6.4.3.1 Groundwater/Lake Interactions

Cross-sections shown in Figures 3.5-26 through 3.5-32 show the general relationship between the groundwater system and upland lakes including Oak, Little Sand, Deep Hole, Duck and Skunk Lakes. Well STS-OL-1 installed beneath Oak Lake went dry soon after installation indicating that this lake is perched. As such, Oak Lake will not be subject to impacts on the lake's water budget due to mine dewatering activities. However, wells installed immediately beneath Little Sand, Deep Hole, Duck, and Skunk Lakes all produced static water levels that were above the bottom of the silt/clay and silt lake beds, but lower than the lake surface. This indicates that these hydraulically connected lakes are primarily recharging the groundwater system. The rate of recharge out of the lakes is a function of the hydraulic gradient across the lake bed and the permeability of the lake bed. As such the recharging nature of these lakes is head dependent. Thus Little Sand, Deep Hole, Duck, and Skunk Lakes are classified as head dependent recharge lakes.

Dames & Moore (1985) performed an annual water budget analysis of the lakes to quantify the various components that make up the water budget of Oak, Little Sand, Deep Hole, Duck and Skunk Lakes. The Dames & Moore report is provided in its entirety in Appendix 3.6-9. The annual water budgets were based on field determined estimates of surface runoff to the lakes, precipitation, evaporation, and surface water inflow and outflow. Recharge to the groundwater system was computed as the difference between all surface inputs and outputs to the lake surface. The results of the water budget analysis are summarized in Table 3.6-20. The results of water budget analysis indicate that net movement of water through the lake beds of the head dependent recharge lakes is to the groundwater system.

Given the elevation of the lake beds with respect to the surrounding groundwater system, the potential for regional groundwater inflow to the lakes appears to be plausible only for Little Sand Lake. On the upgradient side of Little Sand Lake, i.e., the north and northeast side of the lake, the recorded groundwater elevations are in close proximity to the lake surface. A comparison of lake stage to groundwater elevations shown in Figure 3.6-30 shows that typically lake elevations are above the groundwater elevations. On two occasions the groundwater elevations in wells G40-Y15A and DMA-19 were above the lake stage of Little Sand Lake. Given that these wells are located on the upgradient side of Little Sand Lake and that head is decreasing in a southwesterly direction, it is unlikely that regional groundwater inflow into Little Sand Lake is a significant component of the seepage component of the lakes water budget.

This interpretation was corroborated in December 1994 through the installation of sand points along the north and northeast sides of Little Sand Lake. Groundwater elevations from the sand points with respect to the lake stage of Little Sand Lake are summarized in Table 3.6-21. With the exception of water levels in the F10 wetland, shown on Figures 3.6-3 and 3.10-1, the water levels on the north side of the lake were below the lake stage.

The flow of water between the lakes and the groundwater system is three-dimensional in nature. To better visualize the flow of water between the lakes and the groundwater system a series of

Table 3.6-20

Summary of Annual Water Balance

	Gains			Losses					Lake Level			
	Precipitation	Runoff	TOTAL	Evaporation	Outflow	TOTAL	Lake Storage	Recharge	Start (May) (ft)	Maximum (ft)	Minimum (ft)	Range (ft)
Little Sand Lake												
Wet	41.23	49.39	90.62	22.77	55.10	77.86	4.76	-8.00	1591.7820	1592.2	1591.4	0.8
Dry	22.80	28.95	51.75	29.06	18.37	47.44	-3.69	-8.00	1591.7820	1591.8	1591.3	0.5
Average	30.71	37.28	67.99	25.69	34.30	59.99	.00	-8.00	1591.7820	1591.8	1591.5	0.3
Oak Lake												
Wet	41.23	32.57	73.80	22.77	37.80	60.57	4.11	-9.10	1633.1930	1633.6	1632.8	0.8
Dry	22.80	19.08	41.88	29.06	5.41	34.47	-1.69	-9.10	1633.1930	1633.2	1632.8	0.4
Average	30.71	24.58	55.29	25.69	20.49	46.17	.00	-9.10	1633.1930	1633.4	1633.1	0.3
Duck Lake												
Wet	41.23	25.11	66.34	22.77	15.90	38.67	6.37	-21.30	1611.0580	1611.7	1611.0	0.7
Dry	22.80	14.71	37.51	29.06	0.26	29.33	-13.11	-21.30	1611.0580	1611.1	1610.1	1.0
Average	30.71	18.95	49.66	25.69	2.67	28.36	.00	-21.30	1611.0580	1611.2	1610.9	0.3
Skunk Lake												
Wet	41.23	46.08	87.31	22.77	0.00	22.77	24.74	-39.80	1598.0900	1599.7	1598.1	1.6
Dry	22.80	27.00	49.80	29.06	0.00	29.06	-19.06	-39.80	1598.0900	1598.1	1596.7	1.4
Average	30.71	34.78	65.49	25.69	0.00	25.69	.00	-39.80	1598.0900	1598.3	1598.1	0.2
Deep Hole Lake												
Wet	41.23	44.37	85.60	22.77	50.49	73.25	4.35	-8.00	1606.5145	1606.9	1606.2	0.7
Dry	22.80	26.01	48.81	29.06	15.11	44.18	-3.37	-8.00	1606.5145	1606.5	1606.0	0.5
Average	30.71	33.49	64.20	25.69	30.51	56.20	.00	-8.00	1606.5145	1606.6	1606.2	0.4

General Notes:

1. Units are inches of lake level except as indicated.
2. Negative lake storage values indicate fall in water level.
3. Negative recharge values indicate outward seepage.
4. Derivation of values is explained in Appendix 3.6-9.

Prepared by: SVD1
Checked by: XXC

Table 3.6-21

Summary of December 1994 Little Sand Lake Sand Point Data

Sand Point/ Private Well	East	North	Screened Interval or Bottom Elevation (ft.)	December 1994 Water Elevation (ft.)
CMC-SP-01	2279412.2	114244.4	1589.50-1592.50	1592.99
CMC-SP-02	2279306.4	114181.3	1589.20-1592.20	1592.55
CMC-SP-03A	2278974.6	114628.8	1589.41-1592.41	1592.53
CMC-SP-03B	2278975.8	114672.6	1573.07-1576.07	NS
CMC-SP-04	2279029.3	114726.9	1588.49-1592.49	1592.80
CMC-SP-05A	2278578.4	114907.4	1589.51-1592.51	1592.41
CMC-SP-05B	2278580.5	114908.8	1572.35-1575.35	NS
CMC-SP-06	2278619.2	114977.8	1589.76-1592.76	1591.95
CMC-SP-07	2278023.5	115104.1	1589.89-1592.89	1591.94
CMC-SP-08	2278024.2	115222.1	1589.15-1592.15	1591.07
CMC-SP-09	2279719.9	115000.5	1590.17-1593.17	1592.40
Little Sand Lake	—	—	—	1592.45

NS = Not Stabilized

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Checked by: SGL

hydraulic cross sections were prepared (Foth & Van Dyke, 1994d). These cross-sections are shown in Figures 3.6-31 through 3.6-36. Little Sand and Duck Lakes were selected based on data availability and because they are representative of the conditions around other head dependent recharge lakes. Of the four head dependent recharge lakes in the area, Duck and Little Sand Lakes reside at the highest and lowest topographic elevations, respectively.

All lake profiles show downward gradients beneath the lakes. A transition zone is present at the edges of the lakes where flow changes from primarily vertical to primarily horizontal. This is most evident around Duck Lake and along the down gradient side of Little Sand Lake. On Little Sand Lake flow is out of the lake with stronger downward gradients along the south side of the lake than along the north side of the lake. Hydraulic head data for October 1984 indicates that appreciable groundwater inflow into the lake is unlikely under normal steady state conditions. However, under high groundwater conditions, as in 1986 and 1994, hydraulic head contours indicate that the potential exists for a small amount of lateral groundwater inflow along the northeast side of Little Sand Lake.

Based on the 1994 sand point data from around Little Sand Lake, the area for potential groundwater inflow to the lake is likely limited to the F10 and possibly F9 wetlands. These wetlands are runoff fed. Since downward gradients are observed at well DMA-19/CMC-SP-09, the source of potential groundwater inflow to the lake from these wetlands is from surface water runoff to the wetland and is, for all practical purposes, equivalent to surface water runoff.

Reviewers from the WDNR have expressed concern that the monthly and quarterly groundwater and lake stage measurements do not account for short term transient hydrologic changes due to recharge events for Little Sand Lake and perched wetlands such as Bur Oak Swamp. It has been hypothesized that these short term recharge events, such as the spring snow melt and subsequent heavy precipitation events, could result in transient changes to the hydrologic relationship between the groundwater system and surface water bodies in question.

Specific hypotheses have envisioned short term spring and summer recharge events increasing groundwater levels on the upgradient side of Little Sand Lake whereby groundwater seepage to the lake for a short period of time could account for a significant percentage of the water budget for the lake. With respect to perched wetlands (discussed in Section 3.6.4.3.2), such as Bur Oak Swamp, hypotheses have envisioned these same recharge events increasing the water table elevation to the point that the water table is coupled to the lacustrine clay layer that underlies the wetland. Under the coupled hypothesis, the hydraulic gradient across the clay layer would be reduced, thus increasing the duration of ponded water in the wetland.

Drawdown of the water table due to mine inflow could preclude these hypothesized transient events. In the case of Little Sand Lake, this would result in less water input to the lake which could impact lake stage. In the case of perched wetlands such as Bur Oak Swamp, the reduced duration of ponded water in the wetland could affect the wetlands ecology.

In late February 1995, prior to the spring thaw, NMC initiated an investigation of the short term transient hydrologic relationships between the regional groundwater system and head dependent recharge lakes and perched wetlands. This program, implemented at the request of the WDNR and described in a letter dated February 16, 1995 (CMC, 1995), was intended to assess the spring runoff and recharge event impact on: 1) the potential for groundwater inflow into Little Sand Lake, and 2) the coupling of perched wetlands, such as Bur Oak Swamp, to the groundwater system.

Six sand points (CMC-SP-03A, -03B, -05A, -05B, -11A, and -11B) along the north side of Little Sand Lake and two monitoring wells in Bur Oak Swamp (CMC-BO-101A and -101B) were instrumented with pressure transducers and electronic data loggers. The data loggers were programmed to record, via the pressure transducers, the water level in the well at a frequency of at least once every hour. The equipment was installed in late February and early March of 1995 and was initially scheduled to run until June 1995. At WDNR's request the monitoring was extended and the equipment was left in place until September 7, 1995 to assess changes during summer rain events. Concurrent with the data logger measurements, frequent manual measurements of water levels in the instrumented wells were recorded to check the accuracy of the pressure transducers. In addition, frequent manual water level measurements were recorded in non-instrumented "CMC-SP" series sand points and well DMA-19 which are distributed around the northern part of Little Sand Lake. Lake stage measurements of Little Sand Lake were also frequently recorded from a surveyed staff gage.

Sand points CMC-SP-03A, -03B, -05A, -05B, -11A, and -11B shown on Figure 3.6-3 were monitored via data loggers around the upgradient, northeast, side of Little Sand Lake. The "A" sand points are shallow, screened approximately 1 to 4 feet below land surface. The "B" sand points are deeper, screened at a depth of approximately 19 to 22 feet below land surface. The remaining non-instrumented "CMC-SP" series sand points shown on Figure 3.6-3 are all screened at the water table, whereas well DMA-19 is a piezometer measuring head within the regional aquifer that extends beneath the silty clay lake bed. Note that based on the slow rate of recovery after development, the "B" sand points are presumed to be screened within the lacustrine silty clay layer that comprises the lake bed. Sand points CMC-SP-03A & B and CMC-SP-11A & B are located in head dependent recharge wetlands (F9 and F10) adjacent to Little Sand Lake. Sand point CMC-09 and well DMA-19 are adjacent to the northern boundary of the F10 wetland. The lake stage of Little Sand Lake had been measured frequently since ice out in mid April of 1995 through the time the sand points were in place.

The potential sources of water input to a surface water body such as a lake include direct precipitation, precipitation generated runoff or overland flow, and subsurface stormflow (interflow) and groundwater flow. The continuous monitoring of the shallow sand points along the northeast side of Little Sand Lake provides insight into the overland flow, interflow and baseflow processes that affect the stage of the lake.

Figures 3.6-36a through 3.6-36c show the transient groundwater levels (measured via data loggers and manually) along the upgradient side of Little Sand Lake, daily precipitation, and lake

stage from March 1, 1995 until September 7, 1995. In comparison to the deeper sand points, the shallow sand points show greater and more frequent transient fluctuations suggestive of short lived responses to precipitation events as opposed to longer temporal changes in the regional groundwater regime.

Comparison of water levels in the shallow sand points provides insight into the transient lateral exchange of water between the lake and groundwater system that is affected by overland and groundwater flow phenomena. From the point of ice out on Little Sand Lake in April 1995, until the fall of 1995, the lake stage of Little Sand Lake, ranges from being less than the shallow water table to greater than the shallow water table. This indicates that there are transient exchanges of water from the lake to the shallow water table and from the shallow water table to the lake. As measured by CMC-SP-03A and CMC-SP-11A, the periods where the shallow water table is greater than the lake stage range from several days to several weeks, with the shallow water being anywhere from about one tenth to half a foot above the lake stage. However, this phenomena occurred primarily in the wetlands. Outside the wetlands, as measured by CMC-SP-05A, the water table elevation routinely remained several tenths to half a foot below the lake stage. This suggests that the infrequent short term increases of the water table in the wetland above the lake stage are related to a phenomena other than regional groundwater flow.

With respect to the vertical component of flow between the lake and the groundwater system, Figures 3.6-36a through 3.6-36c show a definite downward vertical gradient between the shallow sand points and nested deeper sand points through the duration of monitoring. This pattern is consistent with previous field data and interpretations that have noted strong downward vertical gradients across the lake bed of Little Sand Lake and other head dependent recharge lakes. Based on the trends of the deep and shallow sand points, it seems evident that reversal of the vertical component of flow between the silty clay lake bed and groundwater system does not occur.

Figures 3.6-36a through 3.6-36c also display concurrent manual measurements of water levels in the sand points around Little Sand Lake. Acquired to verify the accuracy of the pressure transducers, the manual measurements compare favorably to the pressure transducers. In the shallow sand points the manual measurements agree with the pressure transducers to within several hundredths to approximately two tenths of a foot. The deviation between the deeper sand points and the pressure transducers is between approximately one to three tenths of a foot.

Figures 3.6-36d through 3.6-36g display hydrographs of groundwater elevations versus lake stage, based on manual measurements from the non-instrumented wells for 1995. Although based on non-continuous monitoring data, the hydrographs show a similar trend to that observed in the instrumented wells discussed above. Outside the wetland areas, as measured by CMC-SP-06, -07, and -08, the water levels are continuously below the lake stage indicating lateral movement of water from the lake to the shallow water table. Within the F10 wetland and between the F10 and F9 wetland, the water table is periodically above the lake as measured by CMC-SP-01, -02, and -04. Again, these periods of a high shallow water table versus lake stage

range from several days to several weeks or more and appear driven by runoff, precipitation, and the head dependent recharge nature of the wetland.

Well CMC-SP-09 shows a sustained water table elevation above the lake stage. Located approximately 800 feet north of Little Sand Lake, the water levels in CMC-SP-09 are representative of the water table in and near the north side of the F10 head dependent recharge wetland as opposed to the regional groundwater table and is not indicative of a continuous lateral influx to Little Sand Lake. This opinion is supported by the fact that shallow water table sand point CMC-SP-03A, downgradient of CMC-SP-09, is frequently below the lake stage. Moreover, given that the F10 wetland is a head dependent recharge wetland, it is to be expected that the local water table within and around the wetland would be slightly higher than the regional water table and lake.

The F9 and F10 wetlands receive considerable runoff from the surrounding area. Consequently, it is likely that the slight increase of water levels in these wetlands above the lake stage is reflective of the runoff ponding in the wetlands, thus the head dependent recharge nature of the wetlands. Note that during the spring, when the ground is frozen and runoff to wetlands is greatest, the shallow groundwater levels in the wetlands (see CMC-SP-03A and -11A) are one-quarter to one foot greater than the shallow groundwater outside the wetland (CMC-SP-05A, -06, -07, and -08). This indicates a more prolonged surface input to the wetlands where it is stored. The resulting seepage from the wetlands to the lake over these short periods of time is thus more representative of an overland flow and interflow phenomena as opposed to regional groundwater flow to the lake. The transient nature of the wetland water level elevations being greater than the lake stage support the inference of this input being comprised of overland flow during runoff and high precipitation events. This was observed during the month of August 1995, a period of very high precipitation.

During August 1995, the water levels in shallow wells CMC-SP-03A and -11A increased slightly above the lake stage and fluctuated significantly over short periods of time in response to each precipitation event. A more gradual increase and decline than what was observed would be expected if the input were derived from regional groundwater flow. Overall, the preponderance of data suggests a localized groundwater system exists in the vicinity of the F9 and F10 wetlands near Little Sand Lake that occasionally contributes water laterally to the lake. Furthermore, this localized groundwater system appears to be controlled via direct precipitation and runoff to the wetland, and the head dependent nature of the wetlands, as opposed to the regional groundwater influx. The localized groundwater system resides above the silty clay layer that forms the lake bed of Little Sand Lake. Since it is unlikely that runoff to these wetlands will be affected by drawdown of the regional water table due to mine inflow, it is also unlikely that the wetland derived local groundwater system and infrequent short term transient seepage from these wetland areas to the lake will be impacted.

Figure 3.6-36h displays the monthly precipitation record from December 1994 through August 1995. Recharge and runoff during the spring (March through May) is comprised of two components: 1) precipitation as rainfall, and 2) melted snow and ice that accumulated during the

winter months (December through March). Precipitation from December 1994 through May 1995 was approximately 73 percent of the long term average for these months. June was approximately 50 percent of the long term average. July experienced near normal precipitation. Precipitation in August was more than twice the long term monthly average and made up for the deficit from lower winter and spring precipitation. Although the precipitation during winter and spring months was below normal, the capture of the intense recharge event in August 1995 indicates that it is unlikely that transient recharge events lead to a significant groundwater contribution to Little Sand Lake.

An analysis of lake and groundwater chemistry data provides an additional means of assessing groundwater and lake interactions. As summarized in Section 3.7.7.1, all of the upland lakes (Oak, Little Sand, Deep Hole, Duck, and Skunk) have low hardness, alkalinity, and total dissolved solids (TDS). As summarized below, the groundwater in the study area has alkalinity, hardness, and TDS concentrations that are approximately an order of magnitude higher than that of head dependent recharge lakes. In contrast, groundwater fed lakes in the study area, such as those discussed in Section 3.7.7.1, have water chemistries that are very similar to the groundwater.

Oak Lake has no direct contact with the groundwater system. Consequently the groundwater system has no impact on the water chemistry of Oak Lake. The fact that the water chemistry of Little Sand, Deep Hole, Duck, and Skunk Lakes have water chemistries that are nearly identical to Oak Lake, and significantly different than the groundwater and groundwater fed lakes is nearly conclusive evidence that the head dependent recharge lakes, receive no groundwater inflow. However, as Figure 3.6-34 suggests, short term transient recharge events may take place in which groundwater discharges to Little Sand Lake on the north and northeast sides. This possibility is being investigated through continuous water level measurements in sand points on the northeast side of the lake. Once available, these data will be provided in an addendum to this report.

During the late 1980s the region experienced a drought. Additional insight into the interaction of the lakes with the groundwater system is gained by examining the reaction of the lakes and the groundwater system to the drought. Figures 3.6-37 through 3.6-40 show hydrographs of the head dependent recharge lakes compared to nearby groundwater monitoring wells. During the drought, groundwater levels in the vicinity of the upland lakes declined by about four to five feet. However, the lakes did not respond in a similar fashion and showed little response to the drought. The ratio of lake level decline to groundwater decline is about 0.3 for Skunk Lake and 0.1 for Duck Lake. The hydrographs for Little Sand and Deep Hole Lakes show no discernable response to the drought and groundwater level declines. This response is consistent with the hydraulic conductivity and lake bed characterization studies. These studies, described above, indicate that the lake beds consist of a low permeability continuous silty clay/silt layer.

In addition to precipitation, runoff, evapotranspiration, and seepage, the lake stage of Little Sand, Duck, and Deep Hole Lakes are also influenced by outlet creeks on these lakes. In 1996, NMC completed outlet flow and lake stage monitoring for Little Sand, Duck, and Deep Hole Lakes to evaluate the stage-discharge relationship of these water bodies. Results from this field

investigation are described in a memorandum contained in Appendix 3.6-9a (Foth & Van Dyke, 1996a).

In summary, the memorandum concluded that the 1996 flow and stage monitoring data confirm that beaver populations can have a substantial influence on lake elevations. This is evident by the stage decline in Little Sand Lake when the beaver dam was breached which emphasizes the transient nature of the stage-discharge relationship. Given the beaver induced morphological changes that have occurred over the years to the outlets of the lakes, it is to be expected that the stage-discharge relationships have changed slightly and will continue to change provided a beaver population remains. The rating equations developed for the 1996 data support this hypothesis. Although the flow from the lakes is comparable to that measured in the late 1970's, the rating equations indicate that the outflow is controlled by a broader more diffuse outlet structure than existed previously. Overall, the rating curves as currently measured are consistent with the past data. However, they have changed slightly and will continue to fluctuate in the future because of the beaver activity downstream from the discharge.

3.6.4.3.2 Groundwater Wetland Interactions

Wetlands can be classified as either discharge or recharge based on their relationship with the groundwater system. Situations in which the wetland is lower than the water table surrounding it results in groundwater discharging to the wetland. These are referred to as discharge wetlands (Mitsch & Gosslink, 1993; and Todd, 1967). Discharge wetlands are commonly associated with groundwater discharge points such as gaining streams. The use of the term discharge wetland here will be used as described above for the classification of wetlands with respect to the groundwater system.

When a wetland exists above the surrounding water table, water infiltrates the wetland soils and flows to the underlying groundwater system. This is referred to as a recharge wetland (Mitsch & Gosslink, 1993; and Todd, 1967).

Several types of recharge wetlands exist in the study area. If an unsaturated zone exists between the wetland and the underlying groundwater system, the wetland is perched and will not be subjected to impacts from groundwater drawdown provided the wetland is not connected laterally to a head dependent recharge lake. These wetlands are referred to here as Type 1 recharge wetlands.

Wetlands that are perched but are connected laterally to head dependent recharge lakes may be subject to drawdown related impacts due to their connection to the lake. These wetlands, which also recharge the groundwater system, are referred to here as Type 2 recharge wetlands. Type 3 recharge wetlands are head dependent wetlands that exist slightly above the regional water table and contain continuously saturated soils from the wetland surface down to the regional aquifer and are therefore hydraulically connected vertically to the groundwater system.
Schematic diagrams of the various types of wetlands are provided in Figures 3.6-41 through 3.6-44. Within the study area, all wetlands were classified as being either discharge or one of

three types of recharge wetlands. These classified wetlands are shown in Figure 3.6-45. Wetlands that were considered were delineated wetlands within the study area and major wetland systems associated with groundwater discharge areas. The criteria used to classify the wetlands are discussed below.

Discharge wetlands are those that are associated and in close proximity to groundwater discharge points such as Swamp, Hemlock, and Pickerel Creeks. Type 1 recharge wetlands are those wetlands that exist in upland areas, occur in isolated topographic depressions not associated with head dependent recharge lakes and are roughly 15 feet or more above the water table. Figure 3.6-46 shows an inferred depth to groundwater map for the study area that was derived from using the regional potentiometric surface map as representative of the water table with the condition that the head dependent recharge lakes reflect the water table. Type 2 recharge wetlands are those that exist in upland areas, contain an unsaturated zone beneath them, are more than 15 feet above the inferred water table, but are connected laterally to head dependent recharge lakes. Type 3 recharge wetlands were classified based on their association with head dependent recharge lakes. The second criterion used for these wetlands is that the wetland surface resides at a topographic elevation that is less than approximately ten feet above the surrounding groundwater elevation. Study area wetlands are listed by hydrogeological classification in Table 3.6-22. These designations will be used as input to the project's regional groundwater modeling effort.

As described in Section 3.6.4.3.1, continuous monitoring of water levels in Bur Oak Swamp, a Type I recharge wetland, was performed from March 1995 through June 1995 to assess the potential for the regional water table to couple the wetland soils. Figure 3.6-47 shows the transient groundwater elevations in wells installed at the Bur Oak Swamp. Well CMC-BO-101A is installed in the shallow clay deposit that forms the wetland base. Well CMC-BO-101B is screened below the clay deposit in the outwash sands and gravel. As shown by the figure, during the spring, the perched water table increases in response to infiltration from the spring melt and rainfall. However, the water level in the deep well remains nearly constant over time. The deep well is screened in unsaturated outwash deposits and resides about three feet above the regional water table. The water level measured in the well represents stagnant water in the well sump (the unslotted portion of the casing below the slotted well screen). Thus it can be inferred that the water table below the wetland fluctuated during this period of time by no more than approximately three feet. More importantly, it is evident that the water table did not couple to the clay layer that forms the wetland base. Although this data is not conclusive for all perched wetlands, it provides a strong indication that the duration of ponded water in perched wetlands at the site is not affected by short term transient events that couple the regional groundwater system to the perched wetlands. Thus mining induced drawdown of the water table should not alter the ecology of these environments.

In 1996 the WDNR requested that NMC conduct additional studies on the hydrology of Bur Oak Swamp. Specifically, the WDNR requested that NMC conduct studies to evaluate the potential for interflow acting as a significant contributor of water to the wetland. In 1996, NMC completed test pits and initiated a second hydrologic monitoring program in Bur Oak Swamp to

Table 3.6-22

Wetland Type by Hydrogeology

Wetland Number	Wetland Type
A1	Recharge Wetland Type 1
A2	Recharge Wetland Type 1
A3	Recharge Wetland Type 1
B1	Recharge Wetland Type 1
B2	Recharge Wetland Type 1
B3	Recharge Wetland Type 1
B4	Recharge Wetland Type 1
B5	Recharge Wetland Type 1
B8	Recharge Wetland Type 1
D1	Discharge
D2	Recharge Wetland Type 1
D3	Recharge Wetland Type 1
D4	Recharge Wetland Type 1
D4A	Recharge Wetland Type 1
D5	Recharge Wetland Type 1
D8	Recharge Wetland Type 1
D18	Recharge Wetland Type 1
F1	Discharge
F2	Recharge Wetland Type 3
F4	Recharge Wetland Type 3
F5	Recharge Wetland Type 3
F6	Recharge Wetland Type 3
F7	Recharge Wetland Type 3

Table 3.6-22 *(Continued)*

Wetland Number	Wetland Type
F8	Recharge Wetland Type 1
F9	Recharge Wetland Type 3
F10	Recharge Wetland Type 3
F11	Recharge Wetland Type 3
F12	Recharge Wetland Type 3
F13	Recharge Wetland Type 1
F15	Recharge Wetland Type 1
F16	Recharge Wetland Type 1
F17	Recharge Wetland Type 1
F18	Recharge Wetland Type 2
F19	Recharge Wetland Type 2
F21	Recharge Wetland Type 2
F22	Recharge Wetland Type 2
F23	Recharge Wetland Type 2
F24	Recharge Wetland Type 1
F25	Recharge Wetland Type 1
F26	Recharge Wetland Type 1
F27	Recharge Wetland Type 1
F28	Recharge Wetland Type 2
F29	Recharge Wetland Type 2
F30	Recharge Wetland Type 1
F31	Recharge Wetland Type 1
F32	Recharge Wetland Type 1
F33	Recharge Wetland Type 1
F34	Recharge Wetland Type 1

Table 3.6-22 *(Continued)*

Wetland Number	Wetland Type
F35	Recharge Wetland Type 1
F36	Recharge Wetland Type 1
F37	Recharge Wetland Type 2
F38	Recharge Wetland Type 1
F39	Recharge Wetland Type 1
F40	Recharge Wetland Type 3
F42	Recharge Wetland Type 1
F43	Recharge Wetland Type 1
F45	Recharge Wetland Type 1
F46	Recharge Wetland Type 1
F48	Recharge Wetland Type 1
F50	Recharge Wetland Type 1
F51	Recharge Wetland Type 1
F52	Recharge Wetland Type 1
F53	Recharge Wetland Type 1
F54	Recharge Wetland Type 1
F55	Recharge Wetland Type 1
F57	Recharge Wetland Type 1
F58	Recharge Wetland Type 1
F60	Recharge Wetland Type 1
F61	Recharge Wetland Type 1
F62	Recharge Wetland Type 1
F63	Recharge Wetland Type 1
F64	Recharge Wetland Type 1
F65	Recharge Wetland Type 1

Table 3.6-22 *(Continued)*

Wetland Number	Wetland Type
F66	Recharge Wetland Type 1
F69	Recharge Wetland Type 1
F70	Recharge Wetland Type 1
F72	Recharge Wetland Type 1
F81	Recharge Wetland Type 1
F86	Recharge Wetland Type 1
F87	Recharge Wetland Type 1
F90	Recharge Wetland Type 1
F114	Recharge Wetland Type 1
F116	Recharge Wetland Type 1
F119	Recharge Wetland Type 3
F121	Recharge Wetland Type 1
F122	Recharge Wetland Type 1
F122A	Recharge Wetland Type 1
F125	Recharge Wetland Type 1
F126	Recharge Wetland Type 1
F127	Recharge Wetland Type 1
G1	Recharge Wetland Type 1
H1	Recharge Wetland Type 1
I1	Recharge Wetland Type 1
J1	Recharge Wetland Type 1
K1	Recharge Wetland Type 1
K2	Recharge Wetland Type 1
K3	Recharge Wetland Type 1
K4	Recharge Wetland Type 1

Table 3.6-22 *(Continued)*

Wetland Number	Wetland Type
K5	Recharge Wetland Type 1
L1	Recharge Wetland Type 3
M1	Recharge Wetland Type 3
M2	Recharge Wetland Type 1
M3	Recharge Wetland Type 1
M4	Recharge Wetland Type 1
M5	Recharge Wetland Type 1
M6	Recharge Wetland Type 1
N1	Recharge Wetland Type 3
O1	Discharge
O3	Recharge Wetland Type 1
P1	Discharge
P2	Recharge Wetland Type 1
R1	Recharge Wetland Type 1
R1A	Recharge Wetland Type 1
R3	Recharge Wetland Type 1
R7A	Recharge Wetland Type 1
R5	Recharge Wetland Type 1
R7	Recharge Wetland Type 1
R8	Recharge Wetland Type 1
T1	Recharge Wetland Type 3
T2	Recharge Wetland Type 3
T3	Recharge Wetland Type 3
T4	Discharge
T5	Recharge Wetland Type 3

Table 3.6-22 *(Continued)*

Wetland Number	Wetland Type
W1	Discharge
W2	Discharge
X2	Recharge Wetland Type 1
X3	Recharge Wetland Type 1
X4	Recharge Wetland Type 1
Z1	Recharge Wetland Type 1
Z2	Recharge Wetland Type 1
Z3	Recharge Wetland Type 1
Z4	Recharge Wetland Type 1
Z5	Recharge Wetland Type 1
Z6	Recharge Wetland Type 3
Z7	Recharge Wetland Type 1
Z8	Recharge Wetland Type 3
Z9	Recharge Wetland Type 3
Z10	Recharge Wetland Type 3
Z11	Discharge
Z12	Recharge Wetland Type 3
Z13	Recharge Wetland Type 3
Z14	Discharge
Z15	Discharge
Z16	Recharge Wetland Type 3
Z17	Discharge
Z18	Discharge
Z19	Discharge
Z20	Recharge Wetland Type 1

Table 3.6-22 *(Continued)*

Wetland Number	Wetland Type
Z21	Recharge Wetland Type 1
Z22	Recharge Wetland Type 1
Z23	Discharge
Z24	Discharge
Z25	Discharge
Z26	Recharge Wetland Type 1
1	Recharge Wetland Type 1
2	Recharge Wetland Type 1
3	Recharge Wetland Type 1
4	Recharge Wetland Type 1
5	Recharge Wetland Type 1
6	Recharge Wetland Type 1
7	Recharge Wetland Type 1
8	Recharge Wetland Type 1
9	Recharge Wetland Type 1
10	Recharge Wetland Type 1
11	Recharge Wetland Type 1
12	Recharge Wetland Type 1
13	Recharge Wetland Type 1
14	Recharge Wetland Type 1
15	Recharge Wetland Type 1
16	Recharge Wetland Type 1
17	Recharge Wetland Type 1
18	Recharge Wetland Type 1
19	Recharge Wetland Type 1

Table 3.6-22 *(Continued)*

Wetland Number	Wetland Type
20	Recharge Wetland Type 1
21	Recharge Wetland Type 1
PC-1[1]	Discharge
MS-1	Discharge
CR 129-1	Discharge
UN-1	Discharge
HC-1	Discharge
OC-1	Recharge Wetland Type 3
RL-1	Discharge
ML-1	Discharge

[1]Wetlands PC-1 through ML-1 were mapped based on interpretation of 1993 color aerial photograph and field verification. These wetlands are outside the boundaries of the wetland study area, but were added for the groundwater modeling studies.

Prepared by: SVD1
Checked by: RFS

assess the potential occurrence of interflow contributions to the wetland. A detailed memorandum describing the 1996 wetland investigation is contained in Appendix 3.6-9b (Foth & Van Dyke, 1996b). In summary, the results of the 1996 investigation, in addition to data collected in 1995, support a conceptual model of a wetland in which water input is derived primarily from direct precipitation and runoff. Moreover, the work concluded that it is unlikely that interflow is a significant contributor to the Bur Oak Swamp water balance and that the regional groundwater system does not couple to the wetland.

3.6.4.4 1998 Grout Study

The grout program implemented by TRC Hydro-Geo Consultants, Inc. consisted of two phases of testing. The program was implemented to evaluate the feasibility of constructing a grout blanket at the base of the crown pillar and to estimate the reduction in permeability of the grouted layer. The target horizon for the test program was approximately from 220 to 250 feet below ground surface.

The completed grout and verification borehole layout is shown as Figure 3.5-10a in Section 3.5. The locations of the boreholes were determined using a measuring tape and Brunton compass. The four primary grout boreholes include NMC-102 through NMC-105. These boreholes form the perimeter of the 20-feet by 20-feet square test hole pattern. The primary boreholes were the first to be cored, packer tested, and grouted. Subsequently boreholes NMC-106 through NMC-108 were cored and packer tested to assess the effect of grouting the four primary boreholes. Boreholes NMC-106, NMC-107, NMC-109, and NMC-111 functioned as secondary grout boreholes which reduced the grout borehole spacing to 10 feet within the rectangle formed by boreholes NMC-103, NMC-111, NMC-106, and NMC-102. Verification boreholes NMC-110 and NMC-112 were the last to be drilled and functioned to assess the effect of the secondary grout boreholes.

A summary of the packer permeability testing is provided in Table 3.6-22a. Based on the results of the 12-hour pump test, the pre-grouting hydraulic conductivity of the test area was calculated to be 1.5×10^{-3} cm/sec (4.25 ft/day). The average pre-grouting hydraulic conductivity determined by packer testing in the primary grouting boreholes was calculated to be 1.7×10^{-3} cm/sec (4.81 ft/day) (TRC, 1998).

Based on the packer permeability tests performed in secondary grouting boreholes and verification boreholes, the permeability of the bedrock was calculated to be 1.5×10^{-4} cm/sec (0.43 ft/day) after primary grouting, and 8.7×10^{-5} cm/sec (0.25 ft/day) after secondary grouting. These values are based on the geometric mean of packer tests performed in the target grout horizon (approximately 220 to 250 feet). Packer tests were also performed above and below the target grout horizon. The geometric means for these tests were calculated to be 8.7×10^{-4} cm/sec (2.46 ft/day) after primary grouting and 5.2×10^{-5} cm/sec (0.15 ft/day) after secondary grouting. It is noted that some boreholes were grouted above and below the target horizon because of ground conditions and/or changes to the program which were made after the boreholes had been drilled.

Table 3.6-22a

Summary of Packer Permeability Testing

Borehole	Classification	Interval (feet)	Hydraulic Conductivity (cm/sec)	Geo. Mean Borehole Hydraulic Conductivity (cm/sec)	Comments
NMC-102	Primary	195-235	1.6E-03		Grout on fracture at 242.5'
		222-250	1.6E-03	1.6E-03	
NMC-103	Primary	220-222[1]	5.0E-03		No grout observed in core
		235-250[1]	4.7E-03	>4.9E-03	
NMC-104	Primary	221.5-235	3.1E-03		No grout observed in core
		235-250	1.0E-05	1.8E-04	
NMC-105	Primary	221.2-235[1]	5.8E-03		Grout on fractures at 238', 241', 247' and 250'
		235-250	5.7E-03	>5.8E-03	
NMC-106	Secondary	200-218	5.3E-03		Grout on fractures at 210', 224.5' and 229.5'
		215-235[2]	1.5E-03		
		225-250	6.8E-04		
		235-250	4.8E-04		
		250-265	5.1E-04	1.1E-03	
NMC-107	Secondary	200-220	1.6E-04		Grout on fractures at 218', 223.5', 228' and 254'
		216-233	9.4E-04		
		236-250	7.4E-06		
		245-265	2.6E-04	1.3E-04	
NMC-108	Verification - Secondary outside of pattern	200-220	1.5E-03		No grout was observed in core
		220-235	9.4E-05		220-235 from falling head test (Hvorslev, 1951)
		235-250	5.5E-04		
		250-265	1.5E-03	5.8E-04	

Table 3.6-22a *(Continued)*

Borehole	Classification	Interval (feet)	Hydraulic Conductivity (cm/sec)	Geo. Mean Borehole Hydraulic Conductivity (cm/sec)	Comments
NMC-109	Secondary	221-235	6.1E-05		All data from falling head tests (Hvorslev, 1951)
		231-250	1.0E-04	7.8E-05	Grouted fractures in intact core below 240'
NMC-110	Verification - Tertiary	200-220	8.7E-04		Core is highly fractured. Some leakage around
		225-234	1.6E-04		packer in vertical fractures occurred in the
		235-250	1.8E-04		sections from 225'-234', and 235'-250'.
		249-265	7.2E-05	2.1E-04	Grout on many fractures below 220'.
NMC-111	Secondary	200-230.5[3]	1.3E-04		Grouted fractures in intact core below 230'
		230-250	7.5E-05	9.9E-05	
NMC-112	Verification - Tertiary	200-218	2.2E-06		Grout on fractures below 228'. Very poor core
		218-235	7.0E-06		recovery because of highly fractured and sheared
		235-250	2.8E-04	1.6E-05	rock.

Geo. Mean Primary Grouting Borehole Hydraulic Conductivity (cm/sec)	1.7E-03
Geo. Mean Secondary Borehole Hydraulic Conductivity (cm/sec) Between 220' and 250'	1.5E-4
Geo. Mean Secondary Borehole Hydraulic Conductivity (cm/sec) Above and Below Grouted Section	8.7E-04
Geo. Mean Tertiary Borehole Hydraulic Conductivity (cm/sec) Between 220' and 250'	8.7E-05
Geo. Mean Tertiary Borehole Hydraulic Conductivity (cm/sec) Above and Below Grouted Section	5.2E-05

[1]Calculated values are equal to the permeability of the drop pipe used for the packer tests, formation hydraulic conductivities exceed the calculated values.
[2]This value was included in the geometric mean for the secondary boreholes above and below the grouted section. The majority of flow during packer testing occurred in fractured rock above 220'.
[3]This value was included in the secondary borehole geometric mean between 220' and 250'.

(TCR, 1998)

Checked by: SVD1

The results of this analysis indicate that a reduction in permeability of approximately one order of magnitude occurred in the test horizon in response to primary grouting. The decrease in permeability due to secondary grouting was less pronounced, and bedrock permeability after secondary grouting was reduced an additional 42 percent from the permeability after primary grouting.

The results of the pilot grouting program have demonstrated that the hydraulic conductivity of the grouted horizon could be reduced to 1.5×10^{-4} cm/sec (0.43 ft/day) or lower by grouting primary boreholes spaced on 20-foot centers. Secondary grouting of boreholes spaced on 10-foot centers would result in an additional reduction of permeability. The program has demonstrated that secondary grouting could decrease the permeability of the grouted horizon to approximately 8.7×10^{-5} cm/sec (0.25 ft/day). These permeability values for the grouted horizon are conservative because underground grouting boreholes could be aligned at more favorable angles to intersect the predominantly high angle (70°-90°) east-west trending fracture system. This more favorable orientation will increase the number of fractures penetrated by the grouting boreholes. Therefore, it is expected that a more complete grouting of the open fractures will occur during in-mine grouting and additional reductions (to approximately 5×10^{-5} cm/sec [0.14 ft/day]) in permeability would be realized using secondary boreholes spaced on 10-foot centers. In-fill grouting in selected areas with boreholes spaced at tertiary intervals (5-foot centers) would result in additional reductions in permeability. It is estimated that the bulk hydraulic conductivity of the grouted horizon can be reduced to approximately 1×10^{-5} cm/sec (0.028 ft/day) with the use of tertiary boreholes.

The practical lower limit of groutability for bedrock is generally considered to be 1 lugeon or about 1.3×10^{-5} cm/sec (0.037 ft/day) (Houlsby, 1990; Henn, 1996). This value is not the lower limit for the grouted permeability of the bedrock, but rather the lower limit at which grouting is considered to be practicable. Dam foundations are commonly grouted to high engineering standards which approach or exceed 1×10^{-5} cm/sec (0.028 ft/day). Case histories have been published which quantitatively address the reduction in hydraulic conductivity achieved by grouting. Thiers, et al., (1976) described the construction of a grout blanket below the Little Blue Run Dam in Pennsylvania in which the hydraulic conductivity of the fractured bedrock was reduced from between 10^{-3} and 10^{-4} cm/sec to below 10^{-5} cm/sec. Grout boreholes for this project were drilled on 10-foot centers and packer permeability tests were performed to document the reduction in permeability.

Based on professional experience, standard grouting practices for dam foundations, and published studies, a final bulk hydraulic conductivity of 1×10^{-5} cm/sec (0.028 ft/day) for the grouted horizon is considered to be achievable at the Crandon Project. It is acknowledged, however, that a closer spacing of grout boreholes in some areas (approximately 5-foot centers) may be necessary to realize this permeability, and that the use of microfine grouts would probably be required. A more comprehensive discussion of the grouting program is provided in TRC (1998) which is included in HSI GeoTrans, Inc. (1998) in Appendix 4.2-3.

3.6.5 Groundwater Quality

This section of the report addresses groundwater quality from a regional perspective, followed by a discussion of study area groundwater quality. A comparison of water quality data from the 1970/1980 period to the 1994/1995 study is also presented.

3.6.5.1 Regional Groundwater Quality

Information regarding regional groundwater quality is general and described by Olcott (1968) and Oaks and Hamilton (1973). Groundwater in the Fox River - Wolf River Basin and Menominee River - Oconto River Basin is described as being of good quality, derived primarily from coarse grained glacial deposits. The groundwater is hard to very hard and of the calcium-magnesium-bicarbonate type. Total dissolved solids generally range from 175 to 300 mg/L. Iron can be high locally.

3.6.5.2 Study Area Groundwater Quality

In the 1970s and 1980s, groundwater quality data was collected for an area reaching approximately one-quarter mile north of Swamp Creek including monitoring well DMA-16 and approximately one-half mile east of Ground Hemlock Lake including monitoring well DMA-22B. To the south, the area of investigation extended to DMB-24 on the northeast shore of Rolling Stone Lake. On the west, the study area extended to DMA-13 approximately two miles west of Little Sand Lake.

Table 3.6-23 is a list of all wells used in the 1977 through 1980 groundwater quality evaluation. Note that the last six wells on the list are private wells. These wells are not included on Figures 3.6-1 and 3.6-2, which show the location of all environmental monitoring wells.

Table 3.6-24 provides a statistical summary of groundwater quality data for the 1977 to 1980 period for the study area bounded by the features described above. Appendix 3.6-10 contains a summary by well of the 1977 through 1980 groundwater quality data.

Approximately 15 years after the 1977-1980 investigation, another study was initiated by NMC in support of Crandon Project permitting work. The additional study was conducted from May 1994 to May 1995. The data for this study incorporates analyses of samples from 22 groundwater monitoring wells, each for a period of eight months. Eight months (or eight data points) is considered statistically significant for comparison of the 1994/1995 data base to the earlier 1977-1980 data base. Note that for wells CMC-04, -05, -07, DMB-1A, and -08P an additional round of field and laboratory mercury analyses were performed in February 1995. A list of the wells included in the study was previously presented in Table 3.6-2. Laboratory reports for analytical data for these monitoring wells is included in Appendix 3.6-11. A data base for the 1994/1995 data is included in Appendix 3.6-12.

Table 3.6-23

List of Groundwater Monitoring Wells Used in 1977-1980 Groundwater Quality Evaluation

WW-1	DMB-5A	G41-E13
WW-2	DMB-24	G41-G14A
TW-1	DMB-25	G41-G14B
DMA-10	DMB-27	G41-G14C
DMA-13	DMB-28	G41-G15A
DMA-17	DMB-20A	G41-G15B
DMA-19	DMB-29	G41-P18B
DMB-32A	DMA-4	G41-P24
DMA-48	DMC-1	Walentowski
DMB-1A	DMC-2	Fox
DMB-4	DMC-3	McGeshick
DMB-7	DMA-22B	Reynolds Resort
DMB-8	G40-J15	Simonsen
DMB-18	G40-K13	Vollmar
DMB-20	G40-L23	
DMB-21	G40-Q7	
DMB-23	G40-R23	
DMA-16	G41-C15	

Prepared by: WJS
Checked by: SVD1

Table 3.6-24

Summary of Groundwater Quality for Principal Aquifers in the Study Area for the Period July 1977 through August 1980

Parameter	Units	Range	Mean (x)	Standard Deviation	Number of Samples
Field temperature	°C	3.0 - 12.0	7.1	1.8[a]	220
Total laboratory alkalinity	mg/L[b]	14 - 453	123	50	234
Total field alkalinity	mg/L[b]	11 - 487	127	53	221
Specific conductance	μmhos/cm	50 - 1,300	237	107	235
Field conductivity	μmhos/cm[c]	29 - 1,150	178	92	218
Laboratory pH	standard units	6.09 - 11.02	7.6	0.69	204
Field pH	standard units	5.5 - 12.2	7.7	1.0	222
Total hardness	mg/L[b]	16 - 452	125	53	236
Total dissolved solids	mg/L	14 - 836	166	84	235
Chemical oxygen demand	mg/L	<1 - 365	<29	<56	143
Total phosphorus (P)	mg/L	<0.01 - 0.84	<0.06	<0.10	135
Anions					
Arsenic	mg/L	<0.001 - 0.004	<0.001	<0.001	236
Chloride	mg/L	<1 - 78	<4	<10	236
Cyanide, total	mg/L	<0.001 - 0.004	<0.001	<0.001	236
Fluoride	mg/L	<0.12 - 0.57	<0.20	<0.09	142
Nitrate nitrogen	mg/L	<0.01 - 11.0	<0.37	<1.04	235
(N)	mg/L	<0.01 - 0.31	<0.06	<0.06	101
Phosphate (PO_4)	mg/L	<0.01 - 0.31	<0.06	<0.06	101
Sulfate	mg/L	<1 - 86	<9	<9	232

Table 3.6-24 *(Continued)*

Parameter	Units	Range	Mean (x)	Standard Deviation	Number of Samples
Cations					
Aluminum	mg/L	<0.01 - 9.09	<0.53	<1.12	169
Barium	mg/L	<0.01 - 0.24	<0.02	<0.03	142
Cadmium	mg/L	<0.001 - 0.015	<0.002	<0.002	169
Calcium	mg/L	4.9 - 92.4	29.8	12.6	94
Chromium, total	mg/L	<0.001 - 0.021	<0.002	<0.003	169
Cobalt	mg/L	<0.01	<0.01	0	169
Copper	mg/L	<0.001 - 0.09	<0.007	<0.011	232
Iron	mg/L	<0.01 - 38.9	<1.74	<4.34	236
Lead	mg/L	<0.01 - 0.10	<0.01	<0.01	235
Magnesium	mg/L	0.279 - 29.6	12.00	5.12	169
Manganese	mg/L	<0.001 - 10.2	<0.423	<0.989	236
Mercury	mg/L	<0.0001 - 0.0010	<0.0001	<0.0001	169
Molybdenum	mg/L	<0.01 - 0.03	<0.01	<0.01	169
Nickel	mg/L	<0.01 - 0.04	<0.01	<0.01	169
Selenium	mg/L	<0.001 - 0.001	<0.001	0	142
Silver	mg/L	<0.001	<0.001	0	142
Zinc	mg/L	<0.001 - 2.60	<0.052	<0.214	235

[a]Reflects seasonal temperature variation.
[b]All alkalinity and hardness values listed in text are as $CaCO_3$, although the "as $CaCO_3$" has been eliminated to make the text more readable.
[c]Varies with temperature (USEPA, 1976).

*Table derived from the 1985 EMC Environmental Impact Report (EMC, 1985)

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The information in the 1994/1995 data base has undergone several levels of review during the course of the project. As a result of these reviews, the laboratory was asked to verify certain laboratory results. In most cases, the laboratory verified the results as originally reported, while in a limited number of cases the reported results were corrected. The data base in Appendix 3.6-12 contains the verified and corrected laboratory results, while the laboratory results sheets in Appendix 3.6-11 do not. A summary of those data which were corrected is included at the beginning of Appendix 3.6-11.

The locations of the groundwater monitoring wells in the 1994/1995 program are shown on Figures 3.6-2 and 3.6-2a. A summary of the 1994/1995 groundwater quality data base is presented in Table 3.6-25. This data, like the 1977-1980 data, has been evaluated statistically (Appendix 3.6-13). Taken together, the groundwater quality analytical results presented in Tables 3.6-24 and 3.6-25 establish an historical (15 years past) and current (1994/1995) baseline for the proposed project. Note that the statistical comparisons of the 1977-1980 data base to the 1994/1995 data base consider dissolved metals. During the 1994 monitoring program analyses also included total metals for the June and October 1994 rounds. These data are also included in Table 3.6-25.

3.6.5.3 Monitoring Well DMB-1A Baseline Data

Groundwater monitoring well DMB-1A, located at the southwest corner of the TMA, is the one groundwater quality monitoring well which has been sampled through both the 1977-1980 and 1994/1995 monitoring periods. Groundwater quality results from DMB-1A have been evaluated to determine whether the most recent results (July 1994 through February 1995) statistically differ from past results (July 1978 through August 1980). Parameters common to both time periods are included in Table 3.6-26. Summary statistics of the data for each time period are presented in Table 3.6-27.

A review of the data show that cyanide, molybdenum, selenium, silver, cobalt and nickel were not detected in either the 1978 through 1980 samples or the 1994/1995 samples. Parameters that were detected in the 1978 through 1980 samples but not in the 1994 samples include COD, iron, manganese, chromium, cadmium, copper, mercury and zinc. These parameters typically had higher detection limits for the 1994/1995 study.

Lead was detected in the 1994/1995 samples but not the 1978 through 1980 samples. However, the detection limits of the two time periods were again different. The two detected values in the 1994 data were below the 1978 through 1980 detection limit.

The parameters which had detectable values during both time periods were statistically tested by the Mann-Whitney U test. This is the recommended nonparametric statistical test for two samples given by the USEPA guidance document "Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities, 1992 Addendum to Interim Final Guidance" (USEPA, 1992). A summary of the statistical test results along with boxplots of the data are provided in Appendix 3.6-14. Note that for aluminum, the June and July 1994 data were removed from the

Table 3.6-25

Summary of Study Area Groundwater Quality
May 1994 - May 1995

Parameter	Units	Total Samples[1]	Total Detections[1]	Minimum[1]	Maximum[1]	Mean[1][2]	Standard Deviation[1][2]	Mean[1][3]	Standard Deviation[1][3]
pH (Field)	S.U.	182	182	5.98	8.1	7.253	0.534	7.253	0.534
Conductivity (Field)	μmhos/cm	182	182	145	1356	390.2	194.5	390.2	194.5
Temperature (Field)	Degrees C	182	182	5.6	13	9.031	1.451	9.031	1.451
Alkalinity	mg/L	176	176	60	290	147.4	48.9	147.4	48.9
Hardness	mg/L	162	162	36	410	149.8	69.8	149.8	69.8
Total Dissolved Solids	mg/L	176	176	81	544	202.2	92.3	202.2	92.3
Chemical Oxygen Demand	mg/L	175	34	<10	65	9.41	8.09	4.15	9.92
Nitrate + Nitrite	mg/L	175	110	<0.5	2.6	0.736	0.500	0.643	0.597
Nitrogen, Total Kjeldahl	mg/L	175	89	<0.2	1.82	0.307	0.308	0.258	0.343
Chloride	mg/L	176	110	<1	8	1.256	1.216	1.069	1.351
Fluoride	mg/L	176	105	<0.1	1	0.109	0.101	0.088	0.115
Sulfate	mg/L	176	174	<2	200	21.25	32.20	21.24	32.21
Cyanide, total	mg/L	176	0	<0.02	<0.2	0.011	0.010	0	0
Calcium, dissolved	mg/L	176	176	14	98	34.31	16.43	34.31	16.43
Calcium, total	mg/L	43	43	14	94	35.50	15.84	35.50	15.84
Arsenic, dissolved	mg/L	176	11	<0.005	0.086	0.0036	0.0088	0.0013	0.0091
Arsenic, total	mg/L	43	3	<0.005	0.007	0.0027	0.0009	0.0004	0.0016

Table 3.6-25 *(Continued)*

Parameter	Units	Total Samples[1]	Total Detections[1]	Minimum[1]	Maximum[1]	Mean[1][2]	Standard Deviation[1][2]	Mean[1][3]	Standard Deviation[1][3]
Barium, dissolved	mg/L	176	175	<0.01	0.11	0.028	0.018	0.028	0.018
Barium, total	mg/L	43	43	0.01	0.151	0.051	0.040	0.051	0.040
Iron, dissolved	mg/L	176	17	<0.05	0.63	0.051	0.064	0.018	0.071
Iron, total	mg/L	43	29	<0.05	19.2	2.844	4.952	2.831	4.959
Manganese, dissolved	mg/L	176	81	<0.01	1.9	0.096	0.273	0.093	0.274
Manganese, total	mg/L	43	29	<0.01	1.11	0.171	0.270	0.170	0.271
Molybdenum, dissolved	mg/L	176	13	<0.02	0.088	0.0116	0.0073	0.0023	0.0095
Molybdenum, total	mg/L	43	4	<0.02	0.043	0.0120	0.0069	0.0030	0.0097
Selenium, dissolved	mg/L	176	0	<0.005	<0.005	0.0025	0	0	0
Selenium, total	mg/L	43	0	<0.005	<0.005	0.0025	0	0	0
Silver, dissolved	mg/L	176	2	<0.01	0.032	0.0052	0.0022	0.0003	0.0027
Silver, total	mg/L	43	0	<0.01	<0.01	0.005	0	0	0
Chromium, dissolved	mg/L	176	2	<0.005	0.13	0.0033	0.0096	0.0008	0.0098
Chromium, total	mg/L	43	14	<0.005	0.085	0.0109	0.0192	0.0092	0.0199
Cobalt, dissolved	mg/L	176	2	<0.01	0.14	0.0058	0.0102	0.0009	0.0106
Cobalt, total	mg/L	43	1	<0.01	0.01	0.0051	0.0008	0.0002	0.0015
Nickel, dissolved	mg/L	176	3	<0.03	0.13	0.0158	0.0088	0.0010	0.0102
Nickel, total	mg/L	43	3	<0.03	0.082	0.0185	0.0135	0.0046	0.0173
Antimony, dissolved	mg/L	176	4	<0.005	0.052	0.037	0.037	0.00040	0.00399
Antimony, total	mg/L	43	0	<0.05	<0.2	0.063	0.038	0	0

Table 3.6-25 *(Continued)*

Parameter	Units	Total Samples[1]	Total Detections[1]	Minimum[1]	Maximum[1]	Mean[1][2]	Standard Deviation[1][2]	Mean[1][3]	Standard Deviation[1][3]
Magnesium, dissolved	mg/L	176	176	5.33	43.2	16.229	7.913	16.229	7.913
Magnesium, total	mg/L	43	43	6.8	42.9	17.163	7.459	17.163	7.459
Aluminum, dissolved	mg/L	176	13	<0.05	0.347	0.069	0.059	0.016	0.061
Aluminum, total	mg/L	43	25	<0.05	22.2	2.621	4.785	2.597	4.798
Cadmium, dissolved	mg/L	175	28	<0.0001	0.0015	0.00030	0.00024	0.00006	0.00018
Cadmium, total	mg/L	43	9	<0.0001	0.002	0.00037	0.00035	0.00012	0.00036
Copper, dissolved	mg/L	176	1	<0.03	0.11	0.0155	0.0072	0.0006	0.0083
Copper, total	mg/L	43	3	<0.03	0.079	0.0176	0.0110	0.0037	0.0145
Lead, dissolved	mg/L	176	39	<0.001	0.017	0.0014	0.0017	0.0007	0.0019
Lead, total	mg/L	43	19	<0.001	0.015	0.0025	0.0032	0.0020	0.0035
Mercury, dissolved	mg/L	181	39	<0.0002	0.001	0.00016	0.00015	0.00008	0.00019
Mercury, total	mg/L	43	15	<0.0002	0.0007	0.00021	0.00017	0.00015	0.00022
Zinc, dissolved	mg/L	176	12	<0.02	0.15	0.012	0.011	0.002	0.013
Zinc, total	mg/L	43	14	<0.02	0.078	0.018	0.014	0.011	0.018

[1]Includes data from the following monitoring wells: CMC-01P, CMC-01R, CMC-02P, CMC-02R, CMC-03P, CMC-03RR, CMC-04, CMC-05, CMC-06P, CMC-07, CMC-08, CMC-08P, CMC-09, CMC-09P, CMC-10, CMC-10P, DMB-1A, DMB-6, EX-13BU, EX-9BL, EX-9BU, G41-H18B
[2]All non-detects replaced with one-half the detection limit.
[3]All non-detects replaced with zero.

Prepared by: SGL
Checked by: AWZ,SVD1

Table 3.6-26

Historical and Current Groundwater Quality Analytical Results for Well DMB-1A

Parameter	Units	Jul-78	Sep-78	Oct-78	Jan-79	Apr-79	Nov-79	Feb-80	May-80	Aug-80	Jun-94	Jul-94	Aug-94	Sep-94	Oct-94	Nov-94	Dec-94	Jan-95	Feb-95
pH (Field)	S.U.	6.9	7.2	6.9	7.4	7.4	8.3	8.4	8.3	7.2	7.79	6.50	6.43	7.07	7.30	8.02	7.86	7.78	8.05
Conductivity (Field)	μmhos	266	270	177	147	173	180	147		140	358	339	322	361	306	225	324	382	332
Temperature (Field)	Degrees C	6.5	7.0	5.5	4.0	7.5	6.5	7.0	7.0	8.0	9.6	11.2	11.3	9.8	8.5	7.2	8.3	6.7	7.9
Alkalinity	mg/L	206	118	140	134	128	118	100	112	115	164	158	156	160	160	150	150	160	
Hardness	mg/L	216	248	146	142	108	118	132	116	116	168	162	169		170	160	160	170	
Total Dissolved Solids	mg/L	272	146	157	184	186	180	132	103	116	171	186	167	180	200	230	240	200	
Chemical Oxygen Demand	mg/L			39	31	7	<1	<1	<1	23	<10.0	<10.0	<10.0	<20	<20	<10	<10	<10	
Chloride	mg/L	<1	2	<1	<1	<1	4	<1	<1	4	1	1	1	<1	<1	<1	<1	<1	
Fluoride	mg/L			0.15	0.45	0.20	0.23	0.14	<0.12	<0.12	<0.100	<0.100	<0.100	<0.1	0.1	0.1	<0.1	<0.1	
Sulfate	mg/L	<1	8	9	6	14	13	6	8	11	9.00	9.70	12.0	12	13	12	11	10	
Cyanide, total	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.020	<0.020	<0.020	<0.02	<0.020	<0.020	<0.020	<0.020	
Calcium, dissolved	mg/L	56.5	37.1	36.1	37.2	26.8					38.0	38.0	35.9	36	35	33	36	37	
Arsenic, dissolved	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.005	<0.005	<0.005	<0.0050	<0.0050	<0.0050	<0.0050	0.085	
Barium, dissolved	mg/L			<0.01	<0.01	<0.01	0.02	0.02	<0.01	<0.01	0.025	0.021	0.020	0.019	0.019	0.019	0.020	0.019	
Iron, dissolved	mg/L	1.09	0.74	0.43	0.17	0.18	0.29	0.30	0.06	0.05	<0.100	<0.100	<0.100	<0.050	<0.050	<0.050	<0.050	<0.050	
Manganese, dissolved	mg/L	1.36	0.238	0.323	0.269	0.169	0.114	0.130	0.097	0.07	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	
Molybdenum, dissolved	mg/L			<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	
Selenium, dissolved	mg/L			<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.005	<0.005	<0.005	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	
Silver, dissolved	mg/L			<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	
Chromium, dissolved	mg/L			<0.001	<0.001	<0.001	<0.001	0.004	0.002	<0.001	<0.005	<0.005	<0.005	<0.005	<0.0050	<0.0050	<0.0050	<0.0050	
Cobalt, dissolved	mg/L			<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	
Nickel, dissolved	mg/L			<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	
Magnesium, dissolved	mg/L			13.5	11.8	9.9	8.9	12.0	11.5	12.4	19.0	17.6	18.1	19	18	17	18	18	
Aluminum, dissolved	mg/L			0.25	0.09	0.21	0.22	0.35	0.34	0.05	<0.200	<0.200	0.203	<0.050	<0.050	<0.050	<0.050	<0.050	
Cadmium, dissolved	mg/L			0.008	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	

Table 3.6-26 *(Continued)*

Parameter	Units	Jul-78	Sep-78	Oct-78	Jan-79	Apr-79	Nov-79	Feb-80	May-80	Aug-80	Jun-94	Jul-94	Aug-94	Sep-94	Oct-94	Nov-94	Dec-94	Jan-95	Feb-95
Copper, dissolved	mg/L	0.005	0.008	<0.001	0.003	0.005	0.009	<0.001	<0.001	<0.001	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	
Lead, dissolved	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.003	0.002	<0.001	<0.0020	<0.0020	<0.0030	<0.0020	<0.020	
Mercury, dissolved	mg/L			0.0001	0.0006	0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.00020	<0.00020	<0.00020	<0.0002
Zinc, dissolved	mg/L	0.023	0.03	0.010	0.011	0.009	0.010	0.007			<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	

Note: Blank space means no data was collected.

Prepared by: WJS/SGL
Checked by: SVD1

Table 3.6-27

Statistical Comparison of Historical and Current Groundwater Quality Analytical Results for Well DMB-1A

		Jul 1978 - Aug 1980						Jun 1994 - Feb 1995					
Parameter	Units	Total Samples	Total Detections	Percent Detections	Minimum	Maximum	Mean[1]	Total Samples	Total Detections	Percent Detections	Minimum	Maximum	Mean[1]
pH (Field)	S.U.	9	9	100%	6.9	8.4	7.56	9	9	100%	6.43	8.05	7.42
Conductivity (Field)	μmhos	8	8	100%	140	270	187.5	9	9	100%	225	382	327.7
Temperature (Field)	Degrees C	9	9	100%	4	8	6.56	9	9	100%	6.7	11.3	8.94
Alkalinity	mg/L	9	9	100%	100	206	130.1	8	8	100%	150	164	157.3
Hardness	mg/L	9	9	100%	108	248	149.1	7	7	100%	160	170	165.6
Total Dissolved Solids	mg/L	9	9	100%	103	272	164.0	8	8	100%	167	240	196.8
Chemical Oxygen Demand	mg/L	7	4	57%	<1	39	14.50	8	0	0%	<1	<20	6.25
Chloride	mg/L	9	3	33%	<1	4	1.44	8	3	38%	<1	1	0.6875
Fluoride	mg/L	7	5	71%	<0.12	0.45	0.184	8	2	25%	<0.1	0.1	0.0625
Sulfate	mg/L	9	8	89%	<1	14	8.39	8	8	100%	9	13	11.09
Cyanide, total	mg/L	9	0	0%	<0.001	<0.001	0.0005	8	0	0%	<0.02	<0.02	0.01
Calcium, dissolved	mg/L	5	5	100%	26.8	56.5	38.74	8	8	100%	33	38	36.11
Arsenic, dissolved	mg/L	9	0	0%	<0.001	<0.001	0.0005	8	1	13%	<0.005	0.086	0.0129
Barium, dissolved	mg/L	7	2	29%	<0.01	0.02	0.00929	8	8	100%	0.019	0.025	0.0203
Iron, dissolved	mg/L	9	9	100%	0.05	1.09	0.368	8	0	0%	<0.05	<0.1	0.0344
Manganese, dissolved	mg/L	9	9	100%	0.07	1.36	0.308	8	0	0%	<0.01	<0.01	0.005
Molybdenum, dissolved	mg/L	7	0	0%	<0.01	<0.01	0.005	8	0	0%	<0.02	<0.02	0.01
Selenium, dissolved	mg/L	7	0	0%	<0.001	<0.001	0.0005	8	0	0%	<0.005	<0.005	0.0025
Silver, dissolved	mg/L	7	0	0%	<0.001	<0.001	0.0005	8	0	0%	<0.01	<0.01	0.005
Chromium, dissolved	mg/L	7	2	29%	<0.001	0.004	0.00121	8	0	0%	<0.005	<0.005	0.0025
Cobalt, dissolved	mg/L	7	0	0%	<0.01	<0.01	0.005	8	0	0%	<0.01	<0.01	0.005
Nickel, dissolved	mg/L	7	0	0%	<0.01	<0.01	0.005	8	0	0%	<0.03	<0.03	0.015
Magnesium, dissolved	mg/L	7	7	100%	8.9	13.5	11.43	8	8	100%	17	19	18.09
Aluminum, dissolved	mg/L	7	7	100%	0.05	0.35	0.216	8	1	13%	<0.05	0.203	0.0660

Table 3.6-27 *(Continued)*

Parameter	Units	Jul 1978 - Aug 1980						Jun 1994 - Feb 1995					
		Total Samples	Total Detections	Percent Detections	Minimum	Maximum	Mean[1]	Total Samples	Total Detections	Percent Detections	Minimum	Maximum	Mean[1]
Cadmium, dissolved	mg/L	7	1	14%	<0.001	0.008	0.00157	8	0	0%	<0.0001	<0.001	0.00022
Copper, dissolved	mg/L	9	5	56%	<0.001	0.009	0.00356	8	0	0%	<0.03	<0.03	0.015
Lead, dissolved	mg/L	9	0	0%	<0.01	<0.01	0.005	8	2	25%	<0.001	0.003	0.00138
Mercury, dissolved	mg/L	7	3	43%	<0.0001	0.0006	0.00014	9	0	0%	<0.0002	<0.0002	0.0001
Zinc, dissolved	mg/L	7	7	100%	0.007	0.03	0.01429	8	0	0%	<0.02	<0.02	0.01

[1]Nondetects Replaced With One-Half the Detection Limit.

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Checked by: AWZ/SVD1

test due to the relatively high detection limits. All other nondetected values for all tests were replaced with a common value just below the lowest detected value.

Only five of the twelve analytical parameters which were tested had statistically different results between the two time periods. These were conductivity, alkalinity, magnesium, fluoride and aluminum. The 1978 to 1980 average conductivity value was 187.5 compared to an average 1994/1995 value of 327.7. The average alkalinity value between 1978 and 1980 was 130.1 while the average 1994/1995 alkalinity value was 157.3. The average magnesium value between 1978 and 1980 was 11.43 while the average 1994/1995 magnesium value was 18.09. The average fluoride value between 1978 and 1980 was 0.184 while the average 1994/1995 fluoride value was 0.0625. The average aluminum value between 1978 and 1980 was 0.216 while the average 1994/1995 aluminum value was 0.0660.

The differences observed in conductivity, alkalinity and magnesium values between the two sampling periods is considered to be related to the difference in magnesium value alone. Calculations included in Appendix 3.6-14 show that the difference in magnesium concentrations could account for the observed changes in conductivity and alkalinity. The small differences observed between the two sampling periods for fluoride and aluminum are likely related to differences in analytical techniques.

Monitoring well DMB-1A is screened in a calcareous sand (see log in Appendix 3.5-1). Magnesium concentrations in wells installed in carbonate-rock aquifers typically range from 12 to 60 mg/L with standard deviations ranging from 30-100% of the means (Freeze and Cherry, 1979, p. 263). The difference in magnesium concentration between the two sampling periods can be attributed to normal variations observed in groundwater influenced by carbonate materials.

Twenty-nine parameters were sampled from monitoring well DMB-1A from July 1978 to August 1980, and then again from June 1994 to February 1995. Of these 29 analytical parameters, only conductivity, alkalinity, fluoride, aluminum and magnesium were determined to have statistically different concentrations between the two time periods. The differences observed in magnesium, alkalinity and conductivity values between the two sampling periods can be attributed to normal variations expected in magnesium concentrations. Overall, the analysis shows that the data collected in the 1978-1980 time period and that collected in the 1994/1995 study are comparable.

3.6.5.4 Evaluation of Data in Comparison to Drinking Water Standards

The groundwater quality data should be placed into a context which reflects the relative significance of natural groundwater quality. This objective is achieved by comparing the 1977-1980 data set maximum values (Table 3.6-24) and the 1994/1995 data set maximum values (Table 3.6-25) to the NR 809 Drinking Water Standards. The comparison, shown in Table 3.6-28, indicates that the actual concentration values of eleven groundwater quality parameters naturally met or exceeded the primary or secondary NR 809 Drinking Water Standards on one or more occasion during the 1978-1980 or 1994/1995 monitoring activities.

Table 3.6-28

Comparison of NR 809 Drinking Water Standards to Study Area Groundwater Quality

Parameter	Units	NR 809 Drinking Water Standards		1977-1980	1994-1995
		Primary	Secondary	Max	Max
Total Dissolved Solids	mg/L		500*	836[b]	544[b]
Nitrate + Nitrite	mg/L	10		11[a]	2.6
Chloride	mg/L		250	78	8
Fluoride	mg/L	4	2	0.57	1
Sulfate	mg/L		250	86.0	200
Cyanide, total	mg/L	0.2		0.004	<0.2
Arsenic, dissolved	mg/L			0.004	0.086[a]
Arsenic, total	mg/L	0.05			0.007
Barium, dissolved	mg/L			0.24	0.11
Barium, total	mg/L	2			0.151
Iron, dissolved	mg/L				0.63[b]
Iron, total	mg/L		0.3	38.9[b]	19.2[b]
Manganese, dissolved	mg/L				1.9[b]

Table 3.6-28 *(Continued)*

Parameter	Units	NR 809 Drinking Water Standards		1977-1980	1994-1995
		Primary	Secondary	Max	Max
Manganese, total	mg/L		0.05	10.2[b]	1.11[b]
Selenium, dissolved	mg/L				<0.005
Selenium, total	mg/L	0.05		0.001	<0.005
Silver, dissolved	mg/L				0.032
Silver, total	mg/L		0.01	<0.001	<0.01
Chromium, dissolved	mg/L				0.13[a]
Chromium, total	mg/L	0.1		0.021	0.085
Nickel, dissolved	mg/L				0.13[a]
Nickel, total	mg/L	0.1		0.04	0.082
Antimony, dissolved	mg/L				0.052[a]
Antimony, total	mg/L	0.006			<0.2
Aluminum, dissolved	mg/L				0.347[b]
Aluminum, total	mg/L		0.05-0.2	9.09[b]	22.2[b]
Cadmium, dissolved	mg/L				0.0015
Cadmium, total	mg/L	0.005		0.015[a]	0.002

Table 3.6-28 *(Continued)*

Parameter	Units	NR 809 Drinking Water Standards		1977-1980	1994-1995
		Primary	Secondary	Max	Max
Copper, dissolved	mg/L				0.11
Copper, total	mg/L	1.3	1.0	0.09	0.079
Lead, dissolved	mg/L				0.017[a]
Lead, total	mg/L	0.015		0.10[a]	0.015[a]
Mercury, dissolved	mg/L				0.001
Mercury, total	mg/L	0.002		0.001	0.0007
Zinc, dissolved	mg/L				0.15
Zinc, total	mg/L		5	2.6	0.078

*Standard for residue.
[a]Equal to or exceeds primary standard.
[b]Equal to or exceeds secondary standard.

Prepared by: SGL/SVD1
Checked by: AWZ/JWS

These parameters include TDS, Nitrate + Nitrite, total chromium, total iron, total manganese, total arsenic, total antimony, total aluminum, total cadmium, total lead and total nickel.

Particular note should be made of the fact that measured total iron, total manganese, and total aluminum concentrations exceeded an established standard by a factor of 50 or more. This reflects the naturally high iron and manganese content of groundwater in northern Wisconsin. The data base presented in Tables 3.6-24 and 3.6-25 and the analysis presented in Table 3.6-28 are based upon laboratory analyses for the wells listed in Tables 3.6-2 and 3.6-23.

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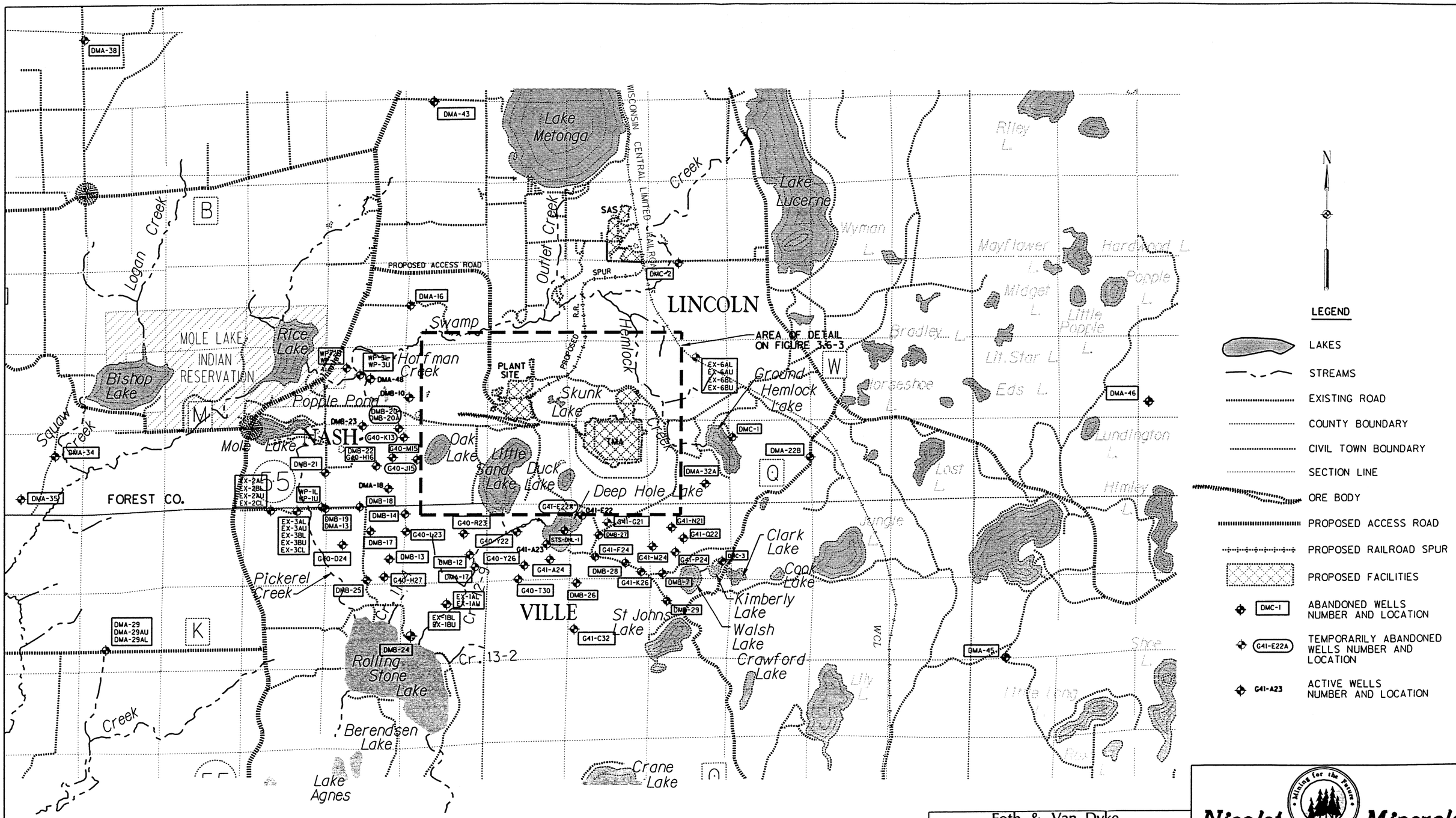
FIGURES FOR SECTION 3.6



NOTE:

1. BASE MAP DERIVED FROM COUNTY MAPS PREPARED BY THE WISCONSIN DEPARTMENT OF TRANSPORTATION
2. ORE BODY OUTLINE IS REPRESENTATIVE OF THE SUBCROP AT THE BASE OF THE OVERBURDEN.

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION
1	11/98	MLD2	REVISED FOR 1998 UPDATE

CHECKED BY:	JKSI	DATE:	MAY '95
APPROVED BY:	SVDI	DATE:	MAY '95
APPROVED BY:	JWS	DATE:	MAY '95

Nicolet Minerals COMPANY

Mining for the Future Commitment

FIGURE 3.6-1

MONITORING WELL LOCATION MAP I

Scale: 0 3000' 6000' Date: MAY, 1995

Prepared By: Foth & Van Dyke By: JOW 93C049

I:\93c049\94c033\4c33f90.dgn Dec. 17, 1998 10:52:31

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AINSWORTH
VILLE
FOREST COUNTY
LANGLADE COUNTY
SHERMAN LN
SWAMP
CREEK
HEMLOCK CREEK
OAK LAKE
LITTLE SAND LAKE
SAND LAKE
DUCK LAKE
DEEP HOLE LAKE
GROUND HEMLOCK LAKE
W SHORE LN
DEEP HOLE LAKE RD
SAND LAKE RD
WALSH LAKE RD
WALSH LAKE
SKUNK LAKE
TW-1 LAKE
19
20
21
25
30
29
28
36
31
33
1
6
5
4
G40-X1A
G40-X1
DMA-47
WP-4U
WP-4L
WP-5L
WP-5U
EX-4CL
EX-4AL
EX-4AU
EX-4BL
EX-4BU
EX-5AL
EX-5AU
EX-5BL
EX-5BU
EX-5CL
CDM-15
DMA-20
G40-Q7
DMA-31
CMC-SCC-102A
CMC-SCC-102B
DMS-2
STS-B1
DMP-1
WW-1
BE-213-3L
BE-213-3U
BE-216-2
BE-211-1
CMC-12P
CMC-OWA2
CMC-OWA1
CMC-OWA3
CMC-OWA4
BE-211-3L
BE-211-3U
BE-216-3L
BE-216-3U
STS-WVS
CDM-4
G40-P10A
WW-2
CMC-09
CMC-09P
DW-3L
DW-3U
TW-2
DW-1A
DW-1U
DW-1L
CMC-11P
BE-211-2L
BE-211-2U
CMC-13P
BE-216-1
DMA-3
CMC-PWA
CMC-PWAR
CMC-OWA5
CDM-18
CDM-19
WW-4
CMC-SP-08
CMC-SP-07
BE-213-1
CDM-17
CDM-16
STS-LSL-1
CDM-20
STS-QL-1
DMA-1
DMA-1N
DMA-1S
DMB-15
DMP-3
STS-LSL-2
G40-S17A
G40-S17
STS-LSL-4
CMC-LSL-104A
CMC-LSL-104B
DMB-16
G40-P20
STS-LSL-6
G40-Y21
DMA-10
DMB-11
DMS-1
DMA-12
STS-SL-3
STS-SL-4
STS-SL-5
STS-SL-1
DMI-2U
DMI-2L
DW-2U
DW-2L
CMC-PWB
STS-EVS
CMC-14P
BE-213-2
G41-B12
CMC-10
CMC-10P
CMC-10PP
CMC-SP-06
DMA-19
CMC-SP-09
CMC-SP-04
DMP-2
CMC-LSL-102A
CMC-LSL-102B
CMC-SP-01
CMC-SP-02
CMC-SP-03A
CMC-SP-03B
CMC-SP-05A
CMC-SP-05B
STS-DL-3
G41-C15B
STS-DL-2
G41-C15A
G41-C15
G40-Y15
G40-Y15A
CMC-SP-11A
CMC-SP-11B
STS-DL-4
G41-C13C
EX-15BL
EX-15AL
EX-15AU
STS-DL-5
STS-DL-1
DMB-6
CMC-06P
G41-E17
DMA-4
CMC-DL-103A
CMC-DL-103B
G41-E13A
G41-E13
DMB-1
DMB-1A
CMC-07
EX-16AL
EX-16AU
EX-16BL
G41-E19A
CMC-SP-10
DMB-4
CMC-BO-101A
CMC-BO-101B
G41-H9
CMC-01
CMC-01P
CMC-01R
EX-9AL
EX-9AU
EX-9BU
EX-9BL
G41-G12
G41-G13
EX-10BL
EX-10BU
EX-10AL
EX-10AU
TW-41
G41-K13
EX-11BL
EX-11BU
EX-11AL
EX-11AU
EX-11CL
G41-G14A
G41-G14B
G41-G14C
EX-12AL
EX-12AU
EX-12BL (B)
EX-12BU
G41-G15
G41-G15A
G41-G15B
G41-H17
DMB-5
DMB-5A
CMC-04
G41-H18
G41-H18A
G41-H18B
G41-J18
CMC-05
EX-13BL
EX-13BU
EX-13AL
EX-13CL
EX-13DL
EX-7AL
EX-7BL
EX-7BU
EX-7CL
WP-6L
WP-6U
DMB-3
EX-8AL
EX-8AU
EX-8BL
EX-8BU
WP-7L
WP-7U
G41-M11
CMC-02
CMC-02P
CMC-02R
DMB-2
G41-K13A
G41-K13B
DMB-8
G41-P16
G41-P18
G41-P18B
CMC-03P
CMC-03RR
CMC-03
CMC-03R
G41-G14D
G41-G14E
G41-G14F
EX-14AL
EX-14AU
EX-14BL
EX-14BU
DMB-9A
DMB-9B
DMB-9C

LEGEND

- LAKES
- STREAMS
- EXISTING ROAD
- COUNTY BOUNDARY
- CIVIL TOWN BOUNDARY
- SECTION LINE
- ORE BODY
- PROPOSED ACCESS ROAD
- PROPOSED RAILROAD SPUR
- PROPOSED FACILITIES
- WP-7L — ABANDONED WELLS NUMBER AND LOCATION
- DMB-2 — TEMPORARY ABANDONED WELLS NUMBER AND LOCATION
- G41-K13 — ACTIVE WELLS NUMBER AND LOCATION

NOTES:

1. BASE MAP DIGITIZED FROM 1" = 1000' SCALE, MAP PREPARED BY AERO-METRIC ENGINEERING, INC., SHEBOYGAN, WISCONSIN. DATE OF PHOTOGRAPHY APRIL 28, 1976.
2. HORIZONTAL DATUM BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM - NORTH ZONE.
3. COUNTY AND TOWNSHIP LINES DIGITIZED FROM 7.5' SERIES USGS MAPS.
4. ORE BODY OUTLINE IS REPRESENTATIVE OF THE SUBCROP AT THE BASE OF THE OVERBURDEN.

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION
1	11/98	MLD2	REVISED FOR 1998 UPDATE

CHECKED BY:	JKSI	DATE:	MAY '95
APPROVED BY:	SVDI	DATE:	MAY '95
APPROVED BY:	GWS	DATE:	MAY '95

Nicolet Minerals COMPANY

Mining for the Future Commitment

FIGURE 3.6-2

MONITORING WELL LOCATION
MAP 2

Scale: 0 1000' 2000'

Date: MAY, 1995

Prepared By: Foth & Van Dyke | By: JOW | 93C049

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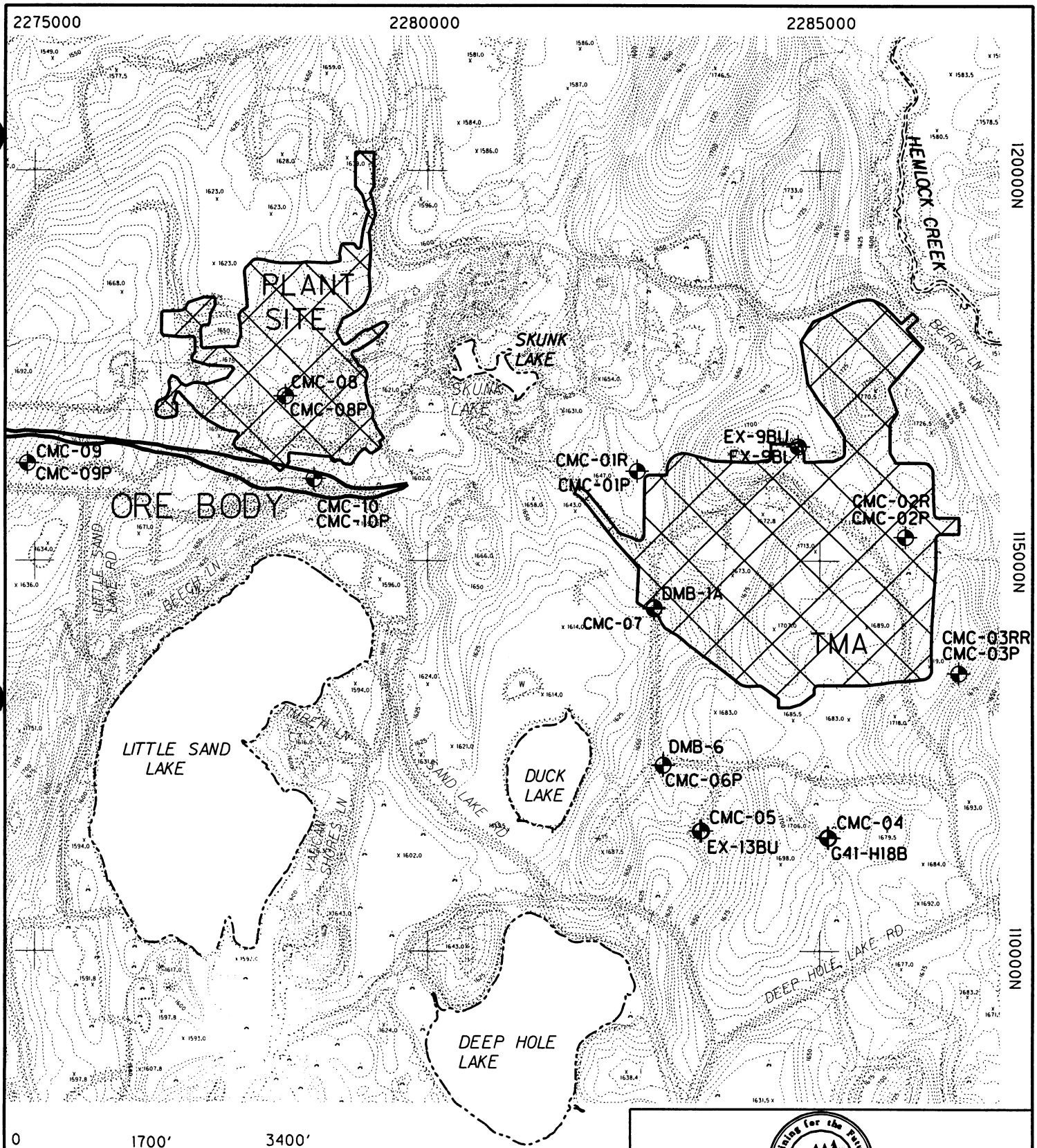

0 1700' 3400'

BAR SCALE

N

Foth & Van Dyke			
REVISED	DATE	BY	DESCRIPTION
1	11/98	MLD2	REVISED FOR 1998 UPDATE

CHECKED BY:	JKS	DATE: DEC. '96
APPROVED BY:	SVDI	DATE: DEC. '96
APPROVED BY:	JWS	DATE: DEC. '96

Nicolet Minerals COMPANY

Mining for the Future Commitment

FIGURE 3.6-2A

LOCATION OF 1994 GROUNDWATER QUALITY VERIFICATION WELLS

Scale:	SEE BAR SCALE	Date:	DECEMBER, 1996
Prepared By: Foth & Van Dyke		By: JRB2	93C049

I:\93c049\3c49f188.dgn Nov. 13, 1998 11:16:31

2,275,000 E
2,280,000 E
2,285,000 E
2,290,000 E
120,000 N
115,000 N

N

24
19
20
21
25
30
29
28
01
36
31
32
33
1
6
5

SWAMP CREEK
HEMLOCK CREEK
CMC-SC-102
CMC-SC-101
CMC-SCC-101
CMC-SCC-102A
CMC-SCC-102B
LINCOLN
NASH-
PLANT SITE
F12
F-15 (BURR OAK WETLAND)
STS-SL-4
STS-SL-3
CMC-SL-104
STS-SL-1
CMC-BO-102
CMC-SL-103A/B/C
STS-SL-5
CMC-BO-101A
CMC-BO-101B
SKUNK LAKE
BERRY LN
TMA
HEMLOCK CREEK
GROUND HEMLOCK LAKE
W SHORE LN
DEEP HOLE LAKE RD
OAK LAKE
STS-OL-1
CMC-SP-05A
CMC-SP-05B
CMC-SP-06
CMC-SP-04
CMC-SP-08
CMC-SP-07
F10
DMA-19
CMC-SP-09
CDM-16
CDM-17
CDM-18
CDM-19
CMC-LSL-102
CMC-SP-03A
CMC-SP-03B
STS-LSL-1
CMC-LSL-102A
CMC-LSL-102B
CMC-SP-01
CMC-SP-02
CMC-LSL-103
G40-Y15
G40-Y15A
F29
STS-DL-3
F28
STS-LSL-3
STS-DL-2
STS-LSL-2
G41-C15B
CMC-LSL-101
CMC-DL-103C
F9
CMC-SP-11A
CMC-SP-11B
G41-C15C
STS-DL-4
LITTLE SAND LAKE
G40-S17A
STS-DL-5
STS-DL-1
G40-S17
STS-LSL-4
DUCK LAKE
SAND LAKE RD
CMC-LSL-104A
CMC-LSL-104B
STS-LSL-5
STS-LSL-6
STS-DL46
FOREST COUNTY
LANGLADE COUNTY
CMC-LSL-105
CMC-SP-10
STS-DHL-1
DEEP HOLE LAKE
AINSWORTH
VILLE

LEGEND

- LAKES
- STREAMS
- EXISTING ROAD
- COUNTY BOUNDARY
- CIVIL TOWN BOUNDARY
- SECTION LINE
- ORE BODY
- PROPOSED ACCESS ROAD
- PROPOSED RAILROAD SPUR
- PROPOSED FACILITIES
- CDM-16 — MONITORING WELL BORING
- CMC-BO-102 — SOIL BORING LOCATION
- CMC-SP-01 — SAND POINT LOCATION
- F9 — INVESTIGATED WETLAND AREA BOUNDRY

NOTES:

1. BASE MAP DIGITIZED FROM 1" = 1000' SCALE, MAP PREPARED BY AERO-METRIC ENGINEERING, INC., SHEBOYGAN, WISCONSIN. DATE OF PHOTOGRAPHY APRIL 28, 1976.
2. HORIZONTAL DATUM BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM - NORTH ZONE.
3. COUNTY AND TOWNSHIP LINES DIGITIZED FROM 7.5' SERIES USGS MAPS.
4. ORE BODY OUTLINE IS REPRESENTATIVE OF THE SUBCROP AT THE BASE OF THE OVERBURDEN.

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION
1	3/96	SVDI	ADDED LITTLE SAND LAKE POINTS
2	1/97	GWS	REVISED TMA LIMITS OF DISTURBANCE
3	11/98	MLD2	REVISED FOR 1998 UPDATE

CHECKED BY:	JKS1	DATE:	MAY. '95
APPROVED BY:	SVDI	DATE:	MAY. '95
APPROVED BY:	GWS	DATE:	MAY. '95

Nicolet Minerals COMPANY

Mining for the Future Commitment

FIGURE 3.6-3

BORING LOCATIONS FOR LAKE BED AND WETLAND CHARACTERIZATION

Scale: 0 800' 1600' Date: MAY, 1995

Prepared By: Foth & Van Dyke By: JRB2 93C049

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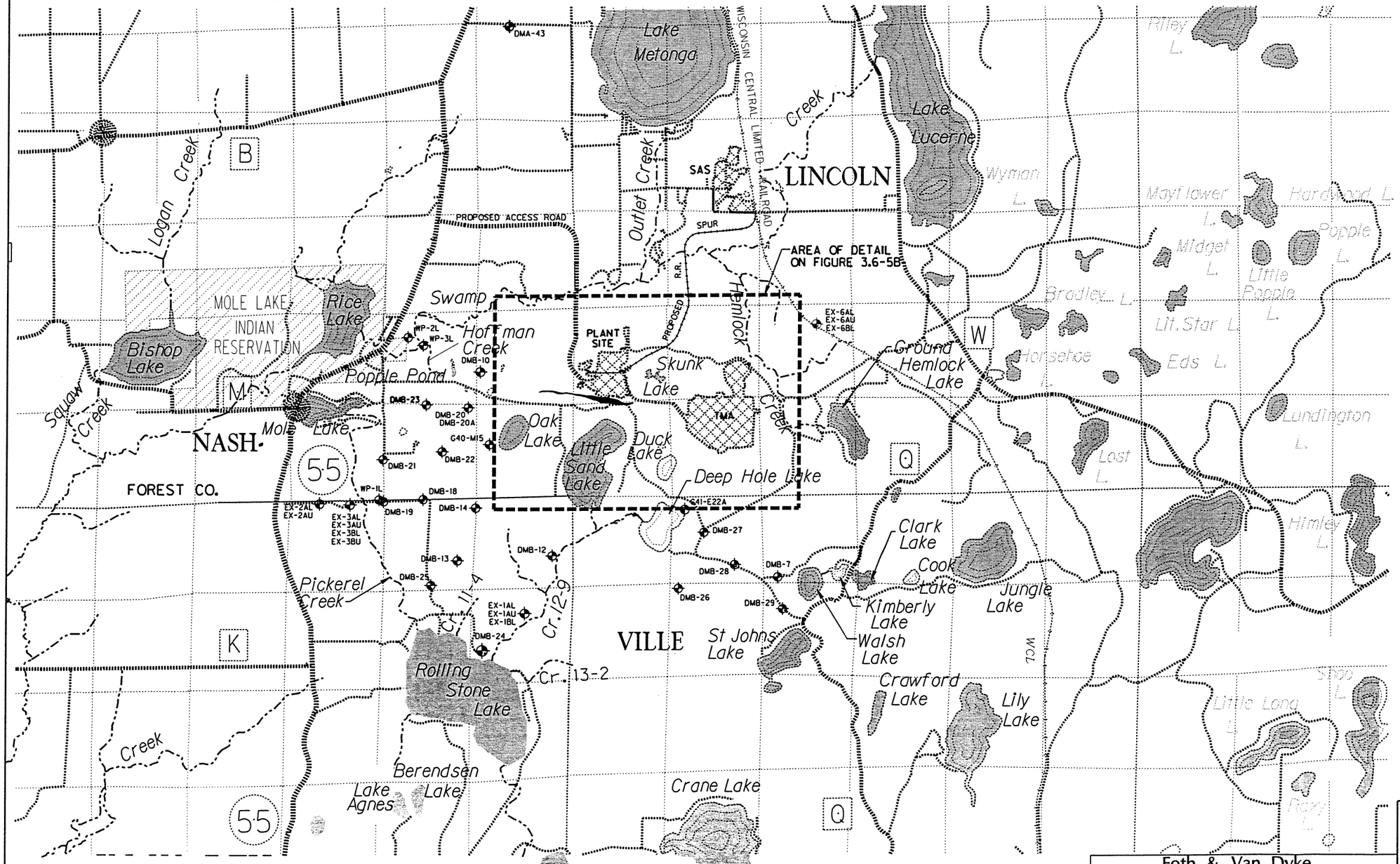

NOTE:

1. BASE MAP DERIVED FROM COUNTY MAPS PREPARED BY THE WISCONSIN DEPARTMENT OF TRANSPORTATION
2. ORE BODY OUTLINE IS REPRESENTATIVE OF THE SUBCROP AT THE BASE OF THE OVERBURDEN.

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION
1	11/98	MLD2	REVISED FOR 1998 UPDATE

CHECKED BY:	JKS1	DATE:	MAY'95
APPROVED BY:	SVD1	DATE:	MAY'95
APPROVED BY:	GWS	DATE:	MAY'95

Nicolet Minerals COMPANY

Mining for the Future Commitment

FIGURE 3.6-4

LOCATION OF GLACIAL OVERBURDEN WELLS USED FOR SLUG TESTS-MAP 1

Scale: 0 3000' 6000' Date: MAY, 1995

Prepared By: Foth & Van Dyke By: JRB2 93C049

\\93c049\94c033\4c33f102.dgn Nov. 13, 1998 12:13:19

2,275,000 E
2,280,000 E
2,285,000 E
2,290,000 E
120,000 N
115,000 N
110,000 N
N
SHERMAN LN
SKUNK CREEK
HEMLOCK CREEK
WP-4L
WP-5L
EX-4AL
EX-4AU
EX-4BL
EX-4BU
EX-5BL
19
20
21
LINCOLN
30
29
28
25
NASH-
PLANT SITE
DMS
SKUNK LAKE
DMB-4
WP-6L
EX-7AL
EX-7BL
EX-7BU
BEAR LN
DMB-3
BE-211-1
BE-211-3L
BE-211-3U
BE-216-3L
BE-216-3U
BE-216-2
DMT-2L
BE-213-3
BE-213-2
DW-3L
DW-3U
DW-1A
DW-1U
DW-1L
BE-211-2L
BE-216-1
BE-213-1
EX-9AU
EX-9BL
EX-8AU
EX-8BL
EX-8BU
EX-8AL
G41-M11
WP-7L
TMA
EX-10AL
EX-10AU
EX-10BL
DMB-2
DMB-1A
DMB-8
HEMLOCK CREEK
GROUND HEMLOCK LAKE
W. SHORE LN
DMA-3
DMA-19
OAK LAKE
DMA-1N
DMA-1S
DMB-15
36
31
32
33
LITTLE SAND LAKE
G40-S17
EX-15AL
EX-15AU
EX-16AL
EX-16AU
EX-16BL
DUCK LAKE
SAND LAKE RD
DMA-4
G41-E17
DMB-6
EX-11AL
EX-11AU
EX-11BL
EX-11BU
EX-12AL
EX-12AU
EX-12BL (B)
DMB-5
DMB-5A
EX-13BL
EX-13BU
EX-13AL
EX-13CL
G41-P16
DEEP HOLE LAKE RD
G41-P18
FOREST COUNTY
LANGLADE COUNTY
G41-E19A
DMB-9A
DMB-9B
DMB-9C
EX-14AL
EX-14AU
EX-14BL
DEEP HOLE LAKE
6
5
4
1
AINSWORTH
VILLE
WALSH LAKE RD
SAND LAKE RD
WALSH LAKE

LEGEND

- LAKES
- STREAMS
- EXISTING ROAD
- COUNTY BOUNDARY
- CIVIL TOWN BOUNDARY
- SECTION LINE
- ORE BODY
- PROPOSED ACCESS ROAD
- PROPOSED RAILROAD SPUR
- PROPOSED FACILITIES
- EX-12A — WELL USED FOR SLUG TESTS

NOTES:

1. BASE MAP DIGITIZED FROM 1'' = 1000' SCALE, MAP PREPARED BY AERO-METRIC ENGINEERING, INC., SHEBOYGAN, WISCONSIN. DATE OF PHOTOGRAPHY APRIL 28, 1976.
2. HORIZONTAL DATUM BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM - NORTH ZONE.
3. COUNTY AND TOWNSHIP LINES DIGITIZED FROM 7.5' SERIES USGS MAPS.
4. ORE BODY OUTLINE IS REPRESENTATIVE OF THE SUBCROP AT THE BASE OF THE OVERBURDEN.

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION
1	11/78	MLD2	REVISED FOR 1998 UPDATE

CHECKED BY:	JKSI	DATE:	MAY '95
APPROVED BY:	SVDI	DATE:	MAY '95
APPROVED BY:	GWS	DATE:	MAY '95

Nicolet Minerals COMPANY

Mining for the Future Commitment

FIGURE 3.6-5

LOCATION OF GLACIAL OVERBURDEN WELLS USED FOR SLUG TESTS-MAP 2

Scale: 0 1000' 2000' | Date: MAY, 1995

Prepared By: Foth & Van Dyke | By: JOW | 93C049

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2275000 E 2276000 E 2277000 E 2278000 E 2279000 E 2280000 E 2281000 E 2282000 E 2283000 E 2284000 E

120000 N
119000 N
118000 N
117000 N
116000 N

EX-5AL
EX-5AU
EX-9AL
SKUNK LAKE
ORE BODY
77 66 253 256 254 257 70 255 165 155 91 213

NOTES:

1. TOPOGRAPHIC BASE MAP DIGITIZED FROM 1" = 1000' SCALE, 5' CONTOUR INTERVAL MAP PREPARED BY AERO-METRIC ENGINEERING, INC., SHEBOYGAN, WISCONSIN. DATE OF PHOTOGRAPHY APRIL 28, 1976.
2. HORIZONTAL DATUM BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM - NORTH ZONE.
3. VERTICAL DATUM BASED ON WISCONSIN STATE PLANE DATUM. CONTOUR INTERVAL IS 25 FEET.
4. COUNTY AND TOWNSHIP LINES DIGITIZED FROM 7.5' SERIES USGS MAPS.
5. ORE BODY OUTLINE IS REPRESENTATIVE OF THE SUBCROP AT THE BASE OF THE OVERBURDEN.

LEGEND

- △ 77 — EXPLORATION HOLE / BEDROCK PIEZOMETER USED FOR BEDROCK PERMEABILITY TEST, SYMBOL DENOTES COLLAR LOCATION AT SURFACE
- LAKES
- 1600 — EXISTING CONTOUR
- x 1677.0 — SPOT ELEVATION
- ORE BODY
- ROADWAY
- TRAIL
- MARSH

Foth & Van Dyke			
REVISED	DATE	BY	DESCRIPTION
1	11/98	MLD2	REVISED FOR 1998 UPDATE

CHECKED BY:	JKSI	DATE: MAY '95
APPROVED BY:	SVDI	DATE: MAY '95
APPROVED BY:	GWS	DATE: MAY '95

Nicolet Minerals COMPANY

FIGUREC 3.6-6

LOCATION OF BEDROCK PACKER AND SLUG TESTS

Scale: 0 375' 750' | Date: MAY, 1995

Prepared By: Foth & Van Dyke | By: GAM | 93C049

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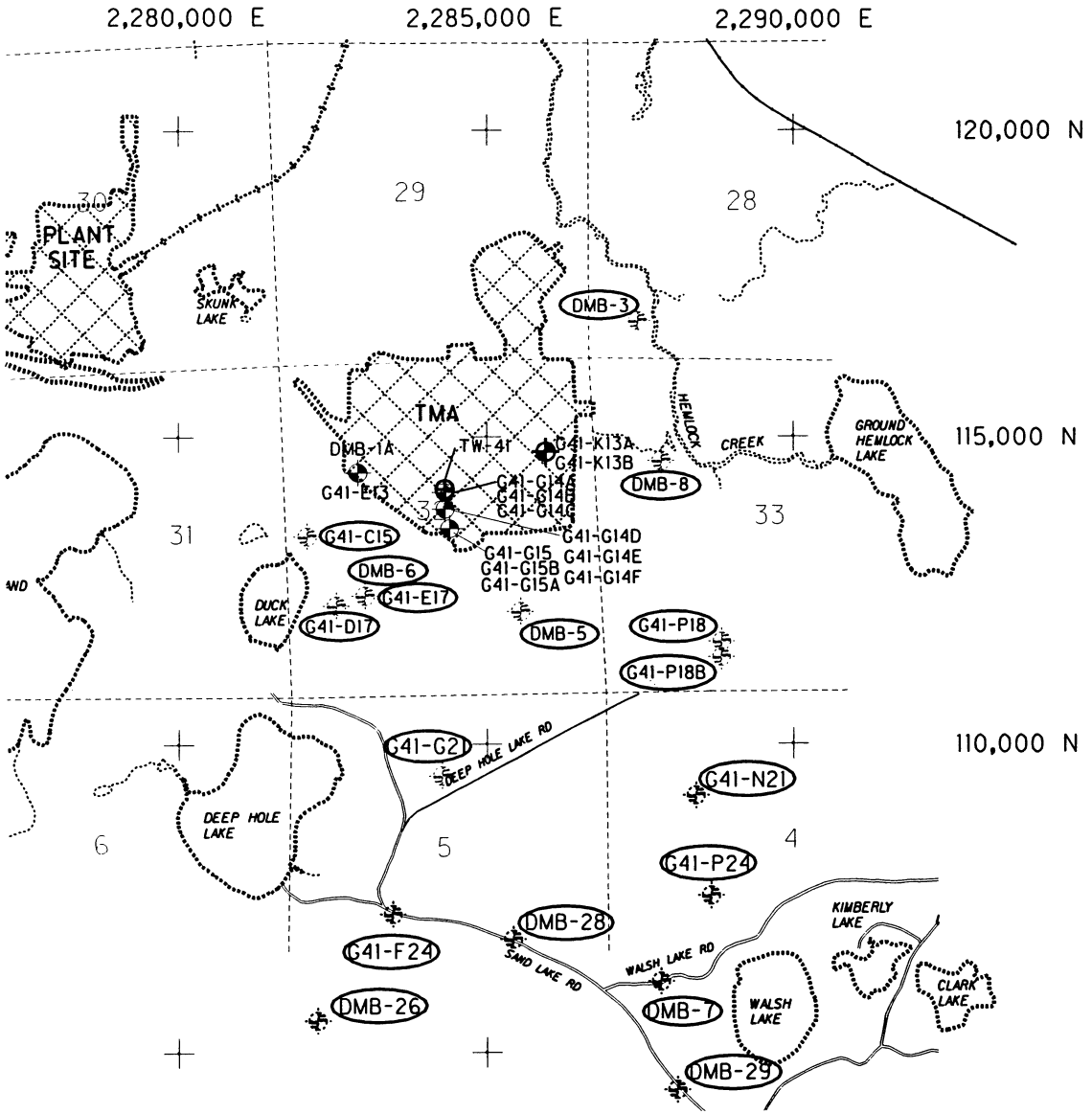

NOTES:

1. BASE MAP DIGITIZED FROM 1" = 1000' SCALE, MAP PREPARED BY AERO-METRIC ENGINEERING, INC., SHEBOYGAN, WISCONSIN. DATE OF PHOTOGRAPHY APRIL 28, 1976.
2. HORIZONTAL DATUM BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM - NORTH ZONE.
3. COUNTY AND TOWNSHIP LINES DIGITIZED FROM 7.5' SERIES USGS MAPS.
4. ORE BODY OUTLINE IS REPRESENTATIVE OF THE SUBCROP AT THE BASE OF THE OVERBURDEN.

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION
1	11/98	MLD2	REVISED FOR 1998 UPDATE

CHECKED BY:	JKSI	DATE: MAY '95
APPROVED BY:	SVDI	DATE: MAY '95
APPROVED BY:	GWS	DATE: MAY '95

Nicolet Minerals COMPANY

Mining for the Future commitment

FIGURE 3.6-7

PUMP TEST SETUP FOR 24 DAY GLACIAL OVERBURDEN PUMP TEST

Scale: 0 1500' 3000'		Date:	MAY, 1995
Prepared By: Foth & Van Dyke	By: KMP		93C049

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2,275,000 E

2,280,000 E

2,285,000 E

2,290,000 E

N

130,000 N

125,000 N

120,000 N

115,000 N

100,000 N

LAKE METONGA

APPROXIMATE LIMITS OF SOIL ABSORPTION SYSTEM SITE

MWH-13
SPH-6
SPH-3
SPH-3A
MWH-16
SGH-02
SPH-5
SPH-4
SPH-4A
MWH-09P
MWH-09
SAS
MWH-10P
MWH-10
MWH-11P
MWH-11
SPH-2
SPH-2A
SGH-01
MWH-15
MWH-19
SPH-1A
SPH-1
MWH-14

AREA E

MWE-04
MWE-18
MWE-11
MWE-16
MWE-08
MWE-14

PLANT SITE

SKUNK LAKE

TMA

OAK LAKE

LITTLE SAND LAKE

DUCK LAKE

GROUND HEMLOCK LAKE

DEEP HOLE LAKE

1624.0 x

X1624.6

X1633.0

1591.8 X

LEGEND

- TREES/BRUSH
- UNPAVED ROAD/TRAIL
- PAVED ROAD
- x 1542.0 EXISTING SPOT ELEVATION
- 1600 EXISTING CONTOUR
- CREEKS/RIVERS/LAKES
- PROPOSED ACCESS ROAD
- SGH-01 ▲ STAFF GAUGE NUMBER AND LOCATION
- SPH-3A ◆ SAND POINT NUMBER AND LOCATION
- MWE-08 ⊕ MONITORING WELL NUMBER AND LOCATION
- SECTION LINE
- ORE BODY
- PROPOSED RAILROAD SPUR
- PROPOSED FACILITIES

0 800' 1600'

BAR SCALE

NOTES:

1. TOPOGRAPHIC BASE MAP DIGITIZED FROM 1" = 1000' SCALE, 5' CONTOUR INTERVAL MAP PREPARED BY AERO-METRIC ENGINEERING, INC., SHEBOYGAN, WISCONSIN. DATE OF PHOTOGRAPHY APRIL 28, 1976.
2. HORIZONTAL DATUM BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM - NORTH ZONE.
3. VERTICAL DATUM BASED ON MEAN SEA LEVEL DATUM. CONTOUR INTERVAL IS 5 FEET.
4. COUNTY AND TOWNSHIP LINES DIGITIZED FROM 7.5' SERIES USGS MAPS.
5. ORE BODY OUTLINE IS REPRESENTATIVE OF THE SUBCROP AT THE BASE OF THE OVERBURDEN.

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION

CHECKED BY:	REM	DATE: DEC. '98
APPROVED BY:	SVDI	DATE: DEC. '98
APPROVED BY:	GWS	DATE: DEC. '98

Nicolet Minerals COMPANY

Mining for the Future Commitment

FIGURE 3.6-7A

WELL LOCATIONS FOR 1998 SOIL ABSORPTION SITE INVESTIGATION

Scale:	SEE BAR SCALE	Date:	DECEMBER, 1998
Prepared By:	Foth & Van Dyke	By:	DAT

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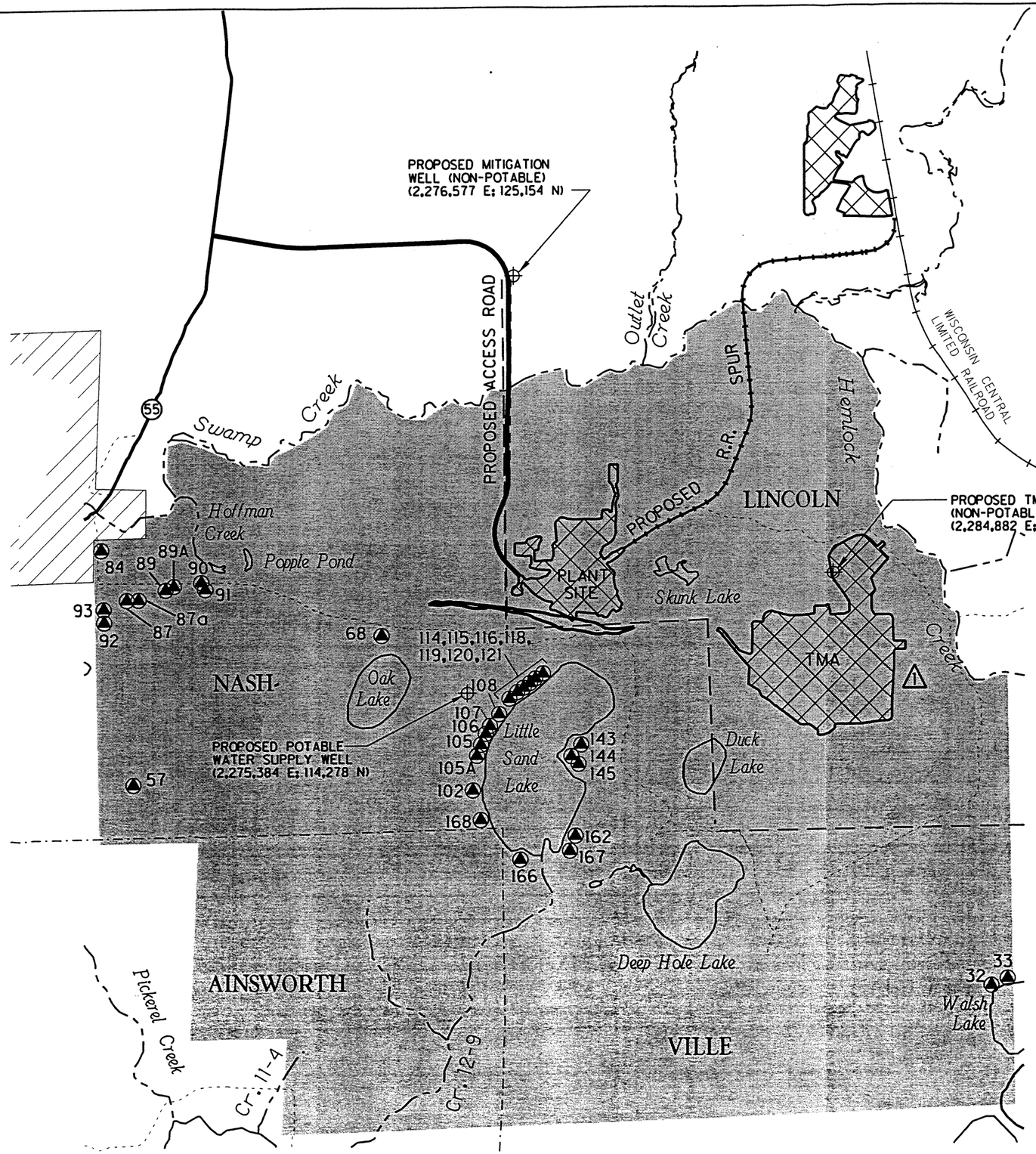
09 DEC 98 mjo3



LEGEND

- STATE HWY
- COUNTY TRUNK HWY
- ROAD
- COUNTY BOUNDARY
- CIVIL TOWN BOUNDARY
- (47) STATE HWY NO.
- [W] COUNTY HWY LETTER
- SURVEY AREA
- ORE BODY
- PROPOSED ACCESS ROAD
- PROPOSED RAILROAD SPUR
- PROPOSED FACILITIES
- ▲68 DOMESTIC WELL NUMBER AND LOCATION
- ⊕ PROPOSED WATER SUPPLY WELL

NOTE:

1. BASE MAP DERIVED FROM COUNTY MAPS PREPARED BY THE WISCONSIN DEPARTMENT OF TRANSPORTATION.
2. ORE BODY OUTLINE IS REPRESENTATIVE OF THE SUBCROP AT THE BASE OF THE OVERBURDEN.

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION
1	12/96	GWS	ADDED NMC WELL LOCATIONS AND REVISED TMA LIMITS OF DISTURBANCE
2	12/98	MLD2	REVISED FOR 1998 UPDATE

CHECKED BY:	JKSI	DATE:	MAY '95
APPROVED BY:	PAE	DATE:	MAY '95
APPROVED BY:	GWS	DATE:	MAY '95

Nicolet Minerals COMPANY

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FIGURE 3.6-8

DOMESTIC WATER WELL SURVEY AREA

Scale: 0 1500' 3000' Date: MAY, 1995

Prepared By: Foth & Van Dyke By: JOW 93C049

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PLANT SITE

25 30 29 36 31 32 1 6 5

TMA

OAK LAKE

LITTLE SAND LAKE

DUCK LAKE

DEEP HOLE LAKE

SAND LAKE RD

68

115 YEAGER
120
116
118
114
119
111
121
122
123
124
125
126
127
128
129
131
MANTEY
DIETZLER
PALLEN
BETTERS
DIX
WALENTOWSKI

PUBLIC ACCESS
134
135
136
137
138
139
140
141

110
108 BECKER
107
106 FRISTSCHE
105 HAFERMAN KELCHNER
105A
104
103 SEAWELL
WEBB 102
PIERITZ
168 KLOEHN

ROBERT KELCHNER
HAROLD PRYOR
WILLIAM BECKER

PARKER
LUENSKI
SCHALLOCK
SCHALLOCK
VERLOTTA
143
144
145

FOREST COUNTY
LANGLADE COUNTY

MIHALKO, et. al.

162 G. JOHNSON
ARCHIE JOHNSON
167 G. BUCKLEY
G. BUCKLEY

L. DILLEY
166
MAUREEN NOTEBOOM
DHUEY

REVISED

N

LEGEND

- LAKES
- STREAMS
- EXISTING ROAD
- COUNTY BOUNDARY
- CIVIL TOWN BOUNDARY
- SECTION LINE
- ORE BODY
- PROPOSED FACILITIES
- CMC PROPERTIES
- 143 DOMESTIC WATER WELL NUMBER AND LOCATION

NOTES:

1. BASE MAP DIGITIZED FROM 1" = 1000' SCALE, MAP PREPARED BY AERO-METRIC ENGINEERING, INC., SHEBOYGAN, WISCONSIN. DATE OF PHOTOGRAPHY APRIL 28, 1976.
2. HORIZONTAL DATUM BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM - NORTH ZONE.
3. COUNTY AND TOWNSHIP LINES DIGITIZED FROM 7.5' SERIES USGS MAPS.
4. ORE BODY OUTLINE IS REPRESENTATIVE OF THE SUBCROP AT THE BASE OF THE OVERBURDEN.

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION
1	10/95	GWS	ADDED NMC PROPERTIES
2	11/98	MLD2	REVISED FOR 1998 UPDATE

CHECKED BY:	JKS1	DATE:	MAY '95
APPROVED BY:	SVD1	DATE:	MAY. '95
APPROVED BY:	GWS	DATE:	MAY. '95

Nicolet Minerals COMPANY

Mining for the Future Commitment

FIGURE 3.6-9

LITTLE SAND LAKE
DOMESTIC WATER WELLS

Scale: 0 400' 800' | Date: MAY, 1995

Prepared By: Foth & Van Dyke | By: JOW | 93C049

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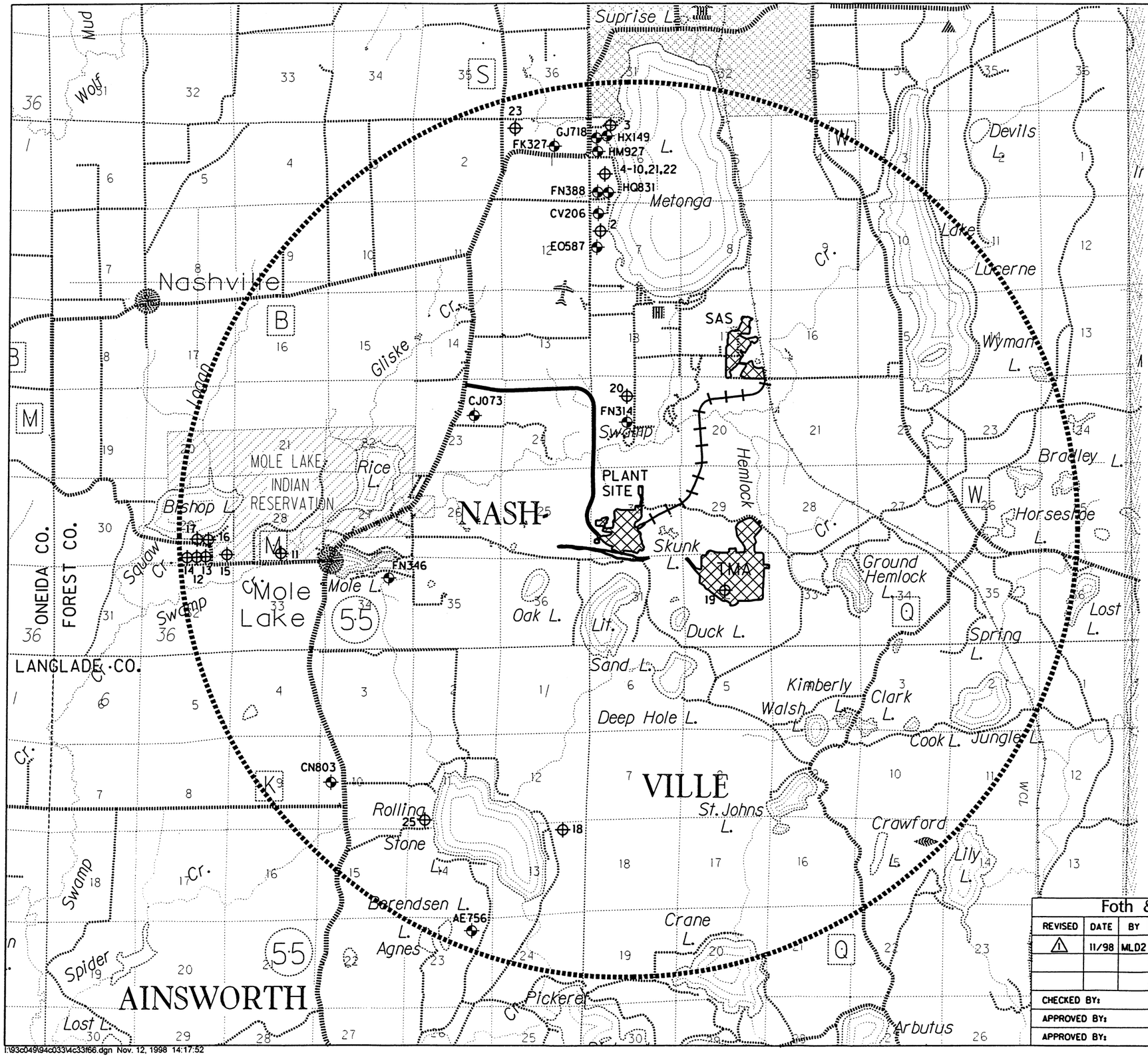
LINCOLN
LAONA
Crandon
NASH-
VILLE
FREEDOM
AINSWORTH
ANGLADE CO.
FOREST CO.
ONEIDA CO.
Nashville
Lennox
Mole Lake
MOLE LAKE INDIAN RESERVATION
PLANT SITE
SAS
Metonga L.
Rice L.
Whiteye L.
Drake
Peshtigo L.
Clear L.
Suprise L.
Bug L.
Otter Spgs.
Dawson L.
Wabikon L.
Lit. Pine L.
Rat R.
Devils L.
Indian L.
Lit. Riley L.
Honey
Lucerne
Wyman L.
Mayflower L.
Hardwood L.
Popple L.
Midget L.
Lit. Popple
Lit. Star L.
Eds L.
Finner
Wood.
Bradley L.
Horseshoe L.
Lundington L.
Himley
Lost L.
Spring L.
Roberts L.
Bass
Richardson
Spr
Ground Hemlock L.
Skunk L.
TMA
Oak L.
Duck L.
Sand L.
Kimberly
Walsh L.
Clark L.
Deep Hole L.
Cook L.
Jungle L.
St. Johns L.
Crawford Lily L.
Lit. Long L.
Zarling L.
Shoe L.
Roxy L.
Mud L.
Deer L.
Bogbrook
Spring Pd.
Kohlhoff
Windmill L.
Bog
Arbutus L.
Crane L.
Borendsen L.
Agnes
Rolling Stone L.
Wamin L.
Aninnan L.
Spider
Lost L.
Miniwakan L.
Pickerel
Pickerel Lake
Hollister L.
Deadman
Tekakwitha L.
Horseshoe
Crystal L.
Campbell
Grass
Loon L.
Perch L.
Hunting
Hindu L.
Spring L.
Harper
Post L.
Leith L.
Lucille L.
Mud Cr.
Wolf R.
Walczak
Swamp Cr.
Swamp
Hemlock
Finnerty
Honey
Indian R.
Rice
Bishop
Mole L.
Swamp
Wolf
Mud
Cr.
R.
Lit.
Sand
Spring
Roberts
Zarling L.
Shoe L.
Long L.
Lit.
Pine L.
Rat R.
Wabikon L.
Dawson L.
Otter Spgs.
Bug L.
Peshtigo L.
Clear L.
Suprise L.
Drake
Whiteye L.
Rice L.
Lit.
Leith L.
Mud Cr.
Wolf R.
Wolf
Lucille L.
Lennox
Nashville
Metonga L.
Lucerne
Wyman L.
Devils L.
Indian L.
Lit. Riley L.
Honey



LEGEND

- U.S. OR STATE HWY
- COUNTY TRUNK ROAD
- TOWN ROAD
- COUNTY BOUNDARY
- CIVIL TOWN BOUNDARY
- SECTION LINE
- (8) U.S. HWY NO.
- (47) STATE HWY NO.
- W COUNTY HIGHWAY LETTER
- NATIONAL & STATE FOREST BOUNDARY
- CORPORATE LIMITS
- UNINCORPORATED VILLAGE
- ORE BODY
- Zarling L. LAKES
- STREAMS
- PROPOSED ACCESS ROAD
- PROPOSED RAILROAD SPUR
- PROPOSED FACILITIES
- 20 PRE - 1988 WELLS COMPLETED IN BEDROCK
- FN314 WELLS COMPLETED IN THE BEDROCK SINCE 1988
- 5 MILE RADIUS AROUND PLANT SITE

N

NOTES:

1. BASE MAP DERIVED FROM COUNTY MAPS PREPARED BY THE WISCONSIN DEPARTMENT OF TRANSPORTATION.
2. ORE BODY OUTLINE IS REPRESENTATIVE OF THE SUBCROP AT THE BASE OF THE OVERBURDEN.

