Foth & Van Dyke

REPORT

Environmental Impact Report for the Kennecott Flambeau Project

Scope I.D.: 87K10

Volume I - Report Narrative

Kennecott Minerals Company
Ladysmith, Wisconsin

April 1989

VOLUME 1
ENVIRONMENTAL IMPACT REPORT
FOR THE
KENNECOTT FLAMBEAU PROJECT

WISCONSIN
GERALD W.
SEVICK
E-15308
Green Bay,
Wis.
PROFESSIONAL ENGINEER
Gerald W. Sevick
4/1/89

Prepared for:

KENNECOTT MINERALS COMPANY

Prepared by:

FOTH & VAN DYKE and Associates Inc.
and Contributors
2737 S. Ridge Road
P. O. Box 19012
Green Bay, Wisconsin 54307-9012

APRIL 1989

Foth & Van Dyke
2737 S. Ridge Road
P. O. Box 19012
Green Bay, Wisconsin 54307-9012
414/497-2500

Kennecott Minerals Company
1515 Mineral Square
P.O. Box 11248
Salt Lake City, Utah 84147
Telephone (801) 322-8460
FAX (801) 583-3129

April 3, 1989

Kennecott

Kathy Curtner, Acting Director
Wisconsin Department of Natural Resources
Bureau of Environmental Analysis and Review
P. O. Box 7921
Madison, WI 53707

87K10-61

Dear Ms. Curtner:

RE: Kennecott Flambeau Project
Environmental Impact Report

Kennecott Minerals Company (Kennecott) is pleased to provide the Wisconsin Department of Natural Resources (WDNR) with 40 complete copies of the report and appendices titled *Environmental Impact Report for the Kennecott Flambeau Project* prepared by Foth & Van Dyke.

As per a previous understanding developed with Mr. Robert Ramharter of your staff, it is our understanding that the WDNR will be responsible for the distribution of the final EIR to appropriate state and federal agencies. Kennecott will distribute the document to appropriate local officials.

This Environmental Impact Report has been prepared and is submitted to support the Mining Permit Application for the Kennecott Flambeau Project which has been simultaneously submitted to Mr. Gordon Reinke, Bureau of Solid Waste Management, WDNR.

Kennecott requests that the Wisconsin Department of Natural Resources initiate the following action on the documents being filed:

1. Prepare and finalize a draft and final Environmental Impact Statement (EIS) for the proposed Project described in the EIR and Mining Permit Application.

2. Coordinate with federal agencies to assure that the Department's EIS will be responsive to the needs of federal agencies that have permitting jurisdiction over the proposed Project.

3. Review and approve all permit applications, license applications, and similar documents regarding the proposed Project that are filed with and require approval of the Department.

If you or your staff have any questions regarding the final EIR please contact me at your convenience.

Sincerely,

KENNECOTT

Lawrence E. Mercando

Lawrence E. Mercando
Director, Process Development

Enclosure

3.6 Groundwater

Existing hydrogeologic and groundwater quality conditions in the vicinity of the proposed mine are discussed in this section. A discussion of these conditions is presented in the following four sub-sections:

3.6.1 Field and Laboratory Methods - discusses the procedures followed during data acquisition from the project site's 92 monitoring wells.

3.6.2 Regional Hydrogeology - discusses hydrogeologic conditions within a five-mile radius of the project area as set forth in NR182.08(2)(c)4.

3.6.3 Project Site Hydrogeology - discusses hydrogeologic conditions within the project area (generally, south of Blackberry Lane, east of the Flambeau River, north of Meadowbrook Creek, and west of Meadowbrook Road.

3.6.4 Groundwater Quality - discusses groundwater quality within the project area.

3.6.1 Field and Laboratory Methods

Extensive hydrogeologic information was collected as part of the 1976 EIS and Mining Permit Application preparations. These data, derived from the installation and testing of 42 monitoring wells, were used in part to determine the groundwater flow and chemistry characteristics within the glacial fluvial and till deposits (i.e., glacial overburden) and the sandstone of the project area. The 1976 effort did not characterize groundwater flow within the Precambrian bedrock because of its low permeability and small impact on the overall hydrologic regime. King (1983) presented, as a Ph.D. dissertation, a hydrogeologic and groundwater modeling study of the project site. This effort summarized site hydrogeology and estimated the hydrologic impacts of the proposed project assuming the 1976 mining plan.

To expand upon and verify this previous work, hydrogeological field and laboratory investigations, involving the installation and testing of 50 additional monitoring wells, were conducted from 1987 to 1989 to further define:

1. The nature and orientation of the groundwater flow in the glacial overburden, sandstone, and Precambrian units.

2. Background groundwater quality from samples collected from monitoring wells at the project site and from private water supply wells near the project site.

Data acquisition methods are first presented for the previous hydrogeologic investigations, including the King dissertation, and then for the 1987-89 hydrogeologic investigation.

3.6.1.1 Previous Initial Hydrogeologic Investigations

The hydrogeological investigations conducted during the 1970s and early 1980s included the installation of water wells and piezometers for water level measurements and single well aquifer response tests (KEN-35, 1987), and the performance of pump tests (KEN-36, 1987). Methods followed for each of the above investigations are presented below.

3.6.1.1.1 Water Wells and Piezometers

In 1970 and 1971, 20 water wells, OW-1 through OW-20, were drilled north and south of the 1976 proposed open pit. Also drilled in 1971 were two large-diameter (ten inches) pump test wells, OTW-29 and OTW-34. In 1972, seven additional wells, OW-39 through OW-45, were drilled in the vicinity of the proposed open pit. Also, in 1972, one groundwater well (ST-9-2) was installed in the northeast portion of the proposed open pit. In 1973, 12 additional groundwater wells were installed in the vicinity of the 1976 proposed open pit. These wells were labeled ST-9-17A, ST-9-19A to ST-9-23A, ST-9-23, ST-9-24, ST-9-26, and ST-9-27A to ST-9-29A. The drilling and soil sampling methods used for the above water well and piezometer borings are described in Section 3.5.1.2 of this report. Well locations are shown on Figure No. 3.5-2. Well construction information and geologic logs of these wells are included as Appendix 3.5-C.

The water wells (OW and OTW designation) were installed using air rotary techniques and were constructed of black steel casing with torch-cut slots. Some wells were slotted over more than one depth interval. Therefore, water quality data collected from the wells in the 1970s are not used for this report. However, water level measurements from wells that were slotted over only one depth interval provide useful data. Logs of the boring cuttings provide useful geologic information, such as the depth to the top of the Precambrian surface.

Piezometers (ST designation) were drilled with hollow-stem augers and constructed with 1.25-inch PVC screen and casing surrounded by pea gravel backfill.

From the date of installation through December 1980, depth to groundwater measurements were taken periodically on all of the OW and OTW waterwells, and on selected ST piezometers (KEN-35, 1977). Hydrographs of water level elevations in many of these wells for this period of record are contained in Appendix 3.6-A.

3.6.1.1.2 Pump Test and Single-Well Aquifer Response Tests

In 1971 and 1972 several of the water wells (OW-5, 6, 8, 9, 18, 29, 34, 39, 40, 41, 42, and 43) were pumped. Transmissivity values were calculated (KEN-36, 1976) from drawdown and recovery water levels in the pumping and nearby wells. Permeability was calculated by dividing the transmissivity by the estimated unit saturated thickness. These data are summarized on Table No. 3.6-1.

Subsequent to each ST piezometer installation, falling head or constant head permeability tests were performed. Results of these tests are provided in Table No. 3.6-2. It should be noted that the screens of these piezometers were wrapped with filter fabric, which is likely to lead to an underestimate of permeability. Therefore these data were used only for comparative purposes in the evaluations performed in this report.

3.6.1.2 1987 to 1989 Hydrogeological Investigations

From 1987 to 1989 several hydrogeologic investigations were completed including: baseline groundwater monitoring well and piezometer installation; groundwater level measurements; 12-month baseline groundwater monitoring program; single-well aquifer response tests; and multi-well pump tests. Subsections discussing the methods used in these investigations are presented below.

3.6.1.2.1 Well and Piezometer Installation

During the period of September 1987 to November 1988, 50 additional groundwater wells and piezometers were installed at the project site. Wells were installed for several different purposes.

In September and October 1987, 15 baseline groundwater monitoring wells, MW-1000 through MW-1005P, as listed on Table No. 3.5-1, were installed to provide groundwater samples for establishing baseline water quality. The wells comprise six nests; locations are indicated on Figure No. 3.5-2. Groundwater samples were also taken, though at a lesser frequency, from well nest PZ-1006. The nests consist of a water table well, a piezometer in the Pleistocene sediments or Cambrian sandstone, and/or a piezometer installed in the upper 50 feet of the Precambrian rock. The drilling of the wells is described in Section 3.5.1.4.1 of this report. Well construction data are summarized on Table No. 3.6-3 and well construction diagrams and well development forms are included in Appendix 3.5-D.

The wells were constructed of two-inch-diameter PVC casing and well screens. Schedule 40 PVC was used for shallow wells in

TABLE NO. 3.6-1

Summary of Data From 1971 Pump Tests

Well No.	Pump Rate (gpm)	Maximum Duration (minutes)	Maximum Drawdown (ft)	Calculated Average Transmissivity (gdf)	Calculated Permeability (cm/sec)	Geologic* Material	Observation Wells Used
OW-5	0.5	42	>16	12	1.1×10^{-5}	Till (and SS)	29, 49
OW-6	2.3	54	--	32	3.0×10^{-5}	Till (and SS)	?
OW-8	7.7	?	8 to 14	2,000	3.8×10^{-3}	SS, S&G	41, 42
OW-9	22 to 52	220	2 to 15	10,000	1.3×10^{-2}	S&G	43
OW-10	0.7 to 1.1	?	8 to 8.5	47	6.3×10^{-5}	Till, and/or S&G	?
OW-16	5.1 to 6.3	?	16.3 to 16.6	2,000	1.3×10^{-3}	S&G	?
OW-18	43 to 52.3	210	9.3	50,000	2.8×10^{-2}	S&G	?
OTW-29	18.2	479	16	2,000	4.7×10^{-3}	S&G	30, 31, 32, 33
OTW-34	2.6 to 6.2	107	14 to 21	400	4.7×10^{-4}	Till, and/or S&G	35, 36, 37, 38
OW-39	1.5	75	8.8	70	2.2×10^{-4}	Till	40
OW-40	2.2	60	4.2	290	2.0×10^{-3}	Till	39, 41
OW-41	13.4	120	12.2	850	2.5×10^{-3}	S&G	8
OW-42	8.9	1,500	17.0	2,000	4.7×10^{-3}	S&G	8, 9, 29, 31, 33
OW-43	39.9	240	0.9	24,000	2.3×10^{-2}	S&G	9

*Approximated from well log, gamma log, and/or adjacent sampled borings.