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION
1	11/98	MLD2	REVISED FOR 1998 UPDATE

CHECKED BY:	JKSI	DATE:	DEC. '96
APPROVED BY:	GWS	DATE:	DEC. '96
APPROVED BY:		DATE:	

Nicolet Minerals COMPANY

Mining for the Future • Commitment

FIGURE 3.6-10A

WELLS COMPLETED IN BEDROCK

Scale: 0 3000' 6000' | Date: DECEMBER, 1996

Prepared By: Foth & Van Dyke | By: JRB2 | 93C049

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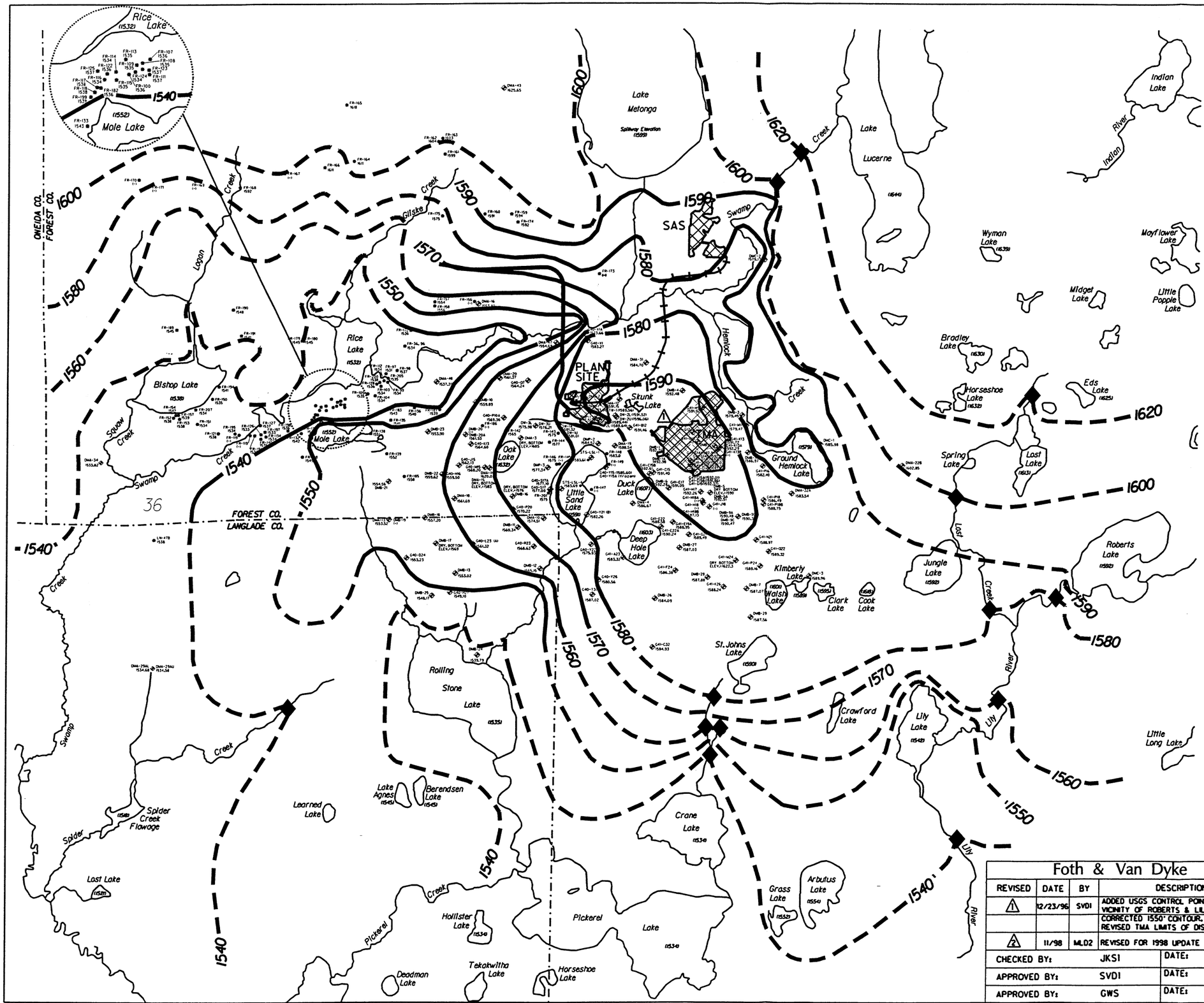

NOTES:

1. BASE MAP DERIVED FROM COUNTY MAPS PREPARED BY THE WISCONSIN DEPARTMENT OF TRANSPORTATION.
2. ORE BODY OUTLINE IS REPRESENTATIVE OF THE SUBCROP AT THE BASE OF THE OVERBURDEN.
3. GROUNDWATER CONTOURS INTERPRETED BY GOLDER ASSOCIATES (1982) BASED ON THE FOLLOWING DATA:
   A. OBSERVATION WELL MEASUREMENTS READ FEB. 22-24, 1982.
   B. USGS WELL DATA AND OTHER WELL DATA FROM DIFFERENT TIME PERIODS.
   C. (-) NO WATER LEVEL RECORDED.

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION
1	12/23/96	SVDI	ADDED USGS CONTROL POINTS IN VICINITY OF ROBERTS & LILY LAKE. CORRECTED 1550' CONTOUR. REVISED TMA LIMITS OF DISTURBANCE.
2	11/98	MLD2	REVISED FOR 1998 UPDATE

CHECKED BY:	JKSI	DATE:	MAY '95
APPROVED BY:	SVDI	DATE:	MAY '95
APPROVED BY:	GWS	DATE:	MAY '95

Nicolet Minerals COMPANY

Mining for the Future • Commitment

FIGURE 3.6-11

REGIONAL POTENTIOMETRIC SURFACE
FEBRUARY, 1982

Scale: 0 3000' 6000' | Date: MAY, 1995

Prepared By: Foth & Van Dyke | By: JOW | 93C049

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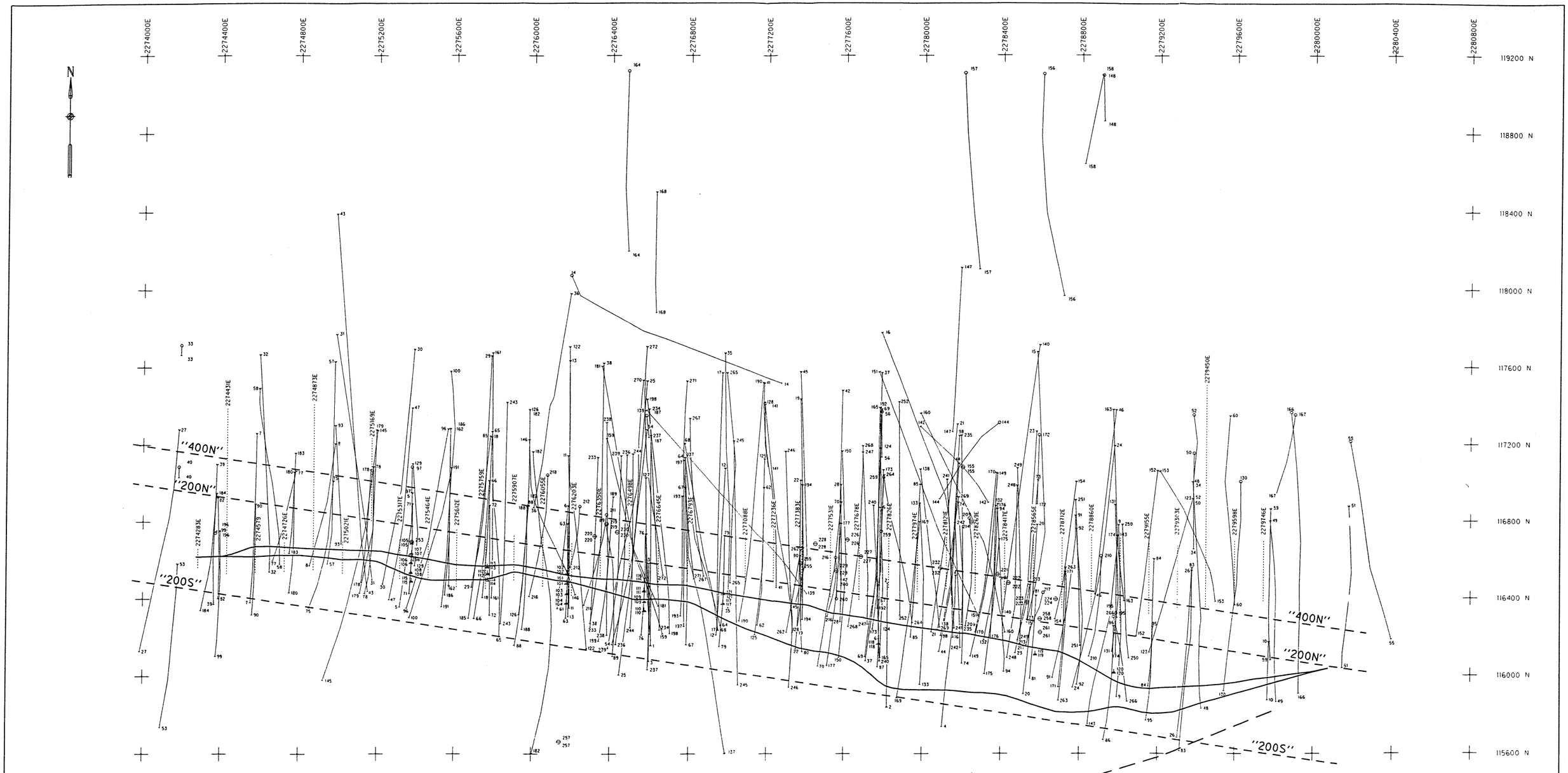

LEGEND

- CORE HOLE TRACE
- WEATHERING CROSS SECTIONS USED TO GENERATE LONGITUDINAL WEATHERING SECTIONS
- ORE BODY
- LOCATION OF LONGITUDINAL WEATHERING SECTIONS SHOWN ON FIGURES 3.6-13 TO 3.6-16
- DUCK LAKE GABBRO DIKE

0 250 500 1000

BAR SCALE (FEET)

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION
1	11/98	MLD2	REVISED FOR 1998 UPDATE

CHECKED BY:	JKS1	DATE: MAY '95
APPROVED BY:	AJE JR./SVD1	DATE: MAY '95
APPROVED BY:	GWS	DATE: MAY '95

Nicolet Minerals COMPANY

Mining for the Future — Community Economy

FIGURE 3.6-12

PLAN MAP SHOWING DRILL HOLE TRACE AND OUTLINE OF CRANDON FORMATION, LOCATION OF WEATHERING CROSS SECTIONS, LOCATION OF LONGITUDINAL WEATHERING SECTIONS AND LOCATION OF GABBRO "DIKE"

Scale: AS SHOWN	Date: MAY, 1995	
Prepared By: Foth & Van Dyke	By: JRB2	93C049

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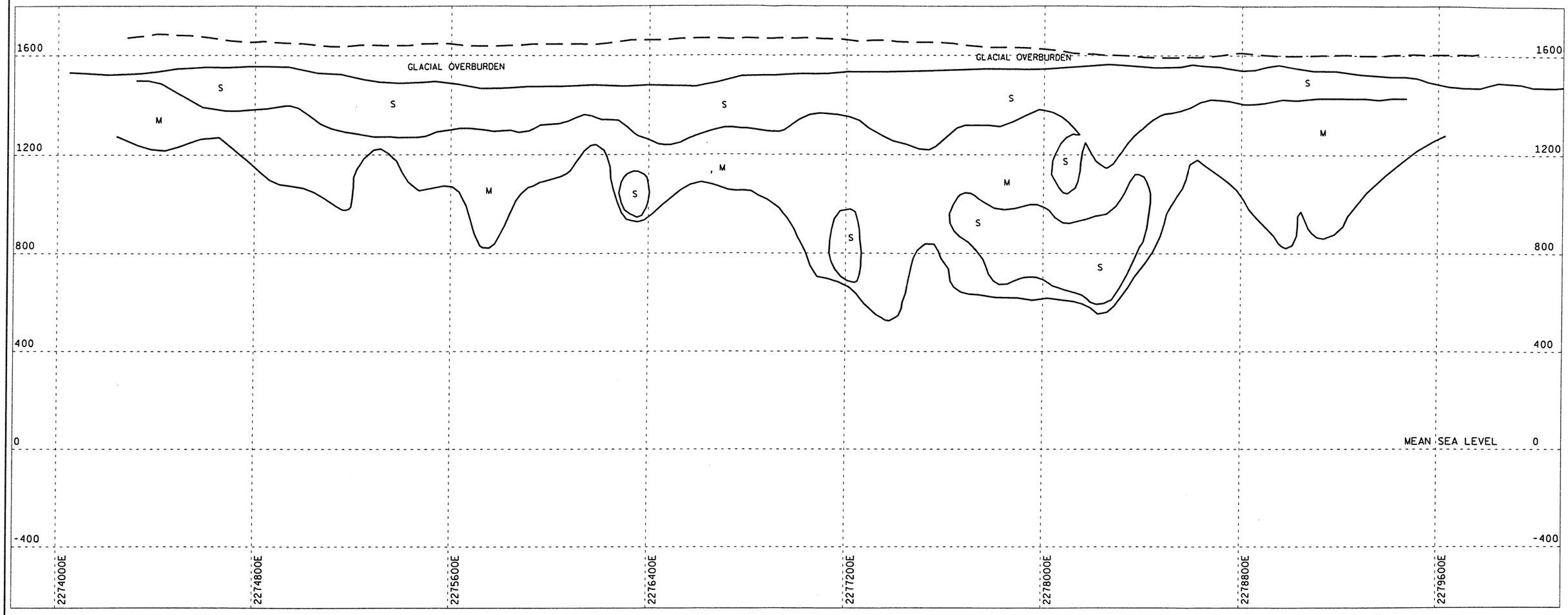

DESTRUCTIVE PROCESS AND WEATHERING INTENSITY RATING

DESTRUCTIVE PROCESSES:

OXIDATION -	TOTAL:	TOTAL OXIDATION OF ALL SULFIDES
	PARTIAL:	PARTIAL OXIDATION OF ALL SULFIDES
	TRACE:	TRACES OR SMALL QUANTITIES OF TRANSPORTED AND/OR INDIGENOUS LIMONITE ON FRACTURES OF BEDDING PLANES
LEACHING -	STRONG:	>5 VOLUME PERCENT SECONDARY POROSITY
	MODERATE:	2-5 VOLUME PERCENT SECONDARY POROSITY
	WEAK:	TRACE - 1 VOLUME PERCENT SECONDARY POROSITY
ARGILLIZATION -	STONG:	PERVASIVE STRONG DEVELOPMENT OF CLAY. ROCK SOFT AND BREAKS EASILY. (ROCK EASILY GOUGES WITH NAIL)
	WEAK:	WEAK OR PARTIAL CLAY DEVELOPMENT, BUT ROCK DOES NO BREAK EASILY
FRACTURING -	STRONG:	> 20 FRACTURES/FOOT
	MODERATE:	5-20 FRACTURES/FOOT
	WEAK:	1-4 FRACTURES/FOOT

WEATHER INTENSITY RATING

STRONG: S	STRONG DEVELOPMENT OF TWO OR MORE OF THE DESTRUCTIVE PROCESSES. ROCKS WILL HAVE VERY LOW COMPRESSIVE STRENGTHS AND WORKINGS WOULD HAVE TO BE SUPPORTED AS NEEDED. SECONDARY PERMEABILITY FEATURES HAVE BEEN SIGNIFICANTLY MODIFIED.
MODERATE: M	STRONG DEVELOPMENT OF ONE OF THE DESTRUCTIVE PROCCESSES (OR MODERATE DEVELOPMENT OF TWO) AND WEAK TO MODERATE DEVELOPMENT OF AT LEAST ONE MORE. ROCKS MAY OR MAY NOT BE STRONG ENOUGH TO HOLD A BACK, DEPENDING UPON WHICH DESTRUCTIVE PROCESSES HAVE BEEN ACTIVE. STRONG DEVELOPMENT OF ARGILLIZATION OR FRACTURING WOULD MAKE THE ROCK VERY WEAK OR UNSTABLE, WHEREAS STRONG DEVELOPMENT OF OXIDATION OR LEACHING MAY NOT SERIOUSLY AFFECT ITS ABILITY TO HOLD A BACK. SECONDARY PERMEABILITY FEATURES HAVE BEEN SLIGHTLY MODIFIED.
LOW:	MODERATE LEACHING WITH ONLY MINOR OTHER EFFECTS. THE COMPRESSSIVE STRENGTH OF THE ROCK IS NOT SERIOUSLY REDUCED. SECONDARY PERMEABILITY FEATURES HAVE UNDERGONE NO OBSERVABLE WEATHERING MODIFICATIONS.
WEAK:	WEAK DEVELOPMENT OF LEACHING AND/OR OXIDATION. ROCK STRENGTHS ARE NOT AFFECTED. SECONDARY PERMEABILITY FEATURES HAVE UNDERGONE NO OBSERVABLE WEATHERING MODIFICATIONS.

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION
1	11/98	MLD2	REVISED FOR 1998 UPDATE

CHECKED BY:	JKS1	DATE: MAY '95
APPROVED BY:	AJE JR./SVD1	DATE: MAY '95
APPROVED BY:	GWS	DATE: MAY '95

Nicolet Minerals COMPANY

FIGURE 3.6-13

LONGITUDINAL SECTION LOOKING NORTH WITHIN THE CRANDON FORMATION

Scale:	HORIZ. 1"=400' VERT. 1"=400'	Date:	MAY, 1995
Prepared By: Foth & Van Dyke	By: AJE JR. JRB2		93C049

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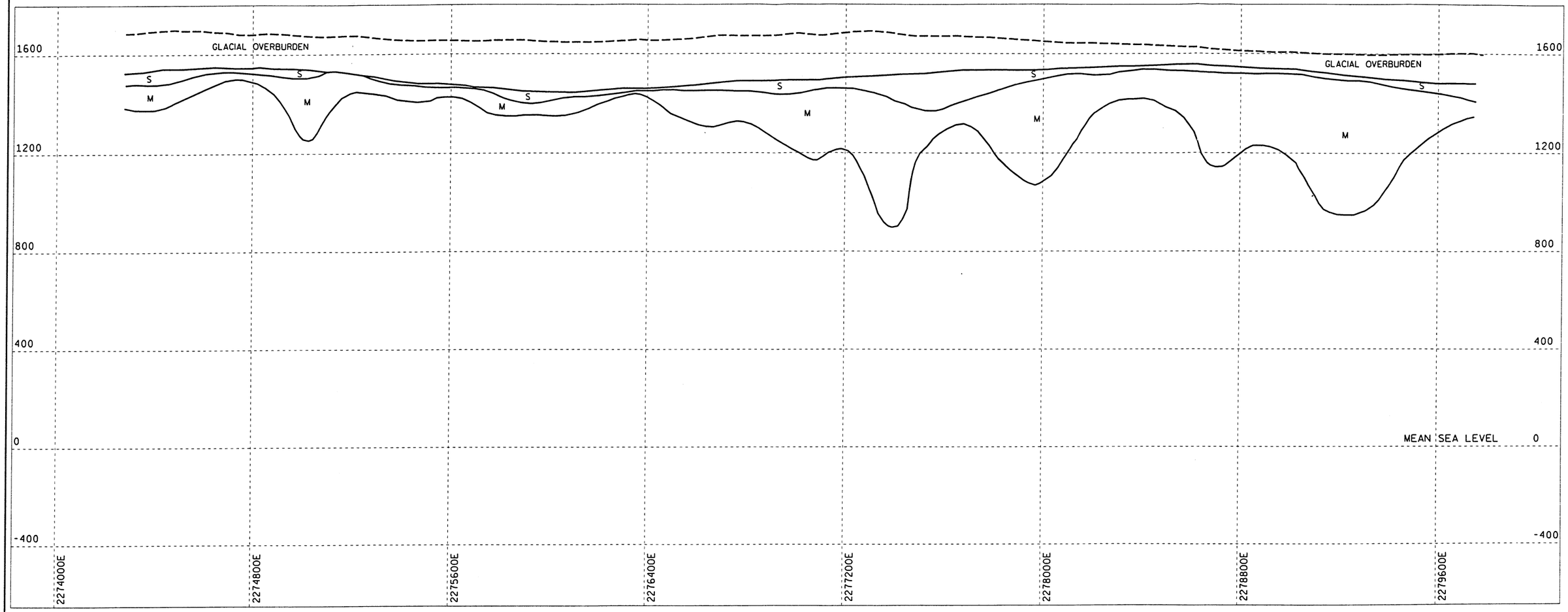

DESTRUCTIVE PROCESS AND WEATHERING INTENSITY RATING

DESTRUCTIVE PROCESSES:

OXIDATION -	TOTAL:	TOTAL OXIDATION OF ALL SULFIDES
	PARTIAL:	PARTIAL OXIDATION OF ALL SULFIDES
	TRACE:	TRACES OR SMALL QUANTITIES OF TRANSPORTED AND/OR INDIGENOUS LIMONITE ON FRACTURES OF BEDDING PLANES
LEACHING -	STRONG:	>5 VOLUME PERCENT SECONDARY POROSITY
	MODERATE:	2-5 VOLUME PERCENT SECONDARY POROSITY
	WEAK:	TRACE - 1 VOLUME PERCENT SECONDARY POROSITY
ARGILLIZATION -	STONG:	PERVASIVE STRONG DEVELOPMENT OF CLAY. ROCK SOFT AND BREAKS EASILY. (ROCK EASILY GOUGES WITH NAIL)
	WEAK:	WEAK OR PARTIAL CLAY DEVELOPMENT, BUT ROCK DOES NO BREAK EASILY
FRACTURING -	STRONG:	> 20 FRACTURES/FOOT
	MODERATE:	5-20 FRACTURES/FOOT
	WEAK:	1-4 FRACTURES/FOOT

WEATHER INTENSITY RATING

STRONG: S	STRONG DEVELOPMENT OF TWO OR MORE OF THE DESTRUCTIVE PROCESSES. ROCKS WILL HAVE VERY LOW COMPRESSIVE STRENGTHS AND WORKINGS WOULD HAVE TO BE SUPPORTED AS NEEDED. SECONDARY PERMEABILITY FEATURES HAVE BEEN SIGNIFICANTLY MODIFIED.
MODERATE: M	STRONG DEVELOPMENT OF ONE OF THE DESTRUCTIVE PROCCESSES (OR MODERATE DEVELOPMENT OF TWO) AND WEAK TO MODERATE DEVELOPMENT OF AT LEAST ONE MORE. ROCKS MAY OR MAY NOT BE STRONG ENOUGH TO HOLD A BACK, DEPENDING UPON WHICH DESTRUCTIVE PROCESSES HAVE BEEN ACTIVE. STRONG DEVELOPMENT OF ARGILLIZATION OR FRACTURING WOULD MAKE THE ROCK VERY WEAK OR UNSTABLE, WHEREAS STRONG DEVELOPMENT OF OXIDATION OR LEACHING MAY NOT SERIOUSLY AFFECT ITS ABILITY TO HOLD A BACK. SECONDARY PERMEABILITY FEATURES HAVE BEEN SLIGHTLY MODIFIED.
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WEAK:	WEAK DEVELOPMENT OF LEACHING AND/OR OXIDATION. ROCK STRENGTHS ARE NOT AFFECTED. SECONDARY PERMEABILITY FEATURES HAVE UNDERGONE NO OBSERVABLE WEATHERING MODIFICATIONS.

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1	11/98	MLD2	REVISED FOR 1998 UPDATE

CHECKED BY:	JKSI	DATE: MAY '95
APPROVED BY:	AJE JR./SVDI	DATE: MAY '95
APPROVED BY:	GWS	DATE: MAY '95

Nicolet Minerals COMPANY

FIGURE 3.6-14
E-W LONGITUDINAL SECTION
200' NORTH OF CRANDON FM HW CONTACT AT SUBCROP-LOOKING DUE NORTH-MOLE LAKE FM

Scale:	HORIZ. 1"=400' VERT. 1"=400'	Date:	MAY, 1995
Prepared By: Foth & Van Dyke	By: JRB2 AJE JR.		93C049

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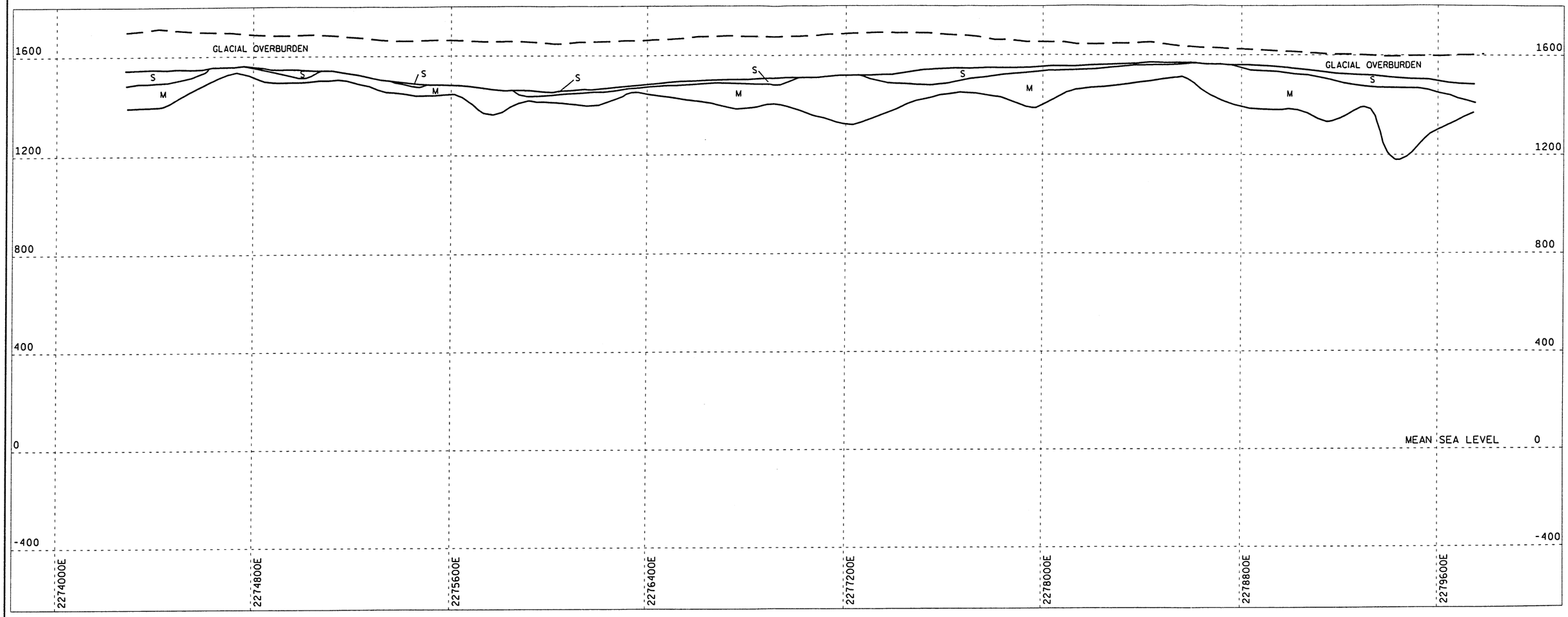

DESTRUCTIVE PROCESS AND WEATHERING INTENSITY RATING

DESTRUCTIVE PROCESSES:

OXIDATION -	TOTAL:	TOTAL OXIDATION OF ALL SULFIDES
	PARTIAL:	PARTIAL OXIDATION OF ALL SULFIDES
	TRACE:	TRACES OR SMALL QUANTITIES OF TRANSPORTED AND/OR INDIGENOUS LIMONITE ON FRACTURES OF BEDDING PLANES
LEACHING -	STRONG:	>5 VOLUME PERCENT SECONDARY POROSITY
	MODERATE:	2-5 VOLUME PERCENT SECONDARY POROSITY
	WEAK:	TRACE - 1 VOLUME PERCENT SECONDARY POROSITY
ARGILLIZATION -	STONG:	PERVASIVE STRONG DEVELOPMENT OF CLAY. ROCK SOFT AND BREAKS EASILY. (ROCK EASILY GOUGES WITH NAIL)
	WEAK:	WEAK OR PARTIAL CLAY DEVELOPMENT, BUT ROCK DOES NO BREAK EASILY
FRACTURING -	STRONG:	> 20 FRACTURES/FOOT
	MODERATE:	5-20 FRACTURES/FOOT
	WEAK:	1-4 FRACTURES/FOOT

WEATHER INTENSITY RATING

STRONG: S	STRONG DEVELOPMENT OF TWO OR MORE OF THE DESTRUCTIVE PROCESSES. ROCKS WILL HAVE VERY LOW COMPRESSIVE STRENGTHS AND WORKINGS WOULD HAVE TO BE SUPPORTED AS NEEDED. SECONDARY PERMEABILITY FEATURES HAVE BEEN SIGNIFICANTLY MODIFIED.
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LOW:	MODERATE LEACHING WITH ONLY MINOR OTHER EFFECTS. THE COMPRESSSIVE STRENGTH OF THE ROCK IS NOT SERIOUSLY REDUCED. SECONDARY PERMEABILITY FEATURES HAVE UNDERGONE NO OBSERVABLE WEATHERING MODIFICATIONS.
WEAK:	WEAK DEVELOPMENT OF LEACHING AND/OR OXIDATION. ROCK STRENGTHS ARE NOT AFFECTED. SECONDARY PERMEABILITY FEATURES HAVE UNDERGONE NO OBSERVABLE WEATHERING MODIFICATIONS.

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION
1	11/98	MLD2	REVISED FOR 1998 UPDATE

CHECKED BY:	JKS1	DATE:	MAY '95
APPROVED BY:	AJE JR./SVD1	DATE:	MAY '95
APPROVED BY:	GWS	DATE:	MAY '95

Nicolet Minerals COMPANY

Mines for the Future Commitment

FIGURE 3.6-15
E-W LONGITUDINAL SECTION
400' NORTH OF CRANDON FM HW CONTACT AT SUBCROP-LOOKING DUE NORTH-MOLE LAKE FM

Scale:	HORIZ. 1"=400' VERT. 1"=400'	Date:	MAY, 1995
Prepared By: Foth & Van Dyke	By: JRB2 AJE JR.		93C049

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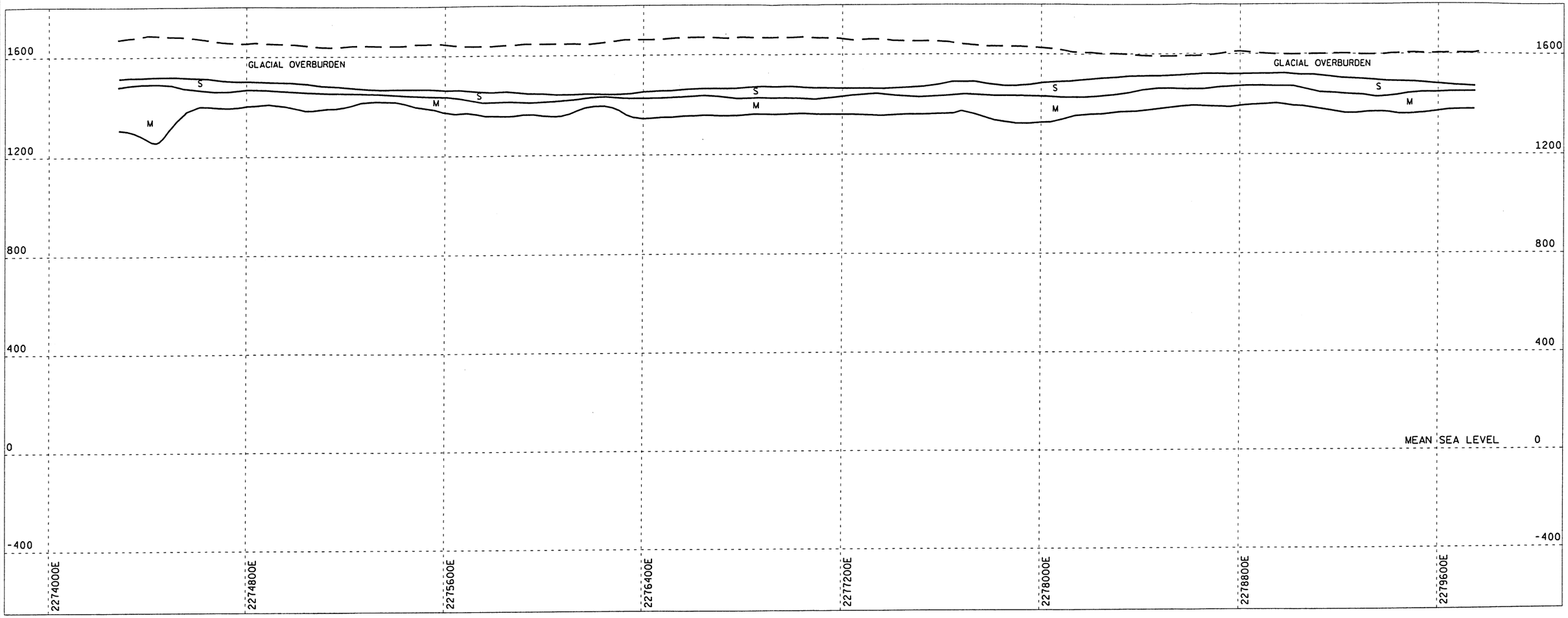

DESTRUCTIVE PROCESS AND WEATHERING INTENSITY RATING

DESTRUCTIVE PROCESSES:

OXIDATION -	TOTAL:	TOTAL OXIDATION OF ALL SULFIDES
	PARTIAL:	PARTIAL OXIDATION OF ALL SULFIDES
	TRACE:	TRACES OR SMALL QUANTITIES OF TRANSPORTED AND/OR INDIGENOUS LIMONITE ON FRACTURES OF BEDDING PLANES
LEACHING -	STRONG:	>5 VOLUME PERCENT SECONDARY POROSITY
	MODERATE:	2-5 VOLUME PERCENT SECONDARY POROSITY
	WEAK:	TRACE - 1 VOLUME PERCENT SECONDARY POROSITY
ARGILLIZATION -	STONG:	PERVASIVE STRONG DEVELOPMENT OF CLAY. ROCK SOFT AND BREAKS EASILY. (ROCK EASILY GOUGES WITH NAIL)
	WEAK:	WEAK OR PARTIAL CLAY DEVELOPMENT, BUT ROCK DOES NO BREAK EASILY
FRACTURING -	STRONG:	> 20 FRACTURES/FOOT
	MODERATE:	5-20 FRACTURES/FOOT
	WEAK:	1-4 FRACTURES/FOOT

WEATHER INTENSITY RATING

STRONG: S	STRONG DEVELOPMENT OF TWO OR MORE OF THE DESTRUCTIVE PROCESSES. ROCKS WILL HAVE VERY LOW COMPRESSIVE STRENGTHS AND WORKINGS WOULD HAVE TO BE SUPPORTED AS NEEDED. SECONDARY PERMEABILITY FEATURES HAVE BEEN SIGNIFICANTLY MODIFIED.
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Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION
1	11/98	MLD2	REVISED FOR 1998 UPDATE

CHECKED BY:	JKS1	DATE: MAY '95
APPROVED BY:	AJE JR./SVDI	DATE: MAY '95
APPROVED BY:	GWS	DATE: MAY '95

Nicolet Minerals COMPANY

FIGURE 3.6-16
E-W LONGITUDINAL SECTION
200' SOUTH OF CRANDON FM FW CONTACT AT SUBCROP-LOOKING DUE NORTH-SAND LAKE FM

Scale:	HORIZ. 1"=400' VERT. 1"=400'	Date:	MAY, 1995
Prepared By: Foth & Van Dyke	By: JRB2 AJE JR.		93C049

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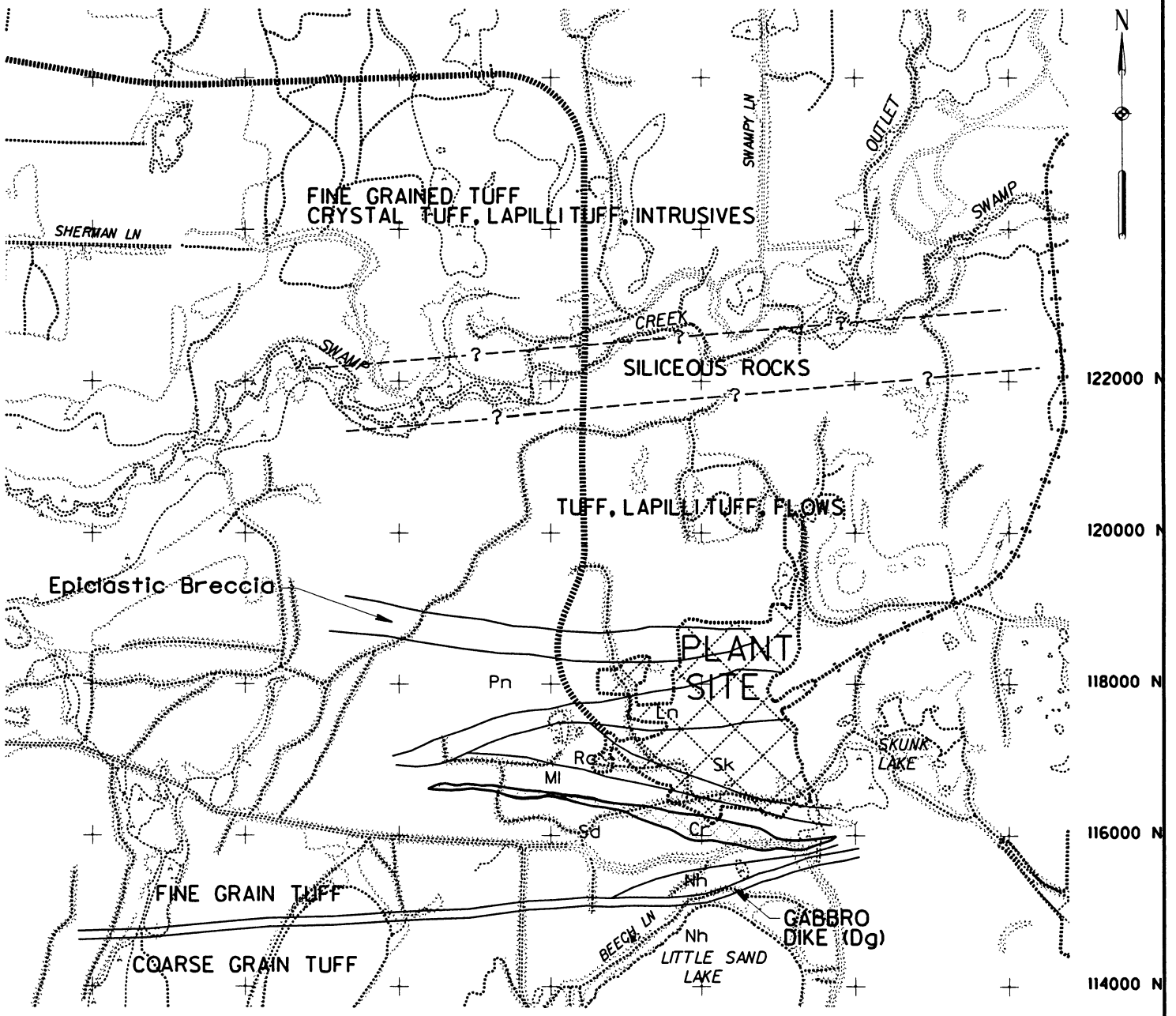

LEGEND

RIVER/LAKE/WATERWAY	
ROADWAY	
TRAIL	
MARSH BOUNDARY	
MARSH	
Nh	NASHVILLE FORMATION
Dg	DUCK LAKE GABBRO DIKE
Pn	PINE FORMATION
Ln	LINCOLN FORMATION
Cr	CRANDON FORMATION
Sk	SKUNK LAKE FORMATION
Sd	SAND LAKE FORMATION
Ml	MOLE LAKE FORMATION
Rc	RICE LAKE FORMATION

NOTES:

1. BASE MAP DIGITIZED FROM 1" = 1000' SCALE, MAP PREPARED BY AERO-METRIC ENGINEERING, INC., SHEBOYGAN, WISCONSIN. DATE OF PHOTOGRAPHY APRIL 28, 1976.
2. HORIZONTAL DATUM BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM - NORTH ZONE.
3. ORE BODY OUTLINE IS REPRESENTATIVE OF THE SUBCROP AT THE BASE OF THE OVERBURDEN.

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION
1	11/98	MLD2	REVISED FOR 1998 UPDATE

CHECKED BY:	JKSI	DATE: MAY '95
APPROVED BY:	SVDI	DATE: MAY '95
APPROVED BY:	GWS	DATE: MAY '95

Nicolet Minerals COMPANY

Mining for the Future

FIGURE 3.6-17

BEDROCK GEOLOGY OF THE STUDY AREA AND APPROXIMATE LOCATION OF GABBRO DIKE

Scale:	NOT TO SCALE	Date:	MAY, 1995
Prepared By: Foth & Van Dyke	By: JOW		93C049

I:\93c049\94c033\4c33f148.dgn Nov. 12, 1998 15:10:34

2275000 E 2276000 E 2277000 E 2278000 E 2279000 E 2280000 E 2281000 E 2282000 E 2283000 E 2284000 E

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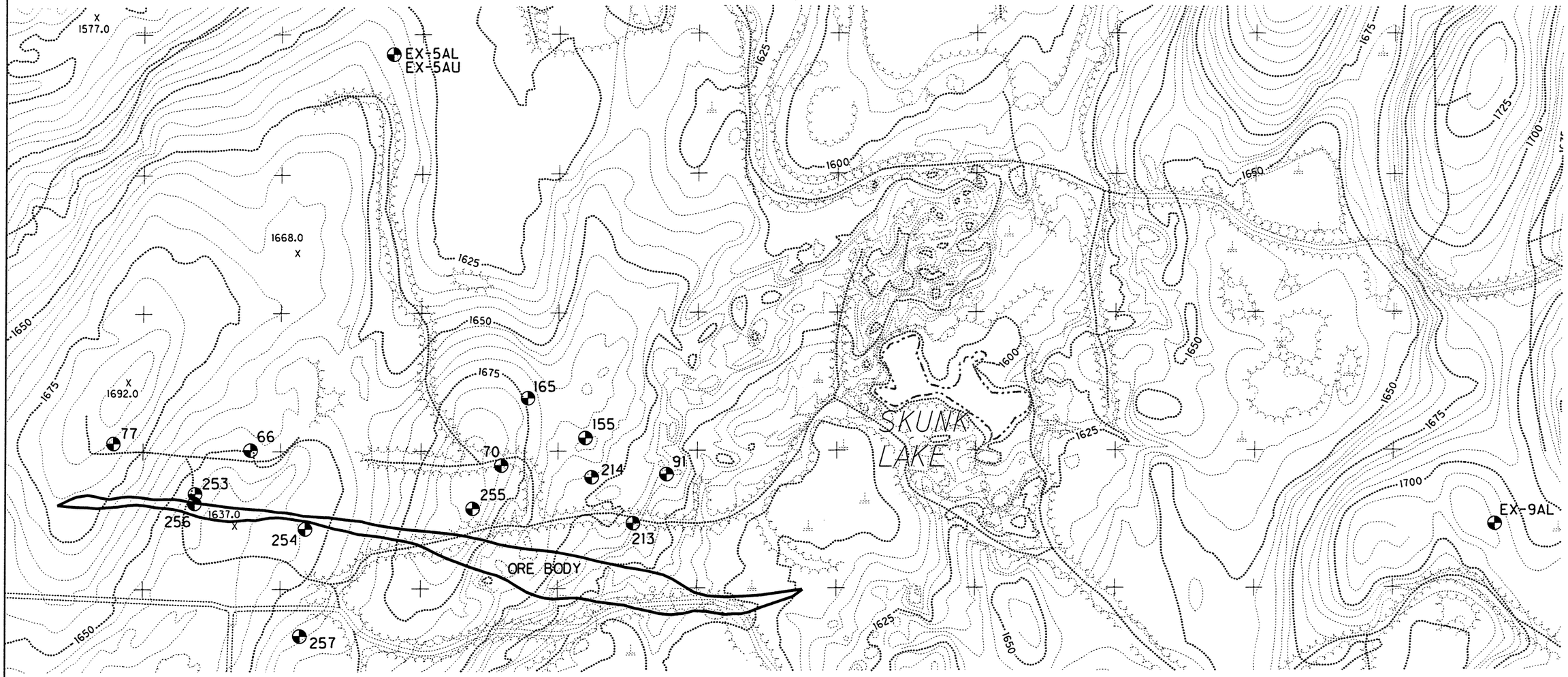
119000 N
118000 N
117000 N
116000 N



NOTES:

1. TOPOGRAPHIC BASE MAP DIGITIZED FROM 1" = 1000' SCALE, 5' CONTOUR INTERVAL MAP PREPARED BY AERO-METRIC ENGINEERING, INC., SHEBOYGAN, WISCONSIN. DATE OF PHOTOGRAPHY APRIL 28, 1976.
2. HORIZONTAL DATUM BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM - NORTH ZONE.
3. VERTICAL DATUM BASED ON MEAN SEA LEVEL DATUM. CONTOUR INTERVAL IS 5 FEET.
4. ORE BODY OUTLINE IS REPRESENTATIVE OF THE SUBCROP AT THE BASE OF THE OVERBURDEN.

LEGEND

- LAKES
- 1600 — EXISTING CONTOUR
- x 1677.0 — SPOT ELEVATION
- ORE BODY
- ROADWAY
- TRAIL
- MARSH
- 77 — EXPLORATION HOLE / BEDROCK PIEZOMETER USED FOR BEDROCK PERMEABILITY TEST, SYMBOL DENOTES COLLAR LOCATION AT SURFACE

N

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION
1	11/98	MLD2	REVISED FOR 1998 UPDATE

CHECKED BY:	JKSI	DATE: MAY '95
APPROVED BY:	SVDI	DATE: MAY '95
APPROVED BY:	GWS	DATE: MAY '95

Nicolet Minerals COMPANY

FIGURE 3.6-18

LOCATION OF BEDROCK PACKER AND SLUG TESTS

Scale: 0 375' 750' | Date: MAY, 1995

Prepared By: Foth & Van Dyke | By: GAM | 93C049

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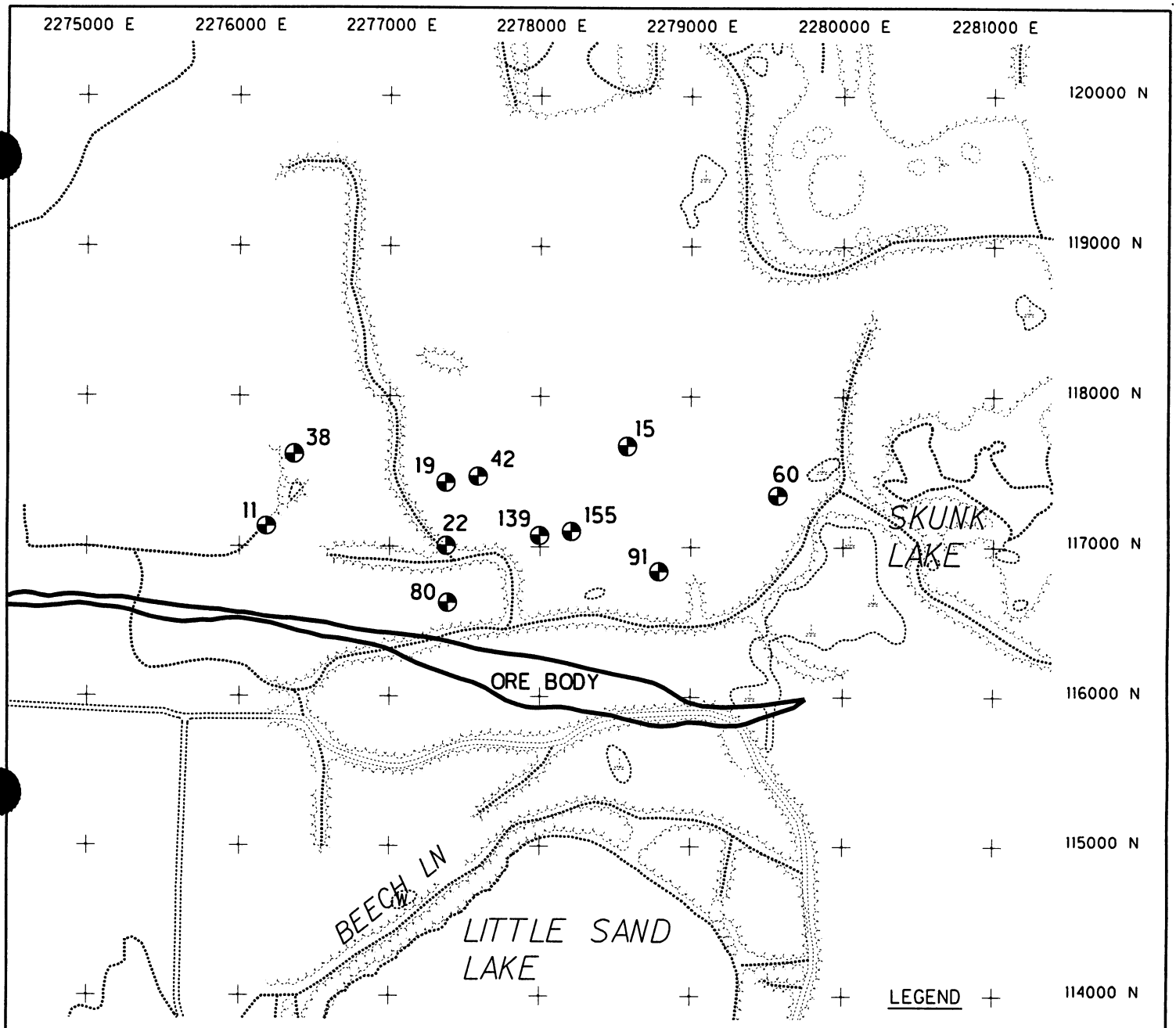

NOTES:

1. BASE MAP DIGITIZED FROM 1" = 1000' SCALE, MAP PREPARED BY AERO-METRIC ENGINEERING, INC., SHEBOYGAN, WISCONSIN. DATE OF PHOTOGRAPHY APRIL 28, 1976.
2. HORIZONTAL DATUM BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM - NORTH ZONE.
3. COUNTY AND TOWNSHIP LINES DIGITIZED FROM 7.5' SERIES USGS MAPS.
4. ORE BODY OUTLINE IS REPRESENTATIVE OF THE SUBCROP AT THE BASE OF THE OVERBURDEN.

N

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION
1	11/98	MLD2	REVISED FOR 1998 UPDATE

CHECKED BY:	JKSI	DATE: MAY '95
APPROVED BY:	SVDI	DATE: MAY '95
APPROVED BY:	GWS	DATE: MAY '95

Nicolet Minerals COMPANY

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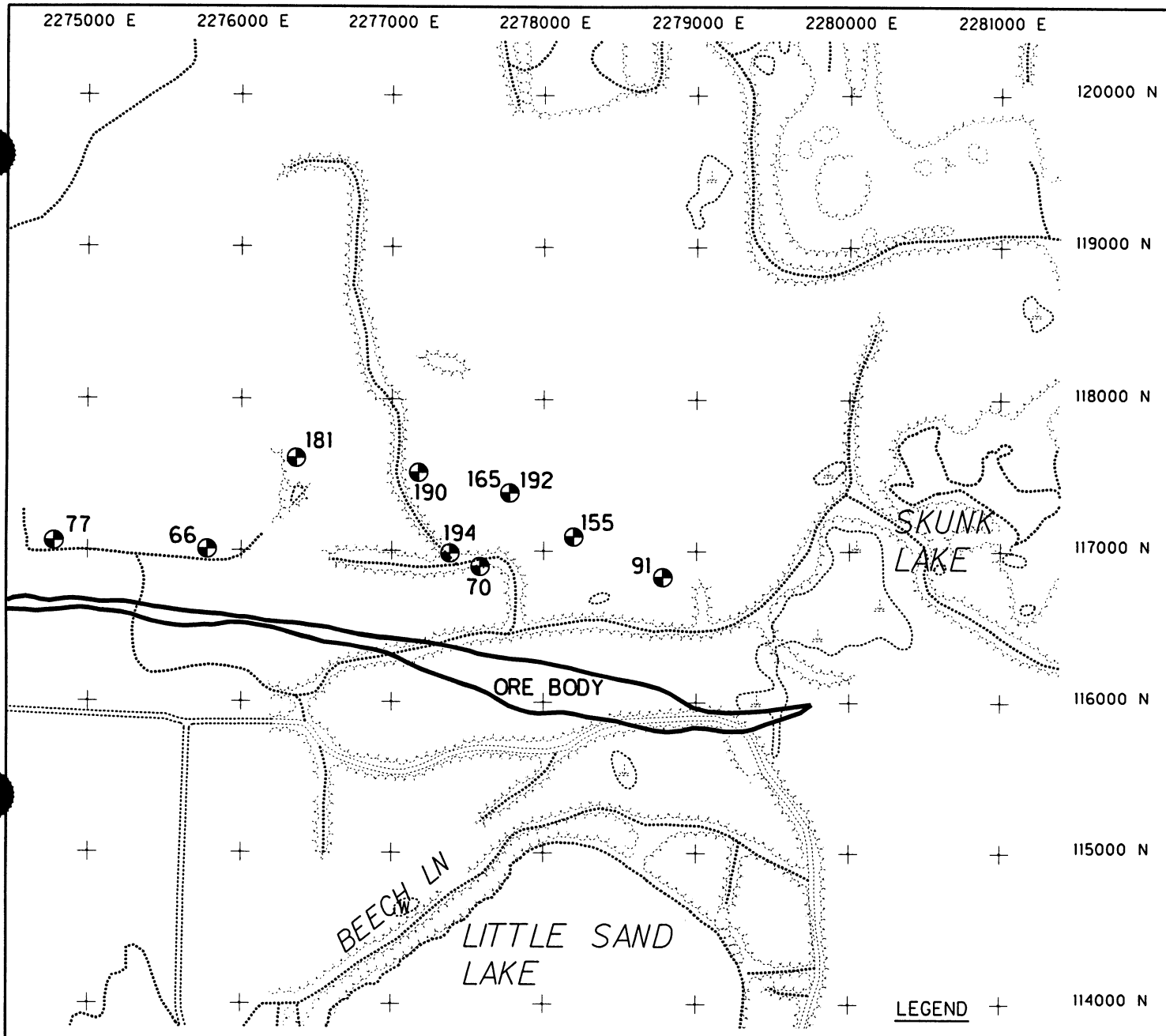
FIGURE 3.6-19

CORE HOLES USED ON DOWN HOLE TEMPERATURE SURVEYS

Scale: 1" = 1000'		Date: MAY, 1995	
Prepared By: Foth & Van Dyke	By: JRB2	93C049	

I:\93c049\94c033\4c33f139.dgn Dec. 17, 1998 12:23:56



NOTES:

1. BASE MAP DIGITIZED FROM 1" = 1000' SCALE, MAP PREPARED BY AERO-METRIC ENGINEERING, INC., SHEBOYGAN, WISCONSIN. DATE OF PHOTOGRAPHY APRIL 28, 1976.
2. HORIZONTAL DATUM BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM - NORTH ZONE.
3. ORE BODY OUTLINE IS REPRESENTATIVE OF THE SUBCROP AT THE BASE OF THE OVERBURDEN.

N

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION
1	11/98	MLD2	REVISED FOR 1998 UPDATE

CHECKED BY:	JKS1	DATE: MAY '95
APPROVED BY:	SVD1	DATE: MAY '95
APPROVED BY:	GWS	DATE: MAY '95

Nicolet Minerals COMPANY

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FIGURE 3.6-20

CORE HOLES USED FOR WATER CHEMISTRY ANALYSIS

Scale:	1" = 1000'	Date:	MAY, 1995
Prepared By: Foth & Van Dyke		By: GAM	93C049

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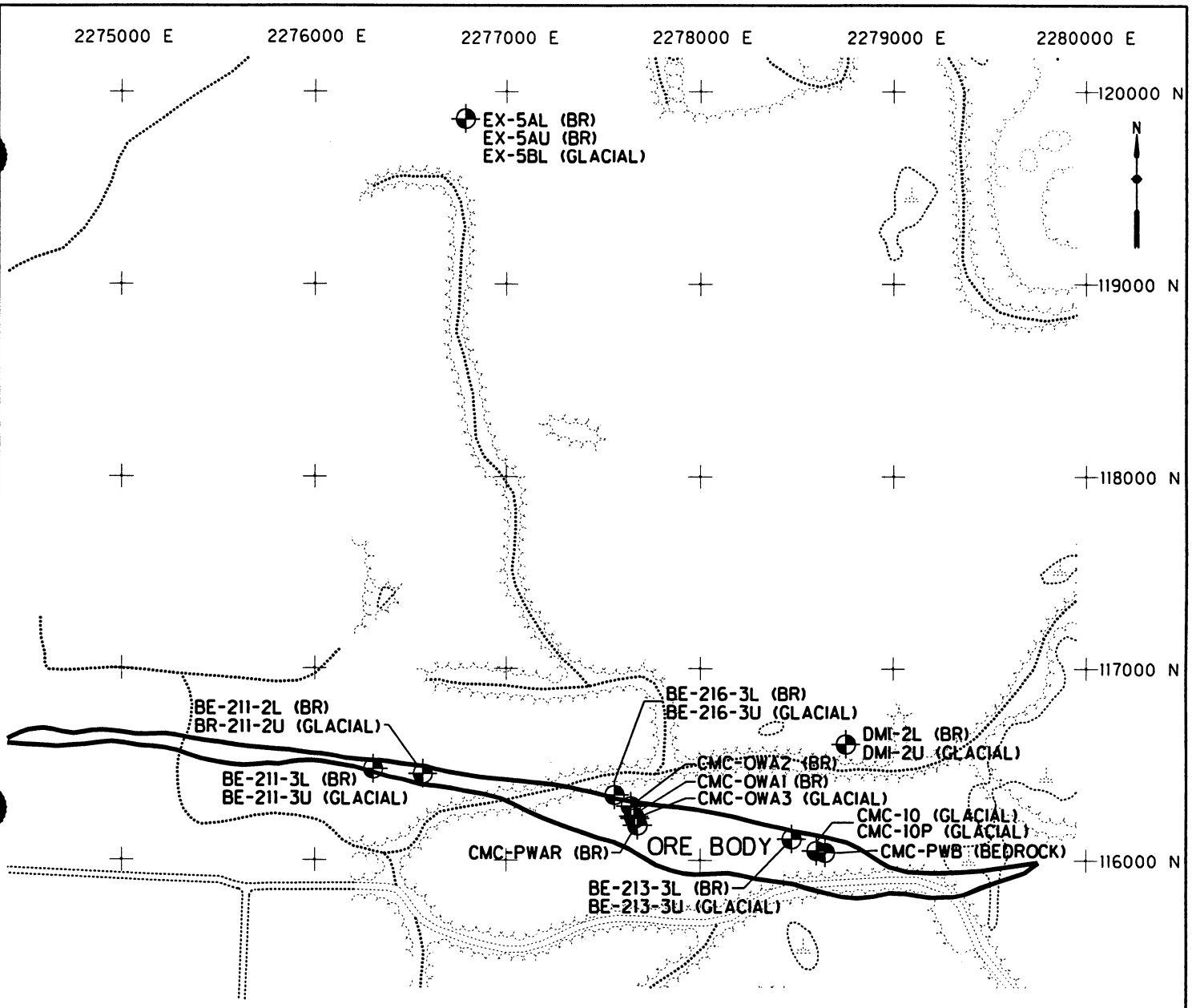

NOTES:

1. BASE MAP DIGITIZED FROM 1" = 1000' SCALE, MAP PREPARED BY AERO-METRIC ENGINEERING, INC., SHEBOYGAN, WISCONSIN. DATE OF PHOTOGRAPHY APRIL 28, 1976.
2. HORIZONTAL DATUM BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM - NORTH ZONE.
3. COUNTY AND TOWNSHIP LINES DIGITIZED FROM 7.5' SERIES USGS MAPS.
4. ORE BODY OUTLINE IS REPRESENTATIVE OF THE SUBCROP AT THE BASE OF THE OVERBURDEN.

LEGEND

- RIVER/LAKE/WATERWAY
- ROADWAY
- TRAIL
- MARSH BOUNDARY
- MARSH
- BE-213-3L (BR) / BE-213-3U (GLACIAL) — MONITORING WELL NUMBER, LOCATION AND COMPARISON

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION
1	11/98	MDL2	REVISED FOR 1998 UPDATE

CHECKED BY:	JKSI	DATE: MAY '95
APPROVED BY:	SVDI	DATE: MAY '95
APPROVED BY:	GWS	DATE: MAY '95

Nicolet Minerals COMPANY

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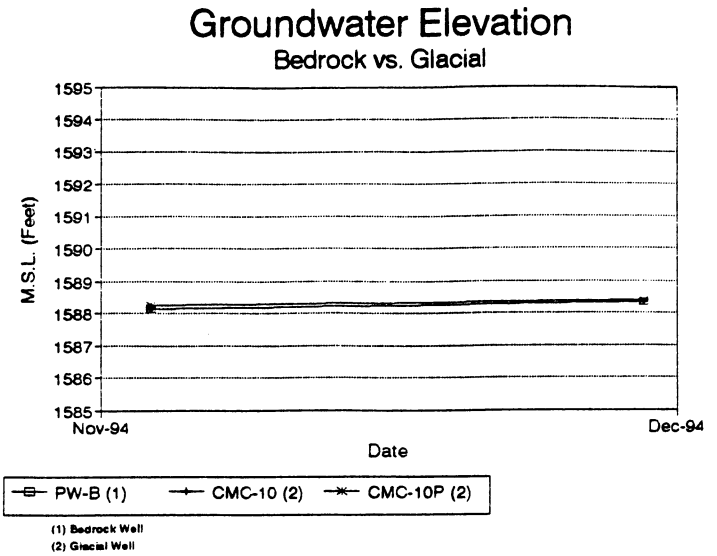
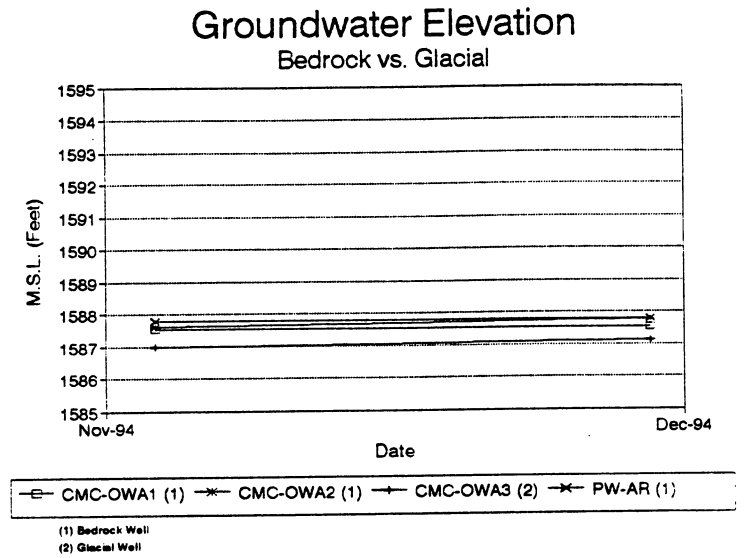
FIGURE 3.6-21

MONITORING WELL LOCATION FOR THE COMPARISON OF BEDROCK VS. GLACIAL HYDROGRAPHS

Scale:	1" = 800'	Date:	MAY, 1995
Prepared By: Foth & Van Dyke		By: GAM	93C049

I:\93c049\94c033\4c33f45.dgn Dec. 17, 1998 13:07:32





Foth & Van Dyke			
REVISED	DATE	BY	DESCRIPTION
1	11/98	MLD2	REVISED FOR 1998 UPDATE

CHECKED BY:	JKSI	DATE:	MAY'95
APPROVED BY:	SVDI	DATE:	MAY'95
APPROVED BY:	JWS	DATE:	MAY'95

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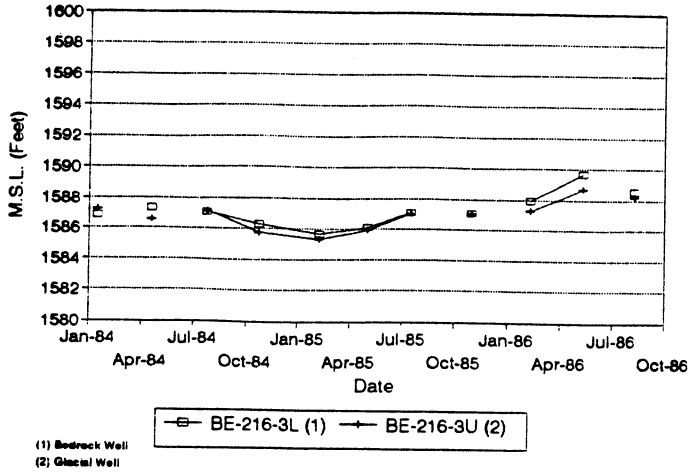
FIGURE 3.6-22

BEDROCK VS. GLACIAL HYDROGRAPHS

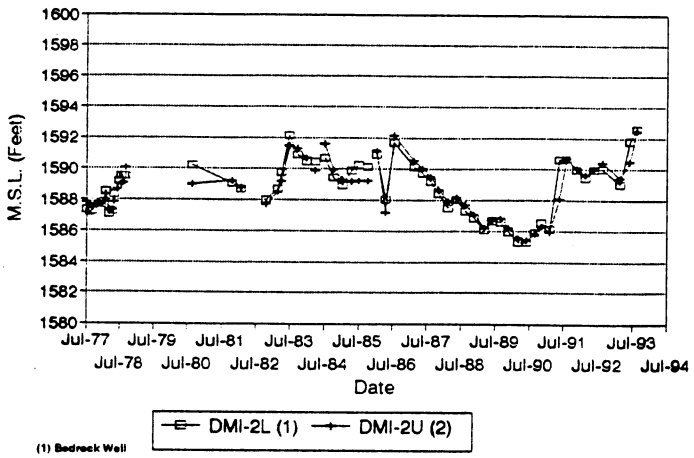
Scale:	AS SHOWN	Date:	MAY, 1995
Prepared By: Foth & Van Dyke		By: JOW	93C049

Groundwater Elevation
Bedrock vs. Glacial



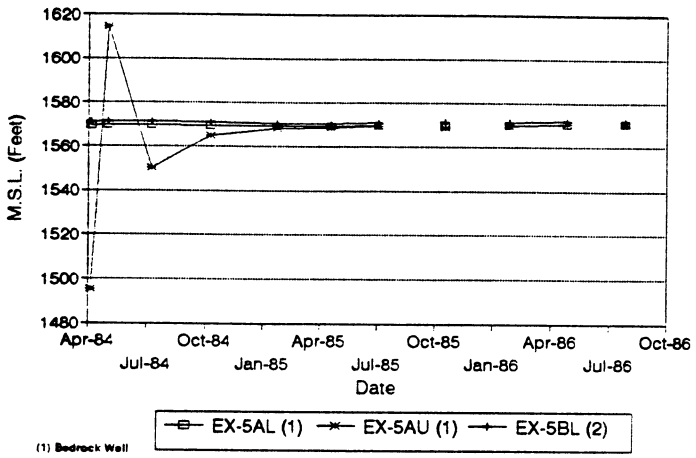
(1) Bedrock Well
(2) Glacial Well

Groundwater Elevation
Bedrock vs. Glacial



(1) Bedrock Well
(2) Glacial Well

Groundwater Elevation
Bedrock vs. Glacial



(1) Bedrock Well
(2) Glacial Well

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION
1	11/98	MLD2	REVISED FOR 1998 UPDATE

CHECKED BY:	JKSI	DATE:	MAY'95
APPROVED BY:	SVDI	DATE:	MAY'95
APPROVED BY:	JWS	DATE:	MAY'95

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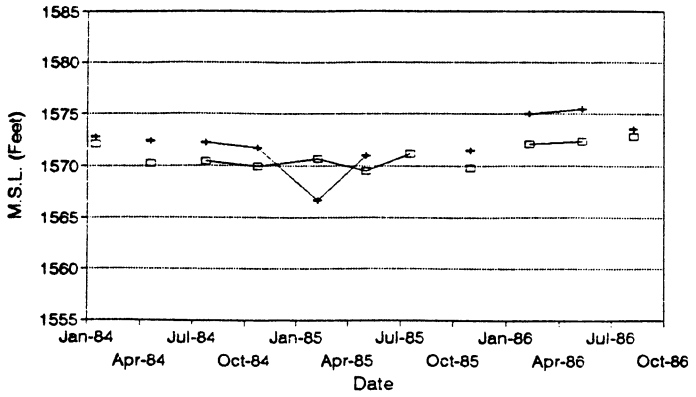
FIGURE 3.6-23

BEDROCK VS. GLACIAL HYDROGRAPHS

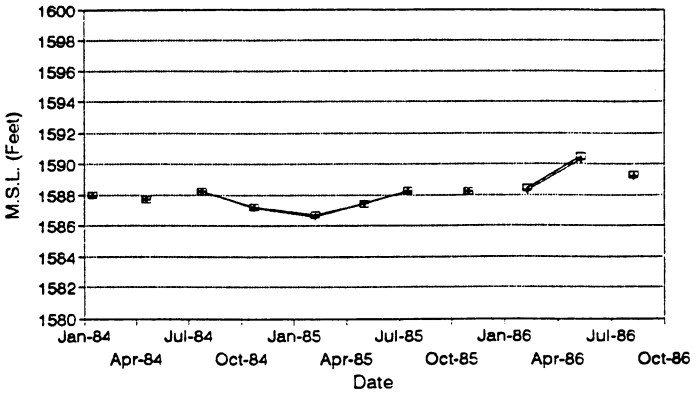
Scale:	AS SHOWN	Date:	MAY, 1995
Prepared By: Foth & Van Dyke		By: JOW	93C049

Groundwater Elevation
Bedrock vs. Glacial



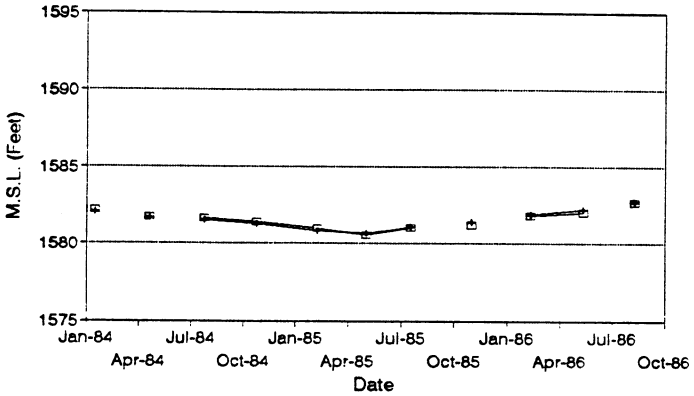
(1) Bedrock Well
(2) Glacial Well

Groundwater Elevation
Bedrock vs. Glacial



(1) Bedrock Well
(2) Glacial Well

Groundwater Elevation
Bedrock vs. Glacial



(1) Bedrock Well
(2) Glacial Well

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION
1	11/98	MLD2	REVISED FOR 1998 UPDATE

CHECKED BY:	JKS1	DATE: MAY'95
APPROVED BY:	SVD1	DATE: MAY'95
APPROVED BY:	JWS	DATE: FEB.'95

Nicolet Minerals COMPANY

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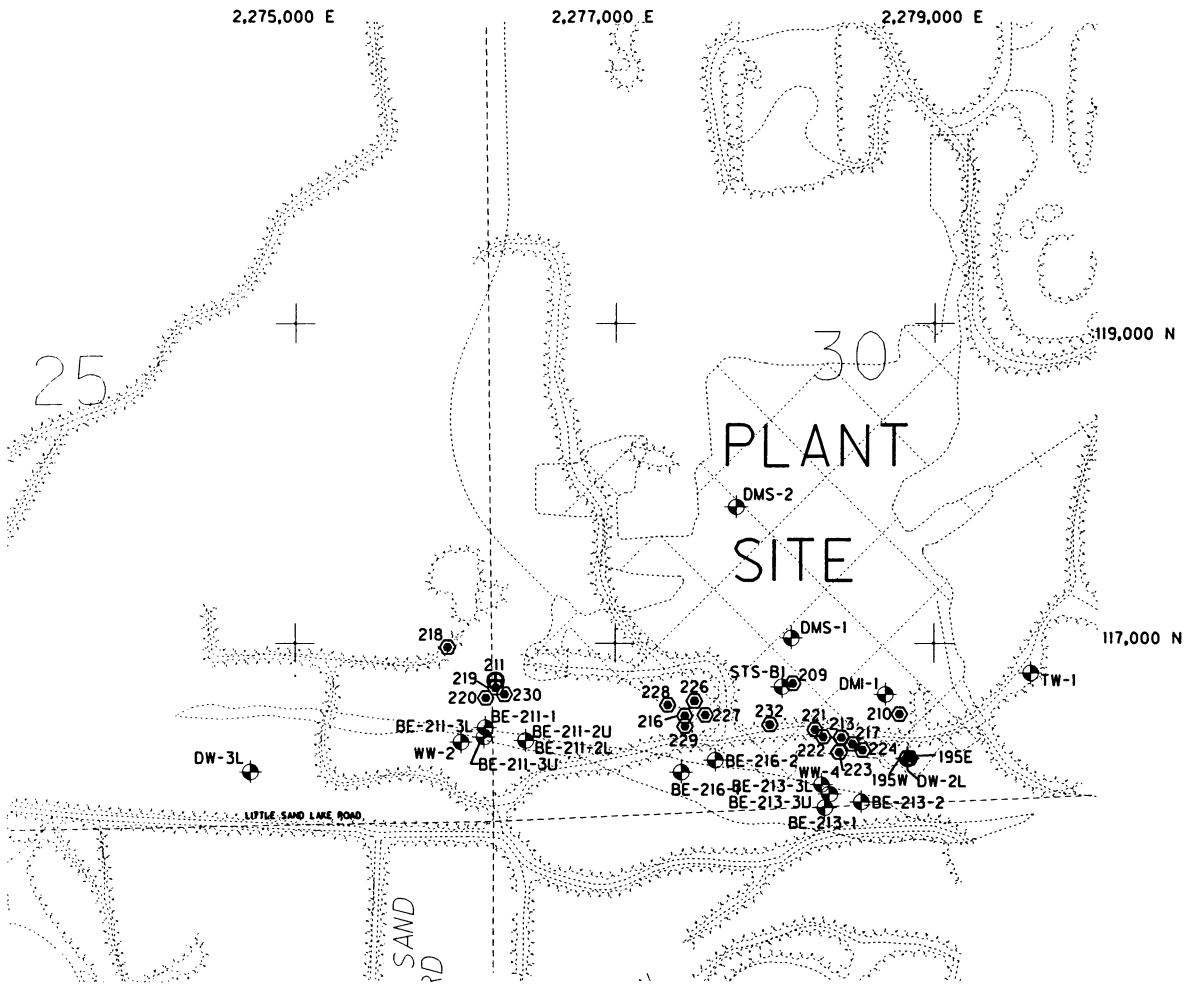
FIGURE 3.6-24

BEDROCK VS. GLACIAL HYDROGRAPHS

Scale: AS SHOWN		Date: MAY, 1995	
Prepared By: Foth & Van Dyke		By: JOW	93C049



LEGEND

- LAKES
- STREAMS
- SECTION LINE
- ORE BODY
- PROPOSED ACCESS ROAD
- PROPOSED HAUL ROAD AND PIPELINE ROUTE
- PROPOSED RAILROAD SPUR
- PROPOSED FACILITIES
- DMI-1 OBSERVATION WELL
- 209 ANGLED CORE HOLE OBSERVATION POINT COLLAR LOCATION
- 211 ANGLED CORE HOLE USED FOR PUMPED WELL COLLAR LOCATION

N

NOTES:

1. BASE MAP DIGITIZED FROM 1" = 1000' SCALE, MAP PREPARED BY AERO-METRIC ENGINEERING, INC., SHEBOYGAN, WISCONSIN. DATE OF PHOTOGRAPHY APRIL 28, 1976.
2. HORIZONTAL DATUM BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM - NORTH ZONE.
3. COUNTY AND TOWNSHIP LINES DIGITIZED FROM 7.5' SERIES USGS MAPS.
4. ORE BODY OUTLINE IS REPRESENTATIVE OF THE SUBCROP AT THE BASE OF THE OVERBURDEN.

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION
1	11/98	MLD2	REVISED FOR 1998 UPDATE

CHECKED BY:	JKSI	DATE: MAY '95
APPROVED BY:	SVDI	DATE: MAY '95
APPROVED BY:	GWS	DATE: MAY '95

Nicolet Minerals COMPANY

Mining for the Future • Commitment

FIGURE 3.6-25

211 PUMP TEST SETUP

Scale: 0 600' 1200' Date: MAY, 1995

Prepared By: Foth & Van Dyke By: KMP 93C049

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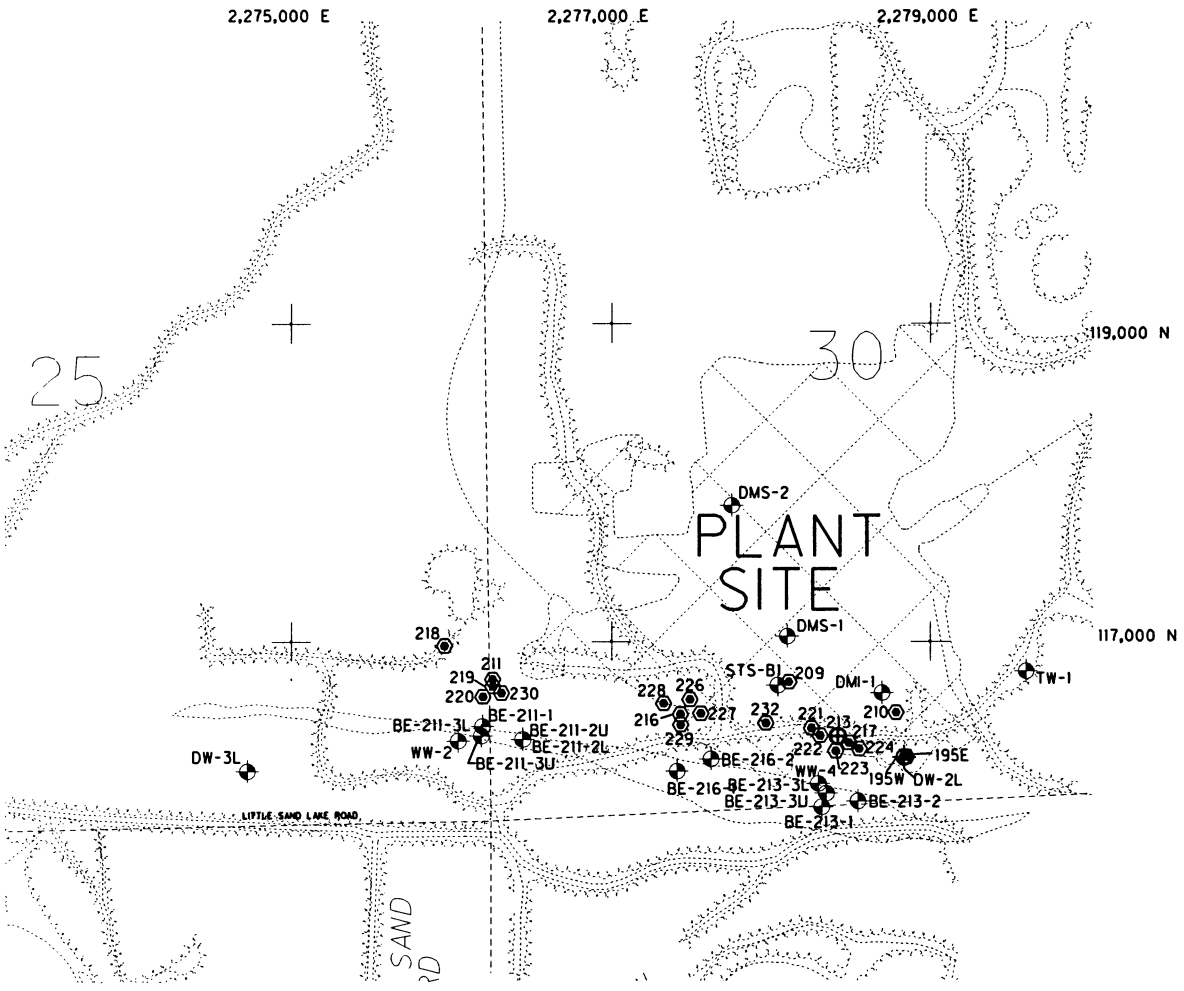

LEGEND

- LAKES
- STREAMS
- SECTION LINE
- ORE BODY
- PROPOSED ACCESS ROAD
- PROPOSED HAUL ROAD AND PIPELINE ROUTE
- PROPOSED RAILROAD SPUR
- PROPOSED FACILITIES
- DMI-1 OBSERVATION WELL
- 209 ANGLED CORE HOLE OBSERVATION POINT COLLAR LOCATION
- 213 ANGLED CORE HOLE USED FOR PUMPED WELL COLLAR LOCATION

N

NOTES:

1. BASE MAP DIGITIZED FROM 1'' = 1000' SCALE, MAP PREPARED BY AERO-METRIC ENGINEERING, INC., SHEBOYGAN, WISCONSIN. DATE OF PHOTOGRAPHY APRIL 28, 1976.
2. HORIZONTAL DATUM BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM - NORTH ZONE.
3. COUNTY AND TOWNSHIP LINES DIGITIZED FROM 7.5' SERIES USGS MAPS.
4. ORE BODY OUTLINE IS REPRESENTATIVE OF THE SUBCROP AT THE BASE OF THE OVERBURDEN.

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION
1	11/98	MLD2	REVISED FOR 1998 UPDATE

CHECKED BY:	JKS1	DATE: MAY '95
APPROVED BY:	SVD1	DATE: MAY '95
APPROVED BY:	GWS	DATE: MAY '95

Nicolet Minerals COMPANY

Mining for the Future • Commitment

FIGURE 3.2-26

213 PUMP TEST SETUP

Scale: 0 600' 1200' Date: MAY, 1995

Prepared By: Foth & Van Dyke By: KMP 93C049

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N

120,000 N

115,000 N

110,000 N

105,000 N

RICE LAKE APPROXIMATE LAKE ELEV. = 1532

MOLE LAKE APPROXIMATE LAKE ELEV. = 1552

OAK LAKE

LITTLE SAND LAKE LAKE ELEV. = 1592.13

DEEP HOLE LAKE LAKE ELEV. = 1605.74

DUCK LAKE LAKE ELEV. = 1611.94

SKUNK LAKE LAKE ELEV. = 1597.60

PLANT SITE

TMA

GROUND HEMLOCK LAKE LAKE ELEV. = 1578.67

KIMBERLY LAKE

CLARK LAKE

WALSH LAKE APPROXIMATE LAKE ELEV. = 1601

ST. JOHNS LAKE APPROXIMATE LAKE ELEV. = 1590

ROLLING STONE LAKE LAKE ELEV. = 1535.07

LEGEND

- TREES/BRUSH
- UNPAVED ROAD/TRAIL
- PAVED ROAD
- WETLAND
- EXISTING SPOT ELEVATION
- EXISTING CONTOUR
- CREEKS/RIVERS/LAKES
- ORE BODY
- PROPOSED ACCESS ROAD
- PROPOSED RAILROAD SPUR
- PROPOSED FACILITIES
- EX-14BU 1592.41 — MONITORING WELL LOCATION, NUMBER AND WATER TABLE ELEVATION
- SG-WP-1 1553.51 — CREEK STAFF GAGE AND WATER LEVEL ELEVATION
- —1580— GROUNDWATER CONTOUR (CONTOUR INTERVAL = 10 FEET)
- —1580— INFERRED GROUNDWATER CONTOUR (CONTOUR INTERVAL = 10 FEET)

NOTES:

1. TOPOGRAPHIC BASE MAP DIGITIZED FROM 1" = 1000' SCALE, 5' CONTOUR INTERVAL MAP PREPARED BY AERO-METRIC ENGINEERING, INC., SHEBOYGAN, WISCONSIN. DATE OF PHOTOGRAPHY APRIL 28, 1976.
2. HORIZONTAL DATUM BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM - NORTH ZONE.
3. VERTICAL DATUM BASED ON MEAN SEA LEVEL DATUM. CONTOUR INTERVAL IS 25 FEET.
4. COUNTY AND TOWNSHIP LINES DIGITIZED FROM 7.5' SERIES USGS MAPS.
5. ORE BODY OUTLINE IS REPRESENTATIVE OF THE SUBCROP AT THE BASE OF THE OVERBURDEN.

0 1400' 2800'
BAR SCALE

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION
1	12-23-96	SVDI	REMOVED SAND POINT DATA. ADDED CREEK STAFF GAUGE DATA. ADDED WELL DMB-20A. DELETED WELL DMB-20. REPLACED 1591 FT. CONTOUR WITH 1592 FT. CONTOUR. REVISED TMA LIMITS OF DISTURBANCE.
2	11/98	MLD2	REVISED FOR 1998 UPDATE

CHECKED BY:	JKSI	DATE:	MAY '95
APPROVED BY:	SVDI	DATE:	MAY '95
APPROVED BY:	GWS	DATE:	MAY '95

Nicolet Minerals COMPANY

Mining for the Future • Commitment

FIGURE 3.6-27

WATER TABLE CONTOUR MAP OCTOBER, 1984

Scale:	AS SHOWN	Date:	MAY, 1995
Prepared By: Foth & Van Dyke		By: JRB2	93C049

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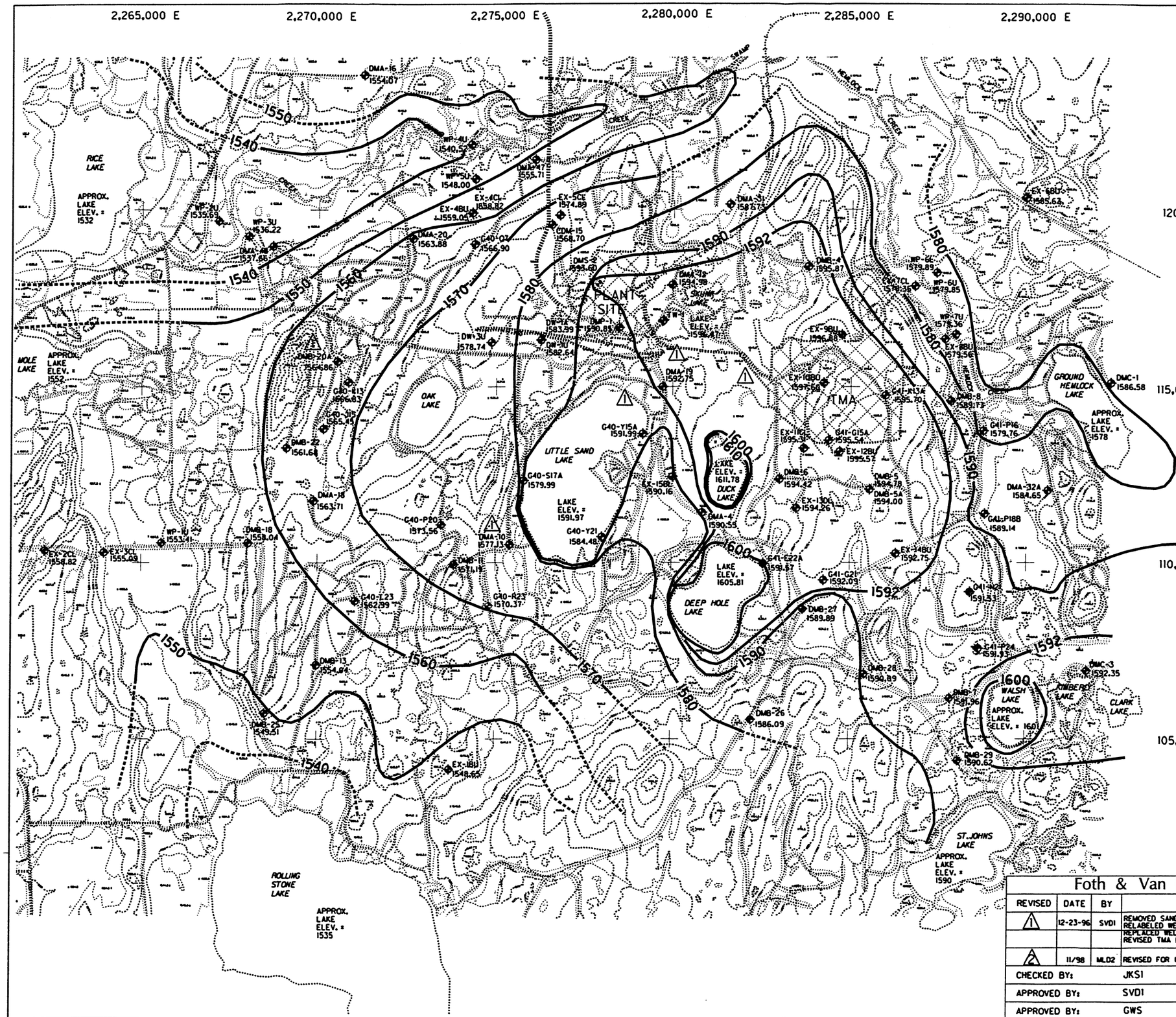

LEGEND

- TREES/BRUSH
- UNPAVED ROAD/TRAIL
- PAVED ROAD
- WETLAND
- EXISTING SPOT ELEVATION
- EXISTING CONTOUR
- CREEKS/RIVERS/LAKES
- ORE BODY
- PROPOSED ACCESS ROAD
- PROPOSED RAILROAD SPUR
- PROPOSED FACILITIES
- EX-7CL 1578.35 — MONITORING WELL LOCATION, NUMBER AND WATER TABLE ELEVATION
- —1580— GROUNDWATER CONTOUR (CONTOUR INTERVAL = 10 FEET)
- ----1580--- INFERRED GROUNDWATER CONTOUR (CONTOUR INTERVAL = 10 FEET)

N

NOTES:

1. TOPOGRAPHIC BASE MAP DIGITIZED FROM 1" = 1000' SCALE, 5' CONTOUR INTERVAL MAP PREPARED BY AERO-METRIC ENGINEERING, INC., SHEBOYGAN, WISCONSIN. DATE OF PHOTOGRAPHY APRIL 28, 1976.
2. HORIZONTAL DATUM BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM - NORTH ZONE.
3. VERTICAL DATUM BASED ON MEAN SEA LEVEL DATUM. CONTOUR INTERVAL IS 25 FEET.
4. COUNTY AND TOWNSHIP LINES DIGITIZED FROM 7.5' SERIES USGS MAPS.
5. ORE BODY OUTLINE IS REPRESENTATIVE OF THE SUBCROP AT THE BASE OF THE OVERBURDEN.

0 1400' 2800'
BAR SCALE

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION
1	12-23-96	SVDI	REMOVED SAND POINT DATA. RELABELED WELL DMB-10 TO DMA-10. REPLACED WELL DMB-20 WITH DMB-20A. REVISED TMA LIMITS OF DISTURBANCE.
2	11/98	MLD2	REVISED FOR 1998 UPDATE

CHECKED BY:	JKSI	DATE:	MAY '95
APPROVED BY:	SVDI	DATE:	MAY '95
APPROVED BY:	GWS	DATE:	MAY '95

Nicolet Minerals COMPANY

Mining for the Future Commitment

FIGURE 3.6-28

HIGH WATER TABLE CONTOUR MAP
AUGUST, 1986

Scale: AS SHOWN		Date:	MAY, 1995
Prepared By: Foth & Van Dyke	By: JRB2		93C049

I:\93c049\94c033\4c33f37a.dgn Nov. 12, 1998 15:57:00

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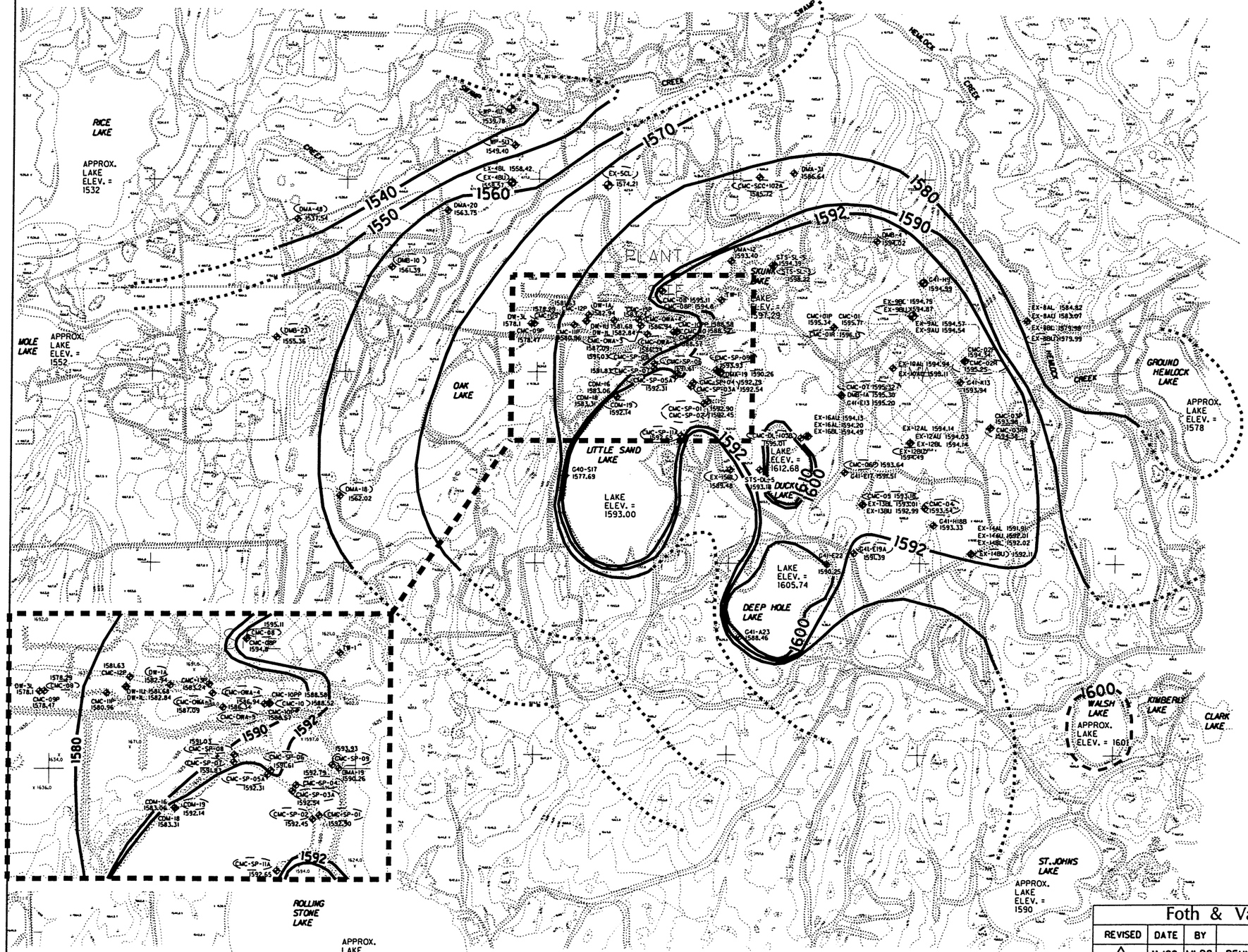
120,000 N

115,000 N

110,000 N

105,000 N



LEGEND

- TREES/BRUSH
- UNPAVED ROAD/TRAIL
- PAVED ROAD
- WETLAND
- 1542.0 — EXISTING SPOT ELEVATION
- 1600 — EXISTING CONTOUR
- CREEKS/RIVERS/LAKES
- ORE BODY
- PROPOSED ACCESS ROAD
- PROPOSED RAILROAD SPUR
- PROPOSED FACILITIES
- EX-10AL 1589.94 — MONITORING WELL LOCATION, NUMBER AND GROUND WATER ELEVATION
- —1590— GROUNDWATER CONTOUR (CONTOUR INTERVAL = 10 FEET
- ···1550··· INFERRED GROUNDWATER CONTOUR
- CMC-02R — WELL USED FOR WATER TABLE CONTOUR

N

NOTES:

1. TOPOGRAPHIC BASE MAP DIGITIZED FROM 1" = 1000' SCALE, 5' CONTOUR INTERVAL MAP PREPARED BY AERO-METRIC ENGINEERING, INC., SHEBOYGAN, WISCONSIN. DATE OF PHOTOGRAPHY APRIL 28, 1976.
2. HORIZONTAL DATUM BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM - NORTH ZONE.
3. VERTICAL DATUM BASED ON MEAN SEA LEVEL DATUM. CONTOUR INTERVAL IS 25 FEET.
4. COUNTY AND TOWNSHIP LINES DIGITIZED FROM 7.5' SERIES USGS MAPS.
5. ORE BODY OUTLINE IS REPRESENTATIVE OF THE SUBCROP AT THE BASE OF THE OVERBURDEN.
6. GROUNDWATER ELEVATIONS MEASURED JUNE 12, 1995.

0 1400' 2800'
BAR SCALE

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION
1	11/98	MLD2	REVISED FOR 1998 UPDATE

CHECKED BY:	JKS	DATE: DEC. '96
APPROVED BY:	SVDI	DATE: DEC. '96
APPROVED BY:	GWS	DATE: DEC. '96

Nicolet Minerals COMPANY

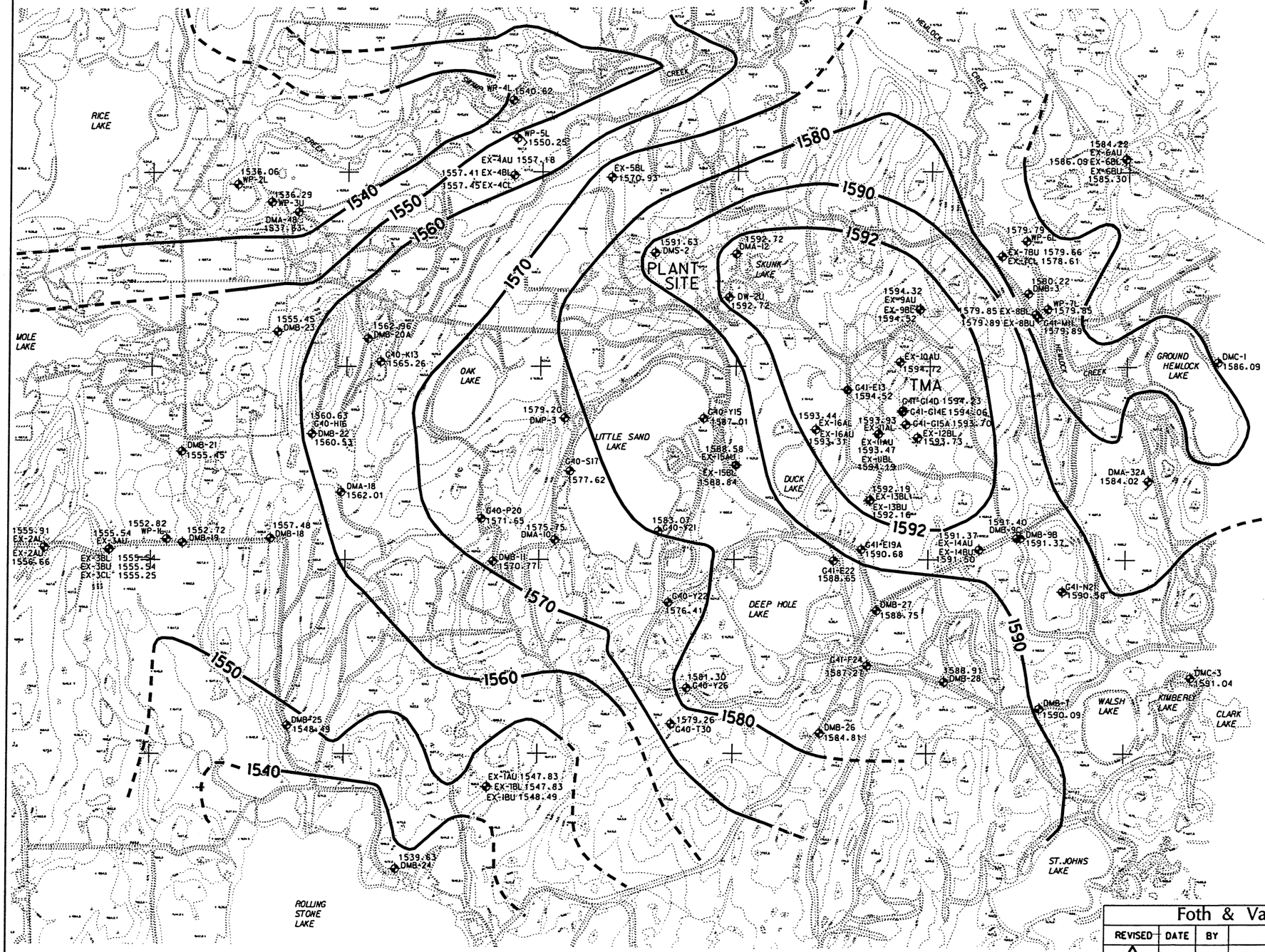
Mining for the Future • Commitment

FIGURE 3.6-28A

WATER TABLE CONTOUR MAP
JUNE, 1995

Scale: AS SHOWN	Date: DECEMBER, 1996	
Prepared By: Foth & Van Dyke	By: JRB2	93C049

I:\93c049\94c033\4c33f59.dgn Dec. 17, 1998 16:39:52



LEGEND

- TREES/BRUSH
- UNPAVED ROAD/TRAIL
- PAVED ROAD
- WETLAND
- 1542.0 EXISTING SPOT ELEVATION
- 1600 EXISTING CONTOUR
- CREEKS/RIVERS/LAKES
- ORE BODY
- PROPOSED ACCESS ROAD
- PROPOSED RAILROAD SPUR
- PROPOSED FACILITIES
- EX-7CL 1578.61 — MONITORING WELL LOCATION, NUMBER AND PIEZOMETRIC HEAD
- —1590— GROUNDWATER EQUIPOTENTIAL LINE (CONTOUR INTERVAL = 10 FEET)
- ···1550··· INFERRED GROUNDWATER EQUIPOTENTIAL LINE

N

NOTES:

1. TOPOGRAPHIC BASE MAP DIGITIZED FROM 1" = 1000' SCALE, 5' CONTOUR INTERVAL MAP PREPARED BY AERO-METRIC ENGINEERING, INC., SHEBOYGAN, WISCONSIN. DATE OF PHOTOGRAPHY APRIL 28, 1976.
2. HORIZONTAL DATUM BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM - NORTH ZONE.
3. VERTICAL DATUM BASED ON MEAN SEA LEVEL DATUM. CONTOUR INTERVAL IS 25 FEET.
4. COUNTY AND TOWNSHIP LINES DIGITIZED FROM 7.5' SERIES USGS MAPS.
5. ORE BODY OUTLINE IS REPRESENTATIVE OF THE SUBCROP AT THE BASE OF THE OVERBURDEN.

0 1400' 2800'
BAR SCALE

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION
1	11/98	MLD2	REVISED FOR 1998 UPDATE

CHECKED BY:	JKSI	DATE:	DEC. '96
APPROVED BY:	SVDI	DATE:	DEC. '96
APPROVED BY:	GWS	DATE:	DEC. '96

Nicolet Minerals COMPANY

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FIGURE 3.6-28B

POTENTIOMETRIC SURFACE OF GLACIAL OUTWASH, OCTOBER 31, 1984

Scale:	AS SHOWN	Date:	DECEMBER, 1996
Prepared By: Foth & Van Dyke		By: JRB2	93C049

I:\93c049\94c033\4c33f60.dgn Dec. 17, 1998 14:20:42

2,265,000 E | 2,270,000 E | 2,275,000 E | 2,280,000 E | 2,285,000 E | 2,290,000 E

120,000 N | 115,000 N | 110,000 N | 105,000 N

RICE LAKE
MOLE LAKE
OAK LAKE
LITTLE SAND LAKE
DUCK LAKE
DEEP HOLE LAKE
ROLLING STONE LAKE
SKUNK LAKE
GROUND HEMLOCK LAKE
WALSH LAKE
KIMBERLY LAKE
CLARK LAKE
ST. JOHNS LAKE
SWAMP CREEK
HEMLOCK CREEK

PLANT SITE
TMA

1540 1550 1560 1570 1580 1590 1592

EX-4AL 1557.68
EX-6AL 1584.22
EX-7AL 1582.32
EX-7BL 1581.27
EX-8AL 1584.68
EX-8AU 1582.97
DMS-1 1594.78
TW-1 1592.29
BE-21I-2U 1583.97
BE-21I-3U 1581.30
BE-21G-3U 1585.73
DW-2U 1589.93
1577.49
DW-3L
DW-3U 1577.39
DW-1L 1582.32
DW-1U 1581.00
G40-M15 1569.95
G41-K13 1593.37
G41-G14B 1593.90
G41-G14F 1593.73
G41-G15 1593.90
EX-12AU 1593.73
G41-C15 1593.18
G41-G17 1592.28
EX-13AL 1592.16
EX-15AL 1587.80
EX-3AL 1555.54
G40-D24 1553.58
G40-H27 1549.41
EX-1AL 1548.13

LEGEND

- TREES/BRUSH
- UNPAVED ROAD/TRAIL
- PAVED ROAD
- WETLAND
- EXISTING SPOT ELEVATION
- EXISTING CONTOUR
- CREEKS/RIVERS/LAKES
- ORE BODY
- PROPOSED ACCESS ROAD
- PROPOSED RAILROAD SPUR
- PROPOSED FACILITIES
- EX-7AL 1582.32 — MONITORING WELL LOCATION, NUMBER AND WATER TABLE ELEVATION
- —1590— GROUNDWATER EQUIPOTENTIAL LINE (CONTOUR INTERVAL = 10 FEET)
- ···1550··· INFERRED GROUNDWATER EQUIPOTENTIAL LINE

N

NOTES:

1. TOPOGRAPHIC BASE MAP DIGITIZED FROM 1" = 1000' SCALE, 5' CONTOUR INTERVAL MAP PREPARED BY AERO-METRIC ENGINEERING, INC., SHEBOYGAN, WISCONSIN DATE OF PHOTOGRAPHY APRIL 28, 1976.
2. HORIZONTAL DATUM BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM - NORTH ZONE.
3. VERTICAL DATUM BASED ON MEAN SEA LEVEL DATUM. CONTOUR INTERVAL IS 25 FEET.
4. COUNTY AND TOWNSHIP LINES DIGITIZED FROM 7.5' SERIES USGS MAPS.
5. ORE BODY OUTLINE IS REPRESENTATIVE OF THE SUBCROP AT THE BASE OF THE OVERBURDEN.

0 1400' 2800'
BAR SCALE

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION
1	11/98	MLD2	REVISED FOR 1998 UPDATE

CHECKED BY:	JKS1	DATE:	DEC. '96
APPROVED BY:	SVD1	DATE:	DEC. '96
APPROVED BY:	GWS	DATE:	DEC. '96

Nicolet Minerals COMPANY

Mining for the future Commitment

FIGURE 3.6-28C

POTENTIOMETRIC SURFACE OF PRE-TO EARLY WISCONSINAN TILL OCTOBER 31, 1984

Scale: AS SHOWN		Date: DECEMBER, 1996	
Prepared By: Foth & Van Dyke	By: JRB2	93C049	

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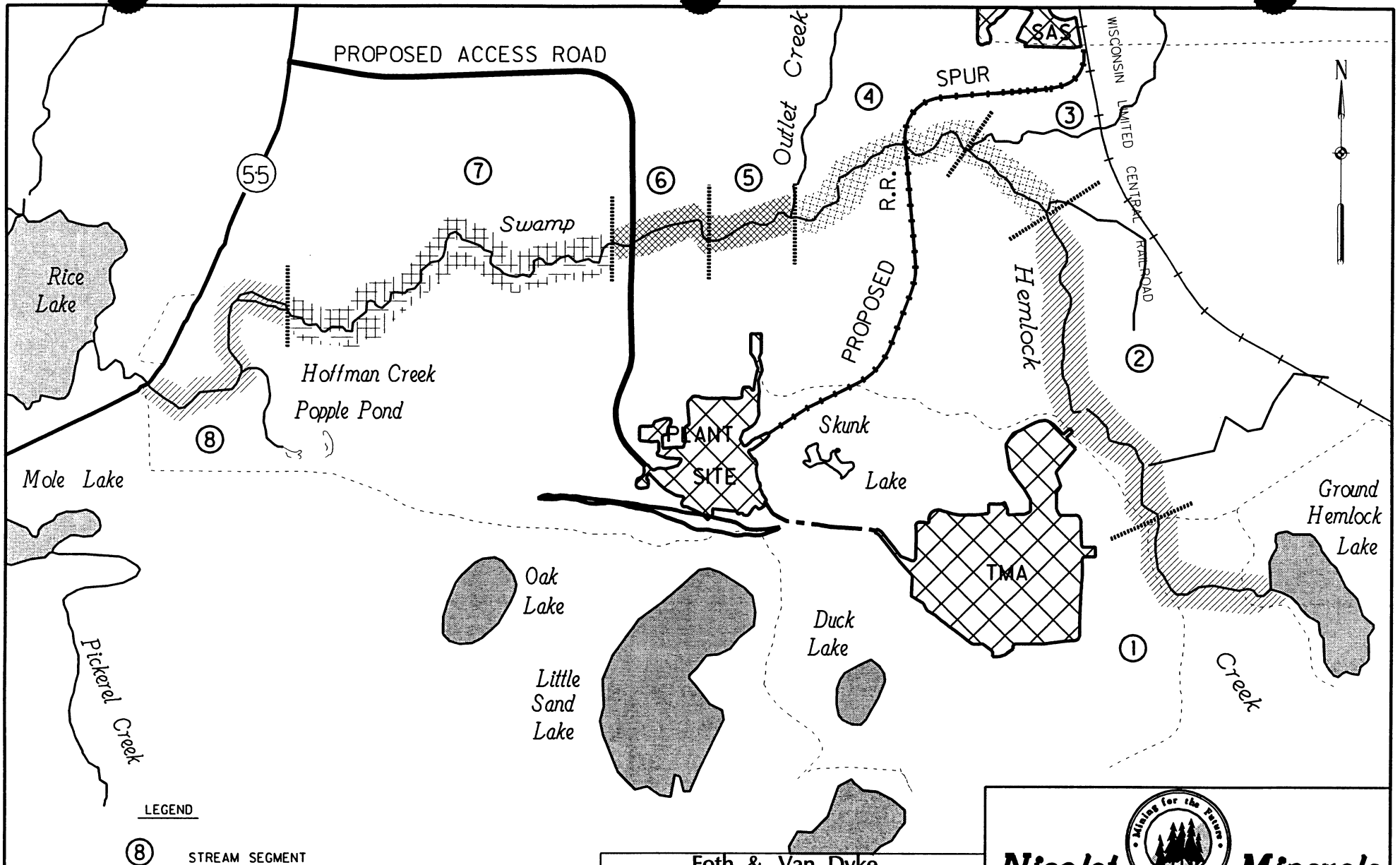

Foth & Van Dyke			
REVISED	DATE	BY	DESCRIPTION
1	12/98	MLD2	REVISED FOR 1998 UPDATE

CHECKED BY:	JKSI	DATE:	MAY '95
APPROVED BY:	RFS	DATE:	MAY '95
APPROVED BY:	GWS	DATE:	MAY '95

Nicolet Minerals COMPANY

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FIGURE 3.6-29

OBSERVED BOTTOM CHARACTERISTICS OF HEMLOCK AND SWAMP CREEKS

Scale:	1" = 3000'	Date:	MAY, 1995
Prepared By: Foth & Van Dyke		By: JOW	93C049

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2,265,000 E 2,270,000 E 2,275,000 E 2,280,000 E 2,285,000 E 2,290,000 E

120,000 N

115,000 N

110,000 N

105,000 N

RICE LAKE
MOLE LAKE
OAK LAKE
LITTLE SAND LAKE
DUCK LAKE
DEEP HOLE LAKE
ROLLING STONE LAKE
SKUNK LAKE
GROUND HEMLOCK LAKE
WALSH LAKE
KIMBERLY LAKE
CLARK LAKE
ST. JOHNS LAKE
PLANT SITE
TMA
CREEK
SWAMP
HEMLOCK CREEK

DMB-20
1580.88 (10/84)

DMA-IN
1620.37 (10/83)

CMC-BO-101A 1628.69 (1/95)

G41-G12
1661.29 (10/84)

CMC-DL-103A
1607.54 (1/95)

G41-C15C
1607.87 (10/84)

G41-H18A
1679.20 (1/84)

G41-M24
1622.44 (9/80)

LEGEND

- TREES/BRUSH
- UNPAVED ROAD/TRAIL
- PAVED ROAD
- WETLAND
- EXISTING SPOT ELEVATION
- EXISTING CONTOUR
- CREEKS/RIVERS/LAKES
- ORE BODY
- PROPOSED ACCESS ROAD
- PROPOSED RAILROAD SPUR
- PROPOSED FACILITIES
- G41-G12 1661.29 (10/84) — PERCHED MONITORING WELL LOCATION GROUNDWATER ELEVATION, (MONTH/YEAR OF MEASUREMENT)

N

NOTES:

1. TOPOGRAPHIC BASE MAP DIGITIZED FROM 1'' = 1000' SCALE, 5' CONTOUR INTERVAL MAP PREPARED BY AERO-METRIC ENGINEERING, INC., SHEBOYGAN, WISCONSIN. DATE OF PHOTOGRAPHY APRIL 28, 1976.
2. HORIZONTAL DATUM BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM - NORTH ZONE.
3. VERTICAL DATUM BASED ON MEAN SEA LEVEL DATUM. CONTOUR INTERVAL IS 25 FEET.
4. COUNTY AND TOWNSHIP LINES DIGITIZED FROM 7.5' SERIES USGS MAPS.
5. ORE BODY OUTLINE IS REPRESENTATIVE OF THE SUBCROP AT THE BASE OF THE OVERBURDEN.