TABLE NO. 3.6-2

Summary of Field Permeability
Conducted by STS (1973)

Test No.	Permeability cm/sec	Description of Zone Tested
ST9-17A	1.38×10^{-3}	Fine coarse sand trace to some gravel-trace silt (SW)
ST9-18	1.96×10^{-8}	Fine coarse sand some fine coarse gravel-trace silt (SW-SM)
ST9-19	2.00×10^{-3}	Sandstone
ST9-19A	3.75×10^{-3}	Fine coarse sand-some fine coarse gravel-trace silt (SW)
ST9-20A	1.56×10^{-6}	1.5′ of fine coarse sand with gravel 5.5′ sandstone
ST9-21	4.64×10^{-4}	Sandstone
ST9-22	2.83×10^{-8}	Sandstone
ST9-22A	9.37×10^{-4}	Fine coarse sand-trace to some gravel-trace silt (SW)
ST9-23	1.00×10^{-3}	Sandstone
ST9-23A	2.35×10^{-3}	Fine coarse sand-some fine medium gravel-trace silt (SW)
ST9-24	1.13×10^{-3}	Sandstone
ST9-25	7.27×10^{-4}	Silty fine coarse sand-trace to some gravel (SM)
ST9-26	5.1×10^{-6}	Silty fine coarse sand-trace to some gravel-trace clay (SM)
ST9-27B	1.70×10^{-5}	Silty fine coarse sand-trace to some gravel-trace clay (SM)
ST9-28B	4.0×10^{-4}	Fine coarse sand-trace to some silt-trace gravel (SM)
ST9-29	4.09×10^{-5}	Silty fine coarse sand-trace to some gravel (SM)

TABLE NO. 3.6-3

Summary of Well Construction Data - Baseline Monitoring Wells

Well No.	MW-1000	MW-1000P	MW-1001	MW-1001G	MW-1001P	MW-1002	MW-1002G	MW-1003
Installation date	10/87	10/87	9/87	9/87	10/87	9/87	9/87	9/87
Elevation of measuring point MSL (ft)	1101.92	1101.75	1143.32	1143.47	1143.26	1103.84	1104.04	1145.58
Ground elevation MSL (ft)	1099.59	1099.38	1141.01	1141.15	1140.78	1101.63	1101.71	1143.41
Casing diameter (inches)	2	2	2	2	2	2	2	2
Type of casing	PVC	PVC	PVC	PVC	PVC	PVC	PVC	PVC
Casing length (from ground surface) (ft)	9	50	22.5	46.5	89.5	5.5	46.5	30.2
Screen diameter (inches)	2	2	2	2	2	2	2	2
Screen length (ft)	10	5	10	5	5	10	5	10
Type of screen	PVC	PVC	PVC	PVC	PVC	PVC	PVC	PVC
Screen slot size (inches)	0.006	0.010	0.010	0.010	0.006	0.010	0.010	0.010
Screened interval (depth in feet)	9-19	50-55	22.5-32.5	46.5-51.5	89.5-94.5	5.5-15.5	46.5-51.5	30.2-40.2
Screened interval (elevation MSL in feet)	1091-1081	1049-1044	1118-1108	1095-1090	1051-1046	1096-1086	1055-1050	1113-1103
Sand pack interval (depth in feet)	6-19	48-55	17.5-33	44.5-53.5	87.5-95	4-16	44.5-52	25.2-40.8
Sand pack interval (elevation MSL in feet)	1094-1081	1051-1046	1124-1108	1097-1088	1053-1046	1098-1086	1057-1050	1118-1103
Type of seal	Bentonite Pellets	Bentonite Pellets & Grout	Bentonite Pellets & Grout	Bentonite Pellets & Grout	Bentonite Pellets & Grout	Bentonite Pellets & Grout	Bentonite Pellets & Grout	Bentonite Pellets & Grout
Depth of borehole (ft)	19	55	33	53.5	95	16	52	40.8
Strata of Completion	Precambrian Rock, & Till	Precambrian Rock	Till	Till, & Sandstone	Precambrian Rock	Sand & Gravel	Sand & Gravel	Sandstone

TABLE NO. 3.6-3 (Cont.)

Well No.	MW-1003P	MW-1004	MW-1004S	MW-1004P	MW-1005	MW-1005S	MW-1005P
Installation date	10/87	9/87	9/87	9/87	9/87	9/87	10/87
Elevation of measuring point MSL (ft)	1145.60	1126.20	1125.77	1126.25	1144.11	1144.02	1144.13
Ground elevation MSL (ft)	1143.16	1123.80	1123.55	1123.91	1141.95	1141.89	1141.67
Casing diameter (inches)	2	2	2	2	2	2	2
Type of casing	PVC	PVC	PVC	PVC	PVC	PVC	PVC
Casing length (from ground surface) (ft)	81.5	11.5	30.8	82	8	42.3	86
Screen diameter (inches)	2	2	2	2	2	2	2
Screen length (ft)	5	10	5	5	10	5	5
Type of screen	PVC	PVC	PVC	PVC	PVC	PVC	PVC
Screen slot size (inches)	0.006	0.010	0.010	0.006	0.010	0.010	0.006
Screened interval (depth in feet)	81.5-86.5	11.5-21.5	30.8-35.8	82-87	8-18	45.3-50.3	86-91
Screened interval (elevation MSL in feet)	1062-1057	1112-1102	1093-1088	1042-1037	1134-1124	1097-1092	1056-1051
Sand pack interval (depth in feet)	79.5-86.5	7-21.5	28.8-38.4	79-87	6-18.5	42.3-51.5	84-91
Sand pack interval (elevation MSL in feet)	1064-1057	1117-1102	1095-1085	1045-1036	1136-1123	1100-1090	1058-1051
Type of seal	Bentonite Pellets & Grout	Bentonite Pellets & Grout	Bentonite Pellets & Grout	Bentonite Pellets & Grout	Bentonite Pellets & Grout	Bentonite Grout	Bentonite Pellets & Grout
Depth of borehole (ft)	86.5	21.5	38.4	87.5	18.5	51.5	91.5
Strata of Completion	Precambrian Rock	Sand & Gravel	Sandstone	Precambrian Rock	Till	Sandstone	Precambrian Rock

unconsolidated sediment; Schedule 80 PVC was used in the wells constructed in bedrock. In each nest, ten-foot- and five-foot-long screens were used for the water table wells and the deeper piezometers, respectively. Screens were factory-slotted with 0.010- or 0.006-inch slots. Joints were flush-threaded.

Filter packs consisting of #30-sieve, silica-based sand were placed around the screens. The filter packs extend approximately five feet above the top of the screens of the water table wells and approximately two feet above the top of the piezometer screens. A bentonite pellet seal at least two feet thick was placed above the filter pack. Bentonite grout was emplaced using a tremie pipe from the top of the bentonite pellets to the ground surface to seal the annular space. The grout was allowed to settle for at least 24 hours and was then topped off to a few feet below the ground surface. Four- or six-inch diameter protective steel casings with locking caps were installed. A sloping concrete apron was placed around the protective steel casing.

The wells were developed by surging and bailing until the water removed was clear of drilling fluid and excess fine sediment. Wells that could be bailed dry were allowed to recover and then surged and bailed. The procedure was repeated until the water cleared.

In addition to the baseline monitoring wells, a total of 35 other piezometers and test wells were installed from 1987 to 1988. The piezometers and test wells were installed for several hydrogeologic programs.

Five, two-inch diameter piezometers were installed to investigate the hydrogeologic conditions in the vicinity of the wetland areas located in the project area. Piezometers PZ-1A and PZ-1B were installed between Wetland Areas 1 and 2, immediately northwest of the proposed open pit. Piezometers PZ-1006, 1006G, and 1006S are located between the proposed open pit and Wetland Area 10a, across HWY 27 to the east. The locations for these piezometers are indicated on Figure 3.5-2. Well construction data for these piezometers are summarized on Table No. 3.6-4. The methods used for drilling and sampling of the borings for these piezometers are described in Section 3.5.1.4.2. Piezometers were installed and developed following the procedure described above. Piezometer construction and well development forms are included in Appendix 3.5-E.

Eleven, two-inch-diameter piezometers were installed to provide additional hydrogeological data for the calculation of permeabilities and the measurement of hydraulic gradients. These piezometers were labeled PZ-1007S, 1008 1008G, 1009, 1009G, SP6, SP8, K2P, K2PP, K4P, and K4PP. Piezometer locations are indicated on Figure 3.5-2. Piezometer construction data are summarized on Table No. 3.6-5. The methods used for drilling and sampling of the borings for these piezometers are described

TABLE NO. 3.6-4

Summary of Well Construction Data - Wetland Piezometers

Well No.	PZ-1006	PZ-1006S	PZ-1006G	PZ-1B	PZ-1A
Installation date	9/87	9/87	9/87	10/87	10/87
Elevation of measuring point MSL (ft)	1149.77	1149.79	1149.71	1106.29	1106.20
Ground elevation MSL (ft)	1147.50	1147.59	1147.39	1103.50	1103.50
Casing diameter (inches)	2	2	2	2	2
Type of casing	PVC	PVC	PVC	PVC	PVC
Casing length (from ground surface) (ft)	5	47	28	0.9	4.3
Screen diameter (inches)	2	2	2	2	2
Screen length (ft)	5	5	5	2	2
Type of screen	PVC	PVC	PVC	PVC	PVC
Screen slot size (inches)	0.010	0.010	0.010	0.010	0.010
Screened interval (depth in feet)	5-10	47-52	28-33	0.9-2.9	4.3-6.3
Screened interval (elevation MSL in feet)	1143-1138	1101-1096	1119-1114	1103-1101	1099-1097
Sand pack interval (depth in feet)	4-10	45-53.8	26-33	0.9-2.9	3.8-6.3
Sand pack interval (elevation MSL in feet)	1144-1138	1103-1094	1121-1114	1103-1101	1100-1097
Type of seal	Bentonite Pellets	Bentonite Pellets & Grout	Bentonite Pellets & Grout	Bentonite Pellets	Bentonite Pellets & Powder
Depth of borehole (ft)	10	53.8	33	2.9	6.3
Strata of Completion	Till	Sandstone	Till	Sand & Gravel	Sand & Gravel

TABLE NO. 3.6-5

Summary of Well Construction Data - Permeability/Gradient Wells

Well No.	PZ-1007S	PZ-1008	PZ-1008G	PZ-1009	PZ-1009G	PZ-K2P	PZ-K2PP
Installation date	11/88	11/88	11/88	11/88	11/88	11/88	11/88
Elevation of measuring point MSL (ft)	1155.09	1147.19	1147.01	1154.03	1154.14	1105.05	1105.13
Ground elevation MSL (ft)	1153.15	1145.43	1145.28	1152.59	1152.44	1102.3	1102.3
Casing diameter (inches)	2	2	2	2	2	2	2
Type of casing	PVC	PVC	PVC	PVC	PVC	PVC	PVC
Casing length (from ground surface) (ft)	43	7	49.2	8.4	45.3	110	187
Screen diameter (inches)	2	2	2	2	2	2	2
Screen length (ft)	5	10	5	10	5	5	5
Type of screen	PVC	PVC	PVC	PVC	PVC	PVC	PVC
Screen slot size (inches)	0.010	0.010	0.010	0.010	0.010	0.010	0.010
Screened interval (depth in feet)	43-48	7-17	49.2-54.2	8.4-18.4	45.3-50.3	110-115	187-192
Screened interval (elevation MSL in feet)	1110-1105	1138-1128	1096-1091	1144-1134	1107-1102	992-987	915-910
Sand pack interval (depth in feet)	40.4-49	5-18	48.3-55.4	5.4-18.4	43.4-50.3	106-121	184-193
Sand pack interval (elevation MSL in feet)	1113-1104	1140-1127	1097-1090	1147-1134	1109-1102	996-981	918-909
Type of seal	Bentonite Pellets & Grout	Bentonite Pellets & Grout	Bentonite Pellets & Grout	Bentonite Pellets & Grout	Bentonite Pellets & Grout	Bentonite Grout	Bentonite Grout
Depth of borehole (ft)	64.6	31	56.5	25	50.3	193	193
Strata of Completion	Sandstone	Till	Sand & Gravel	Till	Till	Precambrian Rock	Precambrian Rock

TABLE NO. 3.6-5 (Cont.)

Well No.	PZ-K4P	PZ-K4PP	PZ-SP6	PZ-SP8
Installation date	11/88	11/88	11/88	11/88
Elevation of measuring point MSL (ft)	1143.04	1143.12	1156.13	1144.39
Ground elevation MSL (ft)	1140.1	1140.1	1154.8	1142.8
Casing diameter (inches)	2	2	2	2
Type of casing	PVC	PVC	PVC	PVC
Casing length (from ground surface) (ft)	85	151	14.3	10
Screen diameter (inches)	2	2	2	2
Screen length (ft)	5	5	10	10
Type of screen	PVC	PVC	PVC	PVC
Screen slot size (inches)	0.010	0.010	0.010	0.010
Screened interval (depth in feet)	85-90	151-156	14.3-24.3	10-20
Screened interval (elevation MSL in feet)	1055-1050	989-984	1140-1130	1133-1123
Sand pack interval (depth in feet)	81-93	148-161	11.3-24.3	7-20
Sand pack interval (elevation MSL in feet)	1059-1047	992-979	1144-1130	1136-1123
Type of seal	Bentonite Grout	Bentonite Grout	Bentonite Pellets & Grout	Bentonite Pellets & Cement
Depth of borehole (ft)	183	183	24.3	20
Strata of Completion	Precambrian Rock	Precambrian Rock	Till & Silt	Till w/ Sand Seams

in Section 3.5.1.4.4. Well construction and well development forms are included in Appendix 3.5-H.

Nine piezometers, five deep and four shallow, were installed in bedrock for the geotechnical testing program. The deep piezometers, labeled PZ-R1, R2, R3, R5, and R7, extend to depths ranging from 120 to 220 feet. The shallow borings extend into the Precambrian rock to depths varying from 16 to 25 feet. Three of these (PZ-S1, PZ-S2, and PZ-S4) were completed as piezometers in the shallow Precambrian rock and one (PZ-S3) was completed in the sandstone. The methods used for drilling and sampling of the borings for these piezometers are described in Section 3.5.1.6.2 and Section 3.5.1.6.3. Wells were installed and developed using the procedure described above with exceptions as noted in Sections 3.5.1.6.2 and 3.5.1.6.3. Piezometer locations are shown on Figure No. 3.5-2 and construction data are summarized on Table No. 3.6-6. Well construction and well development forms are included in Appendix 3.5-I.

Six, six-inch-diameter, open-hole wells, TW-K1 through TW-K6, were installed to investigate the general permeability of the Precambrian rock along the proposed pit perimeter. These six wells were cased down into the Precambrian rock to prevent cave-in of the glacial overburden and sandstone units and to hydraulically isolate the rock from the overburden. However, in three of the wells (TW-K3, TW-K5, and TW-K6) the rock itself caved shortly after drilling. These wells were replaced by test wells TW-3R, TW-5R, and TW-K6R, in which were placed four-inch-diameter PVC pipe and slotted screens.

In addition, two test wells, TW-K17B and TW-K7, were constructed of four-inch diameter PVC and slotted screens. These wells were screened in glacial fluvial sediment located between the west end of the proposed pit and the Flambeau River, and were designed to confirm unit permeability. Also, a two-inch diameter, shallow piezometer (PZ-K8) was installed for permeability testing of the Precambrian rock in the area between the proposed pit and the Flambeau River. The location of the test wells is shown on Figure No. 3.5-2. Well construction data is summarized on Table No. 3.6-7. The methods used for drilling, sampling, installing, and developing the wells is described in Section 3.5.1.4.3. Well construction diagrams and well development forms are included in Appendix 3.5-G.

A sandpoint was installed adjacent to the Flambeau River at the southwest end of the pit. This well, installed in permeable sand two feet from the river's edge, was used to determine the surface elevation of the river during monitoring events when groundwater measurements were made. The location of the sandpoint is indicated in Figure No. 3.5-2.

TABLE NO. 3.6-6

Summary of Well Construction Data - Geotechnical Piezometers

Well No.	PZ-S1	PZ-S2	PZ-S3	PZ-S4
Installation date	12/87	12/87	10/87	12/87
Elevation of measuring point MSL (ft)	1103.07	1105.79	1131.43	1144.03
Ground elevation MSL (ft)	1101.61	1103.40	1128.98	1141.19
Casing diameter (inches)	2	2	2	2
Type of casing	PVC	PVC	PVC	PVC
Casing length (from ground surface) (ft)	35	26.5	28.5	67.5
Screen diameter (inches)	2	2	2	2
Screen length (ft)	5	5	5	5
Type of screen	PVC	PVC	PVC	PVC
Screen slot size (inches)	0.006	0.006	0.010	0.006
Screened interval (depth in feet)	35-40	26.5-31.5	28.5-33.5	67.5-72.5
Screened interval (elevation MSL in feet)	1067-1062	1077-1072	1100-1095	1074-1069
Sand pack interval (depth in feet)	33-41.5	24.5-31.5	26-34	65.5-72.5
Sand pack interval (elevation MSL in feet)	1067-1060	1079-1072	1103-1095	1076-1069
Type of seal	Bentonite Pellets & Grout	Bentonite Pellets & Grout	Bentonite Pellets & Grout	Bentonite Pellets & Grout
Depth of borehole (ft)	41.5	31.5	53	72.5
Strata of Completion	Precambrian Rock	Precambrian Rock	Sandstone	Precambrian Rock

TABLE NO. 3.6-6 (Cont.)

Well No.	PZ-R1	PZ-R2	PZ-R3	PZ-R5	PZ-R7
Installation date	1/88	1/88	1/88	1/88	1/88
Elevation of measuring point MSL (ft)	1103.85	1105.5	1104.04	1124.87	1142.46
Ground elevation MSL (ft)	1101.13	1102.56	1100.79	1121.89	1139.44
Casing diameter (inches)	1.25	1.25	1.25	1.25	1.25
Type of casing	PVC	PVC	PVC	PVC	PVC
Casing length (from ground surface) (ft)	200	165	122	100	80
Screen diameter (inches)	1.25	1.25	1.25	1.25	1.25
Screen length (ft)	20	20	20	20	20
Type of screen	PVC	PVC	PVC	PVC	PVC
Screen slot size (inches)	0.020	0.020	0.020	0.020	0.020
Screened interval (depth in feet)	173-190	143-160	123-140	87-104	87-104
Screened interval (elevation MSL in feet)	928-911	959-941	978-961	1035-1018	1052-1035
Sand pack interval (depth in feet)	160-199	126-221	106-156	74-121	69-126
Sand pack interval (elevation MSL in feet)	941-902	977-882	995-945	1048-1001	1070-1013
Type of seal	Bentonite Grout	Bentonite Grout	Bentonite Grout	Bentonite Grout	Bentonite Grout
Angled length of borehole (ft)	230	255	230	250	290
Strata of Completion	Precambrian Rock	Precambrian Rock	Precambrian Rock	Precambrian Rock	Precambrian Rock

TABLE NO. 3.6-7

Summary of Well Construction Data - Test Wells

Well No.	TW-K1	TW-K2	TW-K3	TW-K3R	TW-K4	TW-K5	TW-K5R
Installation date	3/88	3/88	3/88	3/88	3/88	3/88	3/88
Elevation of measuring point MSL (ft)	1105.34	1105.22	1127.60	1126.80	1143.29	1145.43	1144.81
Ground elevation MSL (ft)	1102.48	1102.26	1124.62	1124.62	1140.10	1143.16	1143.16
Casing diameter (inches)	6	6	6	4	6	6	4
Type of casing	Steel	Steel	Steel	PVC	Steel	Steel	PVC
Casing length (from ground surface) (ft)	36	30.5	38	52	52	57	57
Screen diameter (inches)	6	6	6	4	6	6	4
Screen length (ft)	157	163	125	108	141	136	108
Type of screen	Open hole	Open hole	Open hole	PVC	Open hole	Open hole	PVC
Screen slot size (inches)	-	-	-	0.040	-	-	0.040
Screened interval (depth in feet)	36-193	30.5-193	38-163	52-160	52-193	57-193	57-165
Screened interval (elevation MSL in feet)	1066-909	1072-909	1087-962	1073-965	1088-932	1086-950	1086-978
Sand pack interval (depth in feet)	-	-	-	38-160	-	-	47-165
Sand pack interval (elevation MSL in feet)	-	-	-	1087-965	-	-	1096-979
Type of seal	Bentonite Grout	Bentonite Grout	Bentonite Grout	Bentonite Grout	Bentonite Grout	Bentonite Grout	Bentonite Grout
Depth of borehole (ft)	193	193	163	163	163	193	193
Strata of Completion	Precambrian Rock	Precambrian Rock	Precambrian Rock	Precambrian Rock	Precambrian Rock	Precambrian Rock	Precambrian Rock

TABLE NO. 3.6-7 (Cont.)

Well No.	TW-K6	TW-K6R	TW-K7	PZ-K3	TW-K17B
Installation date	3/88	3/88	9/88	9/88	9/88
Elevation of measuring point MSL (ft)	-	1120.16	1100.33	1102.12	1102.92
Ground elevation MSL (ft)	-	1118.24	1098.18	1099.70	1099.99
Casing diameter (inches)	6	4	4	2	4
Type of casing	Steel	PVC	PVC	PVC	PVC
Casing length (from ground surface) (ft)	60	65	20	18	35
Screen diameter (inches)	6	4	4	2	4
Screen length (ft)	123	118	10	5	10
Type of screen	Open hole	PVC	PVC	PVC	PVC
Screen slot size (inches)	-	0.040	0.040	0.010	0.040
Screened interval (depth in feet)	60-183	65-183	20-30	20-25	35-45
Screened interval (elevation MSL in feet)	-	1053-935	1078-1068	1080-1075	1065-1055
Sand pack interval (depth in feet)	-	40-183	15-32	18-25	30-46
Sand pack interval (elevation MSL in feet)	-	1078-935	1083-1066	1082-1075	1070-1054
Type of seal	Bentonite Grout	Bentonite Grout	Bentonite Pellets & Grout	Bentonite Pellets & Grout	Bentonite Pellets & Grout
Depth of borehole (ft)	183	186	32	25	46
Strata of Completion	Precambrian Rock	Precambrian Rock	Sand & Gravel	Precambrian Rock	Sand & Gravel

3.6.1.2.2 Groundwater Level Measurements

Groundwater levels were measured monthly from September 1987 through September 1988, and in November 1988 and January 1989. Water level measurements are included on the field sampling log sheets presented in Appendix 3.6-B. Static water level elevations for the entire study are tabulated on Table No. 3.6-8.

The depth to groundwater was measured using a Well Wizard M6000 water level indicator. The tape on the water level indicator is marked at 0.05-foot intervals and depths can be estimated to 0.01 feet. Water elevations were then determined by subtracting the depth to water from the elevation of the measuring point (top of 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 done by Morgan and Parmley, Ltd., Ladysmith, Wisconsin. The surveyors are registered land surveyors in the State of Wisconsin.