0 1400' 2800'

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION
1	01/97	GWS	REVISED TMA LIMITS OF DISTURBANCE
2	11/98	MLD2	REVISED FOR 1998 UPDATE

CHECKED BY:	JKSI	DATE:	AUG. '95
APPROVED BY:	SVDI	DATE:	AUG. '95
APPROVED BY:	GWS	DATE:	AUG. '95

Nicolet Minerals COMPANY

FIGURE 3.6-29A

LOCATION OF PERCHED GROUNDWATER

Scale: AS SHOWN		Date:	AUGUST, 1995
Prepared By: Foth & Van Dyke	By: JRB2		93C049

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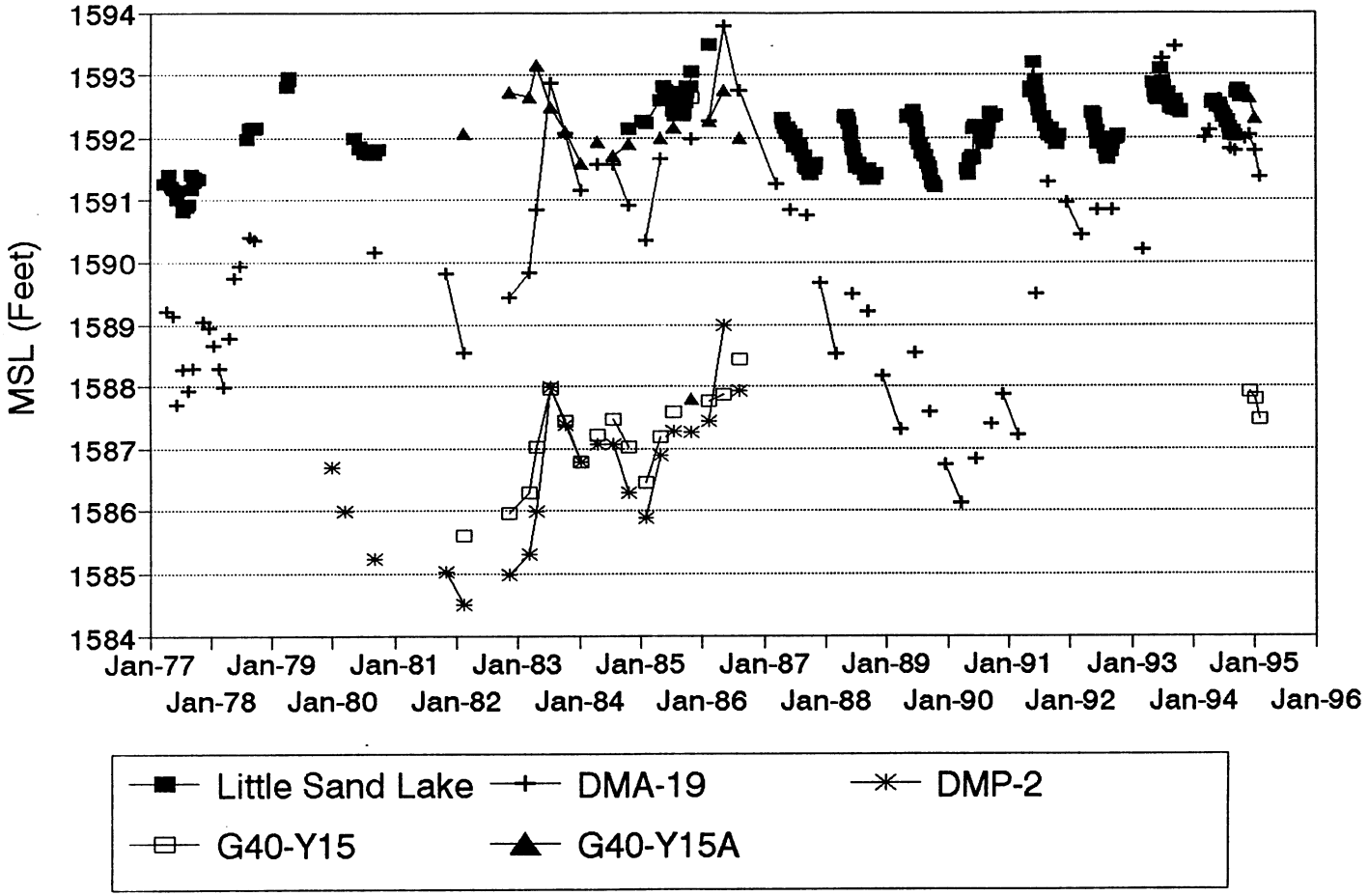
Crandon Project

Surface Water and Groundwater Elevation



Foth & Van Dyke			
REVISED	DATE	BY	DESCRIPTION
1	11/98	MLD2	REVISED FOR 1998 UPDATE

CHECKED BY:	JKSI	DATE: MAY'95
APPROVED BY:	SVDI	DATE: MAY'95
APPROVED BY:	GWS	DATE: MAY'95

Nicolet Minerals COMPANY

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FIGURE 3.6-30

LAKE STAGE OF LITTLE SAND LAKE VS. UPGRADIENT WELLS

Scale:	NTS	Date:	MAY, 1995
Prepared By: Foth & Van Dyke		By: KMP	93C049

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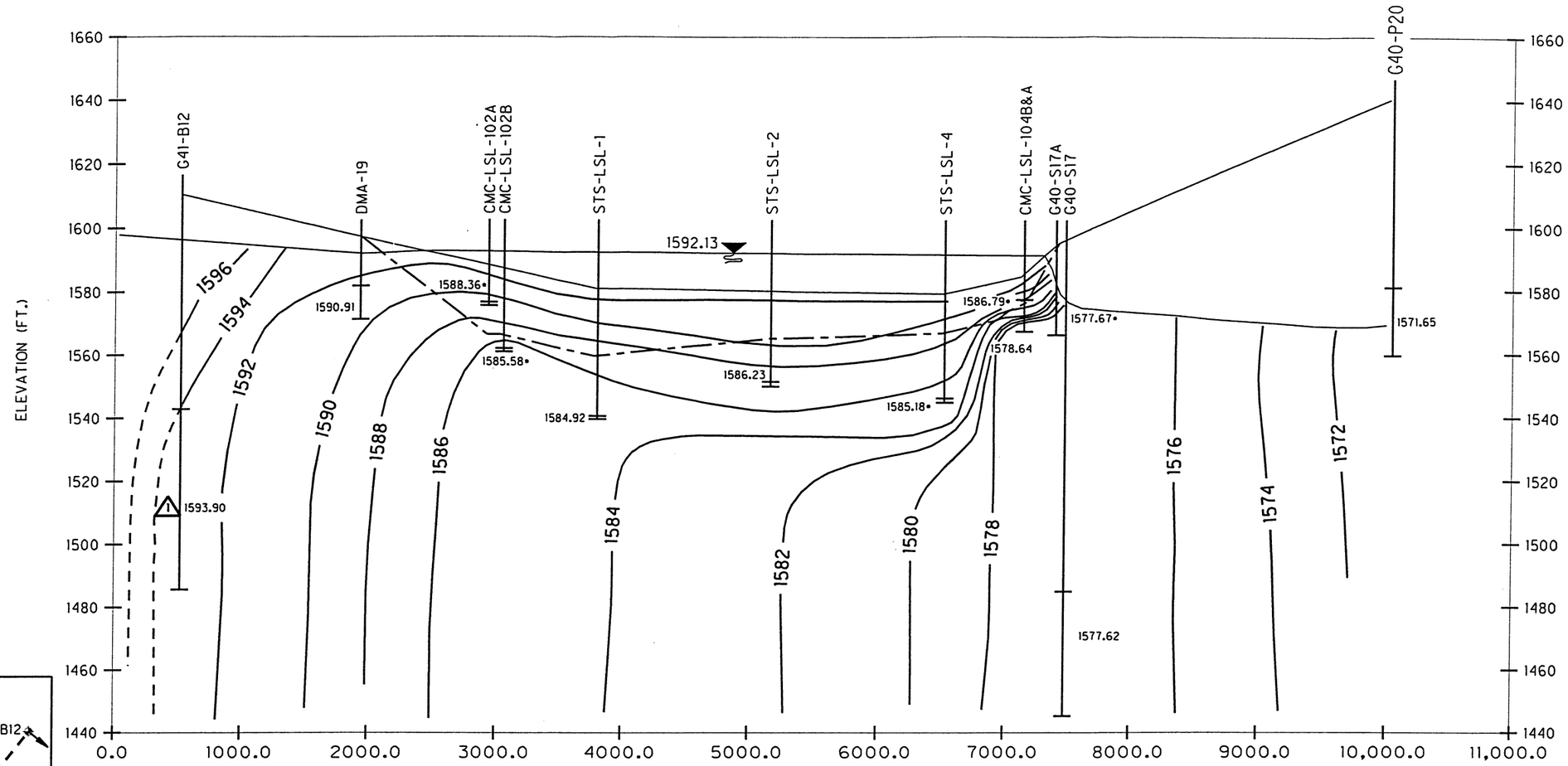
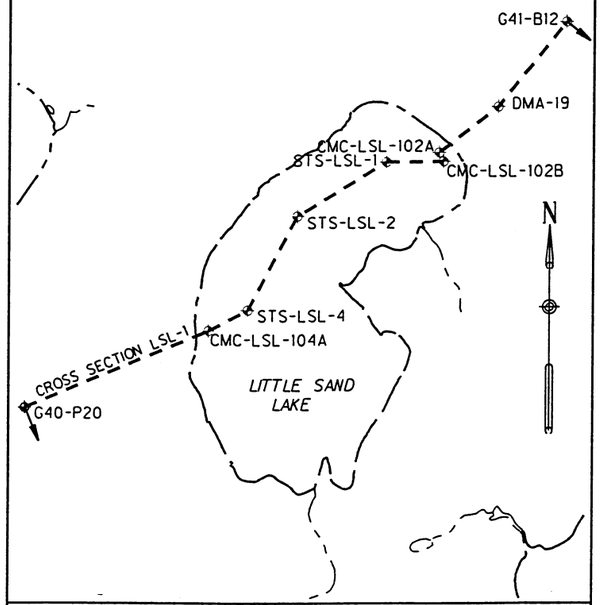


NOTE: • = ADJUSTED WATER LEVEL (SEE FOTH & VAN DYKE DECEMBER, 1994)

CROSS SECTION LSL-1

SCALE: HORIZ. 1''=1000'
VERT. 1''=40'



CROSS SECTION LOCATION MAP

SCALE: 1''=1000'

SOURCE: FOTH & VAN DYKE, DECEMBER 1994

Foth & Van Dyke			
REVISED	DATE	BY	DESCRIPTION
1	9-22-95	SVDI	CORRECTED G41-B12
2	11/98	MLD2	REVISED FOR 1998 UPDATE
CHECKED BY:	JKSI	DATE: MAY '95	
APPROVED BY:	SVDI	DATE: MAY '95	
APPROVED BY:	GWS	DATE: MAY '95	

Nicolet Minerals COMPANY

FIGURE 3.6-31
SECTION LSL-1
LITTLE SAND LAKE HYDRAULIC CROSS SECTION
MEASURED 10/30/84

Scale: AS SHOWN		Date: MAY, 1995	
Prepared By: Foth & Van Dyke	By: KMP	93C049	

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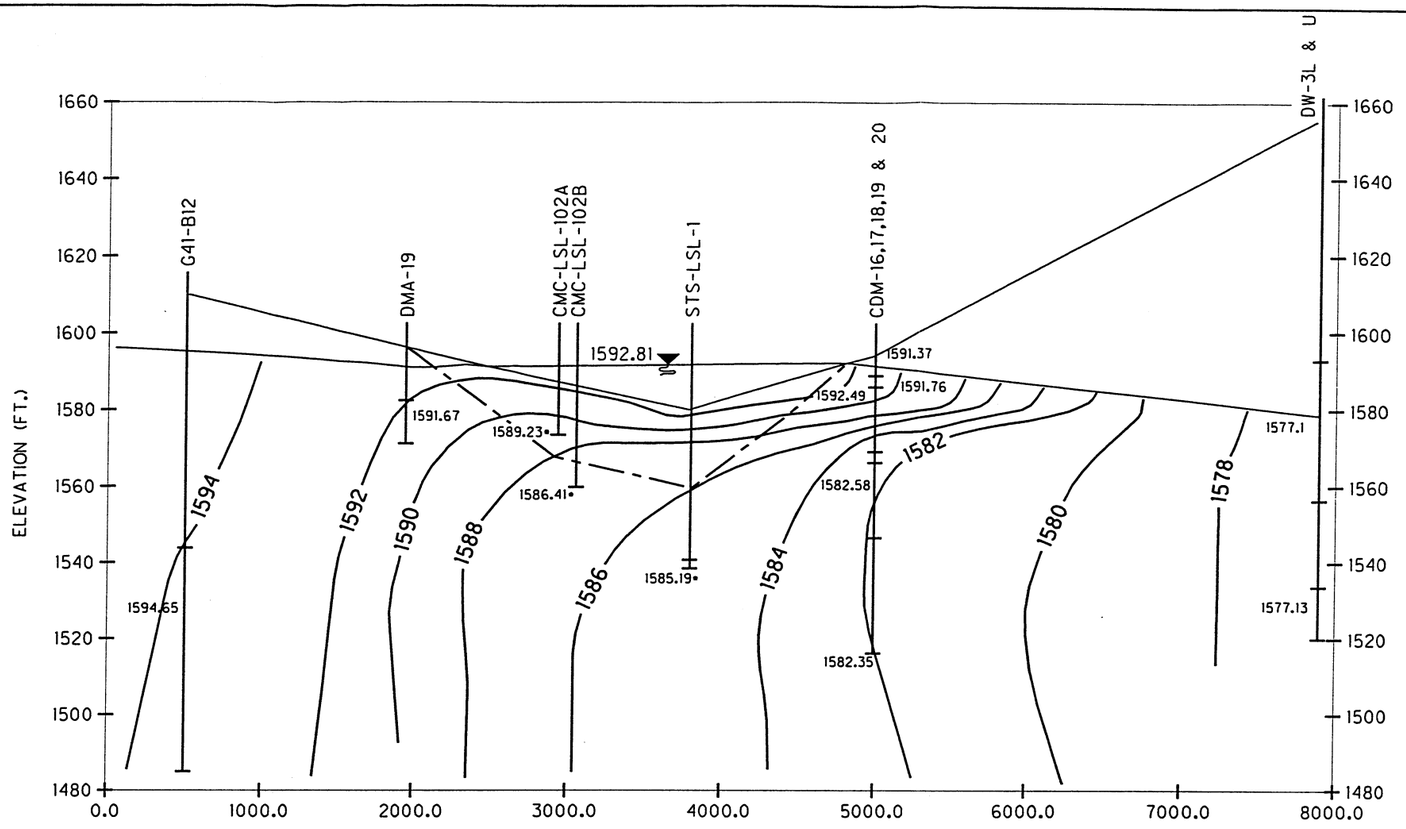
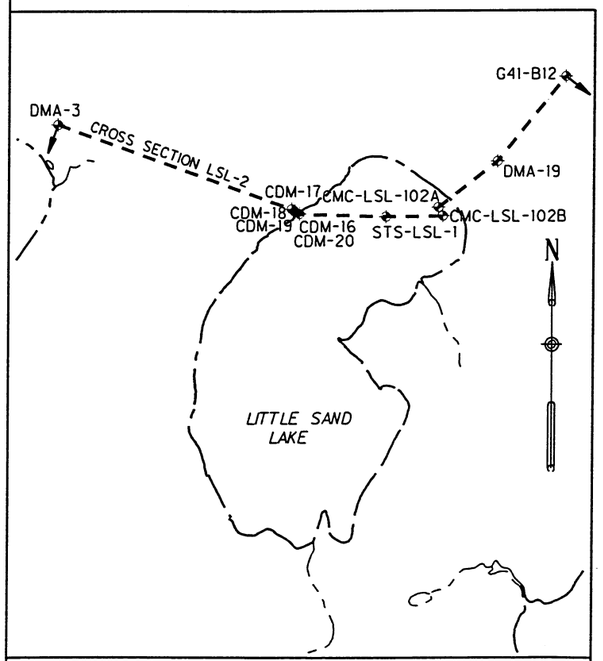


NOTE: • = ADJUSTED WATER LEVEL
(SEE FOTH & VAN DYKE DECEMBER, 1994)

CROSS SECTION LSL- 2

SCALE: HORIZ. 1''=1000'
VERT. 1''=40'



CROSS SECTION LOCATION MAP

SCALE: 1''=1000'

SOURCE: FOTH & VAN DYKE, DECEMBER 1994

Foth & Van Dyke				
REVISED	DATE	BY	DESCRIPTION	
1	11/98	MLD2	REVISED FOR 1998 UPDATE	
CHECKED BY:		JKSI		DATE: MAY '95
APPROVED BY:		SVDI		DATE: MAY '95
APPROVED BY:		GWS		DATE: MAY '95

Nicolet Minerals COMPANY

FIGURE 3.6-32
SECTION LSL-2
LITTLE SAND LAKE HYDRAULIC CROSS SECTION
MEASURED 5/9/85

Scale: AS SHOWN	Date: MAY, 1995
Prepared By: Foth & Van Dyke	By: KMP 93C049

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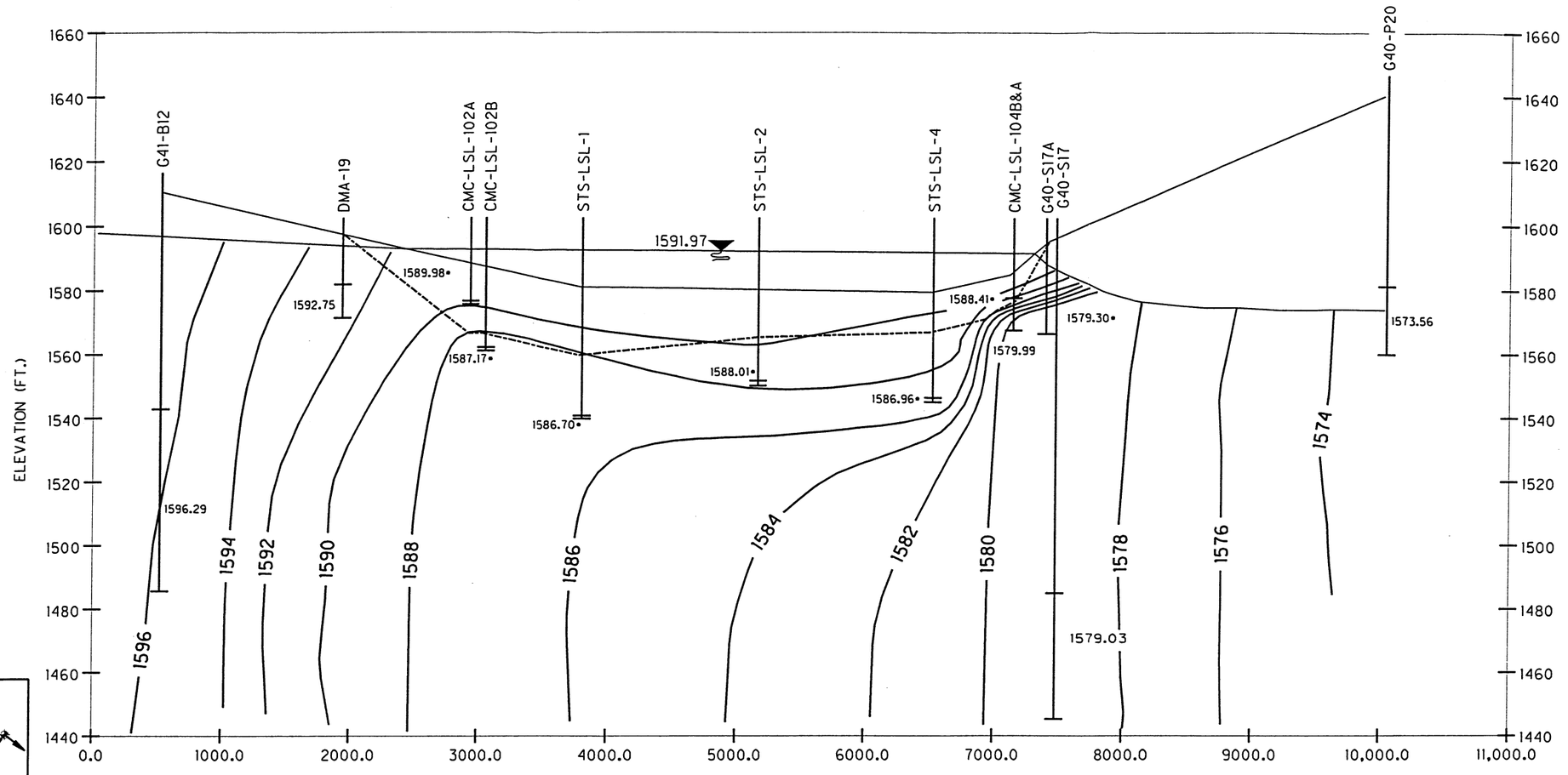
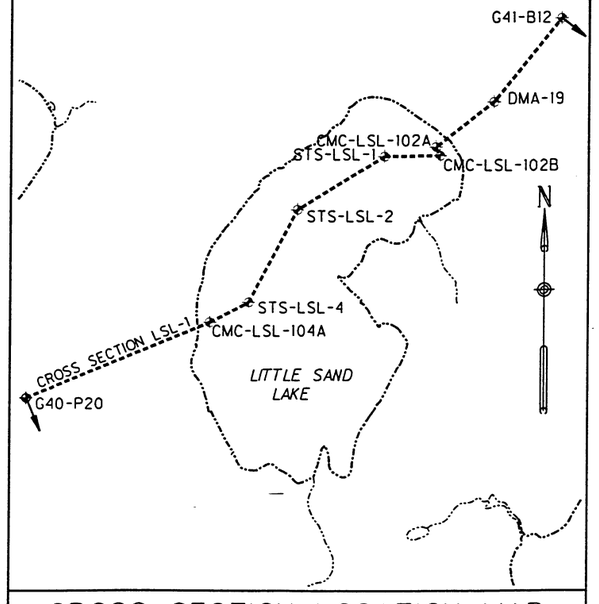


NOTE: • = ADJUSTED WATER LEVEL (SEE FOTH & VAN DYKE DECEMBER, 1994)

CROSS SECTION LSL-1

SCALE: HORIZ. 1"=1000'
VERT. 1"=40'



CROSS SECTION LOCATION MAP

SCALE: 1"=1000'

SOURCE: FOTH & VAN DYKE, DECEMBER 1994

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION
1	11/98	MLD2	REVISED FOR 1998 UPDATE

CHECKED BY:	JKS1	DATE: MAY '95
APPROVED BY:	SVD1	DATE: MAY '95
APPROVED BY:	GWS	DATE: MAY '95

Nicolet Minerals COMPANY

FIGURE 3.6-33
SECTION LSL-1
LITTLE SAND LAKE HYDRAULIC CROSS SECTION
HIGH GW LEVELS - 8/11/86

Scale:	AS SHOWN	Date:	MAY, 1995
Prepared By: Foth & Van Dyke	By: KMP	93C049	

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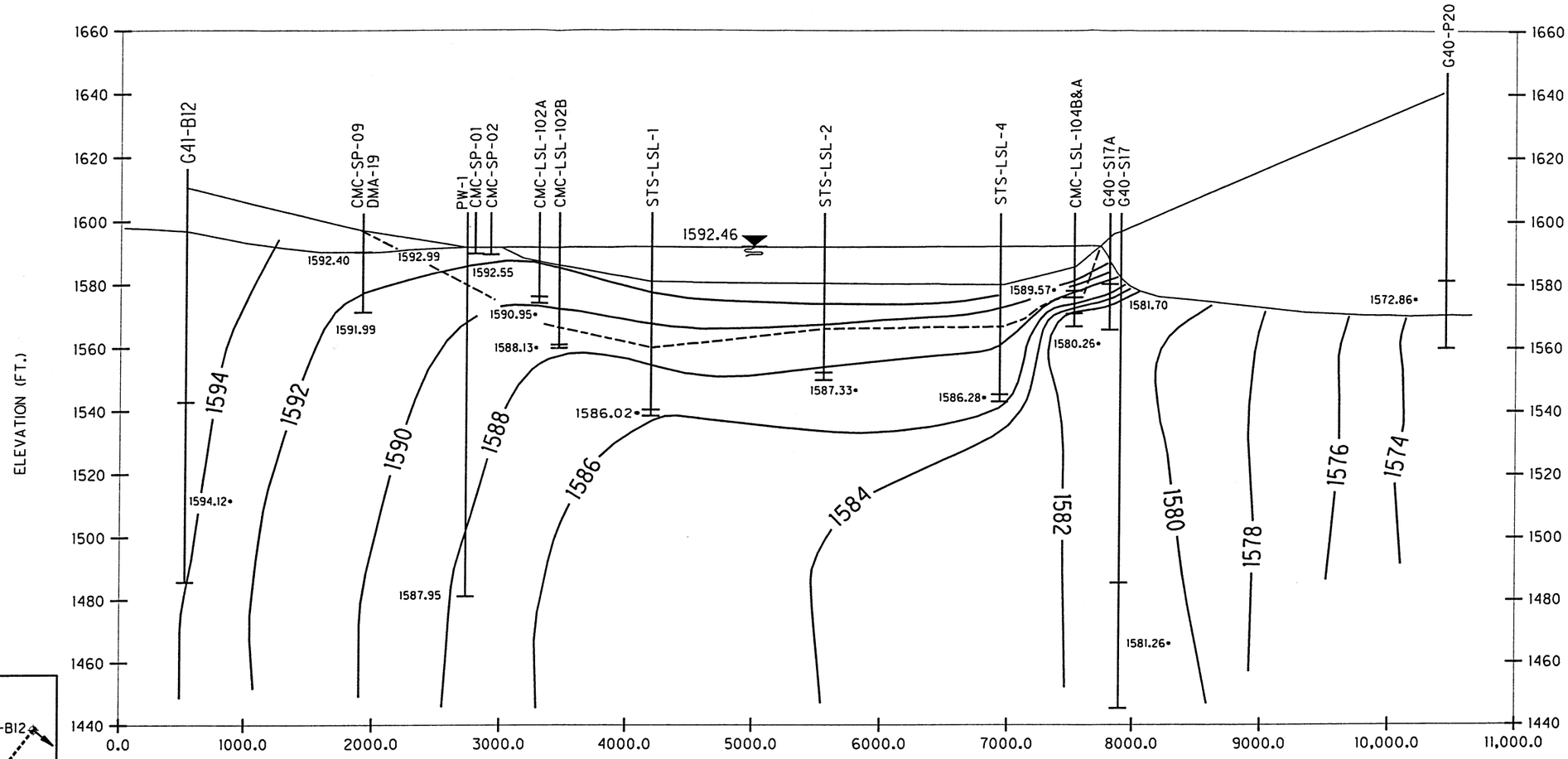
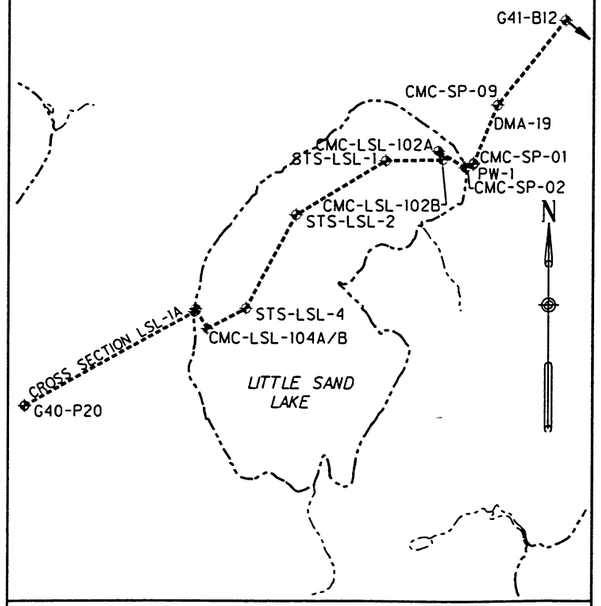


NOTE: • = ADJUSTED WATER LEVEL (SEE FOTH & VAN DYKE DECEMBER, 1994)

CROSS SECTION LSL-1A

SCALE: HORIZ. 1"=1000'
VERT. 1"=40'



CROSS SECTION LOCATION MAP

SCALE: 1"=1000'

SOURCE: FOTH & VAN DYKE, DECEMBER 1994

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION
1	11/98	MLD2	REVISED FOR 1998 UPDATE

CHECKED BY:	JKSI	DATE: MAY '95
APPROVED BY:	SVDI	DATE: MAY '95
APPROVED BY:	GWS	DATE: MAY '95

Nicolet Minerals COMPANY

FIGURE 3.6-34
SECTION LSL-1A
LITTLE SAND LAKE HYDRAULIC CROSS SECTION
MEASURED DECEMBER, 1994

Scale: AS SHOWN		Date: MAY, 1995	
Prepared By: Foth & Van Dyke	By: KMP		93C049

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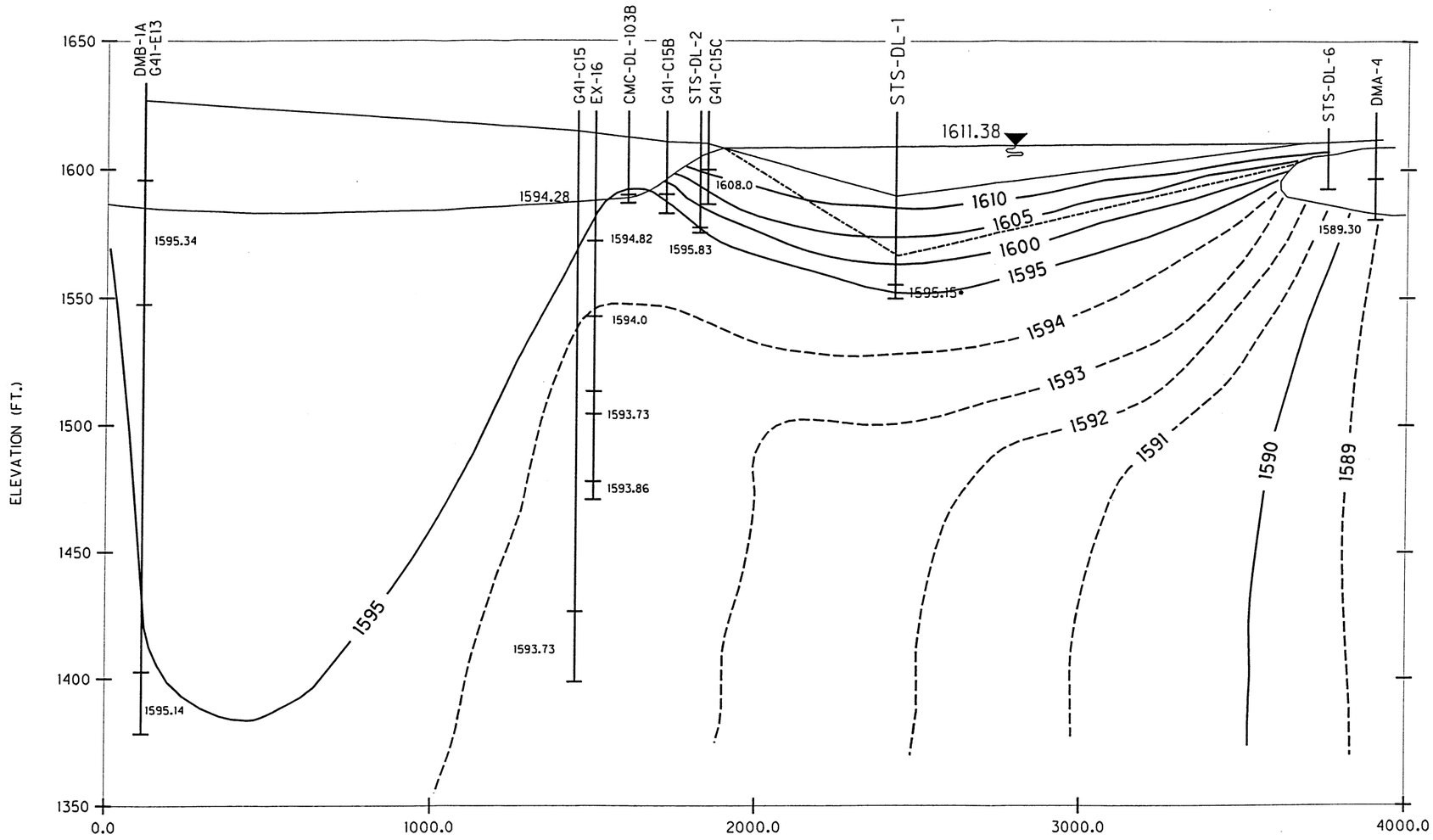
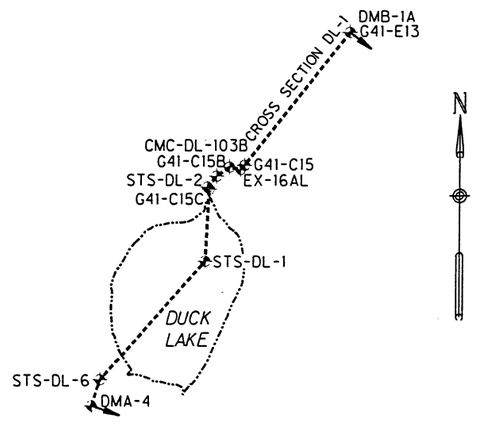


CROSS SECTION DL-1

SCALE: HORIZ. 1''=500'
VERT. 1''=50'

NOTE: • = ADJUSTED WATER LEVEL (SEE FOTH & VAN DYKE DECEMBER, 1994)



CROSS SECTION LOCATION MAP

SCALE: 1''=1200'

SOURCE: FOTH & VAN DYKE, DECEMBER 1994

Foth & Van Dyke			
REVISED	DATE	BY	DESCRIPTION
1	11/98	MLD2	REVISED FOR 1998 UPDATE
CHECKED BY:	JKSI	DATE: MAY '95	
APPROVED BY:	SVDI	DATE: MAY '95	
APPROVED BY:	GWS	DATE: MAY '95	

Nicolet Minerals COMPANY

FIGURE 3.6-35
SECTION DL-1
DUCK LAKE HYDRAULIC CROSS SECTION
MEASURED 2/15/86

Scale: AS SHOWN		Date: MAY, 1995	
Prepared By: Foth & Van Dyke		By: KMP	93C049

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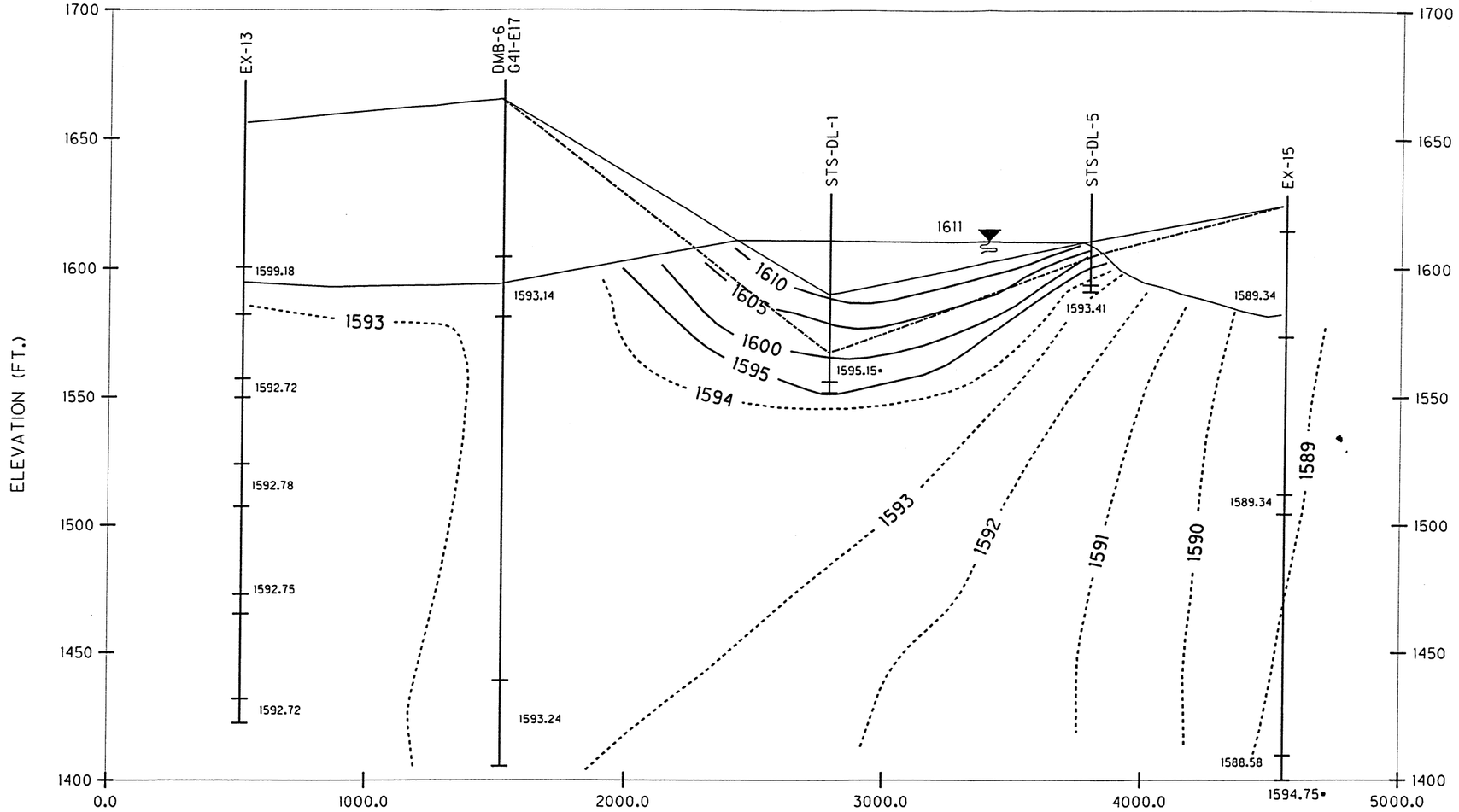
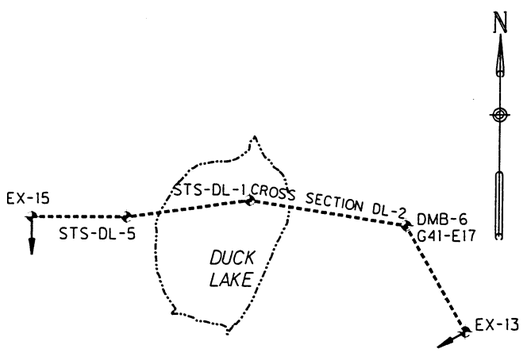


NOTE: • = ADJUSTED WATER LEVEL (SEE FOTH & VAN DYKE DECEMBER, 1994)

CROSS SECTION DL-2

SCALE: HORIZ. 1''=500'
VERT. 1''=50'



CROSS SECTION LOCATION MAP

SCALE: 1''=1200'

SOURCE: FOTH & VAN DYKE, DECEMBER 1994

Foth & Van Dyke			
REVISED	DATE	BY	DESCRIPTION
1	11/98	MLD2	REVISED FOR 1998 UPDATE
CHECKED BY:	JKS1	DATE: MAY '95	
APPROVED BY:	SVDI	DATE: MAY '95	
APPROVED BY:	GWS	DATE: MAY '95	

Nicolet Minerals COMPANY

FIGURE 3.6-36
SECTION DL-2
DUCK LAKE HYDRAULIC CROSS SECTION
MEASURED 2/15/86

Scale: AS SHOWN		Date: MAY, 1995	
Prepared By: Foth & Van Dyke		By: KMP	93C049

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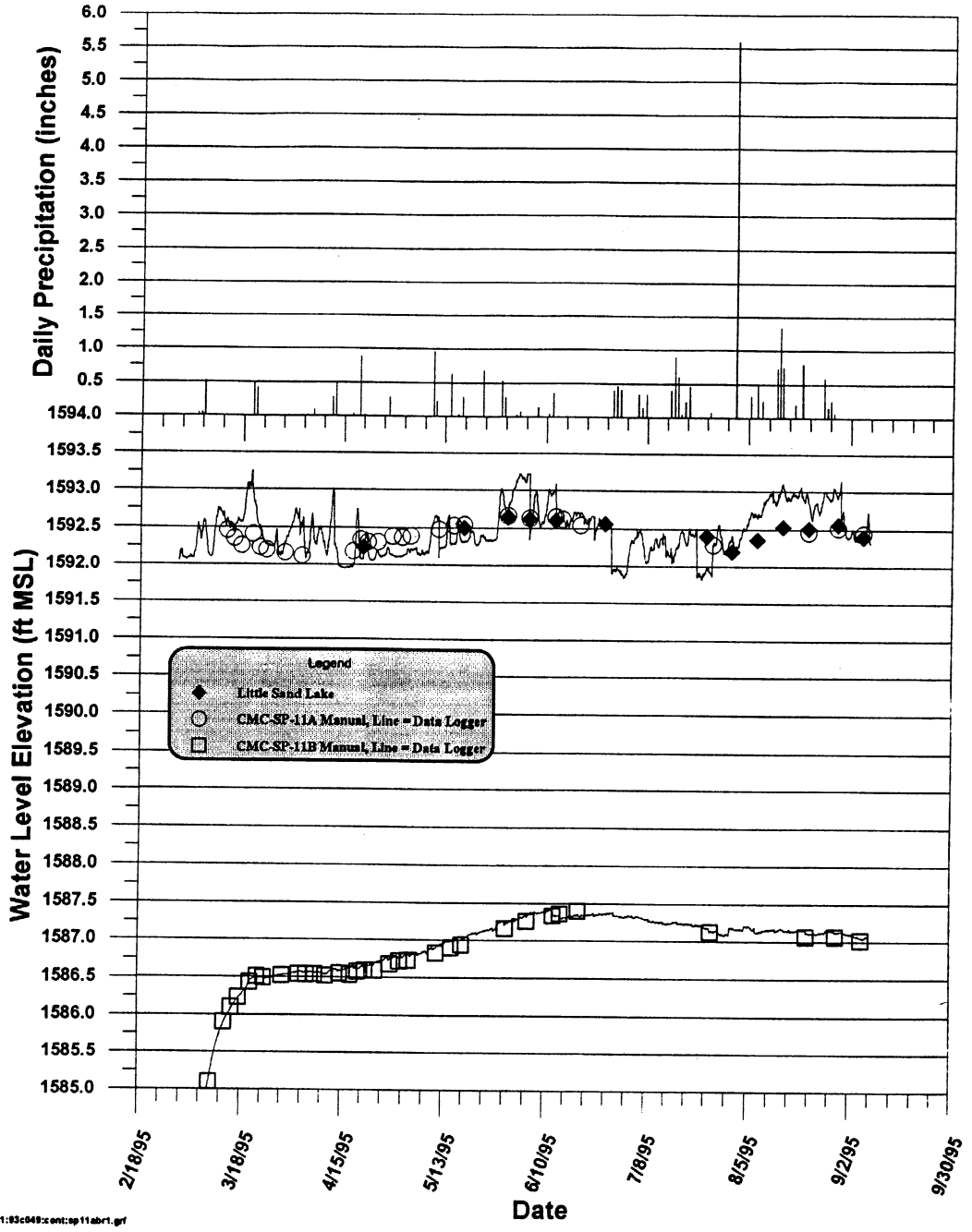
Little Sand Lake, F9 Wetland



svd1:93c049:cont:sp11abr1.grf

Foth & Van Dyke				
REVISED	DATE	BY	DESCRIPTION	
1	11/98	MLD2	REVISED FOR 1998 UPDATE	
CHECKED BY:		JKS1		DATE: MAR. '96
APPROVED BY:		SVD1		DATE: MAR. '96
APPROVED BY:		JWS		DATE: MAR. '96

Nicolet Minerals COMPANY

Mining for the Future • Commitment

FIGURE 3.6-36A

COMPARISON OF TRANSIENT GROUNDWATER LEVELS IN THE F9 WETLAND TO LAKE STAGE OF LITTLE SAND LAKE

Scale: AS SHOWN	Date: MARCH, 1996	
Prepared By: Foth & Van Dyke	By: JRB2	93C049

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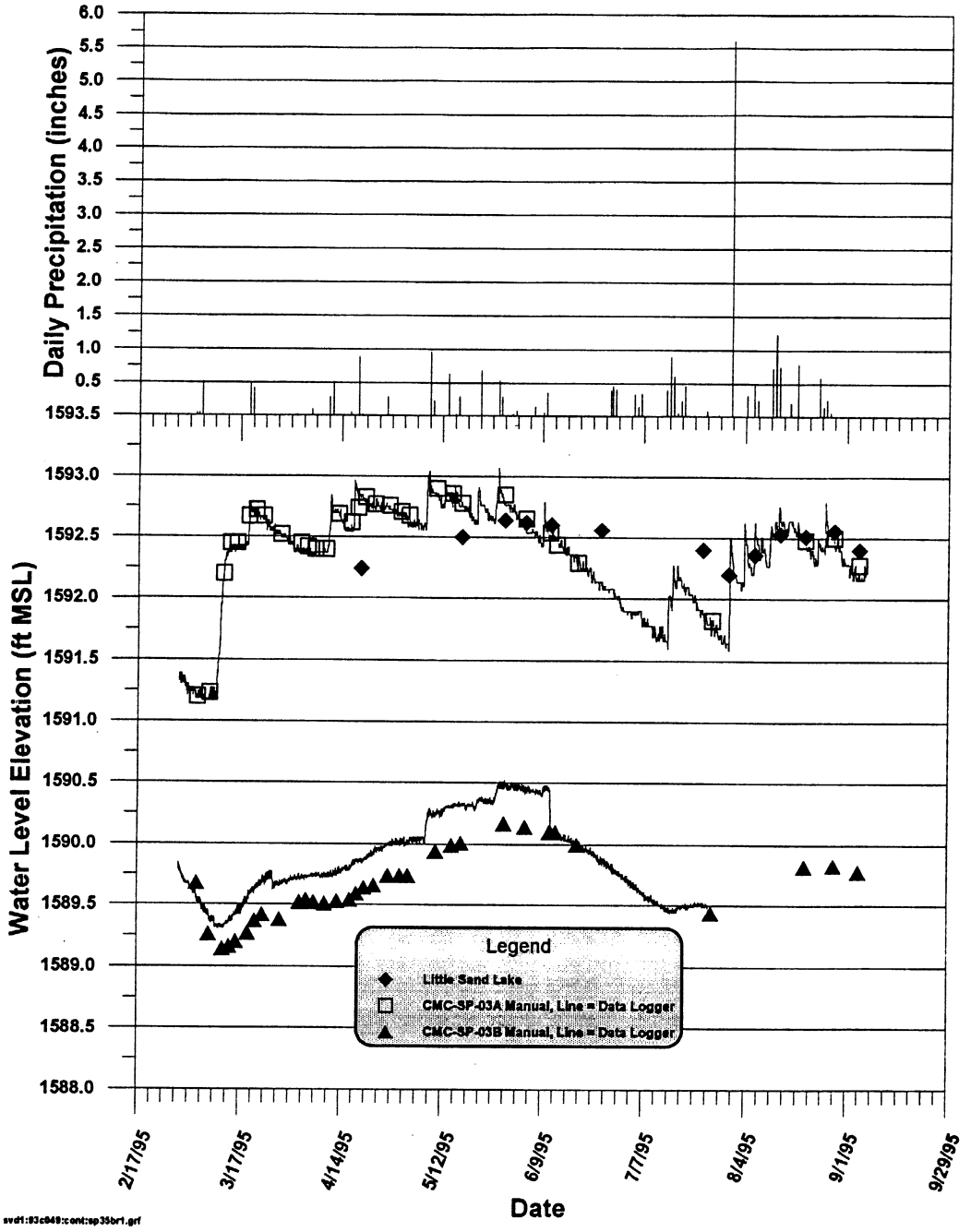
Little Sand Lake, F10 Wetland



Foth & Van Dyke			
REVISED	DATE	BY	DESCRIPTION
1	11/98	MLD2	REVISED FOR 1998 UPDATE
CHECKED BY:	JKS1	DATE: MAR. '96	
APPROVED BY:	SVD1	DATE: MAR. '96	
APPROVED BY:	JWS	DATE: MAR. '96	

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FIGURE 3.6-36B

COMPARISON OF TRANSIENT GROUNDWATER LEVELS IN THE F10 WETLAND TO LAKE STAGE OF LITTLE SAND LAKE

Scale: AS SHOWN	Date: MARCH, 1998	
Prepared By: Foth & Van Dyke	By: JRB2	93C049

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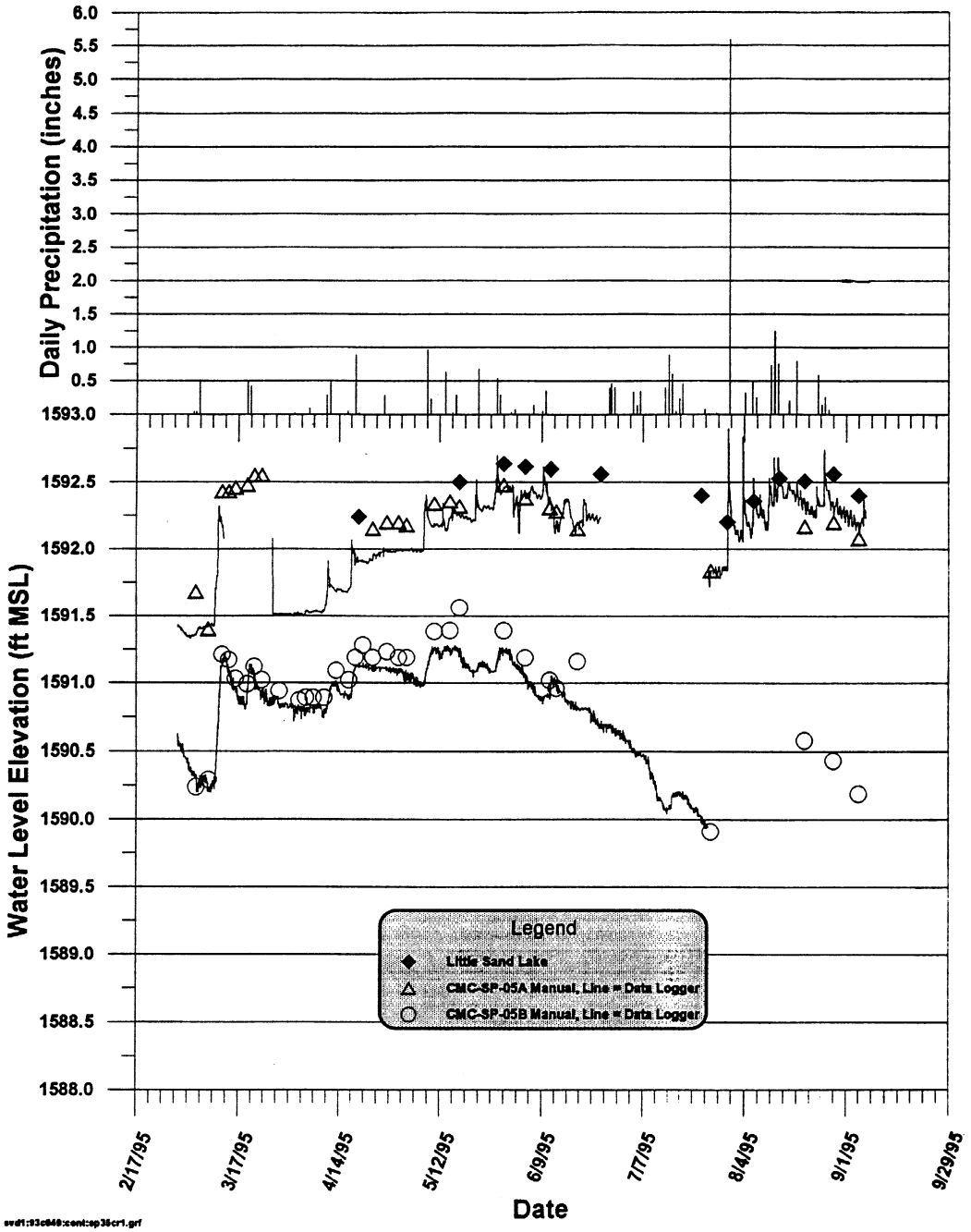
Little Sand Lake, F10 Wetland



svd1:93c049:cont:sp36cr1.grf

Foth & Van Dyke			
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1	11/98	MLD2	REVISED FOR 1998 UPDATE

CHECKED BY:	JKS1	DATE: MAR. '96
APPROVED BY:	SVD1	DATE: MAR. '96
APPROVED BY:	JWS	DATE: MAR. '96

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FIGURE 3.6-36C

COMPARISON OF TRANSIENT GROUNDWATER LEVELS NEAR THE F10 WETLAND TO LAKE STAGE OF LITTLE SAND LAKE

Scale: AS SHOWN		Date: MARCH, 1996	
Prepared By: Foth & Van Dyke	By: JRB2	93C049	

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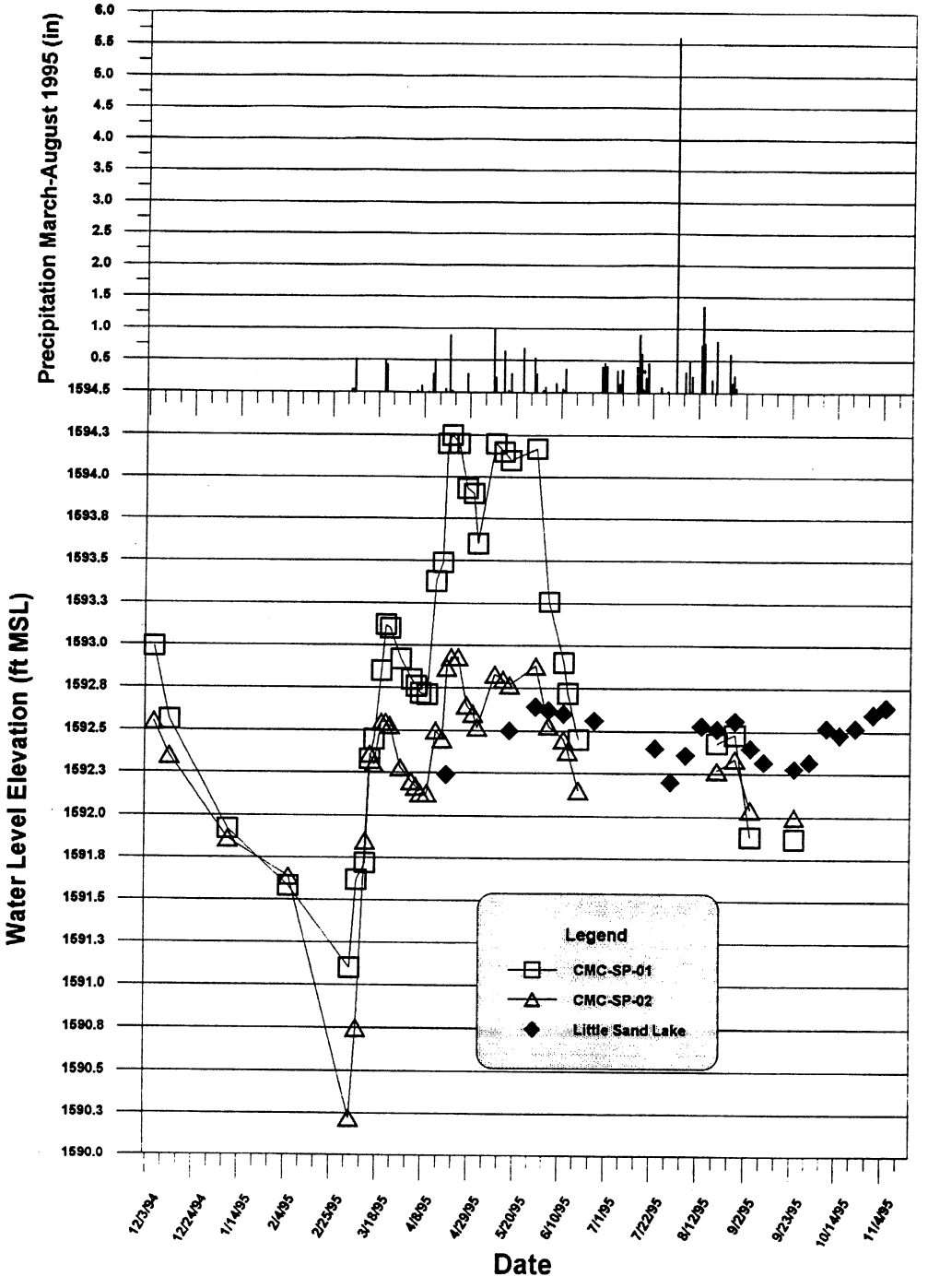

svd1:93c049:cont:miscsp01.grf

Foth & Van Dyke			
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CHECKED BY:	JKS1	DATE: MAR. '96
APPROVED BY:	SVD1	DATE: MAR. '96
APPROVED BY:	JWS	DATE: MAR. '96

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FIGURE 3.6-36D

COMPARISON OF TRANSIENT GROUNDWATER LEVELS AT CMC-SP-01 & CMC-SP-02 TO LAKE STAGE OF LITTLE SAND LAKE

Scale:	AS SHOWN	Date:	MARCH, 1996
Prepared By: Foth & Van Dyke		By: JRB2	93C049

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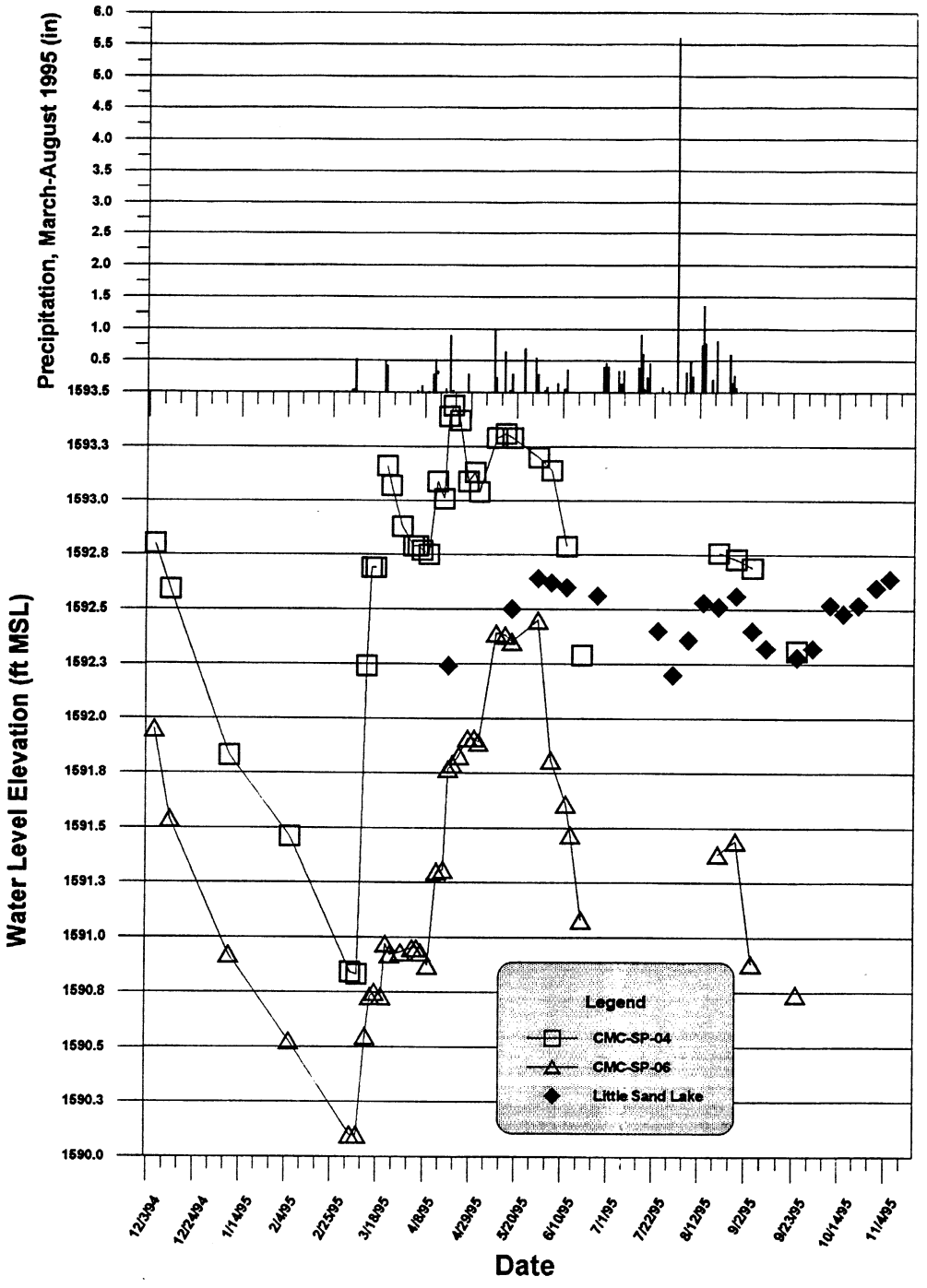

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Foth & Van Dyke				
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1	11/98	MLD2	REVISED FOR 1998 UPDATE	
CHECKED BY:		JKS1		DATE: MAR. '96
APPROVED BY:		SVD1		DATE: MAR. '96
APPROVED BY:		JWS		DATE: MAR. '96

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FIGURE 3.6-36E

COMPARISON OF TRANSIENT GROUNDWATER LEVELS AT CMC-SP-04 & CMC-SP-06 TO LAKE STAGE OF LITTLE SAND LAKE

Scale: AS SHOWN	Date: MARCH, 1996	
Prepared By: Foth & Van Dyke	By: JRB2	93C049

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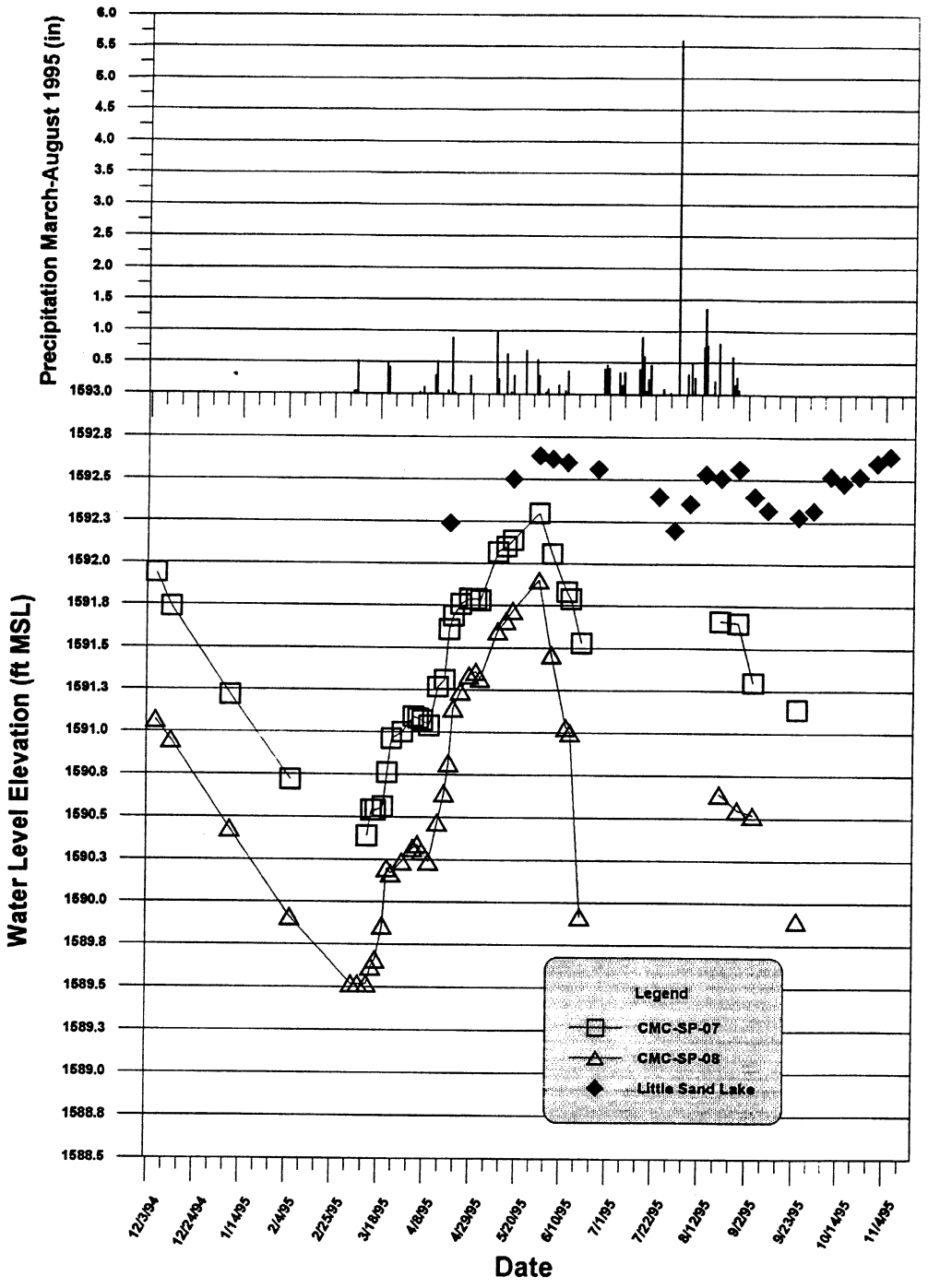

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Foth & Van Dyke			
REVISED	DATE	BY	DESCRIPTION
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CHECKED BY:	JKS1	DATE: MAR. '96
APPROVED BY:	SVD1	DATE: MAR. '96
APPROVED BY:	JWS	DATE: MAR. '96

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FIGURE 3.6-36F

COMPARISON OF TRANSIENT GROUNDWATER LEVELS AT CMC-SP-07 & CMC-SP-08 TO LAKE STAGE OF LITTLE SAND LAKE

Scale: AS SHOWN		Date: MARCH, 1996	
Prepared By: Foth & Van Dyke	By: JRB2	93C049	

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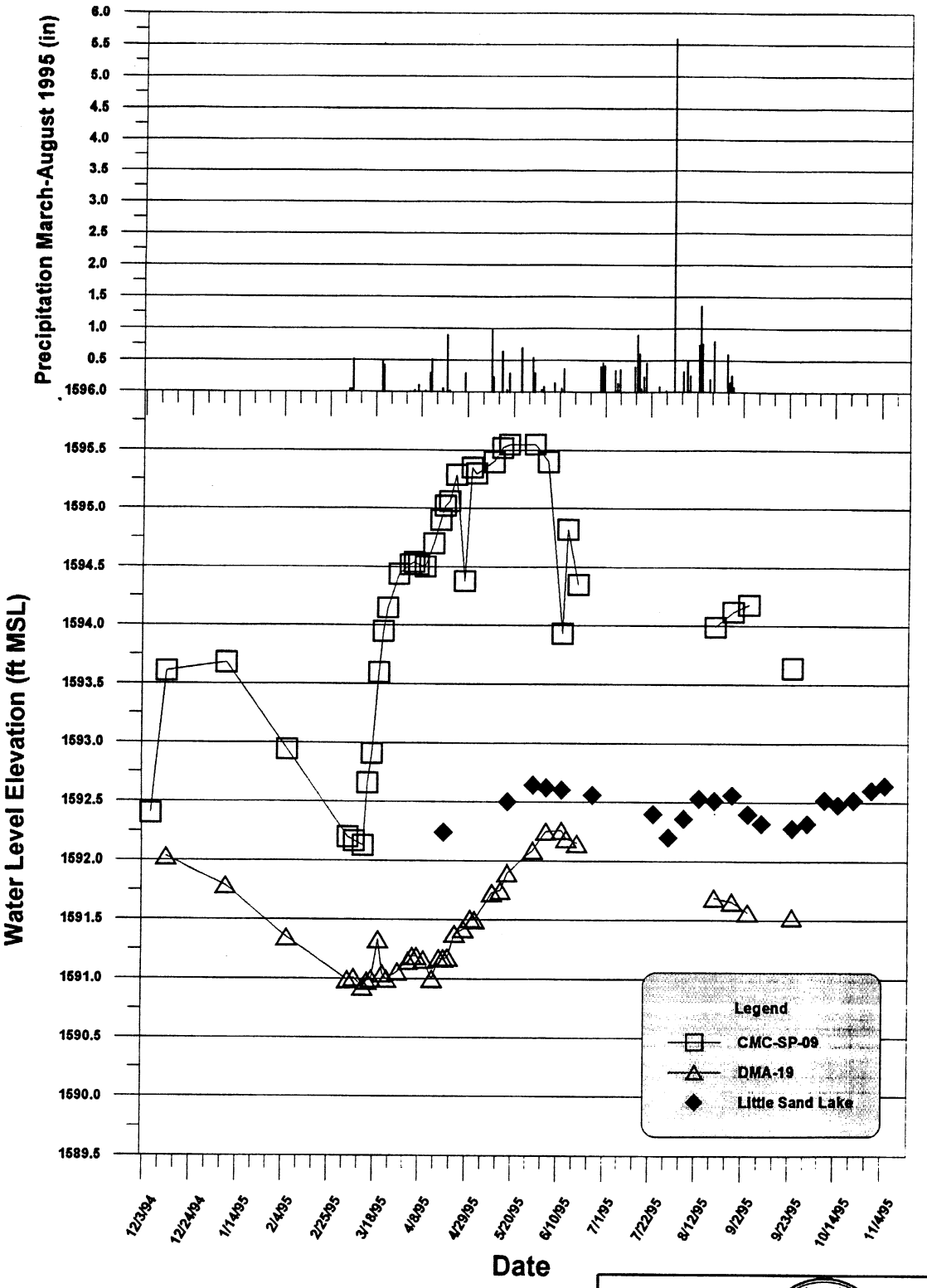

svd1:93c049:cont:miscsp09.grf

Foth & Van Dyke				
REVISED	DATE	BY	DESCRIPTION	
1	8/98	MLD2	REVISED FOR 1998 UPDATE	
CHECKED BY:		JKS1		DATE: MAR. '96
APPROVED BY:		SVD1		DATE: MAR. '96
APPROVED BY:		JWS		DATE: MAR. '96

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FIGURE 3.6-36G

COMPARISON OF TRANSIENT GROUNDWATER LEVELS AT CMC-SP-09 & DMA-19 TO LAKE STAGE OF LITTLE SAND LAKE

Scale: AS SHOWN	Date: MARCH, 1996	
Prepared By: Foth & Van Dyke	By: JRB2	93C049

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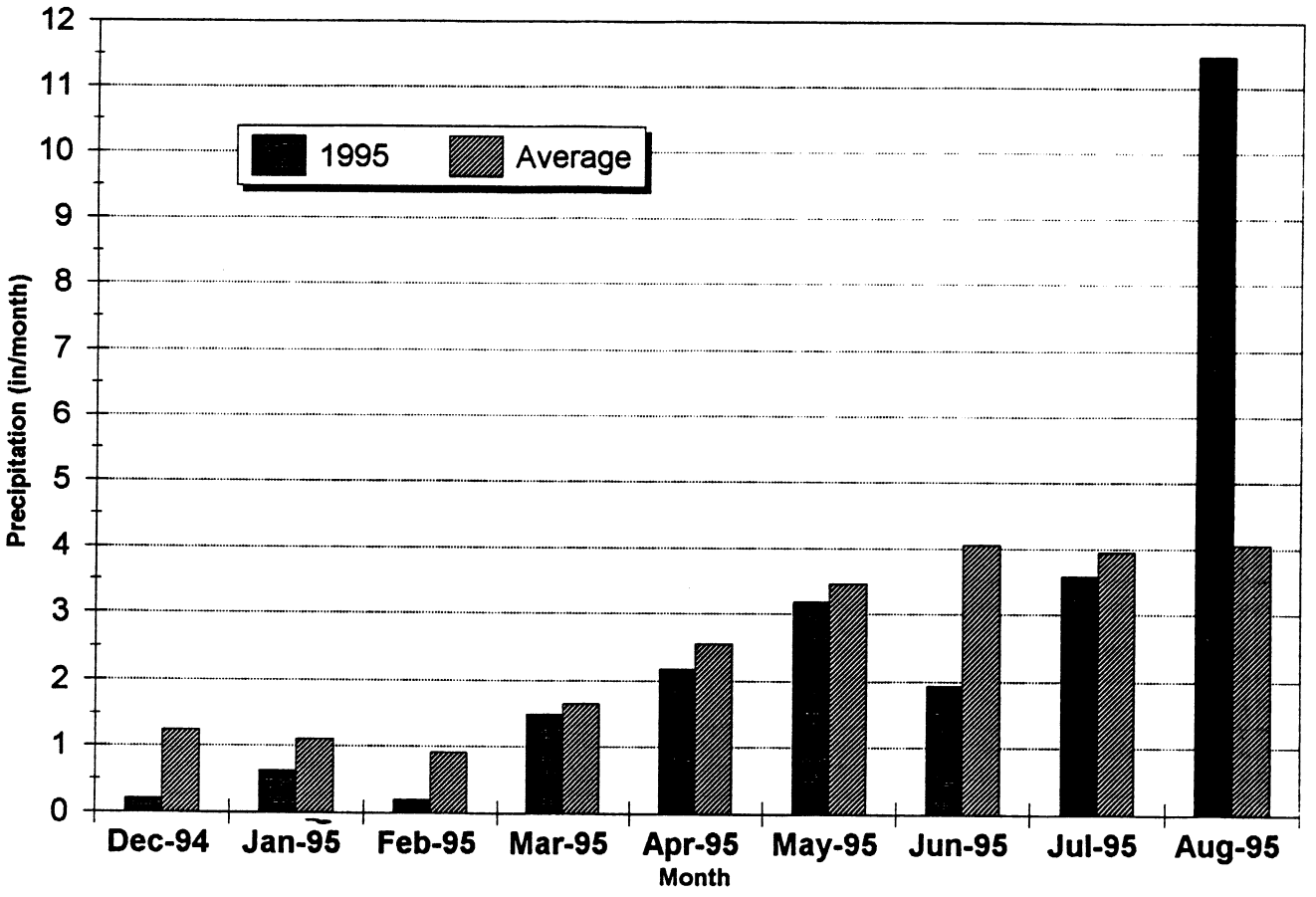
Monthly Precipitation Record
South Pelican Lake



Source: National Oceanic and Atmospheric Administration

Foth & Van Dyke			
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CHECKED BY:	JKS1	DATE: MAR. '96	
APPROVED BY:	SVD1	DATE: MAR. '96	
APPROVED BY:	JWS	DATE: MAR. '96	

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FIGURE 3.6-36H

COMPARISON OF 1995 MONTHLY PRECIPITATION TO LONG TERM AVERAGE

Scale: AS SHOWN	Date: MARCH, 1996
Prepared By: Foth & Van Dyke	By: JRB2 93C049

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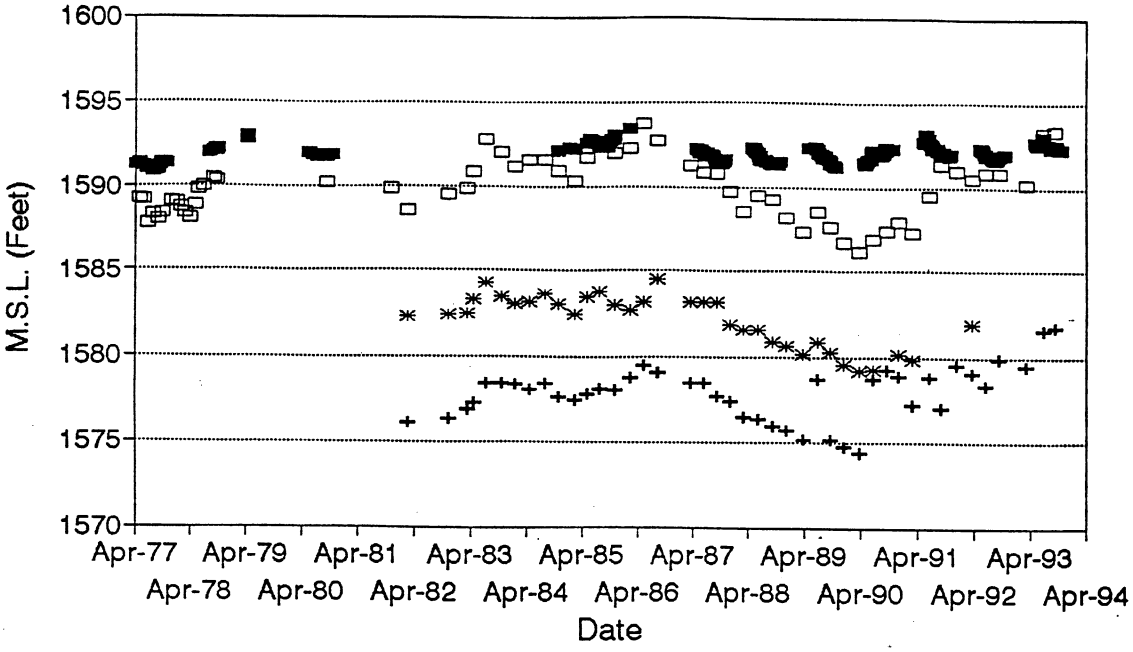
Groundwater and Surface Water Elevation



Foth & Van Dyke			
REVISED	DATE	BY	DESCRIPTION
1	11/98	MLD2	REVISED FOR 1998 UPDATE

CHECKED BY:	JKS1	DATE:	MAY'95
APPROVED BY:	SVDI	DATE:	MAY'95
APPROVED BY:	JWS	DATE:	MAY'95

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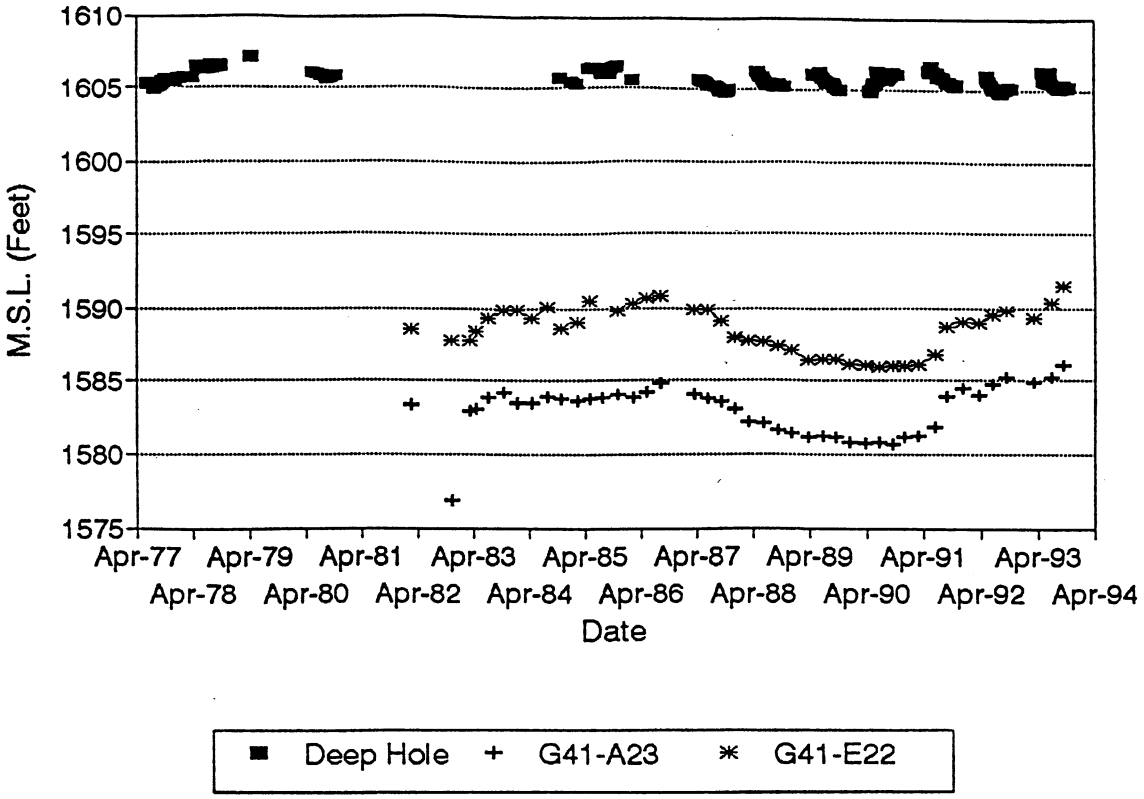
FIGURE 3.6-37

HYDROGRAPHS OF LITTLE SAND LAKE AND SURROUNDING WELLS

Scale:	AS SHOWN	Date:	MAY, 1995
Prepared By: Foth & Van Dyke		By: KMP	93C049

I:\93c049\94c033\4c33fig.dgn Nov. 17, 1998 10:00:23

Groundwater and Surface Water Elevation



■ Deep Hole + G41-A23 * G41-E22

Foth & Van Dyke			
REVISED	DATE	BY	DESCRIPTION
1	11/98	MLD2	REVISED FOR 1998 UPDATE

CHECKED BY:	JKS1	DATE:	MAY'95
APPROVED BY:	SVD1	DATE:	MAY'95
APPROVED BY:	JWS	DATE:	MAY'95

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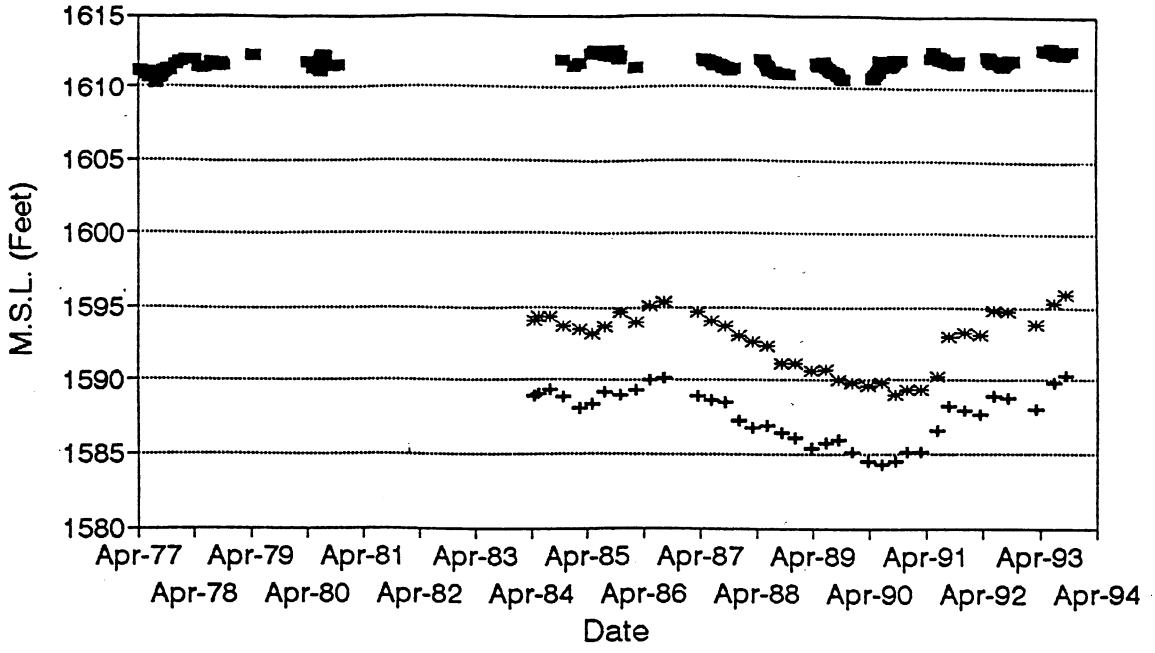
FIGURE 3.6-38

HYDROGRAPHS OF DEEP HOLE LAKE AND SURROUNDING WELLS

Scale:	AS SHOWN	Date:	MAY, 1995
Prepared By: Foth & Van Dyke		By: KMP	93C049

I:\93c049\94c033\4c33fig.dgn Nov. 17, 1998 10:00:30

Groundwater and Surface Water Elevation



Foth & Van Dyke			
REVISED	DATE	BY	DESCRIPTION
1	11/98	MLD2	REVISED FOR 1998 UPDATE

CHECKED BY:	JKS1	DATE:	MAY'95
APPROVED BY:	SVD1	DATE:	MAY'95
APPROVED BY:	JWS	DATE:	MAY'95

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FIGURE 3.6-39

HYDROGRAPHS OF DUCK LAKE AND SURROUNDING WELLS

Scale:	AS SHOWN	Date:	MAY, 1995
Prepared By: Foth & Van Dyke		By: JRB2	93C049

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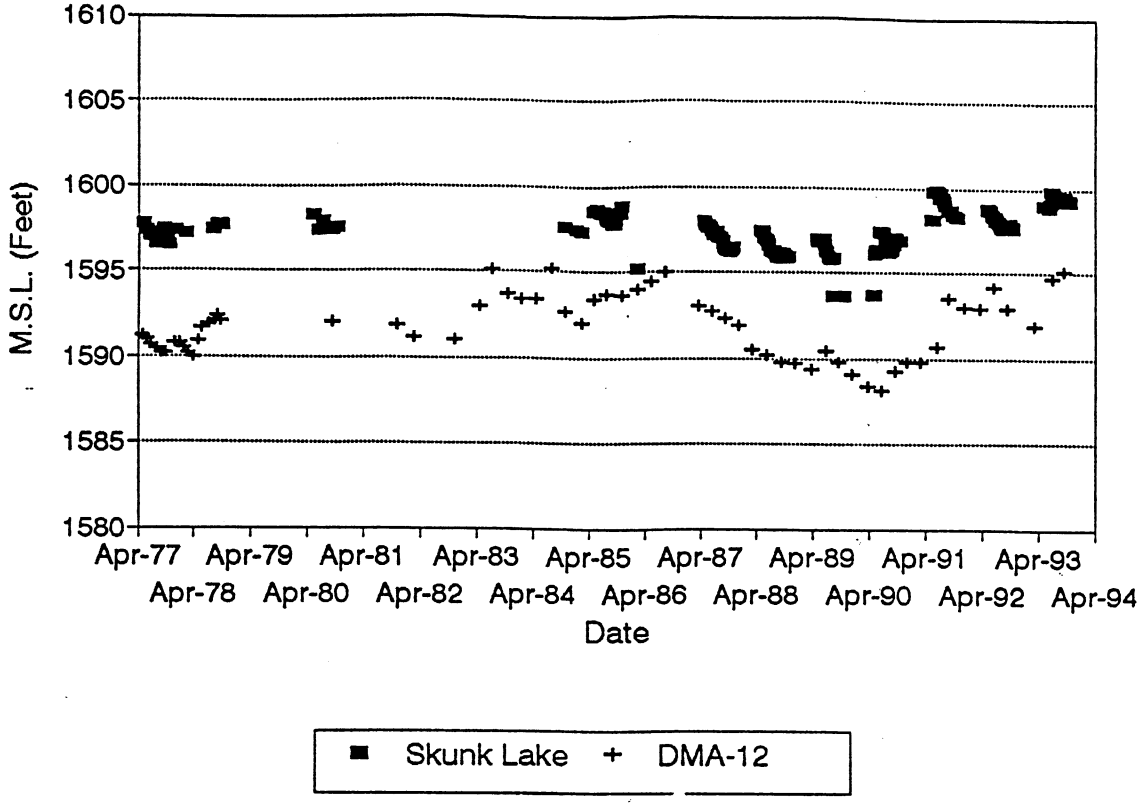
Groundwater and Surface Water Elevation



Foth & Van Dyke			
REVISED	DATE	BY	DESCRIPTION
1	11/98	MLD2	REVISED FOR 1998 UPDATE

CHECKED BY:	JKS1	DATE:	MAY'95
APPROVED BY:	SVD1	DATE:	MAY'95
APPROVED BY:	JWS	DATE:	MAY'95

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FIGURE 3.6-40

HYDROGRAPHS OF SKUNK LAKE AND SURROUNDING WELLS

Scale:		Date:	MAY, 1995
Prepared By: Foth & Van Dyke	By: KMP		93C049

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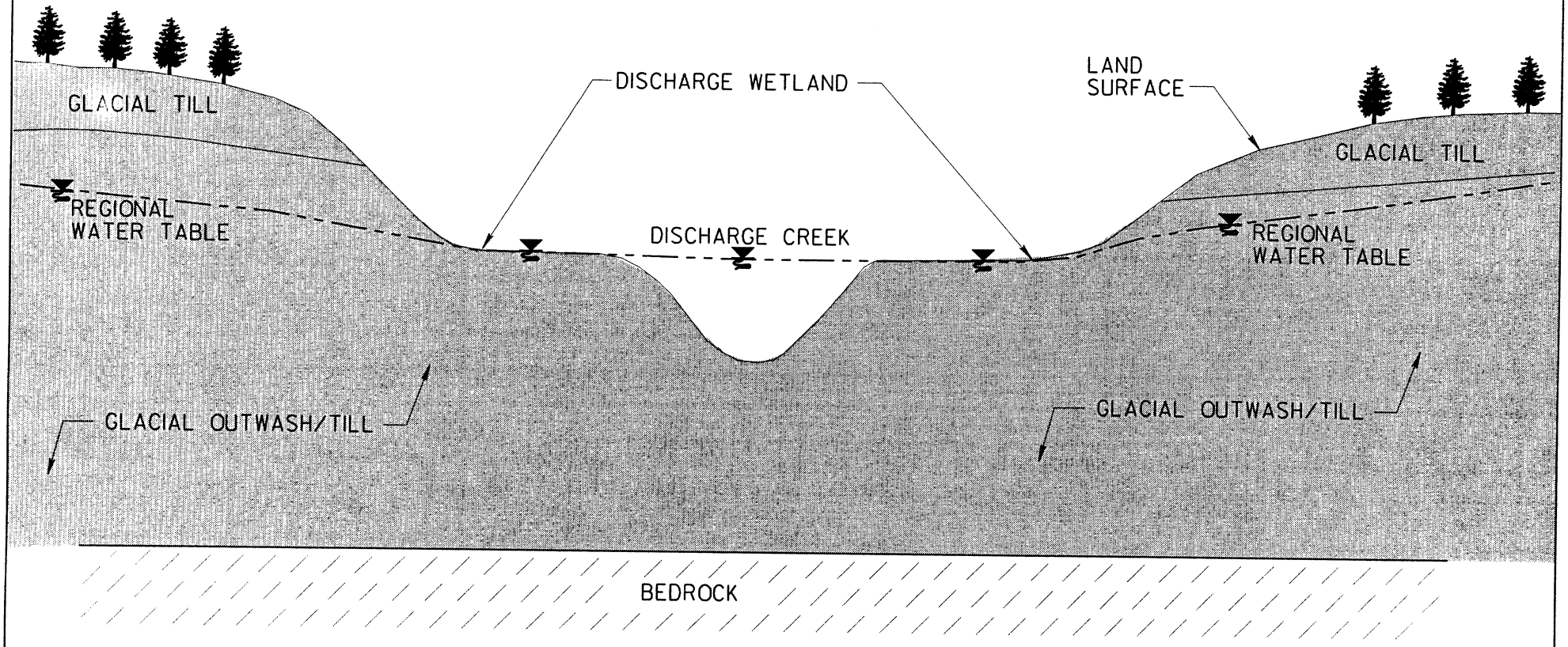

Foth & Van Dyke			
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1	11/98	MLD2	REVISED FOR 1998 UPDATE

CHECKED BY:	JKSI	DATE: MAY '95
APPROVED BY:	SVDI	DATE: MAY '95
APPROVED BY:	GWS	DATE: MAY '95

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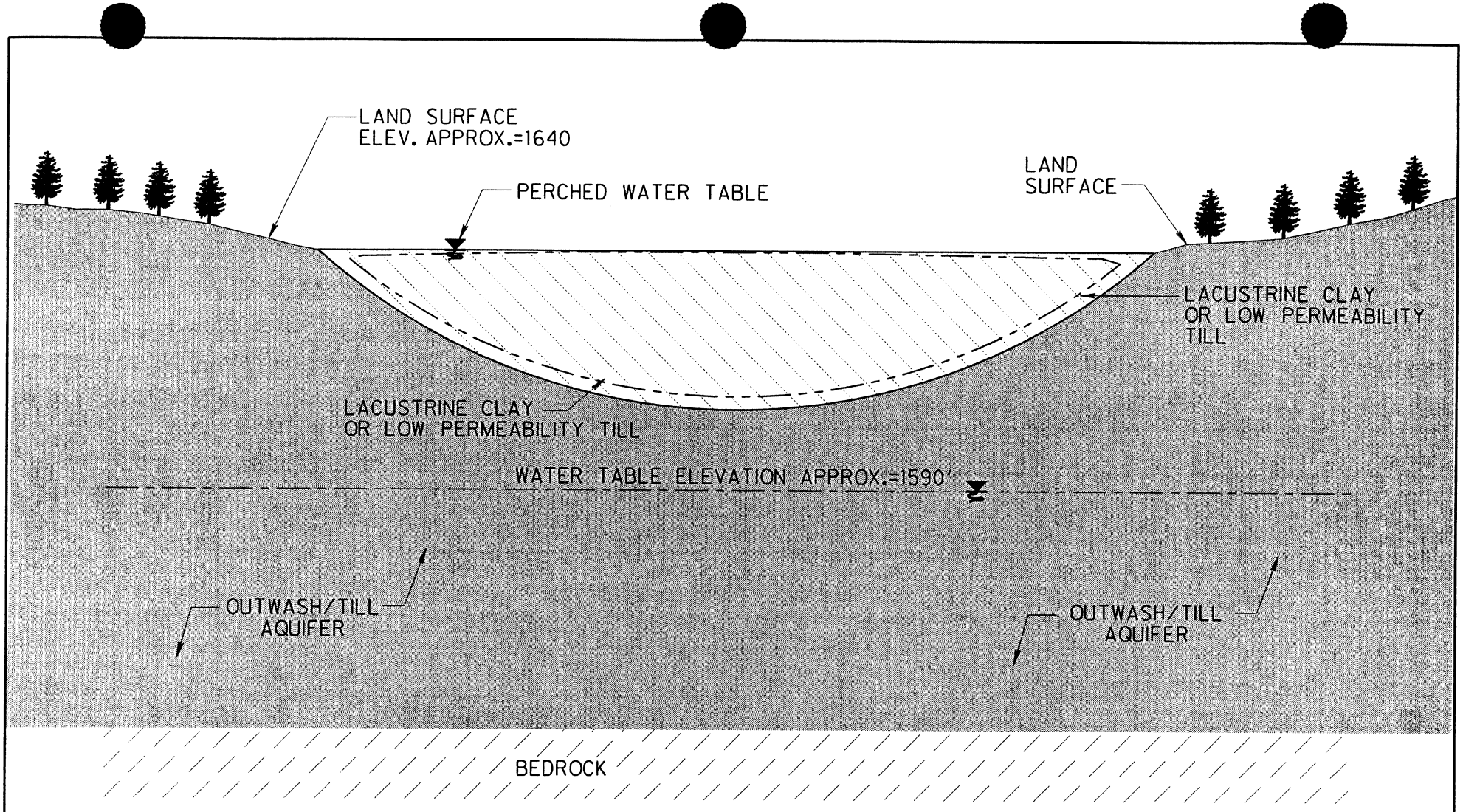
FIGURE 3.6-41

SCHEMATIC OF DISCHARGE TYPE WETLAND

Scale: NOT TO SCALE		Date: MAY, 1995	
Prepared By: Foth & Van Dyke		By: BSH	93C049

I:\93c049\94c033\4c33f147.dgn Nov. 18, 1998 09:18:11



Foth & Van Dyke			
REVISED	DATE	BY	DESCRIPTION
1	11/98	MLD2	REVISED FOR 1998 UPDATE

CHECKED BY:	JKS1	DATE: MAY '95
APPROVED BY:	SVD1	DATE: MAY '95
APPROVED BY:	GWS	DATE: MAY '95

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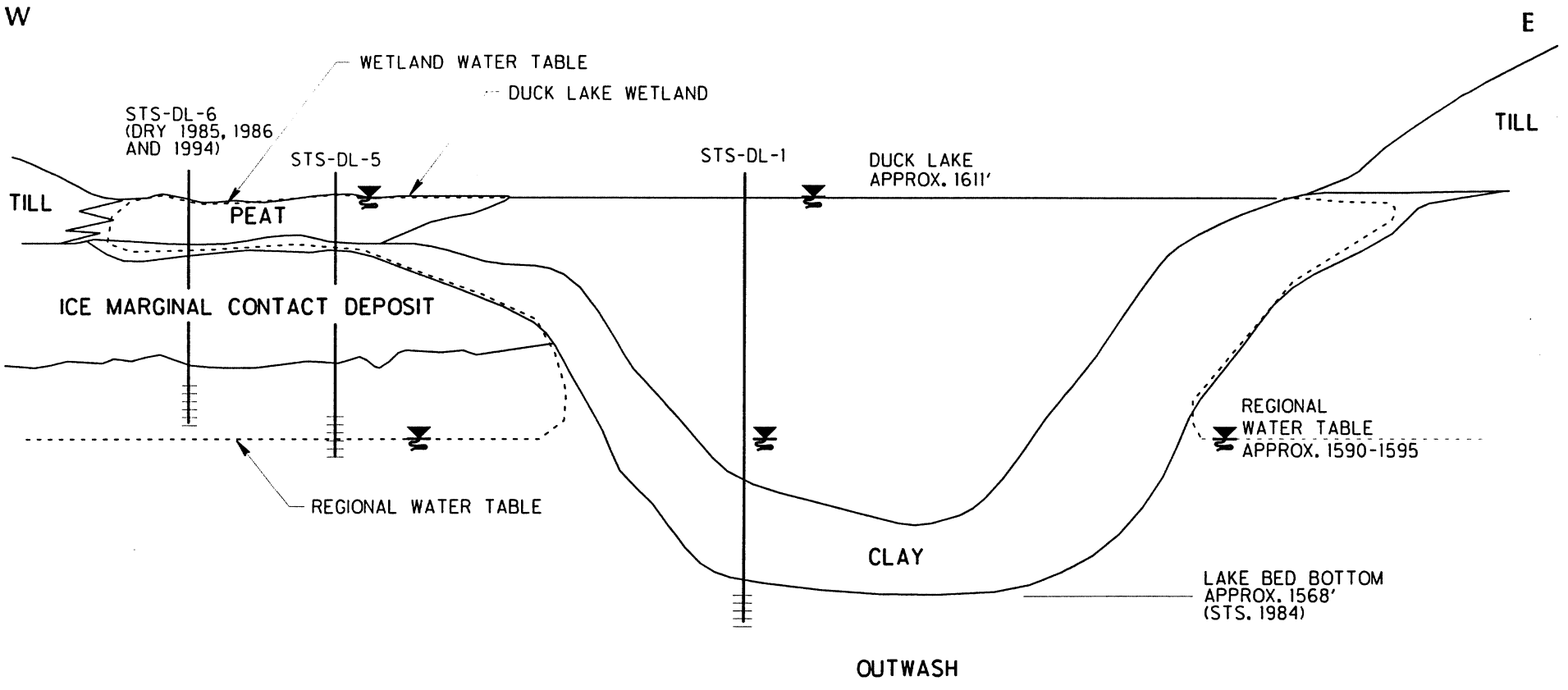
FIGURE 3.6-42

SCHEMATIC OF RECHARGE WETLAND
TYPE 1

Scale: NOT TO SCALE	Date: MAY, 1995	
Prepared By: Foth & Van Dyke	By: BSH	93C049

I:\93c049\94c033\4c33f144.dgn Nov. 18, 1998 09:22:43



Foth & Van Dyke			
REVISED	DATE	BY	DESCRIPTION
1	11/98	MLD2	REVISED FOR 1998 UPDATE

CHECKED BY:	JKS1	DATE: MAY '95
APPROVED BY:	SVD1	DATE: MAY '95
APPROVED BY:	GWS	DATE: MAY '95

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FIGURE 3.6-43

SCHEMATIC OF RECHARGE WETLAND
TYPE 2

Scale: NOT TO SCALE		Date: MAY, 1995	
Prepared By: Foth & Van Dyke		By: BSH	93C049

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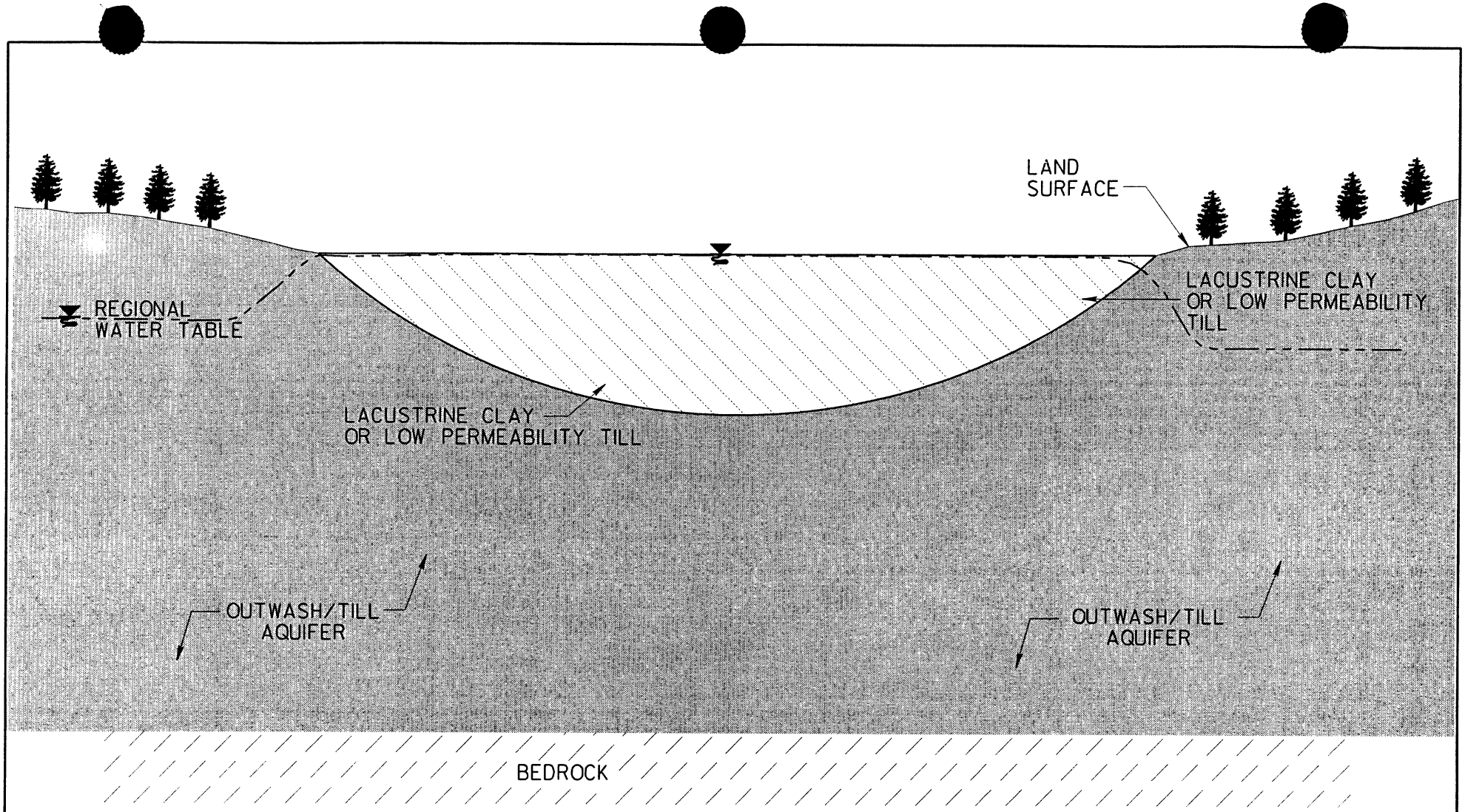

Foth & Van Dyke			
REVISED	DATE	BY	DESCRIPTION
1	11/98	MLD2	REVISED FOR 1998 UPDATE

CHECKED BY:	JKS1	DATE: MAY '95
APPROVED BY:	SVD1	DATE: MAY '95
APPROVED BY:	GWS	DATE: MAY '95

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FIGURE 3.6-44

SCHEMATIC DIAGRAM OF RECHARGE WETLAND TYPE 3

Scale: NOT TO SCALE	Date: MAY, 1995	
Prepared By: Foth & Van Dyke	By: BSH	93C049

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2,260,000 E | 2,265,000 E | 2,270,000 E | 2,275,000 E | 2,280,000 E | 2,285,000 E | 2,290,000 E

N

130,000 N | 125,000 N | 120,000 N | 115,000 N | 110,000 N | 105,000 N | 100,000 N

LAKE METONGA
RICE LAKE
MOLE LAKE
OAK LAKE
LITTLE SAND LAKE
DUCK LAKE
DEEP HOLE LAKE
SKUNK LAKE
GROUND HEMLOCK LAKE
KIMBERLY LAKE
WALSH LAKE
CLARK LAKE
ST JOHNS LAKE
ROLLING STONE LAKE
PLANT SITE
ORE BODY
TMA
SAS

OC-1
Z1 Z2 Z3 Z4 Z5 Z6 Z7 Z8 Z9 Z10 Z11 Z12 Z13 Z14 Z15 Z16 Z17 Z18 Z19 Z20 Z21 Z22 Z23 Z24 Z25 Z26
T1 T2 T3 T4 T5
SC-1 SC-2
HC-1
UN-1
RL-1
ML-1
PC-1
MS-1
CR129-1
W1 W2
P1 P2
01 02 03
A1 A2 A3
B1 B2 B3 B4 B5 B6 B7 B8
D1 D2 D3 D4 D4A D5 D8 D18
R1 R1A R3 R5 R7 R7A R8
F1 F2 F4 F5 F6 F7 F8 F9 F10 F11 F12 F13 F14 F15 F16 F17 F18 F19 F21 F22 F23 F24 F25 F26 F27 F28 F29 F30 F31 F32 F33 F34 F35 F36 F37 F38 F39 F40 F42 F43 F45 F46 F48 F50 F51 F52 F53 F54 F55 F56 F57 F58 F60 F61 F62 F63 F64 F65 F66 F69 F70 F72 F81 F86 F87 F90 F119 F121 F122 F122A F125 F126 F127
G1
I1 I2
J1
K1 K2 K3 K4 K5
L1
M1 M2 M3 M4 M5 M6
N1
X2 X3 X4

LEGEND

- TREES/BRUSH
- UNPAVED ROAD/TRAIL
- PAVED ROAD
- WETLAND
- x 1542.0 EXISTING SPOT ELEVATION
- 1600 EXISTING CONTOUR
- CREEKS/RIVERS/LAKES
- PROPOSED ACCESS ROAD
- WETLAND DIVIDER

- DISCHARGE WETLAND.
- RECHARGE WETLAND TYPE 1. UNSATURATED ZONE EXISTS UNDER WETLAND.
- RECHARGE WETLAND TYPE 2. UNSATURATED ZONE EXISTS UNDER WETLAND. WETLAND IS CONNECTED LATERALLY TO A HEAD DEPENDENT SEEPAGE LAKE WATER BODY.
- RECHARGE WETLAND TYPE 3. HEAD DEPENDENT SEEPAGE WETLAND CONTINUOUSLY SATURATED SOILS FROM WETLAND SURFACE TO REGIONAL GROUNDWATER SYSTEM.

- ORE BODY
- PROPOSED TMA ACCESS ROAD AND TAILINGS PIPELINE ROUTE
- PROPOSED RAILROAD SPUR
- PROPOSED FACILITIES

NOTES:

1. TOPOGRAPHIC BASE MAP DIGITIZED FROM 1" = 1000' SCALE, 5' CONTOUR INTERVAL MAP PREPARED BY AERO-METRIC ENGINEERING, INC., SHEBOYGAN, WISCONSIN. DATE OF PHOTOGRAPHY APRIL 28, 1976.
2. HORIZONTAL DATUM BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM - NORTH ZONE.
3. VERTICAL DATUM BASED ON MEAN SEA LEVEL DATUM. CONTOUR INTERVAL IS 5 FEET.
4. COUNTY AND TOWNSHIP LINES DIGITIZED FROM 7.5' SERIES USGS MAPS.
5. ORE BODY OUTLINE IS REPRESENTATIVE OF THE SUBCROP AT THE BASE OF THE OVERBURDEN.

0 1000' 2000'
BAR SCALE

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION
1	12/23/96	SVDI	CHANGE WETLAND FROM DISCHARGE TO TYPE 1. REVISED TMA LIMITS OF DISTURBANCE.
2	11/98	MLD2	REVISED FOR 1998 UPDATE

CHECKED BY:	JKS1	DATE: MAY '95
APPROVED BY:	SVDI	DATE: MAY '95
APPROVED BY:	GWS	DATE: MAY '95

Nicolet Minerals COMPANY

FIGURE 3.6-45

HYDROGEOLOGIC CLASSIFICATION OF DELINEATED AND MAJOR WETLAND AREAS IN STUDY AREA

Scale: SEE BAR SCALE	Date: MAY, 1995
Prepared By: Foth & Van Dyke	By: KMP 93C049

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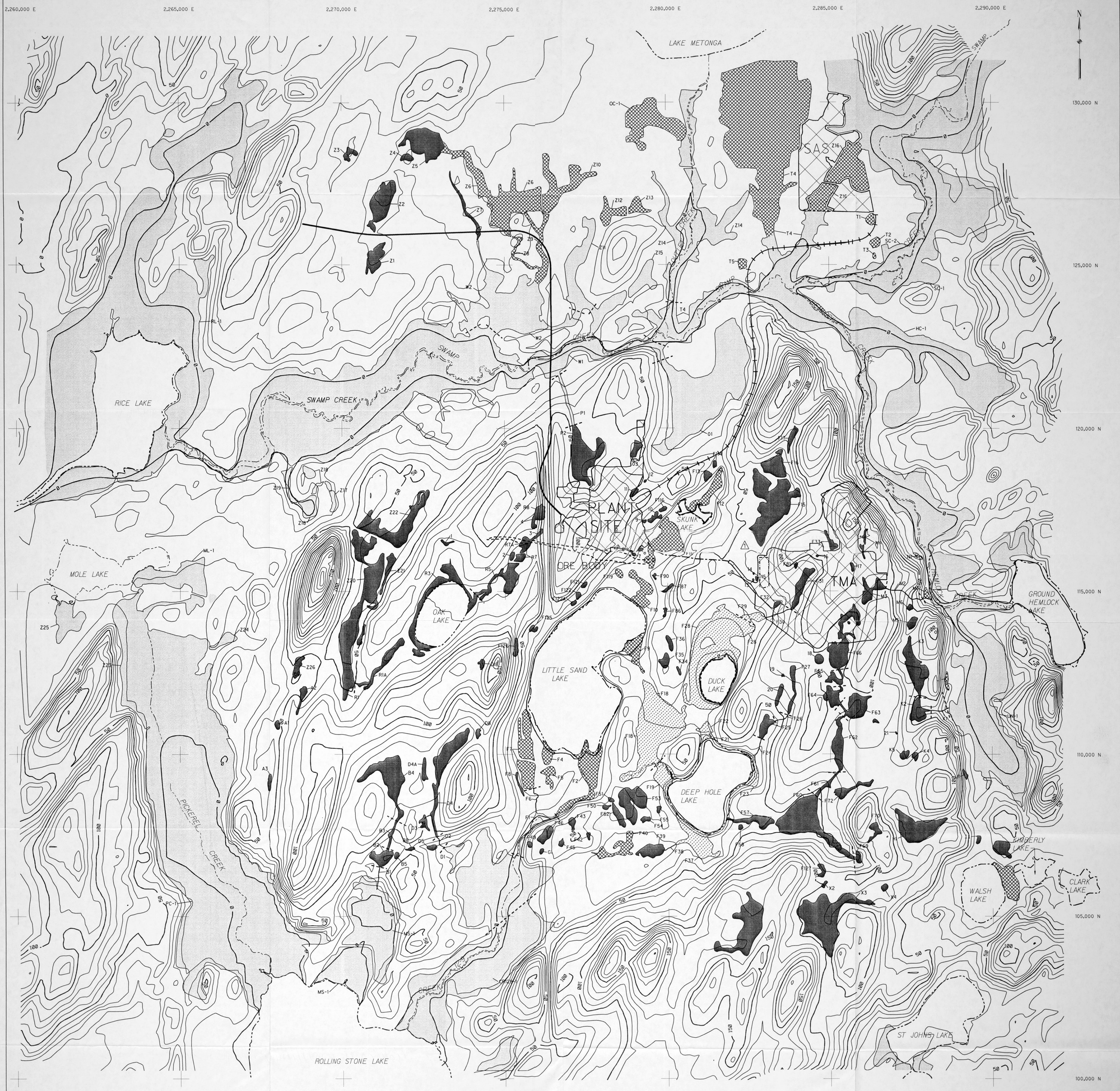
$$$$DATE$$$ $USER



LEGEND

- ISOPACH CONTOUR
- CREEKS/RIVERS/LAKES
- PROPOSED ACCESS ROAD
- WETLAND DIVIDER
- ORE BODY
- DISCHARGE WETLAND TO BE SIMULATED AS DRAINS.
- RECHARGE WETLAND TYPE 1. UNSATURATED ZONE EXISTS UNDER WETLAND.
- RECHARGE WETLAND TYPE 2. UNSATURATED ZONE EXISTS UNDER WETLAND. WETLAND IS CONNECTED LATERALLY TO A HEAD DEPENDENT SEEPAGE LAKE WATER BODY.
- RECHARGE WETLAND TYPE 3. HEAD DEPENDENT SEEPAGE WETLAND CONTINUOUSLY SATURATED SOIL FROM WETLAND SURFACE DOWN TO REGIONAL GROUNDWATER SYSTEM.
- PROPOSED TMA ACCESS ROAD AND TAILINGS PIPELINE ROUTE
- PROPOSED RAILROAD SPUR
- PROPOSED FACILITIES

NOTES:

1. TOPOGRAPHIC BASE MAP DIGITIZED FROM 1" = 1000' SCALE, 5' CONTOUR INTERVAL MAP PREPARED BY AERO-METRIC ENGINEERING, INC., SHEBOYGAN, WISCONSIN. DATE OF PHOTOGRAPHY APRIL 28, 1976.
2. HORIZONTAL DATUM BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM - NORTH ZONE.
3. VERTICAL DATUM BASED ON MEAN SEA LEVEL DATUM. CONTOUR INTERVAL IS 10 FEET.
4. COUNTY AND TOWNSHIP LINES DIGITIZED FROM 7.5' SERIES USGS MAPS.
5. ORE BODY OUTLINE IS REPRESENTATIVE OF THE SUBCROP AT THE BASE OF THE OVERBURDEN.

0 1000' 2000'
BAR SCALE

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION
1	12/23/96	SVD1	REVISED CONTOURING AROUND LITTLE SAND, DEEP HOLE, DUCK & SKUNK LAKES. REVISED TMA LIMITS OF DISTURBANCE.
2	11/98	MLD2	REVISED FOR 1998 UPDATE

CHECKED BY:	JKS1	DATE: MAY '95
APPROVED BY:	SVD1	DATE: MAY '95
APPROVED BY:	GWS	DATE: MAY '95

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FIGURE 3.6-46

ISOPACH OF DEPTH FROM THE GROUND SURFACE TO GROUNDWATER SURFACE

Scale: SEE BAR SCALE	Date: MAY, 1995
Prepared By: Foth & Van Dyke	By: JRB2

93C049

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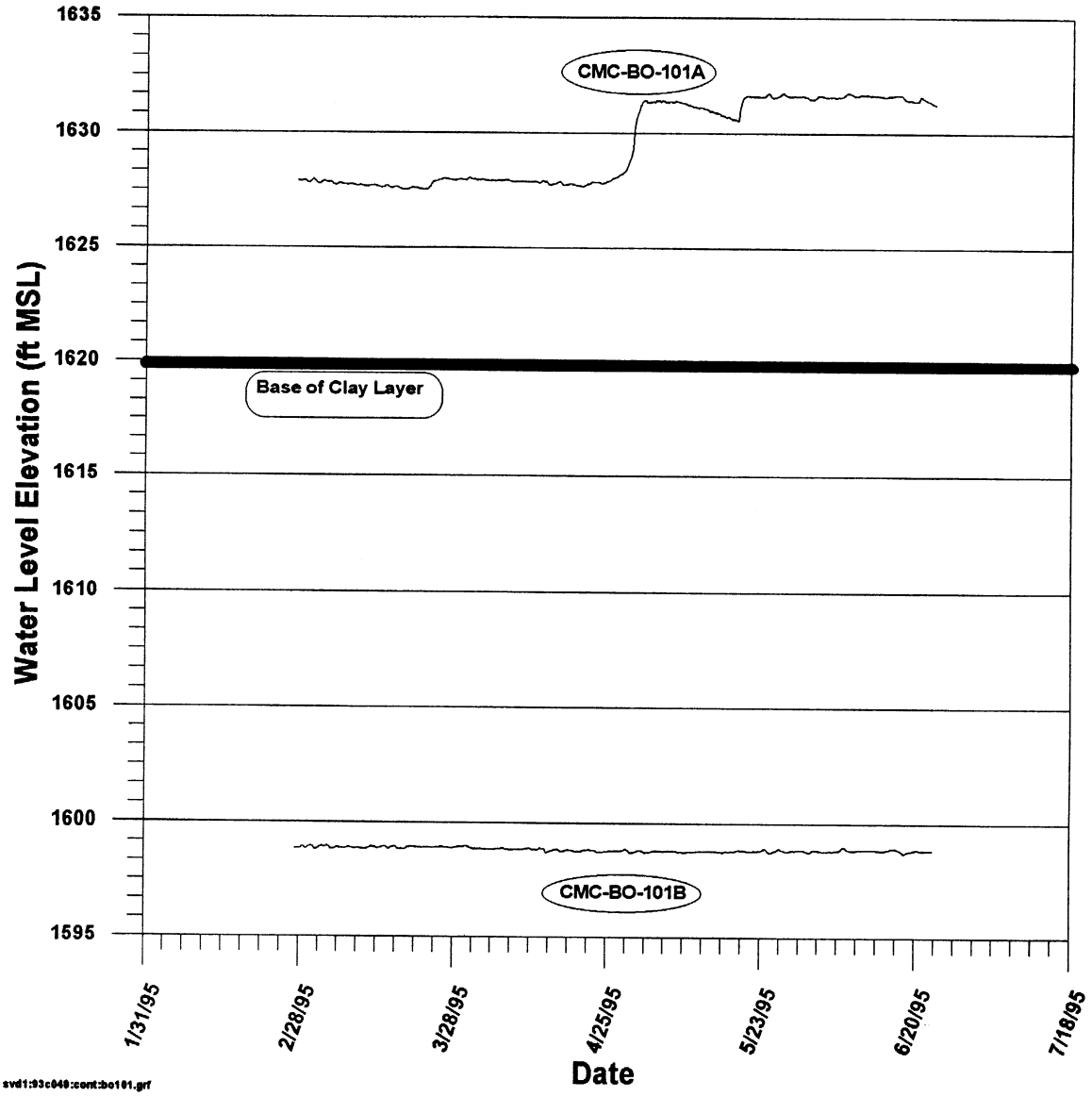
$$$$DATE$$$ $USER



Foth & Van Dyke			
REVISED	DATE	BY	DESCRIPTION
1	11/98	MLD2	REVISED FOR 1998 UPDATE

CHECKED BY:	JKSI	DATE: NOV.'95
APPROVED BY:	SVDI	DATE: NOV.'95
APPROVED BY:	JWS	DATE: NOV.'95

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FIGURE 3.6-47

TRANSIENT GROUNDWATER LEVELS IN THE BUR OAK WETLAND

Scale: AS SHOWN		Date: NOVEMBER, 1995	
Prepared By: Foth & Van Dyke		By: GAM	93C049

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Nicolet Minerals Company

Environmental Impact Report

Section 3.7

Surface Water and Bottom Sediments

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3.7 Surface Water and Bottom Sediments

Data collection and technical studies for the project's surface water monitoring program have been completed for three purposes, 1) to provide data which would be used for the development of WPDES effluent limits, 2) to provide background surface water quality and quantity information, and 3) to provide background surface water sediments information. A discussion of this work is contained in this section of the EIR.

3.7.1 Field and Laboratory Methods

A considerable amount of data has been collected over the past 15 years for the surface waters and sediments within the study area. The historical data collected during these previous studies are presented throughout the text for comparison purposes. Many methodological and analytical advances have occurred since the time of the collection of these data. In particular, the use of "clean techniques" has only been available during the latest 1993-1997 studies. Coupled with analytical advances, these clean techniques should allow greater resolution and sample integrity than previously observed. While changes in methodology and analytical techniques have occurred since the existing water and sediment chemistry data was collected, the historical data has value because it provides a good reference point as to conditions that existed at the time of collection.

Accepted flow monitoring methods have not changed in the past 20 years. As a result, existing data will be used for environmental studies and as part of the project permit applications. Since the time that the original permitting efforts ceased, additional monitoring of lake levels has been conducted on a regular basis by both NMC and Foth & Van Dyke employees. This information is also included in the data base.

A detailed surface water sampling and quality assurance plan (Foth & Van Dyke, 1993) was prepared for the project and submitted to WDNR in December 1993. This plan was also appended to the February 1994 NOI/SOS (Foth & Van Dyke, 1994). In March of 1995 an update to the December 1993 surface water sampling and quality assurance plan was submitted to the WDNR and USCOE (Foth & Van Dyke, 1995). This update, which is included in Appendix 3.7-1, incorporated and supplemented the December 1993 plan.

3.7.1.1 Monitoring Locations

Surface waters in the project area were selected for water quality monitoring and for stream flow and lake level monitoring to establish regional baseline data and to support the evaluation of project design alternatives. Table 3.7-1 provides a listing of the surface water sampling points selected for the project. Figures 3.7-1 and 3.7-2 show the location of these surface water monitoring sites.

The original surface water monitoring program presented in the NOI/SOS included four additional sites not identified in Table 3.7-1. These were SG-23 (Creek 12-9), LG-30A (Martin Spring), LG-31 (Hoffman Springs) and LG-14 (Rice Lake). Sites SG-23 and LG-14 were not monitored because access was unavailable. Sites LG-30A and LG-31 were not monitored for levels since their outlet streams were monitored for flow. In addition, a single surface water

Table 3.7-1

Surface Water Monitoring Frequency

Surface Water	Site ID	Water Quality				
		Monthly Monitoring	Quarterly Monitoring	Single Monitoring Event	Peak Flow Monitoring Event	Flow/Lake Level Monitoring
Swamp Creek	SG-2	X[1]				X[2]
Swamp Creek	SG-2A					X[2]
Swamp Creek	SG-3	X[1]				X[2]
Swamp Creek	SG-5A		X			X[3]
Swamp Creek	SG-AB	X[1]			X	X[2]
Swamp Creek	SG-AA					X[2]
Swamp Creek	SG-V	X[1]			X	X[2]
Wolf River	SG-Y	X[1]			X	X[2]
Wolf River	SG-CC	X[1]			X	X[2]
Pickerel Creek	SG-19	X[1]				X[2]
Pickerel Creek	SG-19A					X[2]
Hemlock Creek	SG-6	X[1]				X[2]
Hemlock Creek	SG-6A					X[2]
Creek 11-4	SG-30	X[1]				X[2]
Hoffman Creek	SG-E	X[1]				X[2]
Outlet Creek	SG-4		X			X[3]
Skunk Lake	LG-15	X[1]				X[4]
Duck Lake	LG-12	X[1]				X[4]
Deep Hole Lake	LG-13	X[1]				X[4]
Little Sand Lake	LG-7	X[1]				X[4]
Oak Lake	LG-11	X[1]				X[4]
Rolling Stone Lake	LG-9		X			
Ground Hemlock Lake	LG-24			X		
Pelican River	SG-PR			X		
Haymeadow Creek	SG-HC			X		

Table 3.7-1 *(Continued)*

Surface Water	Site ID	Water Quality				
		Monthly Monitoring	Quarterly Monitoring	Single Monitoring Event	Peak Flow Monitoring Event	Flow/Lake Level Monitoring
Neptune Creek	SG-NC			X		
Monico Creek	SG-MC			X		
Wisconsin River	WR-HR-01			X		
Wisconsin River	WR-HR-02			X		
Wolf River	SG-WR-3			X		
Creek 19-14	SG-1914			X[1]		
Lake 35-7	LG-357			X[1]		
Drainage Canal to Pickerel Creek	SG-19B			X[1]		

[1] Low level metal analyses performed.
[2] Monthly flow monitoring.
[3] Quarterly flow monitoring.
[4] Lake level monitoring during ice-free periods.

Prepared by: GJB1
Checked by: JJA
Revised by: GJB1
Checked by: JWS

quality monitoring event was performed at SG-PR, SG-HC, SG-NC, SG-MG, SG-WR-1, SG-WR-2 and SG-WR-3 as part of the evaluation of alternative discharge sites. Three sites, SG-1914, SG-19B, and LG-357, had a single surface water quality monitoring event in 1997 as a part of the evaluation of mitigation impact sites. This monitoring was not part of the original program outlined in the NOI/SOS.

In order to establish baseline conditions, a sediment monitoring program was established. The surface water sediments collected for this purpose were sampled from the sites identified in Table 3.7-2. Figures 3.7-1 and 3.7-2 also show the location of all sediment collection sites.

3.7.1.2 Methodology

Table 3.7-1 identifies the type and frequency of surface water monitoring performed at the listed sites. Water quality monitoring was performed either on a monthly, quarterly or single event basis. Peak flow water monitoring was performed on two occasions during major runoff events. Flow monitoring was performed either monthly or quarterly. Lake level monitoring was performed during ice-free periods.

Analytical parameters for stream and lake water quality monitoring are listed in Table 3.7-3. Stream flow monitoring procedures, sample collection procedures, analytical methods, detection limits, quality control targets; etc., are outlined in the Updated Surface Water Quality Assurance Plan (Foth & Van Dyke, 1995) included in Appendix 3.7-1. Surface water samples collected from selected sites identified in Table 3.7-1 were analyzed for low level metals to define background conditions in the event that treated effluent from the project would be directed to them for discharge or for mitigation. The selected sites are within the drainage basin of the Wolf River which has been classified as an Outstanding Resource Water (ORW). As a result, advanced analytical techniques, which have detection limits lower than the standard techniques, were used to quantify aluminum, cadmium, chromium, copper, lead, mercury, and zinc for samples collected from these sites. The parameters measured with the advanced analytical techniques are referred to as "low level metals." The list of parameters for the SG-PR, SG-HC, SG-NC, SG-MC and SG-WR-3 single event water quality monitoring sites was different than that for the other water quality monitoring sites. The parameters for these five sites are listed in Table 3.7-4. Samples WR-HR-01 and -02 from the single event water quality site were analyzed for most of the parameters listed in Table 3.7-3. A summary of the data associated with the single sampling events is included in Appendix 3.7-8. Laboratory data sheets are included in Appendix 3.7-9. The list of parameters for the LG-24 single event water quality monitoring site was different from that of the others. Ground Hemlock Lake (LG-24) sampling was conducted in March 1995 to confirm that this lake was primarily fed by groundwater. This surface water body is not expected to be impacted by the project and, therefore, no low level metal data was collected. The parameters for this site are listed in Table 3.7-4a. A summary of the 1995 data associated with the sampling event is included in Appendix 3.7-8. Laboratory data sheets are included in Appendix 3.7-9.

Table 3.7-2

Surface Water Sediment Sampling Sites

Surface Water	Sampling Station
Swamp Creek	D
Swamp Creek	E
Hemlock Creek	A-1
Oak Lake	G
11-4 Creek (Martin Springs)	M-3
Pickerel Creek	M-5
Rolling Stone Lake	M-2
Rolling Stone Lake	M-4
Deep Hole Lake	L
Duck Lake	K
Little Sand Lake	H
Little Sand Lake	I
Wolf River	Y
Wolf River	Z

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Table 3.7-3

Surface Water Quality Monitoring Parameters

Parameters		
Alkalinity	Phosphorus (Soluble)	Molybdenum
Bicarbonate	Phosphorus (Total)	Selenium
Biochemical Oxygen Demand (5 day)	Modified SAR	Silver
Carbonate	Sulfate	Beryllium
Chemical Oxygen Demand	Cations (Sum)	Thallium
Chloride	Anions (Sum)	Nickel
Cyanide	Cation Anion Balance	Antimony
Fluoride	Total Dissolved Solids	Magnesium
Hardness	Total Suspended Solids	Potassium
Nitrogen-Ammonia	Boron	Sodium
Nitrogen-Nitrate	Calcium	Aluminum
Nitrogen, Kjeldahl	Arsenic	Cadmium
Oil and Grease	Barium	Copper
pH	Iron	Lead
Conductivity	Iron (Total)	Mercury
Temperature	Manganese	Zinc
Dissolved Oxygen	Manganese (Total)	Chromium (Total)
Turbidity		

Prepared by: JJA
Checked by: JWS

Table 3.7-4

Single Event Surface Water Quality Monitoring Parameters

Parameters		
Chloride	Arsenic	Aluminum
Cyanide	Selenium	Cadmium
Nitrogen-Ammonia	Silver	Chromium
pH	Beryllium	Copper
Conductivity	Thallium	Lead
Temperature	Nickel	Mercury
Dissolved Oxygen	Antimony	Zinc

Prepared by: JJA
Checked by: JWS

Table 3.7-4a

Ground Hemlock Lake Single Event Water Quality Monitoring Parameters

Parameters		
Antimony	Potassium	Chloride
Arsenic	Selenium	Cyanide
Barium	Silver	Fluoride
Beryllium	Sodium	Alkalinity
Boron	Thallium	BOD
Calcium	Phosphorus, Total	COD
Iron, Total	Phosphorus, Dissolved	Hardness
Iron, Dissolved	Nitrogen-Ammonia	Oil & Grease
Magnesium	Nitrogen-Nitrate	Oxygen, Dissolved
Manganese, Total	Nitrogen-Organic	pH
Manganese, Dissolved	Sulfate	Temperature
Molybdenum	Solids, Dissolved	Turbidity
Nickel	Solids, Suspended	

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Checked by: RTJ

The list of parameters for the SG-1914, SG-19B, and LG-357 single event water quality monitoring sites was also different from that of the other water quality monitoring sites. The parameters selected were intended to give an indication of the water quality in these water bodies and provide data for calculation of preliminary effluent limits if these sites required the addition of mitigation water. If needed, more detailed background information will be collected prior to mine development. The parameters for these sites are listed in Table 3.7-4b. A summary of the 1997 data associated with the sampling event is included in Appendix 3.7-8. Laboratory data sheets are included in Appendix 3.7-9.

Regarding lake sampling, it should be noted that in contrast to the procedures outlined in Appendix 3.7-1, from April 1994 through July 1994 a non-metallic canoe was used exclusively as a work area for the sample collection team. Based on comments received from WDNR in August 1994, the sampling team subsequently used a plastic drop cloth to prepare a work surface in the bottom of the canoe. This procedure modification was one of the additions included in the update found in Appendix 3.7-1.

Analytical parameters for the sediment sampling program are shown in Table 3.7-5. The table also lists analytical methods, detection limits, and quality control targets used for the program.

Sediment samples from aquatic substrates were collected in October 1994. Core samples were collected using a Wildco 2" Hand Corer. The lexan corer tube was equipped with a lexan nosepiece and PVC flapper and liners. The core tube handle was constructed of 3/16-inch stainless steel and made to receive 5, 10 and 15 foot extension handles. Liners were fitted with plastic eggshell core catchers designed to capture the core while extracting it from the substrate. River sediment samples were collected using the corer with the five foot extension handle. Lake samples were collected from a canoe using the corer with the ten foot extension handle.

For each site, a new core liner was installed in the core sampler. Liners were inserted from the nosepiece end of the sampler. Once the liner was installed, an eggshell core catcher was inserted into the liner end followed by capping of the corer with the tapered nosepiece. Cores were obtained by applying pressure on the handle.

The NOI/SOS (Foth & Van Dyke, February 1994), described a plan to collect sediment samples from the upper one foot of substrate. Most of the sites contained a substrate of firm composition. This firm composition prevented the collection of a 12-inch sediment sample in a single core effort. One to six-inch core increments were the average core capable of being extracted. Therefore, additional cores were taken until a total of 12 inches of cored material was obtained for a sample. Details of the specific composite core collected at each site are provided in Table 3.7-6.

As each core was extracted, it was transferred to a one-liter plastic bottle. Liquid volumes captured during sample collection were discarded from the top of the sampler. Cores were removed from the liner by dissembling the core sampler at the nosepiece. Because of the force

Table 3.7-4b

1997 Single Event Surface Water Quality Monitoring Parameters

Parameters		
Alkalinity, Bicarbonate	COD	Nitrogen - Kjeldahl
Alkalinity, Total	Color	Oil and Grease
Alkalinity, Carbonate	Conductivity	pH
Aluminum	Copper	Phosphorus, Total
Arsenic	Cyanide	Phosphorus, Reactive
Barium	Dissolved Oxygen	Selenium
BOD-5 day	Fluoride	Silver
Boron	Hardness	Solids, Total Volatile
Cadmium	Iron	Solids, Total Suspended
Calcium	Lead	Solids, Total Dissolved
Chloride	Manganese	Sulfate
Chlorophyll	Mercury	Turbidity
Chromium, Total	Molybdenum	Zinc
Chromium, Trivalent	Nitrogen - $NO_2 + NO_3$	
Chromium, Hexavalent	Nitrogen - Ammonia	

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Checked by: JWS

Table 3.7-5

Parameter and Quality Assurance Targets for Bottom Sediment Monitoring

Parameter	Method Reference	Matrix	Precision Targets	Accuracy Targets	TDL (mg/kg)
Chloride	EPA 9252	SW Sed.	25	80-120	1
Cyanide	EPA 9010	SW Sed.	25	80-120	0.5
Fluoride	EPA 340.2	SW Sed.	25	80-120	0.5
Nitrogen-Organic	EPA 350.2	SW Sed.	25	80-120	50
Nitrogen-Kjeldahl	EPA 351.3	SW Sed.	25	80-120	50
Oil and Grease	EPA 413.2	SW Sed.	25	75-125	50
pH	EPA 150.1	SW Sed.	25	N/A	0.1 SU
Phosphorous (total)	EPA 365.3	SW Sed.	25	80-120	5
Total Solids	SM 209F	SW Sed.	25	N/A	1
Total Volatile Solids	SM 209F	SW Sed.	25	N/A	10
Boron	EPA 6010	SW Sed.	25	75-125	10
Calcium	EPA 6010	SW Sed.	25	75-125	100
Aluminum	EPA 6010	SW Sed.	25	75-125	20
Arsenic	EPA 7060	SW Sed.	25	75-125	5
Barium	EPA 6010	SW Sed.	25	75-125	4
Cadmium	EPA 6010	SW Sed.	25	75-125	1
Copper	EPA 6010	SW Sed.	25	75-125	3
Iron (total)	EPA 6010	SW Sed.	25	75-125	5
Lead	EPA 7421	SW Sed.	25	75-125	0.1
Manganese	EPA 6010	SW Sed.	25	75-125	1
Manganese (total)	EPA 6010	SW Sed.	25	75-125	1
Mercury	EPA 7471	SW Sed.	25	75-125	1

Table 3.7-5 *(Continued)*

Parameter	Method Reference	Matrix	Precision Targets	Accuracy Targets	TDL (mg/kg)
Molybdenum	EPA 6010	SW Sed.	25	75-125	0.1
Selenium	EPA 7740	SW Sed.	25	75-125	2
Silver	EPA 6010	SW Sed.	25	75-125	5
Zinc	EPA 6010	SW Sed.	25	75-125	1
Chromium (total)	EPA 6010	SW Sed.	25	75-125	2
Beryllium	EPA 6010	SW Sed.	25	75-125	3
Thallium	EPA 7841	SW Sed.	25	75-125	1
Nickel	EPA 6010	SW Sed.	25	75-125	7.5
Antimony	EPA 6010	SW Sed.	25	75-125	3
Magnesium	EPA 6010	SW Sed.	25	75-125	5
Potassium	EPA 6010	SW Sed.	25	75-125	100
Sodium	EPA 6010	SW Sed.	25	75-125	100

SW Sed. = Surface Water Sediment.
TDL = Target Detection Limit.
SU = Standard Units.

Prepared by: GJB1
Checked by: JJA

SM references the *Standard Methods for the Examination of Water and Wastewater,* 1989.