3.6.1.2.3 Groundwater Sample Collection and Field Testing

The 15 baseline groundwater monitoring wells were sampled monthly for 12 consecutive months (October 1987 to September 1988) to determine baseline water quality at the project site. In addition to the 15 baseline wells, several other monitoring wells and four private wells were sampled during the investigation. These include samples from piezometers PZ-1006G and PZ-1006S, samples from the piezometers that were put in five of the angle holes drilled deep into the Precambrian, and samples from four private wells. In addition, samples tested for a limited set of indicator parameters were collected at 45 more private wells as part of the Kennecott well guarantee program. All the on-site groundwater sampling locations are indicated on Figure No. 3.6-1. The private well locations are indicated on Figure No. 3.6-2.

WDNR personnel were notified prior to each round of sampling so that they were able to observe procedures and/or split samples. WDNR personnel were present during the October 1987, November 1987, January 1988, and May 1988 sampling rounds.

Sampling procedures were observed and accepted by WDNR personnel and were consistent with those published in the WDNR PUBL-WR-153, *Groundwater Sampling Procedures Guidelines,* February 1987; and PUBL-WR-168, *Groundwater Sampling Procedures Field Manual,* September 1987.

Prior to sample collection, each well was purged by removing four times the volume of water in the monitoring well or until

TABLE NO. 3.6-8

Static Water Level Elevations (FT-MSL) in Monitoring Wells and Piezometers

Well No.	9/23/87	10/15/87	10/21/87	11/3/87	12/1/87	1/6/88	2/2/88	2/29/88	4/6/88	5/3/88	6/1/88	7/5/88	8/9/88	9/6/88	11/28/88	1/4/89
MW-1000	NI	1087.26	1087.42	1088.10	1088.47	1089.62	1089.90	1089.06	1091.06	1089.56	1088.51	1087.37	1088.00	1087.96	1088.51	1088.32
MW-1000P	NI	1087.20	1087.67	1087.66	1088.15	1089.43	1089.01	1088.93	1090.68	1088.73	1088.11	1087.74	1088.01	1088.71	1088.69	1088.83
MW-1001	NI	1114.59	1114.46	1114.51	1114.15	1113.48	1113.22	1112.97	1112.83	1112.75	1112.62	1112.37	1112.00	1110.94	1109.94	1109.70
MW-1001G	NI	1113.75	1113.62	1113.79	1113.43	1112.85	1112.56	1112.32	1112.37	1112.34	1112.14	1111.89	1111.72	1111.61	1111.01	1110.82
MW-1001P	NI	1114.19	1114.06	1114.11	1113.84	1113.18	1112.85	1112.70	1112.74	1112.60	1112.41	1112.24	1112.04	1111.91	1111.36	1111.11
MW-1002	NI	1089.64	1089.91	1089.86	1089.79	1090.05	1090.31	1090.13	1090.72	1090.39	1090.03	1089.39	1089.89	1089.44		1089.74
MW-1002G	NI	1089.68	1089.95	1089.89	1089.94	1090.22	1090.49	1090.28	1090.87	1090.66	1090.07	1089.53	1089.97	1089.53	1089.94	1089.92
MW-1003	NI	1111.00	1110.95	1110.87	1110.70	1110.54	1110.33	1110.02	1110.37	1110.73	1110.65	1110.31	1110.01	1109.91	1109.50	1109.50
MW-1003P	NI	1110.98	1110.91	1110.90	1111.22	1110.55	1110.36	1110.18	1110.35	1110.75	1110.63	1110.31	1110.02	1109.88	1109.50	1109.40
MW-1004	NI	1108.57	1108.79	1108.66	1108.88	1108.71	1108.43	1108.30	1109.69	1109.63	1109.02	1108.26	1107.93	1107.70	1107.86	1107.60
MW-1004S	NI	1108.41	1108.63	1108.49	1108.71	1108.55	1108.29	1108.08	1109.56	1109.46	1108.85	1108.05	1107.79	1107.49	1107.67	1107.40
MW-1004P	NI	1106.12	1106.30	1106.41	1106.59	1106.44	1106.17	1105.87	1107.20	1107.25	1106.65	1105.79	1105.43	1105.17	1105.28	1105.23
MW-1005	NI	1137.67	1138.26	1138.89	1139.36	1138.32	1137.30	1136.98	1139.10	1139.42	1138.65	1137.27	1137.07	1136.71	1136.88	1136.10
MW-1005S	NI	1137.56	1137.80	1138.17	1138.58	1138.01	1137.21	1136.82	1138.34	1138.76	1138.29	1137.26	1136.84	1136.51	1136.02	1135.61
MW-1005P	NI	1138.17	1138.31	1138.47	1138.87	1138.42	1137.60	1137.32	1138.53	1139.05	1138.69	1137.80	1137.33	1136.97	1136.38	1135.96
PZ-1006	NI	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry
PZ-1006G	NI	1134.33	1134.21	1134.26	1134.06	1133.82	1133.40	1133.02	1133.82	1133.96	1133.97	1133.50	1133.07	1132.83	1131.94	1131.66
PZ-1006S	NI	1132.94	1132.82	1132.87	1132.62	1132.36	1132.01	1131.60	1132.13	1132.35	1132.43	1132.04	1131.57	1131.46	1130.56	1130.32
7	1115.15	1113.76	NM	1112.54	1111.51	1109.93	1109.32	1108.96	1105.97	1110.12	1111.09	1110.83	1109.95	1109.13	1107.79	1107.57
10	1094.06	1093.27	NM	1093.48	1093.69	1094.34	1094.52	1093.91	1094.81	1094.05	1093.45	1092.96	1093.08	1093.01	1093.54	1093.67
12	1109.04	1108.78	NM	1108.80	1108.70	1108.65	1108.50	1108.35	1109.14	1109.37	1109.08	1108.61	1108.24	1108.04	1107.72	1107.65
14	1118.90	1119.35	NM	1118.01	1116.76	1119.05	1118.38	1117.04	1124.84	1125.55	1124.36	1122.87	1121.83	1121.41	1120.19	1119.45
31	1097.69	1095.31	NM	1095.86	1096.38	1096.63	1096.24	1095.83	1097.82	1096.91	1095.92	1094.91	1094.71	1094.49	1095.06	1095.18
36	1096.75	1096.55	NM	1096.51	1096.41	1096.16	1096.05	1095.76	1096.57	1095.90	1095.54	1094.87	1095.64	1095.74	1096.09	1097.52
37	1093.71	Dry	NM	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry
39	1099.81	1099.56	NM	1099.44	1099.24	1099.19	1099.22	1099.08	1099.26	1099.83	1099.66	1099.03	1098.70	1098.50	1097.99	1097.95
40	1095.02	1094.79	NM	1095.10	1095.45	1095.75	1095.65	1095.31	1096.85	1096.02	1095.26	1094.45	1094.45	1094.35	1094.57	1094.58
41	1095.04	1094.89	NM	1095.47	1096.05	1096.22	1095.89	1095.49	1097.50	1096.91	1095.84	1094.65	1094.40	1094.12	1094.56	1094.80
42	1094.03	1093.77	NM	1094.31	1094.94	1094.87	1094.38	1093.86	1096.10	1095.15	1093.93	1092.99	1092.88	1092.67	1093.08	1093.36
43	1087.90	1086.67	NM	1086.92	1087.06	1088.23	1088.32	1087.77	1088.65	1087.44	1086.85	1086.31	1086.76	1086.85	1087.23	1087.49
45	1091.99	1091.60	NM	1091.94	1092.29	1092.14	1092.14	1091.83	1093.63	1093.59	1092.53	1091.59	1092.05	1091.14	1091.57	1091.29
ST-2	Dry	1113.24	NM	1113.05	1112.77	1112.52	1112.33	1111.93	1114.87	1113.28	1112.33	1112.13	1111.99	1111.79	1111.20	1111.05
ST-17A	1087.45	1086.83	NM	1087.21	1087.46	1088.61	1088.88	1088.03	1089.57	1087.59	1087.03	1086.50	1087.19	1087.18	1088.05	1087.75
ST-19A	1109.32	1108.68	NM	1108.74	1108.97	1108.77	1108.51	1108.27	1109.77	1109.68	1109.07	1108.25	1107.98	1107.71	1107.98	1107.17
ST-20A	1108.98	1108.87	NM	1108.91	1107.94	1108.93	1108.62	1108.37	1109.49	1109.60	1109.14	1108.45	1108.09	1107.87	1107.82	1107.65
ST-22A	Dry	Dry	NM	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry
ST-23	1117.85	1117.32	NM	1117.03	1116.66	1116.25	1116.03	1115.71	1115.45	1115.60	1115.66	1115.49	1115.30	1115.15	1114.51	1114.31
ST-23A	Dry	Dry	NM	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry
ST-24	1114.54	1114.27	NM	1114.10	1113.77	1113.48	1113.29	1113.02	1113.18	1113.45	1113.37	1112.97	1112.01	NM	NM	NM

TABLE NO. 3.6-8 (Cont.)

Well No.	9/23/87	10/15/87	10/21/87	11/3/87	12/1/87	1/6/88	2/2/88	2/29/88	4/6/88	5/3/88	6/1/88	7/5/88	8/9/88	9/6/88	11/28/88	1/4/89
ST-26	1110.60	1110.28	NM	1110.09	1109.73	1109.61	1109.23	1109.00	1108.92	1109.12	1109.07	1108.76	1108.53	1108.38	1108.00	1107.67
ST-27A	Dry	Dry	NM	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Dry
ST-28A	1095.87	Dry	NM	1096.27	1097.34	1097.16	1096.77	1096.49	1099.75	1098.95	1097.82	1096.25	1096.08	1095.52	1099.12	1097.62
ST-29A	Dry	Dry	NM	Dry	Dry	Dry	Dry	Dry	1094.99	1094.27	1092.71	Dry	Dry	Dry	Dry	Dry
Sand Poin	NI	NI	NI	1082.49	1085.64	Frozen	Frozen	1086.64	1086.84	1084.15	1083.61	1083.35	1084.88	1084.71	1085.57	1088.99
PZ-S1	NI	NI	NI	NI	NI	1096.28	1095.67	1095.23	1097.47	1096.85	1094.24	1093.17	1093.01	1092.85	1093.29	1093.49
PZ-S2	NI	NI	NI	NI	NI	1091.63	1091.89	1091.49	1092.76	1092.25	1091.56	1090.58	1090.48	1090.51	1090.58	1090.65
PZ-S3	NI	NI	NI	1113.86	1113.55	1113.32	1113.05	1112.78	1112.98	1113.26	1113.15	1112.79	1112.45	1112.25	1111.66	1111.51
PZ-S4	NI	NI	NI	NI	NI	1116.80	1116.53	1116.25	1116.00	1116.10	1116.21	1116.07	1115.86	1115.75	1115.19	1115.00
PZ-1B S	NI	NI	NI	1102.44	1102.65	1102.20	1101.68	1100.73	1103.13	1102.54	1101.42	Dry	1102.30	1101.17	1102.85	1102.15
PZ-1A N	NI	NI	NI	1100.88	1101.70	1100.82	1100.32	1099.71	1102.83	1101.64	1100.01	1098.91	1098.72	1098.21	1099.61	1099.14
PZ-R1	NI	NI	NI	NI	NI	NI	1089.23	1088.85	1090.40	1088.34	1087.72	1087.09	1087.49	1088.92	1088.04	1087.79
PZ-R2	NI	NI	NI	NI	NI	NI	1091.94	1091.77	1092.81	1091.41	1090.87	1090.29	1090.35	NM	1090.67	1090.91
PZ-R3	NI	NI	NI	NI	NI	NI	1094.88	1093.29	1094.90	1093.77	1093.02	1092.24	1092.38	1092.32	1092.31	1092.74
PZ-R5	NI	NI	NI	NI	NI	NI	1113.06	1110.60	1110.94	1111.34	1111.13	1110.58	1110.22	1110.09	1109.59	1109.39
PZ-R7	NI	NI	NI	NI	NI	NI	1118.13	1115.39	1115.21	1115.40	1115.42	1115.28	1115.07	1114.99	1114.43	1114.26
TW-K1	NI	NI	NI	NI	NI	NI	NI	NI	1096.64	1095.89	1094.94	1093.84	1093.63	1093.42	1093.76	1094.09
TW-K2	NI	NI	NI	NI	NI	NI	NI	NI	1092.27	1090.51	1089.99	1089.37	1089.96	1089.98	Replaced	Replaced
TW-K3	NI	NI	NI	NI	NI	NI	NI	NI	1111.45	1111.65	1111.52	1111.85	1111.58	1111.40	1110.88	1110.73
TW-K4	NI	NI	NI	NI	NI	NI	NI	NI	1116.17	1116.28	1116.39	1116.22	1116.02	1115.94	Replaced	Replaced
TW-K5	NI	NI	NI	NI	NI	NI	NI	NI	1112.66	1112.33	1112.40	1112.70	1112.50	1112.44	1111.93	1111.86
TW-K6R	NI	NI	NI	NI	NI	NI	NI	NI	1108.12	1108.08	1107.59	1107.79	1107.49	1107.26	1107.46	1107.26
TW-K7	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	1088.60	1088.38
TW-K8	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	1091.58	1091.62
TW-17B	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	1087.96	1087.72
PZ-1007S	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	1113.27	1113.20
PZ-1008	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	1134.89	1134.59
PZ-1008G	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	1134.89	1134.49
PZ-1009	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	1139.51	1139.41
PZ-1009G	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	1139.50	1139.34
PZ-SP6	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	1135.39	1135.06
PZ-SP8	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	1134.31	1134.31
PZ-K2P	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	1088.39	1089.34
PZ-K2PP	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	1077.51	1089.53
PZ-K4P	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	1115.30	1115.20
PZ-K4PP	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	1115.35	1115.35

NI = Not Installed
NM = Not Measured

the well was dewatered, whichever came first. The wells were purged with a dedicated PVC bailer. In the piezometers, water was drawn from above the screen in the uppermost part of the water column so that fresh water from the screen moved upward. Detailed field logs of purging procedures were maintained and are contained in Appendix 3.6-B.

Subsequent to purging, samples were removed with the same dedicated PVC bailer used for purging. Upon collection, the specific conductivity and pH of each sample were measured using a Lakewood LCD meter. The meter was calibrated in the field daily.

Aliquots of samples to be analyzed for metals were filtered in the field using a 2.5-liter Geo-Tech filter tank with 40 psi pressure capacity. New nitro-cellulose (0.45 micron) mesh filters were used to filter each sample.

De-ionized water from Foth & Van Dyke's soils laboratory was used to rinse all sampling apparatus between each well sample. If required by sample protocol, samples were preserved in the field using acid ampules. The quality control and quality assurance procedures outlined in WDNR PUBL-WR-168 were followed.

3.6.1.2.4 Single-Well Aquifer Response Tests

Single-well aquifer response test were conducted during 1987 and 1988 in order to update the 1970s permeability data within the three principal geologic units. Bail-down tests were conducted on wells and piezometers completed in the glacial overburden, the Cambrian sandstone, and the Precambrian rock. Packer tests were also conducted in boreholes within the Precambrian rock.

Bail-Down Tests

Bail-down tests were conducted on all monitoring wells and piezometers installed from 1987 to 1988. Bail-down tests were also conducted on test wells, TW-K1, TW-K2, TW-K3, TW-K4, and TW-K6R. The following test procedure was used.

Bail-down tests on fast-recovering wells were begun by putting a pressure transducer, with LCD readout in feet, into a well at a depth below the static water level. Bail-down tests on slow-recovering wells were begun by measuring the depth to groundwater with a water level indicator. The resulting initial starting water level (usually greater than 10.0 feet) or initial depth to water was recorded. In fast-recovering wells, a six-foot-long bailer was lowered into the well and then removed in order to lower the water level in the well. In slow recovering wells, the groundwater level was decreased via bailing. In either case, the minimum water level reading was recorded. At the instant this minimum was reached (allowing a few seconds to allow for water level stabilization), a stop watch was started and increasing water level measurements with time were recorded.

Also noted for the purposes of data evaluation were the well casing diameter, the sand pack radius, the sand pack length, the unit saturated thickness, and the depth of penetration of the well into the saturated unit.

The analytical methodology used to evaluate these data is based upon the work of Hvorslev (1951) and Bouwer and Rice (1976). Permeability data obtained from these aquifer response tests for the Quaternary sediments and the Cambrian sandstone are summarized in Table No. 3.6-9. Data for the Precambrian rock tests are summarized on Table No. 3.6-10. Each table lists the well number, the depth and elevation of the interval tested, the geologic unit tested, and the type of test. The Precambrian rock units listed in Table No. 3.5-10 are the major rock types as described in Section 3.5.3.4.2. Also listed is the location of the well relative to the deposit and hanging wall and footwall rock. The data and calculations supporting the data in these tables are contained in Appendix 3.6-C.

Packer Tests

Packer tests were conducted on the angled boreholes drilled for the geotechnical testing program. The intervals tested were those that appeared, on the basis of field core examination, to be the most fractured. The drilling and test methods used for this program are described in Section 3.5.1.6.2. Packer test permeabilities, test intervals, and corresponding rock units are summarized in Table No. 3.6-9. Supporting data and calculations are contained in Appendix 3.6-C.

3.6.1.2.5 Pump Tests

Short-term pump tests were conducted on test wells TW-K2 and TW-K4 on March 8 to 10, 1989. Additional pump tests were conducted on test wells TW-K3R and TW-K5R on March 24 to 27, 1989. Test well TW-K17B was pumped on September 22, 1988. The wells were pumped at rates ranging from one to 18 gallons per minute using an electric submersible pump. Pump test duration ranged from one to four hours. Drawdown and recovery data were obtained from the pumping wells, and the nearby monitoring wells and piezometers that served as observation wells. Calculated permeability values and drawdowns for the pumping wells and observation wells are listed in Table No. 3.6-11. Supporting data and calculations are contained in Appendix 3.6-C.

3.6.1.2.6 River Level/Groundwater Level Interaction

In order to evaluate the effect of dam-controlled fluctuations of the Flambeau River level on groundwater levels, simultaneous water level measurements were made on the sandpoint adjacent to the river and in several monitoring wells and piezometers near the river in September and October 1988. Twice-daily fluctuations of the Flambeau River range from 0.5 to 2.0 feet.

TABLE NO. 3.6-9

Summary of Permeability
Data for Quaternary Sediments and Cambrian Sandstone

Well Designation	Unit	Bail Tests	Pump Tests Drawdown	Pump Tests Recovery	Test Interval Elevation (ft)	Test Interval Depth (ft)
PZ-1A	Glacial Fluvial	$1.0x10^{-4}$			1097-1100	3.8-6.3
PZ-1B	Glacial Fluvial	$1.0x10^{-5}$			1101-1103	0.9-2.9
TW-K7	Glacial Fluvial		$4.8 X 10^{-3}$		1068-1085	13-30
TW-K17B	Glacial Fluvial		$6.5 x 10^{-3}$		1054-1070	30-46
MW-1002	Glacial Fluvial	$4.3x10^{-3}$			1084-1094	6-16
MW-1002G	Glacial Fluvial	$7.1x10^{-3}$			1049-1054	46-51
MW-1004	Glacial Fluvial	$1.7 x 10^{-1}$			1093-1103	11-21
MW-1005	Till	$4.3 x 10^{-4}$			1124-1134	8-18
PZ-1006	Till	Dry			1137-1142	5-10
PZ-1006G	Till	$8.4x10^{-5}$			1114-1119	28-33
MW-1001	Till	$5.5 x 10^{-3}$			1108-1118	22-32
MW-1000	Till & Precambrian Rock	$2.5 x 10^{-3}$	$3.6 x 10^{-4}$	$4.9 x 10^{-4}$	1079-1099	9-19
MW-1001G	Till, Sandstone	$5.7x10^{-4}$			1089-1094	46-51
PZ-1008	Till	$3.4x10^{-5}$			1127-1140	5-18
PZ-1008G	Till, Sand Seam	$3.9x10^{-3}$			1090-1097	48.3-55.4
PZ-1009	Till	$1.4x10^{-5}$			1134-1147	5.4-18.4
PZ-1009G	Till	$3.4x10^{-5}$			1102-1109	43.4-50.3
PZ-SP6	Till	$3.3x10^{-4}$			1130-1144	11.3-24.3
PZ-SP8	Till	$4.7x10^{-5}$			1123-1136	7-20
MW-1003	Sandstone	$1.8x10^{-3}$			1102-1112	30-40
MW-1004S	Sandstone	$1.3x10^{-3}$			1079-1084	30-35
MW-1005S	Sandstone	$1.6x10^{-3}$			1093-1098	45-50
PZ-1006S	Sandstone/Glacial Fluvial	$9.5x10^{-4}$			1095-1100	47-52
PZ-1007S	Sandstone	$4.3x10^{-4}$			1104-1113	40.4-49
PZ-S3	Sandstone	$1.0x10^{-4}$			1096-1101	28-33

TABLE NO. 3-6-10

Summary of Permeability Test Data for Precambrian Rock

Well Designation	Well/Boring Location**	Precambrian Unit***	Bail Tests	Pump Tests Drawdown	Pump Tests Recovery	Packer Tests	Vertical Test Interval Elevation (ft)	Vertical Test Interval Depth (ft)
MW-1000P	0	1a (SMS)	$9.0x10^{-7}$	$8.0x10^{-4}$	$4.6 x 10^{-4}$		1051-1046	48- 55
MW-1001P	-	-	$7.4x10^{-6}$				1046-1053	87.5 - 95
MW-1003P	H	3a	$9.8x10^{-7}$				1057-1064	79.5 - 86.5
MW-1004P	H	5	$6.0x10^{-6}$				1036-1045	79- 87
MW-1005P	-	-	$1.7x10^{-5}$				1051-1058	84- 91
PZ-S1	H	2c	$3.2x10^{-5}$				1060-1067	33- 41.5
PZ-S2	F	3a	$2.8x10^{-5}$	$1.2x10^{-4}$	$3.8x10^{-5}$		1072-1079	24.5 - 31.5
PZ-S4	F	5	$1.2x10^{-4}$	$5.6x10^{-4}$			1069-1076	65.5 - 72.5
TW-K1	H	2c, 2a	$1.6x10^{-6}$*				909-1066	36-189
TW-K2	O,F	1c, 1b, 2a	$9.9x10^{-5}$	$6.1x10^{-5}$	$8.0x10^{-5}$		909-1072	30-193
PZ-K2P	F	2a	$5.2x10^{-6}$				996-981	106-121
PZ-K2PP	F	2a	$2.8x10^{-7}$				918-909	184-193
TW-K3	F	2c, 2a	$1.8x10^{-5}$*				962-1087	38-163
TW-K3R	F	2c, 2a		$2.0x10^{-6}$	$3.5x10^{-6}$		965-1087	38-160
TW-K4	F	5, 2c	$1.5x10^{-5}$*	$1.5x10^{-5}$	$4.8x10^{-5}$		932-1088	52-193
PZ-K4P	F	5, 2c	$1.6x10^{-4}$				1059-1047	81-93
PZ-K4PP	F	5, 2c	$6.2x10^{-5}$				992-979	148-161
TW-K5	H	2b	$1.7x10^{-6}$*				950-1086	57-193
TW-K5R	H	2b		$4.2x10^{-6}$	$5.2x10^{-6}$		978-1096	47-165
TW-K6	H	5	$7.9x10^{-8}$*				934-1057	60-183
TW-K6R	H	5			$1.3x10^{-6}$		934-1069	48-183
PZ-K8	H	2a	$1.2x10^{-5}$				1082-1075	18-25