EPA references either *Methods for Chemical Analysis of Water and Wastes*, USEPA 600/4-79-020, Revised March 1983, or *Test Methods for Evaluating Solid Waste* (SW846) USEPA, September, 1986.

Table 3.7-6

Sediment Core Extraction Increments by Site for October 1994 Sampling

Sampling Location	Sampling Station	Collection Increments (Total Inches/Total Number of Core)
Swamp Creek (Swampy Lane)	D	1" per core/12 cores
Swamp Creek (Upstream of Hwy. 55)	E	6" per core/2 cores
Hemlock Creek (Deep Hole Road Bridge)	A-1	6" per core/2 cores
Oak Lake (East end)	G	1" per core/12 cores
11-4 Creek (Martin Springs) (North Rolling Stone Lake Road)	M3	3" per core/3 cores
Pickerel Creek (North Rolling Stone Lake Road)	M5	2" per core/3 cores
Rolling Stone Lake (North end)	M2	4" per core/3 cores
Rolling Stone Lake (South end)	M4	3" per core/2 cores
Deep Hole Lake (South end)	L	4" per core/3 cores
Duck Lake (South end)	K	2" per core/6 cores
Little Sand Lake (North end)	H	1" per core/12 cores
Little Sand Lake (South end)	I	6" per core/2 cores
Wolf River (Downstream of Lower Post Lake)	Y	2" per core/5 cores
Wolf River (Cty. T)	Z	6" per core/2 cores

Prepared by: WMW
Checked by: JJA

required to obtain the sample, the liners were wedged onto the nosepiece. Therefore, by removing the nosepiece, the nosepiece and liner with sample intact could be removed as a unit. Cores were removed from the liner by inverting the liner and shaking the core into the plastic bottle. Once filled, the plastic bottles were capped, labeled, and stored in a cooler filled with ice. Samples were hand delivered to the lab within 24 hours of collection.

Documentation of surface water monitoring sampling procedures, sample preservation, sample handling and shipping, etc., was performed in accordance with the procedures outlined in Appendix 3.7-1. In addition, representatives of the WDNR were informed in advance of the schedule of sample collection so that they were able to observe procedures and/or split samples. With the exception of the December 1994 sampling event, WDNR personnel were present during portions of all monthly sampling events from November 1993 through October 1994.

The current surface water data collection for the project occurred between November 1993 and December 1997. This section of the EIR includes all data collected and reported as part of the 1993-1997 surface water sampling program, in addition to pertinent data collected in the 1970s and 1980s. The statistical analyses performed on the 1993/1995 data base were completed using a value of zero for all results below method detection levels. Alternative methods of addressing non-detects when calculating arithmetic means are available and in some instances may be appropriate to use. Future evaluations may incorporate the use of alternate methods for making this calculation.

The information in the current project's data base has undergone several levels of review during the course of this project. As a result of these reviews, the laboratory was asked to verify certain laboratory results. In most cases, the laboratory verified the results as originally reported, however, in a limited number of cases, the reported results were corrected. The data base in Appendix 3.7-8 contains the verified and corrected laboratory results, while the laboratory results sheets in Appendix 3.7-9 do not. Corrections included in the data base are documented in the form of a table and in correspondence from the laboratory, both of which are included at the beginning of Appendix 3.7-9.

3.7.2 Regional Hydrologic Characterizations

3.7.2.1 Drainage Basins

The study area lies within the area of northeast Wisconsin that is drained by the Wisconsin, Wolf, Fox, Peshtigo, Oconto, and Menominee Rivers. The area is entirely within the northern headwaters of the Wolf River drainage basin as shown on Figure 3.7-3. The Wolf River originates approximately 20 miles northwest of the site area and flows south to Lake Poygan in Winnebago County (WDNR, 1977), which is approximately 100 miles south of the study area. The Fox River drains the Lake Poygan-Winnebago system in a northeasterly direction to Green Bay. The Wolf River basin is bordered on the west by the Wisconsin River basin. The Wisconsin River flows south and then west to the Mississippi River. To the north and east of the Wolf River basin, drainage is provided by the Menominee, Peshtigo, and Oconto rivers, which

all flow southeast to Green Bay. In the upper Wolf River basin, the relatively slow-flowing streams frequently pass through lakes and wetlands. Stream gradients were determined from topographic maps and are generally in the range of 7.7 to 10 feet/mile (EMC, 1985).

3.7.2.2 Regional Precipitation

Average annual precipitation in the regional study area is 30.36 inches as reported in Section 3.4.2, Climatology-Meteorology. Precipitation is greatest from May through September and least during mid-winter when it generally occurs as snow. The mean annual accumulation of snow ranges from 40 to 60 inches. Precipitation records measured at the North Pelican at Pelican Lake meteorological station, approximately 15 miles west of the site, are assumed to be representative of the region. Average monthly precipitation values for the period 1961 through 1990 inclusive are given in Table 3.7-7. On the average, the wettest month is June with almost fourteen percent of the annual precipitation and the driest is February with only 2.7 percent.

3.7.2.3 Regional Runoff

Total annual surface water runoff in the drainage basins in the regional study area ranges from 11 to 13 inches (Hindall, 1976). For the Wolf River basin the annual stream discharges range from 10 to 13 inches of surface water runoff per year (Hindall, 1976). The nearest long-term stream gaging station to the site area is the USGS station on the Wolf River at Langlade as shown in Figure 3.7-4. The surface drainage area upstream from this gage encompasses 463 square miles and includes the site area. Mean annual discharge at the Langlade station for the periods of March 1966 through September 1979 and October 1980 through September 1997 is approximately 456 cubic feet/second (USGS, 1997). This discharge rate corresponds to an average surface water runoff depth of 13.37 inches from the surface drainage area of the Wolf River measured by this gage. Statistical monthly stream flow data for the Wolf River at Langlade are given in Table 3.7-8. January and February are typically the months of lowest stream runoff, because most precipitation is retained on the ground surface as snow and ice.

3.7.2.4 Regional Evapotranspiration

Evapotranspiration is defined as the movement of water through vegetation and from a free surface to the atmosphere. Evapotranspiration (E) is generally computed as the difference between precipitation (P) and stream discharge (Q), assuming that there is no net flux of ground water from the regional area (Freeze and Cherry, 1979), and that the amount of water held in storage in both the ground water (S_G) and surface water (S_S) reservoirs remains constant. That is, the average annual amount of ground water that flows from the aquifer is equal to the amount of recharge to the aquifer within the designated watershed or drainage basin, regardless of the porosity/permeability of the aquifer(s), and that the average annual amount of surface water lost

Table 3.7-7

Historic Meteorological Data

Parameter	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov	Dec.	Year
Temperature Data (°F)[1]													
Average High	20.1	25.8	36.9	51.9	66.2	73.2	77.2	73.6	64.4	54.0	37.8	24.1	50.4
Average Low	0.1	2.6	15.0	28.8	40.1	49.7	54.9	53.0	45.4	35.3	23.2	6.9	29.6
Precipitation (in)[1]	1.08	0.82	1.62	2.35	3.18	3.58	3.73	4.14	3.99	2.46	1.96	1.45	30.36

Note: [1]Monthly averages for 30 year period (1961-1990) as measured at North Pelican at Pelican Lake meteorological station.

Source: State Climatologist (Anderson, 1995).

Prepared by: JJA
Checked by: JWS

Table 3.7-8

USGS Statistical Monthly Stream Discharge Record for Water Years 1966-1997 Wolf River at Langlade, WI
USGS Station Number 04074950

	Mean Monthly Stream Discharge (cfs)											
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
Mean	447	455	379	323	317	472	832	623	494	361	330	416
Max	813	788	578	548	482	1227	1330	1312	1013	874	632	813
(Wy)	1986	1986	1986	1969	1984	1973	1976	1973	1991	1968	1972	1968
MIN	196	204	226	193	213	278	263	319	173	183	188	171
(Wy)	1977	1977	1977	1977	1982	1982	1990	1987	1988	1989	1989	1989

Summary Statistics	**For 1996 Calendar Year**		**For 1997 Water Year**		**Water Years 1966 - 1997**	
Annual Total	191311		167654		N.A.	
Annual Mean	523		459		456	
Highest Annual Mean					666	1973
Lowest Annual Mean					326	1988
Highest Daily Mean	2420	April 26	1630	April 6	2420	April 26, 1996
Lowest Daily Mean	297	September 3	250	August 12	137	July 7 1988

(Note: Stream flow data reported in cubic feet per second [cfs])

Table 3.7-8 *(Continued)*

Summary Statistics	For 1996 Calendar Year		For 1997 Water Year		Water Years 1966 - 1997	
Annual Seven -Day Minimum	308	September 1	255	August 7	142	September 28 1989
Instantaneous Peak Flow			1790	April 6	2440	April 26, 1996
Instantaneous Peak Stage			9.85	April 6	10.40	April 26, 1996
Instantaneous Low Flow			247	August 12	119	November 8 1976
Annual Runoff (CFSM)	1.13		0.99		0.98	
Annual Runoff (Inches)	15.37		13.47		13.37	
10 percent exceeds	754		620		766	
50 percent exceeds	412		389		379	
90 percent exceeds	331		321		242	

N.A. = Not applicable.
Drainage Area 463 square miles.

Source: USGS, 1997.

Prepared by: GJB1
Checked by: JJA
Revised by: GJB1
Checked by: LCT

from storage in the surface water system (i.e., in lakes and ponds) is replaced by precipitation. These assumptions have been proven to be generally accurate by empirical studies. Thus, this concept is expressed in the equation (Freeze and Cherry, 1979, p. 205):

$$P = Q + E + \Delta S_S + \Delta S_G$$

where $\Delta S_S = \Delta S_G = 0$ for a given drainage basin. Therefore, the general equation for evapotranspiration becomes:

$$E = P - Q$$

Each unit of this equation has several components that can be evaluated in detail for a specific stream flow rate analysis; however, for a general description of a regional system, such as that described in this subsection, the general equation is sufficient. On this basis, average annual evapotranspiration for the Wolf River surface drainage basin measured by the USGS station at Langlade, in conjunction with the precipitation records from the North Pelican at Pelican Lake meteorological station, is approximately 17.3 inches.

3.7.2.5 Surface Water Use

Water law in Wisconsin is essentially riparian, which means that water rights are acquired with the land adjacent to surface waters. In Wisconsin, permits for diversion of surface water are required for irrigation or agricultural purposes. In the Wolf River basin in Forest and Langlade Counties, there are three diversions of surface water for irrigation registered with the WDNR (Table 3.7-9), all of which are outside the study area. There are no known diversions of surface water for domestic or industrial use in Forest or Langlade Counties, although such diversions may exist on the lower Wolf River.

3.7.3 Hydrologic Characterizations of the Study Area

Surface topography is used to define watersheds or drainage basins. The project area is within the Wolf River drainage basin which is part of the larger Fox River Basin, as illustrated in Figure 3.7-4. Drainage basins are typically separated by defining the high points between the drainage basins. The drainage basins discussed in this section are delineated by the channelized flow in a surface stream and are tributaries to the Wolf River Basin which in turn can be subdivided into numerous smaller drainage basins. The Crandon Project site is near three drainage basins, the Swamp Creek Basin, Hemlock Creek Basin and the Pickerel Creek Basin as shown on Figure 3.7-4. The Hemlock Creek Basin is contained within the Swamp Creek Basin.

These drainage basins are characterized by forested land, lakes, wetland areas and perennial streams that provide drainage paths.

Table 3.7-9

Irrigation Diversion Permits for the Wolf River Drainage Basin in Forest and Langlade Counties

Permittee		Stream	County	Location			Maximum Rate (cfs)	Docket Number
				Section	TWP.	Range		
1.	William Koehler & John Witman	Lily River	Langlade	11, 14, 15	31N 32N	13E	2.22	2-WP-1076
2.	Bula Potato Farms	Wolf River	Langlade	12, 13	34N	11E	2.00	2-WP-1092
3.	Schroeder Brothers	Pollack Creek	Langlade	3, 4, 10	34N	11E	1.50	2-WP-1120

Source: Lang, 1995.

Prepared by: GJB1
Checked by: JJA

The topographic features of the environmental study area are a reflection of its glacial origin. The drainage basins are underlain by glacial drift, including fine grain materials as well as sand and gravel. The surface waters in the drainage basins interact with groundwater in various ways. While some streams such as Swamp Creek, are fed by groundwater movement into them, others provide a source of water to the groundwater system. The rate of interaction between surface waters and groundwater is governed by the porosity of the soil type, stream or lake bed characteristics and the gradients of the groundwater/surface water systems.

The wetlands and the forested lands located within the study area are described in detail under Terrestrial Ecology, Section 3.9, and the topographic features, geology, and glacial drift are described in Section 3.5, Geology. Groundwater characteristics are presented in Section 3.6, Groundwater.

The rate of stream flow is generally dependent on the drainage basin characteristics. Size, surface gradients, vegetation and soil types will impact the stream flow rates. Each surface water system is unique and will exhibit its own characteristics.

Peak stream flow rates are usually associated with spring time snow melt and rain events. Major rain events at other times of the year may also result in peak flow conditions. Flooding conditions will often result in an increase in erosion in the drainage basin. Therefore, peak flow rates will often be associated with maximum sediment transport. The sampling events associated with these studies attempted to capture peak flow conditions on Swamp Creek and the Wolf River.

Low stream flow conditions are usually associated with the winter season and prolonged periods of dry weather during the summer. For example, while precipitation may be available in the winter, no runoff occurs because the moisture is stored as snow. Low flow conditions may also be associated with higher dissolved solids in streams. This condition is typically attributed to a lack of dilution. Routine monthly sampling was conducted to provide data for both high and low flow conditions.

The regional study area lies within the physiographic province known as the Northern Highlands (Hindall, 1976). The Northern Highlands encompasses all or part of 16 Wisconsin counties. Average annual sediment yields from the Northern Highlands region, based on USGS records, are generally less than 10 tons/square mile, and average annual values recorded at 12 stations in the Northern Highlands ranged from 3.1 to 31 tons/square mile (Hindall, 1976). This annual area sediment yield of 10 tons/square mile corresponds to an annual average surface water runoff of 13 inches, which produces an average concentration of approximately 11 mg/L (Hindall, 1976). This suspended sediment concentration is used herein as a standard for comparison to surface water sediment yields within the regional study area.

Rivers and lakes are dynamic entities and therefore will react to major rain events, spring runoff and dry periods. The impact of these flows on lakes is measured by a change in the lakes' water elevations. Although the impact of changes in precipitation on lakes is not typically of the same

magnitude as streams, the characteristics as with streams of a lake's structure and drainage basin will influence the lakes reaction to excessive precipitation or prolonged dry periods. A lake with a small drainage basin which is not fed by groundwater, will typically exhibit the greatest change in elevation due to excessive precipitation or prolonged dry periods. These lakes are in contrast to those which have large drainage basins and are also fed by groundwater. Such lakes will tend to have outlet structures which provide relief to an increase in water input. Groundwater can also provide a stable source of water to a lake and therefore lessen the impacts of changes in input such as prolonged periods of dry weather.

Natural lakes in Wisconsin frequently are classified by the source of water supply. Based on water source and outflows, four categories of lakes as described below have been identified in the 1995 WDNR publication titled, *Wisconsin Lakes* (WDNR, 1995).

- "Drainage lakes - Lakes [that] have both an inlet and outlet where the main water source is stream drainage. Most major rivers in Wisconsin have drainage lakes along their course. Drainage lakes owing one-half of their maximum depth to a dam are considered to be artificial lakes or impoundments."

- "Seepage lakes - These lakes do not have an inlet or an outlet, and only occasionally overflow. As landlocked waterbodies, the principal source of water is precipitation or runoff, supplemented by groundwater from the immediate drainage area. Since seepage lakes commonly reflect groundwater levels and rainfall patterns, water levels may fluctuate seasonally. Seepage lakes are the most common lake type in Wisconsin."

- "Spring lakes - These lakes have no inlet, but do have an outlet. The primary source of water for spring lakes is groundwater flowing into the bottom of the lake from inside and outside the immediate surface drainage area. Spring lakes are the headwaters of many streams and are a fairly common type of lake in northern Wisconsin."

- "Drained lakes - These lakes have no inlet, but like spring lakes, have a continuously flowing outlet. Drained lakes are not groundwater-fed. Their primary source of water is from precipitation and direct drainage from the surrounding land. Frequently, the water levels in drained lakes will fluctuate depending on the supply of water. Under severe conditions, the outlets from drained lakes may become intermittent. Drained lakes are the least common lake type found in Wisconsin."

Of the five lakes in the immediate vicinity of the project, Skunk Lake generally falls into the "seepage lake" category. Oak, Duck, and Deep Hole Lakes generally fall into the "drained lake" category since they do not have continuous flowing inlets, have outlets, and are not groundwater-fed lakes. Little Sand Lake generally falls into the "drainage lake" category since it has both an intermittent inlet and outlet and its main source of water comes from surface water runoff and stream drainage.

These five lakes can be further divided into two subcategories, "perched" and "groundwater head dependent" lakes based on their interaction with the groundwater table. Oak Lake is a perched lake. The bottom of this lake's silty clay lake bed is above the groundwater table. Therefore, the level of the lake is not dependent on the groundwater elevation. While the lake recharges the groundwater in the area, the lake bed restricts the amount of water leaving the lake. A very limited amount of water leaves the lake through percolation.

Duck, Deep Hole, Skunk and Little Sand Lakes can be classified as "groundwater head dependent" lakes. While the elevation of these lake surfaces are above the groundwater system, the bottom of the lake beds are connected to the groundwater system. The elevations of the lakes are influenced by the elevation of the groundwater system. The lake beds in these lakes limit percolation from the lakes to the groundwater system, thus maintaining a higher water elevation in the lakes than the surrounding groundwater system. Further discussion on the relationship between groundwater elevations and surface water elevations can be found in Section 3.6.

Ordinary high water mark elevations, determined and surveyed by the WDNR in July 1983, are shown in Table 3.7-10. Information relating to the determination of ordinary high water mark elevations is included in Appendix 3.7-2. The ordinary high water mark is the point on the bank or shore up to which the presence and action of the water is so continuous as to leave a distinct mark, either by erosion, destruction of terrestrial vegetation, or other easily recognized characteristic. The table also includes statistical information regarding lake levels that have been recorded as part of project activities since the 1970s.

Table 3.7-10

Water Level Summary for Lakes in the Study Area

Location	Gage	Ordinary High Water Mark	Historical Water Level Statistics[1]		
			Maximum	Minimum	Mean
Oak Lake	LG-11	1633.17	1634.42	1632.12	1633.21
Little Sand Lake	LG-7	1591.96	1593.47	1590.81	1592.07
Rolling Stone Lake	LG-9	1535.35	1535.92	1534.94	1535.28
Duck Lake	LG-12	1611.09	1612.88	1610.24	1611.74
Deep Hole Lake	LG-13	1605.83	1607.09	1604.86	1605.64
Skunk Lake	LG-15	1598.09	1599.85	1595.18	1597.66

[1]Statistics through October 1994.

Prepared by: JJA
Checked by: SVD1

3.7.4 Swamp Creek Drainage Basin

A portion of the project area lies within the Swamp Creek drainage basin as shown on Figure 3.7-4. The Swamp Creek drainage basin is located in the northcentral portion of the Wolf River drainage basin as shown on the figure. Headwater streams of the Swamp Creek drainage basin above Rice Lake include upper Swamp Creek which originates from Lake Lucerne, Hemlock Creek which originates from Ground Hemlock Lake, Outlet Creek which originates from Lake Metonga, Hoffman Creek whose headwater is Hoffman Springs, and Creek 19-14. Swamp Creek flows westerly to Rice Lake and then southerly to its confluence with the Wolf River. Water bodies included in the discussion of the Swamp Creek drainage basin are Rice Lake; Hemlock, Swamp, Outlet, 19-14, and Hoffman creeks; Hoffman Springs; Ground Hemlock Lake; Oak Lake; and Lake 35-7.

3.7.4.1 Rice Lake

The data presented for Rice lake is taken from previous project studies completed in the 1970s and 1980s (EMC, 1985). Unsuccessful attempts were made in 1994 to obtain access to Rice Lake from the Mole Lake Sokaogon Chippewa Community. Because of this, additional current data is unavailable.

Rice Lake is located approximately 2.7 miles northwest of the ore body. As shown in Table 3.7-11, it has a total area of 208 acres and a maximum depth of six feet (EMC, 1985). Over much of the lake, depths are typically four feet or less. The shoreline vegetation consists of conifer, shrub, and marsh wetland. The predominant lake substrate is muck. The lake itself has five inlets, the largest being Swamp Creek, which is navigable by small craft. The outlet, lower Swamp Creek, is navigable by small craft and flows to the Wolf River. The lake is entirely within the Swamp Creek drainage basin.

A staff gage (LG 14) was established in Rice Lake on May 26, 1977 and monitored through October 11, 1980 to measure surface water levels. Appendix 3.7-3 provides a record of gage readings at this location. The lake gage fluctuated in response to the groundwater inflow, incident precipitation, and the flow pattern of its tributary streams. During the period from October 1977 to July 1980, a 2.18-foot water level fluctuation was observed. The highest water level during the study period occurred on April 21, 1979, during the 1979 high snowmelt runoff period; however, no reading was taken because the gage was submerged. A measured high water level of 1,535.16 feet MSL was recorded in October 1977. The lowest water level of 1,532.98 feet MSL occurred on July 12, 1980.

Samples for water chemistry analyses were collected at two locations in Rice Lake: Station N, centrally situated in the lake at a depth of approximately three feet, and Station F, located in the southern portion of the lake within the channel of Swamp Creek that meanders through Rice Lake. The depth at Station F was approximately 3.6 feet. Water chemistry samples were collected monthly at both locations from March 1977 through March 1978. Additional samples were collected at Station N in May, August, and October 1978. Unsafe ice conditions were common on this lake in the winter; consequently, no samples were collected from either station

Table 3.7-11

Summary of Water Body Characteristics for the Portion of the Swamp Creek Drainage Basin Within the Study Area[a]

Seepage Water Category/ Water Body, Lakes and Associated Streams	Distance and Direction From Ore Body (mi)	Drainage Basin Area (sq. mi)	Length (mi)	Average Width (ft)	Average Depth (ft)	Maximum Depth (ft)	Surface Area (acres)	Gradient[b] (ft/mi)	Adjoining Wetlands (acres)	Predominant Shoreline Vegetation[c]	Substrate Classification
Rice Lake	2.7 Northwest	—[d]	—	—	—	6	208	—	225	Sedge Meadow (Emergent wetland)	muck
Hemlock Creek	1.6 East	4.3	2.4	14	1.0	—	4.1	2.5	180	Wet-mesic or Wet Northern Forest	muck, sand, gravel
Swamp Creek	1.0 North	151.3	15.5	23.1	1.0	—	8.1	8.1	3,479	Wet-mesic or Wet Northern Forest	muck, sand, gravel and rubble
Outlet Creek	1.2 North	11.4	1.8	13	1.0	—	2.8	15	520	Dry-mesic or Mesic Northern Hardwoods and Wet-mesic or Wet Northern Forest	sand, gravel, muck
Hoffman Creek	1.8 West	1.7	0.5	8.0	0.5	—	0.5	8.1	20	Wet-mesic or Wet Northern Forest	sand, gravel, muck
Ground Hemlock Lake	2.4 East	—	—	—	—	42	88	—	8	Dry-mesic or Mesic Northern Hardwoods	sand, gravel, muck, rubble, boulders
Oak Lake	0.9 Southwest	—	—	—	—	47	51	—	15	Dry-mesic or Mesic Northern Hardwoods	muck, sand, gravel

[a]Steuck and Andrews, 1976; Steuck, et al., 1977, Andrews and Theinen, 1966.
[b]Calculated from topographic maps.
[c]See Terrestrial Biology, Section 3.9.
[d]Not applicable.

Source: EMC, 1985
Checked by: SVD1

in April 1977, and from Station N in December 1977 and January 1978. The maximum, minimum and mean values for the parameters measured are presented in Appendix 3.7-4.

Water chemistry data indicated that Rice Lake was a moderately hard, light brown-stained, neutral pH lake. Mean values for hardness, alkalinity, and specific conductance were 102 and 108 mg/L $CaCO_3$, <81 and 98 mg/L $CaCO_3$, and 197 and 194 μmhos/cm at Stations N and F, respectively. Mean pH values calculated for Stations N and F were 7.3 and 7.1, respectively. Secchi disc transparency was consistently recorded at or near the bottom at both sampling locations. Mean true color determined for Stations N and F were <40 and <24 color units, respectively.

Low dissolved oxygen concentrations were occasionally recorded at both stations in the winter and summer as documented in Appendix 3.7-4. Dissolved oxygen concentrations below 5.0 mg/L were found at Station N in March, July and September 1977. Similarly, concentrations below 5.0 mg/L were found in July, August and September 1977, and January 1978 at Station F.

Depth profiles of water chemistry parameters such as temperature, dissolved oxygen, pH, and conductivity indicated that Rice Lake at these sampling locations was generally well mixed.

Concentrations of metals measured in Rice Lake were either below detection limits or measured at very low levels. Mercury values were consistently below the detection limit of 0.1 μg/L at both stations, with the exception of a concentration of 0.1 μg/L reported for Station N in November 1977. Iron was detected in all samples from Rice Lake. Except for January 1978, in which a concentration of 4.34 mg/L was detected at Station F, concentrations ranged from 0.12 to 0.60 mg/L with a mean of 0.27 mg/L at Station F and from 0.10 to 0.35 mg/L with a mean of 0.20 mg/L at Station N. The anomalously high iron concentration in the water sample collected from Station F in January 1978 also had the highest suspended solids concentration, 28 mg/L, and therefore may reflect inadequate filtration and/or the presence of unfilterable colloidal iron oxides. Lead was below detection limits at both stations on Rice Lake on all sampling dates except July 1977 when a concentration of 0.03 mg/L was recorded at Station N.

Station N was sampled seasonally during 1979 and 1980. The results reported from these analyses generally were similar to those of 1977-1978 and are presented in Appendix 3.7-4. However, neither lead nor mercury were measured in the 1979-1980 samples. Also, lower levels of nitrate and organic nitrogen with mean concentrations both at <0.05 mg/L and dissolved and total solids with mean concentrations of 117 mg/L and 124 mg/L, respectively were reported in the 1979-1980 analytical results.

Bottom sediments were collected in March 1978 for chemical analyses at Station F and N. The analytical results are presented in Appendix 3.7-4.

3.7.4.2 **Hemlock Creek** (SG-6)

Hemlock Creek is a perennial stream that originates from the northwest shore of Ground Hemlock Lake, approximately 2.5 miles southeast of the ore body, and flows 2.4 miles north to its confluence with Swamp Creek (Figure 3.7-2). The stream is adjoined by 180 acres of wetlands, has a drainage area of 4.3 square miles, a total surface area of 4.1 acres, an average width of 14 feet, and an average depth of one foot (Table 3.7-11). Hemlock Creek has a well defined channel that flows through a wooded, flat drainage basin while receiving inputs from two unnamed tributaries originating in adjacent wetlands to the east.

A stream gage (SG-6) was established on Hemlock Creek during the 1977-1980 study and its location is shown on Figure 3.7-2. Flow readings obtained from October 1993 through March 1995 at this location are given in Appendix 3.7-5. Historical flow readings obtained from 1977 through 1980 are provided in Appendix 3.7-6. Because the area surrounding Hemlock Creek is of low relief and highly vegetated, stream flow is relatively constant across its width. Maximum and minimum flows observed on Hemlock Creek were 30.9 cubic feet per second (cfs) and 0.8 cfs in August 1977 and July 1977 respectively. Flows measured at this site during the 1994 study were within the range observed historically (min=3.11 cfs, max=8.56 cfs). In order to address groundwater input into the Hemlock Creek system, flow data was also collected at station SG-6A during the 1993-1995 study. This station was located approximately 0.1 miles downstream of Ground Hemlock Lake and 0.7 miles upstream of Station SG-6. Flow readings obtained at SG-6A ranged from 2.61 cfs to 6.72 cfs between April 1994 and March 1995 and are given in Appendix 3.7-5. In any year, the minimum seven-day average flow rate of Hemlock Creek has a 50-percent chance of being less than 2.0 cfs and a 10-percent chance of being less than 1.4 cfs (Table 3.7-12).

Samples for water chemistry analyses were collected from Hemlock Creek monthly from April 1994 through March 1995 at Station SG-6. Water quality data obtained from analyses of samples collected at the site are presented in Appendix 3.7-8. Summary statistics including maximum, minimum and mean values for these parameters are given in Table 3.7-13 which compares them to similar statistics derived from samples obtained during the 1977-1980 study. Historical data and current laboratory data reports supporting this table can be found in Appendices 3.7-4 and 3.7-9.

In general, the results reported from analyses of samples collected from Hemlock Creek in 1994 and 1995 were similar to those obtained during the 1977-1980 effort. Water chemistry data collected in 1994 indicated that Hemlock Creek was a moderately hard, neutral pH stream according to the classification system contained in Table 3.7-14. Mean values recorded for hardness, alkalinity and specific conductance at Station SG-6 were 97 mg/L as $CaCO_3$, 102 mg/L as $CaCO_3$ and 185 μmhos/cm, respectively. The mean pH value measured in field was 7.54. The concentration of dissolved oxygen in Hemlock Creek was above 5 mg/L during all samplings and ranged from 5.8 mg/L to 14.5 mg/L throughout the sampling period.

Table 3.7-12

Summary of Stream Water Body Discharges in the Study Area

Stream Gaging Location	1978 Water Year		Maximum Recorded Discharge[a]	Minimum Recorded Discharge[a]	1984 Estimated	
	Average Flow	Average Base Flow			Q7,2	Q7,10
Wolf River (at Langlade-USCS)	N/C	N/C	1,840	175	N/C	N/C
Swamp Creek						
S-1	74.4	50.1	274	25.3	24	18
USGS below Rice Lake @ Hwy M	47.9	N/C	209	17	19	15
USGS above Rice Lake @ Hwy 55	33.5	23.6	151	8	11	8
SC-3	N/C	N/C	138	10.3	6.7	4.7
SC-5A	N/C	N/C	N/C	N/C	1.4	1
Outlet Creek (SG 4)	N/C	N/C	206	<0.1	0.8	0.6
Hemlock Creek (SG 6)	3.6	2.3	30.9	0.8	2.0	1.4
Pickerel Creek (SG 19)	3	1.8	23.4	0.1	0.6	0.4
Creek 12-9						
SG-23	N/C	N/C	42.2	1.2	1.5	1.1
SG-8	0.7	0.55	10.1	0.4	0	0

Source: *Krug, 1984, Appendix 3.7-6*

[a]During periods of record prior to November, 1980.

Notes: N/C = Not Calculated.
All values in cubic feet per second.

Prepared by: JJA
Checked by: SVD1

Table 3.7-13

Water Quality Data, SG-6 (Hemlock Creek)
Summary of Monthly Means and Ranges

		1977-1978			1994-1995		
Station: A-1/SG-6	Units	Min.	Max.	Mean	Min.	Max.	Mean
Metals							
Aluminum, Total	µg/L	<10	<10	<10	3.36	58.20	20.40
Arsenic, Total	mg/L	<0.001	0.001	<0.001	<0.005	<0.005	Note 1
Cadmium, Total	µg/L	<1	2	<1	<0.003	0.008	0.002
Copper, Total	µg/L	<1	17	<5	0.101	0.430	0.229
Iron, Total	mg/L	0.02	0.37	0.11	<0.050	0.300	0.129
Lead, Total	µg/L	<10	<10	<10	0.023	0.159	0.082
Manganese, Total	mg/L	0.005	0.196	0.028	<0.010	0.126	0.028
Mercury, Total	ng/L	<100	200	<100	0.50	3.12	1.66
Molybdenum, Total	mg/L	<0.01	<0.01	<0.01	<0.020	<0.020	Note 1
Nickel, Total	mg/L	<0.01	<0.01	<0.01	<0.030	<0.030	Note 1
Zinc, Total	µg/L	<1	14	<5	<0.64	3.94	1.70
Phosphorus							
Phosphorus, Total	mg/L	<0.01	0.04	<0.02	<0.050	0.048	0.011
Nitrogen							
Nitrogen, Ammonia	mg/L	<0.05	0.94	<0.29	<0.10	0.17	0.03
Nitrogen, Nitrate	mg/L	<0.01	0.48	<0.18	<0.50	<0.50	Note 1
Sulfur							
Sulfate	mg/L	<1	9	<4	4.00	16.00	6.95
Solids							
Solids, Dissolved	mg/L	58	384	153	90	190	126
Solids, Suspended	mg/L	1	50	9	<5	6	1
General Parameters							
Alkalinity, Total	mg/L	55	130	101	76	130	102
Biochemical Oxygen Demand	mg/L	1	5	2	<2	7	1
Chemical Oxygen Demand	mg/L	3	14	9	14	22	18
Chloride	mg/L	<1	2	<2	<1	2	1

Table 3.7-13 *(Continued)*

		1977-1978			1994-1995		
Station: A-1/SG-6	Units	Min.	Max.	Mean	Min.	Max.	Mean
Conductivity	µmhos/cm	85	161	136	98	248	185
Cyanide	mg/L	<0.001	0.005	<0.001	<0.020	<0.020	Note 1
Dissolved Oxygen	mg/L	3.2	14.4	9.3	5.8	14.5	9.3
Hardness	mg/L	74	138	107	<5	130	97
pH	SU	5.8	8.1	7.4	6.83	8.05	7.54
Temperature	°C	0	22.0	8.3	0.5	22.5	9.8
Turbidity[a]	NTU	0.6	5.7	2.8	<0.50	3.30	1.40

[a]Turbidity was measured in FTU during the 1977-1978 study.
SU = Standard Units.
Note 1: All data reported as less than detection, therefore no mean value is calculated.

Prepared by: JJA
Checked by: BDH

Table 3.7-14

Hardness, pH and Color Classification System

Hardness[a] (mg/L as $CaCO_3$)	pH[b] (standard units)	Color[c] (color units)
0-60 = soft	0-2 = very acidic	0-20 = clear
61-120 = moderately hard	2-4 = acidic	20-50 = light brown
121-180 = hard	4-6 = slightly acidic	50-100 = medium brown
180+ = very hard	6-8 = neutral	100+ = dark brown
	8-10 = slightly basic	
	10-12 = basic	
	12-14 = very basic	

[a] (USGS, 1985).
[b] This classification is based on narrative text by Steuck and Andrews (1976).
[c] This classification system was developed specifically for the 1985 Crandon Project study (EMC, 1985).

Prepared by: JJA
Checked by: SDJ

All metals analyzed from samples collected at SG-6 during the 1994-1995 study were either below detection limits or were found in low concentrations. During this recent study, low level analyses techniques were used to monitor concentrations of aluminum, cadmium, copper, lead, mercury, zinc and chromium in water samples collected in Hemlock Creek. The lower detection limits associated with these techniques allowed for trace level detections of all these metals. However, aluminum was detected at a level higher than those observed during the 1977-1980 study (mean value = 58.2 μg/L vs <10 μg/L).

In October 1994 a sediment sample was collected from Hemlock Creek at Station A-1. A sample was also collected at this site in March 1978 as part of the previous work that was completed (EMC, 1985). A comparison of the results from these two sampling events is shown in Table 3.7-15. Information pertaining to the analysis of sediment samples is included in Appendices 3.7-4 and 3.7-10.

Surface water sediment composition has a considerable amount of variability. This is most evident in streams where scouring and deposition of sediments can take place within inches of each other. Samples collected from a stream or lake may have variable compositions and represent the variability of the sediments for that surface water. This is evident when comparing the two sets of sampling data for Hemlock Creek. The 1994 data is indicative of inorganic sediments with relatively high calcium, aluminum, iron and magnesium concentrations as well as relatively low volatile solids concentrations, 7,000 mg/kg or 0.7 percent. This sample was collected from a scoured area of the stream. The data collected in 1978 demonstrated a predominantly organic composition with only an 18.29 percent solids concentration and a freon extractables (Oil and Grease) concentration of 1,181 mg/kg. This sample was likely collected from an area of deposition in the stream. The sampling devices may also have impacted the nature of the sample. The 1994 sample was collected with a core type sampler while the 1978 sample was collected with an Ekman dredge.

The concentrations of some metals and inorganic parameters demonstrated fairly good correlation between the 1994 data and the 1978 data. This is likely reflective of the water chemistry within the stream.

3.7.4.3 Swamp Creek

Swamp Creek is a perennial stream that originates at Lake Lucerne, approximately 4.5 miles northeast of the ore body, and joins the Wolf River approximately 7.8 miles downstream and southwest of the ore body as shown in Figure 3.7-2. Swamp Creek has a drainage area of 151.3 square miles, a total surface area of 8.1 acres and a total length of 15.5 miles when measured to its confluence with the Wolf River (Table 3.7-11). Wooded land, wetlands, and undeveloped lands dominate the watershed of the river, and approximately 10 percent of the area surrounding it is used for agricultural purposes (EMC, 1985). The creek's channel is well defined and flows through a relatively flat drainage basin. Swamp Creek flows west along the northern edge of the site area, and through both Rice Lake and a broad wetland before connecting with the Wolf River

Table 3.7-15

Sediment Sampling Data, Hemlock Creek (Station A-1)

Parameter	Units	October 1994 Data	March 1978 Data
pH, Lab	SU	7.5	NDA
Solids, Total	%	86.6	18.29
Solids, Total Volatile	mg/kg	7000	NDA
Ammonia, N	mg/kg	33	NDA
Total Kjeldahl Nitrogen	mg/kg	260	NDA
Total Organic Nitrogen	mg/kg	230	NDA
Chloride	mg/kg	20	NDA
Fluoride	mg/kg	<0.5	NDA
Cyanide, Total	mg/kg	<0.5	NDA
Oil & Grease (Freon Extractables)	mg/kg	240	1181
Boron, Total	mg/kg	<10	NDA
Calcium, Total	mg/kg	2000	NDA
Arsenic, Total	mg/kg	1.4	1.3
Barium, Total	mg/kg	12	NDA
Iron, Total	mg/kg	6200	4026
Manganese, Total	mg/kg	56	179
Molybdenum, Total	mg/kg	<2.0	NDA
Selenium, Total	mg/kg	<0.50	NDA
Silver, Total	mg/kg	<0.50	NDA
Chromium, Total	mg/kg	15	66.2
Cobalt, Total	mg/kg	1.8	NDA
Beryllium, Total	mg/kg	<0.50	NDA
Thallium, Trace ICP	mg/kg	<1.0	NDA
Nickel, Total	mg/kg	3.9	NDA
Antimony, Total	mg/kg	<5.0	NDA
Magnesium, Total	mg/kg	1900	NDA
Phosphorus, Total	mg/kg	170	NDA

Table 3.7-15 *(Continued)*

Parameter	Units	October 1994 Data	March 1978 Data
Potassium, Total	mg/kg	180	NDA
Sodium, Total	mg/kg	28	NDA
Aluminum, Total	mg/kg	2700	NDA
Cadmium, Total	mg/kg	<0.50	1.0
Copper, Total	mg/kg	6.4	6.7
Lead, Total	mg/kg	4.4	7
Mercury, Total	mg/kg	<0.02	<0.01
Zinc, Total	mg/kg	59	46
Vanadium	mg/kg	9.9	NDA

SU = Standard Units.
NDA = No Data Available.

Prepared by: GJB1
Checked by: GJB

(Figures 3.7-1 and 3.7-2). Its major tributaries in the study area are Hemlock, Hoffman, and Outlet creeks, each of which is discussed individually in this section.

An unnamed tributary to Swamp Creek, designated Creek 19-14 is located in Section 19, T35N, R13E. This stream is primarily fed by groundwater. Water quality data was collected from this stream in December 1997. The sampling point for this water body has been designated SG-1914. This stream is a moderately hard to hard water body with a slightly basic pH. The water quality characteristics are found in Table 3.7-15a.

An additional unnamed tributary to Swamp Creek, designated Creek 24-15, is located in Sections 13 and 24, T35N, R12E. Three unnamed tributaries that contribute flow to Creek 24-15 are Creeks 24-4, 24-13 and 24-14. No stream gage measurements were taken in this stream system during these studies. Historically, Creek 24-15 has been described by Steuck (1981) as a medium hard water trout stream (Class IB) with slightly alkaline, light brown water. Other major tributaries to Swamp Creek not included in this investigation are Squaw Creek and Creeks 6-10, 7-5, and 7-9.

Two USGS stream gages and five other stream gages were established by earlier studies and used to monitor stream flow rates in the Swamp Creek system during the 1970s and 1980s. Historical records of gage readings and flow rates for these locations are presented in Appendix 3.7-6.

Table 3.7-11 lists some descriptive characteristics for Swamp Creek and other water bodies located within its drainage basin.

Samples for water chemistry analysis and flow rate transect data were collected from five locations (Figures 3.7-1 and 3.7-2) on Swamp Creek during the 1993-1995 study. The furthest upstream of these, Station SG-5A, was located approximately 2.9 miles northeast of the ore body, and approximately two miles upstream from the confluence of Swamp Creek with Hemlock Creek. Station SG-3 was established two miles downstream from Station SG-5A, about 0.2 mile below the confluence with Outlet Creek, and SG-2 was located 2.1 miles downstream from SG-3, in an area approximately 0.9 mile upstream from Rice Lake. Bottom substrates at the three Swamp Creek sites upstream of Rice Lake were variable. SG-3 was located in a riffle section of the creek containing boulders, rubble, and substrate consisting of gravel and coarse sand. The other stations were located on reaches of the creek with typically slower current velocities and predominantly less coarse substrates. Downstream from Rice Lake, two stations were established: Station SG-AB, approximately 0.3 mile upstream from the Squaw Creek confluence, and SG-V, which was positioned approximately 1.4 miles upstream from the confluence with the Wolf River.

Samples for water chemistry analyses were collected at stations SG-2 and SG-3 monthly from April 1994 through January 1995. Samples were also collected at Stations SG-5A in April, July, and October 1994. Station SG-AB was sampled monthly from December 1993 through October 1994; and samples from Station SG-V were collected monthly from November 1993 through October 1994.

Table 3.7-15a

December 1997 Sampling Data for Creek 19-14

Parameter	Units	December 1997 Data[a]
Alkalinity, Bicarbonate as HCO_3	mg/L	120[b]
Alkalinity, Total as $CaCO_3$	mg/L	97[b]
Alkalinity, Carbonate as $CaCO_3$	mg/L	<1.4
Aluminum, total	μg/L	12.7
Arsenic, total	μg/L	<1.8
Barium, total	μg/L	7.8
BOD-5 day	mg/L	<3.0
Boron, total	μg/L	<18
Cadmium, total	μg/L	<0.030
Calcium, total	mg/L	19
COD (unfiltered)	mg/L	20
Chloride (unfiltered)	mg/L	1.2
Chromium, Trivalent	μg/L	0.08
Chromium, Hexavalent	μg/L	0.56
Chromium, total	μg/L	0.64
Color, APHA (true)	C.P.U.	45
Conductivity, Specific @25^{0}C - field	umhos/cm	183.6
Copper, total	μg/L	0.083
Cyanide, total (distilled)	mg/L	<0.0046
Fluoride, (unfiltered)	mg/L	0.054
Hardness, total as $CaCO_3$	mg/L	85
Iron, total	mg/L	0.06
Lead, total	μg/L	0.015
Manganese, total	μg/L	3.4
Mercury	μg/L	0.0013
Molybdenum	mg/L	<0.0082
Nitrogen, Ammonia as N (unfiltered)	mg/L	0.11
Nitrogen, NO_2+NO_3 as N (unfiltered)	mg/L	0.10
Nitrogen, Kjeldahl as N (unfiltered)	mg/L	0.18

Table 3.7-15a *(Continued)*

Parameter	Units	December 1997 Data[a]
Oil & Grease, (water)	mg/L	<7.8
Oxygen, field	mg/L	11.8
pH, lab	SU	7.7
pH, field	SU	8.19
Phosphorus, total	mg/L	0.025
Phosphorus, reactive as P	mg/L	0.013
Selenium, total	µg/L	<1.6
Silver, total	µg/L	3.7
Solids, total dissolved	mg/L	140
Solids, total suspended	mg/L	<1.0
Solids, total volatile	%DWB	7.4
Sulfate, as SO_4	mg/L	8.4
Turbidity	NTU	0.92
Zinc, total	µg/L	0.77
Chlorophyll		
Corrected Chlorophyll a	µg/L	0.22
Pheophytin a	µg/L	0.25
Trichromatic Chlorophyll a	µg/L	0.34
Trichromatic Chlorophyll b	µg/L	0.40
Trichromatic Chlorophyll c	µg/L	0.82

[a] Two samples were collected from Creek 19-14 as field duplicates. A third was collected for low level analyses for Al, Cd, Cr+3, Cr+6, Cr (total), Cu, Pb, Hg, Zn. The concentrations presented represent an average of the two or three data sets as appropriate.

[b] The alkalinity data was not generated from an average of the duplicate samples that were collected. The duplicate sample data were significantly different. One data set correlated with the hardness, calcium, magnesium, and total dissolved solids data from both samples. Therefore, the data set which correlated was used and the data set for the sample that did not correlate was considered an outlier and was not included.

Prepared by: GJB1
Checked by: LCT

Flow readings were obtained at sites SG-5A, SG-3, SG-2 and SG-V periodically from November 1993 to March 1995 during the time of their respective water chemistry sampling events. River flow was also monitored at SG-AA at the USGS gaging station located at the County Highway M crossing of Swamp Creek during this time. An additional flow measurement station was established on Swamp Creek (SG-2A) in order to address the effect of groundwater input into the Swamp Creek system. Station SG-2A was established above Rice Lake approximately 1.2 miles upstream of Station SG-2. This station was monitored from March 1994 to October 1994, and April 1994 to March 1995, respectively. Stream flow data collected during these time periods is included in Appendix 3.7-5.

Because the area surrounding Swamp Creek is of low relief and highly vegetated, stream flow is relatively constant across its width. Maximum and minimum flows observed during the 1993-1995 study in Swamp Creek ranged from 3.28 cfs and 4.45 cfs at the furthest upstream station, SG-5A, to 36.19 cfs and 171.09 cfs at SG-V, the furthest downstream station. During earlier studies, similar flow measurements were observed within the Swamp Creek system. Measurements conducted during the 1970s and 1980s yielded similar values for SG-5A (minimum = 2.3 cfs, maximum 2.4 cfs) to those measured during the 1993-1995 study period.

Although maximum values observed at SG-3 during earlier studies were higher than those seen in the 1993-1995 study (138.3 cfs versus 38.93 cfs), there is general agreement in the two data sets for flows measured at the furthest mutual downstream station (1994-1995 average flow = 28.07, 1977-1980 average flow = 35.95). Historical flow information and supporting data are given in Appendices 3.7-5 and 3.7-6.

Water quality data obtained from analyses of samples collected during the current study are presented in Appendix 3.7-8. Summary statistics including maximum, minimum and mean values for these parameters are given in Tables 3.7-16 through 20 which compare them to similar statistics derived from samples obtained during the 1977-1980 study.

In general, the results reported from analyses of samples collected from Swamp Creek in 1994 and 1995 were similar to those obtained during the 1977-1980 effort. Water chemistry data indicated that Swamp Creek was a moderately hard, neutral pH stream (Table 3.7-14). Mean values for hardness, alkalinity, and specific conductance at the five sampling stations ranged from 91 to 113 mg/L as $CaCO_3$, 87 to 105 mg/L as $CaCO_3$, and 188 to 207 μmhos/cm, respectively. Mean pH values ranged from 7.10 to 7.47. Dissolved oxygen was measured in concentrations below 5 mg/L at SG-5A in July, and at Stations SG-AB and SG-V during the months of January and February of 1994.

All metals analyzed from samples collected at Swamp Creek during the 1993-1995 study were either below detection limits or were found in low concentrations. During this recent study, low level analyses techniques were used to monitor concentrations of aluminum, cadmium, copper, lead, mercury, zinc and chromium in water samples collected in Swamp Creek. The lower detection limits associated with these techniques allowed for trace level detections of all these

Table 3.7-16

Water Quality Data, SG-V (Swamp Creek)
Summary of Monthly Means and Ranges

		1977-1978			1993-1994		
Station: V/SG-V	Units	Min.	Max.	Mean	Min.	Max.	Mean
Metals							
Aluminum, Total	µg/L	<10	<10	<10	18.30	99.50	40.16
Arsenic, Total	mg/L	<0.001	<0.001	<0.001	<0.005	<0.005	Note 1
Cadmium, Total	µg/L	<1	3	<1	<0.004	0.070	0.012
Copper, Total	µg/L	<1	15	<3	0.179	1.550	0.410
Iron, Total	mg/L	0.26	2.54	0.80	0.260	0.830	0.492
Lead, Total	µg/L	<10	<10	<10	0.093	0.316	0.193
Manganese, Total	mg/L	0.016	0.156	0.062	0.025	0.117	0.060
Mercury, Total	ng/L	<100	<100	<100	1.00	7.16	2.43
Molybdenum, Total	mg/L	<0.01	<0.01	<0.01	<0.020	<0.020	Note 1
Nickel, Total	mg/L	<0.01	<0.01	<0.01	<0.030	<0.030	Note 1
Zinc, Total	µg/L	<1	13	<5	0.80	3.67	1.78
Phosphorus							
Phosphorus, Total	mg/L	<0.01	0.04	<0.03	<0.05	1.11	0.11
Nitrogen							
Nitrogen, Ammonia	mg/L	0.32	1.60	0.95	<0.10	0.48	0.13
Nitrogen, Nitrate	mg/L	<0.01	0.54	<0.21	<0.04	0.73	0.15
Sulfur							
Sulfate	mg/L	<1	8	<5	4.15	26.00	8.33
Solids							
Solids, Dissolved	mg/L	85	161	126	79	154	115
Solids, Suspended	mg/L	1	16	5	<5	8	2
General Parameters							
Alkalinity, Total	mg/L	64	112	81	35	122	87
Biochemical Oxygen Demand	mg/L	1	3	2	<1	9	3
Chemical Oxygen Demand	mg/L	69	69	69	<20	34	17
Chloride	mg/L	<1	4	<3	2	4	3

Table 3.7-16 *(Continued)*

		1977-1978			1993-1994		
Station: V/SG-V	Units	Min.	Max.	Mean	Min.	Max.	Mean
Conductivity	µmhos/cm	0.60	145	110	106	262	188
Cyanide	mg/L	<0.001	0.001	<.001	<0.010	<0.020	Note 1
Dissolved Oxygen	mg/L	3.8	11.6	6.7	2.8	10.6	7.3
Hardness	mg/L	76	124	95	61	140	101
pH	SU	5.8	7.6	6.8	6.60	7.70	7.10
Temperature	°C	0	22.0	8.5	0	20.2	9.3
Turbidity[a]	NTU	1.4	2.9	2.1	<0.50	3.30	1.84

[a]Turbidity was measured in FTU during the 1977-1978 study.

SU = Standard Units.

Note 1: All data reported as less than detection, therefore no mean value is calculated.

Prepared by: JJA

Checked by: BDH

Table 3.7-17

Water Quality Data, SG-2 (Swamp Creek)
Summary of Monthly Means and Ranges

		1977-1978			1994-1995		
Station: E/SG-2	Units	Min.	Max.	Mean	Min.	Max.	Mean
Metals							
Aluminum, Total	µg/L	<10	<10	<10	22.10	60.60	34.62
Arsenic, Total	mg/L	<0.001	0.001	<0.001	<0.005	0.006	0.001
Cadmium, Total	µg/L	<1	4	<2	<0.003	0.051	0.006
Copper, Total	µg/L	<1	10	<4	0.154	6.990	0.952
Iron, Total	mg/L	0.11	0.36	0.23	0.212	0.439	0.324
Lead, Total	µg/L	<10	<10	<10	0.053	0.227	0.124
Manganese, Total	mg/L	0.023	0.085	0.043	0.037	0.142	0.059
Mercury, Total	ng/L	<100	<100	<100	0.98	4.66	2.25
Molybdenum, Total	mg/L	<0.01	<0.01	<0.01	<0.020	<0.020	Note 1
Nickel, Total	mg/L	<0.01	<0.01	<0.01	<0.030	<0.030	Note 1
Zinc, Total	µg/L	<1	17	<5	0.75	3.47	1.58
Phosphorus							
Phosphorus, Total	mg/L	<0.01	0.06	<0.03	<0.050	0.046	0.011
Nitrogen							
Nitrogen, Ammonia	mg/L	0.06	1.00	0.39	<0.10	0.20	0.06
Nitrogen, Nitrate	mg/L	<0.01	0.48	<0.19	<0.50	0.72	0.18
Sulfur							
Sulfate	mg/L	<1	12	<5	4	13	7.19
Solids							
Solids, Dissolved	mg/L	78	372	167	90	190	135
Solids, Suspended	mg/L	<1	12	<4	<5	10	3
Bacteria							
Fecal Coliform Bacteria	ORG/100 ml	2	145	48	<1	<1	Note 1

Table 3.7-17 *(Continued)*

Station: E/SG-2	Units	1977-1978 Min.	1977-1978 Max.	1977-1978 Mean	1994-1995 Min.	1994-1995 Max.	1994-1995 Mean
General Parameters							
Alkalinity, Total	mg/L	55	132	94	70	120	95
Biochemical Oxygen Demand	mg/L	1	9	2	<2	8	2
Chemical Oxygen Demand	mg/L	3	17	10	10	27	21
Chloride	mg/L	<1	5	<2	2	3	3
Conductivity	μmhos/cm	90	165	132	158	259	196
Cyanide	mg/L	<0.001	0.003	<0.001	<0.020	<0.020	Note 1
Dissolved Oxygen	mg/L	6.2	12.4	8.9	6.3	13.2	9.9
Hardness	mg/L	66	130	99	78	130	104
pH	SU	5.8	8.1	7.3	6.46	7.89	7.24
Temperature	°C	0	21.0	8.0	0.2	19.2	8.1
Turbidity[a]	NTU	1.4	4.5	2.2	0.90	5.10	2.29

[a]Turbidity was measured in FTU during the 1977-1978 study.

SU = Standard Units.

Note 1: All data reported as less than detection, therefore no mean value is calculated.

Prepared by: JJA
Checked by: BDH

Table 3.7-18

Water Quality Data, SG-3 (Swamp Creek)
Summary of Monthly Means and Ranges

		1977-1978			1994-1995		
Station: D/SG-3	Units	Min.	Max.	Mean	Min.	Max.	Mean
Metals							
Aluminum, Total	µg/L	<10	<10	<10	11.90	49.9	27.20
Arsenic, Total	mg/L	<0.001	<0.001	<0.001	<0.005	<0.005	Note 1
Cadmium, Total	µg/L	<1	4	<1	<0.004	0.024	0.004
Copper, Total	µg/L	<1	14	<4	0.154	1.48	0.471
Iron, Total	mg/L	0.11	0.41	0.25	0.228	0.379	0.312
Lead, Total	µg/L	<10	<10	<10	0.053	0.208	0.111
Manganese, Total	mg/L	0.020	0.091	0.050	0.037	0.076	0.059
Mercury, Total	ng/L	<100	<100	<100	0.90	3.36	1.85
Molybdenum, Total	mg/L	<0.01	<0.01	<0.01	<0.020	<0.020	Note 1
Nickel, Total	mg/L	<0.01	<0.01	<0.01	<0.030	<0.030	Note 1
Zinc, Total	µg/L	<1	20	<5	0.827	5.38	1.98
Phosphorus							
Phosphorus, Total	mg/L	<0.01	0.04	<0.03	<0.050	0.035	0.009
Nitrogen							
Nitrogen, Ammonia	mg/L	<0.05	0.91	<0.34	<0.10	0.28	0.04
Nitrogen, Nitrate	mg/L	<0.01	0.24	<0.13	<0.05	<0.05	Note 1
Sulfur							
Sulfate	mg/L	<1	12	<5	4.00	12.00	6.99
Solids							
Solids, Dissolved	mg/L	65	434	169	68	190	125
Solids, Suspended	mg/L	2	16	6	<5	7	2.9
General Parameters							
Alkalinity, Total	mg/L	61	128	95	75	130	96
Biochemical Oxygen Demand	mg/L	1	8	3	<2	12	3
Chemical Oxygen Demand	mg/L	3	24	13	12	23	18
Chloride	mg/L	<1	6	<2	1	3	3

Table 3.7-18 *(Continued)*

		1977-1978			1994-1995		
Station: D/SG-3	Units	Min.	Max.	Mean	Min.	Max.	Mean
Conductivity	μmhos/cm	90	165	138	175	262	207
Cyanide	mg/L	<0.001	0.006	<0.001	<0.020	<0.020	Note 1
Dissolved Oxygen	mg/L	6.7	15.0	10.4	7.5	12	9.6
Hardness	mg/L	72	130	101	<5	120	91
pH	SU	5.9	7.8	7.3	6.93	7.96	7.47
Temperature	°C	0	21.0	8.0	0.6	19.3	9.0
Turbidity[a]	NTU	1.2	2.6	1.8	0.65	2.3	1.39

[a]Turbidity was measured in FTU during the 1977-1978 study.

SU = Standard Units.

Note 1: All data reported as less than detection, therefore no mean value is calculated.

Prepared by: JJA
Checked by: BDH

Table 3.7-19

Water Quality Data, SG-5A (Swamp Creek)
Summary of Monthly Means and Ranges

Parameter	Units	Minimum	Maximum	Mean
pH	SU	7.06	7.32	7.16
Conductivity	μmhos	183	208	195
Temperature	°C	2.3	19.3	9.7
Dissolved Oxygen	mg/L	4.8	8.9	7.2
Alkalinity, total	mg/L	94	122	105
Hardness	mg/L	101	129	113
Total Dissolved Solids	mg/L	97	149	119
Total Suspended Solids	mg/L	<5	<5	Note 1
Biochemical Oxygen Demand	mg/L	<3	5	2
Chemical Oxygen Demand	mg/L	<10	12	6
Ammonia	mg/L	<0.10	<0.10	Note 1
Nitrate	mg/L	<0.50	<0.50	Note 1
Nitrogen, Total Kjeldahl	mg/L	0.39	0.48	0.42
Chloride	mg/L	1	2	2
Fluoride	mg/L	<0.1	<0.1	Note 1
Sulfate	mg/L	<1.00	14.00	6.43
Cyanide, total	mg/L	<0.020	<0.020	Note 1
Oil & Grease	mg/L	<1.0	6.2	2.1
Turbidity, Lab	NTU	0.80	1.10	0.95
Cations	Meq/L	2.10	2.66	2.32
Anions	Meq/L	1.69	2.15	1.91
Cation and Anion Balance	%	5.33	13.20	9.68
Boron, Total	mg/L	<0.100	<0.100	Note 1
Calcium, total	mg/L	22.0	29.7	25.2
Arsenic, total	mg/L	<0.005	<0.005	Note 1

Table 3.7-19 *(Continued)*

Parameter	Units	Minimum	Maximum	Mean
Barium, total	mg/L	<0.010	0.017	0.009
Iron, dissolved	mg/L	0.111	0.173	0.141
Iron, total	mg/L	0.173	0.274	0.226
Manganese, dissolved	mg/L	0.015	0.028	0.023
Manganese, total	mg/L	0.067	0.114	0.095
Molybdenum, total	mg/L	<0.020	<0.020	Note 1
Selenium, total	mg/L	<0.005	<0.005	Note 1
Silver, total	mg/L	<0.010	<0.010	Note 1
Chromium, total	mg/L	<0.005	<0.020	Note 1
Beryllium, total	mg/L	<0.005	<0.010	Note 1
Thallium, total	mg/L	<0.005	<0.005	Note 1
Nickel, total	mg/L	<0.003	<0.003	Note 1
Antimony, total	mg/L	<0.005	<0.005	Note 1
Magnesium, total	mg/L	11.0	13.3	11.8
Phosphorus, dissolved	mg/L	<0.050	0.018	0.006
Phosphorus, total	mg/L	<0.050	0.037	0.012
Potassium, total	mg/L	<0.600	0.800	0.267
Sodium, total	mg/L	1.70	1.83	1.78
Sodium Absorption Ratio	std	0.070	0.078	0.073
Aluminum, total	µg/L	<50	<200	Note 1
Cadmium, total	µg/L	<5	<5	Note 1
Copper, total	µg/L	<30	<30	Note 1
Lead, total	µg/L	<50	<50	Note 1
Mercury, total	ng/L	<200	<200	Note 1
Zinc, total	µg/L	<20	<20	Note 1

Note 1: All data reported as less than detection, therefore no mean value is calculated.
SU = Standard Units.

Prepared by: JJA
Checked by: BDH

Table 3.7-20

Water Quality Data, SG-AB (Swamp Creek)
Summary of Monthly Means and Ranges

Parameter	Units	Minimum	Maximum	Mean
pH	SU	6.87	7.71	7.31
Conductivity	μmhos	151	275	203
Temperature	°C	0	20.8	10.6
Dissolved Oxygen	mg/L	3.2	11.1	7.6
Fecal Coliform	org/100mL	<1	<1	Note 1
Alkalinity, total	mg/L	59	124	96
Hardness	mg/L	65	129	103
Total Dissolved Solids	mg/L	79	153	118
Total Suspended Solids	mg/L	<5	12	1
Biochemical Oxygen Demand	mg/L	<1	8	3
Chemical Oxygen Demand	mg/L	<20	29	14
Ammonia	mg/L	<0.10	0.57	0.11
Nitrate	mg/L	0.04	0.79	0.38
Nitrogen, Total Kjeldahl	mg/L	0.25	4.48	1.02
Chloride	mg/L	2	4	3
Fluoride	mg/L	<0.1	0.5	0
Sulfate	mg/L	4.77	18.00	7.68
Cyanide, total	mg/L	<0.010	<0.020	Note 1
Oil & Grease	mg/L	<1.0	6.5	0.94
Turbidity, Lab	NTU	<0.50	7.00	1.92
Cations	Meq/L	1.42	2.72	2.11
Anions	Meq/L	0.09	2.27	1.70
Cation and Anion Balance	%	0.73	92.73	14.69
Boron, total	mg/L	<0.099	<0.200	Note 1
Calcium, total	mg/L	15.0	29.0	22.5
Arsenic, total	mg/L	<0.005	<0.005	Note 1
Barium, total	mg/L	<0.010	0.013	0.008

Table 3.7-20 *(Continued)*

Parameter	Units	Minimum	Maximum	Mean
Iron, dissolved	mg/L	0.100	0.266	0.127
Iron, total	mg/L	0.160	0.508	0.287
Manganese, dissolved	mg/L	<0.010	0.051	0.017
Manganese, total	mg/L	0.025	0.098	0.056
Molybdenum, total	mg/L	<0.020	<0.020	Note 1
Selenium, total	mg/L	<0.005	<0.005	Note 1
Silver, total	mg/L	<0.010	<0.010	Note 1
Chromium, total[1]	µg/L	0.300	0.817	0.533
Chromium, total	mg/L	<0.020	<0.020	Note 1
Beryllium, total	mg/L	<0.001	<0.010	Note 1
Thallium, total	mg/L	<0.005	<0.005	Note 1
Nickel, total	mg/L	<0.030	<0.030	Note 1
Antimony, total	mg/L	<0.005	<0.005	Note 1
Magnesium, total	mg/L	7.0	13.6	10.9
Phosphorus, dissolved	mg/L	<0.050	0.025	0.004
Phosphorus, total	mg/L	<0.050	0.039	0.010
Potassium, total	mg/L	<0.600	1.100	0.493
Sodium, total	mg/L	1.60	3.09	2.52
Sodium, Absorption Ratio	std	0.086	0.148	0.110
Aluminum, total	µg/L	4.5	77.1	21.7
Cadmium, total	µg/L	<0.006	0.011	0.004
Copper, total	µg/L	0.135	2.910	0.543
Lead, total	µg/L	0.052	0.374	0.137
Mercury, total	ng/L	0.90	4.37	2.00
Zinc, total	µg/L	0.11	2.18	1.23

[1]Chromium analyzed using low level techniques.
Note 1: All data reported as less than detection, therefore no mean value is calculated.
SU = Standard Units.

Prepared by: JJA
Checked by: BDH

metals. As consistent with the results from Hemlock Creek only aluminum was detected at a level significantly higher than those observed during the 1977-1980 study (range of means = 21.7 μg/L - 40.16 μg/L vs <10 μg/L).

In October 1994 sediment samples were collected from Swamp Creek at stations D and E. Samples were also collected at these sites in March 1978 as part of the previous project work (EMC, 1985). A comparison of the results from these two sampling events is shown in Table 3.7-21 and Table 3.7-22. Information pertaining to the analysis of sediment samples are included in Appendices 3.7-4 and 3.7-10.

As stated previously, surface water sediment composition has a considerable amount of variability. This is most evident in streams where scouring and deposition of sediments can take place within inches of each other. Samples collected from a stream or lake may have variable compositions and represent the variability of the sediments for that surface water. This is evident when comparing the two sets of sampling data from Swamp Creek. The total solids in the 1994 samples were 81.8 percent and 22.1 percent as compared to 1.02 percent and 16.13 percent in the samples collected in 1978 for sites D and E, respectively.

The 1994 data for sampling site D is indicative of inorganic sediments with relatively high calcium, aluminum, iron and magnesium concentrations as well as relatively low volatile solids concentrations, 3000 mg/kg or 0.3 percent. This sample was collected from a scoured area of the stream. The data collected in 1978 demonstrated a predominantly organic composition with only a 1.02 percent solids concentration and a freon extractables (Oil and Grease) concentration of 4,412 mg/kg. This sample was likely collected from an area of deposition in the stream. The 1978 data for site D also had very high concentrations of cadmium, chromium, copper, iron, and manganese which indicate that the sampling devices may also have impacted the nature of the sample. The 1994 sample was collected with a core type sampler while the 1978 sample was collected with an Ekman dredge sampler.

The 1994 data for sampling site E indicated that this site had a higher level of organic material in the sample. The total solids concentration was 22.1 percent, and of that, the volatile solids concentration was 261,000 mg/kg or 26.1 percent of the total solids. The Nitrogen concentrations were also elevated at this site, which again indicates the presence of higher levels of organic material. This site is likely associated with an area of stream deposition.

The 1978 data for site E had a percent solids level of 16.13 which is a higher than average level for the data collected in 1978. The average percent solids level in 1978 was 8.04 for the Swamp Creek and Pickerel Creek drainage basins. This site also had a lower Freon extractables (oil and grease) level with only 477 mg/kg being observed. This is indicative of an inorganic substrate. This sample was likely collected from an area of stream scouring. Metals measured in Swamp Creek sediments were found either in low concentrations or below detection limits.

Table 3.7-21

Sediment Sampling Data, Swamp Creek (Station D)

Parameter	Units	October 1994 Data	March 1978 Data
pH, Lab	SU	7.5	NDA
Solids, Total	%	81.8	1.02
Solids, Total Volatile	mg/kg	3000	NDA
Ammonia, N	mg/kg	23	NDA
Total Kjeldahl Nitrogen	mg/kg	120	NDA
Total Organic Nitrogen	mg/kg	97	NDA
Chloride	mg/kg	<10	NDA
Fluoride	mg/kg	<0.5	NDA
Cyanide, Total	mg/kg	<0.5	NDA
Oil & Grease (Freon Extractables)	mg/kg	210	4412
Boron, Total	mg/kg	<10	NDA
Calcium, Total	mg/kg	540	NDA
Arsenic, Total	mg/kg	1.8	2.0
Barium, Total	mg/kg	13	NDA
Iron, Total	mg/kg	2700	19894
Manganese, Total	mg/kg	290	3696
Molybdenum, Total	mg/kg	<2.0	NDA
Selenium, Total	mg/kg	<0.50	NDA
Silver, Total	mg/kg	<0.50	NDA
Chromium, Total	mg/kg	3.3	180.8
Cobalt, Total	mg/kg	<1.0	NDA
Beryllium, Total	mg/kg	<0.50	NDA

Table 3.7-21 *(Continued)*

Parameter	Units	October 1994 Data	March 1978 Data
Thallium, Trace ICP	mg/kg	<1.0	NDA
Nickel, Total	mg/kg	<2.0	NDA
Antimony, Total	mg/kg	<5.0	NDA
Magnesium, Total	mg/kg	410	NDA
Phosphorus, Total	mg/kg	140	NDA
Potassium, Total	mg/kg	60	NDA
Sodium, Total	mg/kg	28	NDA
Aluminum, Total	mg/kg	950	NDA
Cadmium, Total	mg/kg	<0.50	4.4
Copper, Total	mg/kg	0.56	51.7
Lead, Total	mg/kg	1.1	<1
Mercury, Total	mg/kg	<0.02	<0.01
Zinc, Total	mg/kg	8.5	66
Vanadium	mg/kg	3.8	NDA

SU = Standard Units.
NDA = No Data Available.

Prepared by: GJB1
Checked by: GJB

Table 3.7-22

Sediment Sampling Data, Swamp Creek (Station E)

Parameter	Units	October 1994 Data	March 1978 Data
pH, Lab	SU	6.8	NDA
Solids, Total	%	22.1	16.13
Solids, Total Volatile	mg/kg	261000	NDA
Ammonia, N	mg/kg	<20	NDA
Total Kjeldahl Nitrogen	mg/kg	1600	NDA
Total Organic Nitrogen	mg/kg	1600	NDA
Chloride	mg/kg	25	NDA
Fluoride	mg/kg	<0.5	NDA
Cyanide, Total	mg/kg	<0.5	NDA
Oil & Grease (Freon Extractables)	mg/kg	460	477
Boron, Total	mg/kg	<10	NDA
Calcium, Total	mg/kg	1800	NDA
Arsenic, Total	mg/kg	1.4	6.3
Barium, Total	mg/kg	10	NDA
Iron, Total	mg/kg	2100	8815
Manganese, Total	mg/kg	130	1084
Molybdenum, Total	mg/kg	<2.0	NDA
Selenium, Total	mg/kg	1.2	NDA
Silver, Total	mg/kg	<0.50	NDA
Chromium, Total	mg/kg	4.5	57.9
Cobalt, Total	mg/kg	<1.0	NDA
Beryllium, Total	mg/kg	<0.50	NDA

Table 3.7-22 *(Continued)*

Parameter	Units	October 1994 Data	March 1978 Data
Thallium, Trace ICP	mg/kg	<1.0	NDA
Nickel, Total	mg/kg	<2.0	NDA
Antimony, Total	mg/kg	<5.0	NDA
Magnesium, Total	mg/kg	450	NDA
Phosphorus, Total	mg/kg	820	NDA
Potassium, Total	mg/kg	<60	NDA
Sodium, Total	mg/kg	18	NDA
Aluminum, Total	mg/kg	710	NDA
Cadmium, Total	mg/kg	<0.50	1.1
Copper, Total	mg/kg	2.1	13.3
Lead, Total	mg/kg	2.3	12
Mercury, Total	mg/kg	<0.02	<0.01
Zinc, Total	mg/kg	15	74
Vanadium	mg/kg	3.5	NDA

SU = Standard Units.
NDA = No Data Available.

Prepared by: GJB1
Checked by: GJB

3.7.4.4 Outlet (Metonga) Creek

Outlet Creek originates approximately 2.8 miles north of the ore body at the south shore of Lake Metonga and flows southward 1.8 miles to its confluence with Swamp Creek (Figure 3.7-2). The creek has a drainage area of 11.4 square miles, is adjoined by 520 acres of wetlands, has a total surface area of 2.8 acres, and an average width and depth of 13 feet and 1 foot, respectively. It has a well defined channel that flows through a relatively flat drainage basin and has no major tributaries.

A stream gage (SG-4) was established on Outlet Creek during the 1977-1980 study and its location is shown on Figure 3.7-2. This station was located immediately upstream of Keith Siding road which is approximately 0.9 mile upstream from the confluence with Swamp Creek. Flow readings obtained from April 1994 through October 1994 at this location are given in Appendix 3.7-5. Historical readings from 1977 through 1980 are provided in Appendix 3.7-6. Maximum and minimum flows observed in Outlet Creek were <0.1 cubic feet per second (cfs) and 34.0 cfs respectively. Flows measured at this site during the 1993-1995 study were within the range observed historically (min=5.57 cfs, max = 14.64 cfs).

Samples for water chemistry analyses were collected from Outlet Creek in April, July, and October of 1994 at Station SG-4. Water quality data obtained from analyses of samples collected during this time period at this site are presented in Appendix 3.7-8. Summary statistics for the 1994 study period, including maximum, minimum and mean values for these parameters are given in Table 3.7-23 which compares them to similar statistics derived from samples obtained during the 1977-1980 study (Appendix 3.7-4). In general, the results reported from analyses of samples collected from Outlet Creek in 1994 were similar to those obtained during the 1977-1980 effort. Water chemistry data indicated that Outlet Creek was a moderately hard, neutral pH stream. Mean values recorded in 1994 for hardness, alkalinity and specific conductance at Station SG-4 were 100 mg/L as $CaCO_3$, 92 mg/L as $CaCO_3$ and 187 μmhos/cm, respectively. The mean pH value measured in field was 7.26. Dissolved oxygen concentrations measured during the study were consistently high, ranging from 8.0 mg/L to 10.3 mg/L. All metals analyzed from samples collected at SG-4 during the 1994 study were either below detection limits or were found in low concentrations.

3.7.4.5 Hoffman Creek and Springs

Hoffman Creek originates from Hoffman Spring Pond, which is located approximately 1.8 miles west of the ore body. It has a drainage area of 1.7 square miles and flows north approximately 0.5 mile to its confluence with Swamp Creek (Figure 3.7-2). The stream has a total surface area of 0.5 acre, and its watershed is predominantly wetland, wooded, and undeveloped land (Table 3.7-11). It is a stream with a poorly defined channel that derives its water flow from a large, poorly drained wetland area above Hoffman Spring Pond. Oak Lake discharges intermittently to this wetland and, thus, to Hoffman Creek.

Table 3.7-23

Water Quality Data, SG-4 (Outlet Creek)
Summary of Monthly Means and Ranges

		1977-1978			1994		
Station: C/SG-4	Units	Min.	Max.	Mean	Min.	Max.	Mean
Metals							
Aluminum, Total	µg/L	<10	<10	<10	<50	<200	Note 1
Arsenic, Total	mg/L	<0.001	0.001	<0.001	<0.005	<0.005	Note 1
Cadmium, Total	µg/L	<1	4	<1	<5	<5	Note 1
Copper, Total	µg/L	<1	16	<5	<30	<30	Note 1
Iron, Total	mg/L	0.04	0.34	0.12	0.093	0.274	0.192
Lead, Total	µg/L	<10	<10	<10	<50	<50	Note 1
Manganese, Total	mg/L	0.006	0.110	0.025	0.018	0.054	0.030
Mercury, Total	ng/L	<100	200	<100	<200	300	100
Molybdenum, Total	mg/L	<0.01	<0.01	<0.01	<0.020	<0.020	Note 1
Nickel, total	mg/L	<0.01	<0.01	<0.01	<0.030	<0.030	Note 1
Zinc, Total	µg/L	<1	11	<5	<20	<20	Note 1
Phosphorus							
Phosphorus, Total	mg/L	<0.01	0.06	<0.02	<0.050	0.018	0.006
Nitrogen							
Nitrogen, Ammonia	mg/L	<0.05	0.20	<0.14	<0.1	<0.10	Note 1
Nitrogen, Nitrate	mg/L	<0.01	0.84	<0.34	<0.50	<0.50	Note 1
Sulfur							
Sulfate	mg/L	1	8	6	5.29	9.10	6.70
Solids							
Solids, Dissolved	mg/L	29	388	163	88	117	104
Solids, Suspended	mg/L	1	16	5	<5	8	3

Table 3.7-23 *(Continued)*

Station: C/SG-4	Units	1977-1978 Min.	1977-1978 Max.	1977-1978 Mean	1994 Min.	1994 Max.	1994 Mean
General Parameters							
Alkalinity, Total	mg/L	65	110	88	90	96	92
Biological Oxygen Demand	mg/L	1	6	2	<3	7	2
Chloride	mg/L	<1	5	<3	5	5	5
Conductivity	μmhos/cm	90	165	132	181	194	187
Cyanide	mg/L	<0.001	0.002	<0.001	<0.020	<0.020	Note 1
Dissolved Oxygen	mg/L	3.0	9.0	5.9	8	10.3	9.2
pH	SU	5.8	8.0	7.6	6.68	8.03	7.26
Hardness	mg/L	69	118	93	92	110	100
Temperature	°C	0	21.0	8.2	5.8	20.6	13.2
Turbidity[a]	NTU	0.5	6.0	1.7	1.70	3.20	2.45

[a] Turbidity was measured in FTU during the 1978-1978 study.

Note 1: All data reported as less than detection, therefore no mean value is calculated.

SU = Standard Units.

Prepared by: JJA
Checked by: BDH

A stream gage (SG-E) was established on Hoffman Creek during the 1977-1980 study and its location is shown on Figure 3.7-2. This station was located approximately 125 feet downstream from Hoffman Spring Pond. Flow readings obtained from April 1994 through March 1995 at this location are given in Appendix 3.7-5. Historical readings from 1978 through 1979 are provided in Appendix 3.7-6. Minimum and Maximum flows observed in Hoffman Creek were 0.22 cubic feet per second (cfs) and 11.9 cfs, respectively. Flows measured at this site during the 1993-1995 study were similar to those observed during previous studies (min = 0.22 cfs, max = 5.04 cfs).

Samples for water chemistry analysis were collected monthly from April 1994 through March 1995 from sampling Station SG-E which was located in a well mixed region of the stream approximately 100 feet downstream from Hoffman Spring Pond. Water quality data obtained from analyses of samples collected in 1994 and 1995 at this site are presented in Appendix 3.7-8. Summary statistics, including maximum, minimum and mean values for these parameters are given in Table 3.7-24. Collections of samples for water chemistry analysis were not conducted in Hoffman Creek during the 1977-1980 study.

Available water chemistry information derived from samples obtained at SG-E indicate that Hoffman Creek is a hard, neutral pH stream. Mean values recorded for hardness, alkalinity and specific conductance were 144 mg/L as $CaCO_3$, 140 mg/L as $CaCO_3$, and 263 μmhos/cm, respectively. Dissolved oxygen concentrations measured in Hoffman Creek ranged from 5.5 to 10.8 and averaged 8.8 mg/L. The mean pH recorded was 7.33.

All metals analyzed from samples collected at Hoffman Creek during the 1994-1995 study were either below detection limits or were found in low concentrations. During this recent study, low level analyses techniques were used to monitor concentrations of aluminum, cadmium, copper, lead, mercury, zinc and chromium in water samples collected in Hoffman Creek. The lower detection limits associated with these techniques allowed for trace level detections of all these metals.

3.7.4.6 Ground Hemlock Lake

The data presented for Ground Hemlock Lake is taken from previous studies completed in the 1970s and 1980s and one sampling event in March 1995. The earlier time period in which this data was collected, 1970s and 1980s, was before the laboratory certification program NR 149 was enacted. The water quality for Ground Hemlock Lake is reflected in the samples collected in March 1995 and in the data submitted for Hemlock Creek, Site SG-6 which is fed by Ground Hemlock Lake.

Ground Hemlock Lake is located 2.4 miles east of the ore body (Figure 3.7-2). It has a total surface area of 85 acres and a maximum depth of 42 feet. The predominant lake substrate is sand, gravel, rubble boulders, and muck (Table 3.7-11). The lake has no defined inlets and is the headwaters of Hemlock Creek.

Table 3.7-24

Water Quality Data, SG-E (Hoffman Creek)
Summary of Monthly Means and Ranges

Parameter	Units	Minimum	Maximum	Mean
pH	SU	6.70	7.86	7.33
Conductivity	μmhos	227	297	263
Temperature	°C	4.1	20.6	9.6
Dissolved Oxygen	mg/L	5.5	10.8	8.8
Alkalinity	mg/L	129	150	140
Alkalinity, Bicarbonate	mg/L	129	150	140
Hardness	mg/L	129	150	144
Total Dissolved Solids	mg/L	110	230	163
Total Suspended Solids	mg/L	<5	5	1
Biochemical Oxygen Demand	mg/L	<2	9	1
Chemical Oxygen Demand	mg/L	<10	<10	Note 1
Ammonia	mg/L	<0.10	<0.10	Note 1
Nitrate	mg/L	<0.50	0.76	0.27
Nitrogen, total Kjeldahl	mg/L	<0.20	0.50	0.27
Chloride	mg/L	1	2	2
Fluoride	mg/L	<0.1	0.8	0.1
Sulfate	mg/L	6.88	11.00	8.32
Cyanide, total	mg/L	<0.020	<0.020	Note 1
Oil Grease	mg/L	<1.0	14.0	1.67
Turbidity, Lab	NTU	<0.50	1.42	0.75
Cations	Meq/L	2.76	3.34	3.02
Anions	Meq/L	0.37	2.71	2.33
Cation and Anion Balance	%	7.04	78.17	15.02
Boron, total	mg/L	<0.099	<0.200	Note 1
Calcium, total	mg/L	29.2	36.0	32.3
Arsenic, total	mg/L	<0.005	<0.005	Note 1

Table 3.7-24 *(Continued)*

Parameter	Units	Minimum	Maximum	Mean
Barium, total	mg/L	<0.010	<0.010	Note 1
Iron, dissolved	mg/L	<0.050	0.227	0.024
Iron, total	mg/L	<0.050	0.087	0.013
Manganese, dissolved	mg/L	<0.010	<0.010	Note 1
Manganese, total	mg/L	<0.010	0.016	0.003
Molybdenum, total	mg/L	<0.020	<0.020	Note 1
Selenium, total	mg/L	<0.005	<0.005	Note 1
Silver, total	mg/L	<0.010	<0.010	Note 1
Chromium, total	mg/L	<0.020	<0.020	Note 1
Chromium, total[1]	µg/L	0.300	1.920	1.22
Beryllium, total	mg/L	<0.005	<0.010	Note 1
Thallium, total	mg/L	<0.005	<0.005	Note 1
Nickel, total	mg/L	<0.030	<0.030	Note 1
Antimony, total	mg/L	<0.005	<0.005	Note 1
Magnesium, total	mg/L	14.6	17	15.8
Phosphorus, dissolved	mg/L	<0.050	0.017	0.004
Phosphorus, total	mg/L	<0.050	0.030	0.007
Potassium, total	mg/L	<0.600	1.100	0.272
Sodium, total	mg/L	2.27	2.70	2.41
Sodium Absorption Ratio	std	0.080	0.090	0.086
Aluminum, total	µg/L	10.7	73.3	28.4
Cadmium, total	µg/L	<0.003	0.014	0.002
Copper, total	µg/L	0.107	0.649	0.283
Lead, total	µg/L	0.022	0.192	0.078
Mercury, total	ng/L	0.54	2.93	1.18
Zinc, total	µg/L	0.57	6.66	1.67

[1]Chromium analyzed utilizing low level techniques.

Prepared by: JJA
Checked by: BDH

Note 1: All data reported as less than detection, therefore no mean value is calculated.
SU = Standard Units.

The shoreline vegetation is predominantly upland hardwoods with the remainder being a coniferous wetland. The effects of associated wetlands on lake levels of spring lakes such as Ground Hemlock vary depending upon the hydrologic characteristics of the wetland. In a spring-fed lake the primary source of water supply to the lake is groundwater. If the wetland associated with the lake is also groundwater fed, then the level of water in both should fluctuate similarly, although there would be a delayed yield of water to the lake from the wetland that would tend to stabilize the lake level. If, however, the wetlands surrounding the lake are perched, as many in the study area are, then the wetland discharge to the lake could also have a stabilizing effect on the level of the lake.

Surface water levels in Ground Hemlock Lake were measured at LG-24 during the 1970s and 1980s. Appendix 3.7-3 provides a record of gage readings at this location. Lake levels fluctuated in response to groundwater inflow, incident precipitation, and local runoff from rainfall. During the period of study, a 0.58-foot water level fluctuation was observed, reflecting maintenance of a fairly constant water level within the system. The high water level of 1,579.10 feet MSL during the study period occurred on May 13, 1980, whereas the low lake level reading of 1,578.52 feet MSL was recorded on July 16, 1980 (EMC, 1985).

The water chemistry sampling station at Ground Hemlock Lake was centrally located at approximately the 36.1-foot depth contour. Samples were collected at this location from two separate levels: 3.3 feet (GH-1) and 19.7 to 32.8 feet (GH-2). Samples at GH-2 were always collected in the hypolimnion, when present. Water chemistry collections for Ground Hemlock Lake continued monthly from November 1979 through October 1980 and from May 1979 through October 1980 at GH-1 and GH-2, respectively. Maximum, minimum, and mean values calculated from the results of the analyses of the water samples are presented in Appendix 3.7-4.

The results of the water chemistry data are shown in Table 3.7-24a and 3.7-24b. These data indicate that Ground Hemlock Lake is a moderately hard, clear, neutral to slightly basic pH lake. The 1979-1980 mean values for hardness, alkalinity, and specific conductance were 112 and 128 mg/L as $CaCO_3$, 110 and 129 mg/L as $CaCO_3$, and 213 and 257 μmhos/cm at GH-1 and GH-2, respectively. Mean hardness and pH values indicated that the deeper waters were somewhat harder and closer to a neutral pH (GH-2: 128 mg/L as $CaCO_3$ and pH 7.7) than the near surface waters (GH-1: 112 mg/L as $CaCO_3$ and pH 8.2). The March 1995 data, also included in Tables 3.7-24a and 3.7-24b, confirmed these characteristics.

Temperature and dissolved oxygen concentration profiles indicated that Ground Hemlock Lake stratified during the summer (Appendix 3.7-11). A rapid temperature decrease with depth (metalimnion) was recorded in June between 13.1 and 26.2 feet, and maximum dissolved oxygen (12.0 mg/L) was measured concurrently at 16.4 feet. The metalimnion and oxygen maximum became more pronounced in July and August, respectively. In July, the metalimnion exhibited its most extreme temperature change, a 29°F drop between 9.8 and 23 feet. In August, the dissolved oxygen concentration at 16.4 feet within the metalimnion was so high (>20 mg/L) that it was not measurable with standard field measures.

Table 3.7-24a

Water Quality Data, LG-24-40 (Ground Hemlock Lake)
Summary of Monthly Means and Ranges for Hypolimnetic Water

		1979-80			March
Station: GH-2/LG-24-40	Units	Min.	Max.	Mean	1995
Metals					
Aluminum, Total	mg/L	<0.01	<0.01	<0.01	NDA
Antimony, Total	μg/L	NDA	NDA	NDA	<5
Arsenic, Total	mg/L	<0.001	<0.001	<0.001	<0.005
Barium, Total	mg/L	NDA	NDA	NDA	0.024
Beryllium	mg/L	NDA	NDA	NDA	<0.01
Boron	mg/L	NDA	NDA	NDA	<0.10
Cadmium, Total	mg/L	<0.001	<0.001	<0.001	NDA
Calcium	mg/L	NDA	NDA	NDA	24
Chromium, Hexavalent	mg/L	<0.01	<0.01	<0.01	NDA
Chromium, Trivalent	mg/L	<0.001	<0.001	<0.001	NDA
Cobalt	mg/L	<0.01	<0.01	<0.01	NDA
Copper, Total	mg/L	<0.001	<0.001	<0.001	NDA
Iron, Total	mg/L	<0.01	0.09	<0.04	<0.050
Iron, Dissolved	mg/L	NDA	NDA	NDA	<0.050
Lead, Total	mg/L	<0.01	<0.01	<0.01	NDA
Magnesium	mg/L	NDA	NDA	NDA	11
Manganese, Total	mg/L	0.010	0.278	0.103	<0.010
Manganese, Dissolved	mg/L	NDA	NDA	NDA	<0.010
Mercury, Total	ng/L	<100	<100	<100	NDA
Molybdenum, Total	mg/L	<0.01	<0.01	<0.01	<0.020
Nickel, Total	mg/L	<0.01	<0.01	<0.01	<0.030

Table 3.7-24a *(Continued)*

Station: GH-2/LG-24-40	Units	1979-80 Min.	1979-80 Max.	1979-80 Mean	March 1995
Potassium, Total	mg/L	NDA	NDA	NDA	0.72
Selenium	mg/L	NDA	NDA	NDA	<0.005
Silver	mg/L	NDA	NDA	NDA	<0.010
Sodium	mg/L	NDA	NDA	NDA	1.6
Thallium	μg/L	NDA	NDA	NDA	<5
Zinc, Total	mg/L	<0.001	0.004	<0.001	NDA
Phosphorus					
Phosphorus, Total	mg/L	0.05	0.17	0.11	0.08
Phosphorus, Soluble	mg/L	<0.01	<0.01	<0.01	<0.05
Nitrogen					
Nitrogen, Ammonia	mg/L	<0.01	0.10	<0.05	0.2
Nitrogen, Nitrate	mg/L	<0.05	<0.05	<0.05	<0.50
Nitrogen, Nitrite	mg/L	<0.01	<0.01	<0.01	NDA
Nitrogen, Organic	mg/L	0.17	0.39	0.28	0.3
Sulfur					
Sulfate	mg/L	1	11	4	5.4
Sulfide	mg/L	<0.01	0.76	<0.23	NDA
Sulfur, Total	mg/L	0.33	3.63	1.60	NDA
Solids					
Solids, Total Dissolved	mg/L	118	199	153	140
Solids, Total Suspended	mg/L	2	34	17	<5

Table 3.7-24a *(Continued)*

Station: GH-2/LG-24-40	Units	1979-80 Min.	1979-80 Max.	1979-80 Mean	March 1995
General Parameters					
Alkalinity, Total	mg/L	98	146	129	100
Biological Oxygen Demand	mg/L	1	12	7	<3
Chemical Oxygen Demand	mg/L	14	27	20	<10
Chloride	mg/L	<1	2	<2	1
Conductivity	μmhos/cm	153	210	180	236
Cyanide	mg/L	<0.001	<0.001	<0.001	<0.02
Fluoride	mg/L	NDA	NDA	NDA	<0.1
Hardness	mg/L	88	148	128	130
Oil & Grease	mg/L	<1	<1	<1	<4.6
Oxygen, Dissolved	mg/L	0.2	5.2	1.4	0.3
pH	SU	7.2	8.9	7.7	7.4
Temperature	°C	7.5	12.0	8.7	6.3
Turbidity[a]	NTU	4.4	28.0	16.4	2.3

[a]Turbidity was measured in FTU during the 1977-1978 study.
SU = Standard Units.
NDA = No Data Available.

Prepared by: GJB1
Checked by: LCT

Table 3.7-24b

Water Quality Data, LG-24-5 (Ground Hemlock Lake)
Summary of Monthly Means and Ranges for Epilimnetic Water

Station: GH-1/LG-24-5	Units	1979-80 Min.	1979-80 Max.	1979-80 Mean	March 1995
Metals					
Aluminum, Total	mg/L	<0.01	0.02	<0.01	NDA
Antimony, Total	μg/L	NDA	NDA	NDA	<5
Arsenic, Total	mg/L	<0.001	<0.001	<0.001	<0.005
Barium, Total	mg/L	NDA	NDA	NDA	0.16
Beryllium	mg/L	NDA	NDA	NDA	<0.01
Boron	mg/L	NDA	NDA	NDA	<0.10
Cadmium, Total	mg/L	<0.001	0.003	<0.001	NDA
Calcium	mg/L	NDA	NDA	NDA	27
Chromium, Hexavalent	mg/L	<0.01	<0.01	<0.01	NDA
Chromium, Trivalent	mg/L	<0.001	<0.001	<0.001	NDA
Cobalt	mg/L	<0.01	<0.01	<0.01	NDA
Copper, Total	mg/L	<0.001	0.004	<0.001	NDA
Iron, Total	mg/L	<0.01	0.04	<0.02	<0.050
Iron, Dissolved	mg/L	NDA	NDA	NDA	<0.050
Lead, Total	mg/L	<0.01	0.03	<0.01	NDA
Magnesium	mg/L	NDA	NDA	NDA	12
Manganese, Total	mg/L	0.005	0.025	0.011	<0.010
Manganese, Dissolved	mg/L	NDA	NDA	NDA	<0.010
Mercury, Total	ng/L	<100	<100	<100	NDA
Molybdenum, Total	mg/L	<0.01	<0.01	<0.01	<0.020
Nickel, Total	mg/L	<0.01	<0.01	<0.01	<0.030

Table 3.7-24b *(Continued)*

Station: GH-1/LG-24-5	Units	1979-80 Min.	1979-80 Max.	1979-80 Mean	March 1995
Potassium, Total	mg/L	NDA	NDA	NDA	0.85
Selenium	mg/L	NDA	NDA	NDA	<0.005
Silver	mg/L	NDA	NDA	NA	<0.010
Sodium	mg/L	NDA	NDA	NDA	1.8
Thallium	μg/L	NDA	NDA	NDA	<0.005
Zinc, Total	mg/L	<0.001	0.011	<0.004	NDA
Phosphorus					
Phosphorus, Total	mg/L	0.02	0.06	0.04	<0.05
Phosphorus, Soluble	mg/L	<0.01	0.01	<0.01	<0.05
Nitrogen					
Nitrogen, Ammonia	mg/L	<0.01	0.30	<0.17	0.2
Nitrogen, Nitrate	mg/L	<0.05	<0.05	<0.05	<0.50
Nitrogen, Nitrite	mg/L	<0.01	<0.01	<0.01	NDA
Nitrogen, Organic	mg/L	<0.01	0.41	<0.17	0.2
Sulfur					
Sulfate	mg/L	2	7	5	5.0
Sulfide	mg/L	<0.01	0.09	<0.02	NDA
Sulfur, total	mg/L	0.68	2.31	1.74	NDA
Solids					
Solids, Total Dissolved	mg/L	99	167	130	130
Solids, Total Suspended	mg/L	<1	9	<4	<5

Table 3.7-24b *(Continued)*

Station: GH-1/LG-24-5	Units	1979-80 Min.	1979-80 Max.	1979-80 Mean	March 1995
General Parameters					
Alkalinity, Total	mg/L	84	122	110	110
Biological Oxygen Demand	mg/L	1	12	5	<3
Chemical Oxygen Demand	mg/L	10	62	26	<10
Chloride	mg/L	<1	4	<2	<1
Conductivity	μmhos/cm	132	200	155	275
Cyanide	mg/L	<0.001	<0.001	<0.001	<0.020
Fluoride	mg/L	NDA	NDA	NDA	<0.1
Hardness	mg/L	92	124	112	120
Oil & Grease	mg/L	<1	<1	<1	<4.6
Oxygen, Dissolved	mg/L	1.1	12.5	8.6	6.8
pH	SU	6.7	8.9	8.2	7.4
Temperature	°C	2.5	24.5	10.3	6.7
Turbidity[a]	NTU	0.7	4.5	2.5	1.4

[a]Turbidity was measured in FTU during the 1977-1978 study.
SU = Standard Units.
NDA = No Data Available.

Prepared by: GJB1
Checked by: JWS

Metalimnetic oxygen maxima as observed in Ground Hemlock Lake during June, July, and August are common phenomena that occur in clear, thermally stratified lakes and, typically, are generated by a bloom of blue-green algae (Eberly, 1959; Reynolds and Walsby, 1975). Observations made by a scuba equipped diver in August confirmed the presence of a sharply defined, dense growth of phytoplankton within the metalimnion (EMC, 1985).

Very low dissolved oxygen concentrations (typically <1 mg/L) were recorded from June through September 1980, and again in March 1995, at or below the metalimnion. This region of low dissolved oxygen concentration rose from a depth of 26.2 feet in June to 19.7 feet by September. By October, the autumn overturn had occurred, as indicated by the uniform vertical temperature distribution and the diminished dissolved oxygen gradient.

In general, the concentrations of metals in Ground Hemlock Lake were either below detection limits or at very low levels. Lead was below detection limits at both sampling levels throughout this study except at GH-1 in December 1979 and April 1980 when concentrations of 0.02 mg/L and 0.03 mg/L were recorded, respectively.

3.7.4.7 Oak Lake

Oak Lake is located approximately 0.9 mile southwest of the ore body (Figure 3.7-2). It has a total surface area of 51 acres and a maximum depth of 47 feet. The shoreline vegetation surrounding it is predominantly upland hardwoods with the remainder being composed of bog, meadow, and shrub wetlands. The lake substrate is predominantly muck, sand and gravel (Table 3.7-11). The lake has no defined inlets and provides an intermittent headwater source of water to Hoffman Creek.

Oak Lake receives water directly from precipitation and from runoff within its drainage basin. During most of the year it appears to have no surface water connection to the remainder of the Hoffman Creek drainage basin; however, when a sufficient amount of water is delivered to the lake by thunderstorms or during snowmelt, it discharges surface water to Hoffman Creek (EMC, 1985). At those times, surface water enters Oak Lake around its edges and from the north through a culvert under Sand Lake Road. Surface water leaves Oak Lake and flows into a broad wetland area via a poorly defined, intermittent outlet on the lake's southwest margin. Water flow in this outlet proceeds southwest and then north through a wetland area via a second culvert under Sand Lake Road.

A stream gage (SG-10) located on the outlet stream of Oak Lake was monitored during the 1977-1978 study. Staff gage readings recorded at SG-10 are given in Dames & Moore, 1985. Flow measurements made by these earlier studies indicated that the area immediately surrounding Oak Lake was a groundwater aquifer recharge area, which contributes to the discharge area at Hoffman Springs.

Staff gage LG-11 was established on Oak Lake during the 1977-1980 study. Lake levels calculated from data obtained at this location between April 1977-October 1994 are given in

Appendix 3.7-3. During this time period, the level in Oak Lake varied from a low of 1632.12 to a high of 1634.42, and averaged 1633.21.

The water chemistry sampling station designated LG-11 was positioned in the northcentral portion of Oak Lake. Collections of samples for water chemistry analysis were conducted monthly at this location from April 1994 through March 1995. Throughout the majority of this period at those times when the lake was determined to be well mixed, these samples were collected from the approximate center of the water column (LG-11). At the request of the WDNR, during the winter of 1995 when the lake was stratified, as indicated by the presence of a chemocline or thermocline, water samples were generally collected from both the hypolimnion (LG-11-H) and epilimnion (LG-11-E) portions of the lake. Analyses on these latter samples were completed for the same list of parameters as for other lake samples with the exception of metals. Water quality data obtained from analyses of samples collected during this time period at this site are presented in Appendix 3.7-8. Summary statistics including maximum, minimum and mean values for these parameters are given in Tables 3.7-25 through 3.7-25b which compares them to similar statistics derived from samples obtained during the 1977-1980 study.

In general, the results reported from analysis of water samples collected from LG-11 in 1994 and 1995 were similar to those obtained during the 1977-1980 effort. Results of water chemistry analysis indicated that Oak Lake was a soft, slightly acidic to neutral pH lake. As shown in Table 3.7-25 the average hardness, alkalinity, and specific conductance values in Oak Lake were 7 mg/L as $CaCO_3$, 1 mg/L as $CaCO_3$ and 22 μmhos/cm respectively. Surface water pH values ranged from 5.34 to 6.76 and averaged 6.29 throughout the period of study.

As shown in Table 3.7-25 the average dissolved solids levels recorded in the 1994-1995 samples were much lower than those recorded in the 1978 work. A review of the data indicates that the monthly results from the 1994-1995 work were consistent throughout the year, while the results from the 1978 work contained a wider range of values. The wide range of values recorded in 1978 could be the result of natural lake variations or variations in sampling and testing procedures.

Monthly dissolved oxygen concentration profiles indicated that Oak Lake showed signs of stratification during the summer of 1994 (Figure 3.7-5). This is consistent with historical data collected during the late 1970s, which indicated that Oak Lake was in the stratified state in July and August of 1977 and August of 1978. In 1994 a rapid decrease in both water temperature and dissolved oxygen level with depth (metalimnion) was evident in August between 22 and 31 feet. By September the metalimnion had ascended to between 19 and 29 feet. Finally in October temperatures were similar throughout the water column, indicating that the fall mixing cycle had occurred. At that time dissolved oxygen concentrations ranged from 9.4 at the surface to 8.2 at one foot from the bottom, and were consistent throughout the majority of the water column. A metalimnetic oxygen maxima such as that recorded in Oak Lake in July of 1977 was not observed during the summer of 1994. Dissolved oxygen data collected in Oak Lake during the 1977-1980 study can be found in Appendix 3.7-11.

Table 3.7-25

Water Quality Data, LG-11 (Oak Lake)
Summary of Monthly Means and Ranges[a]

		1978			1994-1995		
Station: G-1/G-2/LG-11	Units	Min.	Max.	Mean	Min.	Max.	Mean
Metals							
Aluminum, Total	µg/L	<10	<10	<10	11.70	31.40	20.05
Arsenic, Total	mg/L	<0.001	<0.001	<0.001	<0.005	0.006	0.001
Cadmium, Total	µg/L	<1	4	<1	0.004	0.025	0.013
Copper, Total	µg/L	<1	<19	<5	0.287	0.764	0.414
Iron, Total	mg/L	0.01	0.15	0.05	<0.050	0.490	0.067
Lead, Total	µg/L	<10	<10	<10	0.077	0.262	0.142
Manganese, Total	mg/L	0.007	0.061	0.023	<0.010	0.120	0.023
Mercury, Total	ng/L	<100	200	<100	0.84	2.35	1.26
Molybdenum, Total	mg/L	<0.01	<0.01	<0.01	<0.020	<0.020	Note 1
Nickel, Total	mg/L	<0.01	<0.01	<0.01	<0.030	<0.030	Note 1
Zinc, Total	µg/L	1	36	11	2.33	4.78	3.23
Phosphorus							
Phosphorus, Total	mg/L	<0.01	0.03	<0.02	<0.050	0.019	0.005
Nitrogen							
Nitrogen, Ammonia	mg/L	0.11	0.22	0.16	<0.10	0.15	0.03
Nitrogen, Nitrate	mg/L	<0.01	0.16	<0.07	<0.50	0.71	0.07
Sulfur							
Sulfate	mg/L	2	9	6	3.6	9.0	5.2
Solids							
Solids, Dissolved	mg/L	2	216	53	<5	44	22
Solids, Suspended	mg/L	1	10	3	<5	7	1

Table 3.7-25 *(Continued)*

Station: G-1/G-2/LG-11	Units	1978 Min.	1978 Max.	1978 Mean	1994-1995 Min.	1994-1995 Max.	1994-1995 Mean
General Parameters							
Alkalinity, Total	mg/L	<1	8	<4	<5	5	1
Biochemical Oxygen Demand	mg/L	1	6	2	<2	10	1
Chemical Oxygen Demand	mg/L	7	7	7	<10	16	10
Chloride	mg/L	<1	6	<2	<1	1	0
Conductivity	μmhos/cm	11	32	23	17	27	22
Cyanide	mg/L	<0.001	0.002	<0.001	<20	<20	Note 1
Hardness	mg/L	1	24	11	<5	10	7
pH	SU	5.8	7.5	6.2	5.34	6.76	6.29
Temperature	°C	1.0	25.1	10.7	0.1	22.9	13.3
Turbidity[b]	NTU	0.7	2.5	1.3	0.21	2.40	1.02

[a] This table includes a summary of all data collected for Oak Lake. For statistical comparison purposes, data was collected from the epilimnion (LG-11-E) and the hypolimnion (LG-11-H) on the same date. This data was first averaged together to obtain one composite value for each parameter for that date. This value was then used in the calculations for the statistics included in Table 3.7-25.

[b] Turbidity was measured in FTU during the 1977-1978 study.

Note 1: All data reported as less than detection, therefore no mean value is calculated.

SU = Standard Units.

Prepared by: JJA
Checked by: BDH

Table 3.7-25a

Water Quality Data, LG-11-H (Oak Lake)
Summary of Means and Ranges for Hypolimnetic Water

		1978			1995		
Station: G-2/LG-11-H	Units	Min.	Max.	Mean	Min.	Max.	Mean
Phosphorus							
Phosphorus, Total	mg/L	0.04	0.04	0.04	<0.050	<0.050	Note 1
Nitrogen							
Nitrogen, Ammonia	mg/L	0.18	0.18	0.18	<0.10	0.20	0.10
Nitrogen, Nitrate	mg/L	0.15	0.15	0.15	<0.50	<0.50	Note 1
Sulfur							
Sulfate	mg/L	7	8	8	4.6	4.7	4.7
Solids							
Solids, dissolved	mg/L	40	46	43	11	39	25
Solids, suspended	mg/L	1	2	2	<5	<5	Note 1
General Parameters							
Alkalinity, Total	mg/L	2	2	2	<5	5	3
Biochemical Oxygen Demand	mg/L	2	2	2	<3	<3	Note 1
Chemical Oxygen Demand	mg/L	ND	ND	ND	13	14	14
Chloride	mg/L	<1	<1	<1	<1	<1	Note 1
Conductivity	μmhos/cm	ND	ND	ND	29.6	63.2	46.4
Cyanide	mg/L	<0.001	<0.001	<0.001	<0.020	<0.020	Note 1
Hardness	mg/L	8	12	10	6	7	7
pH[Lb]	SU	5.3	6.0	5.7	5.30	5.50	5.40
Turbidity[a]	NTU	0.8	1.3	1.1	0.60	0.60	0.60

Lb = Laboratory pH Value.
a = Turbidity was measured in FTU during the 1977-1978 study.
ND = No Data
Note 1: All data reported as less than detection, therefore no mean value is calculated.
SU = Standard Units.

Prepared by: JJA
Checked by: BDH

Table 3.7-25b

Water Quality Data, LG-11-E (Oak Lake)
Summary of Means and Ranges for Epilimnetic Water

		1978			1995		
Station: G-1/LG-11-E	Units	Min.	Max.	Mean	Min.	Max.	Mean
Phosphorus							
Phosphorus, Total	mg/L	<0.01	<0.01	<0.01	<0.050	<0.050	Note 1
Nitrogen							
Nitrogen, Ammonia	mg/L	0.20	0.20	0.20	<0.10	0.20	0.10
Nitrogen, Nitrate	mg/L	<0.01	<0.01	0.07	<0.50	<0.50	Note 1
Sulfur							
Sulfate	mg/L	8	8	8	4.50	4.60	4.55
Solids							
Solids, dissolved	mg/L	32	36	34	28	46	37
Solids, suspended	mg/L	1	2	2	<5	<5	Note 1
General Parameters							
Alkalinity, Total	mg/L	<1	2	1	<5	5	3
Biological Oxygen Demand	mg/L	1	1	1	<3	<3	Note 1
Chemical Oxygen Demand	mg/L	7	7	7	13	17	15
Chloride	mg/L	<1	2	1	<1	<1	Note 1
Conductivity	μmhos/cm	11	32	23	26.3	74.3	50.3
Cyanide	mg/L	<.001	<0.001	<0.001	<0.020	<0.020	Note 1
Hardness	mg/L	8	12	10	6	8	7
pH[Lb]	SU	5.8	6.0	5.9	5.10	5.20	5.15
Turbidity[a]	NTU	0.8	2.4	1.6	0.60	0.70	0.65

[Lb] Laboratory pH Value.

[a] Turbidity was measured in FTU during the 1977-1978 study.

Note 1: All data reported as less than detection, therefore no mean value is calculated.

SU = Standard Units.

Prepared by: JJA
Checked by: BDH

Profiles of oxygen conducted during the winter of 1994-1995 indicated that Oak Lake was also stratified during February and March of 1995. Although the temperature throughout the water column was uniform throughout this period, a distinct chemocline (change in chemical composition with depth) was observed between 21 and 28 and 23 and 29 feet, respectively, during these months (Figures 3.7-5 and 3.7-6).

All metals analyzed from samples collected at LG-11 during the 1994-1995 study were either below detection limits or were found in low concentrations. During this recent study, low level analyses techniques were used to monitor concentrations of aluminum, cadmium, copper, lead, mercury, zinc and chromium in water samples collected in Oak Lake. The lower detection limits associated with these techniques allowed for trace level detections of all these metals. Only aluminum was detected at a level substantially higher than those observed during the 1977-1980 study (mean value = 20.07 mg/L vs <10 mg/L).

In October 1994 a sediment sample was collected from Oak Lake at Station G. A sample was also collected at this site in March 1978 for the previous work that was completed (EMC, 1985). A comparison of the results from these two sampling events is shown in Table 3.7-26.

The data from 1994 indicates that the substrate for Oak lake is predominantly inorganic. Relatively low levels of metals, calcium and magnesium were observed. It is likely that silica materials such as quartz dominate the composition of the sediments in Oak Lake, although the organic content of the sediments can vary dependant upon the position within the lake. In general, a relatively small layer of organic sediment can typically be found in the deeper waters of lakes with predominantly inorganic substrate.

The variability of the data between 1994 and 1978 may have resulted from the collection of samples from different locations within the lake. In addition to the variability in sampling locations, the method used to collect samples was also different. The core sampler used in 1994 may have collected a greater proportion of the inorganic sediments than the Ekman dredge sampler used in 1978. In either case, the data provides background information and illustrates the potential variability in the measurement of sediment characteristics.

3.7.4.8 Lake 35-7

An unnamed lake in the Pickerel Creek watershed, designated Lake 35-7 is located in Section 35, T35N, R12E. This lake is primarily fed by groundwater and has a relatively small watershed. Although the lake does not have a clearly defined outlet, it is considered a spring lake. The outlet from the lake is through the adjacent wetland which indirectly feeds into Mole lake. Water quality data was collected from this lake in December 1997. The sampling point for this water body has been designated LG-357. This lake is a hard water body with a neutral pH. Oxygen levels in the lake ranged from 1.0 to 2.8 mg/L which is not sufficient to support either warm or cold water sport fish communities. The water quality characteristics for this lake are found in Table 3.7-26a.

Table 3.7-26

Sediment Sampling Data, Oak Lake (Station G)

Parameter	Units	October 1994 Data	March 1978 Data
pH, Lab	SU	6.0	NDA
Solids, Total	%	78.7	6.53
Solids, Total Volatile	mg/kg	7000	NDA
Ammonia, N	mg/kg	30	NDA
Total Kjeldahl Nitrogen	mg/kg	200	NDA
Total Organic Nitrogen	mg/kg	170	NDA
Chloride	mg/kg	<10	NDA
Fluoride	mg/kg	<0.5	NDA
Cyanide, Total	mg/kg	<0.5	NDA
Oil & Grease (Freon Extractables)	mg/kg	950	3951
Boron, Total	mg/kg	<10	NDA
Calcium, Total	mg/kg	84	NDA
Arsenic, Total	mg/kg	<0.40	1.5
Barium, Total	mg/kg	3.5	NDA
Iron, Total	mg/kg	550	4388
Manganese, Total	mg/kg	52	91
Molybdenum, Total	mg/kg	<2.0	NDA
Selenium, Total	mg/kg	<0.50	NDA
Silver, Total	mg/kg	<0.50	NDA
Chromium, Total	mg/kg	<0.50	16.8
Cobalt, Total	mg/kg	<1.0	NDA
Beryllium, Total	mg/kg	<0.50	NDA

Table 3.7-26 *(Continued)*

Parameter	Units	October 1994 Data	March 1978 Data
Thallium, Trace ICP	mg/kg	<1.0	NDA
Nickel, Total	mg/kg	<2.0	NDA
Antimony, Total	mg/kg	<5.0	NDA
Magnesium, Total	mg/kg	85	NDA
Phosphorus, Total	mg/kg	<100	NDA
Potassium, Total	mg/kg	<60	NDA
Sodium, Total	mg/kg	11	NDA
Aluminum, Total	mg/kg	400	NDA
Cadmium, Total	mg/kg	<0.50	2.9
Copper, Total	mg/kg	<0.50	11.0
Lead, Total	mg/kg	2.8	60
Mercury, Total	mg/kg	<0.02	<0.01
Zinc, Total	mg/kg	5.5	205
Vanadium	mg/kg	1.2	NDA

SU = Standard Units.
NDA = No Data Available.

Prepared by: GJB1
Checked by: GJB

Table 3.7-26a

December 1997 Sampling Data for Lake 35-7

Parameter	Units	December 1997 Data
Alkalinity, Bicarbonate as HCO_3	mg/L	130
Alkalinity, Total as $CaCO_3$	mg/L	100
Alkalinity, Carbonate as $CaCO_3$	mg/L	<1.4
Aluminum, total	µg/L	8.5
Arsenic, total	µg/L	<1.8
Barium, total	µg/L	6.1
BOD-5 day	mg/L	4.0
Boron, total	µg/L	<18
Cadmium, total	µg/L	<0.030
Calcium, total	mg/L	21
COD (unfiltered)	mg/L	25
Chloride (unfiltered)	mg/L	<0.56
Chromium, Trivalent	µg/L	0.039
Chromium, Hexavalent	µg/L	0.43
Chromium, total	µg/L	0.47
Color, APHA (true)	C.P.U.	80
Conductivity, Specific @25°C - field	umhos/cm	188.3
Copper, total	µg/L	0.11
Cyanide, total (distilled)	mg/L	<0.0046
Fluoride, (unfiltered)	mg/L	0.058
Hardness, total as $CaCO_3$	mg/L	95
Iron, total	mg/L	0.30
Lead, total	µg/L	0.25
Manganese, total	µg/L	41
Mercury	µg/L	0.0016

Table 3.7-26a *(Continued)*

Parameter	Units	December 1997 Data
Molybdenum	mg/L	<0.0082
Nitrogen, Ammonia as N (unfiltered)	mg/L	0.39
Nitrogen, NO_2+NO_3 as N (unfiltered)	mg/L	0.048
Nitrogen, Kjeldahl as N (unfiltered)	mg/L	0.60
Oil & Grease, (water)	mg/L	<7.2
Oxygen, field	mg/L	1.0-2.8
pH, lab	SU	6.9
pH, field	SU	7.53
Phosphorus, total	mg/L	0.010
Phosphorus, reactive as P	mg/L	<0.0021
Selenium, total	µg/L	<1.6
Silver, total	µg/L	2.9
Solids, total dissolved	mg/L	160
Solids, total suspended	mg/L	1.0
Solids, total volatile	%DWB	12
Sulfate, as SO_4	mg/L	8.9
Turbidity	NTU	0.69
Zinc, total	µg/L	1.3
Chlorophyll		
Corrected Chlorophyll a	µg/L	1.99
Pheophytin a	µg/L	0.331
Trichromatic Chlorophyll a	µg/L	2.26
Trichromatic Chlorophyll b	µg/L	0.030
Trichromatic Chlorophyll c	µg/L	0.243

Prepared by: GJB1
Checked by: LCT

3.7.5 Pickerel Creek Drainage Basin

The portion of the study area that resides within the Pickerel Creek drainage basin is shown on Figures 3.7-1 and 3.7-2. The Pickerel Creek drainage basin has ground and surface water features that are characteristic of the study area, as was described previously. The Pickerel Creek drainage basin is located approximately in the center of the Wolf River drainage basin (Figure 3.7-4). Surface water drainage within it flows to the southwest via Pickerel Creek to its confluence with the Wolf River. Specific key basin characteristics are given in Table 3.7-27. Selected surface water features included in the discussion of the Pickerel Creek drainage basin are Rolling Stone Lake; Pickerel Creek, drainage Canal to Pickerel Creek and Creeks 12-9, 12-2 and 11-4; and Little Sand, Duck, Deep Hole, and Skunk Lakes. These features are described individually below.

3.7.5.1 Rolling Stone Lake

Rolling Stone Lake is located 3.5 miles south of the ore body as shown on Figures 3.7-1 and 3.7-2. It has a surface area of 672 acres with a reported maximum depth of 12 feet. The lake substrates are primarily composed of sand, gravel, muck, detritus and rubble (Table 3.7-27). The lake has two primary inlets, which are Pickerel Creek and Creek 12-9, both located along its north shore. Creek 11-4 is also an inlet to Rolling Stone Lake along the north shore. The lake has a simple man-made outlet structure at its southeast end that serves to partially control water levels (EMC, 1985).

The shoreline of Rolling Stone Lake is approximately 60 percent woodland and 40 percent wetland. As previously discussed, the influence of a wetland on water level fluctuations in associated lakes is dependent upon the individual hydrologic characteristics such as the source of water and the lakes relative position with respect to the groundwater aquifer as well as the interrelationship between the wetland and the lake. Because the main source of water for the lake is stream discharge, fluctuations within the two water bodies generally occurs only if the surrounding wetlands are also fed predominantly by stream discharge. If the wetland water source is groundwater, limited correlation in water level fluctuations would be expected. The wetland would be expected to increase the attenuation influence of the lake on stream discharge by increasing the storage capacity. Surrounding wetlands may also provide a source of water during drought periods.

Surface water levels in Rolling Stone Lake were measured at LG-9 during the 1977-1978 study. Data located in Appendix 3.7-3 provides a historical record of gage readings at this location. During the period of study, a 0.98-foot water level fluctuation was observed. The high water level during the study period was 1535.92 feet MSL. The lowest water level recorded was 1534.94 feet MSL.

The 1994 study on Rolling Stone Lake concentrated on the systems water chemistry. Samples for water chemistry analyses were collected in April, July and October 1994 at Rolling Stone Lake at Station LG-9 which was located in the east central portion of the lake (Figure 3.7-1).

Table 3.7-27

Summary of Water Body Characteristics for the Portions of the Pickerel Creek and Wolf River Drainage Basins Within the Study Area[a]

Pickerel Creek Drainage Basin

Surface Water Category/ Water Body	Distance and Direction from Ore Body (mi)	Drainage Basin Area (sq mi)	Length (mi)	Average Width (ft)	Average Depth (ft)	Maximum Depth (ft)	Surface Area (acres)	Gradient[b] (ft/mi)	Adjoining Wetlands (acre)	Predominant Shoreline Vegetation[c]	Substrate Classification
Lakes and Associated Streams											
Rolling Stone Lake	3.5 South	_d	—	—	—	12	672	—	1,067	Dry-mesic or Mesic Northern Hardwoods	sand, gravel, muck, detritus, rubble
Pickerel Creek	2.9 Southwest	44.3	9.2	45	1.75	—	50	4.3	1,164	Wet-mesic or Wet Northern Forest	muck
Creek 12-9	1.4 South	6.0[e]	1.6	9.0	1.0	—	1.7	35	23	Wet-mesic or Wet Northern Forest	muck, sand, gravel
Creek 11-4	2.8 Southwest	0.4	0.5	5.0	0.3	—	0.3	31	53	Wet-mesic or Wet Northern Forest	muck, sand, gravel
Little Sand Lake	0.4 South	—	—	—	—	21	248	—	20	Dry-mesic or Mesic Northern Hardwoods	sand, gravel, muck
Duck Lake	1.1 Southeast	—	—	—	—	10	26	—	22	Bog (Scrub/Shrub Wetland)	muck

Table 3.7-27 *(Continued)*

Surface Water Category/ Water Body	Distance and Direction from Ore Body (mi)	Drainage Basin Area (sq mi)	Length (mi)	Average Width (ft)	Average Depth (ft)	Maximum Depth (ft)	Surface Area (acres)	Gradient[b] (ft/mi)	Adjoining Wetlands (acre)	Predominant Shoreline Vegetation[c]	Substrate Classification
Pickerel Creek Drainage Basin											
Deep Hole Lake	1.5 Southeast	—	—	—	—	10	97	—	35	Dry-mesic or Mesic Northern Hardwoods	muck, sand, gravel, rubble
Skunk Lake	0.4 East	—	—	—	—	6	6	—	5	Dry-mesic or Mesic Northern Hardwoods	muck
Wolf River Drainage Basin											
Wolf River											
Above Langlade Co	7.6 Southwest	460[f]	61.50[g]	149	1.9	—	185.9	6.4[h]	8,156	Wet-mesic and Wet Northern Forest and Aspen	sand, gravel, silt, detritus, peat

[a]Steuck and Andrews, 1976; Steuck, et. al., 1977; Andrews and Threinen, 1966.
[b]Calculated from topographic maps.
[c]EMC, 1985.
[d]Not applicable.
[e]Calculated from data generated in the 1985 study.
[f]USGS, 1978.
[g]Northwestern Wisconsin Regional Planning Commission, 1970.
[h]Measured between Pine Lake and Langlade, Wisconsin.

Source: EMC, 1985.

Prepared by: JJA
Checked by: SDJ

Water quality data obtained from analyses of samples collected during this time period at this site are presented in Appendix 3.7-8. Summary statistics including maximum, minimum and mean values for these parameters are given in Table 3.7-28 which compares them to similar statistics derived from samples obtained during the 1977-1978 study (Appendix 3.7-4).

In general, the results reported from analyses of water samples collected from LG-9 in 1994 and 1995 were similar to those obtained during the 1977-1979 effort. Results of water chemistry analysis indicated that Rolling Stone was a moderately hard, neutral pH lake. Mean hardness, alkalinity, and specific conductance values at Station LG-9 were 77 mg/L as $CaCO_3$, 81 mg/L as $CaCO_3$ and 121 μmhos/cm. Surface water pH values ranged from 7.36 to 7.94 and averaged 7.71 throughout the period of study.

In April of 1994 the total phosphorus concentration within the water column of Rolling Stone Lake was measured at 0.417 mg/L, an unexpectedly high value compared to the 1977-1978 mean of 0.03 mg/L. Subsequent samplings in July and October of 1994 revealed levels of phosphorus closer to those observed historically (0.019 and <0.05 mg/L, respectively).

The mean dissolved oxygen concentration measured in 1994 in surface water at LG-9 was 7.4, although the lake was not sampled during the months it was ice covered. Dissolved oxygen data collected in 1994 on Rolling Stone Lake can be found in Appendix 3.7-8.

Previous studies conducted during the 1970s and 1980s observed dissolved oxygen (D.O.) concentrations below 5.0 mg/L (EMC, 1985) in Rolling Stone Lake during February, March and April and noted low D.O. readings in the near bottom waters in January and July 1978 suggesting that it experiences high decomposition and productivity which are characteristics of a lake in eutrophy. This situation was verified by the WDNR who classified Rolling Stone Lake as eutrophic in a 1978 report (WDNR, 1978). The report indicated that at that time there had been little change in the water quality of Rolling Stone Lake over the past fifteen years; and that the present trophic status of Rolling Stone Lake was part of its natural maturation process.

Metals measured in water samples collected from Rolling Stone Lake during 1994 were generally either below detection limits or found in low concentrations.

In October 1994 sediment samples were collected from Rolling Stone Lake at Stations M-2 and M-4 (Figure 3.7-1). Samples were also collected at these sites in March 1978 for the previous project work (EMC, 1985). A comparison of the results from these two sampling events is shown in Table 3.7-29 and Table 3.7-30 below. Information pertaining to the analysis of sediment samples is included in Appendices 3.7-4 and 3.7-10.

The 1994 data shows the variability of sediment composition within Rolling Stone Lake. Sampling site M-2 is indicative of a lake that receives predominantly organic deposition. It has a lower total solids concentration (3.0 percent), coupled with a higher concentration of volatile solids (259,000 mg/kg, 25.9 percent of the total solids), as well as higher levels of nitrogen and phosphorus which are reflective of organic sediments.

Table 3.7-28

Water Quality Data, LG-9 (Rolling Stone Lake)
Summary of Monthly Means and Ranges

Station Period: M-4/LG-9	Units	1977-1978 Min.	1977-1978 Max.	1977-1978 Mean	1994 Min.	1994 Max.	1994 Mean
Metals							
Aluminum, total	μg/L	<10	<10	<10	<50	314	104.67
Arsenic, total	mg/L	<0.001	<0.001	<0.001	<0.005	<0.005	Note 1
Cadmium, total	μg/L	<1	3	<1	<5	<5	Note 1
Copper, total	μg/L	<1	1	<1	<30	<30	Note 1
Iron, Total	mg/L	0.03	0.46	0.14	<0.1	0.129	0.083
Lead, total	μg/L	<10	10	<10	<50	<50	Note 1
Manganese, total	mg/L	0.004	0.199	0.052	<0.010	0.017	0.011
Mercury, total	ng/L	<100	<100	<100	<200	300	100
Molybdenum, total	mg/L	<0.01	<0.01	<0.01	<0.020	<0.020	Note 1
Nickel, total	mg/L	<0.01	<0.01	<0.01	<0.030	<0.030	Note 1
Zinc, total	μg/L	3	18	8	<20	<20	Note 1
Phosphorus							
Phosphorus, total	mg/L	0.02	0.05	0.03	<0.050	0.417	0.145
Nitrogen							
Nitrogen, Ammonia	mg/L	0.34	1.09	0.55	<0.10	0.10	0.03
Nitrogen, Nitrate	mg/L	<0.01	0.34	<0.18	<0.50	<0.50	Note 1
Sulfur							
Sulfate	mg/L	5	8	7	4.06	11	6.72
Solids							
Solids, Dissolved	mg/L	83	157	116	92	105	97
Solids, Suspended	mg/L	2	12	5	<5	<5	Note 1

Table 3.7-28 *(Continued)*

Station Period: M-4/LG-9	Units	1977-1978 Min.	1977-1978 Max.	1977-1978 Mean	1994 Min.	1994 Max.	1994 Mean
General Parameters							
Alkalinity, total	mg/L	70	114	87	77	87	81
Biochemical Oxygen Demand	mg/L	2	5	3	<3	8	3
Chemical Oxygen Demand	mg/L	31	31	31	15	23	19
Chloride	mg/L	<1	4	<2	<1	1	1
Conductivity	μmhos/cm	25	165	118	17	182	121
Cyanide	mg/L	<0.001	<0.001	<.001	<0.020	<0.020	Note 1
Dissolved Oxygen[b]	mg/L	1.1	13.0	7.8	6.2	8.5	7.4
Hardness	mg/L	72	124	93	68	82	77
pH	SU	5.7	9.0	7.7	7.36	7.94	7.71
Temperature	°C	1.0	22.0	9.9	8.0	23.3	14.1
Turbidity[a]	NTU	0.9	4.5	2.1	0.6	1.5	1.1

[a] Turbidity was measured in FTU during the 1977-1978 study.
[b] Measured at 0.5 feet.
SU = Standard Units.
Note 1: All data reported as less than detection, therefore no mean value is calculated.