Well Designation	Well/Boring Location**	Precambrian Unit***	Bail Tests	Pump Tests Drawdown	Pump Tests Recovery	Packer Tests	Vertical Test Interval Elevation (ft)	Vertical Test Interval Depth (ft)
PZ-R1A	H	2a				$4.0x10^{-6}$	995- 999	103-107
	H	2a				$6.2x10^{-5}$	903- 909	193-199
	H	2a, 2c	$1.8x10^{-4}$				903- 952	160-199
	H	2c				0	983- 977	118-124
	H	2c				0	964- 960	134-141
	H	2c				0	956- 951	145-150
PZ-R2	O	1a				$4.4x10^{-5}$	1039-1062	40- 63
	F	2a				$9.9x10^{-6}$	984- 989	113-118
	F	2a				$6.1x10^{-6}$	950- 954	148-152
	F	3a				$5.3x10^{-6}$	899- 909	193-203
	F	3a				$6.0x10^{-6}$	898- 902	200-204
	F	2a, 3a	$1.7x10^{-5}$	$7.7x10^{-5}$	$8.5x10^{-5}$		881- 976	126-221
PZ-R3	O	1a, 1b				$6.2x10^{-6}$	1014-1018	81- 85
	O	2a				$4.4x10^{-5}$	990- 994	105-109
	O	1c				$5.7x10^{-6}$	895- 904	193-204
	O	1a, 2a, 1c	$7.2x10^{-5}$				943- 993	106-156
B-R4	H	2a				$1.3x10^{-5}$	911- 915	202-206
PZ-R5	F	2a, 5				$3.0x10^{-5}$	1010-1014	107-111
	F	2c				$6.6x10^{-6}$	913- 919	202-208
	F	2c				0	916- 921	201-206
	F	2c, 5	$1.3x10^{-4}$	$1.3x10^{-4}$	$1.1x10^{-4}$		991-1047	74-130
B-R6	H	2b				$1.1x10^{-6}$	933- 940	199-206
	O	1a				$4.4x10^{-6}$	820- 825	314-319
PZ-R7	O	1a				$1.5x10^{-4}$	1045-1057	82- 94
	F	4c				$2.1x10^{-5}$	976- 990	149-163
	F	5				$5.7x10^{-6}$	926- 932	207-213
	O	1a, 1c	$2.0x10^{-4}$				1020-1073	66-119

*Data for calculation obtained during well construction or during development.
**Well Test/Location

O -Ore horizon
H -Hanging wall
F -Footwall

***Precambrian Rock Unit

1a-Sericite-Quartz Schist
SMS-Semimassive sulfides
1b-Metachert
1c-Massive Sulfide
2a-Biotite-Sericite-Quartz-Chlorite Schist (Local Andalusite)
2b-Biotite-Chlorite-Quartz-Sericite Schist (Local Andalusite)
2c-Biotite-Quartz-Chlorite Schist
3a-Quartz-Augen Schist
4c-Amphibole-Chlorite Schist
5 -Metadacite

TABLE NO. 3.6-11

Summary of Pump Test Data

Pumping Well	Date and Pump Test No.	Rate (gpm)	Duration (min.)	Well	Total Drawdown (ft.)	Permeability (cm/sec) Drawdown	Permeability (cm/sec) Recovery
TW-K2	(1) 3-10-88	13.3	195	TW-K2	17.02	6.1×10^{-5}	8.0×10^{-5}
				MW-1000	0.82	3.6×10^{-4}	4.9×10^{-4}
				MW-1000P	0.60	8.0×10^{-4}	4.6×10^{-4}
				PZ-S2	2.22	1.2×10^{-4}	3.8×10^{-5}
				PZ-R2	5.55	7.7×10^{-5}	4.5×10^{-5}
				ST-9-40	1.05	1.0×10^{-3}	1.6×10^{-3}
TW-K3R	(1) 3-24-88	2.0	224	TW-K3R	150.00	7.7×10^{-6}	2.0×10^{-5}
				PZ-R5	1.08	1.3×10^{-4}	1.1×10^{-4}
	(2) 3-25-88	1 to 2	287	TW-K3R	56.4	4.0×10^{-6}	-
				PZ-R5	0.93	1.2×10^{-4}	1.2×10^{-4}
TW-K4	(1) 3-8-88	5	172	TW-K4	75.23	1.7×10^{-5}	4.1×10^{-5}
				PZ-S4	1.04	6.0×10^{-4}	5.6×10^{-4}
	(2) 3-9-88	5.3	110	TW-K4	43.75	1.4×10^{-5}	5.6×10^{-5}
				PZ-S4	0.85	6.0×10^{-4}	5.6×10^{-4}
TW-K5R	(1) 3-27-88	1.2	207	TW-K5R	71.55	4.2×10^{-6}	5.2×10^{-6}
				PZ-R7	0	-	-
TW-K17B	(1) 9-22-88	18.0	64	TW-K17B	6.64	5.9×10^{-3}	7.1×10^{-3}
				TW-K7	3.04	5.4×10^{-3}	4.3×10^{-3}

The pressure wave created by this stage change caused groundwater elevation changes in the following wells, all located within 400 feet of the river.

MW-1000	TW-K1	ST-9-17A	PZ-R1
MW-1000P	TW-K2	ST-9-26	PZ-R2
MW-1001G	TW-K7		PZ-R3
	TW-K17B		PZ-S1
			PZ-S2
			PZ-K8

Measurements in these wells were made using electric water level indicators and ISCO Model 1870 Flow/Level meters with pen and graph-paper recorders. The field data are included in Appendix 3.6-D.

A method of determining transmissivity from cyclic water-level fluctuations is described by Ferris (1963). However, to calculate transmissivity, the storage coefficient must be known. Therefore, permeability values in the glacial overburden and Precambrian units were determined only within an order of magnitude using this method. If a water table condition storage coefficient of 0.1 is assumed for the overburden (Driscoll, 1986), permeability values range from 1×10^{-2} to 1×10^{-3} cm/sec. If a confined condition storage coefficient of 0.001 is assumed in the bedrock (Driscoll, 1986), permeability values range from 1×10^{-4} to 1×10^{-5} cm/sec. Calculations supporting these ranges are contained in Appendix 3.6-D.

3.6.2 Regional Hydrogeology

According to NR182.08(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 up to five miles from the site." Figure No. 3.6-3 illustrates the five-mile radial area surrounding the open pit location. NR182.08(2)(c)4 states that the regional hydrogeology discussion should include "depth to groundwater, flow directions, recharge and discharge areas, groundwater divides, aquifers, and the identification of the aquifers used by all public and private wells within at least 1200 feet of each proposed site." Each of these topics, plus regional groundwater quality, is discussed below.

3.6.2.1 Depth to Groundwater

Depths to groundwater in the regional area are relatively shallow, usually less than twenty feet. There are three main reasons for this. First, the regional topography is relatively flat, with less than 100 feet of total relief between the recharge zone and the discharge zone in any typical shallow groundwater flow system. Second, average precipitation results in groundwater recharge of approximately five inches per year (see Appendix 3.6-C). This recharge rate is sufficient to

maintain a mounded water table condition. Third, the till comprises the uppermost stratigraphic unit over a majority of the region (see Section 3.6.1.4). The permeability of this till is sufficiently low to enhance the mounding effect of the precipitation recharge.

3.6.2.2 Flow Directions

The region is characterized by a temperate zone climate so that there is sufficient groundwater recharge to maintain stream base flows year round. Therefore, groundwater movement in the region normally flows from recharge (i.e., upland areas) to discharge zones (i.e., adjacent flowing streams). However, in certain localized areas, groundwater flows toward man-made discharge zones, such as the cones of depression created by active water supply wells.

3.6.2.3 Recharge and Discharge Areas

As shown in Figure No. 3.6-3, the regional area is dominated by three principal groundwater flow systems. The major portion of the five-mile radial area, and the flow system within which the site occurs, is drained by the Flambeau River including Meadowbrook Creek flow system. The northwestern sector of the five-mile radial area is a flow system drained by the two branches of the Twin Creek flow system. The southeast sector is a flow system drained by the Deer Tail Creek flow system.

A groundwater discharge zone is defined as an area within which the net vertical component of groundwater movement is upward (Freeze and Cherry, 1979). Within the groundwater flow systems of the region, the discharge zone width is restricted to a narrow band, probably no more than a hundred yards wide in most cases, centered on the streams themselves. All of the remaining portions of the groundwater flow systems may be delineated as recharge areas.

The thickness of each flow system, as well as the presence of deeper intermediate flow systems, is a function of the distribution of permeabilities with depth and the degree of regional topographic relief. Generally, stacked flow systems are more likely to occur as both the thickness of permeable formations and the degree of topographic relief increase.

In the region of this study, both of these factors are relatively minimal. The only permeabilities of significance occur in the sandstone and glacial-fluvial sediments above the bedrock, and the saturated thickness of these layers seldom exceeds fifty feet in the region (Young and Hindall, 1972). As already discussed, the topographic relief is limited. Therefore the region is generally characterized by shallow (single layer) groundwater flow systems.

A baseflow separation analysis was performed on the Flambeau River watershed for Hydrologic Year 1988 (see Appendix 3.6-D). This analysis showed that 7.25 inches left the watershed via surface water flow in the Flambeau River, as measured at the gaging station below the Thornapple Dam. Of this 7.25 inches, the baseflow analysis showed that 5.10 inches moved into the river via the shallow groundwater flow system. The remaining 2.15 inches entered the river as direct overland runoff.

The 5.10 inches of groundwater runoff, distributed over the entire 1,860-square-mile Flambeau watershed, amounts to 2.20×10^{10} ft^3 of water. A comparison can be made between this volume and the total amount of groundwater in storage in all the Flambeau flow systems. The systems average saturated thickness is approximately 50 feet, and the average effective porosity is 20 percent, a representative median for glacial materials (Driscoll, 1986). Multiplying the area times the thickness times the effective porosity yields a water volume of 5.18×10^{11} ft^3. Therefore, at the rate the flow systems supplied water for baseflow in Hydrologic Year 1988, the combined Flambeau groundwater flow systems in the Flambeau River watershed yielded 4.2 percent of their water as groundwater discharge. At this rate, the average time for the flow systems to flush themselves is approximately 23.5 years. This must be assumed to be a maximum flushing time since 1988 was a drought year. In an average year, the flushing would be faster. In any case, even 23.5 years is a relatively short period of time in hydrogeologic terms, implying that the size of the typical Flambeau River flow system is relatively small and localized.

The baseflow analysis also noted that there are 834 miles of stream channel located in the Flambeau watershed. Therefore, in Hydrologic Year 1988, the total amount of groundwater runoff, 2.20×10^{10} ft^3, was equivalent to approximately 2.64×10^7 ft^3 of water per mile of stream channel. Since this groundwater runoff was derived from 5.10 inches of watershed water then it can be calculated that the amount of flow system drained by the average mile of channel is 2.23 square miles. Since the stream channel is typically centered within the flow system boundaries, it then follows that the average distance from the discharge point, the stream, to the average upland recharge point is half of this distance or 1.12 miles. The stream distribution on Figure No. 3.6-2 confirms that this recharge estimate is representative of the five mile radial region around the site. It is also consistent with the previously stated conclusion that the region's groundwater flow systems are relatively small and localized.

3.6.2.4 Groundwater Divides

Figure No. 3.6-2, as discussed above, shows the typical distribution of the groundwater flow systems in the regional area. The divides separating the flow systems are located beneath the topographically high ground separating the flowing

stream discharge areas. The groundwater divides are in approximately the same position as the overlying surface water watershed divides.

3.6.2.5 Groundwater Aquifers

The definition of the term aquifer is clear enough in its meaning, but often leaves considerable room for interpretation in its application. The classic definition of an aquifer is that it is a permeable water-bearing geologic unit that has the capacity to transmit significant quantities of water under ordinary hydraulic gradients (Freeze and Cherry, 1979). The room for interpretation lies in the term "significant quantities". Typically, the interpretation is made in the context of an existing or potential water use. If the use is a household well, a thin formation of modest permeability may serve as an aquifer. If the use is a high capacity well for public supply or industrial purposes, the same formation may not qualify as an aquifer.

Water quality may also be factored into the definition of the term by considering whether or not the quality of the water in a formation is suited to the application in question. If it is not, then the formation cannot be termed an aquifer since it is not possible to obtain significant quantities of usable water from the formation. This version of the definition of "aquifer" is used in this report.

Four fundamental geologic units are present in the five-mile radial region. These are the Precambrian bedrock, the Cambrian sandstone, the till, and the glacial-fluvial sediment.

The bulk of the Precambrian bedrock does not yield quantities of water sufficient enough to serve even as a single household supply. Isolated fractured or weathered zones within this rock may occasionally be able to produce water, but normally the Precambrian unit as a whole is not characterized as an aquifer.

The Cambrian sandstone, where it is present and of sufficient thickness, is normally permeable enough to serve as an aquifer for single-well private supplies.

The till, like the Precambrian bedrock, has relatively low permeability. Occasional thin sand or gravel lenses render it marginally usable as a single household well aquifer.

The glacial-fluvial sediment is moderately to highly permeable and in most areas is even more useful as an aquifer for public and industrial uses than is the sandstone.

3.6.2.6 Regional Groundwater Quality

According to Young and Hindall (1972), groundwater in the Ladysmith area typically has total dissolved solids concentrations in excess of 300 mg/L. They point out that sodium, potassium, chloride, and sulfate concentrations are higher than in most of the rest of the Chippewa River Basin (of which the Flambeau River Basin is a part).

Hindall (1979), as part of a study for the U. S. Geological Survey, further reports on iron and manganese problems in the Ladysmith area groundwater. The six private wells and one public well tested by Hindall, were all located within five miles of the project site. Iron concentrations ranged from 0.01 mg/L to 14 mg/L, and averaged 4.2 mg/L. Manganese concentrations ranged from <0.01 mg/L to 0.65 mg/L, and averaged 0.34 mg/L. Both these average concentrations exceed the U. S. Public Health Service's Secondary Drinking Water Standards (these are aesthetic standards based on taste and odor thresholds) for iron, 0.3 mg/L, and manganese, 0.05 mg/L. Hindall speculates that the source of these concentrations is natural, from the aquifer materials.

Residents of the area readily and effectively deal with these aesthetic problems through the use of water softening, a simple and inexpensive technique that removes objectionable metal ions.

3.6.2.7 Aquifer Use

An evaluation of water supply well logs in the area obtained from the Wisconsin Department of Natural Resources and from the Wisconsin Geological and Natural History Survey (see Appendix 3.6-F) indicates that the majority (95%) of private wells in the area obtain their water either from the glacial-fluvial aquifers or from thin lenses of permeable material in the till. A few wells were drilled as deep as the sandstone and the Precambrian bedrock. Of the logs for approximately 200 private wells that occur within a two to three mile radius of the mine, five (2.5%) indicated that the well was completed in sandstone and six (3%) in the Precambrian.

3.6.3 Project Site Hydrogeology

The Kennecott project site is adjacent to the Flambeau River, a major groundwater discharge feature. Part of the site, in fact, is within the groundwater discharge area.

The geology of the site area is, in many respects, the geology of the Flambeau River watershed in microcosm. Most of the same types of geologic units found in the watershed (e.g., till, glacial-fluvial sediments, sandstone, Precambrian bedrock) are found on the site.

The period of record during which the bulk of the current investigation was conducted, from October of 1987 through September of 1988, was a relatively dry period. Precipitation in the watershed for the period was only 25.8 inches, 5.4 inches below the 31.2 inches long-term average (NOAA, 1988).

Therefore, groundwater levels over much of the project site underwent a net decline during the study. In spite of this, however, there was a spring recharge event during March and April of 1988 that allowed observations of the water table in a rising mode followed subsequently by a falling mode during the dry period between May and August 1988.

The following discussion is divided into the topics of groundwater occurrence, groundwater recharge/discharge regime, and groundwater use.

3.6.3.1 Groundwater Occurrence

Site area groundwater occurs within several units. Surficial glacial deposits include till and glacial-fluvial materials. The bedrock includes Cambrian-age sandstone and Precambrian-age metavolcanics and metasediments.

3.6.3.1.1 Surficial Deposits

The major units present on site are shown in plan view on Figure 3.5-15, and in cross section on Figure Nos. 3.5-4 and 3.5-5.

Glacial Fluvial Sediment

Adjacent to the river is a zone of glacial-fluvial sediment. It is present at the surface primarily to the northwest of the open pit, thickening in a northwest direction as the bedrock surface elevation declines in that direction. It also is present in thin layers beneath some of the tills. The glacial fluvial sediment consists of interbedded sands and gravels, cobbles, and boulders. The permeability of the material is somewhat variable due to the interbedding of well sorted and poorly sorted units. This is shown on Table No. 3.6-9, where the in-field testing of the piezometers installed into these various units ranged from 1.0×10^{-5} cm/sec to 1.7×10^{-1} cm/sec. The formation median and logarithmic mean permeability values are 4.8×10^{-3} and 2.7×10^{-3} cm/sec, respectively. Thus, despite the permeability variations, much of this material would be useful as an aquifer for modest amounts of groundwater withdrawal, but not generally for high capacity purposes.

The specific yield (effective porosity) of the glacial fluvial sediment is likely to be similar to "typical" sand and gravel mixes, between 15 and 25 percent (Driscoll, 1986). Pump testing has shown the aquifer to be under water table conditions. Therefore, a reasonable estimate of the storativity of the material is 20 percent.

Till

The till lies to the east of the glacial-fluvial material, over the deposit, and to the southeast of the orebody. To the south of the topsoil it lies very close to the river. It ranges in thickness from zero at the outwash boundary to 70 feet immediately east of the proposed open pit. Two principal till areas are present as discussed above in Section 3.5.3.3. Adjacent to the glacial-fluvial material is an older terraced zone developed during the initial glacial meltback period. Topographically it is somewhat lower than the other till area, which is an upland till plain found on the eastern side of the project site. Both the till units are significantly less permeable than the glacial-fluvial material. As shown on Table No. 3.6-9, permeabilities in the units show some variability, ranging from 1.4 x 10^{-5} cm/sec to 5.5 x 10^{-3} cm/sec. The formation median and logarithmic mean permeability values are 3.6 x 10^{-4} and 2.7 x 10^{-4} cm/sec, respectively.

The most representative permeabilities for the till materials are those toward the lower end of the range. Permeability results on the higher end of the range were obtained from wells whose screens, in order to be functional, often were preferentially installed into intercepted sand and gravel layers within the till.

The specific yield (effective porosity) of the till can be determined from the density and moisture content testing of soil and rock samples discussed in Appendix 3.5-I. The average dry density of three undisturbed till samples was 126.7 lbs/ft^3. Dividing by 62.4 lbs/ft^3, the density of water, yields an average specific gravity of 2.03. The mineralogy of the till is mostly quartz, and quartz-containing rock fragments. The specific gravity of quartz is 2.65. Therefore, the total porosity of the till may be obtained by dividing 2.03 by 2.65, multiplying the quotient by 100, and subtracting the product from 100, yielding the result of 23.4 percent. The specific yield of till is probably less than half the total porosity (Driscoll, 1986). A reasonable estimate of specific yield for this till, therefore, is ten percent.

The suitability of the till as an aquifer is marginal, at best. The occasional thin sand lenses may provide sufficient water for a private residence. More often, wells must be drilled through the till into the underlying glacial-fluvial sediment or sandstone.

3.6.3.1.2 <u>Bedrock</u>

<u>Sandstone</u>

Underlying the till and overlying the Precambrian in most of the project site area is the Cambrian sandstone, a material that varies from friable to well cemented. Its thickness ranges from zero nearer the river to 34 feet in the central part of the project site area. As shown on Table No. 3.6-9, the permeabilities in this unit range from 1.0 x 10^{-4} cm/sec to 1.8 x 10^{-3} cm/sec. The formation median and logarithmic mean

permeability values are 1.1 x 10^{-3} and 7.3 x 10^{-4} cm/sec, respectively.

As was the case with the till, the specific yield (effective porosity) of the sandstone can be determined from the density and moisture content testing of rock and soil samples discussed in Appendix 3.5-I. The average dry density of the two sandstone samples tested was 111.8 lbs/ft^3, equivalent to a specific gravity of 1.79. Also like the till, the mineralogy of the sandstone is quartz, with a specific gravity of 2.65. Therefore, dividing 1.79 by 2.65, multiplying the quotient by 100, and subtracting the product from 100 yields a total porosity of 32.6 percent. In a friable, well sorted sandstone such as this, the specific yield is probably not much less than the total porosity (Driscoll, 1986). Therefore, a reasonable estimate of specific yield for this sandstone is 30 percent.

Because of limited thickness, sandstone yields in the project site area are marginal, probably only suitable in most cases for a private household supply.

<u>Precambrian</u>

The Precambrian bedrock in the site area is a series of overturned schists dipping steeply to the northwest. In the upper ten to fifty feet of the bedrock the schists are highly clay-altered, and appear in the field as a rather soft, almost claylike material. Deeper zones are harder, exhibiting significant jointing. It is in these joint fractures that the Precambrian permeability occurs. Overall, the permeabilities in the Precambrian unit are the lowest of any of the materials found on site. As shown on Table No. 3.6-10, permeability values are in the range of 7.9 x 10^{-8} cm/sec to 6.2 x 10^{-4} cm/sec. The formation median and logarithmic mean permeability values are 1.3 x 10^{-5} and 1.6 x 10^{-5} cm/sec, respectively.