Prepared by: JJA
Checked by: BDH

Table 3.7-29

Sediment Sampling Data, Rolling Stone Lake (Station M-2)

Parameter	Units	October 1994 Data	March 1978 Data
pH, Lab	SU	6.8	NDA
Solids, Total	%	3.0	4.48
Solids, Total Volatile	mg/kg	259,000	NDA
Ammonia, as N	mg/kg	60	NDA
Total Kjeldahl Nitrogen	mg/kg	900	NDA
Total Organic Nitrogen	mg/kg	840	NDA
Chloride	mg/kg	<10	NDA
Fluoride	mg/kg	<0.5	NDA
Cyanide, Total	mg/kg	<0.5	NDA
Oil & Grease (Freon Extractables)	mg/kg	540	3304
Boron, Total	mg/kg	<10	NDA
Calcium, Total	mg/kg	280	NDA
Arsenic, Total	mg/kg	<0.40	2.9
Barium, Total	mg/kg	1.1	NDA
Iron, Total	mg/kg	130	605
Manganese, Total	mg/kg	3.6	112
Molybdenum, Total	mg/kg	<2.0	NDA
Selenium, Total	mg/kg	0.63	NDA
Silver, Total	mg/kg	<0.50	NDA
Chromium, Total	mg/kg	0.59	6.6
Cobalt, Total	mg/kg	<1.0	NDA
Beryllium, Total	mg/kg	<0.50	NDA
Thallium, Trace ICP	mg/kg	<1.0	NDA

Table 3.7-29 *(Continued)*

Parameter	Units	October 1994 Data	March 1978 Data
Nickel, Total	mg/kg	<2.0	NDA
Antimony, Total	mg/kg	<5.0	NDA
Magnesium, Total	mg/kg	52	NDA
Phosphorus, Total	mg/kg	750	NDA
Potassium, Total	mg/kg	<60	NDA
Sodium, Total	mg/kg	8.0	NDA
Aluminum, Total	mg/kg	110	NDA
Cadmium, Total	mg/kg	<0.50	0.7
Copper, Total	mg/kg	<0.50	4.8
Lead, Total	mg/kg	0.41	11
Mercury, Total	mg/kg	<0.02	<0.01
Zinc, Total	mg/kg	3.2	79
Vanadium	mg/kg	<1.0	NDA

SU = Standard Units.
NDA = No Data Available.

Prepared by: GJB1
Checked by: GJB

Table 3.7-30

Sediment Sampling Data, Rolling Stone Lake (Station M-4)

Parameter	Units	October 1994 Data	March 1978 Data
pH, Lab	SU	7.4	NDA
Solids, Total	%	71.4	4.20
Solids, Total Volatile	mg/kg	5000	NDA
Ammonia, N	mg/kg	38	NDA
Total Kjeldahl Nitrogen	mg/kg	260	NDA
Total Organic Nitrogen	mg/kg	220	NDA
Chloride	mg/kg	<10	NDA
Fluoride	mg/kg	<0.5	NDA
Cyanide, Total	mg/kg	<0.5	NDA
Oil & Grease (Freon Extractables)	mg/kg	460	2381
Boron, Total	mg/kg	<10	NDA
Calcium, Total	mg/kg	450	NDA
Arsenic, Total	mg/kg	<0.40	2.6
Barium, Total	mg/kg	3.3	NDA
Iron, Total	mg/kg	1600	4377
Manganese, Total	mg/kg	14	138
Molybdenum, Total	mg/kg	<2.0	NDA
Selenium, Total	mg/kg	1.2	NDA
Silver, Total	mg/kg	<0.50	NDA
Chromium, Total	mg/kg	3.1	21.9
Cobalt, Total	mg/kg	<1.0	NDA
Beryllium, Total	mg/kg	<0.50	NDA
Thallium, Trace ICP	mg/kg	<1.0	NDA

Table 3.7-30 *(Continued)*

Parameter	Units	October 1994 Data	March 1978 Data
Nickel, Total	mg/kg	<2.0	NDA
Antimony, Total	mg/kg	<5.0	NDA
Magnesium, Total	mg/kg	380	NDA
Phosphorus, Total	mg/kg	250	NDA
Potassium, Total	mg/kg	91	NDA
Sodium, Total	mg/kg	17	NDA
Aluminum, Total	mg/kg	750	NDA
Cadmium, Total	mg/kg	<0.50	0.9
Copper, Total	mg/kg	0.96	7.2
Lead, Total	mg/kg	1.1	33
Mercury, Total	mg/kg	<0.02	<0.01
Zinc, Total	mg/kg	5.1	76
Vanadium	mg/kg	3.2	NDA

SU = Standard Units.
NDA = No Data Available.

Prepared by: GJB1
Checked by: GJB

The 1994 data for site M-4 is representative of an inorganic substrate. The total solids concentration of 71.4 percent and total volatile solids level of 5000 mg/kg (0.5 percent of the total solids) present in the sample are indicative of an inorganic substrate.

Nitrogen and phosphorus levels were somewhat elevated at both sampling sites in 1994. The total Kjeldahl Nitrogen (TKN) concentrations for M-2 and M-4 were 900 mg/kg and 260 mg/kg, respectively. These corresponded to phosphorus concentrations of 750 mg/kg and 250 mg/kg. This is typical for a eutrophic lake such as Rolling Stone.

The variability of the data between 1994 and 1978 may have resulted from the collection of samples from different locations within the lake. In addition to the variability in sampling locations, the method used to collect samples was also different. The core sampler used in 1994 may have collected a greater proportion of the inorganic sediments than the Ekman dredge sampler used in 1978. In either case, the data provides background information and illustrates the potential variability in the measurement of sediment characteristics.

3.7.5.2 Pickerel Creek

Pickerel Creek has a surface area of 50 acres and a total length of 9.2 miles. It is a perennial stream with a drainage area of 44.3 square miles that originates in a large wetland area north-northwest of Rolling Stone Lake (Table 3.7-27). The drainage basin of Pickerel Creek is predominantly wooded and undeveloped and includes large tracts of adjoining wetlands in the headwaters. The stream originates in the wetlands south of Mole Lake, approximately 2.9 miles west of the ore body, and intermittently flows south to Rolling Stone Lake, through a flat drainage basin (Figure 3.7-2). Pickerel Creek emerges from the southern most bay in Rolling Stone Lake and flows west to its eventual confluence with the Wolf River.

A stream gage SG-19 was established on Pickerel Creek during the 1977-1980 study. Its location is shown on Figure 3.7-2. Flow readings obtained from April 1994 through March 1995 at this location are given in Appendix 3.7-5. Historical readings from 1977 through 1980 are provided in Appendix 3.7-6. Maximum and minimum flows observed on Pickerel Creek were 23.4 cubic feet per second (cfs) and <0.1 cfs in April 1979 and June 1978, respectively. Flows measured at this site during the 1993-1995 study were within the range observed historically (min=0.93 cfs, max=5.58 cfs). Flow data was also collected at Station SG-19A during the 1993-1995 study. This station was located approximately 1.5 miles upstream of Rolling Stone Lake and 1.4 miles upstream of Station SG-19 (Figure 3.7-2). Flow readings obtained at SG-19A ranged from 0.43 cfs to 1.12 cfs between May 1994 and March 1995 and are given in Appendix 3.7-5. In any year, the minimum seven-day average flow rate of Pickerel Creek has a 50 percent chance of being less than 0.6 cubic cfs, and a 10-percent chance of being less than 0.4 cfs (Table 3.7-12).

Samples for water chemistry analyses were collected from Pickerel Creek monthly from April 1994 through March 1995 at Station SG-19. Water quality data obtained from analyses of samples collected during this time period at this site are presented in Appendix 3.7-8. Summary

statistics including maximum, minimum and mean values for these parameters are given in Table 3.7-31 which compares them to similar statistics derived from samples obtained during the 1977-1978 study.

In general, the results reported from analyses of samples collected from Pickerel Creek in 1994 and 1995 were similar to those obtained during the 1977-1980 effort. Water chemistry data indicated that Pickerel Creek was a moderately hard, neutral pH stream. Mean values recorded in 1994 for hardness, alkalinity and specific conductance at Station SG-19 were 81 mg/L as $CaCO_3$, 72 mg/L as $CaCO_3$ and 157 μmhos/cm, respectively. The mean pH value measured in field was 7.33. The concentration of dissolved oxygen in Pickerel Creek was above five mg/L during all samplings and ranged from 8.1 mg/L to 13.4 mg/L throughout the sampling period.

All metals analyzed from samples collected at SG-19 during the 1994 study were either below detection limits or were found in low concentrations. During this recent study, low level analyses techniques were used to monitor concentrations of aluminum, cadmium, copper, lead, mercury, zinc and chromium in water samples collected in Pickerel Creek. The lower detection limits associated with these techniques allowed for trace level detections of all these metals. However, aluminum was detected at a level higher than those observed during the 1977-1980 study (mean value = 34.75 mg/L vs <10 mg/L).

In October 1994 two sediment samples were collected from Pickerel Creek at Station M-5 (Figure 3.7-2). The samples were collected within a few feet of each other to demonstrate the variability of sediments within the stream. A sample was also collected at this site in March 1978 (EMC, 1985). A comparison of the results from these two sampling events is shown in Table 3.7-32. Information pertaining to the analyses of sediment samples is included in Appendices 3.7-4 and 3.7-10.

Surface water sediment composition has a considerable amount of variability. This is most evident in streams where scouring and deposition of sediments can take place within inches of each other. Samples collected from a stream or lake may have variable compositions and represent the variability of the sediments for that surface water. This is demonstrated in both samples collected in 1994 and can also be seen when comparing the data from the two sampling events.

The 1994 data for M-5 and the duplicate for the same site show characteristics of organic and inorganic substrates. The volatile solids content, which is equivalent to the organic portion of the sediment, for M-5 was 37.9 percent of the total solids content (379,000 mg/kg). In contrast to this, the duplicate sample taken at M-5 had a volatile solids content of 0.57 percent (5,700 mg/kg) and appears to be composed primarily of inorganic substrate. Data also indicated higher levels of other analytical parameters including: manganese, calcium, phosphorous, and nitrogen within the sample composed primarily of organic substrate.

Table 3.7-31

Water Quality Data, SG-19 (Pickerel Creek)
Summary of Monthly Means and Ranges

		1977-1978			1994-1995		
Station: M-5/SG-19	Units	Min.	Max.	Mean	Min.	Max.	Mean
Metals							
Aluminum, Total	µg/L	<10	<10	<10	9.12	68.40	34.75
Arsenic, Total	mg/L	<0.001	<0.001	<0.001	<0.005	<0.005	Note 1
Cadmium, Total	µg/L	<1	4	<1	<0.003	0.014	0.005
Copper, Total	µg/L	<1	28	<4	0.093	0.613	0.295
Iron, Total	mg/L	0.09	0.59	0.31	0.110	0.770	0.400
Lead, Total	µg/L	<10	<10	<10	0.073	0.315	0.149
Manganese, Total	mg/L	0.006	0.073	0.038	0.013	0.100	0.043
Mercury, Total	ng/L	<100	200	<100	0.81	7.95	3.59
Molybdenum, Total	mg/L	<0.01	<0.01	<0.01	<0.020	<0.020	Note 1
Nickel, Total	mg/L	<0.01	<0.01	<0.01	<0.03	<0.03	Note 1
Zinc, Total	µg/L	1	12	6	0.71	6.58	2.74
Phosphorus							
Phosphorus, Total	mg/L	0.02	0.12	0.06	<0.050	0.060	0.023
Nitrogen							
Nitrogen,	mg/L	0.05	1.47	0.70	<0.10	0.20	0.05
Ammonia	mg/L	<0.01	0.34	<0.22	<0.50	0.72	0.23
Nitrogen, Nitrate							
Sulfur							
Sulfate	mg/L	<1	9	<5	5	28	11
Solids							
Solids, Dissolved	mg/L	86	152	122	58	190	119
Solids, Suspended	mg/L	<1	11	<4	<5	19	6

Table 3.7-31 *(Continued)*

Station: M-5/SG-19	Units	1977-1978 Min.	1977-1978 Max.	1977-1978 Mean	1994-1995 Min.	1994-1995 Max.	1994-1995 Mean
General Parameters							
Alkalinity, Total	mg/L	42	110	73	42	120	72
Biochemical Oxygen Demand	mg/L	1	4	2	<2	9	2
Chemical Oxygen Demand	mg/L	69	69	69	23	45	32
Chloride	mg/L	<1	4	<2	<1	2	1
Conductivity	μmhos/cm	20	125	92	94	241	157
Cyanide	mg/L	<0.001	<0.001	<0.001	<0.020	<0.020	Note 1
Dissolved Oxygen	mg/L	5.5	12.2	9.0	8.1	13.4	10.0
Hardness	mg/L	60	116	83	46	120	81
pH	SU	5.8	7.5	6.9	6.37	8.13	7.33
Temperature	°C	0	14.8	4.8	1.1	14.8	7.8
Turbidity[a]	NTU	0.8	2.8	1.5	<0.5	9.9	2.78

[a]Turbidity was measured in FTU during the 1977-1978 study.
SU = Standard Units.

Prepared by: JJA
Checked by: BDH

Note 1: All data reported as less than detection, therefore no mean value is calculated.

Table 3.7-32

Sediment Sampling Data, Pickerel Creek (Station M-5)

Parameter	Units	October 1994 Data	October 1994 Dup. Data	March 1978 Data
pH, Lab	SU	6.6	6.7	NDA
Solids, Total	%	16.9	65.0	11.28
Solids, Total Volatile	mg/kg	379000	5700	NDA
Ammonia, N	mg/kg	82	61	NDA
Total Kjeldahl Nitrogen	mg/kg	1300	430	NDA
Total Organic Nitrogen	mg/kg	1200	370	NDA
Chloride	mg/kg	24	23	NDA
Fluoride	mg/kg	<0.5	<0.5	NDA
Cyanide, Total	mg/kg	<0.5	<0.5	NDA
Oil & Grease (Freon Extractables)	mg/kg	600	340	1445
Boron, Total	mg/kg	<10	<10	NDA
Calcium, Total	mg/kg	2500	1900	NDA
Arsenic, Total	mg/kg	1.4	1.3	2.3
Barium, Total	mg/kg	15	11	NDA
Iron, Total	mg/kg	2300	2100	7079
Manganese, Total	mg/kg	82	56	635
Molybdenum, Total	mg/kg	<2.0	<2.0	NDA
Selenium, Total	mg/kg	<0.50	0.82	NDA
Silver, Total	mg/kg	<0.50	<0.50	NDA
Chromium, Total	mg/kg	3.0	2.7	33
Cobalt, Total	mg/kg	<1.0	<1.0	NDA
Beryllium, Total	mg/kg	<0.50	<0.50	NDA

Table 3.7-32 *(Continued)*

Parameter	Units	October 1994 Data	October 1994 Dup. Data	March 1978 Data
Thallium, Trace ICP	mg/kg	<1.0	<1.0	NDA
Nickel, Total	mg/kg	<2.0	<2.0	NDA
Antimony, Total	mg/kg	<5.0	<5.0	NDA
Magnesium, Total	mg/kg	440	510	NDA
Phosphorus, Total	mg/kg	530	180	NDA
Potassium, Total	mg/kg	72	<60	NDA
Sodium, Total	mg/kg	20	15	NDA
Aluminum, Total	mg/kg	630	730	NDA
Cadmium, Total	mg/kg	<0.50	<0.50	0.8
Copper, Total	mg/kg	1.2	1.2	6.6
Lead, Total	mg/kg	1.2	0.81	8
Mercury, Total	mg/kg	<0.02	<0.02	<0.01
Zinc, Total	mg/kg	11	9.8	62
Vanadium	mg/kg	3.4	3.1	NDA

SU = Standard Units.
NDA = No Data Available.

Prepared by: GJB1
Checked by: GJB

The total solids content of samples collected in 1994 was consistently higher than in the sample collected in 1978 (16.9 percent and 65.0 percent versus 11.28 percent). This further illustrates the variability that exists within the sediment composition of an aquatic system.

3.7.5.3 Pickerel Creek Drainage Canal

A man-made surface water structure referred to as the drainage canal is located on the east side of Pickerel Creek and is in Section 34, T35N, R12E. This structure is primarily fed by groundwater and is included in the Pickerel Creek watershed. The canal discharges to Pickerel Creek near the origin of the creek and provides a means of conveying groundwater and surface water to the creek. Water quality data was collected from the drainage canal in December 1997. The sampling point for this water body has been designated SG-19B. This water body is a hard water body with a slightly basic pH. Oxygen level in this water body was at 3.2 mg/L, which is not sufficient to support cold water sport fish communities and is marginal for warm water sport fish. The water quality characteristics are found in Table 3.7-32a.

3.7.5.4 Creek 12-9

The data presented for Creek 12-9 is taken from the previous project studies completed in the 1970s and 1980s. As of March 1995, attempts to gain access to Creek 12-9 from private parties were unsuccessful. Because of this, additional current data is unavailable.

Creek 12-9 originates in a wetland area adjacent to the southern shore of Little Sand Lake; however, stream flow directly from the lake is intermittent (Figure 3.7-2). The stream has a drainage area of 6.0 square miles, a total surface area of 1.7 acres, and flows southward 1.6 miles prior to its entrance into Rolling Stone Lake, which serves as it's confluence with Pickerel Creek. Creek 12-9 has an average width of nine feet, an average depth of one foot, and is adjoined by 23 acres of wetlands (Table 3.7-27). Its drainage basin primarily contains lakes and wetlands, and is wooded. Duck and Deep Hole lakes contribute surface water drainage intermittently to Little Sand Lake, which is the headwater of Creek 12-9 (EMC, 1985).

Extensive adjoining wetlands provide a source of base flow to Creek 12-9. They tend to maintain the flow in the stream under drought conditions longer than would be expected in their absence. These wetlands also dampen changes in both high and low flows. This dampening is proportional to their surface area and hydraulic connection to the stream. The wetland to the west of Creek 12-9 contains a small tributary, Creek 12-2, which feeds into Creek 12-9. This tributary is intermittent in its upper reaches.

Two stream gages were established on Creek 12-9 during earlier studies (SG-8 and SG-23) to monitor surface water levels. Appendix 3.7-3 provides the record of gage readings at these locations. Creek 12-9 has essentially no base flow as measured 0.1 mile downstream of Little Sand Lake. Although the Creek 12-9 drainage basin is very steep, it consists of about 50 percent

Table 3.7-32a

December 1997 Sampling Data for the Pickerel Creek Drainage Canal

Parameter	Units	December 1997 Data
Alkalinity, Bicarbonate as HCO_3	mg/L	150
Alkalinity, Total as $CaCO_3$	mg/L	120
Alkalinity, Carbonate as $CaCO_3$	mg/L	<1.4
Aluminum, total	μg/L	30
Arsenic, total	μg/L	<1.8
Barium, total	μg/L	11
BOD-5 day	mg/L	5.0
Boron, total	μg/L	<18
Cadmium, total	μg/L	<0.030
Calcium, total	mg/L	25
COD (unfiltered)	mg/L	10
Chloride (unfiltered)	mg/L	<0.56
Chromium, Trivalent	μg/L	0.21
Chromium, Hexavalent	μg/L	0.38
Chromium, total	μg/L	0.59
Color, APHA (true)	C.P.U.	60
Conductivity, Specific @25^{0}C - field	umhos/cm	291
Copper, total	μg/L	0.063
Cyanide, total (distilled)	mg/L	<0.0046
Fluoride, (unfiltered)	mg/L	0.066
Hardness, total as $CaCO_3$	mg/L	100
Iron, total	mg/L	1.1
Lead, total	μg/L	0.061
Manganese, total	μg/L	76
Mercury	μg/L	0.0013

Table 3.7-32a *(Continued)*

Parameter	Units	December 1997 Data
Molybdenum	mg/L	<0.0082
Nitrogen, Ammonia as N (unfiltered)	mg/L	0.087
Nitrogen, NO_2+NO_3 as N (unfiltered)	mg/L	<0.031
Nitrogen, Kjeldahl as N (unfiltered)	mg/L	0.24
Oil & Grease, (water)	mg/L	<8.1
Oxygen, field	mg/L	3.2
pH, lab	SU	7.1
pH, field	SU	8.30
Phosphorus, total	mg/L	0.030
Phosphorus, reactive as P	mg/L	0.0030
Selenium, total	µg/L	<1.6
Silver, total	µg/L	3.6
Solids, total dissolved	mg/L	170
Solids, total suspended	mg/L	<1.0
Solids, total volatile	%DWB	10
Sulfate, as SO_4	mg/L	9.3
Turbidity	NTU	2.6
Zinc, total	µg/L	0.59
Chlorophyll		
Corrected Chlorophyll a	µg/L	0.651
Pheophytin a	µg/L	0.869
Trichromatic Chlorophyll a	µg/L	1.17
Trichromatic Chlorophyll b	µg/L	0.344
Trichromatic Chlorophyll c	µg/L	0.450

Prepared by: GJB1
Checked by: LCT

wetlands and lakes. Discharge measured at SG-A, which is located on the primary surface water stream flowing into Little Sand Lake, and those lower surface water discharges measured at SG-8, reflect the storage effect of Little Sand Lake. The difference between flows measured and the time lag between SG-8 and SG-23 is primarily attributable to local runoff and wetland contribution flowing into Creek 12-9 as well as discharge from the stream to the groundwater between Little Sand Lake and SG-23.

From August 15 through 17, 1978, intensive monitoring of storm water runoff was conducted for the Creek 12-9 drainage (Dames & Moore 1985). A large increase in discharge rate measured at SG-23 indicated that storm runoff was reaching SG-23 by several routes. During periods of rapid storm runoff, the flow at SG-23 was a combination of groundwater and local surface water runoff that had passed directly through Little Sand Lake to Stream 12-9 (EMC, 1985, Section 2.3). During the study period, the highest flow rate of 42.2 cfs was recorded at SG-23 on April 20, 1979. A low flow rate of 1.2 cfs occurred on October 2, 1978 at the same site.

Samples for water chemistry analyses were collected monthly from March 1977 through September 1978 at Station M-1, which was located approximately 328 feet upstream from Rolling Stone Lake. Maximum, minimum, and mean values calculated from data collected at this location are presented in Appendix 3.7-4.

Results of water chemistry analyses indicated that Creek 12-9 was a moderately hard, neutral pH stream. Mean values for hardness, alkalinity, and specific conductance were 108 mg/L as $CaCO_3$, 110 mg/L as $CaCO_3$, and 197 μmhos/cm, respectively. Mean pH was 7.4. Dissolved oxygen concentrations were greater than 5.0 mg/L throughout the study. The lowest value recorded was 5.2 mg/L in March 1977. Metals measured in water samples from Creek 12-9 were generally below detection limits. Mercury was however, detected at Station M-1 in December 1977 at a concentration of 0.1 μg/L.

No sediment samples were collected from Creek 12-9 during the current study period because access to the stream was unavailable. Data was collected in 1978 for previous project work (EMC, 1985). This data is presented in Table 3.7-33.

Historical data indicate that the substrate at sampling point M-1 on Creek 12-9 was primarily inorganic. In addition to this, high percent solids, iron, chromium, and manganese were also indicated within the sample. As with the other sites, it is anticipated that considerable variability in sediment composition exists within Creek 12-9.

Suspended sediment samples were collected at SG-8 and SG-23 in 1978 and the respective results are presented in Appendix 3.7-4. The average total suspended solids was 8.1 mg/L, which is less than the average 11 mg/L for the Northern Highlands region (Hindall, 1976), indicating that Creek 12-9 is essentially free of suspended sediments. The volatile portion of the suspended solids acts as an indicator of the organic content of sediment carried by Creek 12-9; the remainder is clastic sediment. In Creek 12-9, volatile solids averaged <4.8 mg/L.

Table 3.7-33

Sediment Sampling Data, Creek 12-9 (Station M-1)

Parameter	Units	March 1978 Data
Solids, Total	%	17.81
Oil & Grease (Freon Extractables)	mg/kg	1275
Arsenic, Total	mg/kg	3.0
Iron, Total	mg/kg	11,243
Manganese, Total	mg/kg	1796
Chromium, Total	mg/kg	92.1
Cadmium, Total	mg/kg	1.7
Copper, Total	mg/kg	8.3
Lead, Total	mg/kg	12
Mercury, Total	mg/kg	<0.01
Zinc, Total	mg/kg	152

Prepared by: GJB1
Checked by: GJB

3.7.5.5 Creek 11-4

The headwaters for Creek 11-4 begin in a beaver pond (Martin Springs) located north of Rolling Stone Lake (Figure 3.7-2). This creek has a watershed of 0.4 square miles, a total surface area of 0.3 acre, and flows a distance of approximately 0.5 miles south/southwest prior to its entrance into Rolling Stone Lake. Creek 11-4 has an average width of 5 feet, an average depth of 0.3 foot, and is adjoined by 53 acres of wetlands (Table 3.7-27) (1985 EIR).

Samples for water chemistry analysis and measurements of stream flow were obtained from Creek 11-4 at Station SG-30, which was located 0.3 miles upstream from Rolling Stone Lake. Water samples and on site measurements were collected from this location monthly from April 1994 through March 1995. The maximum and minimum flows observed at SG-30 were 1.49 cubic feet per second (cfs) and 0.55 cfs in March 1995 and February 1995 respectively. The average flow measured at SG-30 throughout the study period was 0.96 cfs (Appendix 3.7-5).

Water quality data obtained from analyses of samples collected during the current study at this site are presented in Appendix 3.7-8. Summary statistics including maximum, minimum and mean values for these parameters are given in Table 3.7-34 which compares them to similar statistics derived from samples obtained during the 1977-1980 study. In general, the results reported from analyses of samples collected from Creek 11-4 in 1994 and 1995 were similar to those obtained during the 1977-1980 effort. Water chemistry data obtained from analysis of samples collected in 1994 indicated that Creek 11-4 was a moderately hard, neutral pH stream. Mean values recorded for hardness, alkalinity, and specific conductance were 122 mg/L as $CaCO_3$, 116 mg/L as $CaCO_3$, and 232 μmhos/cm, respectively. Mean pH at this station was 7.58 standard units. Dissolved oxygen concentrations ranged from 5.1 to 13.1 mg/L (mean: 9.2 mg/L).

All metals analyzed from samples collected at SG-30 during the 1994 and 1995 study were either below detection limits or were found in low concentrations. During this recent study, low level analyses techniques were used to monitor concentrations of aluminum, cadmium, copper, lead, mercury, zinc and chromium in water samples collected in Creek 11-4. The lower detection limits associated with these techniques allowed for trace level detections of all these metals.

However, aluminum was detected at levels higher than those observed during the 1977-1980 study (mean value - 78.27 μg/L vs. <1- μg/L). In October 1994, a sediment sample was collected from Creek 11-4 at Station M-3. A sample was also collected at this site in March 1978 for previous project work (EMC, 1985). A comparison of the results from these two sampling events is shown in Table 3.7-35. Information pertaining to the analysis of sediment samples is included in Appendices 3.7-4 and 3.7-10.

Table 3.7-34

Water Quality Data, SG-30 (Creek 11-4)
Summary of Monthly Means and Ranges

		1977-1978			1994-1995		
Station: M-3/SG-30	Units	Min.	Max.	Mean	Min.	Max.	Mean
Metals							
Aluminum, Total	µg/L	<10	<10	<10	7.71	182.00	78.27
Arsenic, Total	mg/L	<0.001	0.001	<0.001	<0.005	<0.005	Note 1
Cadmium, Total	µg/L	<1	4	<1	<0.006	0.024	0.010
Copper, Total	µg/L	<1	10	<2	0.229	1.130	0.452
Iron, Total	mg/L	0.11	0.40	0.26	<0.050	0.300	0.096
Lead, Total	µg/L	<10	20	<10	0.037	0.465	0.202
Manganese, Total	mg/L	0.006	0.201	0.069	0.011	0.057	0.023
Mercury, Total	ng/L	<100	<100	<100	0.59	5.58	2.36
Molybdenum, Total	mg/L	<0.01	<0.01	<0.01	<0.020	<0.020	Note 1
Nickel, Total	mg/L	<0.01	<0.01	<0.01	<0.03	<0.03	Note 1
Zinc, Total	µg/L	<1	10	<5	0.817	7.350	2.98
Phosphorus							
Phosphorus, Total	mg/L	0.02	0.09	0.06	<0.050	0.100	0.032
Nitrogen							
Nitrogen,	mg/L	0.60	1.35	0.90	<0.10	0.20	0.05
Ammonia	mg/L	<0.01	0.19	<0.10	<0.50	<0.50	Note 1
Nitrogen, Nitrate							
Sulfur							
Sulfate	mg/L	<1	9	<4	6.00	19.00	9.31
Solids							
Solids, Dissolved	mg/L	84	210	141	104	200	150
Solids, Suspended	mg/L	1	13	5	<5	13	3

Table 3.7-34 *(Continued)*

Station: M-3/SG-30	Units	1977-1978 Min.	1977-1978 Max.	1977-1978 Mean	1994-1995 Min.	1994-1995 Max.	1994-1995 Mean
General Parameters							
Alkalinity, Total	mg/L	46	138	84	84	150	116
Biochemical Oxygen Demand	mg/L	1	4	2	<2	10	3
Chemical Oxygen Demand	mg/L	69	69	69	17	36	26
Chloride	mg/L	<1	2	<2	<1	1	1
Conductivity	μmhos/cm	80	185	123	129	307	232
Cyanide	mg/L	<0.001	<0.001	<0.001	<0.020	<0.020	Note 1
Dissolved Oxygen	mg/L	3.0	9.0	5.9	5.1	13.1	9.2
Hardness	mg/L	60	138	93	94	160	122
pH	SU	5.8	7.3	6.9	7.16	7.98	7.58
Temperature	°C	0	23.0	10.0	0.5	24.2	11.0
Turbidity[a]	NTU	0.8	5.7	1.8	<0.50	9.50	1.81

[a]Turbidity was measured in FTU during the 1977-1978 study.
SU = Standard Units.
Note 1: All data reported as less than detection, therefore no mean value is calculated.

Prepared by: JJA
Checked by: BDH

Table 3.7-35

Sediment Sampling Data, Creek 11-4 (Station M-3)

Parameter	Units	October 1994 Data	March 1978 Data
pH, Lab	SU	6.7	NDA
Solids, Total	%	63.6	7.31
Solids, Total Volatile	mg/kg	61000	NDA
Ammonia, N	mg/kg	54	NDA
Total Kjeldahl Nitrogen	mg/kg	700	NDA
Total Organic Nitrogen	mg/kg	650	NDA
Chloride	mg/kg	14	NDA
Fluoride	mg/kg	<0.5	NDA
Cyanide, Total	mg/kg	<0.5	NDA
Oil & Grease (Freon Extractables)	mg/kg	550	1560
Boron, Total	mg/kg	<10	NDA
Calcium, Total	mg/kg	1600	NDA
Arsenic, Total	mg/kg	1.8	0.1
Barium, Total	mg/kg	14	NDA
Iron, Total	mg/kg	3500	4715
Manganese, Total	mg/kg	99	558
Molybdenum, Total	mg/kg	<2.0	NDA
Selenium, Total	mg/kg	0.68	NDA
Silver, Total	mg/kg	<0.50	NDA
Chromium, Total	mg/kg	3.4	15.8
Cobalt, Total	mg/kg	1.5	NDA
Beryllium, Total	mg/kg	<0.50	NDA
Thallium, Trace ICP	mg/kg	<1.0	NDA

Table 3.7-35 *(Continued)*

Parameter	Units	October 1994 Data	March 1978 Data
Nickel, Total	mg/kg	<2.0	NDA
Antimony, Total	mg/kg	<5.0	NDA
Magnesium, Total	mg/kg	860	NDA
Phosphorus, Total	mg/kg	150	NDA
Potassium, Total	mg/kg	170	NDA
Sodium, Total	mg/kg	23	NDA
Aluminum, Total	mg/kg	1500	NDA
Cadmium, Total	mg/kg	<0.50	0.7
Copper, Total	mg/kg	3.1	6.6
Lead, Total	mg/kg	1.7	3
Mercury, Total	mg/kg	<0.02	<0.01
Zinc, Total	mg/kg	13	80
Vanadium	mg/kg	5.6	NDA

SU = Standard Units.
NDA = No Data Available.

Prepared: GJB1
Checked by: GJB

The data collected in 1994 indicates that a mixture of organic and inorganic sediments are found in Creek 11-4. The total solids content of 63.6 percent that was observed is indicative of inorganic materials. The sediments also contained 61,000 mg/kg of volatile solids which is equivalent to 6.1 percent organic matter. The 1978 data also indicated a near average total solids content, 7.31 percent as compared to an average solids content in 1978 of 8.04 percent. In addition, the 1978 data had a freon extractables content of 1,560 mg/kg which is slightly below the average concentration of 2,753 mg/kg, which indicates that a moderate amount of organic matter is present.

As stated previously, surface water sediment composition can have a considerable amount of variability due to deposition. Samples collected from a stream or lake may have variable compositions and represent the variability of the sediments for that surface water. It appears that the data from 1994 and 1978 have shown some degree of correlation. The variability that exists is likely the result of the particular sampling location and/or the nature of the different sampling methods.

3.7.5.6 Little Sand Lake

Little Sand Lake is located 0.4 mile south of the ore body (Figure 3.7-2). It has a surface area of 248 acres and a maximum depth of 21 feet. Eighty-six percent of the lake has a depth of 10 feet or less (EMC, 1985). The shoreline vegetation is predominantly upland hardwoods with some wetland. The lake substrate consists primarily of sand, gravel and muck (Table 3.7-27). Little Sand Lake has a single intermittent inlet stream on its east side and a single intermittent outlet stream to the south. It receives water intermittently from the lakes upstream of it, namely Duck and Deep Hole (EMC, 1985).

A staff gage (LG-7) was established on Little Sand Lake during the 1977-1980 study. Lake levels calculated from data obtained at this location between April 1977 and October 1994 are given in Appendix 3.7-3. Throughout this time a 2.66-foot low to high water level difference was observed with minimum (1590.81 MSL) and maximum (1593.47 MSL) measurements occurring in July 1977 and February 1986 respectively. Lake level readings calculated from measurements made during the 1993-1995 study were within the range observed historically (min=1592.01, max=1592.76).

The water quality sampling station for Little Sand (LG-7) was located in the south central portion of the lake. The depth measured at LG-7 was 15-18 feet. Collections of samples for water quality analysis were conducted monthly at this location from April 1994 through March 1995.

Water quality data obtained from analyses of samples collected during this time period at this site are presented in Appendix 3.7-8. Summary statistics including maximum, minimum and mean values for these parameters are given in Table 3.7-36 which compares them to similar statistics derived from samples obtained during the 1977-1980 study. In general, the results reported from analyses of samples collected from Little Sand Lake in 1994 and 1995 were similar to those obtained during the 1977-1980 effort. Results from water chemistry analysis indicated that Little

Table 3.7-36

Water Quality Data, LG-7 (Little Sand Lake)
Summary of Monthly Means and Ranges

		1977-1978			1994-1995		
Station: H/LG-7	Units	Min.	Max.	Mean	Min.	Max.	Mean
Metals							
Aluminum, total	µg/L	<10	<10	<10	33.50	122	72.15
Arsenic, total	mg/L	<0.001	0.001	<0.001	<0.005	<0.005	Note 1
Cadmium, total	µg/L	<1	3	<1	0.030	0.071	0.054
Copper, total	µg/L	<1	43	<7	0.345	0.975	0.575
Iron, Total	mg/L	0.01	0.13	0.04	<0.100	0.114	0.042
Lead, total	µg/L	<10	30	<10	0.196	0.445	0.304
Manganese, total	mg/L	0.018	0.108	0.050	<0.010	0.037	0.011
Mercury, total	ng/L	<100	<100	<100	1.69	2.27	1.94
Molybdenum, total	mg/L	<0.01	<0.01	<0.01	<0.020	<0.020	Note 1
Nickel, total	mg/L	<0.01	<0.01	<0.01	<0.030	<0.030	Note 1
Zinc, total	µg/L	7	35	17	7.94	21.70	11.53
Phosphorus							
Phosphorus, total	mg/L	<0.01	0.17	<0.04	<0.050	0.014	0.004
Nitrogen							
Nitrogen, Ammonia	mg/L	0.08	0.35	0.23	<0.10	0.10	0.03
Nitrogen, Nitrate	mg/L	<0.01	0.34	<0.13	<0.50	0.72	0.07
Sulfur							
Sulfate	mg/L	3	14	9	3.05	7.80	5.14
Solids							
Solids, Dissolved	mg/L	2	173	40	5	51	29
Solids, Suspended	mg/L	<1	12	<4	<5	5	1

Table 3.7-36 *(Continued)*

Station: H/LG-7	Units	1977-1978 Min.	1977-1978 Max.	1977-1978 Mean	1994-1995 Min.	1994-1995 Max.	1994-1995 Mean
General Parameters							
Alkalinity, total	mg/L	<1	6	<2	<5	35	4
Biochemical Oxygen Demand	mg/L	1	7	2	<2	7	1
Chemical Oxygen Demand	mg/L	7	7	7	10	27	18
Chloride	mg/L	<1	6	<2	<1	1	0
Conductivity	μmhos/cm	11	59	29	13	47	22
Cyanide	mg/L	<0.001	0.004	<0.001	<0.020	<0.020	Note 1
Hardness	mg/L	6	24	12	<5	8	4
Dissolved Oxygen[b]	mg/L	2.8	11.8	9.1	5.2	12.3	9.0
pH	SU	4.8	6.1	5.4	5.42	6.75	6.29
Temperature	°C	1.5	24.9	10.9	1.1	25.3	13.8
Turbidity[a]	NTU	0.7	1.4	1.0	<0.50	2.00	0.80

[a]Turbidity was measured in FTU during the 1977-1978 study.
[b]Dissolved oxygen measured at 3 feet below surface.
SU = Standard Units.
Note 1: All data reported as less than detection, therefore no mean value is calculated.

Prepared by: JJA
Checked by: BDH

Sand Lake was a soft, slightly acidic pH lake. Mean hardness, alkalinity and specific conductance values at Station LG-7 were 4 mg/L as $CaCO_3$, 4 mg/L as $CaCO_3$ and 22 μmhos/cm, respectively. Surface water pH values ranged from 5.42 to 6.75 and averaged 6.29 throughout the period of study.

Monthly dissolved oxygen profiles showed that Little Sand Lake remained well mixed and oxygenated throughout the 1993-1995 sampling period (Figure 3.7-7 and 3.7-8). This is consistent with results from studies conducted in the 1970s and 1980s (Appendix 3.7-4). During the 1993-1995 study a mean dissolved oxygen concentration of 9.0 mg/L was recorded from a three-foot depth at LG-7. Concentrations ranged from 5.2 mg/L to 12.3 mg/L at the surface and 5.2 mg/L to 10.6 mg/L near the lake bottom (15-18 feet). Oxygen levels below 5 mg/L were not observed within the water column of Little Sand Lake (Appendix 3.7-8). Dissolved oxygen and temperature data collected in Little Sand Lake during previous studies can be found in Dames & Moore (1985).

All metals analyzed from samples collected at LG-7 during the current study were either below detection limits or were found in low concentrations. During this recent study, low level analyses techniques were used to monitor concentrations of aluminum, cadmium, copper, lead, mercury, zinc, and chromium in water samples collected in Little Sand Lake. The lower detection limits associated with these techniques allowed for trace level detections of all these metals. Only aluminum was detected at a level significantly higher than those observed during the 1977-1980 study (mean value = 72.15 mg/L vs <10 mg/L).

In October 1994 sediment samples were collected from Little Sand Lake at Stations H and I. A duplicate sample was also collected at station H which will be referred to as H-Duplicate. Samples were also collected at these sites in March 1978 for the previous project work (EMC, 1985). A comparison of the results from these two sampling events is shown in Tables 3.7-37 and 3.7-38. Information pertaining to the analysis of sediment samples is included in Appendices 3.7-4 and 3.7-10.

The 1994 data illustrates the variability in sediment composition within Little Sand Lake. Sampling site I is indicative of a higher level of organic deposition. The lower total solids concentration, 33.7 percent, coupled with a higher concentration of volatile solids, 109,000 mg/kg (10.9 percent of the total solids) as well as higher levels of nitrogen and phosphorus are reflective of the greater amount of organic material that is present in the sediments.

The 1994 data for site H, from both the first sample, H, and the second sample, H-Duplicate, are representative of an inorganic substrate. Total solids concentrations of 65.6 and 74.8 percent, coupled with total volatile solids concentrations of only 19,000 mg/kg (1.9 percent of the total solids) and 7,000 mg/kg (0.7 percent of the total solids), are indicative of inorganic substrates.

Table 3.7-37

Sediment Sampling Data, Little Sand Lake (Station H)

Parameter	Units	October 1994 Data	October 1994 Dup. Data	March 1978 Data
pH, Lab	SU	5.5	5.5	NDA
Solids, Total	%	65.6	74.8	7.34
Solids, Total Volatile	mg/kg	19000	7000	NDA
Ammonia, N	mg/kg	38	23	NDA
Total Kjeldahl Nitrogen	mg/kg	290	180	NDA
Total Organic Nitrogen	mg/kg	250	160	NDA
Chloride	mg/kg	22	25	NDA
Fluoride	mg/kg	<0.5	<0.5	NDA
Cyanide, Total	mg/kg	<0.5	<0.5	NDA
Oil & Grease (Freon Extractables)	mg/kg	390	360	2548
Boron, Total	mg/kg	<10	<10	NDA
Calcium, Total	mg/kg	250	160	NDA
Arsenic, Total	mg/kg	0.74	0.95	0.3
Barium, Total	mg/kg	7.9	4.3	NDA
Iron, Total	mg/kg	2300	1800	6014
Manganese, Total	mg/kg	61	42	119
Molybdenum, Total	mg/kg	<2.0	<2.0	NDA
Selenium, Total	mg/kg	0.80	0.60	NDA
Silver, Total	mg/kg	<0.50	<0.50	NDA
Chromium, Total	mg/kg	3.7	2.8	18.4
Cobalt, Total	mg/kg	1.9	1.4	NDA
Beryllium, Total	mg/kg	<0.50	<0.50	NDA

Table 3.7-37 *(Continued)*

Parameter	Units	October 1994 Data	October 1994 Dup. Data	March 1978 Data
Thallium, Trace ICP	mg/kg	<1.0	<1.0	NDA
Nickel, Total	mg/kg	2.4	2.1	NDA
Antimony, Total	mg/kg	<5.0	<5.0	NDA
Magnesium, Total	mg/kg	420	340	NDA
Phosphorus, Total	mg/kg	<100	<100	NDA
Potassium, Total	mg/kg	170	110	NDA
Sodium, Total	mg/kg	30	12	NDA
Aluminum, Total	mg/kg	2900	1900	NDA
Cadmium, Total	mg/kg	<0.50	<0.50	2.3
Copper, Total	mg/kg	1.6	0.82	10.5
Lead, Total	mg/kg	3.2	2.5	38
Mercury, Total	mg/kg	<0.02	<0.02	<0.01
Zinc, Total	mg/kg	32	30	150
Vanadium	mg/kg	5.5	4.4	NDA

SU = Standard Units.
NDA = No Data Available.

Prepared by: GJB1
Checked by: GJB

Table 3.7-38

Sediment Sampling Data, Little Sand Lake (Station I)

Parameter	Units	October 1994 Data	March 1978 Data
pH, Lab	SU	5.2	NDA
Solids, Total	%	33.7	4.23
Solids, Total Volatile	mg/kg	109000	NDA
Ammonia, N	mg/kg	88	NDA
Total Kjeldahl Nitrogen	mg/kg	690	NDA
Total Organic Nitrogen	mg/kg	600	NDA
Chloride	mg/kg	35	NDA
Fluoride	mg/kg	<0.5	NDA
Cyanide, Total	mg/kg	<0.5	NDA
Oil & Grease (Freon Extractables)	mg/kg	590	3972
Boron, Total	mg/kg	<10	NDA
Calcium, Total	mg/kg	160	NDA
Arsenic, Total	mg/kg	0.76	5.0
Barium, Total	mg/kg	8.2	NDA
Iron, Total	mg/kg	1100	9265
Manganese, Total	mg/kg	20	1079
Molybdenum, Total	mg/kg	<2.0	NDA
Selenium, Total	mg/kg	1.2	NDA
Silver, Total	mg/kg	<0.50	NDA
Chromium, Total	mg/kg	2.8	22.3
Cobalt, Total	mg/kg	<1.0	NDA
Beryllium, Total	mg/kg	<0.50	NDA
Thallium, Trace ICP	mg/kg	<1.0	NDA

Table 3.7-38 *(Continued)*

Parameter	Units	October 1994 Data	March 1978 Data
Nickel, Total	mg/kg	2.1	NDA
Antimony, Total	mg/kg	<5.0	NDA
Magnesium, Total	mg/kg	250	NDA
Phosphorus, Total	mg/kg	350	NDA
Potassium, Total	mg/kg	230	NDA
Sodium, Total	mg/kg	20	NDA
Aluminum, Total	mg/kg	2100	NDA
Cadmium, Total	mg/kg	<0.50	4.1
Copper, Total	mg/kg	1.6	20.9
Lead, Total	mg/kg	2.6	156
Mercury, Total	mg/kg	<0.02	<0.01
Zinc, Total	mg/kg	10	218
Vanadium	mg/kg	4.5	NDA

SU = Standard Units.
NDA = No Data Available.

Prepared by: GJB1
Checked by: GJB

The metals concentrations in H and H-Duplicate compare very closely. This shows consistency in sampling techniques, analytical methods and the substrate at this site. Except for mercury, the metals data for site I in the 1978 sampling event are considerably higher than those from 1994. This may be a result of variability in the sampling location, sampling methods or analytical techniques. It is likely that the variability in sediments may be reflected in this data. The arsenic, chromium, copper, lead and zinc data in 1978 for site I were on the upper end of the concentrations for that data set. Because of the uniformity in sampling and analytical techniques used during the 1978 study period, the variation in present data is likely attributable to actual variability within the composition of the sediments. Therefore, the sediment sample collected at site I in 1978 likely did contain higher than average concentration of metals.

3.7.5.7 Duck Lake

Duck Lake is located approximately 1.1 miles southeast of the ore body (Figure 3.7-2). It has a surface area of 26 acres and a maximum depth of 10 feet. The shoreline is characterized by swamp conifer or bog vegetation with mixed hardwoods in the upland areas. The lake sediments are primarily muck (Table 3.7-27). The lake has no clearly defined inlet stream and an intermittent outlet stream, which flows through a major wetland before discharging into Little Sand Lake (EMC, 1985).

Staff Gage LG-12 was established on Duck Lake during the 1977-1980 study. Lake levels calculated from data obtained at this location between April 1977 and October 1994 are given in Appendix 3.7-3. During this time period, a 2.64-foot fluctuation was recorded. Lake levels throughout the period varied from a high of 1612.88 MSL to a low of 1610.24, and averaged 1611.74 MSL through the study period.

The water chemistry sampling location designated LG-12 was positioned in the south central portion of Duck Lake. Collection of samples for water chemistry analysis were conducted monthly at this location from April 1994 through March 1995. Water quality data obtained from analyses of samples collected during this time period at this site are presented in Appendix 3.7-8. Summary statistics including maximum, minimum and mean values for these parameters are provided in Table 3.7-39 which compares them to similar statistics derived from samples obtained during the 1977-1980 study.

In general, the results reported from analysis of water samples collected from LG-12 in 1994 and 1995 were similar to those obtained during the 1977-1978 effort. Results of water chemistry analysis indicated that Duck Lake is a soft, slightly acidic pH lake. Mean hardness, alkalinity and specific conductance values were 7 mg/L as $CaCO_3$, 1 mg/L as $CaCO_3$, and 19 μmhos/cm, respectively. The pH values for the surface water at Duck Lake ranged from 4.91 to 6.37, and averaged 5.62 throughout the duration of the study.

Table 3.7-39

Water Quality Data, LG-12 (Duck Lake)
Summary of Monthly Means and Ranges

		1977-1978			1994-1995		
Station: K/LG-12	Units	Min.	Max.	Mean	Min.	Max.	Mean
Metals							
Aluminum, Total	µg/L	<10	<10	<10	62.30	154.00	91.86
Arsenic, Total	mg/L	<0.001	0.001	<0.001	<0.005	<0.005	Note 1
Cadmium, Total	µg/L	<1	6	<2	<0.006	0.039	0.020
Copper, Total	µg/L	<1	38	<5	0.447	3.490	0.902
Iron, Total	mg/L	0.02	1.01	0.26	0.100	0.170	0.130
Lead, Total	µg/L	<10	<10	<10	0.413	2.18	0.997
Manganese, Total	mg/L	0.036	0.500	0.077	0.010	0.040	0.022
Mercury, Total	ng/L	<100	<100	<100	2.30	3.95	3.10
Molybdenum, Total	mg/L	<0.01	<0.01	<0.01	<0.020	<0.020	Note 1
Nickel, Total	mg/L	<0.01	<0.01	<0.01	<0.030	<0.030	Note 1
Zinc, Total	µg/L	6	63	19	4.68	10.10	6.41
Phosphorus							
Phosphorus, Total	mg/L	<0.01	0.05	<0.03	<0.050	0.028	0.009
Nitrogen							
Nitrogen, Ammonia	mg/L	0.47	2.44	1.28	<0.10	0.67	0.08
Nitrogen, Nitrate	mg/L	<0.01	1.27	<0.24	<0.50	<0.50	Note 1
Sulfur							
Sulfate	mg/L	<1	14	<10	2.35	10.00	6.56
Solids							
Solids, Dissolved	mg/L	1	85	46	8	54	29
Solids, Suspended	mg/L	1	17	7	<5	<5	Note 1

Table 3.7-39 *(Continued)*

Station: K/LG-12	Units	1977-1978 Min.	1977-1978 Max.	1977-1978 Mean	1994-1995 Min.	1994-1995 Max.	1994-1995 Mean
General Parameters							
Alkalinity, Total	mg/L	<1	18	<3	<5	4	1
Biochemical Oxygen Demand	mg/L	1	10	4	<2	10	2
Chemical Oxygen Demand	mg/L	7	34	20	21	36	31
Chloride	mg/L	<1	6	<2	<1	1	0
Conductivity	μmhos/cm	22	40	30	13	39	19
Cyanide	mg/L	<0.001	0.002	<0.001	<0.020	<0.020	Note 1
Dissolved Oxygen[b]	mg/L	0.5	13.9	7.7	6.4	13.6	9.3
Hardness	mg/L	4	26	15	<5	12	7
pH	SU	4.5	6.0	5.0	4.91	6.37	5.62
Temperature	°C	0.5	27.5	11.7	2.4	25.3	14.1
Turbidity[a]	NTU	0.9	5.6	2.0	<0.5	2.4	1.1

[a]Turbidity was measured in FTU during the 1977-1978 study.
[b]Measured at 0.5 feet below surface.
SU = Standard Units.
Note 1: All data reported as less than detection, therefore no mean value is calculated.

Prepared by: JJA
Checked by: BDH

Dissolved oxygen concentrations measured in the surface water of Duck Lake ranged from 6.4 mg/L to 13.6 mg/L. Concentrations were above 5 mg/L throughout the water column during all samplings except in those regions within two feet of the lake bottom where lower concentrations were measured in September 1994, January 1995 and March 1995. Depth profiles of water temperature indicated that Duck Lake was generally well mixed throughout the year. Periods when the lower level of the lake had low oxygen content indicated that mixing may be limited at times. This mixing is not restricted because of temperature related density factors however.

All metals analyzed from samples collected at LG-12 during the 1994 and 1995 study were either below detection limits or were found in low concentrations. During this recent study, low level analyses techniques were used to monitor concentrations of aluminum, cadmium, copper, lead, mercury, zinc and chromium in water samples collected in Duck Lake. The lower detection limits associated with these techniques allowed for trace level detections of all these metals. However, aluminum was detected at a level higher than those observed during the 1977-1980 study (mean value = 91.86 μg/L vs <10 μg/L).

In October 1994 a sediment sample was collected from Duck Lake at Station K. A sample was also collected at this site in March 1978 for the previous work that was completed (EMC, 1985). A comparison of the results from these two sampling events is shown in Table 3.7-40. Information pertaining to the analysis of sediment samples is included in Appendices 3.7-4 and 3.7-10.

The sediment sample collected from Duck Lake in 1994 is representative of a predominantly inorganic substrate. The volatile solids portion, a measure of the organic content, measured within the sample was 7.5 percent (75,000 mg/kg) of the total solids present. The nitrogen and phosphorus levels were however high, which confirms that a portion of the sample is of organic origin.

The 1978 sample also showed some indications of organic material being present. The freon extractables level was the highest concentration for the 1978 sediment data set. This parameter is also an indicator of organic matter in a sediment sample.

The other parameters had mixed correlations between 1994 and 1978. This may be attributable to sampling methods, analytical methods, or, more likely, variability in the sediments in Duck Lake.

3.7.5.8 Deep Hole Lake

Deep Hole Lake is located approximately 1.5 miles southeast of the ore body (Figure 3.7-2). It has a surface area of 97 acres and a maximum depth of 10 feet. The shoreline vegetation there is characteristically upland hardwood and wooded, shrub-meadow wetland. The major components of the lake littoral sediments are sand, muck, gravel and rubble (Table 3.7-27).

Table 3.7-40

Sediment Sampling Data, Duck Lake (Station K)

Parameter	Units	October 1994 Data	March 1978 Data
pH, Lab	SU	6.1	NDA
Solids, Total	%	63.2	4.96
Solids, Total Volatile	mg/kg	75000	NDA
Ammonia, N	mg/kg	86	NDA
Total Kjeldahl Nitrogen	mg/kg	1000	NDA
Total Organic Nitrogen	mg/kg	910	NDA
Chloride	mg/kg	64	NDA
Fluoride	mg/kg	<0.5	NDA
Cyanide, Total	mg/kg	<0.5	NDA
Oil & Grease (Freon Extractables)	mg/kg	690	5504
Boron, Total	mg/kg	<10	NDA
Calcium, Total	mg/kg	340	NDA
Arsenic, Total	mg/kg	<0.40	<0.1
Barium, Total	mg/kg	9.2	NDA
Iron, Total	mg/kg	210	2152
Manganese, Total	mg/kg	4.3	83
Molybdenum, Total	mg/kg	<2.0	NDA
Selenium, Total	mg/kg	<0.50	NDA
Silver, Total	mg/kg	<0.50	NDA
Chromium, Total	mg/kg	1.3	8.8
Cobalt, Total	mg/kg	<1.0	NDA
Beryllium, Total	mg/kg	<0.50	NDA

Table 3.7-40 *(Continued)*

Parameter	Units	October 1994 Data	March 1978 Data
Thallium, Trace ICP	mg/kg	<1.0	NDA
Nickel, Total	mg/kg	<2.0	NDA
Antimony, Total	mg/kg	<5.0	NDA
Magnesium, Total	mg/kg	93	NDA
Phosphorus, Total	mg/kg	100	NDA
Potassium, Total	mg/kg	75	NDA
Sodium, Total	mg/kg	11	NDA
Aluminum, Total	mg/kg	840	NDA
Cadmium, Total	mg/kg	<0.50	1.5
Copper, Total	mg/kg	0.82	12
Lead, Total	mg/kg	1.2	4
Mercury, Total	mg/kg	<0.02	<0.01
Zinc, Total	mg/kg	12	64
Vanadium	mg/kg	1.4	NDA

SU = Standard Units.
NDA = No Data Available.

Prepared by: GJB1
Checked by: GJB

Although the lake has no clearly defined inlet or outlet, an intermittent inlet is present through the wetlands to the east, and two intermittent outlets exist. During periods of high water levels, surface water discharge can occur from the main outlet of Deep Hole Lake through a shallow marsh located in the west central portion of the lake. A secondary outlet is located on the southwest side in the lake (EMC, 1985).

Staff gage LG-13 was established on Deep Hole Lake during the 1977-1980 study (Figure 3.7-2). Lake levels calculated from data obtained at this location between June 1977 and October 1994 are given in Appendix 3.7-3. During this time period a 2.23-foot fluctuation was recorded. Lake levels throughout this period varied from a high of 1607.09 MSL on April 21, 1979, to a low of 1604.86 MSL on October 12, 1987.

The water chemistry sampling location designated LG-13 was positioned in the central portion of Deep Hole Lake. Collections of samples for water chemistry analysis were conducted monthly at this location from April 1994 through March 1995. Water quality data obtained from analyses of samples collected during this time period at this site are presented in Appendix 3.7-8. Summary statistics including maximum, minimum and mean values for these parameters are given in Table 3.7-41 which compares them to similar statistics derived from samples obtained during the 1977-1980 study.

In general, the results reported from analysis of water samples collected from LG-13 in 1994 and 1995 were similar to those obtained during the 1977-1980 effort. Results of water chemistry analysis indicated that Deep Hole Lake was a soft, slightly acidic pH lake. Mean hardness, alkalinity and specific conductance values at Deep Hole Lake were 8 mg/L as $CaCO_3$, 2 mg/L as $CaCO_3$, and 28 μmhos/cm, respectively. The pH values measured in surface waters at Deep Hole Lake ranged from 5.31 to 6.63 and averaged 5.95 throughout the duration of the study.

Dissolved oxygen concentrations measured in the surface water of Deep Hole Lake ranged from 8.2 to 12.8 mg/L. Concentrations of dissolved oxygen were above 5 mg/L during all samplings except in the region within one foot of the bottom sediment where a concentration of 2.2 mg/L was measured in September 1994.

All metals analyzed from samples collected at LG-13 during the 1994 study were either below detection limits or were found in low concentrations. During this recent study, low level analyses techniques were used to monitor concentrations of aluminum, cadmium, copper, lead, mercury, zinc and chromium in water samples collected from Deep Hole Lake. The lower detection limits associated with these techniques allowed for trace level detections of all these metals. However, only aluminum was detected at a level higher than those observed during the 1977-1980 study (mean value = 145.9 μg/L vs <10 μg/L).

Table 3.7-41

Water Quality Data, LG-13 (Deep Hole Lake)
Summary of Monthly Means and Ranges

		1977-1978			1994-1995		
Station: L/LG-13	Units	Min.	Max.	Mean	Min.	Max.	Mean
Metals							
Aluminum, total	µg/L	<10	<10	<10	90.40	248.0	145.90
Arsenic, total	mg/L	<0.001	0.001	<0.001	<0.005	<0.005	Note 1
Cadmium, Total	µg/L	<1	7	<2	0.009	0.151	0.033
Copper, total	µg/L	<1	11	<3	0.493	1.070	0.719
Iron, total	mg/L	0.05	0.42	0.14	0.146	0.410	0.198
Lead, total	µg/L	<10	<10	<10	0.421	1.620	0.805
Manganese, total	mg/L	0.014	0.086	0.029	0.018	0.075	0.029
Mercury, total	ng/L	<100	<100	<100	2.39	3.01	2.73
Molybdenum, total	mg/L	<0.01	<0.01	<0.01	<0.020	<0.020	Note 1
Nickel, total	mg/L	<0.1	<0.01	<0.1	<0.030	0.070	0.006
Zinc, total	µg/L	6	20	12	6.03	14.90	8.37
Phosphorus							
Phosphorus, total	mg/L	<0.01	0.12	<0.04	<0.05	0.097	0.019
Nitrogen							
Nitrogen, Ammonia	mg/L	0.33	0.77	0.48	<0.10	0.34	0.05
Nitrogen, Nitrate	mg/L	<0.01	0.39	<0.11	<0.50	0.71	0.08
Sulfur							
Sulfate	mg/L	4	13	9	3.94	12.0	7.89
Solids							
Solids, Dissolved	mg/L	8	196	53	15	78	40
Solids, Suspended	mg/L	1	17	5	<5	<5	Note 1

Table 3.7-41 *(Continued)*

Station: L/LG-13	Units	1977-1978 Min.	1977-1978 Max.	1977-1978 Mean	1994-1995 Min.	1994-1995 Max.	1994-1995 Mean
General Parameters							
Alkalinity, Total	mg/L	<1	28	<5	<2	5	2
Biochemical Oxygen Demand	mg/L	1	9	3	<2	6	1
Chemical Oxygen Demand	mg/L	3	21	12	15	29	23
Chloride	mg/L	<1	4	<2	<1	<1	Note 1
Conductivity	μmhos/cm	18	85	30	21	40	28
Cyanide	mg/L	<0.001	0.004	<0.001	<0.020	<0.020	Note 1
Dissolved Oxygen[b]	mg/L	1.3	14.8	8.4	8.2	12.8	10.4
Hardness	mg/L	8	36	16	<5	13	8
pH	SU	5.4	6.6	6.0	5.31	6.63	5.95
Temperature	°C	0.6	24.0	11.9	2.8	24.6	14.0
Turbidity[a]	NTU	0.6	2.7	1.4	0.90	2.98	1.51

[a]Turbidity was measured in FTU during the 1977-1978 study.
[b]Measured at 0.5 feet below surface.
SU = Standard Units.
Note 1 = All data reported as less than detection, therefore no mean value is calculated.

Prepared by: JJA
Checked by: BDH

In October 1994 a sediment sample was collected from Deep Hole lake at Station L (Figure 3.7-2). A sample was also collected at this site in March 1978 for the previous work that was completed (EMC, 1985). A comparison of the results from these two sampling events is shown in Table 3.7-42. Information pertaining to the analysis of sediment samples is included in Appendices 3.7-4 and 3.7-10.

The sediment sample collected from Deep Hole Lake in 1994 is representative of a predominantly inorganic substrate. The volatile solids portion, a measure of the organic content, measured within the sample was 4.9 percent (49,000) of the total solids present. Nitrogen and phosphorus levels were however high, which confirms that a portion of the sample is of organic origin.

The 1978 sample also showed some indications of organic material being present. The freon extractables level, another indicator of organic constituents, was above the average for the sediment concentrations reported in the 1978 data set. The 1978 concentration data was considerably higher than the 1994 data for parameters other than mercury. This may be attributable to sampling methods, analytical methods, or, more likely, variability in the sediments in Deep Hole lake.

3.7.5.9 Skunk Lake

Skunk Lake is located 0.4 mile east of the ore body in the uppermost portion of the Pickerel Creek drainage basin (Figure 3.7-2). It has a surface area of six acres and a maximum depth of six feet; however, depths in most of the lake are <3.0 feet (Table 3.2-27). The shoreline of Skunk Lake is predominantly upland hardwoods with the remainder being marsh wetland. The bottom substrate consists primarily of muck. Skunk Lake is located in a topographic depression and appears to have neither a surface water inlet nor outlet.

Staff gage LG-15 was established on Skunk Lake during the 1977-1980 study. Lake levels calculated from data obtained at this location between May 1977 and October 1994 are given in Appendix 3.7-3. During this time period a 4.67 foot fluctuation was recorded in the water level in Skunk Lake. Lake levels throughout this time varied from a high of 1599.85 MSL on June 17, 1991, to a low of 1595.18 MLS on February 15, 1986.

The water chemistry sampling station designated LG-15 was positioned in the eastern portion of Skunk Lake. Samples were collected from this location monthly from April 1994 through March 1995. Water quality data obtained from analyses of samples collected during this time period at this site are presented in Appendix 3.7-8. Summary statistics including maximum, minimum and mean values for these parameters are given in Table 3.7-43 which compares them to similar statistics derived from samples obtained during the 1977-1980 study.

Table 3.7-42

Sediment Sampling Data, Deep Hole Lake (Station L)

Parameter	Units	October 1994 Data	March 1978 Data
pH, Lab	SU	5.8	NDA
Solids, Total	%	59.6	6.47
Solids, Total Volatile	mg/kg	49000	NDA
Ammonia, N	mg/kg	45	NDA
Total Kjeldahl Nitrogen	mg/kg	610	NDA
Total Organic Nitrogen	mg/kg	560	NDA
Chloride	mg/kg	22	NDA
Fluoride	mg/kg	<0.5	NDA
Cyanide, Total	mg/kg	<0.5	NDA
Oil & Grease (Freon Extractables)	mg/kg	490	3818
Boron, Total	mg/kg	<10	NDA
Calcium, Total	mg/kg	210	NDA
Arsenic, Total	mg/kg	<0.40	4
Barium, Total	mg/kg	8.0	NDA
Iron, Total	mg/kg	660	2507
Manganese, Total	mg/kg	14	92
Molybdenum, Total	mg/kg	<2.0	NDA
Selenium, Total	mg/kg	<0.50	NDA
Silver, Total	mg/kg	<0.50	NDA
Chromium, Total	mg/kg	1.2	14.7
Cobalt, Total	mg/kg	<1.0	NDA
Beryllium, Total	mg/kg	<0.5	NDA

Table 3.7-42 *(Continued)*

Parameter	Units	October 1994 Data	March 1978 Data
Thallium, Trace ICP	mg/kg	<1.0	NDA
Nickel, Total	mg/kg	<2.0	NDA
Antimony, Total	mg/kg	<5.0	NDA
Magnesium, Total	mg/kg	150	NDA
Phosphorus, Total	mg/kg	150	NDA
Potassium, Total	mg/kg	66	NDA
Sodium, Total	mg/kg	12	NDA
Aluminum, Total	mg/kg	970	NDA
Cadmium, Total	mg/kg	<0.5	1.4
Copper, Total	mg/kg	1.1	15
Lead, Total	mg/kg	3.7	12
Mercury, Total	mg/kg	<0.02	<0.01
Zinc, Total	mg/kg	8.9	83
Vanadium	mg/kg	2.1	NDA

SU = Standard Units.
NDA = No Data Available.

Prepared by: GJB1
Checked by: GJB

Table 3.7-43

Water Quality Data, LG-15 (Skunk Lake)
Summary of Monthly Means and Ranges

		1977-1978			1994-1995		
Station: J/LG-15	Units	Min.	Max.	Mean	Min.	Max.	Mean
Metals							
Aluminum, Total	µg/L	<10	<10	<10	36.90	182.0	74.23
Arsenic, Total	mg/L	<0.001	<0.001	<0.001	<0.005	<0.005	Note 1
Cadmium, Total	µg/L	<1	<5	<2	<0.006	0.011	0.005
Copper, Total	µg/L	<1	92	<11	0.250	0.907	0.462
Iron, Total	mg/L	0.08	1.30	0.45	0.106	0.740	0.242
Lead, Total	µg/L	<10	20	<10	0.120	0.289	0.199
Manganese, Total	mg/L	0.018	0.724	0.221	0.040	0.280	0.119
Mercury, Total	ng/L	<100	<100	<100	1.26	3.29	2.09
Molybdenum, Total	mg/L	<0.01	<0.01	<0.01	<0.020	<0.020	Note 1
Nickel, Total	mg/L	<0.01	<0.01	<0.01	<0.030	<0.030	Note 1
Zinc, Total	µg/L	4	25	9	3.32	6.64	4.95
Phosphorus							
Phosphorus, Total	mg/L	0.07	0.54	0.20	<0.050	0.301	0.060
Nitrogen							
Nitrogen, Ammonia	mg/L	0.61	3.06	1.57	<0.10	0.34	0.13
Nitrogen, Nitrate	mg/L	<0.01	0.63	<0.17	<0.50	<0.50	Note 1
Sulfur							
Sulfate	mg/L	<1	1	<1	<1.00	11.00	5.65
Solids							
Solids, Dissolved	mg/L	5	310	67	15	62	40
Solids, Suspended	mg/L	1	56	12	<5	11	1.1

Table 3.7-43 *(Continued)*

		1977-1978			1994-1995		
Station: J/LG-15	Units	Min.	Max.	Mean	Min.	Max.	Mean
General Parameters							
Alkalinity, Total	mg/L	4	30	10	<5	15	5
Biochemical Oxygen Demand	mg/L	2	13	8	<2	15	5
Chemical Oxygen Demand	mg/L	NDA	NDA	NDA	33	50	40
Chloride	mg/L	<1	2	<2	<1	2	0
Conductivity	μmhos/cm	16	45	27	11	59	23
Cyanide	mg/L	<0.001	0.006	<0.002	<0.020	<0.020	Note 1
Dissolved Oxygen[b]	mg/L	0.4	10.5	5.1	0.9	8.0	4.9
Hardness	mg/L	4	32	15	<5	14	7
pH	SU	5.2	6.6	5.8	4.81	5.96	5.42
Temperature	°C	0.8	26.0	8.7	1.6	24.1	12.3
Turbidity[a]	NTU	0.9	8.7	2.9	0.85	8.2	2.53

[a]Turbidity was measured in FTU during the 1977-1978 study.
[b]Measured at 0.5 feet.

Prepared by: JJA
Checked by: BDH

SU = Standard Units.
Note 1 = All data reported as less than detection, therefore no mean value is calculated.
NDA = No Data Available.

In general, the results reported from analysis of samples collected from LG-15 in 1994 and 1995 were similar to those obtained during the 1977-1980 effort. Results of water chemistry analysis indicated that Skunk Lake is a soft, slightly acidic pH lake. Mean hardness, alkalinity and specific conductance values were 7 mg/L as $CaCO_3$, 5 mg/L as $CaCO_3$ and 23 μmhos/cm, respectively. The pH values measured in surface waters at Skunk Lake ranged from 4.81 to 5.96 and average 5.42 throughout the duration of study.

Dissolved oxygen levels were consistently low throughout the study duration in Skunk Lake. Measurements made at a depth of three feet ranged from 0.9 mg/L to 8.0 mg/L. Dissolved oxygen concentrations within the top foot of water in Skunk Lake were generally higher than those made at three feet and ranged from a high of 8.0 mg/L in April 1994 to a low of 0.9 in February of 1995.

All metals analyzed from samples collected at LG-15 during the 1994 study were either below detection limits or were found in low concentrations. During this recent study, low level analyses techniques were used to monitor concentrations of aluminum, cadmium, copper, lead, mercury, zinc and chromium in water samples collected in Skunk Lake. The lower detection limits associated with these techniques allowed for trace level detections of all these metals. However, aluminum was detected at a level higher than those observed during the 1977-1980 study (mean value = 74.23 μg/L vs <10 μg/L).

3.7.6 Wolf River Drainage Basin

The portion of the Wolf River studied is included in the area shown on Figure 3.7-4. Characteristics of the drainage basin upstream from Langlade are summarized in Table 3.7-27. Two of its major drainage sub-basins, the Swamp Creek basin and the Pickerel Creek basin, are described specifically in subsections 3.7.4 and 3.7.5, respectively. Swamp Creek and Pickerel Creek have drainage areas of 151 square miles (Table 3.7-11) and 44.3 square miles (Table 3.7-27), respectively, and the Wolf River at Langlade has a drainage area of 460 square miles.

The Wolf River originates in Hiles Mill Pond in Forest County and flows south approximately 223 miles to Lake Poygan in Winnebago County (WDNR, 1977). Its course of flow meanders along the western margin of the study area. Principal tributaries to the Wolf located upstream from the town of Langlade are Swamp Creek, Pickerel Creek, Hunting River, Lily River, and Nine Mile Creek. Ninety-five percent of the Wolf River drainage basin is wooded and undeveloped, whereas the remaining five percent is farmland (Steuck, et al., 1977). Table 3.7-8 presents stream discharge data for the Wolf River at Langlade. Above the community of Lily the river has a flat gradient, reflecting the large areas of lakes and wetlands through which it flows. Below Pearson the character of the river begins to change as it exhibits a steeper gradient. As calculated from USGS topographic maps, the gradient above Pearson averages 3.7 feet/mile, while below this area the gradient increases to 9.8 feet/mile (EMC, 1985).

River flow data and samples for water chemistry analyses were collected from the Wolf River monthly from November 1993 through October 1994 at Station SG-Y located approximately 1.2 miles upstream from the confluence with Swamp Creek, and at SG-CC, located approximately 2.1 miles upstream of the confluence with Pickerel Creek (Figure 3.7-1). River flow was monitored on the Wolf River at both SG-Y and SG-CC at the respective times that samples for water chemistry analyses were collected at those sites. The data associated with flow monitoring on the Wolf River is given in Appendices 3.7-5 and 3.7-6. Maximum and minimum flows measured at the upstream Wolf River site SG-Y were 135 cfs and 39 cfs (mean = 80 cfs). Flows measured at the downstream site SG-CC were consistently higher (min=75 cfs, max = 218 cfs) than those measured at SG-Y (mean = 129 cfs). The flows averaged 129 cfs between November 1993 and September 1994. Samples were also collected from these sites during storm flow events. Peak flows were not obtained at these times because of unsafe conditions.

Water quality data obtained from analyses of samples collected during the current study period at this site are presented in Appendix 3.7-8. Summary statistics including maximum, minimum and mean values for these parameters are given in Tables 3.7-44 and 3.7-45 which compare them to similar statistics derived from samples obtained during the 1977-1980 study. In general, the results reported from analyses of samples collected from the Wolf River in 1993 and 1994 were similar to those obtained during the 1977-1980 effort. Water chemistry information indicated that the Wolf River is a moderately hard, neutral pH stream. Mean hardness, alkalinity and conductivity values were 61 and 78 mg/L as $CaCO_3$, 55 and 69 mg/L as $CaCO_3$, and 138 and 154 μmhos/cm at Stations SG-Y and SG-CC, respectively. The mean pH values recorded on the Wolf River ranged from 7.35 at SG-Y to 7.01 at SG-CC. Maximum and minimum dissolved oxygen values measured on the Wolf River were 10.9 mg/L and 2.8 mg/L at SG-CC and 11.4 and 6.2 mg/L at SG-Y.

All metals analyzed from samples collected at sites SG-Y and SG-CC during the 1993-1994 study were either below detection limits or were found in low concentrations. During this recent study, low level analyses techniques were used to monitor concentrations of aluminum, cadmium, copper, lead, mercury, zinc and chromium in water samples collected from the Wolf River. The lower detection limits associated with these techniques allowed for trace level detections of all these metals. Aluminum was detected at levels higher than those observed during the 1977-1980 study (range of means = 27.7 - 42.2 vs 10 μg/L).

In October 1994 sediment samples were collected from the Wolf River at stations Y and Z. Samples were also collected at these sites in March 1978 for the previous work that was completed (EMC, 1985). A comparison of the results from these two sampling events is shown in Table 3.7-46 and Table 3.7-47. Information pertaining to the analysis of sediment samples is included in Appendices 3.7-4 and 3.7-10.

The analytical results for sediment collections made on the Wolf River in 1994 were similar to those derived from collections made in 1978. This is illustrated by comparison of metals concentration results between the two sampling periods, which are in general agreement.

Table 3.7-44

Water Quality Data, SG-CC[a] (Wolf River)
Summary of Monthly Means and Ranges

		1977-1978			1993-1994		
Station: Z/SG-CC	Units	Min.	Max.	Mean	Min.	Max.	Mean
Metals							
Aluminum, total	µg/L	<10	<10	<10	20.40	98.40	42.15
Arsenic, total	mg/L	<0.001	<0.001	<0.001	<0.005	<0.005	Note 1
Cadmium, total	µg/L	<1	3	<2	<0.004	0.032	0.009
Copper, total	µg/L	<1	4	<1	0.163	1.100	0.428
Iron, total	mg/L	0.31	1.45	0.61	0.358	0.780	0.500
Lead, total	µg/L	<10	10	<10	0.131	0.557	0.237
Manganese, total	mg/L	0.016	0.160	0.068	0.035	0.139	0.071
Mercury, total	ng/L	<100	900	<200	1.00	7.18	2.63
Molybdenum, total	mg/L	<0.01	<0.01	<0.01	<0.020	<0.020	Note 1
Nickel, total	mg/L	<0.01	<0.01	<0.01	<0.030	<0.030	Note 1
Zinc, total	µg/L	<1	23	<9	0.97	6.48	2.02
Phosphorus							
Phosphorus, total	mg/L	<0.01	0.04	<0.03	<0.050	0.046	0.012
Nitrogen							
Nitrogen, Ammonia	mg/L	0.51	1.51	1.00	<0.10	1.47	0.19
Nitrogen, Nitrate	mg/L	<0.01	0.54	<0.27	<0.04	<0.50	Note 1
Sulfur							
Sulfate	mg/L	<1	8	<5	4.12	24.00	8.65
Solids							
Solids, Dissolved	mg/L	72	174	122	6	125	89
Solids, Suspended	mg/L	1	11	4	<5	7	2

Table 3.7-44 *(Continued)*

Station: Z/SG-CC	Units	1977-1978 Min.	1977-1978 Max.	1977-1978 Mean	1993-1994 Min.	1993-1994 Max.	1993-1994 Mean
General Parameters							
Alkalinity, Total							
Biochemical Oxygen Demand	mg/L	0.46	90	63	40	97	69
Chemical Oxygen Demand	mg/L	1	2	2	<2	8	3
Chloride	mg/L	7	55	31	17	32	23
Conductivity	mg/L	<1	4	<3	2	3	3
Cyanide	μmhos/cm	75	135	99	111	213	154
Dissolved Oxygen	mg/L	<0.001	<0.001	<0.001	<0.010	<0.020	Note 1
Hardness	mg/L	1.4	12.6	6.8	2.8	10.9	7.8
pH	mg/L	56	104	73	52	104	78
Temperature	SU	6.4	7.5	7.0	5.96	7.64	7.01
Turbidity[b]	°C	0	22.0	9.3	0	20	10
	NTU	1.2	3.3	2.0	1.60	2.80	2.13

[a] Station SG-CC was positioned approximately three miles upstream of Station Z.
[b] Turbidity was measured in FTU during the 1977-1978 study.
SU = Standard Units.
Note 1 = All data reported as less than detection, therefore no mean value is calculated.

Prepared by: JJA
Checked by: BDH

Table 3.7-45

Water Quality Data, SG-Y (Wolf River)
Summary of Monthly Means and Ranges

		1977-1978			1993-1994		
Station: Y/SG-Y	Units	Min.	Max.	Mean	Min.	Max.	Mean
Metals							
Aluminum, total	µg/L	<10	<10	<10	13.40	60.70	27.70
Arsenic, total	mg/L	<0.001	<0.001	<0.001	<0.005	<0.005	Note 1
Cadmium, total	µg/L	<1	5	<2	<0.006	0.039	0.008
Copper, total	µg/L	<1	5	<2	0.137	4.090	0.652
Iron, total	mg/L	0.34	0.71	0.47	0.270	0.820	0.409
Lead, total	µg/L	<10	10	<10	0.098	0.307	0.193
Manganese, total	mg/L	0.014	0.179	0.069	0.026	0.219	0.072
Mercury, total	ng/L	<100	<100	<100	1.00	4.55	2.27
Molybdenum, total	mg/L	<0.01	<0.01	<0.01	<0.020	<0.020	Note 1
Nickel, total	mg/L	<0.01	<0.01	<0.01	<0.030	<0.030	Note 1
Zinc, total	µg/L	<1	21	<9	1.04	3.73	1.76
Phosphorus							
Phosphorus, total	mg/L	<0.01	0.12	<0.04	<0.050	0.767	0.077
Nitrogen							
Nitrogen, Ammonia	mg/L	0.39	1.36	1.01	<0.10	0.81	0.15
Nitrogen, Nitrate	mg/L	<0.01	0.59	<0.15	<0.04	<0.50	Note 1
Sulfur							
Sulfate	mg/L	<1	9	<6	3.47	21.00	7.16
Solids							
Solids, Dissolved	mg/L	57	166	110	50	135	86
Solids, Suspended	mg/L	1	13	4	<5	5	0

Table 3.7-45 *(Continued)*

		1977-1978			1993-1994		
Station: Y/SG-Y	Units	Min.	Max.	Mean	Min.	Max.	Mean
General							
Parameters	mg/L	36	80	52	41	88	55
Alkalinity, total							
Biochemical	mg/L	1	3	2	<1	9	3
Oxygen Demand							
Chemical Oxygen	mg/L	10	52	31	20	36	28
Demand	mg/L	<1	4	<2	2	4	3
Chloride	μmhos/cm	50	120	84	92	197	138
Conductivity	mg/L	<0.001	<0.001	<0.001	<0.010	<0.020	Note 1
Cyanide	mg/L	6.1	16.1	9.2	6.2	11.4	8.6
Dissolved Oxygen	mg/L	42	92	60	39	93	61
Hardness	SU	5.8	7.6	6.9	6.44	10.87	7.35
pH	°C	1.0	22.0	10.2	1.1	21.9	11.2
Temperature	NTU	1.1	3.0	2.1	1.70	4.10	2.90
Turbidity[a]							

[a]Turbidity was measured in FTU during the 1977-1978 study.
SU = Standard Units.
Note 1 = All data reported as less than detection, therefore no mean value is calculated.

Prepared by: JJA
Checked by: BDH

Table 3.7-46

Sediment Sampling Data, Wolf River (Station Y)

Parameter	Units	October 1994 Data	March 1978 Data
pH, Lab	SU	6.3	NDA
Solids, Total	%	74.4	45.78
Solids, Total Volatile	mg/kg	104000	NDA
Ammonia, N	mg/kg	<20	NDA
Total Kjeldahl Nitrogen	mg/kg	150	NDA
Total Organic Nitrogen	mg/kg	150	NDA
Chloride	mg/kg	<10	NDA
Fluoride	mg/kg	<0.5	NDA
Cyanide, Total	mg/kg	<0.5	NDA
Oil & Grease (Freon Extractables)	mg/kg	250	229
Boron, Total	mg/kg	<10	NDA
Calcium, Total	mg/kg	410	NDA
Arsenic, Total	mg/kg	0.69	0.3
Barium, Total	mg/kg	7.2	NDA
Iron, Total	mg/kg	3500	2571
Manganese, Total	mg/kg	28	102
Molybdenum, Total	mg/kg	<2.0	NDA
Selenium, Total	mg/kg	<0.50	NDA
Silver, Total	mg/kg	<0.50	NDA
Chromium, Total	mg/kg	4.8	14.5
Cobalt, Total	mg/kg	1.6	NDA
Beryllium, Total	mg/kg	<0.50	NDA

Table 3.7-46 *(Continued)*

Parameter	Units	October 1994 Data	March 1978 Data
Thallium, Trace ICP	mg/kg	<1.0	NDA
Nickel, Total	mg/kg	3.4	NDA
Antimony, Total	mg/kg	<5.0	NDA
Magnesium, Total	mg/kg	620	NDA
Phosphorus, Total	mg/kg	170	NDA
Potassium, Total	mg/kg	150	NDA
Sodium, Total	mg/kg	15	NDA
Aluminum, Total	mg/kg	1900	NDA
Cadmium, Total	mg/kg	<0.50	0.1
Copper, Total	mg/kg	3.2	2.8
Lead, Total	mg/kg	18	4
Mercury, Total	mg/kg	<0.02	<0.01
Zinc, Total	mg/kg	8.9	11
Vanadium	mg/kg	11	NDA

SU = Standard Units.
NDA = No Data Available.

Prepared by: GJB1
Checked by: GJB

Table 3.7-47

Sediment Sampling Data, Wolf River (Station Z)

Parameter	Units	October 1994 Data	March 1978 Data
pH, Lab	SU	6.5	NDA
Solids, Total	%	46.0	67.66
Solids, Total Volatile	mg/kg	66000	NDA
Ammonia, N	mg/kg	81	NDA
Total Kjeldahl Nitrogen	mg/kg	790	NDA
Total Organic Nitrogen	mg/kg	710	NDA
Chloride	mg/kg	29	NDA
Fluoride	mg/kg	<0.5	NDA
Cyanide, Total	mg/kg	<0.5	NDA
Oil & Grease (Freon Extractables)	mg/kg	350	74
Boron, Total	mg/kg	<10	NDA
Calcium, Total	mg/kg	1100	NDA
Arsenic, Total	mg/kg	0.89	0.4
Barium, Total	mg/kg	14	NDA
Iron, Total	mg/kg	3500	2601
Manganese, Total	mg/kg	82	144
Molybdenum, Total	mg/kg	<2.0	NDA
Selenium, Total	mg/kg	0.76	NDA
Silver, Total	mg/kg	<0.50	NDA
Chromium, Total	mg/kg	4.8	33.1
Cobalt, Total	mg/kg	1.6	NDA
Beryllium, Total	mg/kg	<0.50	NDA

Table 3.7-47 *(Continued)*

Parameter	Units	October 1994 Data	March 1978 Data
Thallium, Trace ICP	mg/kg	<1.0	NDA
Nickel, Total	mg/kg	1.9	NDA
Antimony, Total	mg/kg	<5.0	NDA
Magnesium, Total	mg/kg	780	NDA
Phosphorus, Total	mg/kg	530	NDA
Potassium, Total	mg/kg	120	NDA
Sodium, Total	mg/kg	30	NDA
Aluminum, Total	mg/kg	2200	NDA
Cadmium, Total	mg/kg	<0.50	0.1
Copper, Total	mg/kg	2.5	2.8
Lead, Total	mg/kg	2.2	1
Mercury, Total	mg/kg	<0.02	<0.01
Zinc, Total	mg/kg	17	11
Vanadium	mg/kg	8.0	NDA

SU = Standard Units.
NDA = No Data Available.

Prepared by: GJB1
Checked by: GJB

The 1994 data for sampling both sites are indicative of a mixture of organic and inorganic sediments. there are moderate levels of volatile solids found in both. Site Y had a volatile solids content of 10.4 percent (104,000 mg/kg) while site Z had a volatile solids content of 6.6 percent, (66,000 mg/kg).

3.7.7 Hydrological Relationships

3.7.7.1 Surface Water/Groundwater

Geography and climate have combined to provide a water surplus in northern Wisconsin. The excess of rainfall over evapotranspiration is reflected in the abundant groundwater resources, and the numerous lakes, wetlands, and perennial streams within the area. The streams of the study area share very similar characteristics. They are small, often not well defined, have varying surface water runoff characteristics, act as groundwater collectors with base water flow derived largely from groundwater, and, as a result, have similar water chemistry.

Groundwater and surface water in the study area are interrelated. In some cases, groundwater contributes to surface water flows, while in other cases surface water primarily contributes to the groundwater system.

When groundwater is a significant component of the input to a surface water system, the water chemistry of the surface water reflects the chemistry of the groundwater. In the study area, this correlation is seen in the hardness of the surface water. Using the classification system presented in Table 3.7-14, the groundwater in the study area is classified as moderately hard to very hard. The average hardness reported in Section 3.6.5 of the EIR is approximately 150 mg/L as $CaCO_3$. Those surface waters within the area which are fed by groundwater via direct connection to the water table or by groundwater-fed tributaries also exhibit a moderate hardness. In contrast, when a surface water in the study area is fed primarily by precipitation and surface water runoff, the water is characteristically soft.

To illustrate the correlation between water chemistry and the interaction of groundwater and surface water, Table 3.7-48 was prepared. The table compares alkalinity, hardness, pH, field conductivity, total solids, etc. for the various lakes, streams and rivers within the study area. Of the lakes, Little Sand, Oak, Duck, Skunk, and Deep Hole all have soft water. The hardness concentrations found in these lakes are less than 10 mg/L as $CaCO_3$ on the average. The maximum mean hardness recorded for these lakes was 8 mg/L in Deep Hole Lake. The hardness and other water chemistry data indicate that these lakes receive all or most of their water from surface water sources. In contrast, based on the 1994-1995 data, Rolling Stone Lake had an average hardness of approximately 77 mg/L as $CaCO_3$ and Ground Hemlock Lake had an average hardness of approximately 125 mg/L as $CaCO_3$. This is an indication that groundwater is an important factor in the water balance for these lakes. The groundwater component for Rolling Stone Lake is not just a result of the direct discharge of groundwater to the lake. Creeks 11-4 and 12-9 and Pickerel Creek have moderate hardness levels and contribute groundwater to Rolling Stone Lake through their tributarial relationship. The average 1994-1995 water hardness

Table 3.7-48

Summary of Water Chemistry Data to Identify Similar Water Bodies in the Study Area

		Mean of 1993-1997 Values						
Water Body	Sampling Station[a]	Alkalinity mg/L as $CaCO_3$	Hardness mg/L as $CaCO_3$	pH	Field Conductivity mhos/cm	Total Dissolved Solids mg/L	Hardness Classification[b]	pH Classification[b]
Little Sand Lake	LG-7	4	4	6.29	22	29	Soft	Slightly Acidic
Oak Lake	LG-11	1	7	6.29	22	22	Soft	Slightly Acidic
Duck Lake	LG-12	1	7	5.62	19	29	Soft	Slightly Acidic
Skunk Lake	LG-15	5	7	5.42	23	40	Soft	Slightly Acidic
Deep Hole Lake	LG-13	2	8	5.95	28	40	Soft	Slightly Acidic
Rolling Stone Lake	LG-9	81	77	7.71	121	97	Moderately Hard	Neutral
Lake 35-7	LG-357	100	95	7.53	188	160	Moderately Hard	Neutral
Ground Hemlock Lake	LG-24	105	125	7.4	256	135	Moderately Hard	Neutral
Creek 19-14	SG-1914	97	85	8.19	184	140	Moderately Hard	Slightly Basic
Hemlock Creek	SG-6	102	97	7.54	185	126	Moderately Hard	Neutral
Outlet Creek	SG-4	92	100	7.26	187	104	Moderately Hard	Slightly Acidic
Swamp Creek	SG-5A	105	113	7.16	195	119	Moderately Hard	Neutral
Swamp Creek	SG-3	96	91	7.47	207	125	Moderately Hard	Neutral
Swamp Creek	SG-2	95	104	7.24	196	135	Moderately Hard	Neutral
Swamp Creek	SG-AB	96	103	7.31	203	118	Moderately Hard	Neutral
Swamp Creek	SG-V	87	101	7.10	188	115	Moderately Hard	Neutral
Creek 11-4	SG-30	116	122	7.58	232	150	Moderately Hard	Neutral

Table 3.7-48 *(Continued)*

Water Body	Sampling Station[a]	Alkalinity mg/L as $CaCO_3$	Hardness mg/L as $CaCO_3$	pH	Field Conductivity mhos/cm	Total Dissolved Solids mg/L	Hardness Classification[b]	pH Classification[b]
		Mean of 1993-1997 Values						
Drainage Creek	SG-19B	120	100	8.30	291	170	Moderately Hard	Slightly Basic
Pickerel Creek	SG-19	72	81	7.33	157	119	Moderately Hard	Neutral
Wolf River	SG-Y	55	61	7.35	138	86	Moderately Hard	Neutral
Wolf River	SG-CC	69	78	7.01	154	89	Moderately Hard	Neutral
Hoffman Creek	SG-E	140	144	7.33	263	163	Hard	Neutral
Groundwater[c]	—	147.4	149.8	7.25	390.2	202.2	Hard	Neutral

[a] See Figures 3.7-1 and 3.7-2.
[b] See Table 3.7-14.
[c] See Table 3.6-25 (May 1994 through May 1995 Data).

Prepared by: JJA
Checked by: BDH
Revised by: GJB1
Checked by: LCT

data for Creek 11-4 and Pickerel Creek were 122 and 81 mg/L as $CaCO_3$, respectively. The 1977 and 1978 data for Creek 12-9 indicated an average hardness of 108 mg/L as $CaCO_3$. These tributaries are a factor in determining the water chemistry of Rolling Stone Lake. Given the chemistry of these creeks, most of their water is from groundwater discharge also.

Lake 35-7 is a moderately hard water lake primarily dependent on a direct groundwater feed. 1997 data indicated a hardness of 95 mg/L.

In general, the streams in the study area contain moderately hard to hard water. Based on the 1993-1997 data, the average hardness of the streams ranged from a low of approximately 61 mg/L as $CaCO_3$ for the Wolf River at sampling site SG-Y to a high of 144 mg/L as $CaCO_3$ for Hoffman Creek. This is an indication that the groundwater component of these streams varies from moderate to high. Since the water in the Wolf River is softer, it would seem that groundwater flow plays a smaller role in the Wolf River's hydrological system than in Hoffman Creek where an average hardness of 144 mg/L as $CaCO_3$ was observed, indicating that it is primarily groundwater fed.

3.7.7.2 Wetlands

In order to optimize the design of the proposed Crandon Project so that wetland impacts could be minimized, an evaluation of the existing wetland hydrology was performed. Initial efforts to model existing wetland conditions with typical hydrologic forecasting methods (such as USGS, SCS TR-55) showed that under general rainfall events, very little runoff would be generated from the drainage basin tributaries to the various wetlands. The full canopy wooded vegetation cover and generally permeable soils of study area upland drainage areas result in very little surface runoff moving downslope into the wetlands. This effort showed that single-event hydrologic modeling would not provide the information needed for the evaluation of hydrologic impacts. It also highlighted the fact that the high infiltration/percolation potential of the upland drainage areas under study have an effect on the overall wetland hydrology which needs to be evaluated accordingly.

The method ultimately used for evaluation of the wetland hydrology is a general water balance analysis. This method was chosen to address the need to model spring snowmelt/runoff which is the primary source of upland drainage area runoff to the wetlands. The analysis focuses on monthly water budgets based on monthly averages of climatological data from the nearby North Pelican at Pelican Lake meteorological station. Details regarding the methodology used to complete the analysis are contained in Appendix 4.2-5.

Using the selected methodology, the hydrologic water balance was determined for selected wetlands which could potentially be affected by construction and operations of the Crandon Project. These wetlands and their tributary drainage basins are shown in Figures 1 and 2 (Appendix 4.2-5) for existing conditions in the area of the proposed plant site and TMA, respectively. With the use of the water balance program, runoff was calculated for each basin. The results are shown in Tables 3.7-49 and 3.7-50, where 3.7-49 lists existing conditions in the area of the proposed plant site, and Table 3.7-50 lists existing conditions in the area of the proposed TMA.

Table 3.7-49

Annual Existing Conditions Draining Basin Water Balance Runoff Calculations for Plant Site

Drainage Basin I.D	Upland Area (acres)	Wetland Area (acres)	Runoff in AC-FT	
			Basin	Cumulative
P2	177.28	18.09	48.47[a] 4.84[b]	53.31
O3	48.29	2.22	13.20[a] 0.59[b]	13.79
O11	7.36	0.72	2.01[a] 0.19[b]	2.20
O12	3.75	0.11	1.03[a] 0.03[b]	1.06
F116	12.80	0.60	3.50[a] 0.16[b]	3.66
6	3.48	0.16	0.95[a] 0.04[b]	0.99
8	6.36	0.27	1.74[a] 0.07[b]	1.81
9	9.04	0.19	2.47[a] 0.05[b]	2.52
10	7.40	1.41	2.04[a] 0.38[b]	2.42
F11	79.49	18.37	21.73[a] 4.92[b]	26.65
F119	16.38	1.11	4.48[a] 0.30[b]	4.78
R7A	63.53	3.93	17.37[a] 1.05[b]	18.42

[a]Upland Area Basin.
[b]Wetland Area Basin.

Prepared by: SRB
Checked by: MDL
Revised by: JWS
Checked by: GJB1

Table 3.7-50

Annual Existing Conditions Drainage Basin Water Balance Runoff Calculations for TMA

Drainage Basin I.D	Upland Area (acres)	Wetland Area (acres)	Runoff in AC-FT	
			Basin	Cumulative
F31	60.95	6.45	16.66[a]	
			1.73[b]	18.39
F29	81.97	3.16	22.41[a]	40.80
			0.85[b]	41.65[c]
F33	17.37	1.82	4.75	4.75
			0.49	5.24
F15	118.73	36.47	32.46[a]	37.70
			9.76[b]	47.46[c]
F66	70.90	16.10	19.39[a]	
			4.31[b]	23.70
M4	17.12	1.37	4.68[a]	4.68
			0.37[b]	5.05
M3	34.53	4.51	9.44[a]	14.49
			1.21[b]	15.70[c]
M1	49.90	1.09	20.10[a]	35.80
			0.29[b]	36.09[c]

[a]Upland Area Basin.
[b]Wetland Area Basin.
[c]Cumulative runoff for F29, F15, M3, and M1 includes outflow from F31, F33, M4, and M3, respectively.

Prepared by: SRB
Checked by: MDL
Revised by: JWS
Checked by: GJB1

The model calculated the upland area runoff first, and then calculated the wetland runoff pertaining to the upland area. These runoff values were then accumulated to give total basin runoff. For example, TMA basin F31 in Table 3.7-50 had an upland area basin annual runoff of 16.66 ac-ft. The wetland of basin F31 had a runoff of 1.73 ac-ft. Therefore, the accumulated runoff for existing conditions of basin F31 is 18.39 ac-ft.

3.7.7.3 Flood Potential

The streams in both the Swamp Creek and Pickerel Creek drainage basins have the potential to experience flooding as a result of rainfall, snowmelt, or a combination of rainfall and snowmelt. In these relatively small basins, peak stream water flows are most commonly caused by rainfall events. The flood potential is low along these streams, however, in comparison to basins of similar size in other regions because of the relatively high permeability of the surficial soils, which allows water to infiltrate into the groundwater system (Section 3.6, Groundwater). In addition, the extensive areas of lakes and wetlands associated with the drainage basins, along with the highly vegetated woodland topography facilitate the storage of relatively large volumes of water, thereby keeping flood peaks low. No significant floods, as such, have occurred during the study period.

All the streams studied in both the Swamp Creek and Pickerel Creek drainage basins are subject to localized flooding caused by beaver dams. Historical data indicates that during the summer of 1979, the level of Ground Hemlock Lake was raised in this manner (EMC, 1985). Historically, flooding caused by beaver activity has also been observed in Hemlock Creek near water chemistry sampling Station A-1, on Swamp Creek near sampling Station E, in Hoffman Spring Pond, on Hoffman Creek, in Creek 11-4 downstream from water chemistry sampling Station M-3, and in Creek 12-9 near SG-23 (EMC, 1985). Flooding of this nature is unpredictable and somewhat independent of precipitation events.

Portions of Hemlock, Swamp, Outlet and Hoffman Creeks have all been mapped or partially mapped by the Federal Emergency Management Agency (FEMA) for flood hazards. Neither Pickerel Creek, Creek 12-9, nor Creek 11-4 have been mapped by FEMA. No other published information is known to exist on flooding for these streams. However, because there are no residences or other structures with a potential for flood damage along any of these creeks in either basin, historic flooding could have occurred and remained unrecorded.

Flooding in the lakes in the study area consists of temporary rises in lake level due to increased inflow. There is little potential for hazard to human life or structures on these lakes from flooding however, because the drainage areas are small and the lake level fluctuations are minor.

Besides localized flooding caused by excessive precipitation events, there is no potential for flooding associated with lakes and streams in the immediate vicinity of the proposed plant and TMA sites. Both sites are situated at the high end of drainage basins, above any location where any stream has formed. As such, there is no floodplain infringement at the proposed plant and TMA sites.

Various mapped or unmapped floodplains will be crossed by portions of the various corridors associated with the proposed mining activity. These floodplain interactions, such as the access road crossing of Swamp Creek, will require specific design features to assure full compliance with floodplain zoning and regulatory requirements.

3.7.8 Summary and Conclusions

The project study area primarily lies within the Swamp and Pickerel Creek drainage basins, which reside within the Wolf River drainage basin. The study area is characterized by forested lands, wetland areas, and small perennial streams, and contains two basic lake types: drainage (recharge) and seepage (discharge).

For the Wolf River drainage basin at Langlade, the highest average monthly stream discharge occurs in May and June when snowmelt runoff is highest and the lowest in the months of January, February and March when precipitation is retained on the ground surface as snow and ice.

The streams in the study area transport small quantities of sediment. This appears to be a result of the factor that land in the study area is forested, soils are granular, slopes are moderate, stream velocities are low, and the many lakes and wetlands in the area serve as sediment traps.

A correlation exists between surface water and groundwater chemistry and hydrologic flow. Soft water lakes are generally upland in nature and receive most if not all their water from surface water flows. Hard water lakes are associated with groundwater discharge areas and have water chemistry that more closely resembles that of the groundwater.

The characteristics of the surface water bodies as indicated by water chemistry measurements appear to be consistent over time as shown by comparing the data collected from the current study to that collected previously. Noted variations in sediment data is attributable to the variability of sediment deposition.

Flood potential in the study area is low in comparison to basins of similar size in other regions due to the extensive areas of lakes and wetlands associated with the drainage basins, along with the highly vegetated woodland topography, which facilitates the storage of relatively large volumes of water, thereby keeping flood peaks low. Neither the plant site nor TMA are located in areas where flooding associated with lakes and streams will occur.

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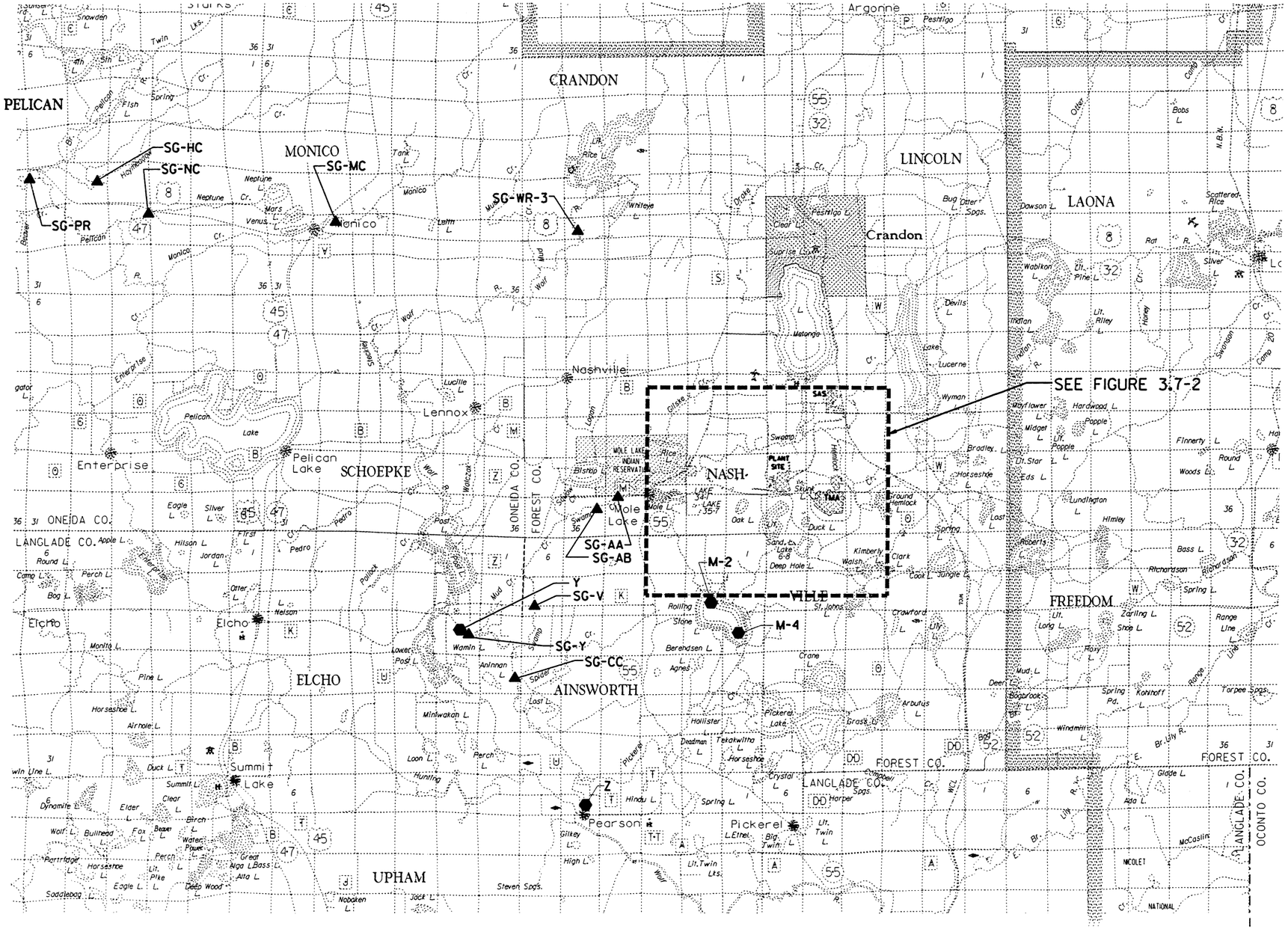
FIGURES FOR SECTION 3.7



N

LEGEND

- U.S. OR STATE HWY
- COUNTY TRUNK ROAD
- TOWN ROAD
- COUNTY BOUNDARY
- CIVIL TOWN BOUNDARY
- SECTION LINE
- (8) U.S. HWY NO.
- (47) STATE HWY NO.
- (W) COUNTY HIGHWAY LETTER
- NATIONAL & STATE FOREST BOUNDARY
- CORPORATE LIMITS
- UNINCORPORATED VILLAGE
- ORE BODY
- PROPOSED ACCESS ROAD
- PROPOSED RAILROAD SPUR
- PROPOSED FACILITIES
- SG-AB — SURFACE WATER MONITORING STATION
- M-2 — SURFACE WATER SEDIMENT SAMPLING STATION

NOTES:

1. BASE MAP DERIVED FROM COUNTY MAPS PREPARED BY THE WISCONSIN DEPARTMENT OF TRANSPORTATION.
2. ORE BODY OUTLINE IS REPRESENTATIVE OF THE SUBCROP AT THE BASE OF THE OVERBURDEN.
3. SURFACE WATER STATIONS ARE APPROXIMATE LOCATIONS.

Foth & Van Dyke			
REVISED	DATE	BY	DESCRIPTION
1	11/98	MLD2	REVISED FOR 1998 UPDATE

CHECKED BY:	JKSI	DATE:	MAY '95
APPROVED BY:	GJBI	DATE:	MAY '95
APPROVED BY:	GWS	DATE:	MAY '95

Nicolet Minerals COMPANY

FIGURE 3.7-1

SURFACE WATER AND SEDIMENT MONITORING STATION LOCATION MAP 1

Scale: 0 7500' 15,000 | Date: MAY, 1995

Prepared By: Foth & Van Dyke | By: KMP | 93C049

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130,000 N | 125,000 N | 120,000 N | 115,000 N | 110,000 N

LEGEND

- LAKES
- STREAMS
- EXISTING ROAD
- COUNTY BOUNDARY
- CIVIL TOWN BOUNDARY
- SECTION LINE
- ORE BODY
- PROPOSED ACCESS ROAD
- PROPOSED RAILROAD SPUR
- PROPOSED FACILITIES
- ▲SG-2 SURFACE WATER MONITORING STATION
- ⬢M-2 SURFACE WATER SEDIMENT SAMPLING STATION

N

NOTES:

1. BASE MAP DIGITIZED FROM 1" = 1000' SCALE, MAP PREPARED BY AERO-METRIC ENGINEERING, INC., SHEBOYGAN, WISCONSIN. DATE OF PHOTOGRAPHY APRIL 28, 1976.
2. HORIZONTAL DATUM BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM - NORTH ZONE.
3. COUNTY AND TOWNSHIP LINES DIGITIZED FROM 7.5' SERIES USGS MAPS.
4. ORE BODY OUTLINE IS REPRESENTATIVE OF THE SUBCROP AT THE BASE OF THE OVERBURDEN.
5. SURFACE WATER STATIONS ARE APPROXIMATE LOCATIONS.

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION
1	11/98	MLD2	REVISED FOR 1998 UPDATE
2	11/98	GJB1	ADDED MONITORING LOCATIONS

CHECKED BY:	JKS1	DATE:	MAY '95
APPROVED BY:	GJB1	DATE:	MAY '95
APPROVED BY:	GWS	DATE:	MAY '95

Nicolet Minerals COMPANY

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FIGURE 3.7-2

SURFACE WATER AND SEDIMENT MONITORING STATION LOCATION MAP 2

Scale: 0 1500' 3000' | Date: MAY, 1995

Prepared By: Foth & Van Dyke | By: KMP | 93C049

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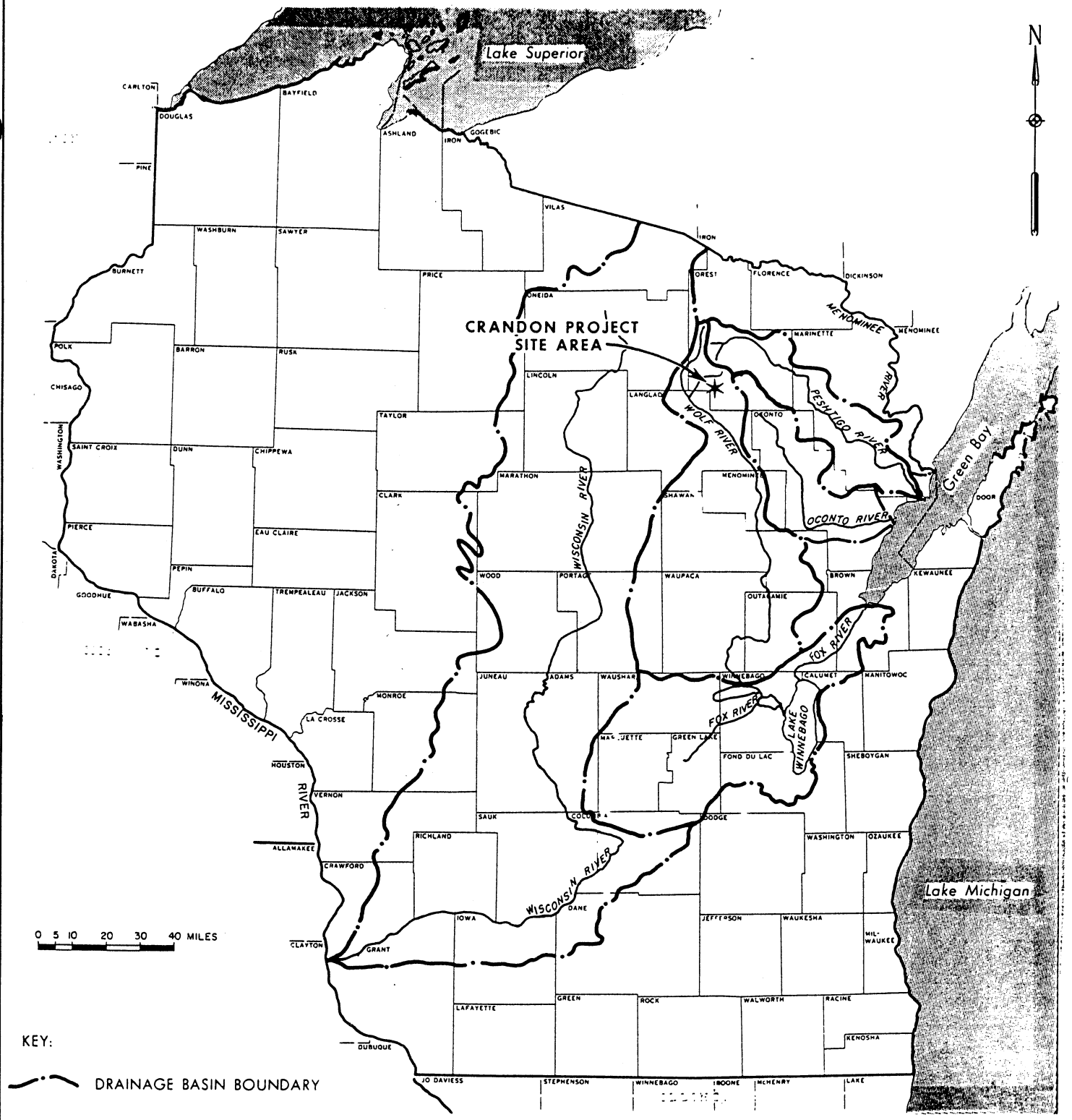

SOURCE: 1985, ENVIRONMENTAL IMPACT REPORT.

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION
1	11/98	MLD2	REVISED FOR 1998 UPDATE

CHECKED BY:	JKSI	DATE: MAY '95
APPROVED BY:	GJBI	DATE: MAY '95
APPROVED BY:	GWS	DATE: MAY '95

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FIGURE 3.7-3

MAJOR DRAINAGE BASINS IN NORTHEASTERN WISCONSIN

Scale: NOT TO SCALE		Date: MAY, 1995	
Prepared By: Foth & Van Dyke		By: KMP	93C049

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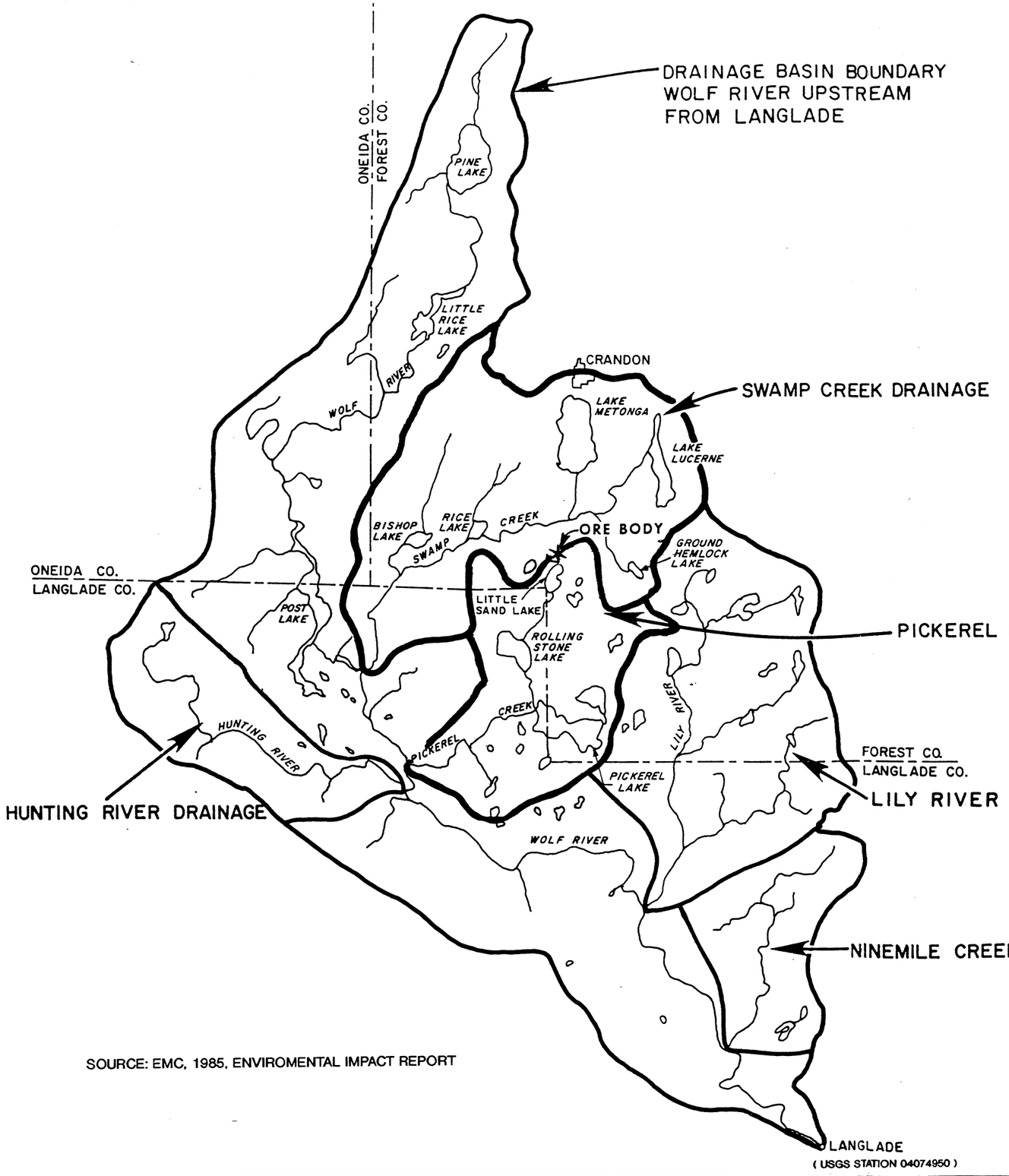

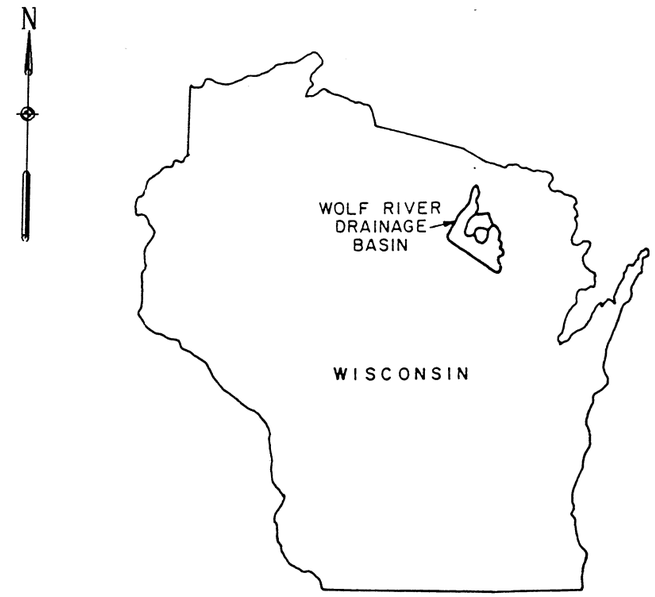

5 0 5 MILES

SOURCE: EMC, 1985, ENVIROMENTAL IMPACT REPORT

Foth & Van Dyke				
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CHECKED BY:		JKSI	DATE:	MAY '95
APPROVED BY:		GJBI	DATE:	MAY '95
APPROVED BY:		GWS	DATE:	MAY '95

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FIGURE 3.7-4

DRAINAGE BASINS OF THE WOLF RIVER UPSTREAM FROM LANGLADE

Scale: AS SHOWN		Date: MAY, 1995	
Prepared By: Foth & Van Dyke		By: KMP	93C049

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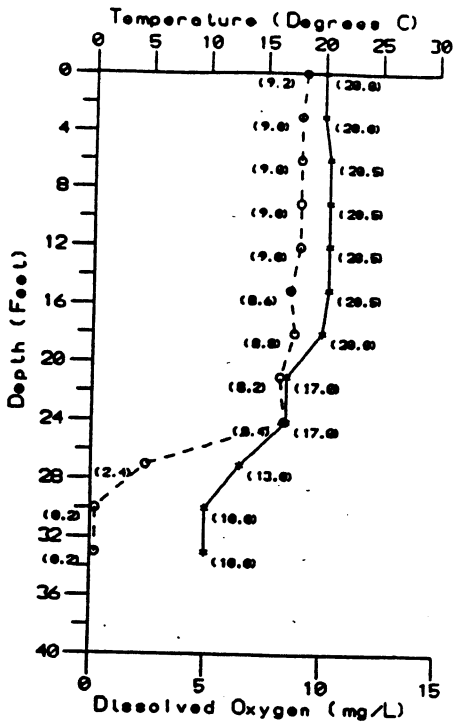
Aug. 10, 1994



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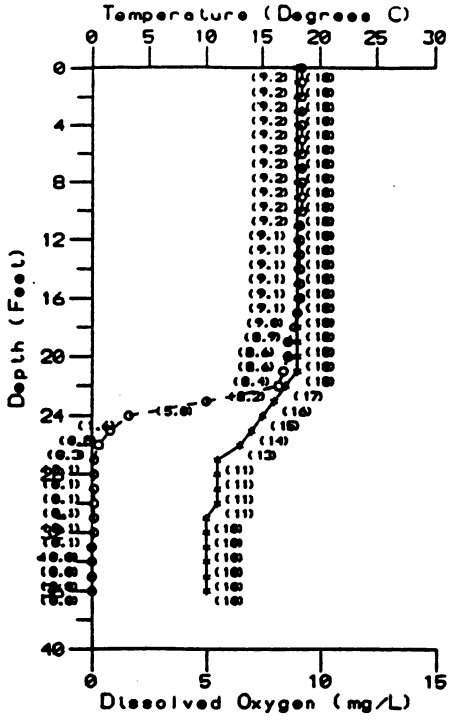

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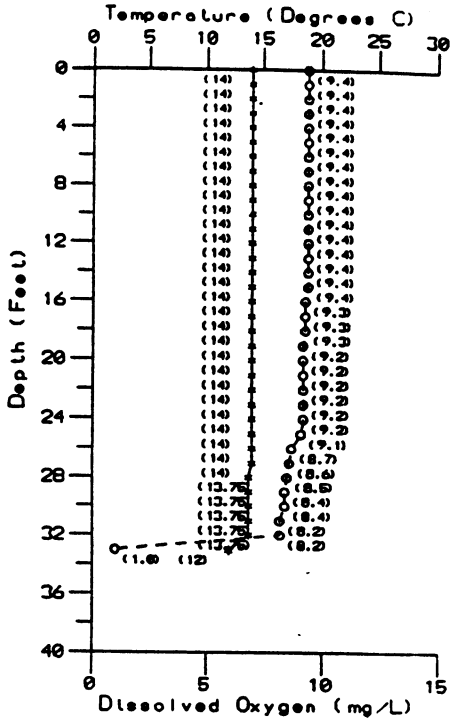

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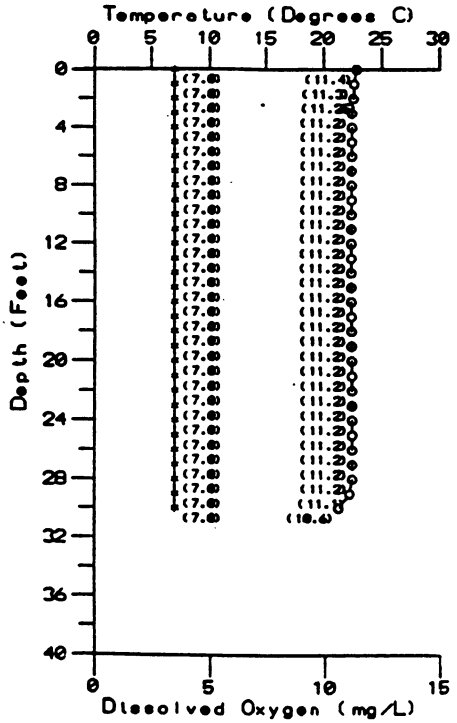

KEY:

Dissolved Oxygen

Temperature

Foth & Van Dyke			
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CHECKED BY:	JKSI	DATE:	NOV. '95
APPROVED BY:	GJBI	DATE:	NOV '95
APPROVED BY:	GWS	DATE:	NOV '95

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FIGURE 3.7-5

DISSOLVED OXYGEN/TEMPERATURE PROFILES FOR OAK LAKE LG-11 AUG. 1994-NOV. 1994

Scale:	NONE	Date:	NOVEMBER, 1995
Prepared By: Foth & Van Dyke		By: KMP	93C049

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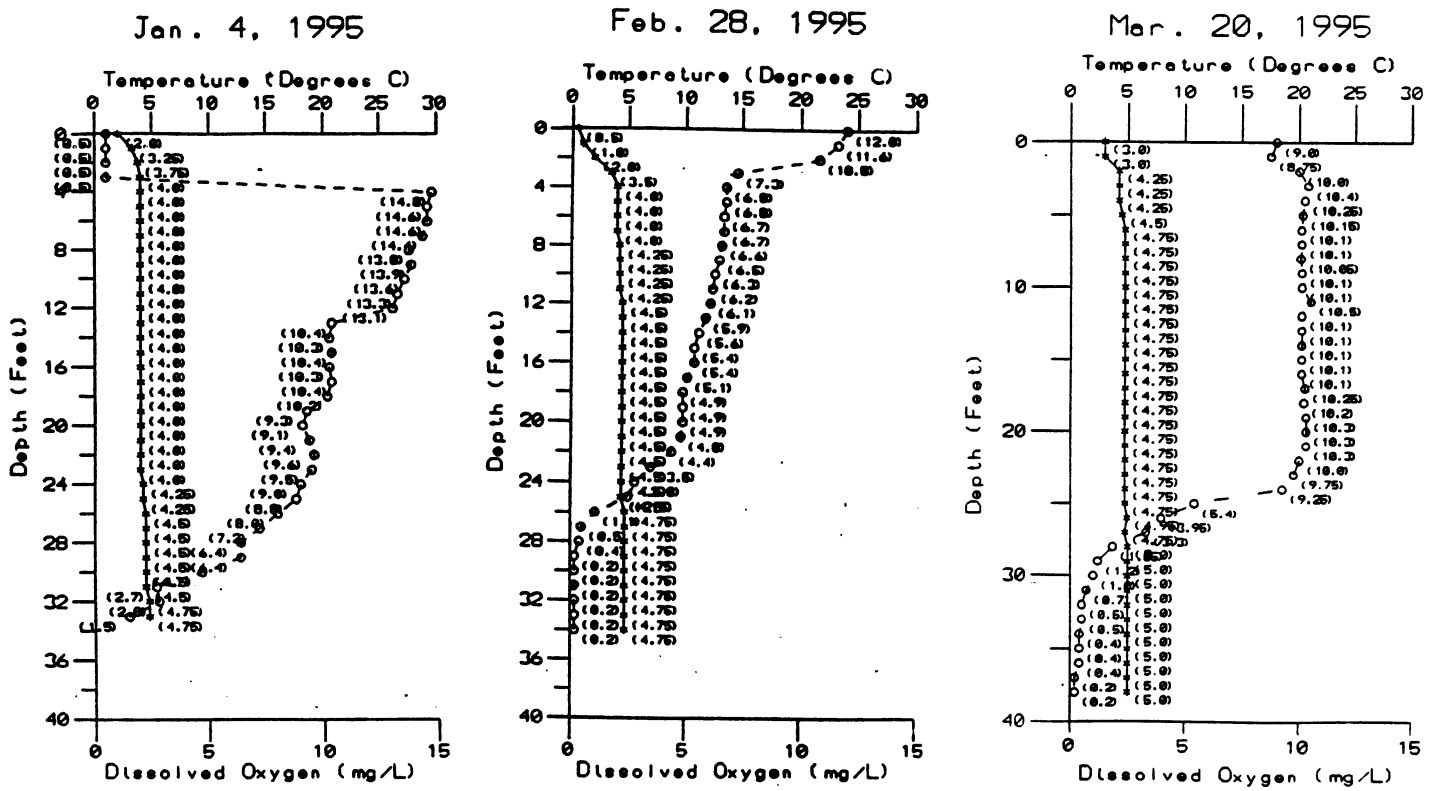

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CHECKED BY:	JKSI	DATE: NOV '95
APPROVED BY:	GJBI	DATE: NOV '95
APPROVED BY:	GWS	DATE: NOV '95

Nicolet Minerals COMPANY

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FIGURE 3.7-6

DISSOLVED OXYGEN/TEMPERATURE PROFILES FOR OAK LAKE LG-11 JAN. 1995-MARCH, 1995

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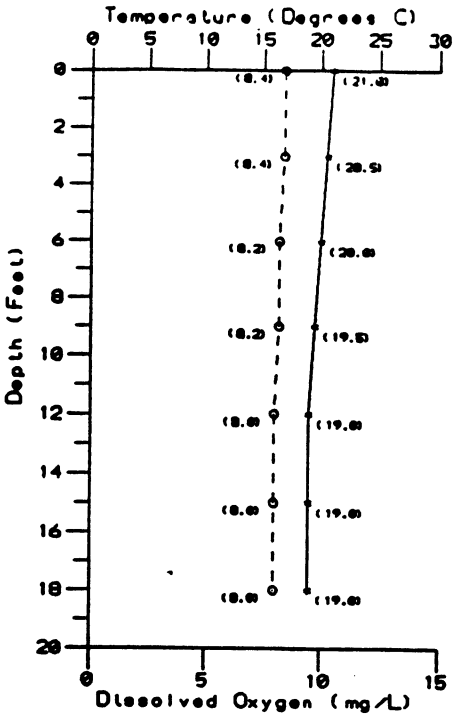

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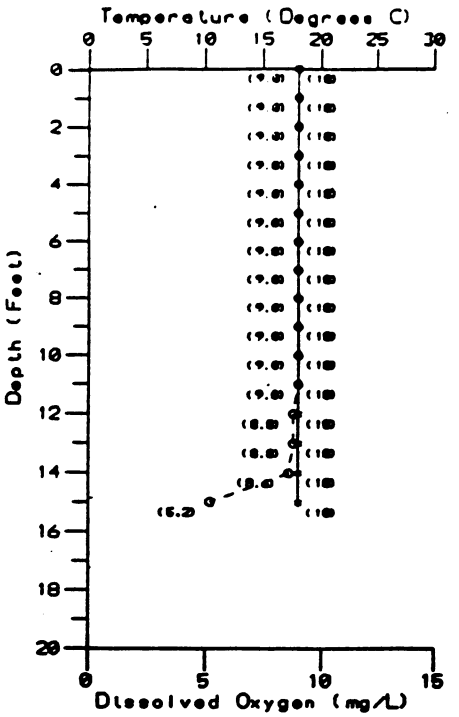

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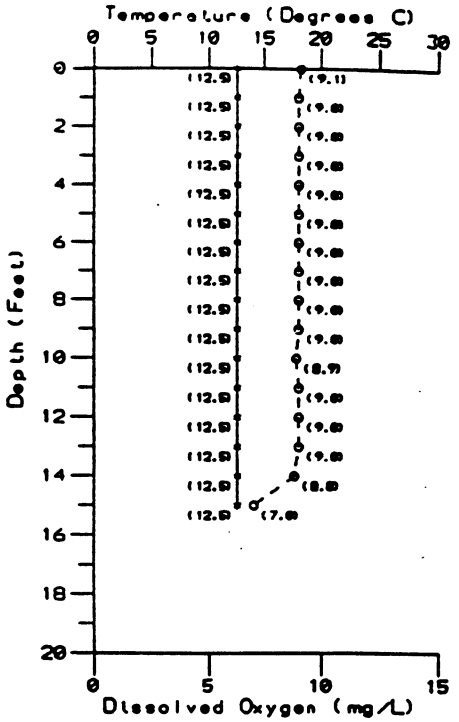
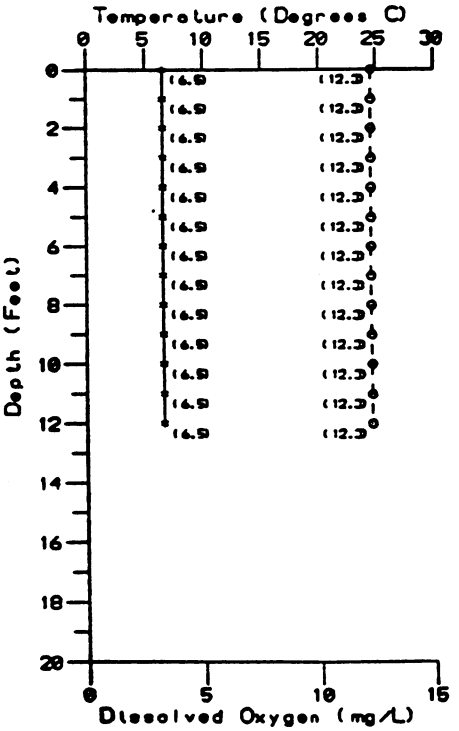


Nov. 9, 1994



KEY:

Dissolved Oxygen

Temperature

Foth & Van Dyke			
REVISED	DATE	BY	DESCRIPTION
1	12/98	MLD2	REVISED FOR 1998 UPDATE
CHECKED BY:	JKSI	DATE: FEB. '96	
APPROVED BY:	GJBI	DATE: FEB. '96	
APPROVED BY:	GWS	DATE: FEB. '96	

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FIGURE 3.7-7

DISSOLVED OXYGEN/TEMPERATURE PROFILES
FOR LITTLE SAND LAKE LG-7
AUG. 1994 - NOV. 1994

Scale: NONE	Date: FEBRUARY, 1996
Prepared By: Foth & Van Dyke	By: JOW 93C049

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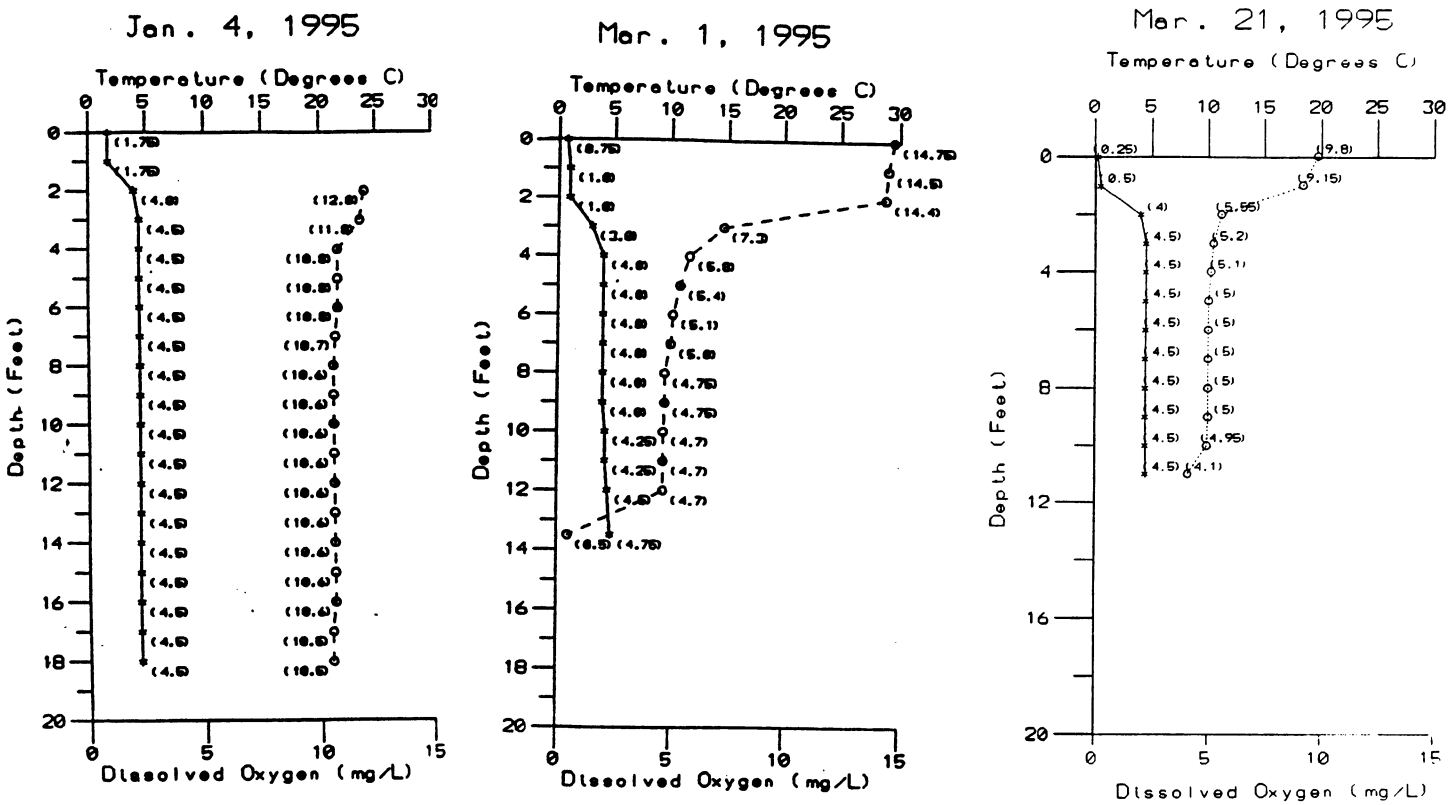

KEY:

Dissolved Oxygen

Temperature

Foth & Van Dyke			
REVISED	DATE	BY	DESCRIPTION
1	12/98	MLD2	REVISED FOR 1998 UPDATE
CHECKED BY:	JKSI	DATE:	FEB. '96
APPROVED BY:	GJBI	DATE:	FEB. '96
APPROVED BY:	GWS	DATE:	FEB. '96

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FIGURE 3.7-8

DISSOLVED OXYGEN/TEMPERATURE PROFILES
FOR LITTLE SAND LAKE LG-7
JAN. 1995 - MAR. 1995

Scale: NONE	Date: FEBRUARY, 1996
Prepared By: Foth & Van Dyke	By: JOW 93C049

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Environmental Impact Report

Section 3.8

Aquatic Biology

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3.8 Aquatic Biology

The purpose of this study was to survey surface waters around the project area for the presence of aquatic threatened, endangered and special concern species included on the Wisconsin Heritage Inventory List.

Biological studies relative to the Crandon Project were first completed in the late 1970s and early 1980s. These early studies provide a basic biological data base for the study area. Recent studies have added to the data base by providing additional information, with an emphasis on threatened, endangered, and special-concern species.

This section of the EIR provides the basic methodology for the collection of aquatic biological specimens, including quality control for handling of samples; the results of the findings of both the 1970s and 1980s studies and the recent 1993 and 1994 studies; and finally, a discussion of the significance of the findings.

3.8.1 Field Methodology

Aquatic biology studies on water bodies within the study area were undertaken from the mid 1970s to mid 1980s, and November 1993 through September 1994. The study area for the aquatic biology program includes those locations of sampling stations selected for monitoring as shown on Figure 3.8-1 (1970s and 1980s) and Figure 3.8-2 (1993 and 1994). Locations identified in Figure 3.8-2 were established based on review of project objectives and site reconnaissance with WDNR (October 1993). The objective of the investigations was to provide aquatic biological population studies (1970s and 1980s data) and actual field data on federal or state listed threatened, endangered, or special concern species, i.e., species "listed" by the Wisconsin Heritage Inventory. Work conducted in 1993 and 1994 differs from previous field studies conducted in 1977 and 1978 by Ecological Analysts (Dames & Moore, 1982) because the emphasis was on listed species. The Dames & Moore work generally identified organisms to order or family while the 1993 and 1994 studies of listed species provided identifications to species. In addition, since target species were identified prior to initiation of 1993-1994 field studies, sampling locations and time windows were selected to coincide with the life cycle and habitats of the target species.

Studies included an investigation of the Swamp Creek and Upper Pickerel Creek drainage basins and the Wolf River upstream and downstream of the confluence with Swamp Creek. A list of all monitoring locations used in 1977-1978 is provided in Table 3.8-1.

3.8.1.1 1993/1994 Sampling Location Selection

The purpose of the studies conducted in 1993-1994 was to supplement previous studies conducted in the late 1970s and early 1980s by providing information relative to the abundance and distribution of aquatic threatened, endangered or special concern species in lakes and streams within the study area. As described in Section 3.8.1, the study area is entirely within the Wolf

Table 3.8-1

Sampling Stations for Aquatic Biology Studies in the Study Area 1977-1978

Water Body	Stations
Swamp Creek Drainage Basin	
Rice Lake	F, N
Hemlock Creek	A-1, A-2
Hoffman Creek	E-1
Swamp Creek	B, D, E
Oak Lake	G
Pond 25-11*	25-11
Hoffman Springs	E-2
Hoffman Pond	E-3
Pickerel Creek Drainage Basin	
Rolling Stone Lake	M-2, M-4
Pickerel Creek	M-5
Creek 12-9*	M-1
Creek 11-4*	M-3
Little Sand Lake	H, I
Duck Lake	K
Deep Hole Lake	L
Skunk Lake	J
Pond 31-13*	31-13
Pond 6-8*	6-8
Pond 35-7*	35-7
Pond 34-1*	34-1
Wolf River	Y, Z

*WDNR Identification Code for unnamed streams and lakes.

Source: Dames & Moore, 1982
Checked by: WMW

River drainage basin and is characterized by forested lands, lakes, wetland areas, and perennial and intermittent streams that provide drainage routes. The proposed mine facilities lie on a watershed divide (a line defining locations where water flows perpendicularly away from the line) that separates the Swamp Creek basin and the Pickerel Creek basin, both of which are part of the larger Wolf Rover drainage basin (Figure 3.8-1).

Lakes in the study area that were investigated can be characterized as seepage or discharge.

Seepage lakes included in this study are situated above the groundwater system, that is, the lake surface elevation is above the elevation of the groundwater system with water levels apparently maintained by a low-permeability soil layer. Groundwater is recharged by seepage from these lakes through the lake bed. In contrast, groundwater flows into the discharge lakes included in this study.

Seepage lakes in the study area are characteristically low in pH and have soft water that is low in alkalinity. Seepage lakes include Oak, Duck, Skunk, Little Sand, and Deep Hole Lakes. Discharge lakes within the study area have water slightly basic in pH and are moderately hard with moderate alkalinity. Examples of discharge lakes are Rolling Stone and Ground Hemlock. Streams in the study area have similar characteristics to discharge lakes. They are generally small, often not well defined, and have a base flow derived largely from the groundwater system. Typically, pH of the water is neutral and hardness and alkalinity values are similar to those in discharge lakes.

Streams and lakes receive nutrients from their watersheds through the active transport of vegetation and soil minerals via surface runoff. The water quality and sediment quality of water bodies is directly influenced by the volume and quality of inputs from terrestrial portions of their watersheds.

The selection of sampling locations for 1993 and 1994 work was based on two criteria. The first criterion deals with the spatial relationship of organisms or populations of organisms with respect to proposed mining activities. In this respect, sampling locations proximal to the mining activities were chosen to evaluate species in the near vicinity of the project area and TMA. In addition, distal sampling locations were chosen to evaluate species distribution peripheral to the mining activity including downstream Swamp Creek and Wolf River environs.

The second criterion for selection of sampling locations deals with the need to include as many types of habitats as possible. The study area includes many lentic and lotic environments. A total of six lakes were studied as well as a cold water spring (Hoffman Springs) and Popple Pond. Small streams (Hemlock Creek, Swamp Creek above Rice Lake, Martin Springs, Creek 12-9, Pickerel Creek, Hoffman Creek) and larger streams (Swamp Creek below Rice Lake, Wolf River) provided a diverse habitat from which to select representative sampling locations. Within these habitats, substrates which were sampled included sand, cobble, gravel, rock, and muck. Submerged and emergent vegetation were sampled, including overhanging vegetation and

submerged detritus. Sampling from areas with distinctive vegetative types included alder swamp, bog, marsh, sedge meadow, and hardwood.

A description of each sampling site follows. A characterization of habitats and habitat descriptions were provided in the 1977-1978 data collection effort. These characterizations are discussed in Section 3.8.1.6 below. For a review of sampling locations, refer to Figures 3.8-1 and 3.8-2. Sample locations for data collected in 1993 and 1994 use an identification code of a CMC-AB- prefix followed by a five digit site identifier. In most cases site locations duplicated those of samples collected in the 1970s and 1980s. Therefore in the following site description the 1993-1994 identifier will be followed with the 1977-1978 identifier in parenthesis, e.g., CMC-AB-HL-200 (A-1). The former is found on Figure 3.8-2, while the latter can be cross-referenced on Figure 3.8-1.

CMC-AB-HL-100 Hemlock Creek at West Lake Road crossing. Upstream of the road consists of a pool with muck bottom surrounded by hardwoods. Downstream of the road the creek meanders through an open meadow bordered by alder, birch, and spruce. The substrate is mostly muck though some washed sand was observed. Intermittent flooding because of beaver activity prevents thorough washing of substrates even during periods of high water. Fish surveys were conducted at this site.

CMC-AB-HL-200 Hemlock Creek at Berry Lane crossing, also known as Deep Hole Road Crossing (A-1). The bottom consists of hard sand covered with six to 12 inches of organic detritus. Banks are lined with sedge meadow interspersed with alder, birch, black ash, and spruce/balsam. Beaver activity is a major factor in the amount of debris located in pools. Fish and mussel surveys and light trapping activities were conducted at this location. Adult Odonata were also collected here as well as other biological studies in 1977-1978.

CMC-AB-SC-200 Swamp Creek at Keith Siding Road. This site is a fully canopied hardwood reach with muck bottom. Organic debris exists including leaf litter and fallen timber. Fish surveys and light trapping activities were conducted at this location.

CMC-AB-SC-250 Swamp Creek at confluence with Hemlock Creek. This site is an open sedge meadow with erodible banks. Muck bottom along banks gives way to sand bottom in middle covered with detritus. Submerged vegetation (*Elodea*) is common growing on sand bars throughout area. Numerous small mollusks (fingernail clams) were observed in areas of washed gravel below beaver dams. Macroinvertebrate collections, mussel midden collections, and Odonata exuviae collections were conducted at this location.

CMC-AB-SC-300 Swamp Creek south of Swampy Lane access (D). This is a true riffle area with many large rocks throughout the area. This heavily timbered, closed canopy segment contained many large trees downed across the stream. Macroinvertebrate, fish, adult Odonata, Odonata exuviae, and mussel collections were completed in this stream

segment. Light trapping was also conducted along the stream at this location as well as biological studies conducted in 1977-1978.

CMC-AB-SC-301 Swamp Creek about 1/4 mile downstream of Swampy Lane Access. This true riffle area contained fewer boulders than SC-300, with more cobble and gravel. There is a slightly more open canopy here than at site SC-300. Macroinvertebrate, fish, adult Odonata, Odonata exuviae, and mussel collections were completed in this stream segment.

CMC-AB-SC-400 Swamp Creek at Highway 55 crossing. Substrate at this site consists of muck bottom. Some beds of wild rice occur immediately upstream along with pockets of water lily. Open canopy dominates with scattered hardwoods. Swamp Creek upstream from this site is almost pondlike. Fish collections were conducted at this location.

CMC-AB-SC-500 Swamp Creek downstream of County M. This segment is a meandering stream averaging about three feet in depth. Several sand bars exist with dense beds of *Elodea*. Up to one foot of muck is deposited between sand bars. Birch and alder are common along erodible sandy banks. Adult Odonata, mussel, and fish collections were conducted at this location. Light trapping was also conducted at this location.

CMC-AB-SC-501 Swamp Creek from Schallock's Bridge downstream to SC-500. Bottom substrate and vegetation are similar to SC-500. Banks of the meandering stream are typically sedge meadow with alder/birch mix. One area of rock/cobble occurs in a deeper hole (four to five feet) about 1/2 mile upstream of SC-500. Macroinvertebrate, fish, mussel, adult Odonata, and Odonata exuviae collections were conducted at this location.

CMC-AB-SC-502 Swamp Creek from SC-500 downstream about 1/2 mile. For macroinvertebrate and mussel collections, this reach included about 1/2 mile. For fish collections, this area was expanded to include the distance down to the forest road crossing, about an additional 3/4 mile. Substrate and habitat in this segment are similar to SC-501. Macroinvertebrate, fish, mussel, adult Odonata, and Odonata exuviae collections were conducted at this location.

CMC-AB-SC-700 Swamp Creek at Highway K crossing. Samples were taken downstream of this crossing. Bottom center consists of sand, fairly firm, while sides of the stream were of muck bottom. Culverts create distinct back current up to 20 yards downstream depositing detritus along side wings of stream. Overhead canopy is hardwood. Mussel collections were conducted at this location.

CMC-AB-WR-200 Wolf River at Lower Post Lake outfall (Y). Substrate at the outfall is made up of riprap. The pool downstream of the outfall is of sand bottom. Some muck

occurs along shore near the outfall. The river at this point is wide (open) with hardwood shore. Fish and mussel collections were conducted at this location as well as biological studies conducted in 1977-1978.

CMC-AB-WR-301 Wolf River immediately upstream of confluence with Swamp Creek. The stream is fairly flat, with pools in excess of four feet in depth. Most of the substrate is sand. One area of cobble/rock is located along the west bank about four feet in depth. Large sand bars are common. River segment up to 1/4 mile upstream of the confluence with Swamp Creek is wide, 30 to 60 feet, with hardwood canopy. Macroinvertebrate, fish, mussel, adult Odonata, and Odonata exuviae collections were conducted at this location.

CMC-AB-SGI-CC Wolf River at Lost Lake Road access. Substrate at this access point is covered with some boulders and many smaller rocks. River stage through this point is greater than three feet except where sand bars occur upstream and downstream of this point. The access point is generally of hardwood canopy while upstream and downstream bank vegetation is characteristically sedge meadow. Substrate is devoid of muck bottom except in areas of backwater. Macroinvertebrate, fish, mussel, adult Odonata, and Odonata exuviae collections were conducted at this location. Light trapping was also conducted at this location.

CMC-AB-PK-200 Pickerel Creek at North Rolling Stone Lake Road access (M-5). Substrate is generally muck bottom. Stream is narrow with alder/birch canopy. Fish collections were conducted at this location as well as biological studies conducted in 1977-1978.

CMC-AB-MS-100 Martin Springs at North Rolling Stone Lake Road access (M-3). Stream near the access road is similar to PK-200. Stream upstream of access road about 30 yards meanders through a sedge meadow including a drawn down beaver pond before entering the wooded canopy. The center of the stream in the meadow is of firm sand while edges are of muck. Macroinvertebrate, adult Odonata, and Odonata exuviae collections were conducted at this location. Light trapping was also conducted at this location as well as biological studies conducted in 1977-1978. This stream is WDNR Creek 11-4.

CMC-AB-SC-12-9 Creek 12-9 at entrance to Rolling Stone Lake (M-1). Substrate is mostly of muck bottom. Creek meanders through dense alder just prior to entering Rolling Stone Lake. Much detritus carried by 12-9 (mostly conifer needles) are deposited at the mouth. Macroinvertebrate collections were conducted at this location in 1993 and 1994 as well as biological studies conducted in 1977-1978.

CMC-AB-PK-300 Pickerel Creek at outfall from Rolling Stone Lake. The outfall is made up of a rock spillway. Rock continues several yards downstream of outfall. Fish, crayfish, and mussel collections were conducted at this location.

CMC-AB-HS-005 Hoffman Springs (E-3). This is a shallow pond which is spring fed. Substrate is of muck bottom containing one or more feet of organic detritus, much of the litter is conifer needles. Macroinvertebrate, adult Odonata, and Odonata exuviae collections were conducted at this location in 1993 and 1994. Light trapping was also conducted at this location in 1994 as well as minnow trapping in 1978.

CMC-AB-HC-100 Hoffman Creek beginning at farm lane between Hoffman Creek and Hoffman Springs and continuing about 1/4 mile downstream (E-1 and E-2). This is a shallow stream with a washed sand bottom in the center and detritus along banks. Undercut banks are prevalent. Beds of watercress are common from the farm lane downstream. This segment of stream is a noted brook trout spawning area. Macroinvertebrate, adult Odonata, and Odonata exuviae collections were completed at this location in 1993 and 1994 as well as minnow trapping and trout redd surveys in 1977 and 1978.

CMC-AB-SK-005 Skunk Lake (J). A soft bottom lake located immediately east of the project area. The lake is overgrown with submerged and emergent vegetation, apparently in an advanced stage of succession. The lake is bordered on the south, west, and east by hardwoods, with marsh in various portions of north edges. Macroinvertebrate, adult Odonata, and Odonata exuviae collections were conducted at this location in 1993 and 1994. Light trapping was also conducted at this location in 1994. General biological collections were conducted in 1977 and 1978.

CMC-AB-DL-005 Duck Lake. The west and north end of this lake are characteristic of bog habitat, while the south and east sides of the lake are bordered in hardwood. Scant emergent vegetation exists, while stained water reduces the ability to observe submerged vegetation. The bottom is soft and muck occurs along bog edges, while firm bottom with some rock occurs along the south and east shorelines. The lake drains to Little Sand Lake. The lake is located southeast of the mining site in fairly close proximity to the proposed tailings management area. Macroinvertebrate, fish, mussel, adult Odonata, and Odonata exuviae collections were conducted at this location.

CMC-AB-OL-005 Oak Lake (G). Substrate is of sand throughout entire periphery. Scant emergent and submergent vegetation exists. The lake is bordered by hardwoods throughout its entirety except for a sedge meadow along east shore south of boat landing. When discharge occurs, the lake drains north to the Swamp Creek watershed. The lake is located southwest of the project area. Macroinvertebrate, fish, mussel, adult Odonata, and Odonata exuviae collections were conducted at this location in 1993 and 1994. General biological collections were conducted in 1977 and 1978.

CMC-AB-SL-005 Little Sand Lake (H and I). Substrate is sand along the north and east ends, some cobble on the east end, with softer bottom toward the south end. Some larger boulders and rock are located near the outfall at the south end of the lake. Emergent and submerged vegetation are not abundant. Lake drains south to Pickerel

chain. The lake is located immediately south of the project area. Macroinvertebrate, fish, mussel, adult Odonata, and Odonata exuviae collections were conducted at this location in 1993 and 1994. Light trapping was also conducted at this location in 1994. General biological collections were conducted in 1977 and 1978.

CMC-AB-DH-005 Deep Hole Lake (L). Substrate is sand around most of lake. Scattered boulder/rock occur along the south shore. Emergent and submerged vegetation are scattered throughout the lake. Deep Hole drains northwest to Little Sand Lake. Hardwoods border most of the lake except the outfall where succession creates more of a marshy habitat. Macroinvertebrate, fish, mussel, and Odonata exuviae collections were conducted at this location in 1993 and 1994. General biological collections were conducted in 1977 and 1978.

CMC-AB-RS-005 Rolling Stone Lake (M-2 and M-4). This lake receives drainage from Little Sand Lake and Pickerel Creek (Mole Lake). This is a true discharge lake with abundant emergent and submergent vegetation. Substrate is sandy, firm throughout most of the lake, an exception being the north end where three inlets create areas of soft muck bottom. Some rock shoreline is prevalent. Macroinvertebrate, fish, mussel, and Odonata exuviae collections were conducted at this location in 1993 and 1994. General biological collections were conducted in 1977 and 1978.

CMC-AB-PP-005 Popple Pond (25-11). This pond is located east of Hoffman Springs and west of the mining site. The pond drains to the Swamp Creek drainage basin. The pond is bordered on the east and south by hardwoods while north and west edges are marshy and open. Substrate is of muck. Emergent and submerged vegetation is prolific. Macroinvertebrate, adult Odonata, and Odonata exuviae collections were conducted at this location in 1994. Aquatic macrophyte collections and minnow trapping were conducted in 1977.

CMC-AB-OC-200 Outlet Creek at Keith Siding Road crossing. Substrate is of sand with scant debris. Undercut banks are present. The stream is fully canopied with hardwood. This stream is the outlet from Lake Metonga and joins Swamp Creek to the south at about the area where the riffle on Swamp Creek begins. A beaver dam is present on Swamp Creek at about the same point where Outlet Creek enters. Creek stage levels may be controlled by a low head spillway at the outlet of Lake Metonga. Light trapping was conducted at this location.

CMC-AB-RR-100 Railroad North from Hemlock Road about 1/2 mile. This segment of terrestrial habitat is interspersed with ponds, marshes and bog-type habitat. This segment was investigated for presence of adult dragonflies.

3.8.1.2 Methods for Phytoplankton

At each phytoplankton sampling station, duplicate samples were collected with water pumps (Schwoerbel, 1972). Two calibrated centrifugal pumps were deployed in tandem and equipped with a pair of intake hoses of 19-mm (0.75-inch) inside diameter. Water was pumped from 1-m (3.3-foot) intervals in the water column. Two pumps in tandem were utilized in the collection to increase volume in order to minimize sampling time. In Rice and Skunk Lakes, which are shallow (depth <2.0m [6.6 feet]), the entire volume was withdrawn from mid-depth. For each replicate, an integrated sample of 50 liters (13.2 gallons) of water was collected in a large container. After thorough mixing of the sample, a minimum subsample of one liter (0.26 gallon) was obtained. Each phytoplankton sample was preserved in the field with three percent buffered formalin, shipped to the laboratory, and stored. Although Weber (1973) recommends preservation of phytoplankton with 5 percent buffered formalin, experience has demonstrated that a three percent solution is more desirable in that it reduces cellular distortion and provides adequate preservation.

Each sample was analyzed in the laboratory using a Sedgewick-Rafter counting cell for the identification and enumeration of species present (Weber, 1973; American Public Health Association [APHA] et al., 1976). All planktonic algae were identified to the lowest possible taxon, generally species. Individuals enumerated were expressed as units/mL where a "unit" is equivalent to a filament, colony, partial colony, mass, or one complete diatom cell (two valves). A minimum of 400 individuals was counted to facilitate an accurate estimate of the density (number/liter) and relative abundance of algal taxa. Less than 400 individuals were enumerated if, on the basis of four strips traversed, the densities were very sparse or were at a level that would excessively exceed the 400 minimum if a fifth strip was enumerated. The majority of the samples were analyzed within three months of the date of collection. Algae were identified using taxonomic keys presented in Collins (1909), Smith (1920, 1924, 1950), Lackey (1938), Patrick (1959), Thompson (1959), Prescott (1962, 1970), Patrick and Reimer (1966), Weber (1966), Whitford and Schumacher (1969), and Taft and Taft (1971). Identifications and enumerations were verified by reanalysis of approximately 10 percent of the samples by either Dr. Theodore S. Roeder, Associate Professor, University of Wisconsin at Stevens Point or Mr. Mason G. Fenwick, Assistant Professor, Northern Illinois University at DeKalb, Illinois. Consultation for identification was also provided by Dr. Gary B. Collins and Mr. Benjamin H. MacFarland, Aquatic Biologists, U.S. EPA, Cincinnati, Ohio.

Diversity was calculated using the formula presented in Shannon and Weaver (1949) and numbers of organisms identified to the lowest possible taxa (based on $\log_{10}$). Samples for chlorophyll a analysis were obtained from lake stations where phytoplankton was collected (Table 3.8-2 and Table 3.8-3), except in March 1977. Samples were filtered on site, and the filters were placed in vials containing aqueous acetone solution (Weber, 1973). Approximately 500 mL (0.13 gallons) of sample was filtered utilizing 0.45 micron membrane filters. The sample vials were wrapped in aluminum foil, packed in ice, and shipped in insulated containers via air freight on the day of collection to Aqualab, Inc. for analysis. The analysis was conducted in accordance with Section 602c, "Determination of Chlorophyll a in the Presence of Pheophytin

Table 3.8-2

Schedule of Seasonal Biological Sampling in the Swamp Creek Drainage Basin During 1977 and 1978

		1977								1978				
Water Body	Sample/Station(s)	Mar	May	June	July	August	September	October	November	March	April	May	August	October
Rice Lake	Phytoplankton/ Zooplankton													
	F	X	X	X	X	X	X	X	—	—	—	—	—	—
	N	X	X	X	X	X	X	X	—	X	X	X	X	—
	Chlorophyll a													
	F	—	X	X	X	X	X	X	—	X	—	—	—	—
	N	—	X	X	X	X	X	X	—	X	—	X	X	—
	Periphyton													
	F	—	X	X	X	X[a]	X	X	—	—	—	—	—	—
	N	—	X	—	X	X[a]	X	X	—	—	—	X	X	—
	Aquatic Macrophytes -													
	Lake Survey	—	—	—	—	X	—	—	—	—	—	—	—	—
	Benthos													
	F	X	X	—	—	X[a]	—	X	—	X[b]	—	—	—	—
	N	X	X	—	—	X[a]	—	X	—	X[b]	—	X	X	—
	Fish - Lake Survey													
	Electroshocking	—	X	—	—	X[a]	—	X	—	—	—	X	X[a]	—
	Gill Net	—	—	—	—	—	—	—	—	—	—	X	—	—
	Fyke Net	—	X	—	—	X[a]	—	X	—	—	—	X	X	—
	Minnow Trap	—	—	—	—	—	—	—	—	—	—	X	X	—

Table 3.8-2 (*Continued*)

Water Body	Sample/Station(s)	1977 Mar	May	June	July	August	September	October	November	1978 March	April	May	August	October
	Tissue Chemistry - Lake Survey													
	Aquatic Macrophytes	—	—	—	—	X[a]	—	—	—	—	—	—	—	—
	Benthos	—	—	—	—	X[a]	—	—	—	—	—	—	—	—
	Fish	—	—	—	—	X[a]	—	—	—	—	—	—	X[a]	—
Hemlock Creek	Periphyton													
	A-1	—	—	—	—	—	—	X	—	—	—	X	X	—
	Benthos													
	A-1	—	—	X	—	X[a]	—	X	—	X	—	X	X	—
	Fish													
	Trout Redd Reconnaissance - Creek Survey	—	—	—	—	—	—	X	X	—	—	—	—	—
	Electroshocking													
	A-1	—	X	—	—	X[a]	—	X	—	—	—	X	X	—
	A-2	—	X	—	—	X[a]	—	X	—	—	—	—	—	—
	Tissue Chemistry													
	Fish													
	A-1	—	—	—	—	—	—	—	—	—	—	—	X	—
	A-2	—	—	—	—	X[a]	—	—	—	—	—	—	—	—
Hoffman Creek	Fish													
	Trout Redd Reconnaissance - Creek Survey	—	—	—	—	—	—	—	X	—	—	—	—	—
	Electroshocking													
	E-1	—	—	X	—	X[a]	—	X	—	—	—	—	—	—

Table 3.8-2 (*Continued*)

Water Body	Sample/Station(s)	1977 Mar	May	June	July	August	September	October	November	1978 March	April	May	August	October
Swamp Creek	Periphyton													
	D	X	X	X	X	X[a]	X	X	—	—	—	X	X[a]	—
	E	X	X	X	—	X[a]	X	X	—	—	—	X	X[a]	—
	Benthos													
	D	X	X	—	—	X[a]	—	X	—	X	—	X	X[a]	—
	E	X	X	—	—	X[a]	—	X	—	X[b]	—	X	X[a]	—
	Fish													
	Trout Redd Reconnaissance - Creek Survey	—	—	—	—	—	—	X	X	—	—	—	—	—
	Electroshocking													
	B	—	X	—	—	X[a]	—	X	—	—	—	—	—	—
	D	—	X	—	—	X[a]	—	X	—	—	—	X	X[a]	—
	Tissue Chemistry													
	Aquatic Macrophytes													
	E	—	—	—	—	X[A]	—	—	—	—	—	—	—	—
	Benthos													
	D	—	—	—	—	X[a]	—	—	—	—	—	—	—	—
	E	—	—	—	—	X[a]	—	—	—	—	—	—	—	—
	Fish													
	B	—	—	—	—	X[a]	—	—	—	—	—	—	—	—
	D	—	—	—	—	X[a]	—	—	—	—	—	—	X[a]	—
Outlet Creek and Tributaries of Hemlock Creek	Fish													
	Trout Redd Reconnaissance - Creek Survey	—	—	—	—	—	—	—	X	—	—	—	—	—

Table 3.8-2 (*Continued*)

Water Body	Sample/Station(s)	1977 Mar	May	June	July	August	September	October	November	1978 March	April	May	August	October
Oak Lake	Phytoplankton/Zooplankton													
	B	X	X	X	X	X	X	X	—	X	—	X	X	—
	Chlorophyll a													
	G	—	X	X	X	X	X	X	—	X	—	X	X	—
	Periphyton													
	G (near shore)	-	X	X	X	X[a]	X	X	—	—	—	X	—	—
	Aquatic Macrophytes -													
	Lake Survey	—	—	—	—	X	—	—	—	—	—	—	—	—
	Benthos													
	G	X[b]	X	—	—	X[a]	—	X	—	X	—	X	X[a]	—
	Fish - Lake Survey													
	Metered Larval Net	—	X	X	X	—	—	—	—	—	—	—	—	—
	Electroshocking	—	—	—	—	X	—	—	—	—	—	X	X[a]	—
	Bill Net	—	X	—	—	X[a]	—	X	—	—	—	X	X[a]	—
	Seining	—	X	—	—	X[a]	—	—	—	—	—	X	X	—
	Tissue Chemistry -													
	Lake Survey													
	Aquatic Macrophytes	—	—	—	—	X[a]	—	—	—	—	—	—	—	—
	Benthos	—	—	—	—	X[a]	—	—	—	—	—	—	—	—
	Fish	—	—	—	—	X[a]	—	—	—	X	—	—	X[a]	—
Pond 25-11[c]	Aquatic Macrophytes -													
	Pond Survey													
	Fish	—	—	—	—	X	—	—	—	—	—	—	—	—
	Minnow Trap													
	25-11	—	—	—	—	—	—	X	—	—	—	—	—	—

Table 3.8-2 (*Continued*)

Water Body	Sample/Station(s)		1977 Mar	May	June	July	August	September	October	November	1978 March	April	May	August	October
Hoffman Springs	Aquatic Macrophytes - Spring Survey		—	—	—	—	X	—	—	—	—	—	—	—	—
	Fish Minnow Trap	E-2	—	—	—	—	—	—	—	—	—	—	—	—	X
Hoffman Pond	Fish Minnow Trap	E-3	—	—	—	—	—	—	—	—	—	—	—	—	X

Notes: Additional sampling was conducted on Swamp Creek downstream from Rice Lake. For this information, see report by Ecological Analysts, Inc. (1983, 1984a,b).
— indicates no sample collected.
[a]Sample collected in late July.
[b]Sample collected in late February.
[c]WDNR identification code.

Source: Dames & Moore, 1982
Checked by: WMW

Table 3.8-3

Schedule of Seasonal Biological Sampling in the Pickerel Creek Drainage Basin During 1977 and 1978

		1977							1978						
Water Body	Sample/Station(s)	March	May	June	July	August	September	October	March	May	June	July	August	September	October
Pickerel Creek	Periphyton														
	M-5	—	—	—	—	—	—	X	—	X	—	—	X[a]	—	—
	Benthos														
	M-5	—	—	—	—	—	—	X	X[b]	X	—	—	X[a]	—	—
	Fish														
	Trout Redd Reconnaissance - Creek Survey	—	—	—	—	—	—	—	—	—	—	—	—	—	X
	Electroshocking														
	M-5	—	—	—	—	—	—	X	—	X	—	—	X[a]	—	—
	Tissue Chemistry Fish														
	M-5	—	—	—	—	—	—	—	—	—	—	—	X[a]	—	—
Creek 12-9	Periphyton														
	M-1	—	—	—	—	—	—	X	—	X	—	—	X[a]	—	—
	Benthos														
	M-1	—	—	—	—	—	—	X	X[b]	X	—	—	X[a]	—	—
	Fish														
	Trout Redd Reconnaissance - Creek Survey	—	—	—	—	—	—	—	—	—	—	—	—	—	X
	Electroshocking														
	M-1	—	—	—	—	—	—	X	—	X	—	—	X	—	—
	Minnow Trap														
	M-1	—	—	—	—	—	—	—	—	X	—	—	—	—	—

Table 3.8-3 (*Continued*)

Water Body	Sample/Station(s)	1977 March	May	June	July	August	September	October	1978 March	May	June	July	August	September	October
	Tissue Chemistry														
	Fish														
	M-1	—	—	—	—	—	—	—	—	—	—	—	X	—	—
Creek 11-4	Periphyton														
	M-3	—	—	—	—	—	—	X	—	X	—	—	X[a]	—	—
	Benthos														
	M-3	—	—	—	—	—	—	X	X[b]	X	—	—	X[a]	—	—
	Fish														
	Electroshocking														
	M-3	—	—	—	—	—	—	X	—	X	—	—	X[a]	—	—
	Minnow Trap														
	M-3	—	—	—	—	—	—	—	—	X	—	—	—	—	—
	Tissue Chemistry														
	Fish														
	M-3	—	—	—	—	—	—	—	—	—	—	—	X[a]	—	—
Rolling Stone Lake	Phytoplankton/Zooplankton														
	M-2	—	—	—	—	—	—	X	X	X	—	—	X	—	—
	M-4	—	—	—	—	—	—	X	X	X	—	—	X	—	—
	Chlorophyll a														
	M-2	—	—	—	—	—	—	X	X	X	—	—	X	—	—
	M-4	—	—	—	—	—	—	X	X	X	—	—	X	—	—
	Periphyton														
	M-2	—	—	—	—	—	—	X	—	X	—	—	X[a]	—	—
	M-4	—	—	—	—	—	—	X	—	X	—	—	X[a]	—	—

Table 3.8-3 (*Continued*)

Water Body	Sample/Station(s)	1977 March	May	June	July	August	September	October	1978 March	May	June	July	August	September	October
	Aquatic Macrophytes - Lake Survey	—	—	—	—	—	—	—	—	—	—	—	X[a]	—	—
	Benthos														
	M-2	—	—	—	—	—	—	X	X	X	—	—	X[a]	—	—
	M-4	—	—	—	—	—	—	X	X	X	—	—	X[a]	—	—
	Fish - Lake Survey														
	Electroshocking	—	—	—	—	—	—	—	—	X	—	—	X[a]	—	—
	Gill Net	—	—	—	—	—	—	X	—	X	—	—	—	—	—
	Fyke Net	—	—	—	—	—	—	—	—	X	—	—	X[a]	—	—
	Minnow Trap	—	—	—	—	—	—	—	—	X	—	—	—	—	—
	Tissue Chemistry - Lake Survey														
	Fish	—	—	—	—	—	—	—	—	X	—	—	X	—	—
Deep Hole Lake	Phytoplankton/Zooplankton														
	L	—	—	—	—	—	—	X	X	X	X	X	X	X	X
	Chlorophyll a														
	L	—	—	—	—	—	—	X	X	X	X	X	X	X	X
	Periphyton														
	L (near shore)	—	—	—	—	—	—	X	—	X	X	X	X[a]	X	X
	Aquatic Macrophytes - Lake Survey	—	—	—	—	X	—	—	—	—	—	—	—	—	—
	Benthos														
	L	—	X	—	—	X[a]	—	X	X	X	—	—	X[a]	—	—

Table 3.8-3 (*Continued*)

Water Body	Sample/Station(s)	1977 March	May	June	July	August	September	October	1978 March	May	June	July	August	September	October
	Fish - Lake Survey														
	Electroshocking	—	—	—	—	—	—	—	—	X	—	—	X[a]	—	—
	Gill Net	—	X	—	—	X[a]	—	X	—	X	—	—	X[a]	—	—
	Minnow Trap	—	—	—	—	—	—	—	—	X	—	—	—	—	—
	Tissue Chemistry - Lake Survey														
	Fish	—	—	—	—	X[a]	—	—	—	—	—	—	X[a]	—	—
Duck Lake	Phytoplankton/Zooplankton														
	K	—	—	—	—	—	—	X	X	X	X	X	X	X	X
	Chlorophyll a														
	K	—	—	—	—	—	—	X	X	X	X	X	X	X	X
	Periphyton														
	K (near shore)	—	—	—	—	—	—	X	—	X	X	X	X	X	X
	Aquatic Macrophytes - Lake Survey	—	—	—	—	X	—	—	—	—	—	—	—	—	—
	Benthos														
	K	—	X	—	—	X[a]	—	X	X[b]	X	—	—	X	—	—
	Fish - Lake Survey														
	Electroshocking	—	—	—	—	—	—	—	—	—	—	—	X[a]	—	—
	Bill Net	—	X	—	—	X[a]	—	X	—	X	—	—	X	—	—
	Minnow Trap	—	—	—	—	—	—	—	—	X	—	—	—	—	—
	Tissue Chemistry - Lake Survey														
	Fish	—	—	—	—	—	—	—	—	X	—	—	X[a]	—	—

Table 3.8-3 (*Continued*)

Water Body	Sample/Station(s)	1977 March	May	June	July	August	September	October	1978 March	May	June	July	August	September	October
Little Sand Lake	Phytoplankton/Zooplankton														
	H	X	X	X	X	X	X	X	X	X	—	—	X	—	—
	I	X	X	X	X	X	X	X	X	X	—	—	X	—	—
	Chlorophyll a														
	H	—	X	X	X	X	X	X	X	X	—	—	X	—	—
	I	—	X	X	X	X	X	X	X	X	—	—	X	—	—
	Periphyton														
	H (near shore)	—	X	X	X	X[a]	X	X	—	X	—	—	X	—	—
	I (near shore)	—	X	X	X	X[a]	X	X	—	X	—	—	X	—	—
	Benthos														
	H	X[b]	X	—	—	X[a]	—	X	X[b]	X	—	—	X	—	—
	I	X[b]	X	—	—	X[a]	—	X	X[b]	X	—	—	X	—	—
	Aquatic Macrophytes -														
	Lake Survey	—	—	—	—	X	—	—	—	—	—	—	—	—	—
	Fish - Lake Survey														
	Metered Larval Net	—	X	X	X	—	—	—	—	—	—	—	—	—	—
	Electroshocking	—	—	—	—	X[a]	—	—	—	X	—	—	X	—	—
Skunk Lake	Phytoplankton/Zooplankton														
	J	—	—	X	X	X	X	X	—	—	—	—	—	—	—
	Chlorophyll a														
	J	—	—	X	X	X	X	X	X	—	—	—	—	—	—
	Periphyton														
	J	—	—	X	X	X[a]	X	X	—	—	—	—	—	—	—
	Aquatic Macrophytes -														
	Lake Survey	—	—	—	—	X	—	—	—	—	—	—	—	—	—

Table 3.8-3 (*Continued*)

Water Body	Sample/Station(s)	1977 March	1977 May	1977 June	1977 July	1977 August	1977 September	1977 October	1978 March	1978 May	1978 June	1978 July	1978 August	1978 September	1978 October
	Benthos														
	J	—	X	—	—	X[a]	—	—	—	—	—	—	—	—	—
	Fish - Lake Survey														
	Electroshocking	—	—	—	—	—	—	—	—	X	—	—	—	—	—
	Minnow Trap	—	—	—	—	—	—	—	—	X	—	—	—	—	—
Pond 6-8[c]	Aquatic Macrophytes -														
	Pond Survey	—	—	—	—	X	—	—	—	—	—	—	—	—	—
	Fish														
	Minnow Trap 6-8	—	—	—	—	—	—	X	—	—	—	—	—	—	—
Pond 31-13[c]	Aquatic Macrophytes -														
	pond Survey	—	—	—	—	X	—	—	—	—	—	—	—	—	—
	Fish														
	Minnow Trap 31-13	—	—	—	—	—	—	X	—	—	—	—	—	—	—
Pond 34-1[c]	Aquatic Macrophytes -														
	Pond Survey	—	—	—	—	X	—	—	—	—	—	—	—	—	—
	Fish														
	Minnow Trap 34-1	—	—	—	—	—	—	X	—	—	—	—	—	—	—
Pond 35-7[c]	Aquatic Macrophytes -														
	Pond Survey	—	—	—	—	X	—	—	—	—	—	—	—	—	—
	Fish														
	Minnow Trap 35-7	—	—	—	—	—	—	X	—	—	—	—	—	—	—

Note: — Indicates no sample collected.
[a]Sample collected in late July.
[b]Sample collected in February.
[c]WDNR identification code.

Source: Dames & Moore, 1982
Checked by: WMW

a" in Standard Methods for the Examination of Water and Wastewater (APHA et al., 1971). The chlorophyll a data reported present pheophytin a corrected data.

No additional phytoplankton studies were conducted in the 1993-1994 study effort because no phytoplankton species are listed as endangered or threatened on the Wisconsin Heritage Inventory.

3.8.1.3 Methods for Zooplankton

At each zooplankton sampling station, duplicate samples were collected with water pumps (Schwoerbel, 1972). Two calibrated centrifugal pumps were deployed in tandem and equipped with a pair of intake hoses of 19-mm (0.75-inch) inside diameter. For each sample, the intake hoses were lowered to a position immediately above the substrate and then raised at approximately 152-mm (six inch) intervals to obtain an integrated sample of the water column. Each sample consisted of a minimum of 250 liters (66 gallons) of water pumped through a No. 20 mesh net, 76 micron meter (0.003 inch). To reduce the potential of forcing zooplankton through the mesh, the net was suspended in water. The samples were concentrated into prelabeled containers and preserved with a five percent buffered formalin (Weber, 1973).

Enumeration by subsampling was conducted by the open grid method (Weber, 1973). To facilitate counting organisms in the subsample, a brass grid was used to subdivide an 80 x 100 x 5-mm (3.15 x 4 x 0.2-inch) chamber. All organisms for the entire subsample, usually two to five mL, or a minimum of 300 organisms were enumerated and identified to the lowest possible taxon, generally species.

Taxonomic keys used for zooplankton identifications were Ahlstrom (1940, 1943), Edmondson (1959), and Ruttner-Kolisko (1974) for rotifera; Brooks (1957, 1959) and Deevey and Deevey (1971) for cladocera; Yeatman (1959) and Torke (1976) for cyclopoid copepods; and Wilson (1959) for calanoid copepods.

Cyclopoid and calanoid copepodites and nauplii were reported as such. Identifications were verified by Dr. Byron G. Torke, Assistant Professor, Ball State University, Muncie, Indiana, through review of reference slide mounts of the voucher specimens.

Individuals enumerated were expressed in number per liter. Diversity was calculated on all mature individuals identified to be lowest positive taxon using the formula presented in Shannon and Weaver (1949) (based on $\log_{10}$). The relative abundance was calculated and expressed as the percent of all organisms collected. No additional zooplankton studies were conducted during the 1993-1994 collection effort.

3.8.1.4 Methods for Periphyton

Qualitative samples of periphytic algae were collected from commonly occurring natural substrates found at near-shore areas in the vicinity of the sampling stations. Entire substrates

such as plants or rocks, along with material scraped from larger substrates, such as logs or boulders, were preserved in five percent formalin (Weber, 1973) and transported to the laboratory for analysis.

In the laboratory, algae were scraped from the collected substrates and two aliquots were withdrawn from the well mixed sample. One aliquot was transferred to a Sedgewick-Rafter counting cell for enumeration and non-diatom identification (APHA et al., 1976). Strips of the counting cell were examined until a minimum of 250 diatom cells were enumerated. Diatoms were identified from the other aliquot using standard diatom mounts (APHA et al., 1976) after centrifugation and mounting with Cover Bond. Raw counts of diatoms were extrapolated to whole samples through Diatom Species Proportional Counts (Weber, 1973). Periphyton were identified to lowest possible taxon, generally species, and counts were expressed as relative abundance.

Verification of identification and enumerations was completed by reanalysis of 10 percent of the samples by Mr. Keith E. Kamburn, Phytologist, Kentucky Nature Preserves Commission, Frankfort. No additional periphyton studies were conducted during the 1993-1994 collection effort.

3.8.1.5 Methods for Aquatic Macrophytes

The survey consisted of the observation of macrophyte beds during a systematic reconnaissance of each water body. The extent of growth was visually estimated and described as "dense" when coverage was continuous, "moderate" when growths were common, or "sparse" when the growth was rarely encountered (Weber, 1973). Representative specimens were collected, dried in a plant press, and mounted for identification. Species were identified using taxonomic keys presented in Gleason and Cronquist (1963). An estimation of the relative composition was made, and a general map outlining the macrophyte beds was subsequently prepared. A reference collection of pressed and dried specimens of each species was prepared. Identifications were verified through review of mounted specimens by Dr. Hugh H. Iltis, Professor of Botany and Director of the Herbarium, University of Wisconsin, Madison, Wisconsin.

In addition to the survey of aquatic macrophytes in study area lakes and ponds (Tables 3.8-2 and 3.8-3), an inventory to determine the relative abundance of aquatic macrophytes in Swamp Creek and the Wolf River was completed in June 1983. The inventory was initiated 0.4km (0.25 mile) upstream of the previously proposed discharge site on Swamp Creek and terminated on the Wolf River approximately 1.2 km (0.75 mile) downstream from the confluence with Swamp Creek at the bend in Lost Lake Road. The relative abundance of aquatic macrophyte species was determined by visual estimates.

An inventory of aquatic macrophytes was also conducted in 1994. The results of this inventory are provided in Section 3.9 in conjunction with the 1994 plant inventory.

3.8.1.6 Methods for Benthic Macroinvertebrates Collected in 1977 and 1978

Quantitative sampling consisted of two, three, or five replicate samples in 1977, and three replicate samples in 1978. Samples were collected utilizing an Ekman sampler, except at Station D on Swamp Creek, where a Surber sampler was used. Sampler selection was based on predominant substrate type, which was visually determined at each station. The substrates encountered were visually characterized according to the classification system presented in Weber (1973) and in Table 3.8-4. Samples were screened in the field through a No. 30 U.S. Standard sieve and preserved in 10 percent buffered formalin with rose bengal stain added to facilitate subsequent sorting (APHA, et al., 1976).

Qualitative sampling, consisting of hand-picked or dip-net samples of miscellaneous substrates near each sampling station, was conducted in 1977 and 1978 (Table 3.8-5). Typically, shoreline areas were investigated for suitable substrates such as rocks or sticks that might provide benthic habitat. Also, a dip-net was swept through aquatic macrophytes and overhanging terrestrial vegetation, if present, as well as surficial sediments. Organisms were preserved in 10 percent buffered formalin.

In the laboratory, benthic organisms were sorted manually from the substrate materials and placed in vials containing 70 percent ethanol (APHA et al., 1976). Chironomidae and Oligochaeta were subsequently mounted in CMC-10 medium on glass slides. All organisms were identified to the lowest possible taxon and enumerated. Enumeration and identification were verified by review of samples and reference specimens by an investigator other than the original analyst. Taxonomic keys used for identification of invertebrates were Ross (1944), Roback (1957), Saether (1971), Brown (1972), Bryce and Hobart (1972), Mason (1973), Stewart and Loch (1973), Hilsenhoff (1975), Wiggins (1977), Oliver (1978), and Pennak (1978) for insects; Brousefield (1958), Hobbs (1972), Holsinger (1972), Williams (1972), and Pennak (1978) for crustacea; Brinkhurst (1964), Hiltunen (1967, 1973), and Brinkhurst and Jamieson (1971) for Oligochaeta; Klem (1972) and Pennak (1978) for Hirudinea; and Baker (1928), Eddy and Hodson (1961), and Pennak (1978) for Mollusca.

Numbers of individuals collected in quantitative samples were expressed as number per square meter of substrate. Diversity was calculated using Brillouin's formula (based on $\log_{10}$) (Pielou, 1966) and the number of organisms identified in the sample:

$$H = \left(\frac{1}{N}\right) ln \frac{N!}{N_1!N_2!...N_s!}$$

where: H = Diversity;
N = The total number of individuals in the sample;
$N_1N_2...$ = The number of individuals in taxa 1, 2..., and
S = The total number of taxa in the collection.

Table 3.8-4

Categories for the Field Classification of the General Substrate Characteristics* of the Water Bodies in the Study Area

Type	Size or Characteristic
Inorganic Components	
Bedrock or solid rock	
Boulders	>256 mm (10 inches) in diameter
Rubble	64 to 256 mm (2-1/2 to 10 inches) in diameter
Gravel	2 to 64 mm (1/12 to 2-1/2 inches) in diameter
Sand	0.06 to 2.0 mm in diameter; gritty texture when rubbed between fingers
Silt	0.004 to 0.06 mm in diameter
Clay	<0.004 mm in diameter; smooth slick feeling when rubbed between fingers
Marl	Calcium carbonate; usually gray; often contains fragments of mollusc shells or Chara; effervesces freely with hydrochloric acid
Organic Components	
Detritus	Accumulated wood, sticks, and other undecayed coarse plant materials
Fibrous peat	Partially decomposed plant remains; parts of plants readily distinguishable
Pulpy peat	Very finely divided plant remains; parts of plants not distinguishable; varies in color from green to brown; varies greatly in consistency, often being semi-fluid
Muck	Black, finely divided organic matter; completely decomposed

*Weber, 1973

Source: Dames & Moore, 1982
Checked by: WMW

Table 3.8-5

Substrate Types Sampled for the Collection of Qualitative Benthic Macroinvertebrates

Location	Sampling Station	Substrate
Swamp Creek Drainage Basin		
Rice Lake	F	Aquatic vegetation, peat, muck, detritus
Rice Lake	N	Aquatic vegetation, peat, muck, detritus
Hemlock Creek	A-1	Silt, sand, detritus, sticks
Swamp Creek	D	Rocks, gravel, sticks, shoreline vegetation
Swamp Creek	E	Shoreline vegetation, aquatic vegetation, sticks, detritus
Oak Lake	G	Squatic macrophytes, sticks, sand
Pickerel Creek Drainage Basin		
Rolling Stone Lake	M-2	Aquatic macrophytes, detritus, sticks
Rolling Stone Lake	M-4	Aquatic macrephytes, rocks, gravel, muck
Pickerel Creek	M-5	Shoreline vegetation, detritus, sticks
Creek 12-9	M-1	Shoreline vegetation, detritus, sticks
Creek 11-4	M-3	Shoreline vegetation, detritus, sand, sticks
Little Sand Lake	H	Shoreline vegetation, detritus, sticks
Little Sand Lake	I	Aquatic macrophytes, rocks, sand, sticks
Duck Lake	K	Aquatic macrophytes, muck, peat, detritus, sticks
Deep Hole Lake	L	Aquatic macrophytes, rubble, sand, gravel, muck, detritus
Skunk Lake	J	Aquatic macrophytes, muck
Wolf River	Y	Sand, detritus, sticks
Wolf River	Z	Aquatic macrophytes, rocks, gravel, sand, detritus

Source: Dames & Moore, 1982
Checked by: WMW

The taxa level used to calculate diversity was the lowest possible taxon to which each organism was identified. In general, this was as follows:

Coelenterata: genus
Platyhelminthes: order
Nematoda: phylum
Oligochaeta
Naididae: species
Tubificidae: species (except immatures)
Enchytraeidae: family
Lumbriculicae: family
Branchiobdellida: family
Hirudinea: family, genus, species
Crustacea: genus, species
Hydracarina: order
Insecta: genus, species
Mollusca: genus

The relative abundance of taxa collected in quantitative samples was calculated and expressed as the percent of all organisms collected.

3.8.1.7 Methods for Aquatic Macroinvertebrates Collected in 1993 and 1994

Aquatic macroinvertebrate collections occurred three times, once in November 1993 and twice in 1994 (May and August). During each sampling event, sites identified in Figure 3.8-2 were sampled. Some sites were not accessible in 1993 due to ice conditions while other sites were not available in 1994 because of restrictions to private access. Areas which were targeted for field investigation included lakes and streams local to proposed mining activities as well as streams which may be impacted by mining. Table 3.8-6 lists the sample sites and collection dates.

In general, three collection techniques were used for aquatic macroinvertebrates, including kick seining with an 8 x 18 inch, 800 to 900 micron mesh rectangular net, surber sampler, and Ekman dredge. The rectangular net was used in all habitats to search bottom substrate, undercut banks, and sweep aquatic vegetation. The rectangular net was supplemented in riffle areas with the surber sampler and in soft bottom habitat with the Ekman dredge. Where the surber sampler and Ekman dredge were used, triplicate samples were collected, washed in a 600 to 800 micron filter, and preserved in formalin. Each microhabitat was sampled by two biologists for a minimum of one hour or until a five minute period produced no new species, whichever was the longer period.

Some organisms, such as the nymphs of Ephemeroptera and Plecoptera and larvae of Trichoptera and Coleoptera are difficult to identify to species. Where genera of these groups were found in the fall 1993 aquatic collections and contained potentially listed species, light trapping for adult specimens was conducted in the vicinity of the sampling station during June, July, and August 1994. Light trapping sites are identified on Figure 3.8-3.

Table 3.8-6

1993/1994 Aquatic Species Work Effort

Date	Location and Type of Sampling Performed								
	CMC-AB-HL-100	CMC-AB-HL-200	CMC-AB-SC-200	CMC-AB-SC-250	CMC-AB-SC-300	CMC-AB-SC-301	CMC-AB-SC-400	CMC-AB-SC-500	CMC-AB-SC-501
11-08-93									I
11-09-93					I				
11-10-93									
11-11-93									
05-09-94									
05-10-94								F	F
05-11-94	F	F	F			I,F	F		I
05-12-94				I					
05-13-94									
05-14-94									
06-01-94				E					
06-02-94									
06-03-94						E			
06-04-94									
06-05-94									E
06-14-94									

Table 3.8-6 *(Continued)*

Date	Location and Type of Sampling Performed								
	CMC-AB-HL-100	CMC-AB-HL-200	CMC-AB-SC-200	CMC-AB-SC-250	CMC-AB-SC-300	CMC-AB-SC-301	CMC-AB-SC-400	CMC-AB-SC-500	CMC-AB-SC-501
06-15-94									
06-16-94						E			
06-27-94		A			E,A				
06-28-94					T				
06-29-94		T	T					T	E,A
06-30-94					E,A				
07-01-94		A							
07-28-94		M							
07-29-94									
07-30-94									
07-31-94					M	M			
08-01-94				I					
08-02-94									I,M
08-03-94						I			
08-04-94		M							
08-05-94									
09-28-94								T	
09-29-94		T							

Table 3.8-6 *(Continued)*

Date	Location and Type of Sampling Performed									
	CMC-AB-SC-502	CMC-AB-SC-700	CMC-AB-WR-200	CMC-AB-WR-301	CMC-AB-SGI-CC	CMC-AB-SK-005	CMC-AB-DL-005	CMC-AB-SL-005	CMC-AB-OL-005	CMC-AB-RS-005
11-08-93	I				I					
11-09-93				I,M						
11-10-93								I	I	
11-11-93										
05-09-94				F	F					
05-10-94	F			I	I				I	
05-11-94	I					I		F		
05-12-94								I	F	F
05-13-94							I			I
05-14-94										
06-01-94								E		
06-02-94						E				E
06-03-94							E			
06-04-94				E	E				E	
06-05-94	E									
06-14-94				F	F				F	
06-15-94										
06-16-94					E			F		

Table 3.8-6 *(Continued)*

Date	Location and Type of Sampling Performed									
	CMC-AB-SC-502	CMC-AB-SC-700	CMC-AB-WR-200	CMC-AB-WR-301	CMC-AB-SGI-CC	CMC-AB-SK-005	CMC-AB-DL-005	CMC-AB-SL-005	CMC-AB-OL-005	CMC-AB-RS-005
06-27-94										
06-28-94					T					
06-29-94	E,A			E,A	E,A					
06-30-94						T		T,A		
07-01-94						A			A	
07-28-94					M					
07-29-94										
07-30-94			M	M	M					
07-31-94										
08-01-94	M			I	I					
08-02-94	I									M,I
08-03-94						I	I	I		
08-04-94							M		I	
08-05-94										M
09-28-94					T					
09-29-94		M			M	T				

Table 3.8-6 *(Continued)*

Date	Location and Type of Sampling Performed								
	CMC-AB-DH-005	CMC-AB-PP-005	CMC-AB-HS-005	CMC-AB-HC-100	CMC-AB-MS-100	CMC-AB-12/9-100	CMC-AB-OC-200	CMC-AB-PK-200	CMC-AB-PK-300
11-08-93									
11-09-93					I				
11-10-93						I			
11-11-93			I						
05-09-94									
05-10-94									
05-11-94								F	
05-12-94	I								
05-13-94	F	I			I	I			
05-14-94			I	I					
06-01-94		E							
06-02-94					E				
06-03-94	E		E	E					
06-04-94									
06-05-94									
06-14-94									
06-15-94	F								
06-16-94									

Table 3.8-6 *(Continued)*

Date	Location and Type of Sampling Performed								
	CMC-AB-DH-005	CMC-AB-PP-005	CMC-AB-HS-005	CMC-AB-HC-100	CMC-AB-MS-100	CMC-AB-12/9-100	CMC-AB-OC-200	CMC-AB-PK-200	CMC-AB-PK-300
06-27-94									
06-28-94					T				
06-29-94							T		
06-30-94			T,E,A	E,A	E,A				
07-01-94									
07-28-94									
07-29-94									
07-30-94									
07-31-94									
08-01-94					I				
08-02-94	I								
08-03-94	M	I							
08-04-94			I	I					
08-05-94									M
09-28-94					T				
09-29-94			T						

F = Fish I = Invertebrate E = Odonata Exuviae T = Light trapping

M = Mussel A = Adult Odonata N = Odonata Nymph

Prepared by: JCP

Checked by: WMW

A special effort to collect riffle beetles was expended in June 1994. The only true riffle area in the project area on Swamp Creek is south of Swampy Lane (encompassed by site designations CMC-AB-SC-300 and CMC-AB-SC-301 shown on Figure 3.8-2). This area was sampled by two people hand picking beetles off of submerged vegetation for one hour.

All macroinvertebrate samples were preserved on site with 10 percent formalin. A chain of custody form was completed for samples. Preserved samples were shipped to Dr. Ken Tennessen in Florence, Alabama, for identification. General macroinvertebrate specimens were identified by Dr. Tennessen. For light trapping collections, Ephemeraptera were identified by Dr. Bob Waltz of the Indiana Department of Natural Resources, while Trichoptera were identified by Dr. Brian Armitage of Ohio Biological Survey. Specimens of *Alloperla* sp., a stone fly, were identified by Dr. Bill Stark of Mississippi College. Voucher specimens of all threatened, endangered, or species of concern were sent to Bill Smith, WDNR for documentation.

Members of the Trichoptera (caddisfly group), Plecoptera (stonefly group), Coleoptera (beetle group) and Ephemeroptera (mayfly group) can be difficult to identify to species in the nymph or larval stage. Therefore, efforts were expended to collect members of these groups in the adult stage using light traps.

Common camping type lanterns were used as light traps. Each lantern contained two ultraviolet lights powered by eight size D batteries that were replaced with fresh batteries prior to each night of sampling.

Each light was positioned over a collecting pan. The pan was filled with 70 percent alcohol to a depth of approximately ¾ inch. Light trapping commenced at dusk and continued for a minimum of two hours at each site. Light trap locations are shown on Figure 3.8-3. Four lanterns were used for trapping per night of effort during the week of June 27, 1994 to July 1, 1994.

After the collection period, all specimens captured in the alcohol were transferred in the field to labeled four ounce or eight ounce jars. Jars were transferred to the lab where they were emptied into a sorting pan. All Trichoptera, Plecoptera, Coleoptera and Ephemeroptera were saved for identification by Dr. Tennessen. At the request of Bill Smith, Ephemeroptera were sent to the WDNR for further handling. To expedite identification of samples, Ephemeroptera were subsequently returned to Dr. Tennessen and identifications were completed by Dr. Bob Waltz.

3.8.1.8 Methods for Odonata Collection

Collection efforts for Odonata (dragonflies and damselflies) included searches for nymphs (aquatic), adults (terrestrial), and the exuviae (casings left after emergence of nymphs from aquatic environment). Nymphs were collected during the general macroinvertebrate collection time periods described above - November 1993, May 1994, and August 1994. Exuviae were collected from shoreline locations throughout June 1994. Adult Odonata were collected or

identified on the wing from late June into August, 1994. Collection methods and locations of Odonata nymph sampling are described above in Section 3.8.1.6.

Exuviae collections were conducted in June with the greatest level of effort being expended from June 1, 1994 through June 5, 1994 because this was the peak emergence period for adults. Additional sampling was conducted on June 16, 1994, and again from June 27, 1994 to July 1, 1994 to provide back-up collections and allow thorough coverage of the emergence period. Sites were selected which represented preferred habitat of adults of the targeted group.

Stations at all streams and lakes as shown on Figure 3.8-2 were sampled from June 1, 1994 through June 5, 1994. Two people either in a canoe or wading conducted the sampling. At each site all exuviae observed in an approximate 100 meter distance of shoreline were collected. In small streams both left and right banks (facing downstream) were sampled and specimens were composited. Small stream sites for exuviae collection were located on Hemlock Creek, Swamp Creek downstream to County Highway M, Creek 12-9, Martin Springs (Creek 11-4), and Hoffman Springs. For larger streams (Swamp Creek downstream of County Highway M and sampling sites on the Wolf River) 100 meter sections were sampled on both right and left banks and collections were kept separate at each bank. Sample segregation on larger streams permitted evaluation of habitat preferences by species (qualitative and quantitative) which may be due to substrate, exposed shore, shoreline vegetation, or possibly time of day.

At each lake, a minimum of 100 meters of shoreline was sampled. In small lakes an effort was made to cover as much of the shoreline as possible. On larger lakes three to four tracts covering 25 to 33 meters in length were sampled. An effort was made to sample all major shoreline habitats available at a particular lake (emergent vegetation such as cattails, exposed shoreline, bog habitats, timbered shoreline including downed timber, branches, and stumps in the water, rock shores and embankment).

Exuviae were hand-picked within a minimum three foot strip from the water's edge landward at all collection sites. The sampling width increased if flat shoreline allowed emerging Odonata to penetrate further. Likewise, where steep banks occurred, the search area was more vertical than horizontal.

All samples were placed in plastic containers and preserved in 70 percent alcohol. Identifications were completed by Dr. Ken Tennessen, with assistance from Bill West representing Foth & Van Dyke. Voucher specimens were hand delivered to Bill Smith of the WDNR for documentation.

On June 16, 1994, Foth & Van Dyke accompanied Bill Smith of the WDNR for a one-day site collection effort on the Wolf River at the Lost Lake Road access and on Swamp Creek downstream of the Swampy Lane access. These locations are identified on Figure 3.8-4. Collections were not limited by time or distance of shoreline. Specimens were retained by Bill Smith for identification.

From June 27, 1994 to July 1, 1994, Foth & Van Dyke, accompanied by Dr. Tennessen, completed the last exuviae collections. Sites on the Wolf River, Swamp Creek upstream and downstream of the previously proposed discharge site, and two sites at and downstream of Swampy Lane were sampled. These sites are shown of Figure 3.8-5. This activity essentially duplicated the sampling area of June 1, 1994 to June 5, 1994, efforts at these sites. This second effort collected specimens which could emerge later than the late May/early June time period. Specimens were placed in plastic containers and preserved in 70 percent alcohol. All exuviae were identified by Dr. Tennessen with assistance by Bill West, (Foth & Van Dyke). Voucher specimens were hand delivered to Bill Smith for documentation.

3.8.1.9 Methods for Adult Odonata

Many Odonata can be located and identified by collecting exuviae or specimens in the nymph stages. However, for some species and in some instances, collection techniques discussed above for these stages could result in little or no success. Therefore, to provide a more complete collection effort, adults were sampled from June 27, 1994 through July 1, 1994. Dr. Tennessen, accompanied by Bill West, collected adult Odonata specimens from most of the same stream, river and lake sites as previously identified, as well as several access roads, meadows, woodland swamps and other stream access locations throughout the general project area. These collection sites are shown on Figure 3.8-6.

In general, all adult collections used long handled (four to six feet) sweep nets. Most specimens could be readily collected on the wing. Common species were collected, identified, the sex identified, recorded, and released. Special concern species were collected, identified, sexed, recorded and saved in plastic envelopes in the field. These specimens were placed in acetone in the lab. Voucher specimens were hand delivered to Bill Smith for documentation.

Dr. Tennessen identified some specimens on the wing which were either common and not worth the effort to collect or which were out of reach, and therefore unable to collect. Tentative identifications of visual observations were compared with other collection data (nymph and exuviae collections).

Final adult Odonata collection activities were conducted by Bill West (Foth & Van Dyke) from July 28, 1994, through August 4, 1994. All specimens collected were placed in plastic envelopes in the field, placed in acetone in the lab, and sent to Dr. Tennessen for identification. Voucher specimens were sent to Bill Smith, WDNR for documentation. Figure 3.8-7 shows the collection sites of this effort.

3.8.1.10 Methods for Collection of Fish in 1977 and 1978

Fish surveys were conducted in the study area during ice-free sampling periods (Table 3.8-2) by Ecological Analysts, Inc., Deerfield, Illinois. A variety of fish sampling techniques were utilized to overcome the selectivity inherent in each type of fish sampling gear. Sampling techniques included gill and fyke netting, beach haul or minnow seining, electroshocking, and minnow

trapping. Sampling stations where these techniques were used are shown on Figure 3.8-8. In addition, larval fish were sampled at stations located in Oak and Little Sand Lakes and a trout redd reconnaissance was conducted in several creeks (Figure 3.8-9).

Experimental monofilament gill nets, each 24.4 m (80 feet) in length, were fished along the bottom for two consecutive 12-hour periods at selected lake areas. The nets were 1.8 m (six feet) deep and consisted of eight 3.0-m (10-foot) panels. Each panel has an individual mesh size, with the panels arranged so mesh size increased in approximately 12.7-mm (0.5-inch) increments from 12.7 mm (0.5-inch) to 101.6 mm (four inches) bar measure. Care was taken to avoid areas of potentially low dissolved oxygen.

Modified fyke nets with a rectangular entrance 0.9 m (three feet) high and 1.8 m (six feet) wide were utilized. The remainder of the net assembly included four hoops, 0.8 m (2.5 feet) in diameter with a single Crowfoot-style throat and a 18.3 m (60-foot) lead. The entire net was composed of 1.3 cm (0.5 inch) mesh netting. The nets were set for a 24-hour period in shallow areas at depths less than 1.2 m (four feet) with the lead attached to a shoreline stake and the remaining lead and trap extended perpendicularly offshore. A double lead net was utilized in Rice Lake.

Seining was conducted during daylight with a beach haul seine or a minnow seine to obtain qualitative samples along suitable shoreline areas at depth of 1.2 m (four feet) or less. The beach haul seine had dimensions of 36.6 x 1.8 m (120 x 6 feet), a mesh size of 12.7 mm (0.5 inch) bar measure, and contained a 1.8 x 1.8 m (6 x 6 foot) back of 6.4 mm (0.25 inch) mesh. The minnow seine had dimensions of 7.6 x 1.2 m (25 x 4 feet) and a mesh size of 6.4 mm (0.25 inch). Two to four hauls were collected depending on the quantity of fish collected.

Electrofishing was conducted in selected areas (Figure 3.8-8) with either a Coffelt VPP-2C stream electroshocker unit, a Smith-Root Type VII backpack unit, or a boat-mounted boom electroshocker unit. The Coffelt and Smith-Root units were utilized primarily for stream sampling, and the boom electroshocker for lakes and the Wolf River. Because of inaccessibility or motorboat usage constraints, the Coffelt unit was mounted in a row boat for use in Rice, Duck, and Skunk Lakes. Both AC and DC currents were utilized in the water bodies studied depending on the conductivity of the water and the specific electrofishing equipment employed for sampling.

Stream electrofishing at Swamp Creek (Stations B and D) and Hemlock Creek (Station A-2) was conducted over a distance of approximately 305 m (1,000 feet). In areas where the streams were greatly obstructed, Creek 11-4 (M-3), Pickerel Creek (M-5), Creek 12-9 (M-1), and Hemlock Creek (A-1), electrofishing was conducted over a distance of approximately 100 m (328 feet). In Hoffman Creek (Station E), which was also greatly obstructed, the distance was 85 m (279 feet). All stream electrofishing was conducted during daylight in an upstream direction. Daytime electrofishing on the Wolf River was conducted for 30 minute intervals along shoreline areas with the boom electroshocker unit. For all stream electrofishing with the Coffelt unit and the Smith-Root unit, a pulsed current of 250 to 300 volts DC (at two to three amps for the Coffelt

unit and one amp for the Smith-Root unit) was utilized. A pulsed current for 250 to 300 volts AC (two to three amps) was used in the Wolf River.

Except for Rice Lake, lake electrofishing was conducted at night (1900 to 2330 hours) along selected shoreline areas for 30 minute intervals. In Rice Lake, sampling was conducted during the daylight within the Swamp Creek channel area of the lake for a 30 minute interval. A pulsed current of 250 to 300 volts DC (two to three amps) was utilized for Rice Lake and Rolling Stone Lake, and a pulsed current of 250 to 300 volts AC (two to three amps) was utilized for all other lake sampling. Minnow traps baited with bread were set for two consecutive 12 hour periods in several small ponds in the study area and in Deep Hole, Duck, Skunk, Rice, and Rolling Stone Lakes, and Creeks 11-4 and 12-9 (Figure 3.8-8).

Fish collected were identified, enumerated, measured (mm, total length), and weighed (g) on a spring scale. Identifications were made using taxonomic keys presented in Hubbs and Lagler (1958) and Becker and Johnson (1970). If catches were large, approximately 100 or more fish, the total number for each species was recorded, lengths were obtained from as many fish as practical, and a representative sample, approximating the size frequency of captured fish, was weighed. All fish were examined externally for incidence of parasitism, fungal growths, or apparent disease. Obvious external characterization of gonadal conditions were also recorded. Except for fish preserved for later identification, enumeration, to serve as voucher specimens or utilized for tissue chemistry, all fish were returned to the water.

Relative abundance of species caught by the various collection techniques and condition factors for the processed fish were calculated. Relative abundance was expressed as the percent that a species contributed to the catch for a particular collection technique. The condition factor is an expression of the relative well-being of fish (Carlander, 1969). The heavier a fish is at a given length, the larger the factor, and, by implication, the better the "condition" of the fish. The factor is expressed in the form $K = W \times 10^5/L^3$ where W is the weight of the fish in grams, L is the total length of the fish in millimeters, and 10^5 is a factor to bring the value of K near unity.

Because Oak or Little Sand Lakes were considered as potential water sources, larval fish were sampled at 1 month intervals during May, June, and July 1977. Duplicate samples were collected in two areas in Little Sand Lake and one in Oak Lake (Figure 3.8-8) with a 0.6 m (two foot) diameter metered (TSK type) flow net, constructed of 00 mesh, 752 mm (0.3 inch), with a terminal oceanographic bucket. The net was towed at a low constant speed 0.5 m (1.6 feet) below the surface for five minutes for each replicate.

Potential brook trout spawning areas were located by traversing Swamp Creek upstream of Rice Lake, Hemlock Creek, Outlet Creek, and Hoffman Creek during October and November 1977 and segments of Creek 12-9 and Pickerel Creek during October 1978 (Figure 3.8-9). A fisheries biologist either walked or canoed each creek. Mr. Ronald A. Theis, Fisheries Biologist, WDNR, participated in the survey along Swamp Creek upstream of Keith Siding Road, portions of Hemlock Creek, and Creek 26-14. Potential spawning areas were characterized as riffles or the downstream edges of pools that contained sand and gravel substrate with indication of

groundwater discharge, such as seeps and springs (Latta, 1965). Potential reeds were considered to be in areas where brook trout were observed to be congregated in suitable riffle areas.

Fish identifications were verified by Mr. Donald M. Fago, Fishery Biologist, WDNR, Madison; Dr. George E. Becker, Professor, University of Wisconsin at Stevens Point; or Dr. Lawrence M. Page, Associated Taxonomist, Illinois Natural History Survey, Urbana.

3.8.1.11 Methods for Fish Collected in 1993 and 1994

Sampling for target fish species that were listed by the WDNR and could potentially occur in the study area was conducted in May and June of 1994 by EA Engineering, Deerfield, Illinois. May is the period of time when spring activity for these species in the study area is high. The second period of activity occurred in the middle of June.

Three methods were used for fish collection including boat mounted electroshocking, pram mounted electroshocking, and seining. Application of these methods at particular sites depended on access, water depth, and size of water body. Many times seining was used to supplement shocking efforts at the same site. At all locations, habitats likely to harbor the targeted species were noted, and specific sampling efforts were expended to maximize the potential of collecting these species if they were present.

Boat electrofishing was used on Rolling Stone, Deep Hole, and Little Sand Lakes, on the Wolf River, and on Swamp Creek from Shallock's bridge to the Firelane bridge. Lakes were sampled at night while streams were shocked during the day. A Coffelt Model VVP15 controller and a 4000 watt generator were used to produce pulsed DC current. One to three hours were expended electroshocking each lake. The larger the lake, the greater effort was expanded. Approximately three hours were spent shocking the Wolf River while about two hours were spent shocking Swamp Creek downstream of County Highway M.

A pram mounted shocking device was used on Swamp Creek in the riffle area immediately downstream of the Swampy Lane access, Pickerel Creek, Creek 11-9, and Hemlock Creek. The pram operates similar to the boat electroshocking system except the pram is used in shallow water or narrow streams where the boat cannot navigate. Output by the pram was controlled by a Coffelt Model VVP2C powered by a 1500 watt generator. Pulsed DC was used at all stations. Slightly more than one hour was expended pram shocking the riffle area of Swamp Creek. One hour was spent pram shocking on Hemlock Creek with about one half hour each expended at Pickerel Creek (upstream of Rolling Stone Lake) and Creek 11-4 (Martin Springs).

Seining was conducted at Oak, Duck, Rolling Stone, and Deep Hole Lakes. Depending on conditions, a 30 foot long seine with 1/8 inch mesh, or a ten foot long straight seine with 1/8 inch mesh was used. Seining was used at stream locations with the exception of Pickerel Creek, Hemlock Creek off West Hemlock Road, Wolf River below the confluence with Swamp Creek and Swamp Creek below the access at Swampy Lane. Slightly more than five hours was expended, two hours of which included seining in Rolling Stone and Deep Hole Lakes.

Additional seining was conducted in Oak and Duck Lakes, with about two hours expended in other streams.

Figure 3.8-10 shows the location of fish collection activities. No threatened, endangered, or species of concern were captured, therefore, none were saved as voucher specimens.

3.8.1.12 Methods for Tissue Chemistry of Specimens Collected in 1977 and 1978

Trace metal analyses were performed on the tissues of selected aquatic species. Aquatic macrophytes, benthos, and fish were collected during 1977 from water bodies in the Swamp Creek drainage basin (Swamp and Hemlock Creeks and Oak and Rice Lakes) and the Pickerel Creek drainage basin (Deep Hole and Little Sand Lakes). During 1978, fish samples were again collected from these same water bodies and from additional location in the Pickerel Creek drainage basin (Duck and Rolling Stone lakes, Pickerel Creek, and Creeks 11-4 and 12-9).

Common aquatic macrophytes were collected from the shoreline. The lower portions of the main stalks of larger species (i.e., bur reed cattail, water lily) and the entire plant above the substrate of smaller species (i.e., pipewort, spike rush, wild rice) were collected and used in the analyses. At least a 30 g sample (wet weight) of tissue was obtained. Samples were rinsed in distilled water in the field to remove sediment particles attached to the plants (Mathis and Kevern, 1973). Except for wild rice from Rice Lake, macrophytes were placed in a separate plastic bag and analyzed as a composite sample of the aquatic macrophyte community at each sampling station. Wild rice plants from Rice Lake were analyzed separately.

Benthic macroinvertebrate organisms were collected for tissue analysis in conjunction with qualitative benthos collections, which consisted of hand-picked or dip-net sampling of miscellaneous substrates near each sampling station. Two or more grams of tissue were collected. In the field, organisms were rinsed in distilled water to remove sediment particles (Copeland and Ayers, 1972). Except for crayfish from Rice Lake, benthic organisms were placed whole in a separate plastic bag for each station and analyzed as a composite sample of the benthic community at each sampling station. Muscle tissue from crayfish tails was analyzed separately.

Fish for tissue analysis were collected by electroshocking, gill nets, and fyke nets. All fish were measured and weighed prior to dissection in the field. Dissections were performed with a stainless steel knife (Copeland, et al., 1973), which was cleaned after each dissection with distilled water. Tissues were gently rinsed in distilled water (Mathis and Kevern, 1973) and placed in a plastic bag. Two fish types were utilized in 1977: muscle (skinless fillet), because it is the most commonly consumed portion, and liver, because the presence of some trace metals in low concentrations is better detected in this tissue (Hannerz, 1967).

In 1978, tissue from a commonly occurring fish species was selected for analysis. Generally, samples consisted of muscle tissues composited from 25 yellow perch that were similar in size from each body of water. However, black bullhead, white sucker, redbelly dace, and mottled

sculpin comprised the samples from Hemlock Creek, Swamp Creek, Rice Lake, and Creek 11-4 because yellow perch were not found. For small fish such as redbelly dace, mottled sculpin, and young white sucker, whole fish were used for analysis (Table 3.8-7). For composite samples, care was taken to select fish of similar size and to excise tissue samples of similar size. In addition to the composite sample from each water body, an additional 23 yellow perch of a wide range of lengths from Little Sand Lake were analyzed individually to document intraspecies variation of metal concentrations. Immediately after collection, all tissue samples were placed on ice in an insulated container and frozen within eight hours of collection. In the laboratory, the tissues were homogenized in an electric blender, food processor, or manual grinding depending on amount and consistency of tissue.

In preparation for analysis, the homogenized tissue samples were separated into subsamples for analysis for the specific parameters as follows:

Subsample	Parameters
1	cadmium, chromium, cobalt, copper, lead, manganese, zinc, and percent moisture
2	arsenic
3	mercury

Subsample 1 was weighed to determine wet weight, dried to constant weight at 135 - 150° C (275 - 302° F) and the final dry weight determined. The relationship between wet and dry tissue weights was expressed as percent moisture and was used to convert metal concentrations based on dry weight to concentrations based on weight. The sample was ashed at 450° C (842° F) and subsequently dissolved in hydrochloric acid and analyzed by atomic absorption (AA) spectroscopy using direct aspiration (Horowitz, 1975).

Subsample 2 was weighed wet, dissolved in 1 + 1 sulfuric and concentrated nitric acids and analyzed for arsenic using AA and the hydride generation technique (USEPA, 1974). The percent moisture was used to convert arsenic concentrations based on dry weight to concentrations based on wet weight.

Subsample 3 was weighed wet, dissolved in concentrated sulfuric and nitric acids, potassium permanganate, and potassium persulfate. Sodium chloride hydroxylamine hydrochloride solutions was then added and the sample analyzed for mercury using AA and the conventional cold vapor technique (USEPA, 1974). The percent moisture was used to convert mercury concentrations based on dry weight to concentrations based on wet weight. All analyses were performed using a Perkin-Elmer model 306 atomic absorption spectrophotometer.

Table 3.8-7

Determination of Trace Metals in Fish Tissues Collected From Water Bodies in the Study Area in 1978

Location Station	Month of Collection	Number of Individuals that Comprised the Sample	Species	Tissue Analyzed
Swamp Creek Drainage Basin				
Rice Lake	August	25	Black bullhead	muscle
Hemlock Creek Station A-1	August	24	White sucker	muscle
Swamp Creek Station D	May	21	White sucker	whole fish
Station D	August	7	Mottled sculpin	whole fish
Oak Lake	August	25	Yellow perch	muscle
Pickerel Creek Drainage Basin				
Rolling Stone Lake	May	20	Yellow perch	muscle
	August	26	Yellow perch	muscle
Pickerel Creek M-5	August	25	Yellow perch	muscle
Creek 12-9 M-1	August	5	Yellow perch	muscle
Creek 11-4 M-3	August	25	Redbelly dace	whole fish
Little Sand Lake	August	20	Yellow perch	muscle
Little Sand Lake	August	1*	Yellow perch	muscle
Duck Lake	May	20	Yellow perch	muscle
	August	25	Yellow perch	muscle
Deep Hole Lake	August	25	Yellow perch	muscle

*23 yellow perch were analyzed individually.

Source: Dames & Moore, 1982
Checked by: WMW

3.8.1.13 Methods for Tissue Chemistry of Fish and Crayfish Collected in 1994

As part of the 1994 macroinvertebrate investigation, crayfish were collected for tissue analysis. Five sites were selected for crayfish collection including the Wolf River upstream and downstream of the confluence with Swamp Creek, Swamp Creek upstream and downstream of the previously proposed treated wastewater discharge location, and Little Sand Lake. These locations were extended or changed during collections due to lack of specimens (Figure 3.8-11).

Crayfish were collected in May 1994 using 8 x 18 inch, 800 to 900 micron mesh rectangular net. In deeper water, the net was used with kick-seining techniques. In shallow water, two feet or less, kick-seining was supplemented with hand picking.

Upon collection, crayfish were transferred to a ziplock bag. A minimum of ten specimens were collected per site. All crayfish from one site were composited into a single sample, iced in the field and frozen at the field station. Samples were shipped to the lab in a frozen condition. Parameters included in the tissue analysis included arsenic, cadmium, chromium, cobalt, copper, lead, mercury, manganese, and zinc.

As part of the 1994 fish investigation, fish were collected for tissue analysis. Five sites were selected for fish collection including the Wolf River upstream and downstream of the confluence with Swamp Creek, Swamp Creek upstream and downstream of the previously proposed discharge location, and Little Sand Lake. Figure 3.8-12 shows the locations of the fish collection efforts.

At each station, ten perch six inches or larger were to be collected using shocking or seining techniques. If ten perch of the size limit were not available, smaller size perch or other fish species were substituted. At each location, all captured fish were scaled and filleted so that the skin was left intact. All fish livers from an individual site were composited into a single sample for metals analysis. Tissue samples were analyzed for arsenic, cadmium, chromium, copper, colbalt, manganese, lead, and zinc. Paired fillets were individually analyzed for mercury.

All collections of fish and processing of fillets and livers of fish were conducted by EA Associates, Deerfield, IL. Once processed, fillets and composite liver samples were frozen and delivered to Foth & Van Dyke. Foth & Van Dyke completed the chain of custody forms and shipped frozen samples to the laboratory for analysis.

3.8.1.14 Methods for Mussel Collection

Mussel collections were conducted on lakes and streams in the study area from July 27, 1994 to August 7, 1994. Three methods which were utilized for collection of specimens included diving, snorkeling, and wading using a water "telescope".

Diving was used in waters greater than two feet deep. This included all lakes, the Wolf River, and Swamp Creek excluding the riffle area downstream of the access at Swampy Lane. Some snorkeling was conducted in lakes (restricted to shallow water), Swamp Creek in the riffle area, and

in Hemlock Creek. The water telescope was used in the riffle area of Swamp Creek. Sampling sites are shown on Figure 3.8-13.

At each sampling site mussels were located by a team of divers or snorkelers or a combination of these. At good locations, mussels were found in high numbers. At Wolf River sites and Swamp Creek downstream of County Highway M, one diver plus a spotter worked to collect specimens. These were placed in a mesh bag. One replicate would include 20 specimens. As a bag was filled, a third person transferred the specimens to an onshore location for identification. This process continued until no new specimens were identified for six consecutive replicates. In most cases this effort took a minimum of four hours for the diver to collect and return all identified specimens.

Identifications were completed by Don Helms of Helms & Associates. Voucher specimens of threatened, endangered, or species of concern were saved for WDNR documentation. Live specimens were returned to the stream where found. Many of the streams and lakes did not have sufficient mussels to fulfill the criteria described above, i.e., fewer than 20 mussels were found to complete one replicate. In these sites a minimum of four hours each for up to four personnel was expended in the search for mussels. In areas where middens (shells found on shore or in shallow water) were located, these were collected to supplement live specimen findings. Fairly good midden collections were located along the Wolf River and Swamp Creek. Scant midden collections were found elsewhere (Hemlock Creek).

On September 29, 1994, Foth & Van Dyke accompanied Dave Heath of WDNR in an effort to conduct additional mussel collection activities. Mussels were collected from the Wolf River (Site CMC-AB-SGI-CC) and Swamp Creek (Site CMC-AB-SC-700). The purpose of the collection was threefold: 1) verify specimen identifications provided by Don Helms; 2) search for possible threatened species collected earlier by Great Lakes Indian Fish and Wildlife Commission (GLIFWC) representatives; and 3) search for an additional listed species known as the salamander mussel.

The collection effort at the Wolf River site included 1.5 manhours of diving, while the effort at Swamp Creek was approximately one manhour. Since the Wolf River site had been searched intensively by Don Helms and GLIFWC in July and August 1994, Dave Heath did not use the methodology of collecting six replicate samples of 20 specimens each. Rather, he searched the area identifying specimens as he searched. Voucher specimens of questionable species were retained.

Approximately 190 specimens were collected at the Swamp Creek site. These were identified, enumerated and sexed (where possible) on site and returned to the water. Voucher specimens of questionable species were retained.

3.8.1.15 Methods for Quality Control

Field and laboratory quality control procedures were utilized during the aquatic biology studies as a means of assuring that they were completed according to currently accepted standards of practice for ecological investigations.

3.8.1.15.1 Field Procedures

A daily log of field activities was maintained by the field team leader who signed and dated the entries. These entries were supplemented by information from the daily logs of individual field personnel. Daily logs were completed during 1977-1978 as well as 1993-1994 field activities.

Two types of field data sheets were used for aquatic ecology field work which was conducted in 1977 and 1978. One data sheet was used for recording data pertaining to plankton, periphyton, benthos, and larval fish. The second data sheet was used to record data on juvenile and adult fish captured. Data regarding sample station number (or location), date, time, weather conditions, and sampling equipment used were entered on both types of sheets. A separate data sheet was utilized by Helms & Associates and Dave Heath (WDNR) to record the results of mussel field investigations.

Plankton pumps were calibrated daily by recording the time that elapsed for a known volume of water to pass through the pump. This was done at least four separate times prior to each sampling to calculate an average time per unit volume. This calibration was utilized to determine the pumping intervals for zooplankton and phytoplankton sampling so that equal volumes of water were withdrawn at each depth interval.

The meter on the larval fish net was calibrated prior to each use in the field. Calibration was performed by making subsurface (depth 0.5-m [1.6-foot]) tows over a measured distance. Meter values, for tows made with the complete device and tows made with the terminal bucket removed, were compared with the manufacturers' standards and recorded in the daily field log. If more than five percent difference was recovered, the meter was returned to the manufacturer for maintenance.

3.8.1.15.2 Laboratory Procedures

Chemical analyses for chlorophyll a and tissue trace metals for samples collected in 1977-1978 were conducted by Aqualab, Inc. For the analysis of biological samples collected in 1977-1978, a continuous daily log was maintained at the Environmental Laboratory in the Dames & Moore Park Ridge, Illinois office, and all log entries were signed and dated. Each set of biological samples brought into the laboratory was accompanied by a copy of the field sampling notes and data sheets. The field notes were placed in the project files following their review and the transfer of pertinent data to laboratory data sheets. Upon receipt in the laboratory, all samples were arranged in order of station and depth at which each was collected to verify that all samples were present. Permanent tags with assigned laboratory numbers were attached to each sample container. Field identification tags or labels were retained until sample processing was completed. A continuous master list of all laboratory sample numbers with brief sample descriptions was maintained. The assigned laboratory numbers were used in all data records and on labels for preserved and mounted specimens.

Pertinent sample history and analytical data for each biological sample were recorded on pre-prepared laboratory data sheets. Completion of laboratory analysis for biological samples was verified by checking against the master list. All original data were filed by month and segment of

the biological sampling program. Release of any samples for quality control analysis was accompanied by a transmittal sheet. Information on transmittal of samples was documented in the laboratory log.

All preserved and identified biological specimens were labeled, where applicable, with names of organisms, job number, and laboratory number. Upon completion of laboratory analysis, each voucher sample was carefully examined for correct label information, sufficient volume of preservative, and proper sealing for storage. The samples were then organized and stored in a container labeled with description of contents, date of samples, job number, and location.

A master file was maintained with a list of all the laboratory equipment subject to calibration and the information on:

1. Calibration requirements;

2. Sources of calibration standards (for example, National Bureau of Standards, equipment vendor specifications, recognized natural physical constants); and

3. Location of individual equipment maintenance and calibration logs.

Individual equipment logs contained the dates of calibration and the next date of calibration (or a statement that calibration was not required). Where appropriate, tags or stickers for recording dates of calibration were affixed to the piece of equipment. Mandatory recall requirements and acceptance criteria, where applicable, were recorded in the equipment log.

For verification of specimen identifications, every tenth sample was reanalyzed by another professional employee with comparable technical expertise or by an outside expert. For the Crandon Project, independent verification was undertaken by the following outside experts:

Fish	Mr. D. Fago, WDNR, Madison Dr. L. Page, Illinois Natural History Survey, Urbana Dr. G. Becker, University of Wisconsin at Stevens Point
Phytoplankton	Dr. T. Roeder, University of Wisconsin at Stevens Point Mr. M. Fenwick, Northern Illinois University, DeKalb
Periphyton	Mr. K. Kamburn, Kentucky Nature Preserves Commission, Frankfort
Zooplankton	Dr. B. Torke, Ball State University, Muncie, Indiana
Aquatic Macrophytes	Dr. H. Iltis, University of Wisconsin at Madison

Outside consultation for phytoplankton identifications was also provided by Dr. Gary B. Collins and Mr. Benjamin H. MacFarland, USEPA, Cincinnati. Benthos identifications and enumerations were reviewed by a Dames & Moore analyst other than the original investigator.

3.8.1.15.3 Data Analyses

All data collected in 1977-1978 were rechecked by a Dames & Moore employee other than the original investigator. This review included proofing all scientific names and checking calculations where applicable and signing and dating the document reviewed. Any discrepancies were reviewed by the originator of the document before changes were made.

All data and scientific names were transcribed onto computer code forms and checked for accuracy by a second individual who made corrections where needed and signed and dated the coding forms.

The transmittal of these materials to the keypunch and computer service was documented and entered into the laboratory log. The completed computer printouts underwent a final documented review upon return from the computer services to check for misspellings and incorrect data calculations. Calculations were performed with a formally verified computer program.

3.8.1.15.4 QA/QC Laboratory Procedures

On June 21 and 22, 1994, Hazelton Environmental Services (HES), acting as a subcontractor for Environmental Testing and Certification Corporation (ETC), received fish and crayfish samples for analysis from Foth & Van Dyke. These samples included crayfish from five site locations, each location consisted of at least ten specimens, 50 fish livers, 50 pairs of fish filets, and applicable QC for inorganic analysis. The samples were received frozen in a cooler and in good condition. Each sample was documented by a chain of custody form.

3.8.1.15.5 Sample Preparation

The samples were prepared for digestion in a room used exclusively for the preparation of samples. The samples were thawed slightly, chopped into pieces, and homogenized in an industrial blender under liquid nitrogen. All samples were stored frozen until extraction. The extraction for metals analysis was performed according to the EPA 6010/7000 method. One blender blank was prepared for the purpose of detecting possible laboratory contamination.

3.8.1.15.6 Inorganic Analysis

The inorganic results were reported on wet and dry weight basis. The data packages, chain of custodies and correspondence are attached in Appendix 3.8-1.

3.8.2 Results of Biological Data Collection Including Endangered, Threatened or Special Concern Species

3.8.2.1 Results of Phytoplankton Collections (1977-78)

3.8.2.1.1 Rice Lake

Phytoplankton samples were collected from Rice Lake at Stations F and N. Sampling was conducted at both stations during March 1977, monthly from May through October 1977, and at Station N during March, May, and August 1978. Density and relative abundance of the eight major taxa identified and enumerated during the study are presented in Table 3.8-8.

Phytoplankton was generally similar at both stations in Rice Lake. Densities in March 1977 were considerably higher at Station N (2,040 units/mL), than at Station F, (262 units/mL). However, during May, June, and October densities were similar at both stations, ranging from 1,441 to 2,166 units/mL at Station F and from 1,765 to 2,372 units/mL at Station N. Peak density was recorded in August at Station N (8,708 units/mL) and in September at Station F (8,234 units/mL).

The number of phytoplankton at Station N was considerably lower in March 1978 (375 units/mL) than in March 1977, but was similar to the number collected at Station F during March 1977. Numbers collected in May and August of 1977 and 1978 were similar.

Golden-brown algae (Chrysophyceae), diatoms (Bacillariophyceae), and blue-green algae (Cyanophyceae) were the major algal families collected in Rice Lake. Golden-brown algae comprised from 55 to 97 percent of the collections from May through October at both stations. During March 1977 diatoms predominated at both stations, and during March 1978 blue-green algae predominated at Station N.

Golden-brown algae primarily consisted of an unidentified *Chrysococcus*-like alga[1] and common diatom species *Fragilaria construens*, *F. crotonensis*, and *F. intermedia*. The blue-green algal species, *Oscillatoria agardhi*, was the most common alga collected in March 1978.

Diversity values varied from 0.1 to 1.0. A low diversity value indicates that most of the individuals observed in the phytoplankton community were taken from only a few taxa. A high diversity value indicates that a number of individuals were broadly distributed over several taxa. Diversity values could theoretically go to infinity depending on the total number of taxa present (Fager, 1972).

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[1]Mr. Benjamin MacFarland of the Environmental Monitoring and Support Laboratory, U.S. EPA, Cincinnati, suggested that organisms tentatively identified as *Chrysococcus rufescens*, *C. hemisphaerica*, *C. cylindrica*, and *C. ovalis* be referred to as unidentified *Chrysococcus*-like algae, based on their size and quality of preservation.

Table 3.8-8

Mean Density[a] (units/mL), Relative Abundance (%) and Diversity[b] of Phytoplankton Collected at Rice Lake - Stations F and N March 1977, May through October 1977, and March, May and August 1978

	1977														1978					
	March		May		June		July		August		September		October		March		May		August	
	units/mL	%	units/mL	%	units/mL	%	units/mL	%	units/mL	%	units/mL	%	units/mL	%	units/mL	%	units/mL	%	units/mL	%
Bacillariophyceae																				
F	177	67	76	5	762	35	225	17	122	3	143	2	55	3	—c	—	—	—	—	—
N	2,010	99	65	4	82	4	176	5	493	6	57	2	66	3	26	7	330	29	74	1
Chlorophyceae																				
F	2	1	104	7	139	6	0	0	8	<1	78	1	4	<1	—	—	—	—	—	—
N	11	1	7	<1	18	1	32	1	92	1	19	1	5	<1	1	<1	40	4	763	8
Chrysophyceae																				
F	2	1	1,208	84	1,200	55	1,067	82	3,636	96	7,978	97	1,988	97	—	—	—	—	—	—
N	0	0	1,590	90	1,853	94	3,444	91	7,878	90	2,823	96	2,295	97	76	20	754	66	7,364	77
Cryptophyceae																				
F	0	0	0	0	0	0	0	0	0	0	0	0	0	0	—	—	—	—	—	—
N	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,298	14
Cyanophyceae																				
F	82	31	45	3	8	<1	0	0	3	<1	0	0	3	<1	—	—	—	—	—	—
N	18	1	93	5	10	<1	0	0	0	0	3	<1	3	<1	272	72	15	1	11	<1

Table 3.8-8 (*Continued*)

	1977														1978					
	March		May		June		July		August		September		October		March		May		August	
	units/mL	%	units/mL	%	units/mL	%	units/mL	%	units/mL	%	units/mL	%	units/mL	%	units/mL	%	units/mL	%	units/mL	%
Dinophyceae																				
F	0	0	0	0	14	1	0	0	0	0	0	0	0	0	—	—	—	—	—	—
N	0	0	2	<1	0	0	0	0	12	<1	0	0	0	0	0	0	1	<1	0	0
Euglenophyceae																				
F	0	0	8	1	17	1	10	1	5	<1	34	<1	0	0	—	—	—	—	—	—
N	0	0	8	<1	3	<1	144	4	233	3	25	1	3	<1	0	0	7	1	36	<1
Xanthophyceae																				
F	0	0	0	0	28	1	0	0	0	0	0	0	0	0	—	—	—	—	—	—
N	0	0	0	0	6	<1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total																				
F	262		1,441		2,166		1,302		3,774		8,234		2,049		—		—		—	
N	2,040		1,765		1,971		3,795		8,708		2,927		2,372		375		1,147		9,548	
Diversity																				
F	1.0		0.3		0.8		0.3		0.1		0.1		0.1		—		—		—	
N	0.6		0.2		0.2		0.3		0.2		0.1		0.1		0.5		0.7		0.4	

[a]Density is the mean of two replicates rounded to the nearest whole number.
[b]Calculated by Shannon-Weaver formula ($\log_{10}$) using numbers of organisms.
— No sample collected.

Source: Dames & Moore, 1982
Checked by: WMW

The highest diversity value of 1.0 at Station F in October 1977 (Table 3.8-8) was associated with a relatively balanced phytoplankton community. Low values (0.1 to 0.2) corresponded to the high (≥90 percent) relative abundance of Chrysophyceae, which was almost exclusively represented by the unidentified *Chrysococcus*-like alga.

The mean chlorophyll a concentration recorded from stations in Rice Lake was ≤11 μg/L and ranged from ≤1 to 49 μg/L. The highest value at each of the two stations was reported in July 1977.

3.8.2.1.2 Oak Lake

Phytoplankton were collected from Oak Lake in March 1977, monthly from May through October 1977 and in March, May, and August 1978. Density and relative abundance of the seven major taxa identified and enumerated are presented in Table 3.8-9.

In 1977 total phytoplankton density was lowest in March, 493 units/mL, ranged from 828 units/mL to 1,516 units/mL in May, June, July and October and peaked in August (13,464 units/mL) and September (9,817 units/mL). In 1978, lowest density was again observed in March (339 units/mL). The density in May (2,548 units/mL) was higher than the previous May, and density in August 3,420 units/mL) did not reach the high level observed the previous year.

In 1977 golden-brown algae predominated in March, May, August, and September. Blue-green algae predominated in June and July. In 1978 golden-brown algae predominated in March whereas blue-green algae were most abundant in May and August.

Unidentified *Chrysococcus*-like algae generally were the common golden-brown algae but *Diachros* sp. predominated in March 1977. *Chroococcus dispersus* var. *minor* was the dominant blue-green alga in June and July 1977, *Aphanotheca clathrata* predominated in May 1978 and *Chroococcus minimus* in August 1978.

The average phytoplankton diversity, calculated from the data presented in Table 3.8-9, was 0.6 for Oak Lake. Minimum diversities of 0.3 and 0.4 occurred in March 1977 and March 1978, respectively, whereas a maximum diversity of 0.9 occurred in October 1977.

The mean chlorophyll a concentration recorded from Oak Lake was less than 16 μg/L, ranging from <1 to 53 μg/L. Peak concentrations occurred in July and September 1977 from both sampling depths.

3.8.2.1.3 Rolling Stone Lake

Phytoplankton samples were collected from Rolling Stone Lake at Stations M-2 and M-4 in October 1977 and March, May, and August 1978. Density and relative abundance of the six major taxa identified and enumerated during the study are presented in Table 3.8-10.

Table 3.8-9

Mean Density[a] (units/mL), Relative Abundance (%), and Diversity[b] of Phytoplankton Collected at Oak Lake - Station G March 1977, May Through October 1977, and March, May and August 1978

	1977														1978					
	March		May		June		July		August		September		October		March		May		August	
	Units/mL	%	units/mL	%	units/mL	%	units/mL	%	units/mL	%	units/mL	%	units/mL	%	units/mL	%	units/mL	%	units/mL	%
Bacillariophyceae	51	10	100	12	47	4	12	1	1,164	9	251	3	125	8	53	15	90	11	21	1
Chlorophyceae	42	8	182	22	221	17	279	23	3,723	28	2,181	22	486	32	10	3	0	0	112	3
Chrysophyceae	400	81	487	59	245	19	426	35	7.064	52	6,575	67	856	56	277	82	761	30	1,356	40
Cyanophyceae	0	0	58	7	767	60	500	41	1,380	10	154	2	44	3	0	0	1,476	58	1,918	56
Dinophyceae	0	0	1	<1	1	<1	4	<1	83	1	0	0	5	<1	0	0	0	0	0	0
Euglenophyceae	0	0	0	0	0	0	1	<1	17	<1	654	7	0	0	0	0	21	1	13	<1
Xanthophyceae	0	0	0	0	0	0	0	0	33	<1	1	<1	0	0	0	0	0	0	0	0
Total	493	100	828	100	1,281	100	1,222	100	13,464	100	9,817	100	1,516	100	339	100	2,548	100	3,420	100
Diversity	0.3		0.7		0.7		0.8		0.8		0.6		0.9		0.4		0.7		0.5	

[a]Density is the mean of two replicate samples rounded to the nearest whole number.

[b]Calculated by Shannon-Weaver formula ($\log_{10}$) using total numbers of organisms.

Source: Dames & Moore, 1982

Checked by: WMW

Table 3.8-10

Mean Density[a](units/mL), Relative Abundance (%), and Diversity[b] of Phytoplankton Collected at Rolling Stone Lake - Stations M-2 and M-4 October 1977, March, May and August 1978

	1977		1978					
	October		March		May		August	
	units/mL	%	units/mL	%	units/mL	%	units/mL	%
Bacillariophyceae								
M-2	51	<1	0	0	327	9	680	3
M-4	170	2	66	<1	453	13	287	1
Chlorophyceae								
M-2	49	<1	0	0	45	1	9,687	42
M-4	30	<1	44	<1	82	2	12,057	47
Chrysophyceae								
M-2	13,509	97	26,640	71	2,761	76	9,462	41
M-4	7,112	81	22,152	68	2,383	69	9,380	37
Cyanophyceaee								
M-2	360	3	10,638	28	363	10	2,790	12
M-4	248	3	10,472	32	3,504	14	3,504	14
Dinophyceae								
M-2	0	0	0	0	24	1	0	0
M-4	0	0	0	0	82	2	0	0
Euglenophyceae								
M-2	0	0	44	<1	111	3	328	1
M-4	1,169	13	0	0	46	1	278	1
Total								
M-2	13,969		37,323		3,630		22,946	
M-4	8,727		32,735		3,468		25,515	
Diversity								
M-2	0.1		0.3		0.6		0.8	
M-4	0.3		0.3		0.7		0.8	

[a]Density is the mean of two replicate samples rounded to the nearest whole number.

[b]Calculated by Shannon-Weaver formula ($\log_{10}$) using total number of organisms presented.

Source: Dames & Moore, 1982

Checked by: WMW

Densities of phytoplankton were similar at the two Rolling Stone Lake stations. Density per sampling period at Stations M-2 and M-4 ranged from 3,630 units/mL and 3,468 units/mL in May 1978 to 37,323 units/mL and 32,735 units/mL in March 1978, respectively.

Golden-brown algae were the most abundant phytoplankton collected during each sampling period except August 1978 when green algae were dominant. Golden-brown algae comprised over 41 percent of the phytoplankton in all samples at Station M-2 and over 37 percent in all samples at Station M-4. Unidentified *Chrysococcus*-like algae were the most abundant forms.

Green algae and blue-green algae were commonly collected but their peak abundances occurred at different times. Blue-green algae were most abundant in March 1978 and comprised from three to 32 percent of the phytoplankton. With the exception of August 1978, green algae comprised less than two percent of any collection.

Individual species of green algae and blue-green algae occurred sporadically and none were common. Organisms that comprised the majority of the green algal maximum in August 1978 were, in decreasing order of abundance, an unidentified green coccoid, *Ankistrodesmus falcatus*, and *Oocystis submarina*. During other months no species comprised more than two percent of any collections. *Spirulina laxa* was the only blue-green alga that was identified in March 1978; it comprised 28 and 32 percent of the phytoplankton at Stations M-2 and M-4, respectively, and was not found in other collections. Diatoms comprised from zero to nine percent of the phytoplankton at Station M-2 and from <1 to 13 percent at Station M-4. *Asterionella formosa*, *Cocconeis placentula*, and *Fragilaria* sp. were the only diatoms that comprised more than one percent of any collection.

Phytoplankton diversity ranged from 0.1 at Station M-2 in October 1977 to 0.8 at both stations in August 1978. In October, when diversity was lowest, golden-brown algae comprised 97 percent of the sample. In August 1978, diversity was highest and no taxon comprised more than 50 percent of the samples.

Mean chlorophyll a concentration in Rolling Stone Lake was 20 μg/L and ranged from 10 to 45 μg/L. Highest values were reported for March 1978 and August 1978 at Stations M-2 and M-4, respectively.

3.8.2.1.4 Little Sand Lake

Phytoplankton samples were collected from Stations H and I in Little Sand Lake in March 1977, monthly from May through October 1977, and in March, May, and August 1978. An additional grab sample was collected in July 1977 from the western shoreline when a red coloration of the water occurred. Density and relative abundance of the seven major taxa identified and enumerated during the study are presented in Table 3.8-11.

Table 3.8-11

Mean Density[a] (units/mL), Relative Abundance (%), and Diversity[b] of Phytoplankton Collected at Little Sand Lake - Station H and I March 1977, May Through October 1977, and March, May and August 1978

	1977														1978					
	March		May		June		July		August		September		October		March		May		August	
	units/mL	%	units/mL	%	units/mL	%	units/mL	%	units/mL	%	units/mL	%	units/mL	%	units/mL	%	units/mL	%	units/mL	%
Bacillariophyceae																				
H	1	8	25	2	1	<1	11	<1	2	<1	15	<1	27	8	2	1	47	1	0	0
I	1	11	5	<1	3	1	0	0	2	2	14	<1	13	2	1	1	59	1	38	<1
Chlorophyceae																				
H	<1	1	27	2	207	59	870	27	174	18	433	9	167	49	1	<1	0	0	494	2
I	<1	1	28	2	262	52	613	30	51	61	430	7	181	29	1	1	0	0	570	2
Chrysophyceae																				
H	<1	<1	1,556	93	60	17	412	13	720	76	362	8	128	37	354	97	4,160	88	1,729	6
I	0	0	1,475	95	81	16	261	13	8	10	136	2	421	68	108	98	5,144	87	2,166	6
Cyanophyceae																				
H	0	0	52	3	77	22	1,931	60	39	4	3,844	82	17	5	0	0	0	0	27,802	93
I	0	0	32	2	141	28	1,133	56	20	24	5,279	90	6	1	0	0	378	6	30,517	92
Dinophyceae																				
H	9	90	8	<1	9	3	0	0	8	1	5	<1	1	<1	6	2	0	0	0	0
I	9	88	7	<1	15	3	8	<1	2	3	0	0	2	<1	0	0	15	<1	0	0

Table 3.8-11 *(Continued)*

	1977														1978					
	March		May		June		July		August		September		October		March		May		August	
	units/mL	%	units/mL	%	units/mL	%	units/mL	%	units/mL	%	units/mL	%	units/mL	%	units/mL	%	units/mL	%	units/mL	%
Euglenophyceae																				
H	0	0	0	0	0	0	0	0	0	0	6	<1	0	0	0	0	495	11	0	0
I	0	0	0	0	1	<1	0	0	<1	<1	0	0	0	0	0	0	294	5	0	0
Xanthophyceae																				
H	0	0	0	0	0	0	0	0	2	<1	0	0	1	<1	0	0	0	0	0	0
I	0	0	0	0	0	0	0	0	0	0	13	<1	0	0	0	0	15	<1	0	0
Total																				
H	10	100	1,668	100	353	100	3,223	100	944	100	4,665	100	342	100	363	100	4,702	100	30,025	100
I	10	100	1,517	100	504	100	2,015	100	84	100	5,871	100	622	100	110	100	5,905	100	33,321	100
Diversity																				
H	0.5		0.5		1.0		0.6		0.5		0.4		1.0		0.1		0.5		0.2	
I	0.3		0.4		0.9		0.6		1.0		0.3		0.6		0.1		0.5		0.2	

[a]Density is the mean of two replicate samples rounded to the nearest whole number.
[b]Calculated by Shannon-Weaver formula ($\log_{10}$) using total numbers of organisms.

Source: Dames & Moore, 1982
Checked by: WMW

In 1977 density at Station H ranged from 10 units/mL in March to 4,665 units/mL in September and at Station I from 10 units/mL to 5,871 units/mL in the same months. With the exception of August 1977, densities were generally similar between stations.

In 1978 densities were considerably higher than during corresponding months in 1977. At Station H density ranged from 363 units/mL in March to 30,025 units/mL in August and at Station I from 110 to 33,321 units/mL in the same months.

Overall, golden-brown algae, blue-green algae, and green algae were most abundant. Golden-brown algae were dominant (>85 percent of the collection) in May 1977 and March and May 1978 at both stations. In August 1977 they comprised 76 percent of the community at Station H but only 10 percent at Station I. In October 1977 they comprised 68 percent of the community at Station I, but only 37 percent at Station H in October 1977. Unidentified *Chrysococcus*-like algae were the dominant forms. Other commonly occurring forms were *Dinobyron sertularia*, *D. divergens*, and *D. bavaricum*.

Blue-green algae exhibited exceptionally high density in August 1978 (>30,000 units/mL), which was five to six times higher than densities enumerated in other sampling periods. Blue-green algae were the most abundant phytoplankton in July and September 1977 and August 1978 at both stations when they comprised 56 to 93 percent of the samples. In other sampling periods they comprised 24 percent or less of the collections. *Merismopedia tenuissima* was the most abundant blue-green algal species.

Green algae were the most abundant group in June 1977 at both stations, at Station I in August 1977, and Station H in October 1977. An unidentified coccoid was the most abundant of the green algae and *Selenastrum minutum* was commonly present.

An additional whole water sample was collected from a near-shore area in July 1977 where local residents noted a red coloration in the water. A single euglenoid member, *Phacus pyrum*, was identified from this sample. The algae occurred in the shallow water area along the northwestern shoreline and appeared to be responsible for the red coloration noted in that area.

The lowest diversity (0.1) occurred at both stations in March 1978 when the unidentified *Chrysococcus*-like algae comprised most of the sample (Table 3.8-11). The highest diversity (1.0) occurred at Station H in June and October 1977 and at Station I in August 1977 when no single taxon comprised more than 61 percent of the collection. The mean chlorphylll a concentration calculated from all samples taken in Little Sand Lake was <11 and 10 μg/L at Stations H and I, respectively.

3.8.2.1.5 Duck Lake

Phytoplankton samples were collected from Duck Lake in October 1977, March 1978, and monthly from May through October 1978. Density and relative abundance of the seven major taxa identified and enumerated during the study are presented in Table 3.8-12.

Table 3.8-12

Mean Density[a] (units/mL), Relative Abundance (%), and Diversity[b] of Phytoplankton Collected at Duck Lake - Station K October 1977, March 1978 and May Through October 1978

	1977		1978													
	October		March		May		June		July		August		September		October	
	units/mL	%	units/mL	%	units/mL	%	units/mL	%	units/mL	%	units/mL	%	units/mL	%	units/mL	%
Bacillariophyceae	38	4	0	0	12	<1	0	0	0	0	0	0	0	<0	16	1
Chlorophyceae	5	<1	60	6	0	0	3,324	29	10,511	44	2,194	10	496	3	93	3
Chrysophyceae	16,408	97	852	87	1,869	38	8,243	71	13,322	56	20,080	89	14,388	93	2,537	90
Cyanophyceae	0	0	5	<1	2,446	50	0	0	0	0	33	<1	89	1	101	4
Dinophyceae	465	3	0	0	390	8	0	0	86	<1	166	1	97	1	43	2
Euglenophyceae	0	0	66	7	150	3	43	<1	0	0	0	0	344	2	40	1
Xanthophyceae	5	<1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	16,922		983		4,867		11,610		23,918		22,473		15,413		2,830	
Diversity	0.2		0.3		0.5		0.4		0.4		0.2		0.3		0.3	

[a] Density is the mean of two replicate samples rounded to the nearest whole number.
[b] Calculated by Shannon-Weaver formula ($\log_{10}$) using total numbers of organisms.

Source: Dames & Moore, 1982
Checked by: WMW

In 1978 numbers of phytoplankton were lowest in March, 983 units/mL, progressively increased to 23,918 units/mL in July, then declined to 2,830 units/mL in October. Density in October 1978 (2,830 units/mL) was considerably lower than the number collected in October 1977 (16,922 units/mL).

Golden-brown algae dominated the phytoplankton collections. Members of this class were the most abundant forms in every sampling period except May 1978 when blue-green algae were the most abundant. Unidentified *Chrysococcus*-like algae were dominant and comprised 95 percent of the golden-brown algae collection.

Green algae were collected in every sampling period except May 1978 and comprised up to a maximum of 44 percent (July 1978). Commonly occurring green algal species were *Oocystis submarina* and *Selenasturm minutum* and unidentified members of the family Spondylomoraceae.

Blue-green algae comprised 50 percent of the organisms enumerated in May 1978 but were four percent or less during the other sampling periods. The only blue-green algae in May were genera of the family Chroococcaceae. Diversity values were low and ranged from 0.2 in October 1977 and August 1978 to 0.5 in May 1978 (Table 3.8-12).

The mean chlorophyll a concentration calculated for all Duck Lake samples was nine μg/L and ranged from two μg/L in June 1977 to 19 μg/L in October 1978. Values exhibited a bimodal distribution with high values in spring and late summer/autumn and low mid-summer levels.

3.8.2.1.6 Deep Hole Lake

Phytoplankton samples were collected from Deep Hole Lake in October 1977, March 1978, and monthly from May through October 1978. Density and relative abundance of the seven major taxa identified and enumerated during the study are presented in Table 3.8-13.

In 1978, phytoplankton density was lowest in March, 768 units/mL, increased to 16,194 units/mL in May, then progressively decreased to 4,758 units/mL in August. In September density increased to 11,710 units/mL then decreased to 9,102 units/mL in October. Density in October 1978 was considerably higher than in October 1977 (1,205 units/mL).

Golden-brown algae was the most abundant class of algae in all sampling periods ($\geq$72 percent) except March, May, and June 1978 when green algae or blue-green algae predominated. Golden-brown algae were represented primarily by unidentified *Chrysococcus*-like forms. Other common golden-brown algae were *Dinobyron sertularia*, *Chrysococcus major*, and *Mallomonas acaroides*.

Green algae was the most numerous class in March and June 1978, when it comprised 75 and 90 percent, respectively, of the collections. Common green algae were *Oocystis submarina*, *Selenastrum minutum*, and *Ankistrodesmus folcatus* var. *acicularis*.

Table 3.8-13

Mean Density[a] (units/mL), Relative Abundance (%), and Diversity[b] of Phytoplankton Collected at Deep Hole Lake - Station L October 1977, March 1978 and May Through October 1978

	1977		1978													
	October		March		May		June		July		August		September		October	
	units/mL	%	units/mL	%	units/mL	%	units/mL	%	units/mL	%	units/mL	%	units/mL	%	units/mL	%
Bacillariophyceae	7	1	1	<1	40	<1	0	0	43	1	27	1	15	<1	11	<1
Chlorophyceae	74	6	577	75	16	<1	13,992	90	1,309	16	428	9	2,649	23	608	7
Chrysophyceae	1,124	93	184	24	5,995	37	1,375	9	3,602	44	4,199	88	8,392	72	8,440	93
Cyanophyceae	0	0	2	<1	9,739	60	38	<1	3,295	40	93	2	59	<1	0	0
Dinophyceae	0	0	0	0	0	0	0	0	11	<1	3	<1	43	<1	0	0
Euglenophyceae	0	0	4	<1	404	2	120	1	0	0	8	<1	552	5	43	<1
Total	1,205		768		16,194		15,525		8,258		4,758		11,710		9,102	
Diversity	0.1		0.3		0.5		0.3		0.6		0.3		0.5		0.5	

[a] Density is the mean of two replicate samples rounded to the nearest whole number.
[b] Calculated by Shannon-Weaver formula ($\log_{10}$) using total numbers of organisms.

Source: Dames & Moore, 1982
Checked by: WM

Blue-green algae was the most abundant algal class in May 1978 when it constituted 60 percent of the sample. Blue-green algae were dominated by unidentified members of the family Chroococcaceae and *Merismopedia tenuissima.*

The minimum diversity of 0.1 occurred in October 1977 when the unidentified *Chrysococcus*-like algae comprised 93 percent of the sample (Table 3.8-13). The maximum diversity of 0.6 occurred in July 1978, when no class comprised more than 44 percent of the sample.

The mean chlorophyll a concentration recorded from Deep Hole Lake was ≤ 4 μg/L, and ranged from <1 to 10 μg/L. The highest mean concentration of 6.5 μg/L (mean of two replicates) occurred in October 1978.

3.8.2.1.7 Skunk Lake

Phytoplankton samples were collected from Station J in Skunk Lake monthly from June to October 1977. Density and relative abundance of the six major taxa identified and enumerated during the study are presented in Table 3.8-14.

Phytoplankton density in Skunk Lake ranged from 571 units/mL in October to 15,727 units/mL in September 1977.

Golden-brown algae comprised 75 percent or more of each sample. The most abundant golden-brown algal species were unidentified *Chrysococcus*-like algae.

Green algae was second in abundance, comprising from one to 25 percent of the phytoplankton collected. *Ankistrodesmus falcatus* was the most common green alga in June and July (92 and 97 percent of the assemblage, respectively) but was uncommon in subsequent collections. *Dictyosphaerium pulchellum, Elakatothrix gelatinosa* and *Scenedesmus brasiliensis* were common green algal species in various periods from August through October 1977.

Primarily because of the dominance of the unidentified golden-brown *Chrysococcus*-like algae, diversity values were low, ranging from 0.1 to 0.3. The highest diversity value occurred in July 1977 when golden-brown algae were lowest in abundance (75 percent of the collection).

The mean chlorophyll a level calculated from all samples was <81 μg/L. Values ranged from <1 μg/L in June 1977 to 395 μg/L in March 1978. During March 1978 when the highest chlorophyll a level was recorded, the phytoplankton samples were collected at a depth of approximately 0.5 m (1.6 feet). The ice cover at the sampling location was approximately 30.5 cm (12 inches) in thickness. There was patchy snow cover, which varied across the lake.

Table 3.8-14

Mean Density[a] (units/mL), Relative Abundance (%), and Diversity[b] of Phytoplankton Collected at Skunk Lake - Station J June Through October 1977

	1977									
	June		July		August		September		October	
	units/mL	%	units/mL	%	units/mL	%	units/mL	%	units/mL	%
Bacillariophyceae	37	<1	14	<1	60	1	48	<1	7	1
Chlorophyceae	1,177	16	1,456	25	729	7	125	1	25	4
Chrysophyceae	6,210	84	4,341	75	9,176	91	15,478	98	532	93
Cyanophyceae	12	<1	0	0	96	1	76	<1	4	1
Euglenophyceae	0	0	0	0	0	0	0	0	1	<1
Xanthophyceae	0	0	0	0	0	0	0	0	1	<1
Total	7,436		5,811		10,060		15,727		571	
Diversity	0.2		0.3		0.2		0.1		0.2	

[a] Density is the mean of two replicate samples rounded to the nearest whole number.
[b] Calculated by Shannon-Weaver formula ($\log_{10}$) using total number of organisms presented.

Source: Dames & Moore, 1982
Checked by: WMW

3.8.2.2 Results of Zooplankton Collections (1977-78)

3.8.2.2.1 Rice Lake

The studies conducted on Rice Lake included collection of zooplankton samples at Stations F and N during March and monthly from May to October 1977. Collections also were made at Station N in March, May, and August 1978. Zooplankton were classified into the orders Copepoda and Cladocera or the phylum Rotatoria; the density and relative abundance of these three major taxa are presented in Table 3.8-15.

The zooplankton community was generally similar at the stations in Rice Lake. In 1977, densities were lower than 50/L at both stations in March, May, and October. Peak densities of 342/L were observed in June at Station F and of 297/L at Station N. During July, August, and September densities at Station F decreased from 77 to 15/L, but at Station N densities increased from 17 to 169/L. During 1978, densities were considerably lower ($\leq$10/L) than in corresponding sampling periods in 1977 collections and were not greater than 10/L.

Community composition at Rice Lake fluctuated throughout the year. In 1977, rotifers were most abundant in March, May, and October at both stations, except at Station N in March when copepods were most common. In June, when highest total numbers were observed, cladocerans were most common, comprising 44 percent of the collection at Station F and 24 percent at Station N. Copepods were most abundant at both stations during July, August, and September, comprising 48 percent or more of the zooplankton collections.

In 1978 at Station N, Copepoda were abundant in March and were codominant with Rotatoria during May and August.

Nauplii were the most abundant copepod forms and cyclopoid copepodites occurred commonly. Common rotifer forms included *Trichocera longiseta*, *Ploesoma* sp., and *Synchaeta* sp. The most abundant cladoceran species were *Acroperus harpae*, *Chydorus sphaericus*, *Diaphanosoma brachyurum*, and *Eubosmina tubicen*. Diversity values during the period of investigation ranged from 0.4 at Station N in October 1977 to 1.2 at both stations in July 1977. The low value of 0.4 corresponded to an abundance of Rotatoria, which were represented primarily by *Synchaeta* sp. (67 percent of the zooplankton community).

3.8.2.2.2 Oak Lake

Zooplankton samples were collected from Oak Lake in March 1977; monthly from May through October 1977; and during March, May, and August 1978. Zooplankton enumerated from these samples were classified into two crustacean orders, Copepoda and Cladocera, or the phylum Rotatoria, and the mean density and relative abundance of these three major taxa are presented in Table 3.8-16.

Table 3.8-15

Mean Density[a] (No./L), Relative Abundance (%), and Diversity[b] of Zooplankton Collected at Rice Lake - Stations F and N March 1977, May Through October 1977, and March, May and August 1978

	1977														1978					
	March		May		June		July		August		September		October		March		May		August	
	No/L	%	No/L	%	No/L	%	No/L	%	No/L	%	No/L	%	No/L	%	No/L	%	No/L	%	No/L	%
Cladocera																				
F	<1	1	2	4	150	44	19	25	1	5	<1	4	<1	5	—	—	—	—	—	—
N	<1	2	3	14	219	74	1	6	19	14	3	2	<1	2	<1	3	3	28	1	13
Copepoda																				
F	4	39	4	8	102	30	52	68	12	55	7	48	<1	14	—	—	—	—	—	—
N	42	88	3	15	56	19	9	51	73	53	104	61	<1	5	5	78	3	36	4	43
Rotatoria																				
F	5	60	36	87	89	26	6	8	9	40	7	47	5	82	—	—	—	—	—	—
N	5	10	15	70	22	8	7	42	45	33	63	37	17	93	1	19	3	36	4	44
Total																				
F	9		42		342		77		22		15		6		—		—		—	
N	47		21		297		17		137		169		18		6		10		9	
Diversity							1.2													
F	0.9		0.9		1.0		1.2		0.9		1.0		0.5		—		—		—	
N	0.9		1.0		0.9				1.0		0.7		0.4		0.7		0.9		0.9	

[a] Density is the mean of two replicate samples rounded to the nearest whole number.
[b] Calculated using the Shannon-Weaver formula ($\log_{10}$) using total numbers of organisms presented.
— No sample collected.

Source: Dames & Moore, 1982
Checked by: WMW

Table 3.8-16

Mean Density[a] (No./L), Relative Abundance (%), and Diversity[b] of Zooplankton Collected at Oak Lake - Station G March 1977, May Through October 1977, and March, May and August 1978

	1977														1978					
	March		May		June		July		August		September		October		March		May		August	
	No/L	%	No/L	%	No/L	%	No/L	%	No/L	%	No/L	%	No/L	%	No/L	%	No/L	%	No/L	%
Cladocera	4	2	23	8	8	5	8	3	8	3	6	1	15	3	11	2	2	1	11	12
Copepoda	142	78	227	74	125	76	223	84	167	68	77	15	66	14	139	28	95	49	70	79
Rotatoria	37	20	56	18	31	19	34	13	72	29	435	84	378	82	344	70	96	50	9	10
Total	182		307		164		264		247		518		459		494		194		89	
Diversity	0.8		0.9		0.6		0.7		0.7		0.6		0.5		0.3		0.5		0.7	

[a]Density is the mean of two replicate samples rounded to the nearest whole number.
[b]Calculated by Shannon-Weaver formula ($\log_{10}$) using total numbers of organisms presented.

Source: Dames & Moore, 1982
Checked by: WMW

In 1977 zooplankton density ranged from 164/L in June to 518/L in September. In 1978, density in March, 494/L, was higher than the previous year, 182/L, whereas densities in May, 194/L, and August, 89/L, were lower than corresponding collections in 1977, 307 and 247/L, respectively.

Copepods dominated the collections in March and May through August 1977 and August 1978 comprising 68 to 84 percent of the collections. Rotifers predominated the collections in September and October 1977 and March 1978, comprising 70 to 84 percent of the collections, and were codominant with copepods in May 1978. Common components of the copepod group were the immature naupliar and copepodite life stages and the adult calanoid *Diaptomus minutus*. *Kellicottia bostoniensis*, *K. longispina*, and *Keratella taurocephala* were commonly collected rotifer species.

Zooplankton diversity ranged from 0.3 in March 1978 to 0.9 in May 1977. The monthly values for samples collected in March and May 1978 were lower than for comparable months sampled in 1977.

3.8.2.2.3 Rolling Stone Lake

Zooplankton samples were collected from Rolling Stone Lake at Stations M-2 and M-4 in October 1977 and March, May and August 1978. Density and relative abundance of the major taxa identified and enumerated during the study are presented in Table 3.8-17.

Total zooplankton density per sampling period ranged from 1/L in March 1978 to 488/L in October 1977 at Station M-2, and from 2/L in March 1978 to 477/L in May 1978 at Station M-4. Densities were similar at both stations except in October 1977 when over twice as many organisms were collected at Station M-2 (488/L) than at Station M-4 (266/L).

Copepoda were the most numerous zooplankton enumerated during the investigation ranging from 12 to 99 percent at Station M-2 to 30 to 95 percent at Station M-4. The immature nauplii and cyclopoid copepodites were the most commonly collected copepod life stages. The adult *Diacyclops thomasi* and *Tropocyclops prasinus mexicanus* were the most commonly collected species. Rotatoria were second in abundance in the zooplanton collections. Rotifers comprised from <1 to 87 percent of the zooplankton at Station M-2 and from one to 68 percent at M-4. *Synchaeta* sp., *Keratella quadrata*, and *Polyarthra* sp. were the most commonly collected organisms. Cladocerans were most abundant in October 1977 when they comprised 70 (341/L) and 31 (71/L) percent of the respective collections at Stations M-2 and M-4. During other collections, they comprised ≤ three percent of the samples. *Eubosmina tubicen* and *Chydorus sphaericus* were the most common species encountered. Zooplankton diversity was lowest (0.4) in October 1977 at Station M-2 and at both stations in May 1978 (Table 3.8-17). Diversity was highest (1.0) at Station M-4 in October 1977.

Table 3.8-17

Mean Density[a] (No./L), Relative Abundance (%), and Diversity[b] of Zooplankton Collected at Rolling Stone Lake - Stations M-2 and M-4 October 1977, March, May, and August 1978

	1977		1978					
	October		March		May		August	
	No./L	%	No./L	%	No./L	%	No./L	%
Cladocera								
M-2	341	70	<1	2	2	<1	4	1
M-4	71	31	<1	2	1	<1	13	3
Copepoda								
M-2	110	22	<1	38	54	12	371	99
M-4	83	37	1	30	240	50	373	95
Rotatoria								
M-2	37	8	1	60	379	87	1	<1
M-4	72	32	1	68	236	49	4	1
Total								
M-2	488		1		434		376	
M-4	226		2		477		390	
Diversity								
M-2	0.4		0.9		0.4		0.6	
M-4	1.0		0.8		0.4		0.8	

[a] Density is the mean of two replicate samples rounded to the nearest whole number.
[b] Calculated by Shannon-Weaver formula ($\log_{10}$) using total numbers of organisms presented. Immature life stages were not included in the calculations.

Source: Dames & Moore, 1982
Checked by: WMW

3.8.2.2.4 Little Sand Lake

Zooplankton samples were collected from Little Sand Lake (Stations H and I) during March 1977, and monthly from May through October 1977 and March, May, and August 1978. Density and relative abundance of the three major taxa are presented in Table 3.8-18.

The lowest density of zooplankton occurred in March 1978 at both stations, 66/L at Station H and 75/L at Station I. The highest density was observed in June 1977 at Station H (419/L) and in May 1977 at Station I (293/L). Generally, collections in corresponding periods in 1977 and 1978 were similar.

Copepods were the most numerous zooplankton at both stations. This subclass comprised 47 percent or more of each collection. The copepods were primarily comprised of immature nauplii and calanoid copepodites, and adult *Diaptomus minutus*. Other adult species included *Diacyclops thomasi* and *Mesocyclops edax*. Rotifers were the second most abundant group at Little Sand Lake and comprised from 18 to 47 percent of the monthly samples. *Keratella taurocephala* was the primary rotifer identified.

Except for June 1977, cladocera never comprised more than 15 percent of the zooplankton community. In June, cladocerans represented 20 percent of the zooplankton sample at Station I, with their highest density (44/L). Cladocerans commonly found in the sample were *Diaphanosoma leuchtenbergianum*, *Eubosmina tubicen*, and *Daphnia dubia*. Zooplankton diversity was similar at Stations H and I and ranged from 0.4 in August 1977 at both locations and in July at Station H to 0.8 in May at Station I (Table 3.8-18).

3.8.2.2.5 Duck Lake

Zooplankton samples were collected from Duck Lake (Station K) during October 1977, March 1978, and monthly from May through October 1978. Density and relative abundance of the three major taxa are presented in Table 3.8-19.

In 1978, zooplankton density ranged from 25/L in May to 419/L in August. Density in October 1978 was considerably less than in October 1977. Rotifers were the most abundant organisms in all sampling periods except July and August 1978 when copepods were dominant. Rotifer abundance ranged from 12 percent in July 1978 to 99 percent in March 1978. *Keratella taurocephala* was the most abundant species. Individuals from the genera *Polyarthra* and *Synchaeta* were also common.

Copepods were highest in density in July (187/L) and August 1978 (283/L) when they comprised 65 and 68 percent of the respective collections. The greatest abundance of cladocerans was observed in June 1978 when they comprised 43 percent (116/L) of the sample. Among the copepods, the nauplii were the most common forms and the most abundant adult form was the cyclopoid *Mesocyclops edax*. *Eubosmina tubicen*, *Holopedium gibberum* and *Diaphanosoma leuchtenbergianum* were the most common cladoceran species.

Table 3.8-18

Mean Density[a] (No./L), Relative Abundance (%), and Diversity[b] of Zooplankton Collected at Little Sand Lake - Stations H and I March 1977, May Through October 1977, and March, May and August 1978

	1977														1978					
	March		May		June		July		August		September		October		March		May		August	
	No/L	%	No/L	%	No/L	%	No/L	%	No/L	%	No/L	%	No/L	%	No/L	%	No/L	%	No/L	%
Cladocera																				
H	<1	<1	0	0	40	9	15	7	7	2	39	12	13	8	1	1	5	2	13	9
I	<1	<1	2	1	44	20	14	8	13	6	22	9	9	4	1	1	2	1	25	15
Copepoda																				
H	73	82	225	59	195	47	148	72	162	57	159	47	100	59	37	56	196	60	104	72
I	102	64	209	71	123	54	120	65	132	57	128	55	100	49	39	52	132	69	100	61
Rotatoria																				
H	16	18	156	41	184	44	42	21	118	41	139	41	55	33	28	43	127	39	28	19
I	57	36	82	28	59	26	50	27	87	38	84	36	95	47	35	46	57	30	40	24
Total																				
H	90		381		419		205		287		338		168		66		329		145	
I	159		293		226		185		233		234		205		75		192		164	
Diversity																				
H	0.5		0.5		0.7		0.4		0.4		0.5		0.5		0.6		0.5		0.6	
I	0.6		0.8		0.7		0.5		0.4		0.5		0.6		0.7		0.6		0.6	

[a] Density is the mean of two replicate samples rounded to the nearest whole number.
[b] Calculated using the Shannon-Weaver formula ($\log_{10}$) using total numbers of organisms presented. Immature life stages were not included in the calculations.

Source: Dames & Moore, 1982
Checked by: WMW

Table 3.8-19

Mean Density[a] (No./L), Relative Abundance (%), and Diversity[b] of Zooplankton Collected at Duck Lake - Station L October 1977, March 1978 and May Through October 1978

	1977		1978													
	Oct		March		May		June		July		Aug		Sept		Oct	
	No./L	%	No./L	%	No./L	%	No./L	%	No./L	%	No./L	%	No./L	%	No./L	%
Cladocera	14	2	1	1	4	16	116	43	65	23	73	17	4	4	13	11
Copepoda	3	<1	1	1	1	6	22	8	187	65	283	68	4	4	9	8
Rotatoria	772	98	143	99	19	79	133	49	36	12	63	15	86	92	88	80
Total	789		145		25		272		288		419		94		110	
Diversity	0.2		0.3		0.7		0.6		0.5		0.7		0.1		0.3	

[a] Density is the mean of two replicate samples rounded to the nearest whole number.
[b] Calculated using the Shannon-Weaver formula ($\log_{10}$) using total numbers of organisms presented. Immature life stages were not included in the calculations.

Source: Dames & Moore, 1982
Checked by: WMW

Zooplankton diversity ranged from a low of 0.1 in September to a high of 0.7 recorded for both May and August (Table 3.8-19).

3.8.2.2.6 Deep Hole Lake

Zooplankton samples were collected from Deep Hole Lake (Station L) in October 1977, March 1978, and monthly from May through October 1978. Density and relative abundance of the three major taxa are presented in Table 3.8-20.

In 1978, density ranged from 68/L in March to 512/L in September. Density in October 1978 (234/L) was less than in October 1977 (693/L).

Rotifers were the most numerous of all zooplankton in October 1977, and June, August, September and October 1978 comprising from 59 to 84 percent of the collection. *Keratella cochlearis* and *K. taurocephala* were the most common rotifers collected.

Copepods were the most abundant organisms in March (72 percent) and May (62 percent) 1978 but comprised no more than 35 percent of any sample during the other sampling periods. Of the copepods, the immature naupliar form was the most abundant, and the cyclopoid and calanoid copepodites and the adult calanoid *Diaptomus minutus* were frequently identified but were never abundant. Cladocera were most abundant in July 1978 (40 percent) but generally did not comprise more than 26 percent of any sample. Although no single cladoceran species occurred in all of the samples, *Eubosmina tubicen*, *Daphnia dubia*, and *Holopedium gibberum* were the most common species.

Zooplankton diversity ranged from a low of 0.6 in March to a high of 1.0 in May (Table 3.8-20). From the maximum in May, diversity decreased through the summer months to 0.6 in September before increasing to 0.9 in October 1978.

3.8.2.2.7 Skunk Lake

Monthly zooplankton samples were collected from Skunk Lake (Station J) from June through October 1977. Density and relative abundance of the three major taxa identified are presented in Table 3.8-21.

The density of zooplankton was highest in July 1977 (1,293/L) but declined in subsequent months to a low of 35/L in October 1977.

Rotifers were the most abundant organisms in all samples and comprised from 47 to 88 percent of the organisms enumerated. *Conochilus unicornis* was the most numerous rotifer identified and represented 90 percent of the total rotifers during the study. Other rotifers identified were *Keratella quadrata* and *K. taurocephala*. The density of copepods was highest in June when 434/L (43 percent) were enumerated and lowest in October when 3/L (eight percent) were

Table 3.8-20

Mean Density[a] (No./L), Relative Abundance (%), and Diversity[b] of Zooplankton Collected at Deep Hole Lake - Station L October 1977, March 1978 and May Through October 1978

	1977		1978													
	Oct		March		May		June		July		Aug		Sept		Oct	
	No./L	%	No./L	%	No./L	%	No./L	%	No./L	%	No./L	%	No./L	%	No./L	%
Cladocera	110	16	<1	<1	8	7	20	16	44	40	15	5	61	12	61	26
Copepoda	51	7	49	72	73	62	31	25	40	35	30	11	58	11	19	8
Rotatoria	532	77	19	28	37	31	73	59	28	25	231	84	394	77	154	66
Total	693		68		118		124		112		275		512		234	
Diversity	0.7		0.6		1.0		0.9		0.8		0.6		0.6		0.9	

[a] Density is the mean of two replicate samples rounded to the nearest whole number.
[b] Calculated using the Shannon-Weaver formula ($\log_{10}$) using total numbers of organisms presented. Immature life stages were not included in the calculations.

Source: Dames & Moore, 1982
Checked by: WMW

Table 3.8-21

Mean Density[a] (No./L), Relative Abundance (%), and Diversity[b] of Zooplankton Collected at Skunk Lake - Station J June Through October 1977

	June		July		August		September		October	
	No./L	%	No./L	%	No./L	%	No./L	%	No./L	%
Cladocera	7	1	9	1	6	2	26	24	16	46
Copepoda	434	43	150	12	88	28	17	16	3	8
Rotatoria	569	56	1,134	88	218	70	68	61	16	47
Total	1,010		1,293		311		112		35	
Diversity	0.5		<0.1		0.1		0.7		0.8	

[a] Density is the mean of two replicate samples rounded to the nearest whole number.
[b] Calculated using the Shannon-Weaver formula ($\log_{10}$) using total numbers of organisms presented. Immature life stages were not included in the calculations.

Source: Dames & Moore, 1982
Checked by: WMW

collected. Immature nauplii were the major component of Copepoda present. Other commonly collected copepods were calanoid copepodites and the adult calanoid *Diaptomus leptopus*.

The temporal distribution of cladocerans was irregular. This group comprised two percent or less (9/L) of the population in June, July and August but 24 percent (26/L) and 46 percent (16/L) in September and October, respectively. *Chydorus sphaericus* and *Daphnia* sp. were the numerically important cladocerans. Zooplankton diversity ranged from a low of <0.1 in July 1977 to a high of 0.8 in October 1977 (Table 3.8-21).

3.8.2.3 Results of Periphyton Collections (1977-78)

3.8.2.3.1 Rice Lake

Periphytic algae samples were collected from Rice Lake in the vicinity of Station F monthly from May through October 1977 and from Station N in May and monthly from July through October 1977, and May and August 1978. The relative abundances of the five major taxa identified during the study are presented in Table 3.8-22.

Diatoms comprised over 85 percent of the collections except during August or September. During August 1977 at Station F diatoms comprised 72 percent of the collections and during September 1977 and August 1978 at Station N diatoms made up 69 and 47 percent of the respective collections. The most abundant diatom enumerated from Rice Lake was *Cocconeis placentula*. The largest relative abundance (35 percent) of algae other than diatoms was recorded for the blue-green algae at Station N in August 1978 when *Chroococcus minor* was the most abundant blue-green algae species.

3.8.2.3.2 Hemlock Creek

Periphytic algae samples were collected from Station A-1 in October 1977 and May and August of 1978. The relative abundances of the four major taxa identified during the study are presented in Table 3.8-22. The periphyton community at Station A-1 consisted primarily of diatoms (≤98 percent) and *Achnanthes minutissima* was most abundant. Other diatoms never comprised more than 10 percent of the periphyton community, except for *Fragilaria pinnata*, 16 percent in August 1978, and *A. microcephala*, 15 percent in May 1978.

3.8.2.3.3 Swamp Creek

Periphytic algae samples were collected at two locations in Swamp Creek upstream of Rice Lake, Stations D and E. Station D was sampled in March and monthly from May through October 1977 and May and July 1978, and Station E was sampled in March and monthly from May through July 1978, and Station E was sampled in March and monthly from May through July, September, and October 1977 and May and August 1978. The relative abundance of the six major taxa identified during the study are presented in Table 3.8-22.

Table 3.8-22

Relative Abundance (%) of Major Taxa of Periphyton Collected From Water Bodies in the Swamp Creek Drainage Basin March, May Through October 1977 and May and August 1978

	1977							1978	
Location/Taxa	March	May	June	July	Aug	Sept	Oct	May	Aug
Rice Lake (F and N)									
Bacillariophyceae									
F	—	97	100	97	72	95	86	—	—
N	—	93	—	87	97	69	98	100	47
Chlorophyceae									
F	—	<1	<1	2	2	4	2	—	—
N	—	6	—	1	1	17	2	<1	2
Chrysophyceae								—	
F	—	0	0	0	19	0	0	0	—
N	—	0	—	0	0	0	0		16
Cyanophyceae									
F	—	2	0	1	6	1	12	—	—
N	—	1	—	12	2	8	0	0	35
Xanthophyceae									
F	—	0	0	0	0	0	0	—	—
N	—	0	—	0	0	6	0	0	0
Hemlock Creek (A-l)									
Bacillariophyceae	—	—	—	—	—	—	99	99	98
Chlorophyceae	—	—	—	—	—	—	0	<1	2
Chrysophyceae	—	—	—	—	—	—	0	<1	0
Cyanophyceae	—	—	—	—	—	—	1	<1	<1
Swamp Creek (D and E)									
Bacillariophyceae									
D	72	62	86	100	48	99	100	100	97
E	98	94	99	—	67	100	100	100	96
Chlorophyceae									
D	0	<1	0	0	<1	0	0	<1	3
E	0	2	1	—	<1	0	<1	0	3

Table 3.8-22 *(Continued)*

Location/Taxa	1977 March	May	June	July	Aug	Sept	Oct	1978 May	Aug
Rice Lake (F and N)									
Chrysophyceae									
D	1	34	0	0	52	0	0	0	0
E	1	0	0	—	33	0	0	0	0
Cyanophyceae									
D	27	3	14	0	<1	1	0	0	<1
E	1	4	0	—	0	0	0	0	<1
Xanthophyceae									
D	0	0	0	0	0	0	0	0	0
E	0	0	0	—	<1	0	0	0	0
Euglenophyceae									
D	0	0	0	0	0	0	0	0	0
E	0	<1	0	—	0	0	0	0	0

— Indicates no sample collected.

Source: Dames & Moore, 1982
Checked by: WMW

Diatoms were the most abundant algae collected at both stations. This group comprised from 48 to 100 percent of the periphyton community at Station D and from 67 to 100 percent at Station E. The two most abundant diatom species encountered at both stations were *Cocconeis placentula* and *Achnanthes minutissima.*

Except for golden-brown algae, other major taxa did not comprise more than 27 percent of any one collection. Golden-brown algae, represented entirely by an unidentified *Chrysococcus*-like alga, accounted for 34 and 52 percent of the total periphyton at Station D in May and August 1977, respectively. The group accounted for 33 percent of the periphyton at Station E in August and were not found in May 1977. This motile algal form probably originated in an upstream, still water area. During the sampling period, there was a large beaver pond upstream of Station D that may have been the source of this algae.

3.8.2.3.4 Oak Lake

Periphyton samples were collected from Oak Lake monthly from May through October 1977 and May and August 1978. The relative abundances of the five major taxa identified are presented in Table 3.8-23.

Diatoms, green algae and golden-brown algae were most abundant in the collections. The relative abundance of diatoms exceeded 40 percent in all months sampled, except May 1977 and August 1978, and reached a maximum of 85 percent in October 1977. Abundant species of diatoms throughout the study were *Tabellaria flocculosa, T. fenestrata,* and *Frustulia rhomboides* var. *crussinevira.*

The highest relative abundances for the green algae were recorded in September 1977 (43 percent) and August 1978 (50 percent). During the other months sampled, the relative abundances for the green algae ranged from 15 percent in both August and October 1977 to 35 percent in July 1977. Species of *Oedogonium* were the most abundant green algae during the study. Golden-brown algae comprised up to 46 percent of the periphyton in May 1977, exhibited similar abundance in August 1977 (32 percent) and 1978 (30 percent) and were absent or found in low abundances in other collections. The unidentified *Chrysococcus*-like algae were the most abundant golden-brown algae.

3.8.2.3.5 Rolling Stone Lake

Periphyite algae samples were collected from Rolling Stone Lake at Stations M-2 and M-4 during October 1977, and May and August 1978. The relative abundances of the four major taxa are presented in Table 3.8-24. Diatoms accounted for 78 percent or more of the periphyton community at both stations during the study. August 1978 was the only month of the study in which the average relative abundance of diatoms was less than 90 percent. Although 30 of the total 72 diatoms enumerated were common to both sampling locations, only *Cocconeis placentula* was abundant at both. *Fragilaria pinorata* was abundant at Station M-2, and *Cybella cistula, Achnanthes minutissima,* and *Rhoicospenia curvata* were abundant at Station M-4.

Table 3.8-23

Relative Abundance (Percent Composition) of Major Taxa of Periphyton Collected from Oak Lake - Station G May Through October 1977, and May and August 1978

	1977						1978	
Taxa	May	June	July	August	September	October	May	August
Bacillariophyceae	22	56	52	49	55	85	44	13
Chlorophyceae	30	30	35	15	43	15	26	50
Chrysophyceae	46	0	0	32	0	0	2	30
Cyanophyceae	1	14	12	5	2	0	<1	6
Euglenophyceae	0	0	0	0	0	0	28	<1

Source: Dames & Moore, 1982
Checked by: WMW

Table 3.8-24

Relative Abundance (%) of Major Taxa of Periphyton Collected from Creek 12-9, Creek 11-4, Pickerel Creek and Rolling Stone Lake October 1977, May and August 1978

	1977	1978	
Location/Taxa	October	May	August
Rolling Stone Lake (M-2)			
Bacillariophyceae	93	99	88
Chlorophyceae	0	0	3
Chrysophyceae	0	0	7
Cyanophyceae	7	1	1
Rolling Stone Lake (M-4)			
Bacillariophyceae	99	97	78
Chlorophyceae	0	3	<1
Chrysophyceae	0	0	21
Cyanophyceae	1	0	1
Pickerel Creek (M-5)			
Bacillariophyceae	99	98	75
Chlorophyceae	0	0	1
Chrysophyceae	0	0	22
Cyanophyceae	1	2	2
Creek 12-9 (M-1)			
Bacillariophyceae	100	92	54
Chlorophyceae	0	7	1
Chrysophyceae	0	0	45
Creek 11-4 (M-3)			
Bacillariophyceae	100	94	54
Chlorophyceae	0	6	0
Chrysophyceae	0	0	40
Cyanophyceae	0	0	6

Source: Dames & Moore, 1982
Checked by: WMW

Unidentified *Chrysococcus*-like algae were the only golden-brown algae enumerated at Stations M-2 and M-4. These algae were collected only in August 1978 and comprised 21 and seven percent of the periphyton at Stations M-4 and M-2, respectively.

3.8.2.3.6 Streams Feeding Rolling Stone Lake

Periphytic algae samples were collected from Pickerel Creek at Station M-5 in October 1977 and May and August 1978. The relative abundances of the four major taxa identified during the study are presented in Table 3.8-24.

Diatoms accounted for 75 percent or more of the periphyton community. Golden-brown algae, blue-green algae and green algae comprised the remaining periphyton. the highest relative abundance for algae other than diatoms was 22 percent for the golden-brown algae in August 1978. Commonly occurring diatoms were *Eunotia curvata*, *Navicula minima*, and *Achnanthes lanceolata* and *A. minutissima*. The only golden-brown algae enumerated were unidentified *Chrysococcus*-like algae, which were encountered only in the August 1978 sample.

Periphytic algae samples were collected at Creek 12-9 (Station M-1) during October 1977 and May and August 1978. The relative abundances of the three major taxa identified during the investigation are presented in Table 3.8-24. Diatoms were the most common algae constituting 100 percent of the sample in October 1977 and subsequently decreasing to a relative abundance of 54 percent of the sample in August 1978. *Achnanthes minutissima* and *Cocconeis placentuala* were the most abundant diatoms.

Golden-brown algae were encountered only in August 1978 when the unidentified *Chrysococcus*-like algae and *Chrysococcus major* comprised 45 percent of the sample.

Periphytic algae samples were collected at Creek 11-4 (Station M-3) during October 1977, and May and August 1978. The relative abundances of the four major taxa identified during the investigation are presented in Table 3.8-24. During the study, diatoms were the most abundant component of the periphyton. The lowest relative abundance (54 percent) of the diatoms occurred in August 1978, and was associated with a golden-brown algae relative abundance of 40 percent. No diatom was particularly dominant. The most abundant species that were found in every sampling period were *Achnanthes lanceolata*, *A. minutissima*, *Nitzschia palea*, and *Cocconeis placentula.*

The only golden-brown algae enumerated were the unidentified *Chrysococcus*-like forms. These algae exhibited a relative density of 40 percent of the periphyton during August 1978, and were not collected in October 1977 and May 1978.

3.8.2.3.7 Little Sand Lake

Periphytic algae samples were collected from Little Sand Lake (Stations H and I) monthly from May through October 1977 and May and August 1978. The relative abundances of the six major taxa identified during the study are presented in Table 3.8-25.

Diatoms were generally the dominant periphytic algal forms collected at Little Sand Lake. Diatoms comprised 53 percent or more of the periphytic algae except during summer and fall when diatoms decreased at times to seven to 32 percent of the samples at Stations H and I, respectively. Only one diatom, *Tabellaria flocculosa*, was consistently abundant at Little Sand Lake. Other common forms found at both stations were *T. fenestrata*, *Frustulia rhomboides* var. *saxonica*, and *Eunotia curvata.*

Green algae were commonly collected in the periphytic community at both stations. Green algae were most abundant at Station H in June 1977 (41 percent) and at Station I in October 1977 (66 percent). Abundant green algal forms were *Oedogonium* sp. and *Mougeotia* sp.

Golden-brown algae typically ranged from 0 to 17 percent but on three occasions (Station H in July 1977 and both stations in August 1978) their abundance increased to 58 to 72 percent of the community. The most common golden-brown algae were the unidentified *Chrysococcus*- like algae and *Chrysococcus major.*

Blue-green algae were found in all collections except May 1978. With the exception of September 1977, when 61 percent of the sample at Station H was composed of blue-green algae, this group comprised 12 percent or less of the collections.

3.8.2.3.8 Duck Lake

Periphytic algae samples were collected from Duck Lake during October 1977 and monthly from May through October 1978. The relative abundances of the seven major taxa are presented in Table 3.8-25.

Diatoms dominated the periphytic algal community in June and October 1978 comprising 70 and 64 percent of the collections, respectively. Diatom abundance was similar to that of green algae in May 1978, and blue-green algae in August and September 1978. *Tabellaria fenestrata* was the most abundant diatom and *T. flocculosa* was commonly collected but in low abundance.

Green algae were most abundant in October 1977 (50 percent) and May 1978 (49 percent). At other times their relative abundance did not exceed 28 percent of the collections. *Oedogonium* sp. and *Ulothrix* sp. were the most abundant green algal forms. Golden-brown algae comprised 37 and 28 percent of the community in August and September 1978, respectively, but other times did not exceed 14 percent. Blue-green algae comprised 40 percent of the collection in July 1978 but did not exceed 8 percent during any other sampling periods. Common golden-brown algae

Table 3.8-25

Relative Abundance (%) of Major Taxa of Periphyton Collected at Deep Hole, Duck, Little Sand and Skunk Lake May Through October 1977 and May Through October 1978

	1977						1978					
Location/Taxa	May	June	July	Aug	Sept	Oct	May	June	July	Aug	Sept	Oct
Little Sand Lake (H)												
Bacillariophyceae	53	55	8	60	22	63	62	—	—	7	—	—
Chlorophyceae	29	41	27	38	15	29	34	—	—	13	—	—
Chrysophyceae	17	0	61	1	2	0	4	—	—	72	—	—
Cyanophyceae	1	4	4	1	61	6	0	—	—	7	—	—
Euglenophyceae	0	0	0	0	0	0	0	—	—	1	—	—
Xanthophyceae	0	0	0	0	0	3	0	—	—	0	—	—
Little Sand Lake (I)												
Bacillariophyceae	61	73	56	52	77	32	68	—	—	18	—	—
Chlorophyceae	11	21	25	43	13	66	20	—	—	22	—	—
Chrysophyceae	16	0	7	3	1	2	13	—	—	58	—	—
Cyanophyceae	12	6	11	2	9	<1	0	—	—	3	—	—
Duck Lake (K)												
Bacillariophyceae	—	—	—	—	—	22	51	70	34	37	32	64
Chlorophyceae	—	—	—	—	—	50	49	20	11	15	20	28
Chrysophyceae	—	—	—	—	—	0	<1	8	14	37	28	2
Cyanophyceae	—	—	—	—	—	1	0	2	40	8	7	1

Table 3.8-25 (*Continued*)

Location/Taxa	1977						1978					
	May	June	July	Aug	Sept	Oct	May	June	July	Aug	Sept	Oct
Little Sand Lake (H)												
Euglenophyceae	—	—	—	—	—	0	0	<1	0	<1	13	5
Xanthophyceae	—	—	—	—	—	0	0	0	0	2	0	0
Dinophyceae	—	—	—	—	—	27	0	0	0	0	0	0
Deep Hole Lake (L)												
Bacillariophyceae	—	—	—	—	—	69	60	66	42	34	43	51
Chlorophyceae	—	—	—	—	—	31	9	16	48	29	36	32
Chrysophyceae	—	—	—	—	—	<1	30	17	4	33	9	5
Cyanophyceae	—	—	—	—	—	0	<1	1	6	4	2	11
Euglenophyceae	—	—	—	—	—	0	0	0	0	0	10	2
Dinophyceae	—	—	—	—	—	0	0	0	0	<1	0	0
Skunk Lake (J)												
Bacillariophyceae	—	83	25	28	98	87	—	—	—	—	—	—
Chlorophyceae	—	14	3	17	2	9	—	—	—	—	—	—
Chrysophyceae	—	0	72	56	0	0	—	—	—	—	—	—
Cyanophyceae	—	3	1	<1	<1	4	—	—	—	—	—	—

— Indicates no sample collected.

Source: Dames & Moore, 1982
Checked by: WMW

included an unidentified *Chrysococcus*-like algae and *Chrysococcus major*. *Hapalosiphon flexuosus* was the most common blue-green algal species.

3.8.2.3.9 Deep Hole Lake

Periphytic algae samples were collected from Deep Hole Lake during October 1977 and monthly from May through October 1978. The relative abundance of the six major taxa identified during the study is presented in Table 3.8-25.

Diatoms, green algae, and golden-brown algae were the predominant groups of periphytic algae. Diatoms were most abundant (43 to 69 percent) in spring and autumn. However, they were similar in abundance to green algae in July 1978 and to green algae and blue-green algae in August 1978. The most abundant diatom species was *Tabellaria flocculosa*, and *T. fenestrata* was commonly collected. Green algae generally were second in abundance to diatoms throughout the study. The most common green algal form encountered was the genus *Oedogonium*. The primary forms of golden-brown algae were the unidentified *Chrysococcus*-like algae.

3.8.2.3.10 Skunk Lake

Periphytic algae samples were collected from Skunk Lake monthly from June through October 1977. The relative abundances of the four major taxa identified during the investigation are presented in Table 3.8-25.

Diatoms were the most abundant periphytic algal class collected in June, September and October 1977 comprising over 80 percent of these samples. However, their abundance decreased to <30 percent of the July and August collections. The most abundant diatom was *Nitzschia palea*. Other common forms were *Frustulia rhomboides* var. *saxonica*, *Tabellaria flocculosa* and *T. fenestrata*.

Golden-brown algae comprised 72 and 56 percent of the July and August samples, respectively. The collections primarily consisted of unidentified *Chrysococcus*-like algae.

3.8.2.3.11 Wolf River

A summary of characteristics of the Wolf River is presented in Table 3.8-26. From its source to the Town of Pearson, the river has a generally flat gradient, 0.7 m/km (3.7 feet/mile), reflecting the large areas of lakes and wetlands through which it flows. Below Pearson the character of the river begins to change and the gradient becomes steeper, 1.9 m/km (9.8 feet/mile), and several rapids are found in this stretch of river.

Samples were collected at the Wolf River at Station Y, located upstream from the confluence with Swamp Creek, and Station Z, located downstream of the confluence with Pickerel Creek (Figure 3.8-1). Periphytic algae samples were collected from the Wolf River, Stations Y and Z,

Table 3.8-26

Relative Abundance (Percent Composition) of Major Taxa of Periphyton Collected from the Wolf River, Stations Y and Z October 1977 Though October 1978

	1977	1978		
Taxa	October	May	August	October
Bacillariophyceae				
Y	96	98	17	100
Z	99	100	37	94
Chlorophyceae				
Y	0	0	19	0
Z	1	0	1	<1
Chrysophyceae				
Y	0	1	58	0
Z	0	0	62	5
Cyanophyceae				
Y	4	0	6	0
Z	0	0	<1	<1

Source: Dames & Moore, 1982
Checked by: WMW

during October 1977 and May, July, and October 1978. The relative abundances of the four major taxa identified during the study are presented in Table 3.8-26.

Periphytic algal communities were generally similar at the two Wolf River stations. Diatoms accounted for 94 to 100 percent of each sample except in August 1978 when their relative abundance decreased to 17 and 37 percent at Stations Y and Z, respectively. *Cocconeis placentula*, *Fragilaria pinnata*, and *Achnanthes minutissima* were the most abundant diatoms at both stations.

In August 1978, golden-brown algae, which generally accounted for five percent or less of any collection, comprised 58 and 62 percent of the samples at Stations Y and Z, respectively. The unidentified *Chrysococcus*-like algae were the only golden-brown algae collected.

3.8.2.4 Results of Aquatic Macrophytic Collections (1977-78)

3.8.2.4.1 Rice Lake

Dames & Moore (1982) described the aquatic macrophyte community of Rice Lake as dense and consisting mainly of emergent species with some submersed and floating species (Figure 3.8-14). Most of the emergent vegetation in the central portion of the lake was wild rice *Zizania aquatica* interspersed with sparse beds of yellow water lily *Nuphar variegatum* and arrowhead *Sagittaria latifolia*. Moderate to dense beds of water marigold *Megalodonta beckii*, flatstem pondweed *Potamogeton zosteriformis*, and pondweed *P. friesii* were also observed.

The channel area where Swamp Creek meanders through Rice Lake was characterized by dense submerged vegetation, primarily coontail *Ceratophyllum demersum* and water weed *Elodea canadensis*, with moderate occurrences of the previously listed emergent species.

The Swamp Creek inlet area of Rice Lake was characterized by a dense emergent growth of bulrush *Scirpus fluviatilis* and bur reed *Sparganium eurycarpum*. The vegetation in the shallow area adjacent to the south shore of the lake was composed of sparse to moderate beds of arrowhead, yellow water lily, water weed, and water lily (*Nymphaea tuberosa*).

Floating vegetation, observed throughout the lake, consisted primarily of big duckweed (*Spirodela polyrhiza*) and star duckweed(*Lemna trisulca*). The common emergent shoreline vegetation included moderate stands of cattail (*Typha latifolia*), sedge (*Scirpus validus*), and water hemlock (*Cicuta bulbifera*). Results of aquatic macrophyte investigation completed in 1994 are included in Section 3.9 where a complete inventory of plants is provided.

3.8.2.4.2 Oak Lake

Aquatic vegetation was present along the northern, eastern, and southwestern shorelines of Oak Lake in the littoral zone in water ≤ m (3.3 feet) in depth (Figure 3.8-14). Stands were sparse and were comprised primarily of spike rush (*Eleocharis smallii*). Water lobelia (*Lobelia dortmann*), pipewort (*Eriocaulon septangulare*), bur reed (*Sparganium angustifolium*), and rush (*Juncus pelocarpus*) were also identified but collectively occupied less than 50 percent of all aquatic macrophytes encountered. The WDNR also found dwarf milfoil (*Myriophyllum tenellum*), waterwort (*Elatine minima*), three-way sedge (*Dulichium arundinaceum*), and marsh purselane (*Ludwigia palustris*) (Ramharter, 1982).

3.8.2.4.3 Pond 25-11

Dense growths of yellow water lily were observed throughout the pond (Figure 3.8-14). The two predominant plant types located in moderate growths along the mud banks of the pond were spike rush (*Eleocharis obtusa*) and carex (*Carex rostrata*). Other incidental shoreline vegetation included St. John's-wort (*Hypericum majus*), beggar's tick (*Bidens cernua*), manna grass (*Glyceria boeralis*), and smartweed (*Polygonum pensylvanicum*).

3.8.2.4.4 Hoffman Springs

The aquatic vegetation was very sparse throughout the pond. The vegetation that was observed in shoreline areas was bitter cress (*Cardamine pensylvanica*) and muskgrass (*Chara* sp.).

3.8.2.4.5 Rolling Stone Lake

Submersed aquatic vegetation in Rolling Stone Lake was dense, floating vegetation was moderate, and emergent vegetation was sparse (Figure 3.8-14).

The submersed vegetation throughout the lake consisted predominantly of water milfoil (*Myriophyllum exalbenscens*), flatstem pondweed and whitestem pondweed (*Potamogeton praelongus*) (WDNR, 1978). Additional observations in the northern littoral area of the lake between Pickerel Creek and Creek 12-9 (Figure 3.8-14) indicated that these same macrophytes were predominant although coontail and water weed were also common. Vegetation beds near Pickerel Creek included sparse stands of sedge (*Carex* sp.), whereas shoreline areas adjacent to Creek 12-9 included moderate beds of white water lily (*Nymphaea* sp.) and yellow water lily (*Nuphar* sp.). Interspersed within these beds in moderate to sparse occurrence were the floating species star duckweed, big duckweed, and duckweed (*Lemna minor*). Additional shoreline vegetation between Creeks 11-4 and 12-9 included sparse stands of bulrush (*Scirpus* sp.). In addition, the WDNR found wild celery (*Vallisneria americana*), sago pondweed (*Potamogeton pectinatus*) and bur reed (*Sparganium* sp.) in Rolling Stone Lake (Ramharter, 1982).

3.8.2.4.6 Little Sand Lake

Aquatic macrophyte vegetation in Little sand Lake was located primarily along shoreline areas in water depths to one m (3.3 feet) (Figure 3.8-14). The pondweed *Potamogeton epihydrus*, which occurred sparsely throughout the lake, was typically found at depths less than one m (3.3 feet).

Aquatic macrophyte beds in the shallow ares along the northern, eastern and southwestern shore areas, characterized primarily by sandy substrates, were dominated by spike rush. This spike rush comprised approximately 75 percent of the vegetative cover in these areas. Other species common in these areas were: yellow water lily (*Nuphar variegatum* and *N. rubrodiscum*), waterwort (*Elatine triandra*), narrow-leaved bur reed (*Sparganium angustifolium*), mud rush (*Juncus pelocarpus*), water lobelia, and bulrush (*Scirpus torreyi*). Vegetation along the northeastern shoreline area that had primarily silt-organic substrate was characterized by yellow water lily (*Nuphar rubrodiscum*), bur reed (*Sparganium fluctuans*), and pondweed (*Potamogeton epihydrus*). Common species in the southeastern portion of the lake were watershield (*Brasenia schreberi*), arrowhead (*Sagittaria graminea*), yellow water lily (*N. rubrodiscum*), pipewort, and fluctuating bur reed (*Sparganium fluctuans*). Sparsely occurring macrophytes, including the white water lily (*Nymphaea tuberosa*) and bur reed (*Sparganium angustifolium*), were observed in the southwestern area of the lake at a water depth of 1.2 m (four feet).

Additional species found by the WDNR were spike rush (*Eleocharis smallii*), quillwort (*Isoete* spp.), three-way sedge, water hemlock (*Cicuta bulbifera*), and dwarf milfoil (Ramharter, 1982).

3.8.2.4.7 Deep Hole Lake

The primary areas of vegetation in the littoral zone of Deep Hole Lake extended from the shoreline to a depth of one m (3.3 feet) (Figure 3.8-14). Common aquatic macrophyte species, in order of apparent relative abundance, were arrowhead (*Sagittaria latifolia*), spike rush (*Eleocharis smallii*), yellow water lily (*Nuphar variegatum*), and pondweed (*P. epihydrus*). These species were observed in moderate stands in all areas along the northern, western, southwestern and eastern shorelines. Bur reed (*Sparganium fluctuans*) and cattail were observed in sparse stands along parts of the southern and eastern lake shoreline areas. The only aquatic macrophyte found at depths less than one m (>3.3 feet) was the pondweed, which occurred infrequently.

Nonwoody vegetation found in shoreline wetland areas was commonly comprised of cut grass (*Leersia oryzoides*), manna grass (*Glyceria canadensis*), and sedges (*Scirpus cyperinus, Carex rostrata*, and *Dulichium arundinaceum*). Less common species in these areas included beggar's tick and marsh St. John's wort (*Triadenum fraseri*).

Additional species found by the WDNR were arrowhead (*Sagittaria* sp.), bladderwort (*Utricularia vulgaris*), water arum (*Calla palustris*), water lobelia, pipewort, rush, *Juncus pelocarpus*, waterwort (*Elatine minima*) and quillwort (*Isoette echinospora*) (Ramharter, 1982).

3.8.2.4.8 Duck Lake

Aquatic macrophytes are primarily limited to sparse growths in southern and northwestern areas of Duck Lake (Figure 3.8-14). Species that were found in these areas and that comprised approximately 75 percent of the macrophyte community were yellow water lily (*Nuphar variegatum*) and bur reed (*Sparganium fluctuans*). Water arum was also observed but was limited in abundance.

Other species occurring in sparse stands were pipewort and water lily (*Nymphaea* sp.). Pipewort was observed along the southern portions of the lake shore, and the water lily primarily along the northwestern shore. A moss mat composed of *Drepanocladus exannulatus* overlaid the sediment over most of the lake.

Uprooted vegetation that consisted primarily of pondweed (*Potamogeton confervoides*), a species listed as threatened in Wisconsin, was found along the east and southeast shoreline in July 1980. The identification of this species was made by Dr. H. Iltis of Madison, Wisconsin, from several intact specimens. In addition to the lake vegetation survey in 1978, littoral areas of the lake were searched in July and October 1980 from a canoe and the deep portions in October 1980 utilizing snorkel and scuba gear, specifically to locate this rooted aquatic plant. No rooted specimens were found.

Additional species found by the WDNR in verification studies were white water lily (*Nymphaea tuberosa*), pipewort, pondweed (*Potamogeton epihydrus*), manna grass (*Glyceria canadensis*), three-way sedge (*Carex limosa*), pitcher plant (*Sarracenia purpurea*), bog cinquefoil (*Potentilla palustris*), iris (*Iris versicolor*), small bur reed (*Sparganium minima*), quillwort (*Isoeste* sp.), *Nitella* sp., and arrowhead (*Sagittaria* sp.) (Ramharter, 1982).

3.8.2.4.9 Skunk Lake

Generally, aquatic vegetation occurred in moderate stands throughout the lake but was most abundant along shoreline areas (Figure 3.8-14). The vegetation was primarily pondweed (*Potamogeton* sp.) and yellow water lily (*Nuphar variegatum*). Shoreline areas were characterized by moderate growths of spike rush.

Additional species reported by the WDNR in Skunk Lake were three-way sedge (*Dulichium arundinaceum*), Robbin's pondweed (*Potamogeton robbinsii*), bulrush (*Scirpus* sp.), cattail (*Typha latifolia*), bladderwort (*Utricularia* sp.), sphagnum moss (*Sphagnum* sp.), leatherleaf (*Chamaedaphne calyculata*), and water moss (*Drepnocladus* sp.) (Druckenmiller, 1983).

3.8.2.4.10 Pond 31-13

Moderate to sparse vegetation growths in Pond 31-13 included bladderwort and yellow water lily (*Nuphar variegatum*) (Figure 3.8-14). Other sparsely occurring shoreline and wetland vegetation included sedges (*Carex oligosperma* and *C. limosa*) and pitcher plant (*Sarracenia* sp.).

3.8.2.4.11 Pond 6-8

Aquatic macrophytes observed in moderate stands in Pond 6-8 were yellow water lily (*Nuphar variegatum*) throughout the pond and water arum along the shoreline and adjacent wetland areas (Figure 3.8-14). Other vegetation occurring in moderate to sparse stands along the shoreline included white water lily, and the sedges *Dulichium arundinaceum* and *Carex limosa*. Common nonwoody, riparian vegetation, which contained a variety of plant types associated with bog areas, included primrose (*Lysimaehia terrestris*), beggar's tick (*Bidens comosa*), marsh cinquefoil, iris, marsh St. John's-wort, sundew (*Drosera* sp.), and pitcher plant.

3.8.2.4.12 Pond 35-7

Yellow water lily (*Nuphar variegatum*) was observed in moderate to dense growths throughout Pond 35-7 (Figure 3.8-14). Other macrophytes occurring moderately to sparsely in limited areas along shoreline or marginal wetland areas were as follows: cattail, water arum, pondweed (*Potamogeton epihydrus*), the sedges *Carex lacustris*, *C. crawfordii* and *C. comosa*, and the grass *Muhlenbergia glomerata*. Additional species found by the WDNR in verification studies were muskgrass, (*Chara* sp.), water hemlock, and pitcher plant (*Sarracenia purpurea*) (Ramharter, 1982).

3.8.2.4.13 Pond 34-1

The aquatic vegetation located within and along the shoreline of Pond 34-1 included sparse growths of bladderwort (*Utricularia vulgaris* var. *americana*), coontail, water arum, bulrush (*Scirpus cyperinus*), and duckweed (*Lemna* ef. *minor*) (Figure 3.8-14). Wetland vegetation occurring in moderate abundance included marsh bluebell (*Campanula aparinoides* var. *grandiflora*) and water hemlock. Additional species found by the WDNR in verification studies were pitcher plant (*Sarracenia purpurea*), yellow water lily (*Nuphar variegatum*), and water hemlock (Ramharter, 1982).

Aquatic macrophytes and vascular plants along the adjacent stream banks were inventoried in Swamp Creek and the Wolf River in June 1983. The relative abundance of rooted aquatic vegetation was higher in the upstream portion of Swamp Creek and was reduced in the downstream segment and in the Wolf River (Table 3.8-27). The most abundant species throughout Swamp Creek and the Wolf River were water-weed (*Anacharis canadensis*), arrowhead (*Sagittaria* sp.), bur reed (*Sparganium* sp.), and pondweed (*Potamogeton epihydrus* and *P. praelongus*). Several small scattered patches of northern manna grass (*Glyceria borealis*) were also present in the lower portion of Swamp Creek in the floating leaf form. No wild rice beds were identified.

Total areal coverage of the bottom by rooted vascular plants ranged from approximately 80 percent in some areas upstream of County Trunk Highway K to 20 percent in portions of the downstream segment of Swamp Creek. Plant species composition of the bottom and adjacent

Table 3.8-27

Mean Density[a] (No./m²), Relative Abundance (%), and Diversity[b] of Bethnic Macroinvertebrates Collected from Wolf River - Stations Y and Z March, May, August, and October 1978

	March		May		August		October	
	No./m²	%	No./m²	%	No./m²	%	No./m²	%
Oligochaeta								
Y	273	1	2,644	31	101	2	29	2
Z	72	1	1,149	13	3,664	28	1,394	26
Isopoda								
Y	0	0	29	<1	0	0	0	0
Z	0	0	0	0	0	0	0	0
Amphipoda								
Y	675	4	1,552	18	0	0	0	0
Z	0	0	646	8	72	1	101	2
Ephemeroptera								
Y	58	<1	14	<1	14	<1	0	0
Z	0	0	29	<1	503	4	0	0
Trichoptera								
Y	302	2	72	1	43	1	0	0
Z	29	<1	460	5	560	4	58	1
Chironomidae								
Y	2,126	11	2,126	25	2,471	37	0	0
Z	503	8	2,399	28	2,313	18	43	1
Gastropoda								
Y	9,180	48	1,135	13	1,437	22	345	18
Z	3,692	58	1,135	13	1,940	15	1,925	36
Pelecypoda								
Y	1,034	5	388	5	2,284	34	1,078	57
Z	1,623	26	129	2	1,451	11	359	7
All Others[c]								
Y	5,387	28	618	7	287	4	445	24
Z	445	7	2,644	21	2,457	19	1,494	28

Table 3.8-27 *(Continued)*

	March		May		August		October	
	No./m²	%	No./m²	%	No./m²	%	No./m²	%
Total								
Y	19,036	100	8,577	10	6,637	100	1,896	100
Z	6,364	100	8,591	0	12,959	100	5,373	100
				10				
				0				
Diversity								
Y	0.6		1.0		0.7		0.6	
Z	0.6		1.0		1.1		0.9	

[a] Density is the mean of three or five replicate samples.
[b] Calculated using Brillouin's formula ($\log_{10}$) using the numbers of organisms.
[c] Includes Coelenterata, Tricladida, Alloeocoela, Nemertea, Nematoda, Hirudinea, Hydracarina, Anisoptera, Zygoptera, Hemiptera, Lepidoptera, Coleoptera and Diptera other than Chironomidae.

Source: Dames & Moore, 1982
Checked by: WMW

bank of Swamp Creek and the Wolf River was typical for the existing substrate and flow conditions.

3.8.2.5 Results of Benthic Macroinvertebrate Collections conducted in 1977 and 1978.

3.8.2.5.1 Rice Lake

Benthic macroinvertebrate samples were collected from Rice Lake at Stations F and N in March, May, August, and October 1977 and March 1978, and from Station N in May and August 1978. The eight major taxa collected in quantitative sampling and their relative abundance are presented in Table 3.8-28. A total of 103 and 114 taxa were identified during quantitative sampling conducted at Stations F and N, respectively, and an additional eight taxa were collected in qualitative samples from Rice Lake.

In 1977, considerably greater fluctuations in density of benthic macroinvertebrates occurred at Station N than at Station F. At Station F density ranged from 16,691/m^2 in August to 32,911/m^2 in October, and at Station N from 6,146/m^2 in March to 57,987/m^2 in August. In 1978 at Station N densities in March, May, and August differed up to seven fold (March) from corresponding months in 1977 but were within the range observed throughout 1977. The four most commonly collected groups at Rice Lake were Chironomidae (midges), Amphipoda (amphipods), Oligochaeta (worms), and Gastropoda (snails) (Table 3.8-28). The common midges at both sampling locations were *Dicrotendipes* sp., *Chironomus* sp., *Procladius* sp., and *Tanytarsus* sp.

The amphipod most commonly found in the benthic samples from the two Rice Lake sampling locations was *Hyalella azteca*; other amphipods identified were *Cragonyx* sp. and *Gammarus pseudolimnaeus*. Enumerations of worms from the two Rice Lake sampling locations indicated that naidid species, *Nais* sp. and *Dero digitata* were most abundant, although immature tubificid forms were occasionally collected in moderate to high densities. *Amnicola* sp. was the most numerous snail collected.

Mean benthic diversity values were similar for these two sampling locations and ranged from 0.8 at Station N in March 1977 to 1.3 at both Stations N and F in May 1977 (Table 3.8-28).

3.8.2.5.2 Hemlock Creek

Macroinvertebrate samples were collected from Hemlock Creek at Station A-1 in June, August, and October 1977, and March, May, and August 1978. The nine major taxa collected in quantitative sampling and their density and relative abundance are presented in Table 3.8-29.

In 1977, total density of benthic forms ranged from 2,069/m^2 in June to 23,877/m^2 in October. In 1978 density ranged from 14,166/m^2 in March to 28,388/m^2 in May. The community was dominated by midges, which comprised from 57 to 92 percent of numbers collected. *Tanytarsus* sp. and *Procladius* sp. were the most abundant genera.

Table 3.8-28

Mean Density[a] (No./m²), Relative Abundance (%), and Diversity[b] of Bethnic Macroinvertebrates Collected from Rice Lake - Stations F and N March, May, August and October 1977, and March, May and August 1978

	1977								1978					
	March		May		August		October		March		May		August	
	No./m²	%	No./m²	%	No./m²	%	No./m²	%	No./m²	%	No./m²	%	No./m²	%
Oligochaeta														
F	1,905	9	3,267	16	5,034	30	10,146	31	3,477	15	—	—	—	—
N	60	1	1,052	4	11,947	21	1,060	6	603	1	144	1	1,250	12
Isopoda														
F	0	0	0	0	0	0	0	0	29	<1	—	—	—	—
N	9	<1	0	0	0	0	0	0	0	0	0	0	29	<1
Amphipoda														
F	9,051	44	3,534	17	4,681	28	2,724	8	3,276	14	—	—	—	—
N	2,095	34	3,026	11	11,534	20	4,431	27	8,347	18	3,189	18	3,592	33
Ephemeroptera														
F	43	<1	34	<1	172	1	17	<1	29	<1	—	—	—	—
N	60	1	17	<1	78	<1	60	<1	0	0	0	0	0	0
Trichoptera														
F	69	<1	69	<1	9	<1	34	<1	72	<1	—	—	—	—
N	60	1	328	1	60	<1	43	<1	58	<1	101	1	115	1
Chironomidae														
F	5,413	26	6,603	32	1,965	12	7,439	23	6,882	30	—	—	—	—
N	2,465	40	17,024	62	23,162	40	3,569	22	9,108	20	3,132	17	2,399	22

Table 3.8-28 (*Continued*)

	1977								1978					
	March		May		August		October		March		May		August	
	No./m²	%	No./m²	%	No./m²	%	No./m²	%	No./m²	%	No./m²	%	No./m²	%
Gastropoda														
F	3,017	15	2,957	14	2,345	14	8,008	24	7,614	33	—	—	—	—
N	595	10	3,526	13	3,198	6	4,888	30	25,041	54	9,051	50	1,911	18
Pelecypoda														
F	379	2	3,120	15	948	6	1,940	6	216	1	—	—	—	—
N	491	8	129	<1	52	<1	466	3	474	1	330	2	431	4
All Others[c]														
F	552	3	1,328	6	1,465	9	2,604	8	1,250	5	—	—	—	—
N	310	5	2,146	7	7,956	14	2,008	12	3002	6	2,212	12	1,006	9
Total														
F	20,429	100	20,912	10	16,691	100	32,911	100	22,843	100	—	—	—	—
N	6,146	100	27,248	0	57,987	100	16,524	100	46,635	100	18,160	100	10,732	100
				10										
				0										
Number of Replicates	5		5		5		5		3		3		3	
Diversity														
F	0.9		1.3		1.1		1.1		1.0		—		—	
N	0.8		1.3		1.1		1.0		1.1		0.9		1.0	

[a] Density is the mean of three or five replicate samples, as indicated above, rounded to the nearest whole number.
[b] Calculated using Brillouin's formula ($\log_{10}$) using the total numbers of organisms presented.
[c] Includes Hydracarina, Coelenterata, Tricladida, Lepidoptera, Coleoptera, Alloeocoela, Hirudinea, Ostracoda, Odonata, Hemiptera, Nematoda, and Diptera other than Chironomidae.

— No sample collected.

Source: Dames & Moore, 1982
Checked by: WMW

Table 3.8-29

Mean Density[a] (No./m^2), Relative Abundance (%), and Diversity[b] of Bethnic Macroinvertebrates Collected from Hemlock Creek - Station A-1 June, August and October 1977, and March, May and August 1978

	1977						1978					
	June		August		October		March		May		August	
	No./m^2	%	No./m^2	%	No./m^2	%	No./m^2	%	No./m^2	%	No./m^2	%
Oligochaeta	216	10	724	3	974	4	101	1	445	2	761	4
Isopoda	0	0	0	0	0	0	0	0	14	<1	0	0
Amphipoda	17	1	0	0	34	<1	29	<1	43	<1	115	1
Ephemeroptera	0	0	95	<1	3,414	14	216	2	302	1	3,060	16
Trichoptera	9	<1	0	0	60	<1	58	<1	101	<1	618	3
Chironomidae	1,172	57	18,300	85	13,326	56	11,809	83	26,205	92	12,140	65
Gastropoda	60	3	0	0	2,612	11	747	5	201	1	58	<1
Pelecypoda	284	14	86	<1	1,155	5	690	5	359	1	230	1
All Others[c]	310	15	2,440	11	2,302	10	517	4	718	3	1,710	9
Total	2,069	100	21,645	100	23,877	100	14,166	100	28,388	100	18,691	100
Number of Replicates	5		5		5		3		3		3	
Diversity	0.6		0.7		1.0		0.9		0.6		1.0	

[a] Density is the mean of three or five replicate samples, rounded to the nearest whole number.
[b] Calculated using Brillouin's formula ($\log_{10}$) using the total number of organisms presented.
[c] Includes Nematoda, Hirudinea, Ostracoda, Hydracarina, Anisoptera, Hemiptera, Megaloptera, Lepidoptera, Coleoptera and Diptera other than Chironomidae.

Source: Dames & Moore, 1982
Checked by: WMW

Benthic organisms from other major taxonomic groups, mayflies and worms, were commonly collected but comprised not more than 16 percent of any sample. Members of the genus *Caenis* were the most abundant mayfly, and the immature tubificid form with hair setae was the most abundant worm enumerated during the study.

Pelecypods (clams) enumerated from Hemlock Creek were typically from the family Sphaeriidae, although one specimen from the family Unionidae was recorded. The mature spaeriids enumerated were *Pisidium* sp. and *Sphaerium* sp. The benthic diversity values at Hemlock Creek were relatively consistent. They ranged from 0.6 in June 1977 and May 1978 to 1.0 in October 1977 and August 1978 and averaged 0.8 (Table 3.8-29).

Taxa collected by the WDNR during verification studies were collected from Swamp Creek at Stations D and E in March, May, August, and October 1977 and March, May, and August 1978. The eight major taxa collected in quantitative sampling and their density and relative abundance are presented in Table 3.8-30. A total of 126 and 106 taxa were identified in quantitative samples and an additional nine and 16 taxa were identified in qualitative samples from Stations D and E, respectively.

Density as consistently higher at Station E than at Station D. In 1977 density at Station D ranged from 1,173/m^2 in March to 3,864/m^2 in October and at Station E from 7,189/m^2 in August to 9,723/m^2 in October. In 1978 density at Station D ranged from 612/m^2 in May to 1,926/m^2 in August and at Station E from 4,856/m^2 in March to 12,298/m^2 in August.

Although midges were the most abundant organisms in the benthic communities at both stations, more were consistently collected at Station E than at Station D. *Micropsectra* sp. and *Rheotanytarsus* sp. were the most abundant genera at Station D, whereas *Procladius* sp., *Tanytarsus* sp., and *Cladotanytarsus* were most abundant at Station E.

Caddisflies comprised from 11 to 44 percent of the total benthos enumerated at Station D during the study, but were ≤ 1 percent at Station E. Twenty-three caddisfly genera were identified in quantitative samples from Station D, whereas only seven genera were identified from Station E. Caddisflies from only two of these genera were identified from both locations. For Station D, the most common and abundant caddisflies were generally *Leucotrichia pictipes*, *Glossosoma* sp., and various *Hydropsyche* species. At Station E, the most common caddisflies were *Platycentropus* sp. and *Phylocentropus* sp.

Mayflies also comprised similar percentages of the total benthos at the two sampling locations, from two to 14 percent at Station D, and from two to 22 percent at Station E. However, the numbers of organisms and the individual genera of mayflies occurring at the two locations were generally quite different. Density of mayflies ranged from 32 to 231/m^2 at Station D and from 172 to 2,000/m^2 at Station E. Only four of the 13 total genera identified in quantitative samples occurred at both sampling locations. At Station D mayflies from the general *Ephemerella* sp., *Baetis* sp., *Paraleptophlebia* sp., and *Stenonema* sp. were common. The most abundant

Table 3.8-30

Mean Density[a] (No./m^2), Relative Abundance (%), and Diversity[b] of Bethnic Macroinvertebrates Collected from Swamp Creek - Stations D and E March, May, August and October 1977, and March, May and August 1978

	1977								1978					
	March		May		August		October		March		May		August	
	No./m^2	%	No./m^2	%	No./m^2	%	No./m^2	%	No./m^2	%	No./m^2	%	No./m^2	%
Oligochaeta														
D	0	0	3	<12	9	2	11	<1	4	<1	0	0	18	1
E	1,207	13	2,474	0	716	10	1,146	12	273	6	216	3	819	7
Amphipoda														
D	0	0	0	0	0	0	0	0	0	0	4	1	0	0
E	1,319	15	698	6	34	<1	138	1	115	2	86	1	345	3
Ephemeroptera														
D	93	8	100	8	179	5	213	6	166	14	68	11	32	2
E	172	2	233	2	716	10	2,000	21	704	14	1,853	22	488	4
Trichoptera														
D	404	34	575	44	460	12	1,363	35	148	12	65	11	274	14
E	78	1	43	<1	17	<1	9	<1	0	0	0	0	158	1
Chironomidae														
D	378	32	189	14	1,955	52	1,151	30	551	46	180	29	540	28
E	3,776	42	5,586	44	2,655	37	2,569	26	1,379	28	2,715	32	3,663	30
Gastropoda														
D	76	6	86	7	166	4	408	11	79	7	32	5	194	10
E	750	8	1,836	15	612	9	560	6	359	7	1,537	18	230	2

Table 3.8-30 *(Continued)*

	1977								1978					
	March		May		August		October		March		May		August	
	No./m²	%	No./m²	%	No./m²	%	No./m²	%	No./m²	%	No./m²	%	No./m²	%
Pelecypoda														
D	11	1	35	3	302	8	175	5	25	2	112	18	392	20
E	1,310	14	974	8	1,336	19	1,776	18	1,825	38	1,552	18	2,572	21
All Others[d]														
D	222	18	319	24	687	18	525	14	234	20	151	25	475	25
E	439	5	793	6	1,103	15	1,526	16	201	4	489	6	4,023	33
Total														
D	1,173		1,307		3,758		3,864		1,206		612		1,926	
E	9,051		12,637		7,189		9,723		4,856		8,448		12,298	
Number of Replicates	5		5		5		5		3		3		3	
Diversity														
D	1.0		1.1		1.1		1.1		0.9		1.0		1.0	
E	1.2		1.2		1.0		1.9		0.8		1.0		1.0	

[a] Density is the mean of three or five replicate samples, as indicated above, rounded to the nearest whole number.
[b] Calculated using Brillouin's formula ($\log_{10}$) using the total number of organisms presented.
[c] Includes Plecoptera, Megaloptera, Coelenterata, Alloeocoela, Hirudinea, Anisoptera, Tricladida, Nematoda, Ostracoda, Zygoptera, Coleoptera, Hydracarina, Hemiptera, and Diptera other than Chironomidae.

Source: Dames & Moore, 1982
Checked by: WMW

mayflies at Station E were from the general *Hexagenia* sp. and *Caenis* sp., although *Baetis* sp. and *Ephemerella* sp. also occurred at this station.

At Station D, worms typically occurred in densities of less than 20/m^2 and typically comprised less than one percent of the benthos enumerated during each sample period. However, at Station E, worms ranged from 216 to 2,474/m^2 in mean densities and comprised from three to 20 percent of the benthic macroinvertebrate community (Table 3.8-30).

Snails comprised from 4 to 11 percent of the benthos at Station D and from 2 to 18 percent at Station E. The major snail at Station D was the freshwater limpet, *Ferrissia* sp., which comprised most of the gastropods identified. At Station E, the snail *Amnicola* sp. comprised most of the snails identified.

Clams comprised from 1 to 20 percent of the benthos identified at Station D and from 8 to 38 percent at Station E. The clams identified from both sampling locations were exclusively from the family Sphaeriidae; mature specimens were identified to the genera *Sphaerium* and *Pisidium*. Plecopterans (stonefiles) were collected in low numbers (<80/m^2) in all months at Station D and were found at Station E in March 1977 only.

Although differences were observed in the species composition of the benthic communities at Stations D and E, diversity values were similar. Values at Station D ranged from 0.9 in March 1978 to 1.1 in May, August, and October 1977. At Station E, values ranged from 0.8 in March 1978 to 1.2 in March and May 1977. Mean diversity at both stations was 1.0.

Information on the composition and density of benthic macroinvertebrates in Swamp Creek downstream in Swamp Creek downstream from County Trunk Highway M is presented in Ecological Analysts, Inc. (1983, 1984a). These results are from qualitative and quantitative sampling of macroinvertebrate communities during 1982 and 1983 in the vicinity of the proposed water discharge site.

Taxa were collected by the WDNR during verification sampling. The samples were obtained with a kick net during October 1979 downstream of Route 55, approximately 1.1 km (0.7 miles) downstream of Station E (Ramharter, 1982).

Quantitative benthic macroinvertebrate samples were collected from one location in Oak Lake (Station G), and qualitative collections were undertaken during March, May, August, and October 1977 and March, May, and August 1978. The major taxa collected in quantitative sampling and their density and relative abundance are presented in Table 3.8-31.

In 1977 total numbers of benthic organisms collected at Oak Lake ranged from 1,172/m^2 in August to 7,741/m^2 in March. In 1978 densities in March (2,256/m^2) and August (819/m^2) were lower than in corresponding collections in 1977, 7,741 and 1,172/m^2, respectively. Density in May was higher in 1978 (7,226/m^2) than in 1977 (4,956/m^2).

Table 3.8-31

Mean Density[a] (No./m²), Relative Abundance (%), and Diversity[b] of Bethnic Macroinvertebrates Collected from Oak Lake - Station G March, May, August and October 1977, and March, May and August 1978

	1977								1978					
	March		May		August		October		March		May		August	
	No./m²	%	No./m²	%	No./m²	%	No./m²	%	No./m²	%	No./m²	%	No./m²	%
Oligochaeta	52	1	119	2	78	7	164	5	0	0	259	4	43	5
Trichoptera	17	<1	32	1	0	0	0	0	0	0	14	<1	29	4
Chironomidae	7,292	94	4,073	82	879	75	1,896	63	1,968	87	5,862	81	646	79
Gastropoda	0	0	11	<1	0	0	0	0	0	0	14	<1	0	0
Pelecypoda	0	0	0	0	17	1	0	0	0	0	230	3	29	4
All Others[c]	379	5	722	15	198	17	974	32	287	13	848	12	72	9
Total	7,741		4,956		1,172		3,034		2,256		7,226		819	
Number of Replicates	5		5		5		5		3		3		3	
Diversity	0.7		0.7		0.6		0.6		0.7		0.7		0.5	

[a] Density is the mean of three or five replicate samples, rounded to the nearest whole number.
[b] Calculated using Brillouin's formula ($\log_{10}$) using the total number of organisms presented.
[c] Includes Hydracarina, Nematoda, Ostracoda, Megaloptera, and Diptera other than Chironomidae.

Source: Dames & Moore, 1982
Checked by: WMW

Midges were the predominant benthic organisms collected from Oak Lake during the study. Midges comprised from 63 to 94 percent of the benthic macroinvertebrates collected. Midges from the genera *Tanytarsus* and *Procladius* were most common.

In general, other benthic invertebrates individually comprised less than seven percent of the total invertebrates collected during any sampling period. The only exception was the Nematoda (roundworms), which comprised 11 (560/m^2), 15 (172/m^2), and 26 (784/m^2) percent of the total benthos in May, August, and October 1977, respectively.

The benthic diversity for Oak Lake varied little with a range of 0.5 in August 1978 to 0.7 in March and May 1977 and 1978 (Table 3.8-31). Taxa collected by the WDNR during verification sampling were obtained with an Ekman sampler during December 1980 in deep and shallow areas of the lake (Ramharter, 1982).

3.8.2.5.3 Rolling Stone Lake

Quantitative benthic macroinvertebrate samples were collected from two locations, Stations M-2 and M-4. Qualitative collections were obtained from Rolling Stone Lake in October 1977 and March, May and August 1978. The seven major taxa collected in quantitative sampling and their density and relative abundance are presented in Table 3.8-32.

There were 75 and 89 individual taxa identified in quantitative sampling at Stations M-2 and M-4, respectively, and the additional 15 taxa identified in qualitative sampling. Numbers of benthic organisms collected were consistently higher at Station M-4 than at M-2. At Station M-2 density ranged from 4,698/m^2 in March 1978 to 22,656/m^2 in October 1977 and at Station M-4 from 10,330 to 43,675/m^2 during the collecting periods. Snails were the dominant benthic organisms, constituting 30 to 71 percent of the benthic organisms collected at Station M-2 and from 24 to 74 percent at Station M-4. The most abundant snails at both locations were *Amnicola* sp. and *Valvata tricarinata*. Midges were the second most numerous benthic organisms comprising from 17 to 31 percent of the organisms collected at Stations M-2 and from seven to 39 percent at Station M-4. *Glyptotendipes* sp., *Chironomus* sp., *Dicrotendipes* sp., and *Endochironomus* sp. were the most common genera. Worms were abundant only in October 1977 and August 1978 when they comprised from 16 to 27 percent of the benthos. During other sampling periods they did not exceed one percent of the benthos. The naidids, *Dero digitata*, *Stylaria lacustris*, *Nais* sp., and *Pristina leidgi*, were the most common worms encountered.

Although densities differed at the two stations, diversity values were similar. Values ranged from 1.1 to 1.2 at Stations M-2 and M-4, respectively, in October 1977 and 0.7 and 0.6 in March 1978 (Table 3.8-32). Taxa collected by the WDNR during verification studies were obtained with an Ekman sampler during December 1980 (Ramharter, 1982).

Table 3.8-32

Mean Density[a] (No./m^2), Relative Abundance (%), and Diversity[b] of Bethnic Macroinvertebrates Collected from Rolling Stone Lake - Stations M-2 and M-4 October 1977 and March, May and August 1978

	1977		1978					
	October		March		May		August	
	No./m^2	%	No./m^2	%	No./m^2	%	No./m^2	%
Oligochaeta								
M-2	3,419	15	29	1	172	1	2,572	15
M-4	5,976	14	115	1	0	0	5,488	24
Amphipoda								
M-2	2,054	9	0	0	29	<1	0	0
M-4	1,494	3	1,020	10	0	0	72	<1
Ephemeroptera								
M-2	86	<1	0	0	0	0	0	0
M-4	474	1	14	<1	0	0	0	0
Trichoptera								
M-2	589	3	144	3	675	6	388	2
M-4	7,787	18	216	2	158	1	43	<1
Chironomidae								
M-2	6,254	28	790	17	2,471	21	5,244	31
M-4	13,634	31	747	7	5,646	39	5,632	24
Gastropoda								
M-2	7,945	35	3,347	71	7,442	65	5,129	30
M-4	10,574	24	7,614	74	7,873	54	9,180	39
Pelecypoda								
M-2	72	<1	58	1	115	1	489	3
M-4	216	<1	115	1	503	3	158	1
All Others[c]								
M-2	2,241	10	330	7	632	5	3,247	19
M-4	3,520	8	488	5	417	3	3,017	13
Total								
M-2	22,656		4,698		11,536		17,068	
M-4	43,675		10,330		14,596		23,590	
Diversity								
M-2	1.1		0.7		0.7		1.0	
M-4	1.2		0.6		0.9		0.9	

[a] Density is the mean of three or five replicate samples, as indicated above, rounded to the nearest whole number.
[b] Calculated using Brillouin's formula ($\log_{10}$) using the total number of organisms presented.
[c] Includes Hydracarina, Coelenterata, Tricladida, Coleoptera, Alloeocoela, Hirudinea, Ostracoda, Odonata, Nematoda, and Diptera other than Chironomidae.

Source: Dames & Moore, 1982
Checked by: WMW

3.8.2.5.4 Pickerel Creek

Quantitative and qualitative benthos collections were obtained from Pickerel Creek (Station M-5) in October 1977 and March, May, and August 1978. The major taxa collected in quantitative sampling and their density and relative abundance are presented in Table 3.8-33. There were 67 taxa identified in quantitative sampling and the additional 15 taxa identified in qualitative sampling. Density of organisms ranged from 5,316/m^2 in March 1978 to 9,338/m^2 in May 1978.

Midges were the most abundant benthic organisms in each collection comprising from 34 to 66 percent of the total. Midges from the genera *Procladius*, *Micropsectra*, *Chironomus*, and *Tanytarsus* were most common. Worms were the next most abundant organisms and comprised from 9 to 27 percent of the organisms collected. In general, the most commonly collected worms were the immature tubificid forms with or without hair setae. Additional worms enumerated from these samples included the tubificids *Aulodrilus pigueti*, *Ilyodrilus templetoni*, *Limnodrilus hoffmeisteri*, and *L. cervix* and the naidids *Slavina appendiculata*, *Mais* sp., *Dero digitata*, and *Pristina leidgi*.

Isopods constituted from seven to 22 percent of the benthos. Mature specimens that could be identified to the species level were *Asellus racovitzai racovitzai*. Clams comprised from seven to 18 percent of the benthos and all specimens were from the family Sphaeriidae. Mature specimens were identified to the genera *Pisidium* and *Sphaerium*. The benthic diversity was consistent during the investigation with values ranging from 0.9 in October 1977 to 1.0 for the remaining three collection periods (Table 3.8-33).

3.8.2.5.5 Creek 12-9

Quantitative and qualitative benthos collections were obtained from Creek 12-9 (Station M-1) in October 1977 and March, May and August 1978. The major taxa collected in quantitative sampling and their density and relative abundance are presented in Table 3.8-34.

There were 75 taxa identified in quantitative sampling and the additional six taxa identified in qualitative sampling. The numbers of organisms enumerated during each sampling period were similar throughout the investigation. Density ranged from 10,516/m^2 in August 1978 to 14,309/m^2 in October 1977. The most abundant benthic organisms were midges and clams. Midges comprised from 13 to 83 percent of the collections. *Micropsectra* sp. was the most abundant midge during the study. *Tanytarsus* sp., *Polypedilum* sp., *Conchapelopia* sp., and *Trichocladius* sp. also occurred commonly. All clams collected in the benthic samples from Creek 12-9 were in the family Sphaeriidae; mature specimens were identified to the genera *Pisidium* and *Sphaerium*. Clams ranged from eight to 75 percent of the benthos. The benthic diversity ranged from 0.6 in March 1978 when midges comprised over 83 percent of the sample to 1.1 in October 1977 when no taxa comprised more than 59 percent of the sample (Table 3.8-34).

Table 3.8-33

Mean Density[a] (No./m^2), Relative Abundance (%), and Diversity[b] of Bethnic Macroinvertebrates Collected from Pickerel Creek - Station M-5 October 1977 and March, May and August 1978

	1977		1978					
	October		March		May		August	
	No./m^2	%	No./m^2	%	No./m^2	%	No./m^2	%
Oligochaeta	1,997	27	1,063	20	819	9	1,465	16
Isopoda	977	13	1,063	20	646	7	1,983	22
Amphipoda	86	1	359	7	244	3	460	5
Trichoptera	14	<1	0	0	14	<1	115	1
Chironomidae	2,543	34	2,241	42	6,192	66	3,965	45
Gastropoda	14	<1	158	3	72	1	43	<1
Pelecypoda	1,336	18	388	7	905	10	690	8
All Others[c]	474	6	43	1	446	5	187	2
Total	7,442		5,316		9,338		8,907	
Diversity	0.9		1.0		1.0		1.0	

[a] Density is the mean of three replicate samples, rounded to the nearest whole number.
[b] Calculated using Brillouin's formula ($\log_{10}$) using the total number of organisms presented.
[c] Includes Nematoda, Hirudinea, Ostracoda, Megaloptera, Hydracarina, Coelenterata, Alloeocoela, and Diptera other than Chironomidae.

Source: Dames & Moore, 1982
Checked by: WMW

Table 3.8-34

Mean Density[a] (No./m^2), Relative Abundance (%), and Diversity[b] of Bethnic Macroinvertebrates Collected from Creek 12-9 - Station M-1 October 1977 and March, May and August 1978

	1977		1978					
	October		March		May		August	
	No./m^2	%	No./m^2	%	No./m^2	%	No./m^2	%
Oligochaeta	201	1	144	1	29	<1	345	3
Isopoda	991	7	316	3	129	0	345	3
Amphipoda	158	1	0	0	0	0	0	0
Ephemeroptera	259	2	0	0	0	0	14	<1
Trichoptera	244	2	101	1	14	<1	158	2
Chironomidae	8,433	59	9,554	83	8,706	65	1,408	13
Gastropoda	0	0	0	0	29	<1	43	<1
Pelecypoda	1,192	8	905	8	3.,850	29	7,902	75
All Others[c]	2,830	20	517	4	560	4	302	3
Total	14,309		11,536		13,318		10,516	
Diversity	1.1		0.6		0.9		0.8	

[a] Density is the mean of three replicate samples rounded to the nearest whole number.
[b] Calculated using Brillouin's formula ($\log_{10}$) using the total number of organisms presented.
[c] Includes Nematoda, Hirudinea, Ostracoda, Plecoptera, Megaloptera, Hydracarina, Lepidoptera, and Diptera other than Chironomidae.

Source: Dames & Moore, 1982
Checked by: WMW

3.8.2.5.6 Creek 11-4

Quantitative and qualitative benthos collections were obtained from Creek 11-4 (Station M-3) in October 1977 and March, May and August 1978. The major taxa collected in quantitative sampling along with their density and relative abundance are presented in Table 3.8-35.

There were 76 taxa identified in quantitative sampling and the additional six taxa identified in qualitative sampling. Subsequent to an exceptionally high density of 86,214/m^2 in October 1977, densities were relatively similar in 1978 ranging from 14,424/m^2 in August to 20,731/m^2 in May. The three most abundant benthic groups were worms, isopods, and clams.

Worms comprised from 37 to 69 percent of the benthos enumerated at Creek 11-4. Most of the worms were from the family Tubificidae of which the immature forms with or without hair setae and *Tubifex tubifex* were most common. Isopods constituted from five to 40 percent of the total benthos enumerated from Creek 11-4. All isopods enumerated were from the genus *Asellus* and adults were identified to *A. racovitzai racovitzai*. Clams, represented exclusively by the family Sphaeriidae, comprised from seven to 25 percent of the benthos collected. Mature specimens were identified to the genera *Sphaerium* and *Pisidium*. Benthic diversity for Creek 11-4 ranged from 0.6 in October 1977 to 0.9 in May 1978 (Table 3.8-35).

3.8.2.5.7 Little Sand Lake

Benthic macroinvertebrates were collected at two locations, Stations H and I, in Little Sand Lake during March, May, August and October 1977 and March, May and August 1978. The seven major taxa collected in quantitative sampling and their density and relative abundance are presented Table 3.8-36. There were 67 taxa identified in quantitative sampling from Station H and 73 from Station I as well as the additional 14 taxa identified in qualitative sampling. Density of benthic organisms in 1977 ranged from 12,266/m^2 in March to 39,962/m^2 in October at Station H and from 8,603/m^2 in August to 38,411/m^2 in October at Station I. In May and October density at both stations was similar but considerable variation occurred in March and August.

In 1978 density ranged from 6,479/m^2 in August to 28,417/m^2 in May at Station H and from 6,828/m^2 in August to 14,870/m^2 in March at Station I. Densities in 1978 generally corresponded to densities observed in 1977.

Midges were the most abundant benthic macroinvertebrates collected at both sampling locations, comprising over 70 percent of the benthos collected during each sampling period. Common and abundant midges were *Pseudochironomus* sp., *Tanytarsus* sp., and *Procladius* sp.

Other organisms what were common but never exceeded 12 percent of the benthos community were worms and caddisflies. Of the worms enumerated, no single species exceeded 4 percent of the total benthos during any one period. At both sampling locations, the common naidids were *Mais* sp. and *Dero digitata*. Less common and irregularly occurring naidid forms included

Table 3.8-35

Mean Density[a] (No./m^2), Relative Abundance (%), and Diversity[b] of Bethnic Macroinvertebrates Collected from Creek 11-4 - Station M-3 October 1977 and March, May and August 1978

	1977		1978					
	October		March		May		August	
	No./m^2	%	No./m^2	%	No./m^2	%	No./m^2	%
Oligochaeta	59,866	69	6,336	37	11,091	54	8,692	60
Isopoda	14,223	16	6,810	40	4,741	23	704	5
Amphipoda	158	<1	560	3	115	1	14	<1
Ephemeroptera	14	<1	0	0	115	1	0	0
Trichoptera	29	<1	0	0	14	<1	0	0
Chironomidae	718	1	1,537	9	2,873	14	1,020	7
Gastropoda	172	<1	72	<1	14	<1	14	<1
Pelecypoda	9,295	11	1,437	8	1,465	7	3,606	25
All Others[c]	1,738	2	216	1	302	1	374	3
Total	86,214		16,967		20,731		14,424	
Diversity	0.6		0.8		0.9		0.7	

[a] Density is the mean of three replicate samples rounded to the nearest whole number.
[b] Calculated using Brillouin's formula ($\log_{10}$) using the total number of organisms presented.
[c] Includes Nematoda, Hirudinea, Ostracoda, Plecoptera, Megaloptera, Hydracarina, Lepidoptera, and Diptera other than Chironomidae.

Source: Dames & Moore, 1982
Checked by: WMW

Table 3.8-36

Mean Density[a] (No./m²), Relative Abundance (%), and Diversity[b] of Bethnic Macroinvertebrates Collected from Little Sand Lake - Stations H and I March, May, August and October 1977, and March, May and August 1978

	1977								1978					
	March		May		August		October		March		May		August	
	No./m²	%	No./m²	%	No./m²	%	No./m²	%	No./m²	%	No./m²	%	No./m²	%
Oligochaeta														
H	207	2	940	6	241	1	940	2	86	<1	1,020	4	747	12
I	293	1	302	2	207	2	681	2	345	2	158	1	431	6
Amphipoda														
H	103	1	0	0	9	<1	9	<1	0	0	0	0	14	<1
I	26	<1	0	0	0	0	0	0	0	0	0	0	0	0
Ephemeroptera														
H	9	<1	17	<1	0	0	181	<1	0	0	14	<1	0	0
I	34	<1	0	0	0	0	17	<1	0	0	0	0	0	0
Trichoptera														
H	681	6	431	3	578	3	733	2	402	2	618	2	460	7
I	1,388	6	621	4	724	8	940	2	776	5	718	6	517	8
Chironomidae														
H	11,154	91	12,896	86	12,913	77	36,411	91	21,895	93	24,854	87	4,597	71
I	22,119	91	13,327	91	6,232	72	27,774	72	13,418	90	9,582	77	5,057	74

Table 3.8-36 *(Continued)*

	1977								1978					
	March		May		August		October		March		May		August	
	No./m²	%	No./m²	%	No./m²	%	No./m²	%	No./m²	%	No./m²	%	No./m²	%
Gastropoda														
H	0	0	0	0	0	0	0	0	0	0	0	0	158	2
I	0	0	0	0	0	0	0	0	14	<1	0	0	0	0
Pelecypoda														
H	17	<1	172	1	216	1	0	0	0	0	0	0	0	0
I	0	0	86	1	52	1	95	<1	29	<1	58	<1	287	4
All Others[c]														
H	95	1	534	4	2,741	16	1,690	4	1,221	5	1,911	7	503	8
I	517	2	353	2	1,388	16	8,904	23	287	2	1,968	16	546	8
Total														
H	12,266		14,990		16,697		39,962		23,604		28,417	100	6,479	
I	24,377		14,688		8,603		38,411		14,870		12,485	100	6,838	
Number of Replicates	5		5		5		5		3		3		3	
Diversity														
H	0.8		0.9		1.1		1.0		1.0		1.0			1.0
I	1.0		0.9		1.1		1.0		1.0		1.1			0.8

[a] Density is the mean of three or five replicate samples, as indicated above, rounded to the nearest whole number.
[b] Calculated using Brillouin's formula ($\log_{10}$) using total number of organisms presented.
[c] Includes Tricladida, Hirudinea, Hydracarina, Zygoptera, Coelenterata, Nematoda, Anisoptera, Neuroptera, Ostracoda and Diptera other than Chironomidae.

Source: Dames & Moore, 1982
Checked by: WMW

Stylaria fossularis, *Slavina appendiculata* and *Vejdovskyella comata*. Immature forms were the most common tubificids recorded throughout the study. No caddisfly species exceeded eight percent of the total benthos identified at any location for any collection period. This group was composed primarily of *Polycentropus* sp., which comprised from 75 to 95 percent of the caddisflies collected from both sampling locations during any sampling period.

Benthic diversity ranged from 0.8 at Station H in March 1977 and Station I in August 1978 to 1.1 at Station H in August 1977 and Station I in August 1977 and May 1978 (Table 3.8-36). Taxa collected by the WDNR during verification studies were obtained with an Ekman grab in deep and shallow portions of the lake during October 1979 (Ramharter, 1982).

3.8.2.5.8 Duck Lake

Benthic macroinvertebrates were identified from quantitative samples and qualitative collections from Duck Lake during May, August, and October 1977 and March, May and August 1978. The five major taxa collected in quantitative sampling and their density and relative abundance are presented in Table 3.8-37. There were 53 taxa identified in quantitative sampling and the additional 12 taxa identified in qualitative sampling. In 1977, benthic density was highest in May, 20,192/m^2, and subsequently decreased to 3,879/m^2 in October. In 1978, the previous year's trend of high spring density was not observed and density ranged from 3,549/m^2 in August to 6,609/m^2 in May.

Worms dominated in August and October 1977 and August 1978 comprising 45 to 75 percent of the collections. During the other sampling periods worms comprised from 18 to 41 percent. Naidid worms, including *Nais* sp., *Vejdovskyella comata*, and *Dero digitata*, were generally abundant but immature tubificid forms, as well as *Aulodrilus pigueti* occurred regularly at low densities. Midges were the most abundant organisms in May 1977 and 1978 comprising 48 and 44 percent of the respective collections. Midges were co-dominant with worms in March 1978 comprising 37 percent of the collections. During the remaining sampling periods midges comprised from eight to 21 percent of the collections. *Tanytarsus* sp. was the most abundant midge and *Polypedilum* sp., *Chironomus* sp., and *Conchapelopia* sp. were also commonly collected.

Other benthic groups that occurred throughout the study were caddisflies and mayflies that comprised up to 16 and eight percent, respectively, of the benthic community. The two most common caddisflies were *Polycentropus* sp. and *Oxyethira* sp., while *Caenis* sp. was the most abundant mayfly. Individual diversity values ranged from 0.8 in March and August 1978 to 1.1 in May 1978. Taxa collected by the WDNR during verification studies were obtained with an Ekman grab in deep and shallow portions of the lake during October 1979 (Ramharter, 1982).

Table 3.8-37

Mean Density[a] (No./m^2), Relative Abundance (%), and Diversity[b] of Bethnic Macroinvertebrates Collected from Duck Lake - Station K May, August and October 1977 and March, May, and August 1978

	1977						1978					
	May		August		October		March		May		August	
	No./m^2	%	No./m^2	%	No./m^2	%	No./m^2	%	No/m^2	%	No./m^2	%
Oligochaeta	8,340	41	9,568	65	1,738	45	1,695	37	1,221	18	2,672	75
Amphipoda	0	0	0	0	0	0	0	0	0	0	14	<1
Ephemeroptera	43	<1	86	1	316	8	101	2	532	8	29	1
Trichoptera	690	3	690	5	216	6	718	16	934	14	273	8
Chironomidae	9,633	48	3,146	21	1,293	33	1,695	37	2,916	44	287	8
All Others[c]	1,487	7	1,250	8	316	8	359	8	1,006	15	273	8
Total	20,192		14,740		3,879		4,569		6,609		3,549	
Number of Replicates	2		2		3		3		3		3	
Diversity	1.0		0.9		0.9		0.8		1.1		0.8	

[a] Density is the mean of three replicate samples rounded to the nearest whole number.
[b] Calculated using Brillouin's formula ($\log_{10}$) using the total number of organisms presented.
[c] Includes Nematoda, Anisoptera, Hydracarina, Ostracoda, Zygoptera, and Diptera other than Chironomidae.

Source: Dames & Moore, 1982
Checked by: WMW

3.8.2.5.9 Deep Hole Lake

Quantitative and qualitative benthic macroinvertebrate samples were collected from Deep Hole Lake in May, August and October 1977 and March, May and August 1978. The six major taxa collected in quantitative sampling and their density and relative abundance are presented in Table 3.8-38. There were 69 taxa identified in quantitative sampling and the 21 additional taxa identified in qualitative sampling. In 1977, density ranged from 11,235/m^2 in May to 23,173/m^2 in October. In 1978, density was lowest in August (6,005/m^2) and highest in May (14,252/m^2).

Midges were the most abundant benthic macroinvertebrates enumerated, comprising 42 to 89 percent of the benthos collected. Overall, the most common and abundant midge was *Tanytarsus* sp., which was recorded in all sampling periods. *Microtendipes* sp., *Procladius* sp., and *Pseudochironomus* sp. also were found regularly. Other groups that were collected in moderate densities included worms, caddisflies and clams. Worms comprised five percent or less of the benthos during all sampling periods except August 1978, when worms comprised 18 percent of the total benthos. Common forms were immature tubificids with hair setae, *Nais* sp., and *Stylaria fossularis*.

Monthly values of benthic diversity ranged from 0.8 in May 1977 to 1.1 in August 1978 (Table 3.8-38). Taxa collected by the WDNR during verification studies were obtained with an Ekman grab in deep and shallow portions of the lake during October 1979 (Ramharter, 1982).

3.8.2.5.10 Skunk Lake

Benthic macroinvertebrates were collected from Skunk Lake in May and August 1977. The three major taxa collected in quantitative sampling and their density and relative abundance are presented in Table 3.8-39.

There were 20 taxa identified from quantitative sampling and an additional two taxa identified in qualitative sampling. Densities of organisms were considerably higher in August (16,615/m^2) than in May (1,940/m^2). The increase in density was largely from an abundance of midge flies and worms. The dominant midge in May was *Psectrocladius* sp., which comprised 21 percent of the sample. In August *Chironomus* sp. was the dominant midge, comprising 81 percent of the sample. *Dero digitata* was the dominant worm in both collections.

Diversity was higher in May (0.6), when no single taxon comprised more than 25 percent of the sample (Table 3.8-39). The low value, 0.3, corresponded to the dominance (86 percent of the sample) of one taxon, Chironomidae.

3.8.2.5.11 Wolf River

Benthic macroinvertebrates were collected at two locations, Stations Y and Z in March, May, August and October 1978. The eight major taxa collected in quantitative sampling and their density and relative abundance are presented in Table 3.8-40.

Table 3.8-38

Mean Density[a] (No./m^2), Relative Abundance (%), and Diversity[b] of Bethnic Macroinvertebrates Collected from Deep Hole Lake - Station L May, August and October 1977 and March, May, and August 1978

	1977						1978					
	May		August		October		March		May		August	
	No./m^2	%	No./m^2	%	No./m^2	%	No/m^2	%	No./m^2	%	No./m^2	%
Oligochaeta	101	1	776	5	589	3	58	1	431	3	1,078	18
Amphipoda	29	<1	0	0	0	0	0	0	0	0	14	<1
Ephemeroptera	0	0	0	0	0	0	14	<1	29	<1	0	0
Trichoptera	144	1	1,013	7	991	4	101	2	273	2	675	11
Chironomidae	9,726	87	11,422	74	19,079	82	9,367	77	11,034	77	2,543	42
Pelecypoda	761	7	991	6	675	3	330	7	991	7	675	11
All Others[c]	474	4	1,142	7	1,839	8	632	10	1,494	10	1,020	17
Total	11,235		15,344		23,173		10,502		14,252		6,005	
Number of Replicates	3		2		3		3		3		3	
Diversity	0.8		1.0		1.0		0.9		1.0		1.1	

[a] Density is the mean of three replicate samples rounded to the nearest whole number.
[b] Calculated using Brillouin's formula ($\log_{10}$) using the total number of organisms presented.
[c] Includes Nematoda, Hirudinea, Ostracoda, Plecoptera, Megaloptera, Hydracarina, Lepidoptera, and Diptera other than Chironomidae.

Source: Dames & Moore, 1982
Checked by: WMW

Table 3.8-39

Mean Density[a] (No./m^2), Relative Abundance (%), and Diversity[b] of Benthic Macroinvertebrates Collected from Skunk Lake - Station J May and August 1977

	May		August	
	No./m^2	%	No./m^2	%
Oligochaeta	560	29	2,263	14
Chironomidae	733	38	14,223	86
Pelecypoda	108	6	22	<1
All Others[c]	539	28	108	1
Total	1,940		16,615	
Diversity	0.6		0.3	

[a]Density is the mean of two replicate samples, rounded to the nearest whole number.
[b]Calculated by Brillouin's formula ($\log_{10}$) using total number of organisms presented.
[c]Includes Hydracarina, Nematoda, and Diptera other than Chironomidae.

Source: Dames & Moore, 1982
Checked by: WMW

Table 3.8-40

Mean Density[a] (No./m^2), Relative Abundance (%), and Diversity[b] of Bethnic Macroinvertebrates Collected from Wolf River - Stations Y and Z March, May, August, and October 1978

	March		May		August		October	
	No./m^2	%	No./m^2	%	No./m^2	%	No./m^2	%
Oligochaeta								
Y	273	1	2,644	31	101	2	29	2
Z	72	1	1,149	13	3,664	28	1,394	26
Isopoda								
Y	0	0	29	<1	0	0	0	0
Z	0	0	0	0	0	0	0	0
Amphipoda								
Y	675	4	1,552	18	0	0	0	0
Z	0	0	646	8	72	1	101	2
Ephemeroptera								
Y	58	<1	14	<1	14	<1	0	0
Z	0	0	29	<1	503	4	0	0
Trichoptera								
Y	302	2	72	1	43	1	0	0
Z	29	<1	460	5	560	4	58	1
Chironomidae								
Y	2,126	11	2,126	25	2,471	37	0	0
Z	503	8	2,399	28	2,313	18	43	1
Gastropoda								
Y	9,180	48	1,135	13	1,437	22	345	18
Z	3,692	58	1,135	13	1,940	15	1,925	36
Pelecypoda								
Y	1,034	5	388	5	2,284	34	1,078	57
Z	1,623	26	129	2	1,451	11	359	7
All Others[c]								
Y	5,387	28	618	7	287	4	445	24
Z	445	7	2,644	21	2,457	19	1,494	28
Total								
Y	19,036	100	8,577	100	6,637	10	1,896	100
Z	6,364	100	8,591	100	12,959	0	5,373	100
						10		
						0		
Diversity								
Y	0.6		1.0		0.7		0.6	
Z	0.6		1.0		1.1		0.9	

[a] Density is the mean of three or five replicate samples.

[b] Calculated using Brillouin's formula ($\log_{10}$) using total number of organisms presented.

[c] Includes Coelenterata, Tricladida, Alloeocoela, Nemertea, Nematoda, Hirudinea, Hydracarina, Anisoptera, Zygoptera, Hemiptera, Lepidoptera, Coleoptera and Diptera other than Chironomidae.

Source: Dames & Moore, 1982

Checked by: WMW

There were 81 and 100 taxa obtained in quantitative sampling and the additional 9 and 13 taxa obtained in qualitative sampling at Stations Y and Z, respectively. Densities of benthic organisms ranged from 1,896 to 19,036/m^2 at Station Y and 5,373 to 12,959/m^2 at Station Z. Benthic macroinvertebrates from several different groups were irregular in abundance, although they were common throughout the study. These groups included snails, midges, worms and clams.

Snails accounted for 13 to 48 percent of the benthos at Station Y and from 13 to 58 percent at Station Z. All of the 13 taxa identified, except *Promenetus exacuous*, which was collected only at Station Y, were collected at both sampling stations on the Wolf River. *Amnicola* sp. was the most common and abundant snail collected at both stations.

Midges comprised 0 to 37 percent of the total benthos enumerated from Station Y and from one to 28 percent at Station Z. Densities of midges at Station Y ranged from 0 in October 1978 to 2,471/m^2 in August 1978, and densities at Station Z ranged from 43/m^2 in October 1978 to 2,399/m^2 in May 1978. Individual genera of midges varied in abundance and occurrence throughout the period of investigation. Organisms that comprised five percent or more of a collection were *Cladotanytarsus* sp., *Polypedilum* sp., and *Trissocladius* sp. at Station Y and *Rheotanytarsus* sp., *Tanytarsus* sp., and *Stictochironomus* sp. at Station Z.

Worms comprised from one to 31 percent of the total benthos enumerated at Station Y and from one to 28 percent at Station Z. The immature tubificid form without hair setae was the most abundant worm at both stations during the study except May and July at Station Z. The naidids *Nais* sp. and *Slavina appendiculata* were most abundant in May whereas the naidid *Uncinais uncinata* was most abundant in July.

Clams comprised from five to 57 percent of the benthos collected at Station Y and from two to 26 percent at Station Z. All pelecypods collected from both Stations Y and Z were from the family Sphaeriidae; mature specimens were identified to the genera *Sphaerium* and *Pisidium*. Diversity values ranged from 0.6 at both stations in March and at Station Y in October to 1.1 at Station Z in August (Table 3.8-40).

3.8.2.6 Results of Aquatic Macroinvertebrate Collection Activities Conducted in 1993 and 1994

Aquatic macroinvertebrate were sampled in November 1993, and May and August, 1994. Light trapping for adult specimens of members of the insect orders Trichoptera, Ephemeroptera, Coleoptera, and Plecoptera was conducted in June, July and August 1994. A general list of specimens collected with site location is provided in Appendix 3.8-2. Only immature (larvae or nymphs) specimens which were in families containing a threatened, endangered, or species of concern were keyed to genus and, where possible, species. Appendix 3.8-3 provides the data summary for adult Trichoptera and Ephemeroptera which were captured during light trapping collection efforts in late June and early July 1994. Table 3.8-41 provides a site location key by

Table 3.8-41

Key to Site Sampling Locations
1993-1994 Aquatic Sampling Program

Site ID	County	Section	Town/Range
CMC-AB-HL-100	Forest	33	35N13E
CMC-AB-HL-200	Forest	28/33	"
CMC-AB-SC-200	Forest	6/21	"
CMC-AB-SC-250	Forest	20	"
CMC-AB-SC-300	Forest	19	"
CMC-AB-SC-301	Forest	19	"
CMC-AB-SC-400	Forest	27	35N12E
CMC-AB-SC-500	Forest	32	"
CMC-AB-SC-501	Forest	32	"
CMC-AB-SC-502	Forest	32	"
CMC-AB-SC-700	Langlade	7	34N12E
CMC-AB-WR-200	Langlade	14	34N11E
CMC-AB-WR-301	Langlade	13	"
CMC-AB-SGI-CC	Langlade	24	"
CMC-AB-SK-005	Forest	30	35N13E
CMC-AB-DL-005	Forest	31/32	"
CMC-AB-SL-005	Forest	31/36/6	35N13E 35N12E 34N13E
CMC-AB-OL-005	Forest	36	35N12E
CMC-AB-RS-005	Langlade	11/12/13/14	34N12E
CMC-AB-DH-005	Forest	5/6	34N13E
CMC-AB-PP-005	Forest	26	35N12E

Table 3.8-41 *(Continued)*

Site ID	County	Section	Town/Range
CMC-AB-HS-005	Forest	26	"
CMC-AB-HC-100	Forest	26	"
CMC-AB-12-9	Langlade	12	34N12E
CMC-AB-OC-200	Forest	18	35N13E
CMC-AB-PK-200	Langlade	11	34N12E
CMC-AB-PK-300	Langlade	13	"
CMC-AB-MS-100	Langlade	11	"
CMC-AB-RR-100	Forest	27/28	35N13E

Prepared by: WMW
Checked by: JJA

Town/Range, and should be used as a reference for all location identification utilized in this section. Macroinvertebrate collection identification data are provided in Appendix 3.8.4. Rice Lake was not sampled in 1993-1994 because the Mole Lake Sakoagan Chippewa would not grant access to project personnel.

No threatened or endangered species of macroinvertebrates were collected or observed in the study area. With the exception of the Odonata (discussed below in Section 3.8.2.7), two special concern species were observed in the study area, including a caddisfly (*Triaenodes dipsius*) and a mayfly (*Caenis youngi*). Larval specimens of the genus *Triaenodes* were first collected in November 1993 at the Wolf River (Site CMC-AB-WR-301). Follow-up light trapping activities for adult specimens in June 1994 yielded a total of six species of *Triaenodes* with *Triaenodes dipsius* being discovered at four stations (CMC-AB-SC-200, CMC-AB-SC-500, CMC-AB-HL-200, and CMC-AB-HS-005). These locations, Hoffman Springs, Swamp Creek at Keith Siding Road, Swamp Creek downstream of County Highway M, and Hemlock Creek, essentially surround the mining site and indicate a wide distribution of the species in the study area. Several specimens of the genus *Triaenodes* were collected in 1977 and 1978 at Stations L, M-1, A-1, Y and Z, however, none of these specimens were keyed to species. Therefore, it is unknown if *T. dipsius* was collected in 1977 and 1978. *Caenis youngi* was found in two locations during light trapping. These locations include site CMC-AB-SC-100 and site CMC-AB--SGI-CC.

One species of stonefly in the genus *Alloperla* was collected in November 1993 as an immature nymph. This genus has not been previously reported for the state of Wisconsin. The nymph was collected at the riffle area of Swamp Creek (CMC-AB-SC-300). A single adult female *Alloperla* sp. was collected in June 1994 during light trapping activities at the same location which is north of the mine site. This specimen could not be identified to species as only males of this genus can be identified reliably.

Crayfish were collected for tissue analysis in May 1994. A total of 13 specimens were collected from the Wolf River Site CMC-AB-SGI-CC. Only two specimens were captured from the Wolf River immediately upstream of the confluence with Swamp Creek. Since the objective was to obtain a minimum of ten specimens, these two were returned to the river. An alternative sampling site above Swamp Creek on the Wolf River was located. This site was at the outfall of Lower Post Lake (Site CMC-AB-WR-200). A total of 12 specimens were collected for tissue analysis below Lower Post Lake. Crayfish were collected from two sites on Swamp Creek, CMC-AB-SC-501 and CMC-AB-SC-502. A total of 11 and 13 specimens were collected from these sites respectively. The collection of crayfish at Little Sand Lake was fruitless as neither specimens nor skeletons were observed anywhere along the periphery of the lake. The lack of crayfish probably has a lot to do with the chemistry of the waters in Little Sand Lake. The first downstream location on the Pickerel Chain where significant numbers of crayfish were observed was at the outfall of Rolling Stone Lake. A total of 12 crayfish were collected at this location (CMC-AB-PK-300) for tissue analysis. Data from the analysis of crayfish tissue is presented in Table 3.8-42.

Table 3.9-42

Tissue Analysis of Crayfish from Selected Locations
May 1994 - Results in mg/kg

Location	Arsenic	Cadmium	Chromium	Cobalt	Copper	Lead	Manganese	Mercury	Zinc
CMC-AB-SC-501	2.10	<0.13	1.80	<1.50	42.3	0.56	1090	0.21	68.1
CMC-AB-SC-502	2.90	<0.14	2.30	<1.50	45.4	0.38	989	0.23	80.5
CMC-AB-PK-300	1.90	<0.11	1.40	<1.20	34.9	0.25	182	0.14	80.2
CMC-AB-WR-200	1.70	<0.12	<1.20	<1.30	55.9	2.50	740	0.31	80.0
CMC-AB-SGI-CC	1.50	<0.12	2.30	<1.30	41.8	0.34	1080	0.21	93.8

Prepared by: WMW
Checked by: JJA

3.8.2.7 Results of Odonata Collection Activities (Nymph, Exuviae, and Adult) During 1993 and 1994

Efforts were made to conduct comprehensive collections of each of the life forms of Odonata species, i.e., nymph, final instar exuviae, and adult. Odonata nymphs were collected in November 1993, and May and August, 1994. Odonata exuviae (final instar shed by emerging adults) were collected throughout June 1994 with the greatest effort being expended during the first week of June. Adult Odonata were collected in June, July, and August 1994. Results of the 1993-1994 Odonata collection activities are provided in Appendix 3.8-5. Odonata identification data is provided in Appendix 3.8-4.

It was not always possible to identify some life forms to species. This is especially true of nymphs and exuviae of some species. At times it is necessary to also collect the adult of a species for positive identification. Examples of species keyed to genus only include *Aeshna* sp., *Gomphus (Gomphus)* sp., *Gomphus (Gomphurus)* sp., and *Somatochlora* sp. Some species of these genera may have also been collected as adult, properly identified to species, and listed elsewhere on the table. Other specimens collected as adults and identified to species may not be a listed species.

In general, members of the Odonata enjoy a wide distribution throughout the study area. No threatened or endangered species of Odonata were collected or observed in the study area. Eleven special concern species were collected from the study area. An additional three species, which may be listed species, were keyed to genus. A single adult damselfly, seen but not collected, may have been a special concern species: *Lestes eurinus*.

Several of the special concern species were found to occur only in the downstream portions of Swamp Creek and the Wolf River. Downstream portions of Swamp Creek include areas downstream of County Highway M. These two areas were particularly populated with gomphids including *Gomphus lineatifrons, G. viridifrons, G.(Gomphus)* sp., and *G.(Gomphurus)* sp. Two other areas which produced characteristic populations of targeted Odonata included the riffle area of Swamp Creek (Sites CMC-AB-SC-300 and CMC-AB-SC-301) and the area of Hemlock Creek in the vicinity of Deep Hole Road bridge (Site CMC-AB-HL-200). Scattered collections and sightings of special concern species were obtained at Hoffman Springs/Hoffman Creek, Popple Pond, Oak Lake, Skunk Lake, Deep Hole Lake, and Duck Lake.

As indicated earlier, these findings indicate Odonata are fairly well distributed throughout the study area both in the vicinity of the mine proper as well as in the vicinity of the lower Swamp Creek and Wolf River.

3.8.2.8 Results of Fish Studies Completed in 1977 and 1978

3.8.2.8.1 Rice Lake

Fish were collected from Rice Lake during May, August, and October 1977 and May and August 1978 by Ecological Analysts, Deerfield, Illinois. Numbers and relative abundance of the species collected are presented in Table 3.8-43.

Fish samples in Rice Lake were numerically dominated by black bullhead. This species was collected in all sampling periods, and it comprised from seven to 96 percent of the fyke net catches and from 12 to 86 percent of the electrofishing samples. Other common species in the collections included pumpkinseed and white sucker. Pumpkinseed comprised up to 88 percent of fyke net and from four to 25 percent of the electrofishing samples. No fish were caught in minnow traps set in May and August 1978.

3.8.2.8.2 Hemlock Creek

Fish were collected from Stations A-1 and A-2 in Hemlock Creek in May, August and October 1977 and from Station A-1 during May and August 1978. Numbers and relative abundance of the species collected are presented in Table 3.8-44.

Most fish collected at both stations were representatives of the family *Cyprinidae* (minnows). Common shiner and northern redbelly dace, collected in all sampling periods, were the most common species. In 1977 common shiner comprised from 12 to 36 percent of the samples at Station A-1 and from three to 29 percent of the samples at Station A-2. In 1978 common shiner and northern redbelly dace comprised 14 to 56 percent and 10 to 25 percent of the respective samples at A-1. Other common minnow species included creek chub and fathead minnow.

Except for small sunfish (*Centrarchidae*) and yellow perch, species generally sought by anglers that occurred in the collections included brook trout and white sucker. In addition, longnose dace and northern pike were collected by the WDNR in verification studies (Ramharter, 1982).

3.8.2.8.3 Hoffman Creek

Fish were collected from Hoffman Creek during June, August and October 1977. Numbers and relative abundance of the species collected are presented in Table 3.8-45.

Brook trout and mottled sculpin were the numerically dominant fish species collected. Both species were captured in all sampling periods. Brook trout constituted from 38 to 57 percent of numbers of fish collected, and mottled sculpin comprised from 11 to 34 percent of the catches.

Table 3.8-43

Numbers and Relative Abundance (Percent of Total Catch) of Fish Collected by Fyke Net (FN), Gill Net (GN), and Electroshocking (ES) - Rice Lake May, August, October 1977 and May, August 1978

	1977												1978									
	May				August				October				May						August			
	FN		ES		FN		ES		FN		ES		FN		GN		ES		FN		ES	
Fish	No	%	No	%	No	%	No	%	No	%	No	%	No	%	No	%	No	%	No	%	No	%
Catostomidae																						
White sucker	1	1	6	25	0	0	1	3	0	0	4	9	2	2	6	40	1	1	5	3	0	0
Shorthead redhorse	0	0	2	8	0	0	0	0	0	0	0	0	1	1	1	7	0	0	0	0	0	0
Centrarchidae																						
Bluegill	0	0	0	0	0	0	0	0	0	0	2	4	0	0	0	0	1	1	0	0	0	0
Rock Bass	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0
Pumpkinseed	0	0	6	25	52	88	3	10	0	0	3	7	1	1	0	0	3	4	0	0	1	14
Cyprinidae																						
Golden shiner	0	0	0	0	0	0	0	0	0	0	5	1	0	0	0	0	0	0	0	0	0	0
Common shiner	0	0	0	0	1	2	0	0	2	7	0	1	0	0	0	0	6	9	0	0	0	0
Blackchin shiner	0	0	0	0	0	0	1	3	0	0	2	0	0	0	0	0	0	0	0	0	0	0
Blacknose shiner	0	0	0	0	0	0	7	24	0	0	0	4 0	0	0	0	0	0	0	0	0	0	0
Esocidae																						
Northern Pike	2	2	0	0	0	0	0	0	2	7	0	0	1	1	4	27	0	0	1	<1	0	0

Table 3.8-43 *(Continued)*

	1977												1978									
	May				August				October				May						August			
	FN		ES		FN		ES		FN		ES		FN		GN		ES		FN		ES	
Fish	No	%	No	%	No	%	No	%	No	%	No	%	No	%	No	%	No	%	No	%	No	%
Ictaluridae																						
Black bullhead	92	96	3	12	4	7	15	52	16	57	28	6	104	95	4	27	58	84	177	95	6	86
Yellow bullhead	1	1	0	0	2	3	0	0	7	25	0	2 0	0	0	0	0	0	0	4	2	0	0
Percidae																						
Yellow perch	0	0	7	29	0	0	0	0	0	0	1	2	0	0	0	0	0	0	0	0	0	0
Salmonidae																						
Brook trout	0	0	0	0	0	0	0	0	1	4	0	0	0	0	0	0	0	0	0	0	0	0
Umbridae																						
Mudminnow	0	0	0	0	0	0	2	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	96		24		59		29		28		45		110		15		69		187		7	

Source: Dames & Moore, 1982
Checked by: WMW

Table 3.8-44

Numbers and Relative Abundance (Percent of Total Catch) of Fish Collected by Electroshocking (ES) - Hemlock Creek - Stations A-1 and A-2 May, August, October 1977 and May, August 1978

	1977												1978			
	May				August				October				May		August	
	A-1		A-2		A-1		A-2		A-1		A-2		A-1		A-1	
Fish	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Catostomidae																
White sucker	3	3	3	2	9	3	12	2	8	3	0	0	2	1	28	13
Centrarchidae																
Rock Bass	0	0	0	0	1	<1	0	0	0	0	0	0	0	0	0	0
Pumpkinseed	0	0	0	0	3	1	0	0	1	<1	0	0	0	0	1	<1
Bluegill	0	0	0	0	3	1	0	0	0	0	0	0	0	0	0	0
Cottidae																
Mottled sculpin	7	7	1	<1	0	0	1	<1	6	2	0	0	3	2	1	<1
Cyprinidae																
Brassy minnow	0	0	0	0	0	0	0	0	15	6	0	0	4	3	36	17
Hornyhead chub	1	1	0	0	0	0	0	0	0	0	0	0	1	<1	1	<1
Golden shiner	0	0	0	0	0	0	0	0	8	3	1	1	0	0	0	0
Common shiner	12	12	4	3	79	28	76	14	97	36	26	29	78	56	30	14
Blackchin shiner	0	0	0	0	0	0	0	0	1	<1	0	0	0	0	0	0
Blacknose shiner	0	0	2	1	18	6	1	<1	1	<1	1	1	2	1	0	0
Northern redbelly dace	11	11	53	34	54	19	299	54	6	2	30	33	14	10	54	25
Fathead minnow	4	4	17	11	11	4	6	1	69	26	0	0	1	<1	5	2
Bluntnose minnow	0	0	2	1	0	0	2	<1	2	1	1	1	1	<1	1	<1
Blacknose dace	7	7	0	0	24	9	0	0	6	2	0	0	3	2	9	4
Creek chub	16	16	5	3	18	6	12	2	27	10	5	6	15	11	26	12
Pearl dace	1	1	0	0	34	12	5	<1	4	2	0	0	0	0	10	5
Cyprinidae (unid. sp.)	4	4	2	1	14	5	87	16	0	0	0	0	0	0	0	0

Table 3.8-44 (*Continued*)

	1977												1978			
	May				August				October				May		August	
	A-1		A-2		A-1		A-2		A-1		A-2		A-1		A-1	
Fish	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Gasterosteidae																
Brook stickleback	22	23	51	32	0	0	12	2	1	<1	11	12	8	6	8	4
Ictaluridae																
Black bullhead	0	0	3	2	0	0	15	3	1	<1	2	2	0	0	2	<1
Percidae																
Johnny darter	3	3	11	7	1	<1	6	1	4	2	5	6	5	4	0	0
Yellow perch	5	5	0	0	9	3	1	<1	2	<1	4	4	0	0	1	<1
Salmonidae																
Brook trout	0	0	0	0	0	0	0	0	7	3	0	0	3	2	0	0
Umbridae																
Mudminnow	1	1	4	3	0	0	21	4	0	0	4	4	0	0	0	0
Total	97		158		279		558		266		90		140		213	

Source: Dames & Moore, 1982
Checked by: WMW

Table 3.8-45

Numbers and Relative Abundance (Percent of Total Catch) of Fish Collected by Electroshocking Hoffman Creek - Station E-1 June, August, October 1977

	1977					
	June		August		October	
Fish	No.	%	No.	%	No.	%
Catostomidae White sucker	0	0	1	3	5	18
Centrarchidae Bluegill	0	0	0	0	1	4
Cottidae Mottle sculpin	23	34	6	19	3	11
Cyprinidae						
Common Shiner	0	0	0	0	1	4
Blacknose dace	4	6	11	34	0	0
Creek chub	—	0	1	3	2	7
Esocidae Northern pike	2	3	0	0	0	0
Salmonidae Brook trout	39	57	12	38	16	57
Umbridae Mudminnow	0	0	1	3	0	0
Total	68		32		28	

Source: Dames & Moore, 1982
Checked by: WMW

3.8.2.8.4 Swamp Creek

Fish were collected from Stations B and D during May, August and October 1977 and at Station D during May and August 1978. Numbers and relative abundance of the species collected are presented in Table 3.8-46.

Minnow species generally numerically dominated the catches at both Stations B and D. Common shiner and creek chub were the most common species and were collected during each sampling period. In 1977 the common shiner comprised from 27 to 66 percent of the samples at Station B and from four to 21 percent of the samples at Station D. Creek chub comprised from six to 11 percent of the samples at Station B and from one to nine percent at Station D. In 1978 common shiner comprised 23 and five percent of the samples in May and August, respectively, and creek chub five and 14 percent of the samples in May and August, respectively, at Station D. Blacknose dace and longnose dace were also abundant minnows at Station D but few were caught at Station B.

White sucker was another commonly collected species. It occurred in all collections, in 1977 and comprised from 14 to 17 percent of the collections at Station B and from one to 37 percent at Station D. Black bullhead was the most abundant species at Station B in August 1977 but were uncommon during other sampling periods. Additional species collected by the WDNR in verification sampling were shorthead redhorse, Iowa darter, bluegill, and rockbass (Ramharter, 1982).

Information on species composition and relative abundance of fish in Swamp Creek downstream of County Trunk Highway M is presented in Ecological Analysts, Inc. (1983, 1984a). These results are from field sampling of fish populations in the vicinity of the proposed water discharge site during 1982 and 1983. The results of chemical analyses of muscle tissue from fish collected in Swamp Creek downstream from County Trunk Highway M are presented in Ecological Analysts, Inc. (1984b). Metal concentrations in four northern pike, six rock bass, and five white suckers collected downstream of County Trunk Highway M are presented in this 1984 report.

3.8.2.8.5 Fish Parasites

The occurrence of external parasites was periodically observed on various fish species. Blackspot (the metacercaria of larval flatworms known as strigeids) was the most commonly observed parasite. Frequently, heavy infestations of blackspot were found on yellow perch, brassy minnow, common shiner, fathead minnow, blacknose dace, and northern creek chub from Station A-1 on Hemlock Creek. Blackspot was observed infrequently on northern pike from Rolling Stone Lake and redbelly dace from Creek 11-4. In addition, the metacercaria of the trematode *Clinostomum marginatum* was observed in yellow perch musculature when tissue was being obtained for chemical analysis. Lesser levels of parasitism were observed on blacknose dace from Hoffman Creek, and longnose dace and mudminnow from Swamp Creek.

Table 3.8-46

Numbers and Relative Abundance (Percent of Total Catch) of Fish Collected by Electroshocking (ES) - Swamp Creek - Stations B and D May, August, October 1977 and May, August 1978

	1977												1978			
	May				August				October				May		August	
	B		D		B		D		B		D		D		D	
Fish	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Catostomidae																
White sucker	29	17	117	37	35	17	9	5	21	14	12	5	31	10	2	1
Centrarchidae																
Pumpkinseed	0	0	0	0	3	1	0	0	0	0	0	0	0	0	0	0
Largemouth bass	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0
Cottidae																
Mottled sculpin	41	24	4	1	1	<1	13	7	5	3	9	4	0	0	7	4
Cyprinidae																
Brassy minnow	0	0	0	0	0	0	0	0	3	2	0	0	0	0	0	0
Hornyhead chub	3	2	1	<1	7	3	2	1	9	6	24	11	9	3	0	0
Golden shiner	1	<1	0	0	0	0	0	0	0	0	0	0	0	0	2	1
Common shiner	46	27	68	21	60	28	8	4	102	66	20	9	75	23	8	5
N redbelly dace	0	0	2	<1	0	0	0	0	0	0	3	1	0	0	0	0
Fathead minnow	1	<1	2	<1	0	0	0	0	0	0	0	0	0	0	0	0
Bluntnose minnow	0	0	1	<1	0	0	2	1	0	0	0	0	0	0	0	0
Blacknose dace	3	2	30	9	0	0	33	18	1	<1	30	13	42	13	50	29
Longnose dace	0	0	41	13	0	0	98	52	0	0	112	50	72	22	68	40
Creek chub	18	11	11	3	3	1	16	9	9	6	3	1	16	5	24	14
Pearl dace	0	0	1	<1	0	0	0	0	0	0	0	0	1	<1	0	0
Cyprinidae (unid. sp.)	2	1	1	<1	0	0	3	2	0	0	0	0	0	0	0	0
Gasterosteidae																
Brook stickleback	8	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 3.8-46 (*Continued*)

	1977												1978			
	May				August				October				May		August	
	B		D		B		D		B		D		D		D	
Fish	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Ictaluridae																
Black bullhead	1	<1	0	0	80	38	0	0	1	<1	0	0	0	0	0	0
Yellow bullhead	0	0	0	0	0	0	0	0	0	0	1	<1	0	0	0	0
Percidae																
Johnny darter	13	8	0	0	4	2	0	0	2	1	1	<1	1	<1	7	4
Yellow perch	2	1	0	0	1	<1	0	0	1	<1	1	<1	0	0	0	0
Salmonidae																
Brook trout	1	<1	39	12	0	0	0	0	0	0	10	5	78	24	4	2
Umbridae																
Mudminnow	0	0	0	0	16	8	4	2	0	0	0	0	0	0	0	0
Total	169		318		211		188		154		226		325		172	

Source: Dames & Moore, 1982
Checked by: WMW

Other parasites or deformities observed on fish included the copepod *Salmincola edwardsii* (gill lice) on brook trout from Hoffman Creek, and deformed or abbreviated opercula on brook trout from Swamp Creek. Deformities of yellow perch such as deformed spines and jaw tumors were also observed.

3.8.2.8.6 Brook Trout Redd Survey

In the autumn, brook trout dig redds (nests) in gravel beds of headwater streams, with areas of groundwater flow particularly favored (Benson, 1953; Latta, 1965; Webster and Eiriksdottir, 1976). Because brook trout support a popular and intensive sport fishery in Wisconsin (Brasch et al., 1973), areas important to spawning brook trout were sought in October and November 1977 in Swamp Creek and its tributaries upstream of Rice Lake. Six potential spawning areas were observed, and their locations are depicted on Figure 3.8-9.

A relatively large potential spawning area was observed in Hoffman Creek approximately 210 m (689 feet) upstream of Station E-1 and extended for approximately 50 m (164 feet). This portion of the creek was characterized as having a sand and gravel bottom and observations of seeps and springs suggested a groundwater discharge. The area generally consisted of riffles, but small pools formed by in-stream obstructions such as fallen branches were also found. Aquatic vegetation was composed of *Nasturtium officinale* (watercress), which occurred in moderately sized clumps.

Brook trout typically disperse to downstream areas during their first summer of life (Hunt, 1965). The collection of trout less than 50 mm (two inches) at Station E-1 in June 1977 indicates that spawning probably occurred in Hoffman Creek in autumn 1976. Four other areas bearing qualities similar to those observed in Hoffman Creek were observed in the Swamp Creek drainage basin (Figure 3.8-14). However, these potential spawning areas were small, less than approximately 5 m (10 feet), and isolated by reaches, characterized by soft, silty, muck bottom, that are typically not suitable as trout spawning habitat. The generally low reproductive potential of brook trout in Swamp Creek is supplemented by the WDNR's stocking of 1,000 legal-sized 152-mm (six-inch) trout in spring in Swamp Creek at the Keith Siding Road bridge (Theis, 1978).

Areas that appeared suitable for spawning brook trout were sought in the three northern tributary streams of Rolling Stone Lake in October 1978. One marginally suitable spawning area was located in Creek 12-9. The substrate in this reach of the creek was characterized by sand, gravel and rubble with some indication of groundwater discharge such as seeps and springs. The creek in this area flowed through uplands into a lowland area and the stream character was primarily riffles. One brook trout was collected during the investigation by electrofishing, which suggests that brook trout production in Creek 12-9 is minimal.

3.8.2.8.7 Oak Lake

Fish were collected from Oak Lake during May, August and October 1977, and May and August 1978 by seine, gill net, or electroshocking. Numbers and relative abundances of the species collected are presented in Table 3.8-47.

Yellow perch was the most abundant species in Oak Lake in gill net and electroshocking catches. This species comprised from 78 to 100 percent of the gill net catches and from 90 to 95 percent of the electroshocking catches, excluding the October 1977 catch. Electroshocking was conducted around the entire lake in association with WDNR staff in October 1977, and although more fish (235) were collected than in other electroshocking collections (70 to 193), yellow perch comprised a similar portion of the catch (96 percent) as in other electroshocking samples (90 to 95 percent). In addition to yellow perch, seven golden shiner and two largemouth bass were collected in October 1977 using the WDNR electrofishing gear.

Yellow perch comprised more than 60 percent of the beach seine catches except for August 1978. In that period, golden shiner comprised 80 percent of the fish collected and yellow perch made up only 17 percent. Generally, golden shiner did not comprise more than seven percent of the catches.

Largemouth bass was the second most abundant species in the catches. It comprised from zero to six percent of the gill net, from three to eight percent of the electroshocking catches, and from <1 to 31 percent of the beach seine catches. In addition, white sucker was collected by the WDNR in verification sampling conducted during September and October 1979 and October 1980 (Ramharter, 1982). Sampling gear was minnow seine, gill nets, fyke nets, minnow traps, and boom shocker.

3.8.2.8.8 Pond 25-11

No fish were collected from minnow traps.

3.8.2.8.9 Hoffman Springs

Two finescale dace were the only fish collected in minnow traps from Hoffman Springs, Station E-2, in October 1978. Fish sampling in Hoffman Springs by the WDNR in October 1983 yielded the following species and numbers: brook trout (230), pearl dace (85), creek chub (14), common shiner (10), white sucker (9), brassy minnow (4), finescale dace (4), golden shiner (3), mottled sculpin (2), and pumpkinseed (1). Most of the brook trout that were captured had been stocked by the landowner three days prior to the WDNR investigation (Steuck, 1983).

Table 3.8-47

Numbers and Relative Abundance (Percent of Total Catch) of Fish Collected by Gill Net (GN)[a], Seine (BS)[b] and Electroshocking (ES) - Oak Lake - Station G May, August, October 1977 and May, August 1978

	1977														1978									
	May				August						October				May						August			
	(BS)		(GN)		(BS)		(GN)		(ES)		(GN)		(BS)		(GN)		(ES)		(BS)		(GN)		(ES)	
Species	no.	%	no.	%	no.	%	no.	%	no.	%	no.	%	no.	%	no.	%	no.	%	no.	%	no.	%	no.	%
Centrarchidae																								
Bluegill	1	1	0	0	0	0	0	0	3	2	0	0	10	7	1	1	0	0	7	1	0	0	1	1
Pumpkinseed	3	3	0	0	2	4	0	0	1	<1	0	0	2	1	2	2	5	3	16	2	0	0	0	0
Largemouth bass	28	31	5	11	8	16	0	0	5	3	1	1	6	4	8	6	5	3	1	<1	0	0	6	8
Cyprinidae																								
Golden shiner	1	1	3	7	0	0	0	0	1	<1	0	0	0	0	1	1	5	3	531	80	0	0	1	1
Longnose dace	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Ictaluridae																								
Black bullhead	0	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Yellow bullhead	0	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Percidae																								
Yellow perch	58	64	35	78	39	80	48	100	173	95	84	98	131	88	113	90	163	92	110	17	34	100	70	90
Total	91		45		49		48		183		86		149		125		178		665		34		78	

[a]One gill net fished in May, August, October 1977; two fished in May August 1978; numbers expressed as catch per set.

[b]Minnow seine was used in May 1977, beach haul seine was used at all other times.

Source: Dames & Moore, 1982

Checked by: WMW

3.8.2.8.10 Hoffman Pond

A total of 328 northern redbelly dace and 53 finescale dace were collected from Hoffman Pond, Station E-3, in October 1978. In addition, mudminnow and brook stickleback were observed in a minnow trap tended by the landowner. In October 1983, the WDNR sampled Hoffman Pond and collected 35 finescale dace, 27 creek chubs, 15 bluegill, eight brook stickleback, and seven central mudminnows (Steuck, 1983).

3.8.2.8.11 Rolling Stone Lake

Fish were collected from Rolling Stone Lake (Stations M-2 and M-4) during October 1977 and May and August 1978. Numbers and relative abundance of the species collected are presented in Table 3.8-48.

Yellow perch was the most abundant species collected in all samples, except in the fyke net catch of May 1978. It comprised 59 percent or more of the electrofishing catches in May and August 1978, was co-dominant with golden shiner in the October 1977 gill net catch, and was the only species collected in minnow traps in May 1978.

Other commonly occurring fish species were white sucker, black bullhead and members of the centrarchid (sunfish) family, particularly bluegill, pumpkinseed, and black crappie. Fish species characterized as "game fish" such as largemouth bass, northern pike and walleye were captured in low numbers in most sampling periods.

3.8.2.8.12 Pickerel Creek

Fish were collected from Pickerel Creek (Station M-5) during October 1977 and May and August 1978. Numbers and relative abundance of the six species collected are presented in Table 3.8-49.

Brook trout and mottled sculpin were the most abundant species and each comprised an average 26 percent of the catches. Brook trout were collected in all three sampling periods but no more than six individuals were captured in any one collection. Mottled sculpin were collected in May and August 1978, and no more than six individuals were captured in any one collection. No fish were collected in the minnow trap set in May 1978.

3.8.2.8.13 Creek 12-9

Fish were collected from Creek 12-9 (Station M-1) during October 1977 and May and August 1978. Numbers and relative abundance of the seven species collected are presented in Table 3.8-50.

Table 3.8-48

Numbers and Relative Abundance (Percent of Total Catch) of Fish Collected by Fyke Net (FN)[a], Gill Net (GN), Minnow Trapping (M) and Electroshocking (ES) Rolling Stone Lake - Stations M-2 and M-4 October 1977 and May and August 1978

	1977		1978													
	October		May										August			
	(GN)		(FN)		(GN)		(ES)		(MT)		(ES)[b]		(FN)		(ES)	
Species	No.	%	No.	%	No.	%	No.	%	No.	%	No	%	No	%	No	%
Catostomidae																
White sucker	1	3	3	30	1	25	3	3	0	0	3	17	2	3	2	2
Centrachidae																
Pumpkinseed	0	0	0	0	0	0	1	1	0	0	0	0	11	19	11	11
Bluegill	0	0	4	40	0	0	15	15	0	0	7	39	5	9	8	8
Largemouth bass	0	0	0	0	0	0	1	1	0	0	0	0	0	0	3	3
Black Crappie	0	0	1	10	0	0	1	1	0	0	3	17	2	3	1	1
Cyprinidae																
Golden shiner	15	38	0	0	0	0	0	0	0	0	0	0	2	3	5	5
Common shiner	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	3
Esocidae																
Northern pike	7	18	0	0	2	50	0	0	0	0	1	6	0	0	2	2
Ictaluridae																
Black bullhead	1	3	2	20	0	0	0	0	0	0	1	6	24	41	4	4

Table 3.8-48 *(Continued)*

	1977		1978													
	October		May										August			
	(GN)		(FN)		(GN)		(ES)		(MT)		(ES)[b]		(FN)		(ES)	
Species	No.	%	No.	%	No.	%	No.	%	No.	%	No	%	No	%	No	%
Percidae																
Yellow perch	15	38	0	0	1	25	78	79	7	100	0	0	12	21	59	59
Walleye	0	0	0	0	0	0	0	0	0	0	3	17	0	0	2	2
Total	39		10		4		99		7		18		58		100	

[a]One fyke net was fished in May 1978; two were fished in August 1978.
[b]Supplemental electroshocking collection along western shoreline; yellow perch were selectively not collected.

Source: Dames & Moore, 1982
Checked by: WMW

Table 3.8-49

Numbers and Relative Abundance (Percent of Total Catch) of Fish Collected by Electroshocking - Pickerel Creek - Station M-5 October 1977 and May and August 1978

	1977		1978			
	October		May		August	
	No.	%	No.	%	No.	%
Catostomidae						
White Sucker	0	0	0	0	5	12
Centrarchidae						
Largemouth bass	1	50	0	0	0	0
Cottidae						
Mottled sculpin*	0	0	6	75	1	2
Percidae						
Yellow perch	0	0	0	0	28	70
Salmonidae						
Brook trout	1	50	1	12	6	15
Umbridae						
Mudminnow	0	0	1	12	0	0
Total	2		8		40	

*Three additional mottled sculpin were collected in supplemental electroshocking in May.

Source: Dames & Moore, 1982
Checked by: RFS

Table 3.8-50

Numbers and Relative Abundance (Percent of Total Catch) of Fish Collected by Electroshocking - Creek 12-9 - Station M-1 October 1977 and May and August 1978

	1977		1978			
	October		May		August	
Species	No.	%	No.	%	No.	%
Centrarchidae						
Largemouth bass	2	33	0	0	0	0
Cottidae						
Mottle sculpin	1	17	6	86	2	22
Cyprinidae						
Blacknose shiner	1	17	0	0	0	0
Ictaluridae						
Black bullhead	0	0	1	14	0	0
Percidae						
Iowa darter	0	0	0	0	1	11
Yellow perch	2	33	0	0	5	56
Salmonidae						
Brook trout	0	0	0	0	1	11
Total	6		7		9	

Source: Dames & Moore, 1982
Checked by: WMW

Mottle sculpin was the most abundant species comprising from 17 to 86 percent of the catches and was the only species collected during each sampling period. Game fish collected at this station included largemouth bass, black bullhead, yellow perch and brook trout. In addition, mudminnow was collected by the WDNR in verification sampling (Ramharter, 1982).

3.8.2.8.14 Creek 11-4

Fish were collected from Creek 11-4 (Station M-3) during October 1977 and May and August 1978. Numbers and relative abundance of the 15 species collected are presented in Table 3.8-51.

Cyprinids were dominant in the electrofishing and minnow trap catches. Seven species of cyprinids were collected, and the northern redbelly dace, which comprised from 11 to 88 percent of electrofishing samples, was the most abundant species in all collecting periods. Fathead minnow, which comprised from seven to 12 percent of the electrofishing catches, was the only other species collected in every sampling period. Game fish included bluegill, largemouth bass and yellow perch. Additional species collected by the WDNR in verification sampling were yellow perch, black crappie, and mottled sculpin (Ramharter, 1982).

3.8.2.8.15 Little Sand Lake

Ten species of fish, representing the families Catostomidae, Centrarchidae, Esocidae, Ictaluridae, and Percidae, were collected in Little Sand Lake during May, August and October 1977 and May and August 1978.

Yellow perch, yellow bullhead, and bluegill were collected in all months sampled and generally were the most abundant species in Little Sand Lake (Table 3.8-52). Yellow perch were the most abundant species in the gill net catches, except in October 1977, comprising 67 to 100 percent of the samples and in electroshocking samples comprising 42 to 87 percent. Yellow bullhead comprised two to 49 percent, and bluegill one to 72 percent (16 per net set) of the fyke net catches. Other species collected were black crappie, largemouth bass, walleye, and northern pike. Although black crappie and largemouth bass comprised small percentages ($\leq$14 percent) of any collection, they were collected in most sampling periods. With the exception of October 1977, where walleye made up the entire gill net catch, walleye and northern pike occurred infrequently and made up five percent or less of the catches.

Electrofishing in October 1977 by the WDNR (Theis, 1978) yielded higher numbers of fish (217) than electrofishing samples for the baseline studies (27 to 134). However, the WDNR sampled the entire lake perimeter, whereas baseline sampling was conducted for approximately 0.5 hour, which encompassed approximately one-half of the lake perimeter. The assemblage of fish collected by the WDNR was similar to other baseline electrofishing samples. Fish collected and their percent of catch were: bluegill, 8; pumpkinseed, 4; black crappie, 4; largemouth bass, <1; northern pike, <1; black bullhead, <1; yellow bullhead, 12; and yellow perch, 71. Additional fish species collected by the WDNR in verification sampling were mudminnow, northern pike, and

Table 3.8-51

Numbers and Relative Abundance (Percent of Total Catch) of Fish Collected by Minnow Trap (MT) and Electroshocking (ES) Creek 11-4 - Station M-3 October 1977 and May and August 1978

	1977						1978	
	October				May		August	
	(ES)		(ES)		(MT)		(ES)	
Species	No.	%	No.	%	No.	%	No.	%
Centrarchidae								
Bluegill	3	11	0	0	0	0	0	0
Largemouth bass	4	15	0	0	0	0	0	0
Cyprinidae								
Brassy minnow	1	4	59	4	40	17	0	0
Blacknose shiner	0	0	37	3	4	2	0	0
Northern redbelly dace	3	11	1030	78	164	71	105	88
Finescale dace	0	0	1	<1	0	0	0	0
Fathead minnow	2	7	156	12	12	5	9	8
Northern creek chub	11	41	0	0	0	0	0	0
Pearl dace	0	0	3	<1	0	0	0	0
Gasterosteidae								
Brook stickleback	0	0	32	2	11	5	1	1
Percidae								
Iowa darter	0	0	0	0	0	0	2	2
Johnny darter	1	4	0	0	0	0	0	0
Yellow perch	2	7	0	0	0	0	0	0
Umbridae								
Mudminnow	0	0	6	<1	0	0	3	2
Total	27		1324		231		120	

Source: Dames & Moore, 1982
Checked by: WMW

Table 3.8-52

Numbers and Relative Abundance (Percent of Total Catch) of Fish Collected by Gill Net (GN)[a], Fyke Net (FN)[b], Seining (BS)[c] and Electroshocking (ES) - Little Sand Lake - Stations H and I May, August, October 1977 and May and August 1978

	1977																			
	May						August								October					
	(BS)		(GN)		(FN)		(BS)		(GN)		(FN)		(ES)		(BS)		(GN)		(FN)	
Fish	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Catostomidae																				
White Sucker	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Centrarchidea																				
Bluegill	2	4	0	0	10	12	20	21	0	0	78	72	1	4	1	10	0	0	3	4
Pumpkinseed	25	44	0	0	3	4	35	36	0	0	23	21	1	4	0	0	0	0	1	1
Black Crappie	0	0	0	0	9	11	0	0	0	0	0	0	2	7	0	0	0	0	29	41
Largemouth bass	4	7	0	0	0	0	12	12	0	0	5	5	0	0	0	0 0	0	0	0	0
Esocidae																				
Northern pike	0	0	0	0	0	0	0	0	1	5	0	0	0	0	0	0	0	0	0	0
Ictaluridae																				
Black bullhead	0	0	0	0	0	0	0	0	0	0	0	0	1	4	0	0	0	0	1	1
Yellow bullhead	0	0	0	0	15	18	0	0	1	5	2	2	5	19	0	0	0	0	34	49
Percidae																				
Walleye	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	100	0	0
Yellow perch	26	46	170	100	44	54	29	30	18	90	1	<1	17	63	0	0	0	0	2	3
Total	57		170		82		96		20		109		27		1		2		70	

Table 3.8-52 *(Continued)*

Fish	1978															
	May								August							
	(BS)		(GN)		(FN)		(ES)		(BS)		(GN)		(FN)		(ES)	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Catostomidae																
White sucker	0	0	0	0	0	0	0	0	0	0	1	33	0	0	0	0
Centrarchidae																
Bluegill	0	0	0	0	1	1	0	0	13	30	0	0	34	45	14	10
Pumpkinseed	0	0	0	0	0	0	3	5	21	48	0	0	7	9	39	29
Black crappie	0	0	0	0	14	20	2	3	0	0	0	0	0	0	0	0
Largemouth bass	0	0	0	0	0	0	0	0	4	9	0	0	5	7	9	7
Esocidae																
Northern pike	0	0	1	4	0	0	0	0	0	0	0	0	0	0	0	0
Ictaluridae																
Black bullhead	0	0	0	0	2	3	1	2	0	0	0	0	0	0	0	0
Yellow bullhead	0	0	0	0	51	73	2	3	0	0	0	0	26	35	16	12
Percidae																
Walleye	0	0	0	0	2	3	0	0	0	0	0	0	0	0	0	0
Yellow perch	4	100	25	96	0	0	54	87	6	14	2	67	3	4	56	42
Total	4		26		70		62		44		3		75		134	

[a]Two gill nets were fished.
[b]One fyke net was fished in May and August 1977; two were fished in October 1977 and May and August 1978.
[c]Minnow net was used May 1977; beach haul seine was used other times.

Source: Dames & Moore, 1982
Checked by: WMW

Iowa darter (Ramharter, 1982). Samples were obtained with fyke nets, minnow seines, and boom electrofisher in May, September and October 1979 and October 1980.

3.8.2.8.16 Duck Lake

Yellow perch, black bullhead, and mudminnow were collected from Duck Lake in May, August and October 1977 and May and August 1978 surveys (Table 3.8-53). Yellow perch, which comprised 73 percent or more of the gill net catches, was the only species caught in minnow traps and it comprised 87 percent of the electroshocking samples. Black bullheads were a minor portion of the catches in 1977 (two to 27 percent) and none were collected in 1978. Mudminnows were collected in low numbers in October 1977 and August 1978.

No additional fish species were collected by the WDNR in verification sampling (Ramharter, 1982). Fish sampling consisted of gill netting and fyke netting in October 1979 and 1981.

3.8.2.8.17 Deep Hole Lake

Walleye, yellow perch, white sucker and golden shiner were the only species collected in Deep Hole Lake during May, August and October 1977 and May and August 1978 surveys (Table 3.8-54). Yellow perch, the most abundant species in all collections, comprised 75 percent or more of the gill net catches, and 67 percent or more of the eletroshocking samples. Walleye comprised minor portions of the electroshocking and gill net catches. No fish were caught in minnow traps fished in May 1978.

Additional fish species collected by the WDNR in verification sampling were mudminnow and bluegill (Ramharter, 1982). Fish sampling was conducted in September and October 1979 utilizing minnow seine, fyke nets, gill nets and boom shocker.

3.8.2.8.18 Skunk Lake

No fish were collected by minnow trapping (May 1977) or modified streamside electroshocking (May 1978) in Skunk Lake. Also no fish were collected by the WDNR in verification sampling in September 1979 (Ramharter, 1982).

3.8.2.8.19 Pond 31-13

No fish were collected in minnow traps set in Pond 31-13.

3.8.2.8.20 Pond 6-8

Two mudminnows were the only fish collected by minnow trapping in Pond 6-8 in 1977.

Table 3.8-53

Numbers and Relative Abundance (Percent of Total Catch) of Fish Collected by Gill Net (GN)[a], Minnow Trap (MT)[b] and Electroshocking (ES) - Duck Lake - Station K May, August, October 1977 and May and August 1978

	1977						1978							
	May		August		October		May				August			
	(GN)		(GN)		(GN)		(GN)		(MT)		(GN)		(ES)	
Species	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Ictaluridae														
Black bullhead	12	27	1	2	1	2	0	0	0	0	0	0	0	0
Percidae														
Yellow perch	32	73	53	98	45	96	453	100	528	100	61	100	26	87
Umbridae														
Mudminnow	0	0	0	0	1	2	0	0	0	0	0	0	4	13
Total	44		54		47		453		528		61		30	

[a]One gill net was fished in May and August 1977 and May 1978; two nets were fished in October 1977 and August 1978.
[b]Three minnow traps were fished.

Source: Dames & Moore, 1982
Checked by: WMW

Table 3.8-54

Numbers and Relative Abundance (Percent of Total Catch) of Fish Collected by Gill Net (GN)*, and Electroshocking (ES) - Deep Hole Lake - Station L May, August, October 1977 and May and August 1978

	1977						1978							
	May		August		October		May				August			
	(GN)		(GN)		(GN)		(ES)		(GN)		(ES)		(GN)	
Species	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Catostomidae														
White sucker	0	0	0	0	0	0	0	0	1	6	0	0	0	0
Cyprinidae														
Golden shiner	0	0	0	0	0	0	0	0	0	0	2	4	0	0
Percidae														
Walleye	0	0	2	3	1	5	9	33	3	19	1	2	3	4
Yellow perch	13	100	62	97	19	95	18	67	12	75	51	94	65	96
Total	13		64		20		27		16		54		68	

*One gill net was fished in May and August 1977; two nets were fished in October 1977 and May and August 1978.

Source: Dames & Moore, 1982
Checked by: WMW

3.8.2.8.21 Pond 35-7

Fish collected from Pond 35-7 in 1977, along with the number collected, and the percent of the catch are: finescale dace, 344 (75 percent); fathead minnow, 59 (13 percent); bluntnose minnow, 55 (12 percent); and brook stickleback, 1 (<1 percent).

3.8.2.8.22 Pond 34-1

One brook stickleback was the only fish collected from minnow traps set in Pond 34-1 in 1977.

3.8.2.8.23 Wolf River

Fish were collected by electroshocking at both Stations Y and Z in May, August and October 1978 (Table 3.8-55).

Common species were white sucker, shorthead redhorse, and common shiner, which comprised up to 27 percent of the fish collected and occurred in every sampling period except August at Station Z. Black bullheads were also common but were not found in the August sampling at either station.

In August at Station Z no fish were captured during electroshocking collections and only small minnows, creek chub, hornyhead chub, common shiner, and an unidentified shiner were collected along the shore by dip net. White sucker, shorthead redhorse, common shiner, rock bass, yellow perch, black crappie, and hornyhead chub were collected by electroshocking conducted at the mouth of the Hunting River, which is located approximately 200 m (656 feet) downstream from Station Z. At the time of sampling, fish apparently avoided this area of the Wolf River for a more suitable area because dissolved oxygen concentrations, measured concurrently with fish sampling, were low, 1.4 mg/L at Station Z, and higher, 5.6 mg/L, at the mouth of the Hunting River. No additional fish species were collected by the WDNR in verification sampling (Ramharter, 1982).

3.8.2.9 Results of Fish Collection Activities Conducted in 1994.

Fish were collected in May and June 1994 by EA Associates, Deerfield, Illinois. Records of findings are provided in Appendix 3.8-6. Fish collection activities conducted in 1994 were not for the purpose of completing a general population survey. The survey targeted threatened, endangered, or species of concern. No threatened, endangered, or species of concern were collected during these efforts. Data regarding fish collections are provided in Appendix 3.8-7.

Fish were collected for tissue analysis in May and June 1994. Two sites on Swamp Creek, CMC-AB-SC-501 and CMC-AB-SC-502 and one site at Little Sand Lake yielded the requisite ten perch in May. Insufficient perch were collected from either of two Wolf River sampling locations in May. Therefore during a second site visit additional effort was expended to collect perch in the Wolf River. This occurred in June 1994. Because the additional collection effort

Table 3.8-55

Numbers and Relative Abundance (Percent of Total Catch) of Fish Collected by Electroshocking - Wolf River - Stations Y and Z May, August and October 1978

	May				August*				October	
	(Y)		(Z)		(Y)		(Y)		(Z)	
Species	No.	%	No.	%	No.	%	No.	%	No.	%
Catostomidae										
White sucker	7	21	10	10	1	12	7	7	18	27
Northern Hog sucker	0	0	2	2	0	0	0	0	0	0
Shorehead redhorse	3	9	6	6	2	25	2	2	1	1
Centrarchidae										
Rock bass	0	0	13	13	0	0	0	0	9	13
Pumpkinseed	0	0	0	0	0	0	3	3	1	1
Bluegill	0	0	1	1	0	0	0	0	0	0
Smallmouth bass	1	3	0	0	0	0	2	2	1	1
Black crappie	1	3	8	8	0	0	0	29	0	0
Cyprinidae										
Brassy minnow	1	3	0	0	0	0	0	0	0	0
Hornyhead chub	0	0	17	17	0	0	3	3	3	4
Golden shiner	0	0	0	0	0	0	1	<1	0	0
Common shiner	1	3	22	22	3	38	2	2	9	13
Blacknose shiner	0	0	0	0	0	0	1	<1	0	0
Bluntnose minnow	0	0	0	0	2	25	2	12	0	0
Creek chub	0	0	1	1	0	0	0	0	0	0
Esocidae										
Northern pike	0	0	0	0	0	0	1	<1	1	1
Ictaluridae										
Black bullhead	14	41	7	7	0	0	5	15	17	25
Yellow bullhead	5	15	1	1	0	0	6	6	2	3
Tadpole madtom	0	0	2	2	0	0	1	<1	1	1
Percidae										
Johnny darter	0	0	0	0	0	0	2	2	0	0
Yellow perch	1	3	9	9	0	0	4	14	4	6
Total	34		99		8		102		67	

*No fish were collected in sampling at Station Z.

Source: Dames & Moore, 1982
Checked by: WMW

failed to obtain sufficient numbers of perch for the study, white sucker was substituted for perch for the tissue analysis. Table 3.8-56 provides the data for the tissue and liver analysis.

3.8.2.10 Results of Mussel Collection Activities Completed in 1993 and 1994

Mussel collections were conducted the last week of July and first week of August 1994. Results of mussel identification are provided in Table 3.8-57. Raw data, including field sheets, are provided in Appendix 3.8-8. No threatened or endangered species of mussels were collected from the lakes, streams, or rivers in the Crandon Project study area. A total of three special concern species were collected from the study area. These include the elktoe (*Alasmidonta marginata*, three specimens all from the Wolf River), the creek heelsplitter (*Lasmigona compressa*, 17 specimens all from Swamp Creek), and the round pigtoe (*Pleurobema coccineum*, 103 specimens from the Wolf River and Swamp Creek). The round pigtoe was the second most abundant species collected in two of the sample locations (CMC-AB-SGI-CC and CMC-AB-SC-502). Most specimens of the creek heelsplitter were found in Swamp Creek at site CMC-AB-SC-501).

While the investigation of the Pickerel Creek drainage was limited upstream of Rolling Stone Lake and 100 feet of the discharge from Rolling Stone Lake (Pickerel Creek), no special concern species were collected from these bodies or upstream locations on this chain. An extensive search for the salamander mussel (*Simpsonaias ambigua*) was conducted in two areas of the Wolf River were there was thought to be suitable habitat. These areas included the river immediately below the Post Lake Dam (Site CMC-AB-WR-200) and the river at the Lost Lake Road access (Site CMC-AB-SGI-CC). Substrate in both of these locations contained large rocks and small boulder. The search for this species involved moving the large rocks/boulders and searching beneath for the target mussel. The cylindrical papershell (*Anodontoides ferussacianus*), a species very similar to the salamander mussel was collected and properly identified in the same habitat from which the salamander mussel, might be located. Supplemental studies conducted by the WDNR (July 1991 and September 1994, unpublished report) have also failed to locate the salamander mussel in this area.

In late July 1994 there was a reported collection of a state threatened species (slippershell, *Alasmidonta viridis*) by Glen Miller of GLIFWC in the same area as Site CMC-AB-SGI-CC. Specimen verification is still pending. During follow-up field work conducted in September 1994 by Dave Heath of WDNR, specimens of the squawfoot (*Strophitis undulatus*) were collected. The squawfoot is morphologically similar to the slippershell. It is believed that the squawfoot, which is not a species of concern, is the likely identification of the GLIFWC specimen. Several specimens of the squawfoot were collected and identified as such by Helms & Associates in the same location during the first week of August 1994.

Table 3.8-56

Concentrations (mg/kg) of Metals in Fish Tissue and Mercury in Fish Livers May/June 1994

	Perch			White Sucker	
	CMC-AB-SC-501	CMC-AB-SC-502	CMC-AB-SL-005	CMC-AB-WR-301	CMC-AB-SGI-CC
Metals					
Arsenic	<0.13	<0.13	0.14	<0.13	<0.16
Cadmium	<0.19	<0.20	3.20	<0.40	<0.31
Chromium	0.95	1.10	0.84	1.30	1.20
Cobalt	0.22	0.34	0.33	<0.43	<0.33
Copper	28.0	17.0	13.1	5.2	6.6
Lead	0.58	0.23	0.35	0.60	0.16
Manganese	8.4	10.6	4.2	9.3	13.7
Zinc	90.2	87.5	68.2	56.4	66.3
Mercury					
1	0.96	0.70	2.80	0.74	1.20
2	0.68	1.00	3.60	1.90	1.10
3	1.50	0.88	2.20	1.30	1.80
4	0.69	0.85	2.40	0.73	0.62
5	0.37	1.10	4.70	0.63	1.10

Table 3.8-56 *(Continued)*

	Perch			White Sucker	
	CMC-AB-SC-501	CMC-AB-SC-502	CMC-AB-SL-005	CMC-AB-WR-301	CMC-AB-SGI-CC
6	0.90	0.92	0.69	1.90	0.86
7	0.79	0.79	3.10	1.90	1.90
8	1.20	1.20	2.80	0.75	1.00
9	0.62	0.36	2.50	0.80	1.10
10	0.71	0.94	3.60	0.64	2.20

Prepared by: WMW
Checked by: JJA

Table 3.8-57

1994 Mussel Inventory

Organism	Site	Date	Status
Alasmodonta marginata	CMC-AB-SGI-CC	7/30/94 9/29/94	Special Concern
Anodonta grandis	CMC-AB-SGI-CC	7/30/94 9/29/94	None
	CMC-AB-WR-301	5/10/94	
	CMC-AB-WR-200	7/30/94	
	CMC-AB-SC-501	8/02/94	
	CMC-AB-SC-502	8/01/94	
	CMC-AB-PK-300	8/05/94	
	CMC-AB-RS-005	8/02/94 8/05/94	
Anodontoides ferussacianus	CMC-AB-SGI-CC	7/30/94 9/29/94	None
	CMC-AB-SC-250	9/30/93	
	CMC-AB-SC-501	8/02/94	
	CMC-AB-SC-502	8/01/94	
	CMC-AB-SC-700	9/29/94	
	CMC-AB-HL-200	8/04/94	
Fusconia flava	CMC-AB-WR-301	5/10/94	None
	CMC-AB-SC-501	8/02/94	
	CMC-AB-SGI-CC	9/29/94	
	CMC-AB-SC-700	9/29/94	
Lampsilis cardium	CMC-AB-WR-200	7/30/94	None
	CMC-AB-WR-301	5/10/94	
	CMC-AB-SGI-CC	7/30/94 9/29/94	
	CMC-AB-SC-501	8/02/94	

Table 3.8-57 *(Continued)*

Organism	Site	Date	Status
	CMC-AB-SC-502	8/01/94	
	CMC-AB-SC-700	9/29/94	
Lampsilis siliquoidea	CMC-AB-WR-200	7/30/94	None
	CMC-AB-WR-301	5/10/94	
	CMC-AB-SGI-CC	7/30/94 9/29/94	
	CMC-AB-SC-250	9/30/93	
	CMC-AB-SC-300	7/31/94	
	CMC-AB-SC-301	7/31/94	
	CMC-AB-SC-501	8/02/94	
	CMC-AB-SC-502	8/01/94	
	CMC-AB-HL-200	7/29/94 8/04/94	
	CMC-AB-SC-700	9/29/94	
Lampsilis siliquoidea	CMC-AB-RS-005	8/05/94	None
Lasmigona costata	CMC-AB-WR-200	7/30/94	None
	CMC-AB-WR-301	5/10/94	
	CMC-AB-SGI-CC	7/30/94 9/29/94	
Lasmigona compressa	CMC-AB-SC-301	7/31/94	Special Concern
	CMC-AB-SC-501	8/02/94	
	CMC-AB-SC-502	8/01/94	
	CMC-AB-SGI-CC	9/29/94	
Pleurobema coccineum	CMC-AB-SC-700	9/29/94	Special Concern
	CMC-AB-SGI-CC	9/29/94	
	CMC-AB-WR-200	7/30/94	

Table 3.8-57 *(Continued)*

Organism	Site	Date	Status
	CMC-AB-WR-301	5/10/94	
	CMC-AB-SGI-CC	7/30/94	
	CMC-AB-SC-501	8/02/94	
	CMC-AB-SC-502	8/01/94	
Strophitus undulatus	CMC-AB-SGI-CC	7/30/94	None
	CMC-AB-PK-300	8/05/94	
	CMC-AB-SC-700	9/29/94	

Prepared by: WMW
Checked by: JJA

3.8.3 Ecological Significance of Findings

The Crandon Project study area is surrounded by two watersheds, the Swamp Creek and Pickerel Creek chains, both of which are within the Wolf River drainage basin. Some of the lakes located within the Crandon Project study area are connected directly via surface flow to one or the other chains, while other lakes are indirectly connected via subsurface flow or are isolated. Hemlock Creek which borders the project study area to the east, is directly connected to the Swamp Creek chain. Some lakes such as Duck Lake, Little Sand Lake, and Deep Hole Lake are at times directly connected to the Pickerel Creek chain via Creek 12-9, however, only during periods of extremely high water is this a direct connection. In most cases, the outlet of Little Sand Lake is no more than recharge to adjacent wetlands. These physical connections are important from the standpoint of species distribution and migration up the Pickerel Chain, especially for species of fish and mussels. Other lakes which appear to have similar isolated conditions include Skunk Lake which indirectly drains toward the Pickerel Chain, and Oak Lake and Popple Pond which drain toward Swamp Creek. Another factor which restricts the migration of fish and mussels includes natural barriers such as beaver dams. This is especially true along Hemlock Creek and Swamp Creek above Rice Lake.

Biologically, the Swamp Creek watershed is connected only with the Wolf River watershed. There are no other surface water connections with any other watersheds via lakes or streams that would allow movements of fish, macroinvertebrates, or other forms of aquatic biota between watersheds. Aquatic insects, most of which are capable of dispersal flight in the adult stage, could conceivably colonize any suitable habitat within the project area, as physical/geographical barriers here are extremely slight. This is especially true for the Odonata. Differences in insect species composition at the different sample sites is much more dependant on specific habitat requirements.

The flow rate of tributary streams to Swamp Creek and Rice Lake is sufficient to support biological populations that could serve as sources for colonization of downstream water bodies. There is no linkage for aquatic species between the Pickerel Creek watershed and any adjacent watersheds except the Wolf River. No surface water connections exist with any other watersheds via lakes or streams that would allow movements of fish, macroinvertebrates, or other forms of aquatic biota between watersheds. The flow rate in tributary streams to Rolling Stone Lake is sufficient to support biological populations that could serve as sources for colonization of downstream water bodies.

Streams of the study area generally share similar physical characteristics. The streams are small, often not well defined, and of low gradient. Generally, the creeks have surface water drainage from and through wetland areas and the creek bottoms are composed of soft muck. However, small areas of firm sand and gravel substrate also exits in portions of most creeks. The Wolf River also drains wetlands but the bottom composition is generally more firm than the creeks. The extent of riffle habitat is minor in most of the streams with the only significant riffle area being found in Swamp Creek north of the project area. This is important for survey purposes, as riffles can support high biological diversity and a relatively high number of "sensitive species".

Previous studies conducted in the 1970s and 1980s (Dames & Moore, 1982; Ecological Analysts, Inc., 1983) reported no threatened, endangered, or special concern species in the fish, mussel, macroinvertebrate, or Odonata groups. With the exception of fish, the lack of such findings in earlier studies is attributable to differences in method of collection, degree of taxonomy required and study objectives.

3.8.3.1 Summary of 1977-1978 Biological Findings

The analysis of periphytic algal samples suggests that communities were generally similar in the running waters. Diatoms comprised the major portions of the collections, and *Cocconeis placentula* or *Achnanthes minutissima* were the most abundant species. Notable exceptions occurred in Pickerel Creek where *Eunotia curvata* and *Navicula minima* were most abundant, and Creek 11-4 where *A. lanceolata* was the most abundant.

Benthic macroinvertebrate data indicate that benthos composition and abundance was primarily dependent on the habitats present; that is, substrate type, current velocity, and dissolved oxygen content. In the creeks, numbers of organisms were highest (consistently >14,000/m^2) in samples from areas of soft silty substrate such as Creek 11-4 and Hemlock Creek. Densities were lowest (<4,000/m^2) in samples from areas of highest current velocity with sand and gravel substrates, such as Station D at Swamp Creek. Midges, which occur over a wide range of substrates (Curry, 1965), were the most abundant benthic taxa at all stations except Creek 11-4 and the Wolf River. In Creek 11-4, worms from the family Tubificidae were abundant in the organic sediment. Brinkhurst (1966) and Brinkhurst and Jamieson (1971) have indicated that most tubificids are generally dominant in soft sediments. The largest densities of clams were typically found in substrates composed of silt with some sand such as occurred at Station E on Swamp Creek, Creek 12-9, and both stations on the Wolf River. DeMarch (1976) reported that the clam *Sphaerium* sp. was very common in substrates composed of sand overlain with silt. Caddisflies, specifically *Leucotrichia pictipes* and *Glossosoma* sp., which were subdominant at Station D in Swamp Creek, are typical of such fast-flowing areas of streams (Wiggins, 1977).

Information on the spatial and temporal relationships of benthic macroinvertebrates in Swamp Creek downstream from County Trunk Highway M is presented in reports by Ecological Analysts, Inc. (1983, 1984a). These reports contain biotic index values for macroinvertebrates and identification of dominant taxa in the vicinity of the previously proposed water discharge site.

Based on electrofishing data, three general fish associations were apparent in streams of the study area. In the smaller, headwater streams such as Hoffman and Pickerel creeks and Creek 12-9, numbers of species were low (five to nine) and brook trout and mottled sculpin were dominant. Station D in Swamp Creek had intermediate characteristics. Swamp Creek is a large stream providing more habitats for varied fish species (15), but because of the steep gradient, it has characteristics of a headwater stream, such as an abundance of brook trout, mottle sculpin, and other trout indicator species, specifically blacknose and longnose dace (Becker, 1976). In the larger sluggish streams (>4.0 m [>13 feet] mean width), including portions of Hemlock

Creek, Swamp Creek, and Creek 11-4 (because of its pond-like characteristics), numbers of species were relatively high (15 to 21) and generally dominated by minnows.

Information on fish communities in Swamp Creek downstream from County Trunk Highway M is presented in reports by Ecological Analysts, Inc. (1983, 1984a). These reports contain documentation on the spatial and temporal characteristics of fish species in the vicinity of the proposed water discharge site and a comparison of the species found in Swamp Creek in relation to those reported in the Wolf River and Rice Lake and in Swamp Creek upstream from Rice Lake.

With few exceptions, phytoplankton densities in the lakes were lowest in samples collected during winter and with improving light conditions and increasing temperature during spring, phytoplanton densities increased and peaked in July, August or September then decreased in the fall. Nitrate, an important nutrient for phytoplankton, was generally highest during winter when phytoplankton levels were lowest, and decreased throughout the year to levels below detection limits in the autumn. Exceptions to the general pattern of summer phytoplankton maxima were observed in samples from Deep Hole and Rolling Stone lakes where phytoplankton exhibited two peaks in abundance: May and September 1978 in Deep Hole, and March and August 1978 in Rolling Stone Lake.

Golden-brown algae were abundant in samples from all lakes, and green algae and blue-green algae were also common. Diatoms, in contrast to their abundance in periphyton, were common only in phytoplankton samples from Rice Lake.

Zooplankton densities were typically lowest in samples collected in March, and spring or autumn pulses were observed. Both spring and autumn pulses were recorded in samples from all lakes except Duck, Deep Hole, and Skunk. Autumn maxima only were observed at Duck and Deep Hole lakes. Skunk Lake, sampled from June through October, exhibited highest density in July and low densities during subsequent months. Densities were typically <400/L in all lakes except when high numbers of rotifers were collected. Rotifers were most abundant in Skunk (up to 1,200/L), Duck, and Deep Hole Lakes. Copepods dominated in Little Sand and Oak Lakes, lakes with the clearest water. Copepods and rotifers were generally co-dominant in Rice and Rolling Stone Lakes, the hard water lakes.

Diatoms comprised the major portion of the periphytic algae samples from the lakes which also was observed in the creeks. Most diatoms are sessile and are associated with littoral substrates (Hutchinson, 1967). Diatom dominance generally was greatest in samples collected during spring and autumn and least during summer. Diatoms were less dominant in the samples from seepage than discharge lakes possibly because the levels of silica were lower in the mineral-poor waters of the seepage lakes. *Cocconeis placentula*, a dominant or sub-dominant in most creeks, was the dominant species in the discharge lakes. *Tabellaria fenestrata* or *T. flocculosa* were the dominant diatoms in the seepage lakes, except Skunk Lake. In Skunk Lake, *Nitzschia palea* was most abundant. Water chemistry data indicate that nutrient levels were highest in Skunk Lake,

which is consistent with the abundance of *N. palea*, an indicator of organic enrichment (Palmer, 1969).

Density of benthic organisms was lowest in samples collected from the uniform muck substrate in Oak Lake (<8,000/m^2) and tended to be highest in the dense vegetation at Rice and Rolling Stone lakes (up to 58,000/m). Midges predominated in samples from all seepage lakes except Duck Lake. Snails, midges and worms were prominent in the discharge lakes. *Tanytarsus* sp. was the most common midge at all lakes except Skunk and Rolling Stone, where *Chironomus* sp. was most common. *Chironomus* sp. is typically predominant in the benthos of eutrophic lakes or areas subject to oxygen depletion (Brundin, 1956). *Tanytarsus* sp. is more sensitive to oxygen depletion and is typically found in less enriched areas (Brundin, 1956).

The seepage lakes of the study area have very low intermittent inflow or outflow, which severely restricts opportunity for interlake fish movements. In general, the fish fauna was characterized as consisting of a few species with yellow perch as the dominant. No fish were found in Skunk Lake. Periodically low dissolved oxygen concentrations apparently make the lake uninhabitable for fish. Based on total species counts from all sampling gear, species richness was highest in lakes that contained varied habitat such as Oak Lake (8 species), and Little Sand Lake (10 species), where sand, gravel, muck and vegetation were present. In Duck Lake, where the bottom substrate primarily consisted of soft muck, only three species were collected. Sunfish, which prefer a firm sand or gravel substrate for spawning, occurred only in Oak and Little Sand Lakes.

The data indicate that the fish communities were generally similar in the two discharge lakes. Fifteen species were collected in Rice Lake and twelve in Rolling Stone Lake. Black bullhead, white sucker, and sunfish species were common in samples from both lakes. However, walleye and black crappie were found in Rolling Stone Lake, but not Rice Lake. Both species prefer water bodies with firm bottoms (Becker, 1976). Although extensive areas of Rolling Stone Lake contain soft sediments, sand and gravel areas exist along the near-shore areas, particularly along the eastern and western shore, whereas no firm substrate was found in Rice Lake. In the Wolf River, 21 species of fish were collected. The collections were generally dominated by suckers, minnow species and black bullhead.

3.8.3.2 Significance of Macroinvertebrate Findings from 1993-1994 Studies

Aquatic macroinvertebrates were collected from November 1993 through August 1994. Most of the collections were instream life stages of macroinvertebrates, such as annelids, leeches, insects, crustaceans and mollusks. However, to help identify some specimens to species, some groups were collected in the adult stages. Adult insect collections were conducted using light trapping techniques. Groups targeted for light trapping included members of the orders Ephemeroptera, Trichoptera, Plecoptera, and Coleoptera.

This discussion will not address Odonata, which will be addressed in a following section. No threatened or endangered aquatic macroinvertebrate species were collected or observed from the

study area during the period of study. Some Trichoptera larvae were collected which were of a genus (*Triaenoides*) which could contain a listed species; however, larvae of this genus cannot be identified to species. Subsequent light trapping for adults of the aquatic forms resulted in the finding of a species of concern (*T. dipsius*) at several locations throughout the study area. Two of the four sites where *Triaenoides dipsius* was collected were sites where streams are flowing toward the mine site (Outlet Creek and Hemlock Creek). Additional sightings occurred at Hoffman Springs and Swamp Creek both west of the mine site.

Though not a listed species, a single stone fly of the genus *Alloperl*a was collected from the riffle area of Swamp Creek. This finding is of a genus which has not been recorded previously from the State of Wisconsin. A female *Alloperla* was collected also at Swamp Creek 300, but only males can be identified to species. The Ephemeropteran *Caenis youngi* was collected from two sites in the study area (Martin Springs and Wolf River). This special concern specie has few sightings in the state.

The results of light trapping illustrate the diversity of the study area as some 65 species of Trichoptera were collected during one week in early summer. Some of the species collected are uncommon and were collected in low numbers, but were widely distributed throughout the study area. Most of the 65 Trichopteran species collected from the ten sites are indicators of good to excellent water quality (Tennessen, June 1994 personal communication).

Distribution of macroinvertebrates and richness of taxa suggests that local populations have colonized available habitat. The finding of several uncommon species in low numbers or where no record has been recorded in the state is not surprising considering the level of effort afforded this study was much more intensive than any prior work in the area. As a result, it is suggested that many species are likely more common, at least in Northern Wisconsin, than previously thought.

3.8.3.2.1 Significance of Tissue Analysis of Crayfish Collected in 1994

The purpose of collecting information regarding the amount of metals in crayfish tissue was to establish a background for the project. Based on local watershed chemistries, it is known that in general, waters of the study area are soft with hardness values ranging from 10 to 100 mg/L. Soft waters generally have more available metals which in turn are often times accumulated in the food chain. Metals data for crayfish taken in the study area fall within the range of similar data for soft water lakes.

3.8.3.3 Significance of 1993 and 1994 Odonata Findings

Dragonflies represent a group of insects which are extremely mobile and have the ability to colonize suitable habitat fairly rapidly, i.e., they do not depend on other organisms or continuous aquatic habitat with which to disperse upstream or downstream, in contrast to fish and mussels which require continuous habitat to disperse. The Odonata are also very opportunistic. It would not be unreasonable to find populations of individual species in marginal habitat for short periods

of time. Because of the mosaic of aquatic habitat in the area, the mobility of Odonata, and the fact that no intensive study of Odonata has ever been conducted in the study area previously, it is reasonable to expect to find numerous species including some listed species in the study area.

A total of 57 species of Odonata were identified from the study area. No species of Odonata categorized by the State of Wisconsin as threatened or endangered were observed or collected in the study area. A total of twelve species listed as special concern species in Wisconsin were observed or collected from the study area. An additional five genera listed as possible special concern species were collected and identified to genus, but species identifications were not possible either because the life form collected did not provide positive species identification or the adult was only observed on the wing and positive identification was impossible. Genera which included unidentified species included *Aeshna* sp., *Calopteryx* sp., *Enallagma* sp., *Epitheca* sp., *Gomphus* sp., *Gomphus (Gomphus)* sp., *Gomphus (Gomphurus)* sp., *Leucorrhinia* sp., and *Somatochlora* sp. A third category of specimens which did not receive species identification included genera for which there are no known listed species. Examples of specimens occurring in this category include *Calopteryx* sp., *Epitheca* sp., and *Leucorrhinia* sp.

The most frequent taxon collected and identified only to genus was *Aeshna* sp. This genus was collected in the nymph stage 15 times at 11 locations, exuviae were collected five times at five different locations. These specimens were collected from a variety of habitats including ponds, lakes, large streams and some smaller streams which do not have a closed canopy, i.e., are bordered by open sedge meadow. Based on adults, four species of *Aeshna* were identified, including *A. canadensis*, *A. umbrosa, A. eremita*, and *A. tuberculifera*, the latter two being special concern species.

In general, aeshnids are commonly seen cruising open water, which includes lakes and ponds and open areas over land. Wider rivers and streams are also common areas to find aeshnids as well as smaller streams if broad expanses of open meadow exist (Tennessen, June 1994, personal communication). Emergent vegetation and other plant materials are favored by the adult, and also are essential for deposition of eggs. The habitat described can be found throughout the study area, including edges of lakes proximal to the plant site (Skunk, Oak, Little Sand, Popple Pond) and lakes and rivers more distal to the plant site (Hemlock Creek, Wolf River, Martin Springs, Swamp Creek). This survey found no indication that any species of aeshnid resident in northern Wisconsin is restricted by lack of habitat in the vicinity (proximal or distal) of the mine site.

Several gomphids were collected from the study area three of which were special concern species. These included *Ophiogomphus carolus, Gomphus lineatifrons* and *G. viridifrons*. Other gomphids which were found as nymphs and therefore only identifiable to genus included *G.(Gomphus)* sp. and *G. (Gomphurus)* sp. *G.(Gomphus)* sp. was thought to be *G. spicatus* which was observed at numerous sites. The *G. (Gomphurus)* sp. specimen was a small nymph which was thought to be *G. ventricosus* (Tennessen, June 1994, personal communication).

G. lineatifrons is a listed species, but is fairly common in northern Wisconsin where suitable stream habitat exists. This species has a preference for medium-sized streams (15 to 20 feet wide), and was found in fairly good number in both the Wolf River and Swamp Creek. *G. lineatifrons* nymphs can tolerate some degree of silt and muck in the substrate, but need a mix of sand and gravel. This microhabitat is common along Swamp Creek and the Wolf River. *G. viridifrons* requires much the same habitat as *G. lineatifrons* and the two species often occur together. *G. viridifrons* appears to prefer slightly larger streams, however (Tennessen, June 1994, personal communication).

These two special concern species appear to be restricted in distribution within the project area based on stream size. Both were found commonly on Swamp Creek downstream of County Highway M and on the Wolf River. Other common, widespread gomphid species (*G. exilis, G. lividus, G. spicatus*) were located throughout the study area including small streams and lakes. These species do not appear to be restricted by stream size and appear to be well distributed throughout the study area.

Three species of *Ophiogomphus* were collected from the study area, including *O. rupinsulensis, O. colubrinus*, and *O. carolus*, the latter a special concern species. The identification of *O. carolus* was based on the nymph stage, and is therefore uncertain. All three species were found in the riffle area of Swamp Creek (CMC-AB-SC-300 and CMC-AB-SC-301).

Six species of *Somatochlora* were collected from the study area. Three species, *S. elongata, S. forcipata*, and *S. kennedyi* are special concern species. In general, members of this genus are difficult to collect as nymphs or exuviae because they usually occur in bog, swamp, and marsh habitat. Although several of the specimens collected were of the nymph and exuviae form, species presence is best assessed using adult collection methods. Most of the adults captured were taken along sandy or dirt roads sometimes well away from an obvious water source. While this is a typical location for finding adult specimens, road habitat does nothing to pinpoint the microhabitat or exact location of the specimen origination.

The only known North American species of *Stylogomphus (S. albistylus)*, a special concern species in Wisconsin, was collected in the riffle area of Swamp Creek. This specie inhabits areas of gentle riffle with rock and gravel substrate (Tennessen, June 1994, personal communication). Suitable habitat may occur upstream and downstream of the riffle area on Swamp Creek.

Two special concern species of the genus *Stylurus* were collected from the Wolf River, one of which was collected only from the riffle area of Swamp Creek. *S. amnicola* is somewhat restricted to larger streams and was only found in the Wolf River. *S. scudderi* which can tolerate a mix of sand and muck was found in both the Wolf River and Swamp Creek (riffle area).

Lestes eurinus, a damselfly special concern species, was possibly sighted at Skunk Lake, as a single adult male was perched on emergent vegetation. No positive identification could be made at the time because the adult specimen was not captured. This species needs fishless habitat such as that which occurs in Skunk Lake (Tennessen, June 1994, personal communication). Several

pond habitats similar to Skunk Lake occur in the study area though not all are fishless. Some similar pond habitat such as Popple Pond and Upper Hoffman Springs have had in the past minnows introduced to them and their status as "fishless" is questionable (Ray Hoffman, personal communication).

Another damselfly special concern species, *Chromagrion conditum*, was collected at Hoffman Springs, in both the nymph and adult stages. Its habitat is primarily shallow, spring-fed runs or small pools in shaded areas. The species is likely to occur in other locations within the study area, but its preferred habitat among the sampling locations chosen was found only at Hoffman Springs.

In general, most habitats which contain Odonata special concern species are replicated throughout the study area as well as outside of the study area. Two areas which are not well duplicated throughout the study area but which are found outside of the study area include the riffle area of Swamp Creek north of the mine site and the large stream complex represented by the lower Swamp Creek/Wolf River study area segments.

Lower Swamp Creek (downstream of County Highway M) and the Wolf River are large enough to supply habitat for several gomphids which require a larger stream. Similar habitat in the study area includes the Wolf River both upstream and downstream of the confluence with Swamp Creek and possibly other peripheral streams such as Squaw Creek, Pickerel Creek below Rolling Stone Lake and Spider Creek.

3.8.3.4 Significance of Fish Findings 1994

No threatened, endangered, or special concern species were observed during the 1994 collection effort. This is consistent with the findings of previous studies as discussed above.

The six species of fish targeted for this study (river redhorse, greater redhorse, pugnose shiner, pugnose minnow, least darter, and weed shiner) are all fish which have been found in the lower Wolf River drainage and have the potential for distribution in the study area. In general, with the exception of Rolling Stone Lake, other lakes within the study area are isolated from the Wolf River drainage system and have little or no opportunity for recruitment. If the target species are present, the best opportunity for observing them would be in the Wolf River. Since none of the areas studied produced target species, it is concluded that there is a high probability that these species do not exist in the study area.

3.8.3.4.1 Significance of Tissue Analysis of Fish Collected in 1994

Metals analysis of fish fillets and livers was conducted at selected locations within the study area. The purpose of the analysis was to provide a certain degree of continuity of data from reports generated in the 1970s and 1980s. This information also serves to establish a background for pre-mining data of the study area.

In comparison to data reported in 1983 by EA Associates (EMI-SW-BA-5), concentrations of metals in white sucker have, in general, decreased slightly by 1994. Some of this may be due to lower detection levels achieved for some metals, however, because of the migratory nature of white sucker, it is impossible to say that a collection of specimens at a certain location on the Wolf River can be duplicated year to year. This data should be used to help establish a range of concentrations observed by the species sampled.

Based on review of the data, it appears as though the perch in Little Sand Lake have a higher average concentration of mercury in their tissue than either perch from the Swamp Creek or white sucker from the Wolf River. Concentrations of arsenic and cadmium in fish liver were also higher in perch from Little Sand Lake than in Swamp Creek and the Wolf River though other metal concentrations appeared about the same in all fish. The chemistry of Little Sand Lake may promote metal uptake in Little Sand Lake over the other sites and the differences may be somewhat related to the difference between lentic and lotic environments in conjunction with stream and lake chemistries.

3.8.3.5 Significance of Mussel Findings

Studies conducted in 1994 represent the first comprehensive mussel surveys conducted in the Crandon Project study area. Previous collection efforts conducted by Dames & Moore in 1977 and 1978 were generally unsuccessful in finding significant populations of any mussels outside of the common fingernail clams. More recent studies conducted by Dave Heath of the Wisconsin Department of Natural Resources (June 1991, unpublished data) concentrated efforts on the Wolf River particularly in the vicinity of Lower Post Lake and the adjacent outfall. The present study included the Wolf River from Lower Post Lake downstream to the Lost Lake Road access, major portions of Swamp Creek, Hemlock Creek, and lakes around the mine site, and the Pickerel Creek drainage basin at Rolling Stone Lake including Pickerel Creek at the outfall from Rolling Stone Lake.

Because few species of mussels had been reported from the study area in the 1970s, the initial premise for the 1994 study was to look for recruitment from the major drainage systems, i.e., the Swamp and Pickerel Creek drainage systems via the Wolf River. The highest probability for success in finding listed species was expected to come from the Wolf River. If listed species are found in the Wolf River, then it would be possible to find similar species closer to the mine by following the Swamp and Pickerel Creek chains. Based on knowledge of the drainage systems, it would be possible to migrate up Swamp Creek somewhat above Rice Lake before a series of beaver dams obstructs upstream movement. Likewise, upstream mobility seems unimpeded in the Pickerel chain until Rolling Stone Lake. Upstream mobility beyond Rolling Stone Lake may be possible via Pickerel Creek, Martin Springs, and Creek 12-9, however, these streams generally originate from groundwater sources and upstream migration from Rolling Stone Lake seems improbable.

Eleven species of mussels were collected and identified from the study area. All of the species collected were collected from the Wolf River many of which were also collected from lower

Swamp Creek. No threatened or endangered species were collected during the 1994 collection efforts. Three special concern species were collected and identified from the study area. All three were collected in the Wolf River and Swamp Creek drainage system (Swamp Creek below County Highway M).

The elktoe (*Alasmodonta marginata*) was found in the Wolf River. One living specimen and two complete dead shells (from middens) were collected from the site downstream of the mouth of Swamp Creek. None were found at the upstream site on the Wolf River and none were found at any of the other sampling locations. Host fish species include white sucker, northern hog sucker, shorthead redhorse, rock bass and warmouth, some of which are quite common in the Wolf River in the study area.

The creek heelsplitter (*Lasmigona compressa*) was found at three of the four locations sampled in Swamp Creek. Ten were found in Swamp Creek below County Highway M (CMC-AB-SC-501), one was found at CMC-AB-SC-502, and six were collected one half mile downstream from Swampy Lane (lower portion of riffle area of Swamp Creek). In addition, a survey by the WDNR in 1991 produced one specimen in a collection of 494 individuals in the Wolf River downstream of the Post Lake dam. The only known host for the creek heelsplitter is carp. Habitat reported by Cummings and Mayer (1992) is creeks and the headwaters of small to medium rivers in fine gravel or sand. It is rarely found on large rivers.

The round pigtoe (*Pleurobema coccineum*) was encountered at both collection sites in the Wolf River and the two sites on Swamp Creek. The species was relatively common in these areas. Its host is unknown. Habitat reported by Cummings and Mayer (1992) is medium to large rivers in mud, sand, or gravel.

Some threatened and endangered species are not expected to be found in the study area because they are generally limited to the Mississippi and Ohio drainage basins (winged maple leaf [Vaughan, 1993], purple warty back, bullhead, monkeyface, buckhorn, and scaleshell [Cummings and Mayer, 1992]). Listed mussel species that occur in the lower Wolf River include snuffbox (*Epioblasma triquetra*), salamander mussel (*Simpsonaias ambigua*), slippershell (*Alasmidonta viridis*), and buckhorn (*Tritogonia verrucosa*) (WDNR, 1995).

It is apparent from this survey that the Wolf River is the dominant factor determining the mussel community in the vicinity of the Crandon Project site. The Wolf River carries the most abundant and diverse population of unionid mollusks. The more remote from the Wolf River, the fewer individuals and less diverse the mussel community became. This is true of both streams and lakes in the area. The three target species encountered in this survey, all listed as special concern, also tended to be found either in the Wolf River or close to it. The reason for this phenomenon may be linked to accessibility of host species, however, chemical and physical factors may contribute as well. The condition of some of the specimens examined certainly indicate a harsh environment that is not conducive to the well being of mollusks. The primary indicator of this is the extreme erosion and pitting observed on many of the specimens.

3.8.3.6 Summary

Overall, within the study area no habitat was noted that is unique to northern Wisconsin. Given this fact, the list of species found was typical of what would be expected within the habitat of the study area. The finding of some uncommon species, for example, *Alloperla* sp. found during nymph collection and light trapping and *Caenis youngi* found at several locations during light trapping was not due to the uniqueness of the habitat, but rather to the thoroughness of the study. It is likely that success in finding uncommon species can be achieved in similar habitats outside the study area using methods based on insect's activity patterns.

Aquatic habitats are colonized by diverse populations of flora and fauna. These populations are dynamic and change from time to time depending on a variety of environmental conditions. Some groups of organisms such as fish and mussels depend on continuous water resources for distribution. In addition, mussels are dependent on host species such as fish and amphibians for dispersal. Many aquatic insects, on the other hand, have terrestrial life stages and are capable of dispersion and distribution without the need for continuous water resources. Because of these diverse biological requirements, the occurrence of natural phenomena such as the drought of 1988-1989 and the location and/or relocations of beaver dams could affect fish and mussel populations more than insect populations.

Throughout this section of the EIR there have been discussions relative to the aquatic habitats found throughout the project study area. It was noted that limiting factors for aquatic faunal distribution include water depth, water quality, spatial distribution of stream impediments such as beaver dams, water temperature, and harshness of the environment such as the scouring effect of riffle areas. Considering these environmental conditions, it would appear that mussels are and will be one of the most limited populations. While mussels are common in the Wolf River downstream of Lower Post Lake, the colonization of streams and lakes on the Swamp Creek and Pickerel Creek chains is limited. Therefore, their functional role within the Crandon Project area is expected to be limited.

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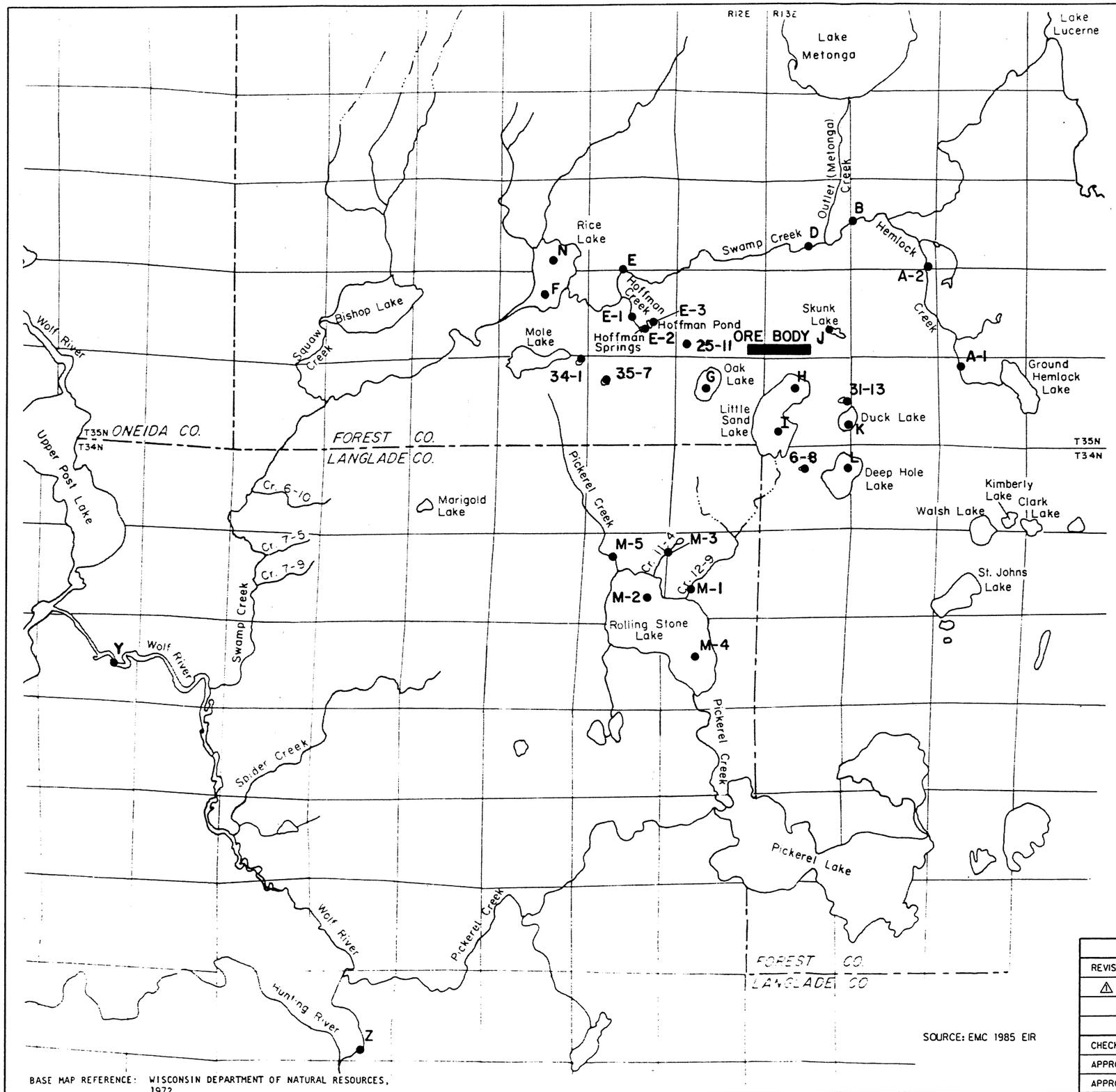
FIGURES FOR SECTION 3.8



KEY:

- STREAM
- 25-11 — WISCONSIN DNR IDENTIFICATION CODE FOR UNNAMED LAKES
- Cr. 11-4 — WISCONSIN DNR IDENTIFICATION CODE FOR UNNAMED STREAMS
- ● AQUATIC ECOLOGY SAMPLING STATION

Note: Additional sampling was conducted in Swamp Creek downstream from Rice Lake. The results of this sampling program are presented in Ecological Analysts, Inc. (1983, 1984a,b).

1 .5 0 1 MILE

SOURCE: EMC 1985 EIR

BASE MAP REFERENCE: WISCONSIN DEPARTMENT OF NATURAL RESOURCES, 1972.

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION
⚠	11/98	MLD2	REVISED FOR 1998 UPDATE

CHECKED BY:	JKSI	DATE: MAY '95
APPROVED BY:	RFS	DATE: MAY '95
APPROVED BY:	GWS	DATE: MAY '95

Nicolet Minerals COMPANY

Mining for the Future • Commitment

FIGURE 3.8-1

AQUATIC ECOLOGY SAMPLING LOCATIONS (PRE 1993/94 WORK)

Scale: AS SHOWN		Date: MAY, 1995	
Prepared By: Foth & Van Dyke	By: JPR	93C049	

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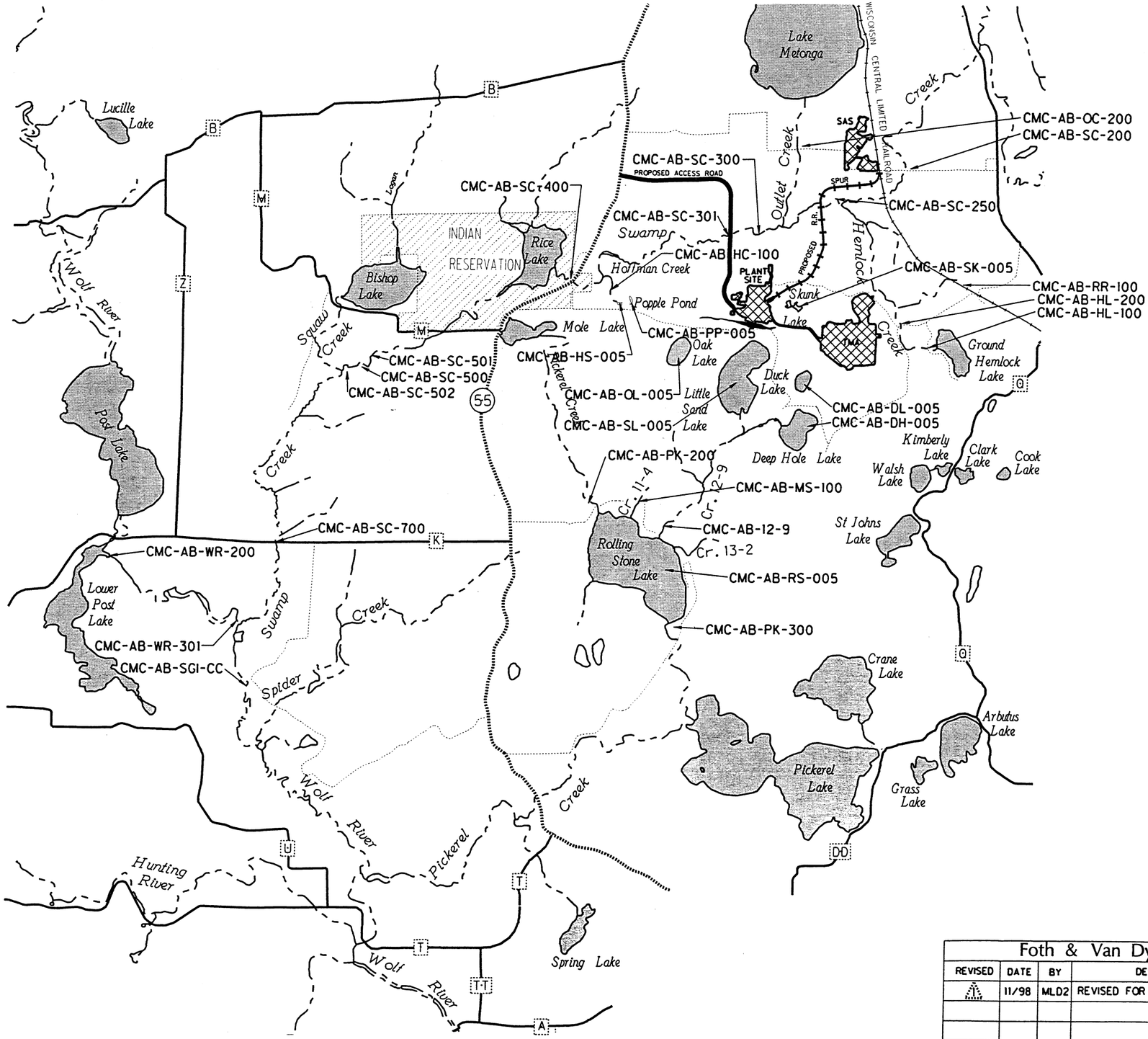

LEGEND

- STATE HWY
- COUNTY TRUNK HWY
- LAKES
- STREAMS
- ORE BODY
- PROPOSED ACCESS ROAD
- PROPOSED TMA ACCESS ROAD AND TAILINGS PIPELINE ROUTE
- PROPOSED RAILROAD SPUR
- PROPOSED FACILITIES

CMC-AB-HL-200 SAMPLING LOCATION

NOTE:

1. BASE MAP DERIVED FROM COUNTY MAPS PREPARED BY THE WISCONSIN DEPARTMENT OF TRANSPORTATION
2. ORE BODY OUTLINE IS REPRESENTATIVE OF THE SUBCROP AT THE BASE OF THE OVERBURDEN.

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION
1	11/98	MLD2	REVISED FOR 1998 UPDATE

CHECKED BY:	JKS1	DATE:	MAY '95
APPROVED BY:	RFS	DATE:	MAY '95
APPROVED BY:	GWS	DATE:	MAY '95

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FIGURE 3.8-2

1993/1994 GENERAL AQUATIC SAMPLE LOCATIONS

Scale: 0 3750' 7500' | Date: MAY, 1995

Prepared By: Foth & Van Dyke | By: JPR | 93C049

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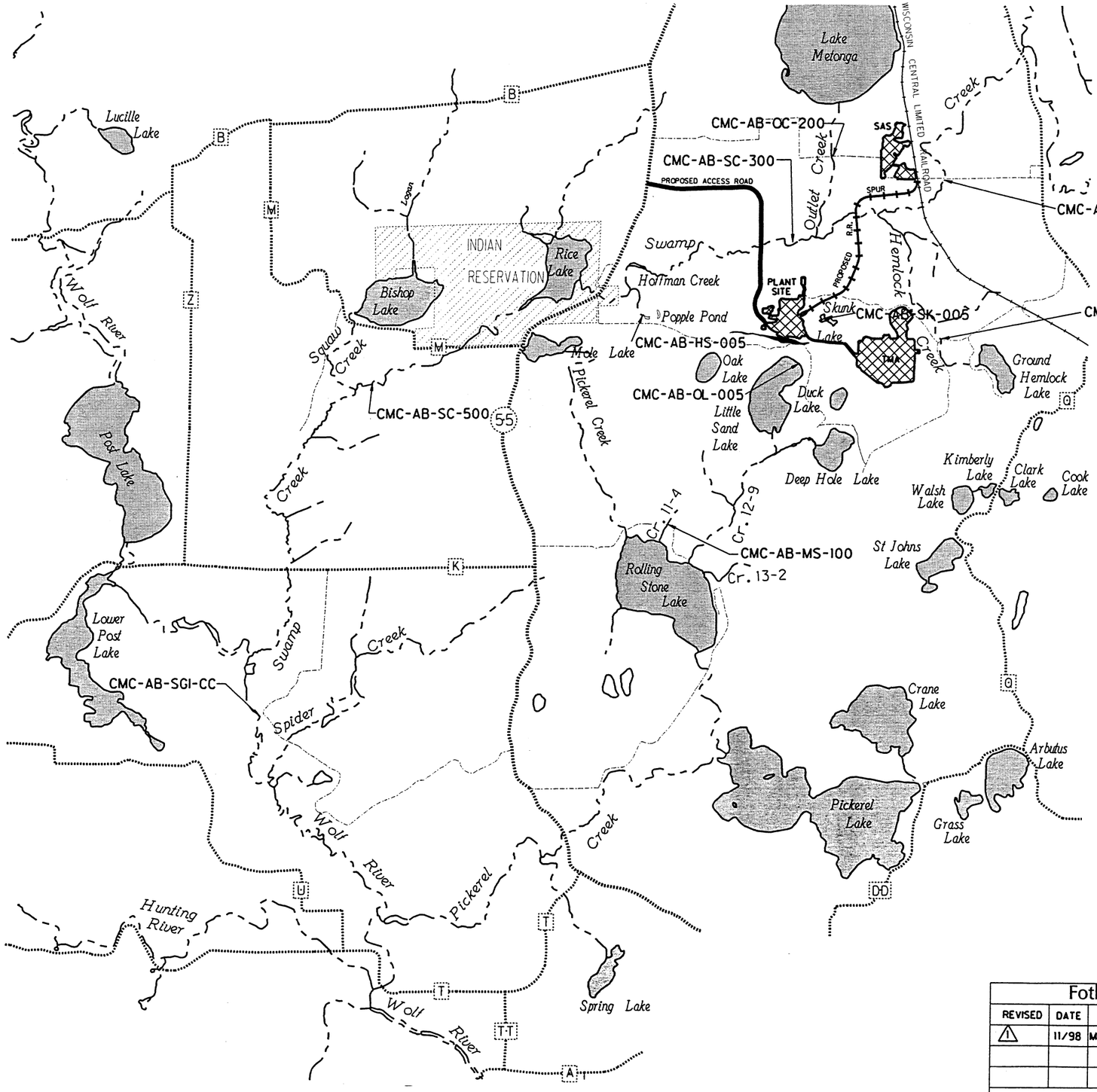

NOTE:

1. BASE MAP DERIVED FROM COUNTY MAPS PREPARED BY THE WISCONSIN DEPARTMENT OF TRANSPORTATION
2. ORE BODY OUTLINE IS REPRESENTATIVE OF THE SUBCROP AT THE BASE OF THE OVERBURDEN.

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION
1	11/98	MLD2	REVISED FOR 1998 UPDATE

CHECKED BY:	JKSI	DATE:	MAY '95
APPROVED BY:	RFS	DATE:	MAY '95
APPROVED BY:	GWS	DATE:	MAY '95

Nicolet Minerals COMPANY

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FIGURE 3.8-3

1994 LIGHT TRAPPING STATIONS

Scale: 0 3750' 7500'	Date: MAY, 1995	
Prepared By: Foth & Van Dyke	By: JPR	93C049

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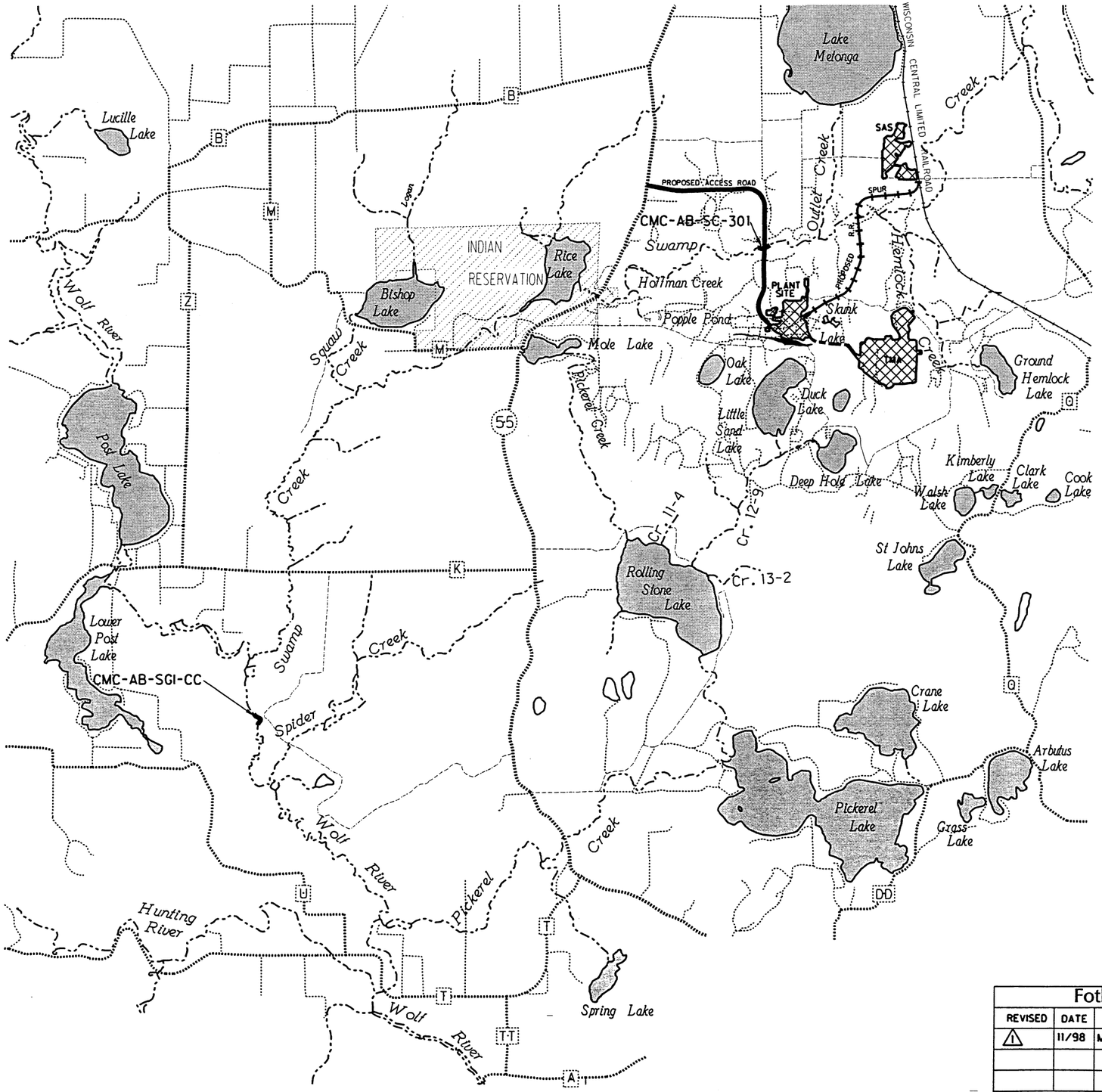

N

LEGEND

- STATE HWY (47)
- COUNTY TRUNK HWY (W)
- LAKES
- STREAMS
- ORE BODY
- PROPOSED ACCESS ROAD
- PROPOSED TMA ACCESS ROAD AND TAILINGS PIPELINE ROUTE
- PROPOSED RAILROAD SPUR
- PROPOSED FACILITIES

CMC-AB-SGI-CC SAMPLING LOCATION

AREA OF SAMPLE COLLECTION

NOTE:

1. BASE MAP DERIVED FROM COUNTY MAPS PREPARED BY THE WISCONSIN DEPARTMENT OF TRANSPORTATION
2. ORE BODY OUTLINE IS REPRESENTATIVE OF THE SUBCROP AT THE BASE OF THE OVERBURDEN.

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION
1	11/98	MLD2	REVISED FOR 1998 UPDATE

CHECKED BY:	JKSI	DATE:	MAY '95
APPROVED BY:	RFS	DATE:	MAY '95
APPROVED BY:	GWS	DATE:	MAY '95

Nicolet Minerals COMPANY

Mining for the Future Commitment

FIGURE 3.8-4

JUNE 1994 WDNR/FOTH & VAN DYKE EXUVIAE COLLECTION SITES

Scale: 0 3750' 7500' | Date: MAY, 1995

Prepared By: Foth & Van Dyke | By: JPR | 93C049

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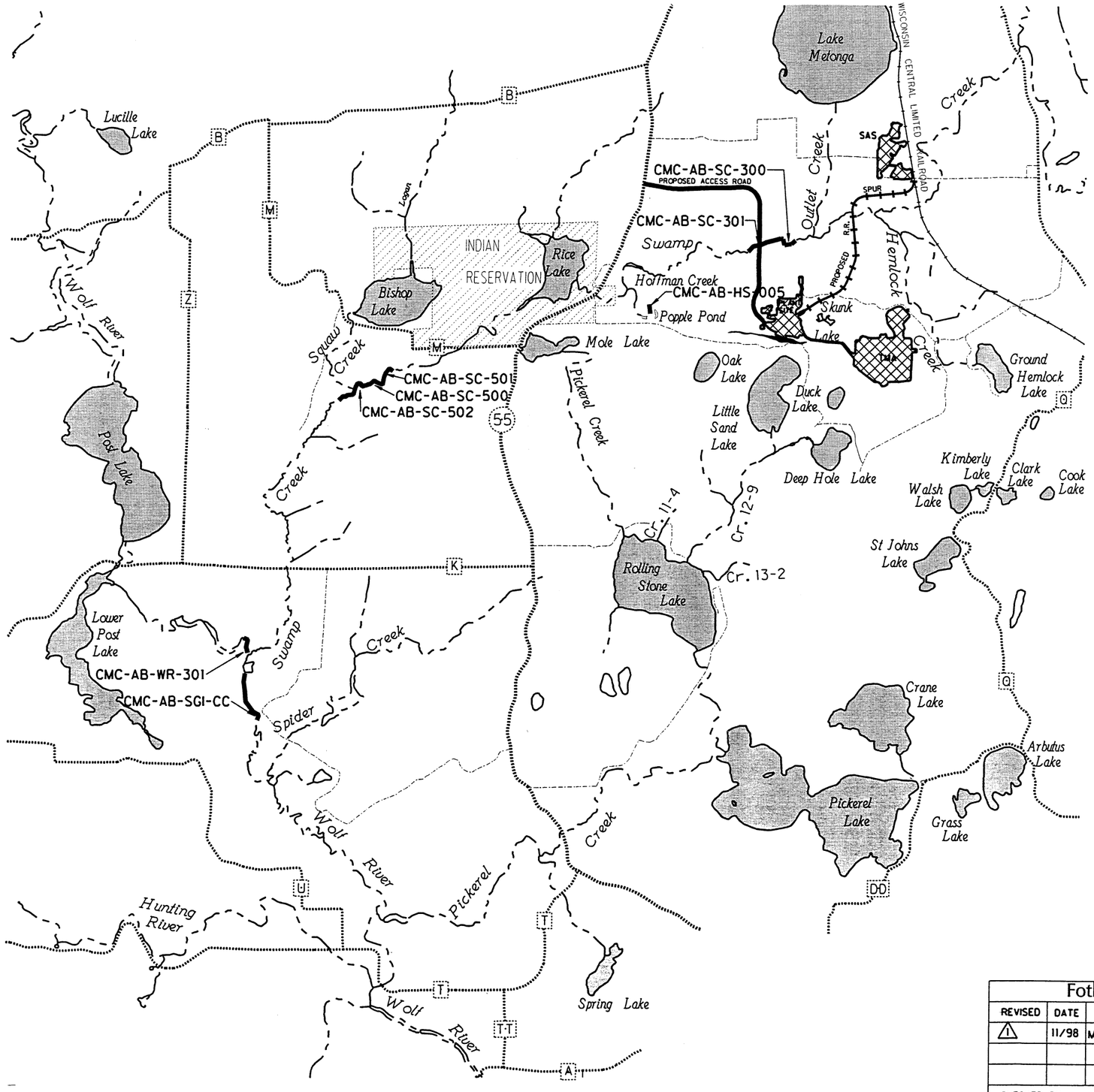

N

LEGEND

- STATE HWY
- COUNTY TRUNK HWY
- LAKES
- STREAMS
- ORE BODY
- PROPOSED ACCESS ROAD
- PROPOSED TMA ACCESS ROAD AND TAILINGS PIPELINE ROUTE
- PROPOSED RAILROAD SPUR
- PROPOSED FACILITIES

CMC-AB-SC-301 SAMPLING LOCATION

AREA OF SAMPLE COLLECTION

NOTE:

1. BASE MAP DERIVED FROM COUNTY MAPS PREPARED BY THE WISCONSIN DEPARTMENT OF TRANSPORTATION
2. ORE BODY OUTLINE IS REPRESENTATIVE OF THE SUBCROP AT THE BASE OF THE OVERBURDEN.

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION
1	11/98	MLD2	REVISED FOR 1998 UPDATE

CHECKED BY:	JKSI	DATE:	MAY '95
APPROVED BY:	RFS	DATE:	MAY '95
APPROVED BY:	GWS	DATE:	MAY '95

Nicolet Minerals COMPANY

Mining for the Future Commitment

FIGURE 3.8-5

JUNE 27 - JULY 1, 1994
ODONATA EXUVIAE COLLECTION LOCATIONS

Scale: 0 3750' 7500' | Date: MAY, 1995

Prepared By: Foth & Van Dyke | By: JPR | 93C049

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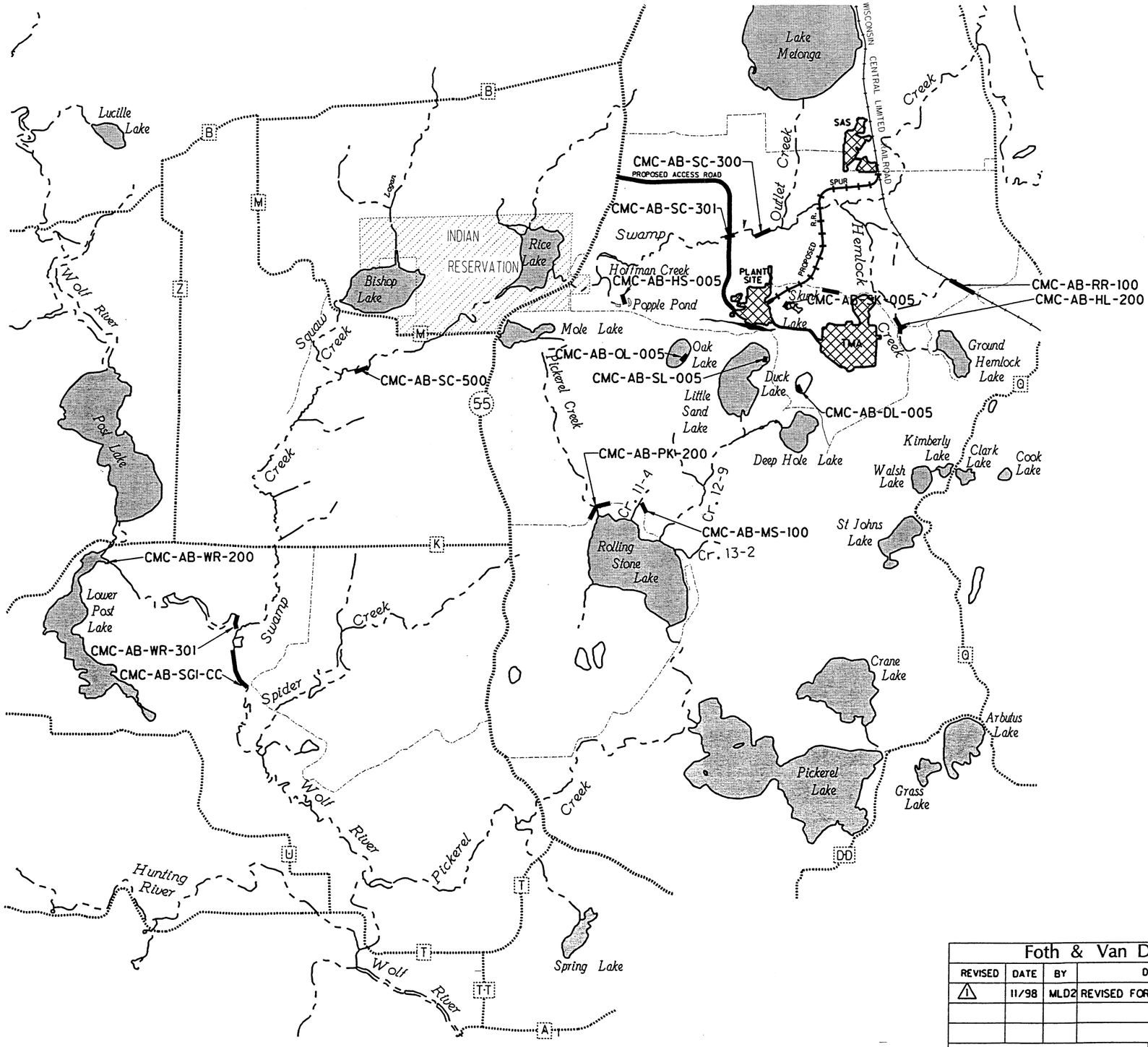

NOTE:

1. BASE MAP DERIVED FROM COUNTY MAPS PREPARED BY THE WISCONSIN DEPARTMENT OF TRANSPORTATION
2. ORE BODY OUTLINE IS REPRESENTATIVE OF THE SUBCROP AT THE BASE OF THE OVERBURDEN.

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION
1	11/98	MLD2	REVISED FOR 1998 UPDATE

CHECKED BY:	JKSI	DATE:	MAY '95
APPROVED BY:	RFS	DATE:	MAY '95
APPROVED BY:	GWS	DATE:	MAY '95

Nicolet Minerals COMPANY

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FIGURE 3.8-6

JUNE 27 - JULY 1, 1994
ADULT ODONATA COLLECTION LOCATIONS

Scale: 0 3750' 7500' | Date: MAY, 1995

Prepared By: Foth & Van Dyke | By: JPR | 93C049

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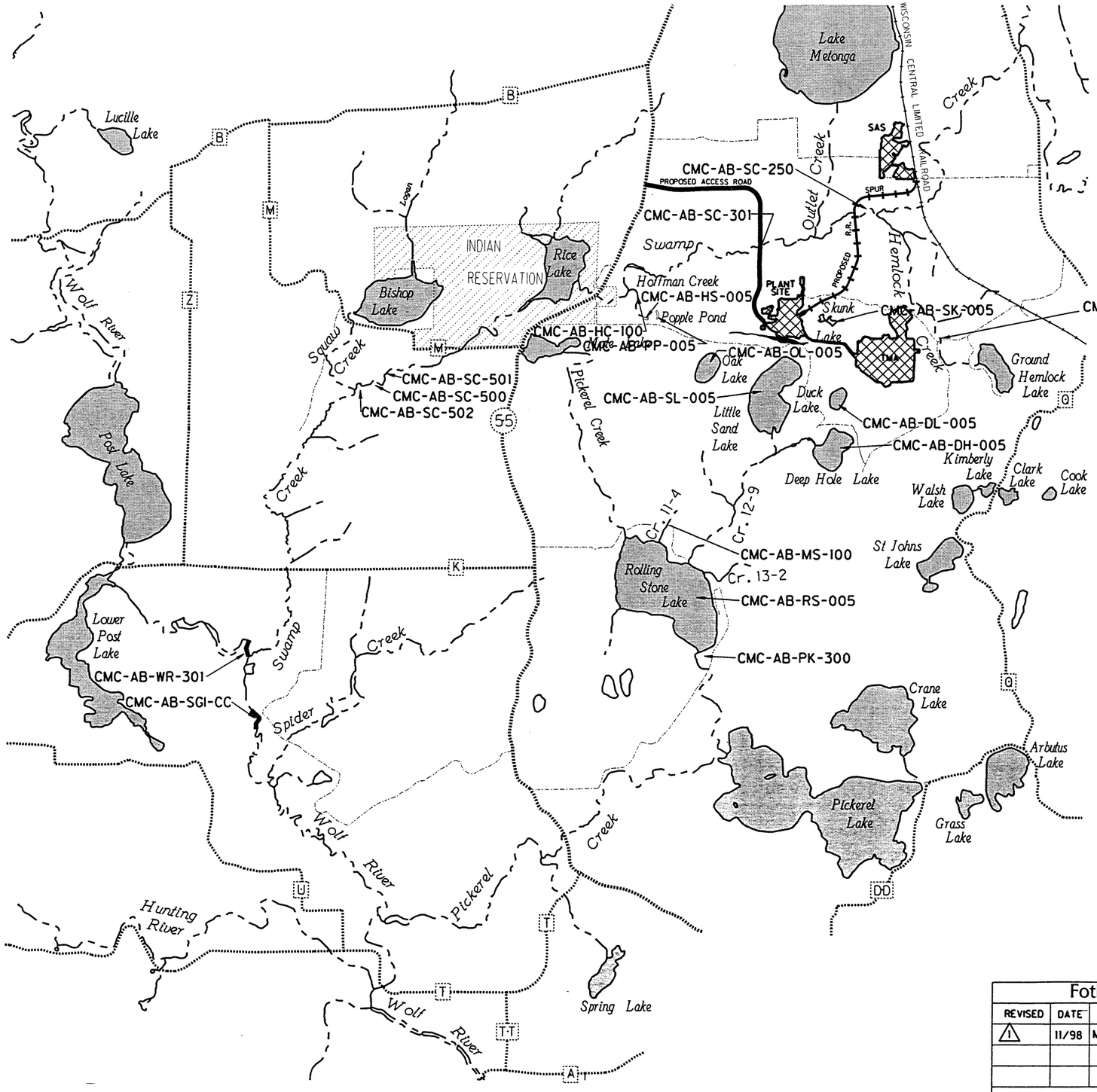

N

LEGEND

- 47 STATE HWY
- W COUNTY TRUNK HWY
- LAKES
- STREAMS
- ORE BODY
- PROPOSED ACCESS ROAD
- PROPOSED TMA ACCESS ROAD AND TAILINGS PIPELINE ROUTE
- PROPOSED RAILROAD SPUR
- PROPOSED FACILITIES

CMC-AB-SC-301 SAMPLING LOCATION

AREA OF SAMPLE COLLECTION

NOTE:

1. BASE MAP DERIVED FROM COUNTY MAPS PREPARED BY THE WISCONSIN DEPARTMENT OF TRANSPORTATION
2. ORE BODY OUTLINE IS REPRESENTATIVE OF THE SUBCROP AT THE BASE OF THE OVERBURDEN.

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION
1	11/98	MLD2	REVISED FOR 1998 UPDATE

CHECKED BY:	JKSI	DATE:	MAY '95
APPROVED BY:	RFS	DATE:	MAY '95
APPROVED BY:	GWS	DATE:	MAY '95

Nicolet Minerals COMPANY

Mining for the Future Commitment

FIGURE 3.8-7

JULY 28 - AUGUST 4, 1994
ADULT ODONATA COLLECTION LOCATIONS

Scale: 0 3750' 7500' | Date: MAY, 1995

Prepared By: Foth & Van Dyke | By: JPR | 93C049

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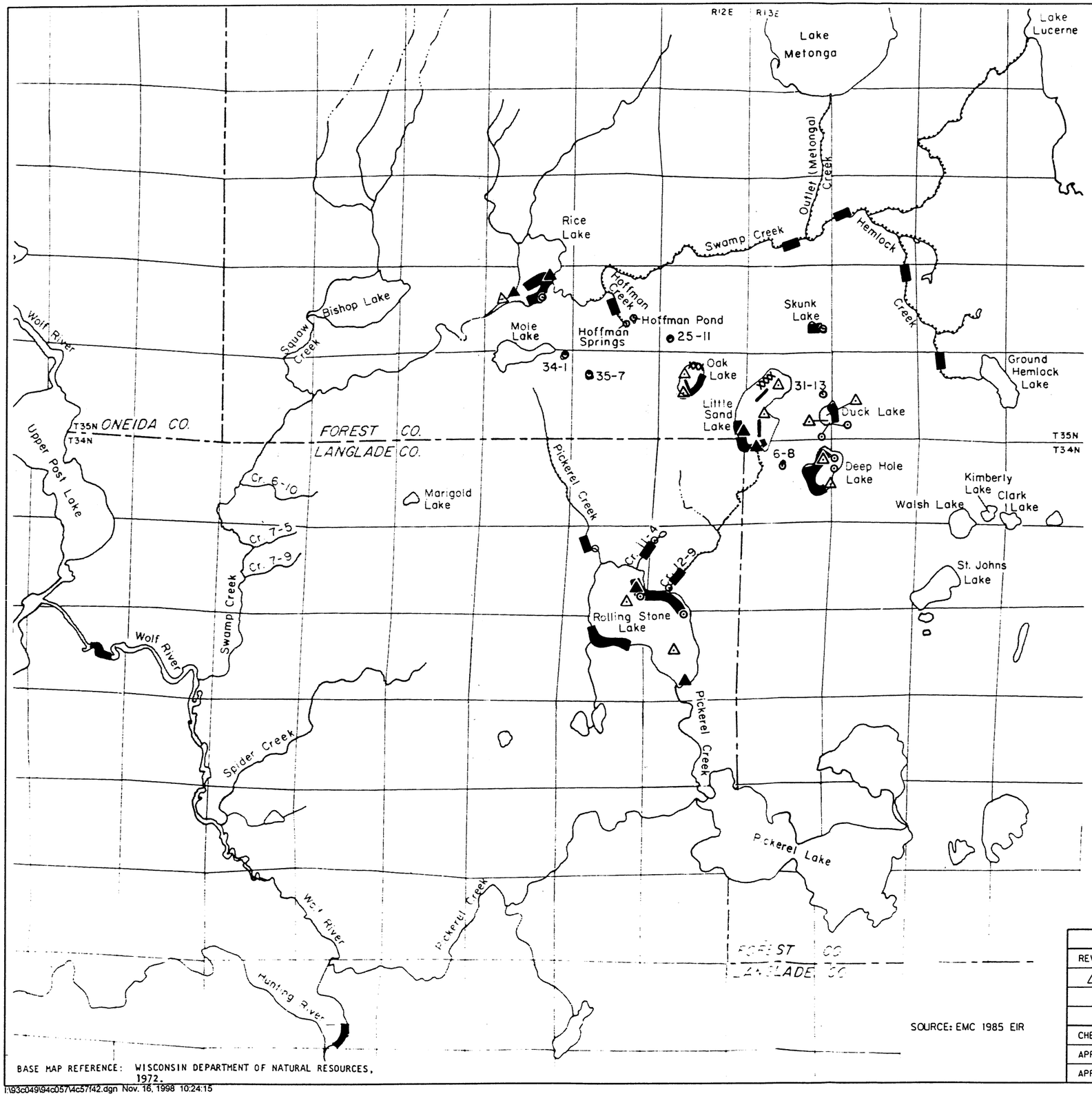

KEY:

- STREAM
- 25-11 — WISCONSIN DNR IDENTIFICATION CODE FOR UNNAMED LAKES
- Cr. 11-4 — WISCONSIN DNR IDENTIFICATION CODE FOR UNNAMED STREAMS
- ELECTROSHOCKING
- FYKE NET
- GILL NET
- MINNOW TRAP
- xxxx — SEINING - BEACH HAUL OR MINNOW SEINE
- TROUT REDD RECONNAISSANCE
- LARVAL FISH

.5 0 MILE

SOURCE: EMC 1985 EIR

BASE MAP REFERENCE: WISCONSIN DEPARTMENT OF NATURAL RESOURCES, 1972.

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION
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APPROVED BY:	GWS	DATE: MAY '95

Nicolet Minerals COMPANY

FIGURE 3.8-8

FISH SAMPLING TECHNIQUES AND LOCATIONS (PRE 1993/94 WORK)

Scale: AS SHOWN	Date: MAY, 1995		
Prepared By: Foth & Van Dyke	By: JPR	93C049	

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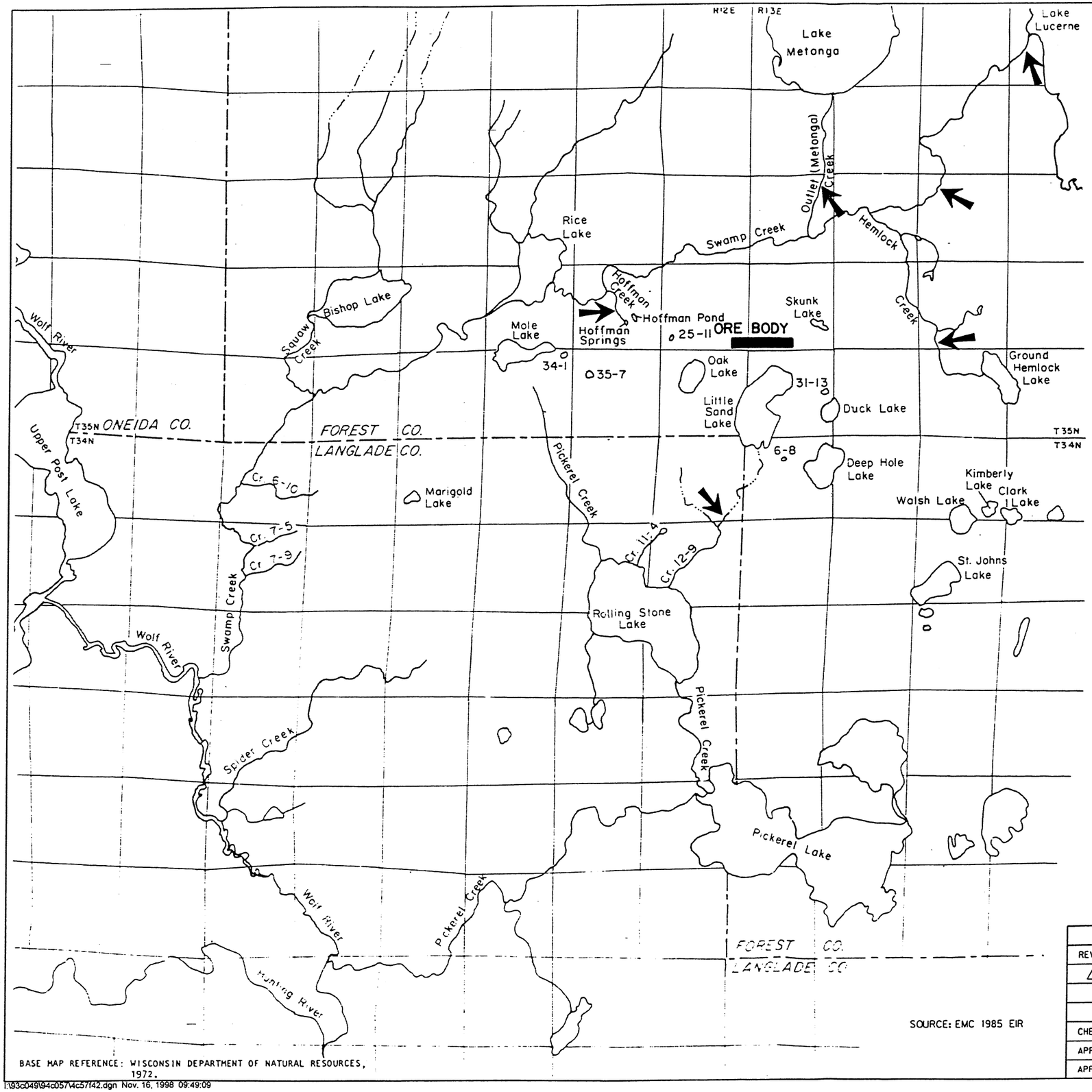

KEY:

- STREAM
- 25-11 — WISCONSIN DNR IDENTIFICATION CODE FOR UNNAMED LAKES
- Cr. 11-4 — WISCONSIN DNR IDENTIFICATION CODE FOR UNNAMED STREAMS
- LOCATION OF POTENTIAL BROOK TROUT SPAWNING AREAS

1 .5 0 1 MILE

SOURCE: EMC 1985 EIR

BASE MAP REFERENCE: WISCONSIN DEPARTMENT OF NATURAL RESOURCES, 1972.

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION
⚠	11/98	MLD2	REVISED FOR 1998 UPDATE

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APPROVED BY:	GWS	DATE: MAY '95

Nicolet Minerals COMPANY

Mining for the Future Commitment

FIGURE 3.8-9

POTENTIAL BROOK TROUT SPAWNING AREAS (PRE-1993/94 WORK)

Scale: AS SHOWN		Date:	MAY, 1995
Prepared By: Foth & Van Dyke	By: JPR		93C049

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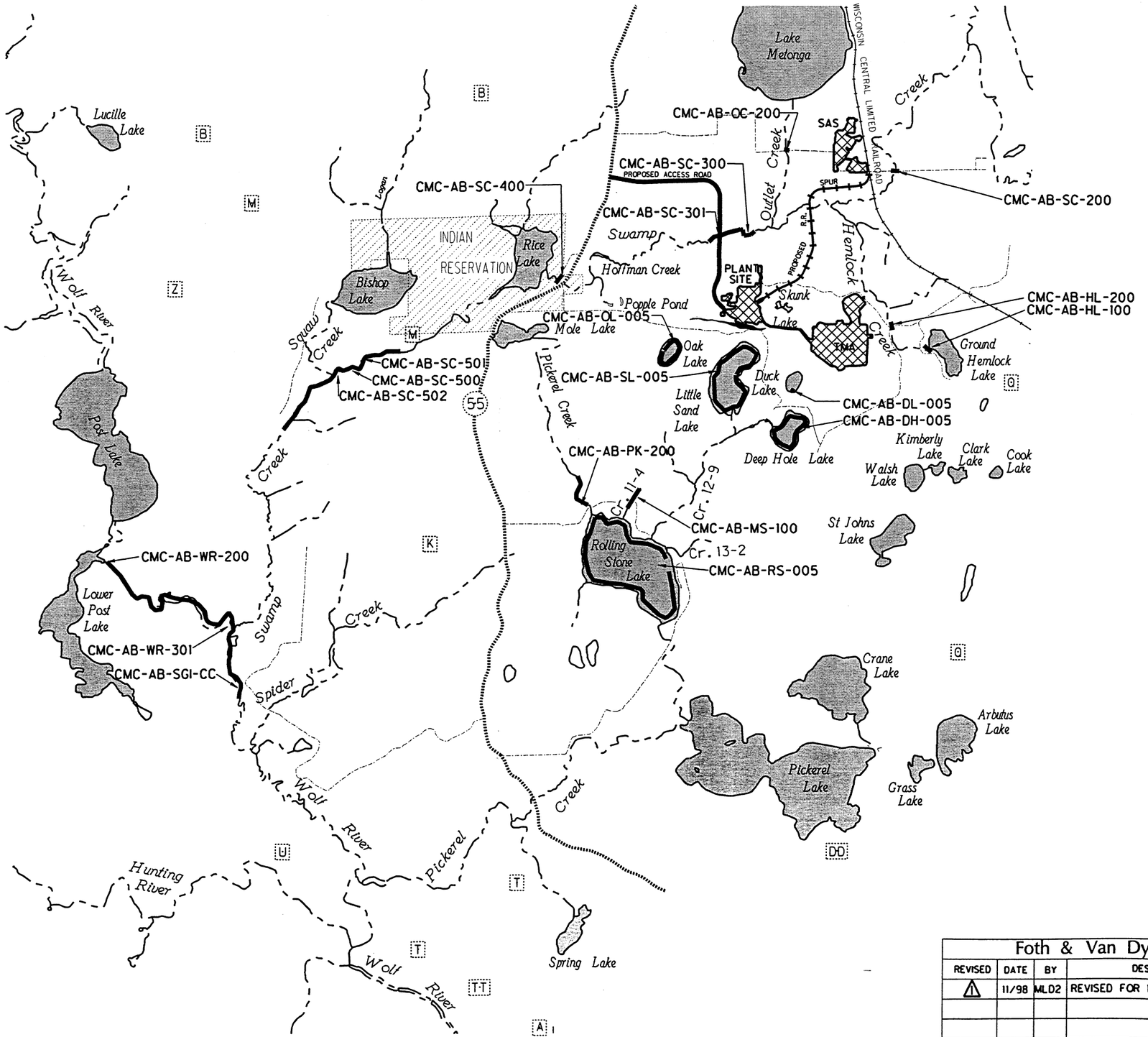

N

LEGEND

- STATE HWY
- COUNTY TRUNK HWY
- LAKES
- STREAMS
- ORE BODY
- PROPOSED ACCESS ROAD
- PROPOSED TMA ACCESS ROAD AND TAILINGS PIPELINE ROUTE
- PROPOSED RAILROAD SPUR
- PROPOSED FACILITIES
- CMC-AB-SC-301 SAMPLING LOCATION
- AREA OF SAMPLE COLLECTION

NOTE:

1. BASE MAP DERIVED FROM COUNTY MAPS PREPARED BY THE WISCONSIN DEPARTMENT OF TRANSPORTATION
2. ORE BODY OUTLINE IS REPRESENTATIVE OF THE SUBCROP AT THE BASE OF THE OVERBURDEN.

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION
1	11/98	MLD2	REVISED FOR 1998 UPDATE

CHECKED BY:	DATE:	MAY '95
APPROVED BY:	DATE:	MAY '95
APPROVED BY:	DATE:	MAY '95

Nicolet Minerals COMPANY

Mining for the Future • Commitment

FIGURE 3.8-10

1994 FISH COLLECTION LOCATIONS

Scale:	Date:	MAY, 1995
Prepared By: Foth & Van Dyke	By: JPR	93C049

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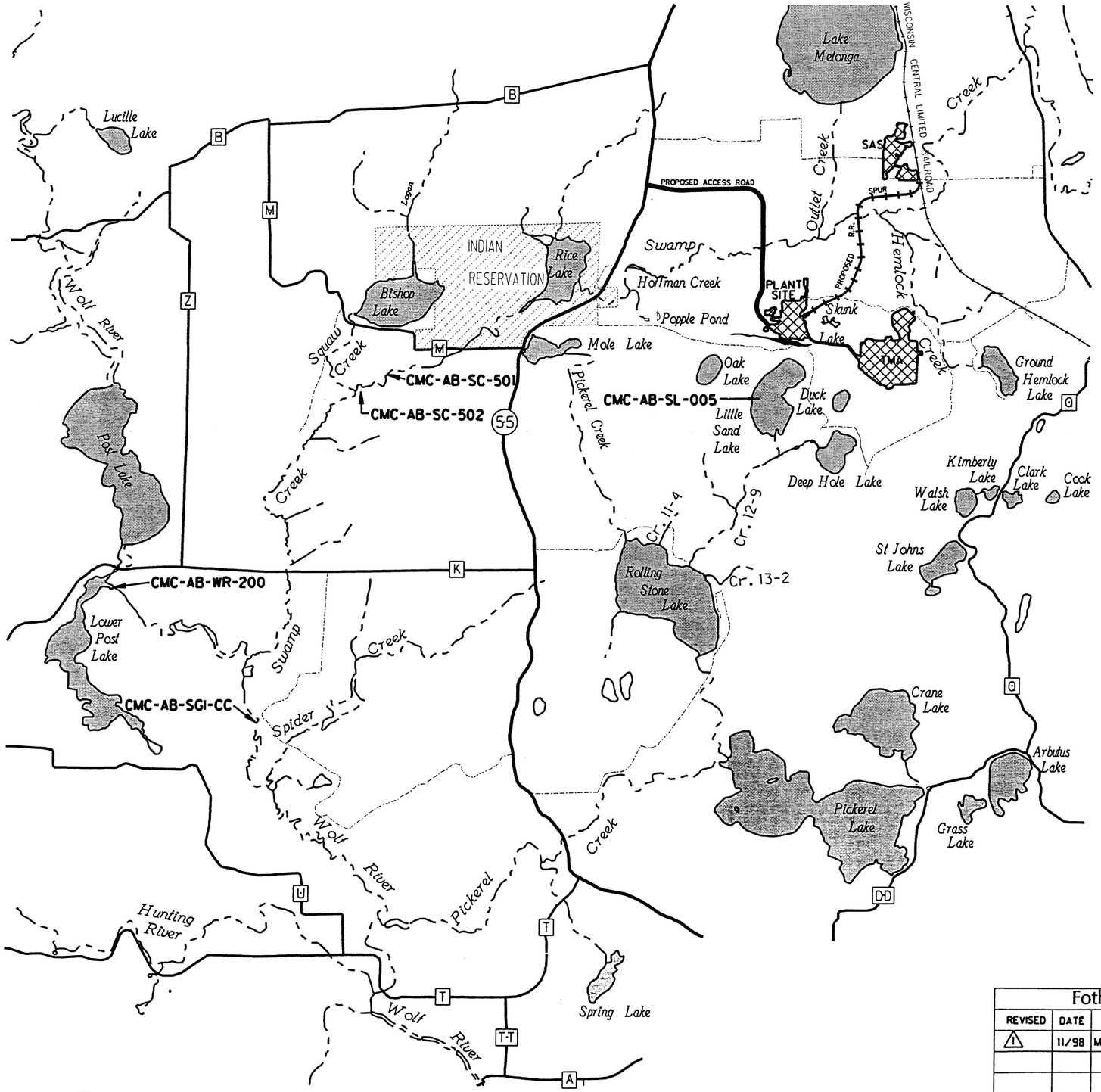

NOTE:

1. BASE MAP DERIVED FROM COUNTY MAPS PREPARED BY THE WISCONSIN DEPARTMENT OF TRANSPORTATION
2. ORE BODY OUTLINE IS REPRESENTATIVE OF THE SUBCROP AT THE BASE OF THE OVERBURDEN.

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION
1	11/98	MLD2	REVISED FOR 1998 UPDATE

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APPROVED BY:	RFS	DATE:	MAY '95
APPROVED BY:	GWS	DATE:	MAY '95

Nicolet Minerals COMPANY

Mining for the Future Commitment

FIGURE 3.8-11

LOCATION FOR CRAYFISH COLLECTION FOR TISSUE ANALYSIS - MAY 1994

Scale: 0 3750' 7500'		Date:	MAY, 1995
Prepared By: Foth & Van Dyke		By: JPR	93C049

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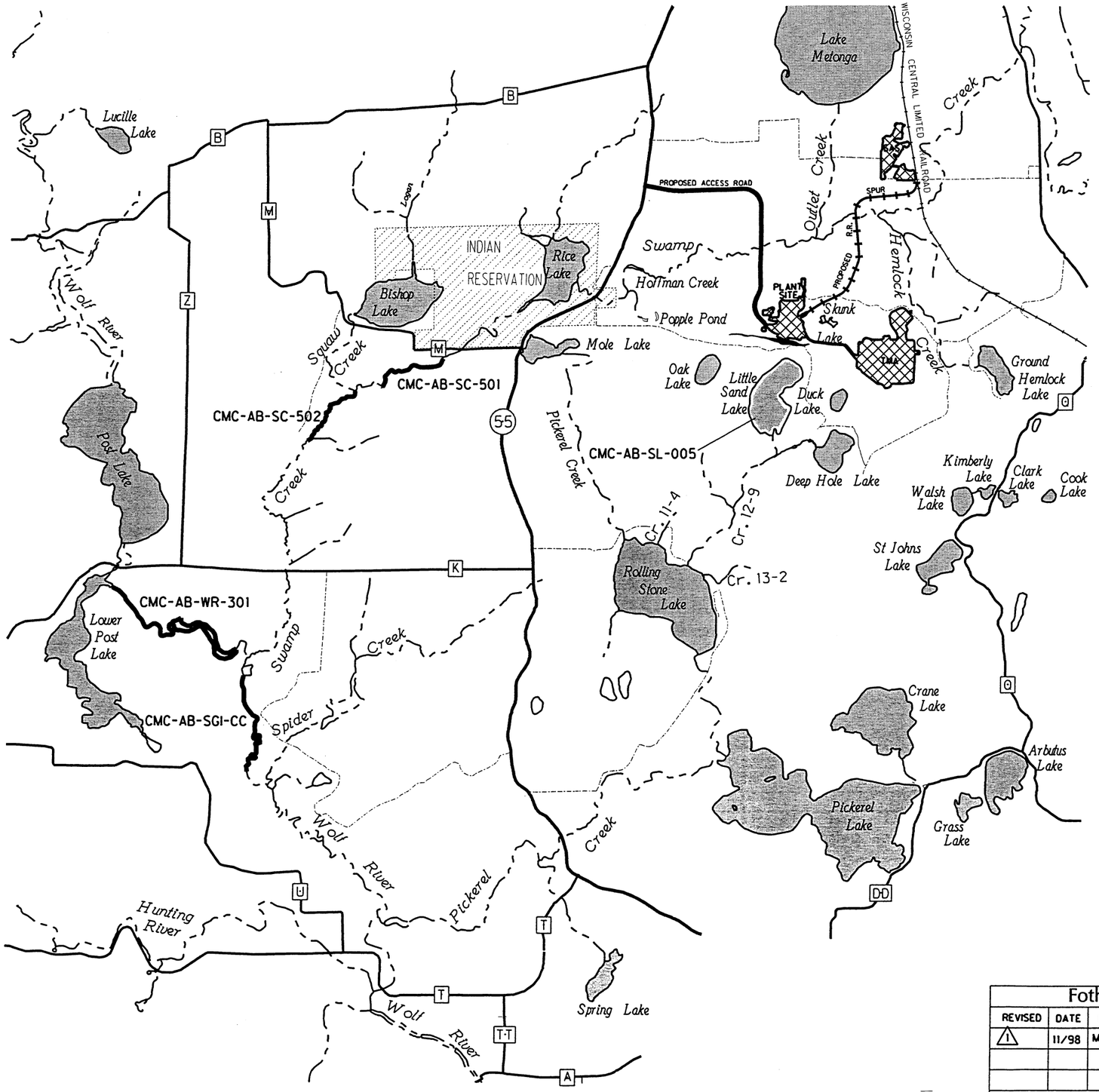

N

LEGEND

- STATE HWY
- COUNTY TRUNK HWY
- LAKES
- STREAMS
- ORE BODY
- PROPOSED ACCESS ROAD
- PROPOSED TMA ACCESS ROAD AND TAILINGS PIPELINE ROUTE
- PROPOSED RAILROAD SPUR
- PROPOSED FACILITIES

CMC-AB-SC-301 SAMPLING LOCATION

AREA OF SAMPLE COLLECTION

NOTE:

1. BASE MAP DERIVED FROM COUNTY MAPS PREPARED BY THE WISCONSIN DEPARTMENT OF TRANSPORTATION
2. ORE BODY OUTLINE IS REPRESENTATIVE OF THE SUBCROP AT THE BASE OF THE OVERBURDEN.

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION
1	11/98	MLD2	REVISED FOR 1998 UPDATE

CHECKED BY:	JKSI	DATE:	MAY '95
APPROVED BY:	RFS	DATE:	MAY '95
APPROVED BY:	GWS	DATE:	MAY '95

Nicolet Minerals COMPANY

Mining for the Future • Commitment

FIGURE 3.8-12

LOCATION FOR FISH COLLECTION FOR TISSUE ANALYSIS - MAY 1994

Scale: 0 3150' 7500' | Date: MAY, 1995

Prepared By: Foth & Van Dyke | By: JPR | 93C049

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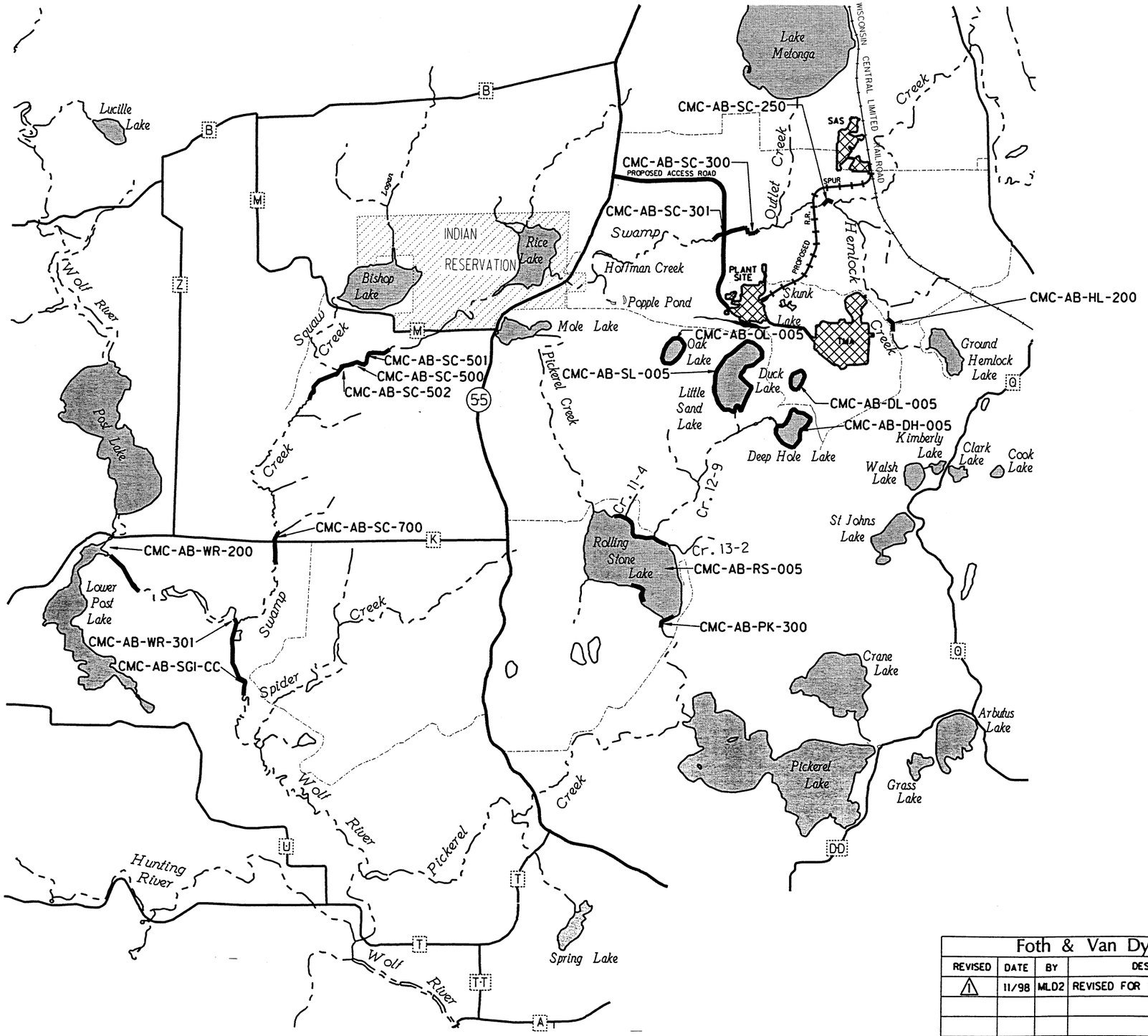

NOTE:

1. BASE MAP DERIVED FROM COUNTY MAPS PREPARED BY THE WISCONSIN DEPARTMENT OF TRANSPORTATION
2. ORE BODY OUTLINE IS REPRESENTATIVE OF THE SUBCROP AT THE BASE OF THE OVERBURDEN.

Foth & Van Dyke

REVISED	DATE	BY	DESCRIPTION
1	11/98	MLD2	REVISED FOR 1998 UPDATE

CHECKED BY:	JKSI	DATE:	MAY '95
APPROVED BY:	RFS	DATE:	MAY '95
APPROVED BY:	GWS	DATE:	MAY '95

Nicolet Minerals COMPANY

Mining for the Future • Commitment

FIGURE 3.8-13

1994 MUSSEL COLLECTION LOCATIONS

Scale: 0 3750' 7500' | Date: MAY, 1995

Prepared By: Foth & Van Dyke | By: JPR | 93C049

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Figure 3.8-14
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