The higher permeabilities in the Precambrian of the site area are found within zones close to the deposit itself. Thin, near-surface metacherts, generally laterally continuous for no more than 400 feet, were observed underlying the hanging wall edges of the massive sulfide unit. The contact between the metachert and the massive sulfide has greater permeability than the bulk of the Precambrian, an effect noticed during the permeability tests conducted in the vicinity of the TW-K2/MW-1000 area. The pump tests indicated that the contact has a permeability of about 1 x 10^{-4} cm/sec.

During the drilling program, geomechanical data, including Rock Quality Designation (RQD), fracture frequency, length of longest piece, rock hardness and broken-zone measurements were taken on core. In their report on the testing, Call (1988) state, "The ore zone appears to be bounded on the hanging wall side by a 20- to 35-foot-thick interval of strongly fractured rock and on the footwall side by a somewhat thicker 40- to 70-foot-thick strongly fractured zone."

Fractured and weathered igneous rocks typically have porosities in the range of zero to 10 percent (Driscoll, 1986). Therefore, a reasonable specific yield (effective porosity) for the Precambrian rocks is five percent.

The Precambrian rocks cannot be classified as aquifer material. The normal yields are generally too low to support even a domestic single family home supply.

3.6.3.2 Groundwater Recharge/Discharge Regime

The groundwater flow regime at the site is straightforward. The majority of groundwater at the site moves within a shallow groundwater flow system. Figure Nos. 3.6-4 and 3.6-5 are water table maps drawn for the extremes in water table conditions that were observed during the period of record. Figure No. 3.6-4 represents the high water table, a condition which occurred in April 1988. Figure No. 3.6-5 represents the low water table, a condition which occurred in September 1988. Figure No. 3.6-6 shows the equipotential surface which is typical of the head distribution in the sandstone unit, and Figure No. 3.6-7 shows the equipotential surface in the shallow bedrock. Figure Nos. 3.6-8 and 3.6-9 are hydrogeological cross-sections which show the distribution of vertical heads with depth. The lines of section for these two figures are shown on the high water table map, Figure No. 3.6-4. Figure Nos. 3.6-10 through 3.6-19 are hydrographs of the water level elevations measured during the current study in selected monitoring wells and piezometer nests. Hydrographs for selected old wells measured in the 1970s are included in Appendix 3.6-A.

3.6.3.2.1 Surficial Deposits

Horizontal Gradients

The water table occurs within the till, the glacial fluvial sediments, and the sandstone. With one exception, shallow groundwater flow in the immediate vicinity of the mine site is to the west, toward the Flambeau River. Near the very northern edge of the project site area, along Blackberry Lane, the water table contour lines bend around to the east, paralleling the eastward bend in the river. In this area, flow is to the northwest and north.

The exception is a mounding condition that occurs adjacent to the southeast side of proposed open pit near piezometers PZ-S6 and PZ-S8. This is caused by the presence of a local topographic high underlain by the low-permeability till. On the eastern side of this mound, shallow groundwater flows for a short distance in an easterly and downward direction before turning back to the west.

Wetland/Groundwater Relationship

Wetland Areas 1 and 2, to the northwest of the proposed pit location, are supported by groundwater but are not classic groundwater discharge areas. The wetlands are located at the western edge of the till, at the foot of a sharp drop in slope. The land surface drops too quickly for the water table surface to conform and, as a result, a seep discharge occurs along the eastern edge of the wetlands. This phenomenon is shown in cross section on Figure No. 3.6-9. However, as the groundwater continues to flow to the west under the wetlands, the water table continues to drop off. At well nest PZ-1A and PZ-1B in the center of the wetlands, there is a very strong downward hydraulic gradient, averaging nearly -0.5 during the period of record (Figure No. 3.6-17). Such a high gradient demonstrates that the glacial-fluvial sediments underlying the wetlands are of low permeability. This in turn shows that only a minimal amount of water, (i.e., the seepage on the eastern side of the wetlands), is sufficient to maintain wetland conditions, even though the great majority of the wetlands occur over a strong groundwater recharge zone.

Evidence exists that Wetland Area 5c, to the southeast of the pit, is hydraulically isolated above the water table. Adjacent well nest 1005 shows that water table elevations typically occur more than four feet below the water level in the wetland. At the same nest are found strong downward hydraulic gradients averaging approximately -0.02, indicating the presence of low permeability materials beneath the wetland.

The hydrogeology of the other wetlands to the west of STH 27 (less than five acres, total; see Figure No. 3.6-20) was not evaluated because they will unavoidably be taken by the project.

Wetland Areas 3c, 10a, and the other wetlands to the east of STH 27 (Wetland Areas 6, 7, 8, and 9), are hydraulically isolated above the water table. A study of soils and hydrologic conditions in Section 10 (the area across Highway 27 to the east of the site) was performed by Kennecott in 1971. The report, contained in Appendix 3.6-G, has logs of backhoe pits excavated into the wetlands in the locations indicated on Figure No. 3.6-20. The presence of a granular unsaturated zone beneath a low-permeability peat layer was common in most of the pits. The depths to the underlying water table encountered in the excavations ranged from four to more than twenty feet. In no case was there evidence that the surficial wetland water level was directly connected to the underlying water table.

These observations are consistent with several other pieces of more recently collected data. Shown on Figure No. 3.6-20 are the locations of the borings drilled along the proposed railroad right-of-way. The depths to water encountered in these borings, as described in the logs in Appendix 3.5-20 are shown on Figure No. 3.6-20, also demonstrate that water table elevation is significantly lower than the wetland water surface. Finally, the depths to water in wells PZ-1006G and PZ-1009, shown on Figure No. 3.6-20, also confirm that the water table is much lower than the wetland water level.

Vertical Gradients

The vertical gradients that were measured throughout the till during the current investigation were downward, or in one case (MW-1003), neutral. This is characteristic of groundwater recharge conditions. Even where the till does occur close to the river, at locations MW-1000 and MW-1001 for example, the permeabilities are still low enough to cause enough mounding of the groundwater so that recharge conditions were maintained most of the time during the period of record.

By contrast, levels recorded in the piezometer nest installed in the glacial fluvial sediments, MW-1002, show that gradients in this unit can be upward even at a location which is not immediately adjacent to the river.

In the Precambrian, upward gradients were observed in most locations, indicating preferential flow in the overlying glacial fluvial or sandstone units. A major exception to this occurs at nest 1004 where strong downward gradients exist in the shallow Precambrian. However, this is a location where the bedrock surface begins to drop off sharply toward the river, evidently causing a localized recharge condition.

Depth to Groundwater

Figure No. 3.6-21 is an isopach map of the depth to groundwater in the project site area. The shallowest depths occur in Wetland Areas 1 and 2 and beneath the upland till plain to the southeast and east of the proposed open pit. The greatest depths to water occur beneath the dissected till terrace where the water table drops off as groundwater flows to the west, but where the land surface remains high.

Flow and Discharge Rates

Based on the logrithmic mean permeability of 2.1 x 10^{-3} cm/sec, a measured hydraulic gradient of 0.02 ft/ft, and an effective porosity of 20 percent, the calculated flow velocity within the glacial fluvial material is 0.60 ft/day. The same numbers may be used to estimate the discharge through that portion of the glacial fluvial sediment which is presently generally downgradient of where the open pit will be. The Figure No. 3.5-4 and Figure No. 3.5-9 cross sections show that, along the river, the saturated glacial fluvial sediment thickness increases in a northerly direction from near zero to more than 60 feet. The width of the open pit on a line normal to groundwater flow is 800 feet. Using an average saturated thickness of 30 feet for this section of the unit the resultant

cross-sectional area would be 24,000 square feet. This dimension, combined with the logarithmic mean permeability and gradient stated above, yields an average discharge through the glacial-fluvial sediments of 21,400 gallons/day (14.9 gallons/minute).

Based on the logarithmic mean permeability of 2.7 x 10^{-4} cm/sec, a measured hydraulic gradient of 0.025 ft/ft, and an effective porosity of ten percent, the average flow velocity within the till is 0.19 ft/day. The same numbers may be used to estimate the existing discharge through that portion of the till which will be displaced by the open pit. Figure No. 3.5-4 shows that along the centerline of the open pit the average saturated thickness of the unit is 15 feet. At this point the width of section of till normal to flow that would intercept the open pit would be approximately 800 feet. Using these two dimensions plus the logrithmic mean permeability and gradient stated above, the average lateral discharge through the till would be 1,700 gallons/day (1.2 gallons/minute).

3.6.3.2.2 Bedrock

Sandstone

Where present, the Cambrian sandstone is the predominant bedrock flow unit. Piezometer nest data show (e.g., MW-1001 and MW-1005, Figure Nos. 3.6-11 and 3.6-15 respectively) that water typically flows into the sandstone from both the underlying Precambrian and the overlying till. This occurs because, in the till areas, the sandstone is the most permeable, continuous material present.

As Figure No. 3.6-6 shows, the general movement of groundwater through the sandstone is to the west toward the river and parallel to the general trend of the water table. No vertical gradients were measured within the sandstone unit, as the unit is too thin for such measurements to be meaningful.

Based on an a logarithmic mean permeability of 7.3 x 10^{-4} cm/sec, a measured hydraulic gradient of 0.025, and an effective porosity of 30 percent, the calculated flow velocity within the Cambrian sandstone is 0.17 ft/day. The same numbers may be used to estimate the discharge through that portion of the sandstone that will be displaced by the open pit. Figure No. 3.5-4 shows that along the centerline of the open pit the average thickness of the unit is 15 feet. At this point the width of section of sandstone normal to flow that would intercept the open pit would be approximately 800 feet. Using these two dimensions plus the average permeability and gradient stated above, the average discharge through the sandstone would be 4,600 gallons/day (3.2 gallons/minute).

Precambrian

Compared to the sandstone, little water moves through the Precambrian bedrock areas. Figure No. 3.6-7 shows that the flow in this unit, such as it is, is also westward toward the river. It is possible that some localized flow to the southwest occurs along the trend of the deposit, through the contact between the discontinuous metachert and the massive sulfide. However, if this occurs, it seems not to have affected the gradients measured in the remainder of the Precambrian unit.

Vertical gradients within the Precambrian were measured at two locations. Away from the river, at nested wells PZ-K4P and PZ-K4PP, the gradient is neutral, consistent with recharge zone conditions. Near the river, at well nest PZ-K2P and PZ-K2PP, the gradient is upward, typical of the discharge zone conditions that would be expected.

Based on the logarithmic mean permeability of 1.6×10^{-5} cm/sec, a measured hydraulic gradient of 0.025 ft/ft, and an effective porosity of five percent, the calculated flow velocity within the Precambrian is 0.022 feet/day. The same numbers are used to estimate the existing discharge through that portion of the Precambrian bedrock that will ultimately be displaced by the open pit. Using a depth of 175 feet, a width normal to flow of 600 feet, the permeability average stated above, and the gradient stated above, the average lateral movement through the Precambrian would be 890 gallons/day (0.62 gallons/minute).

3.6.3.2.3 Groundwater Discharge Summary

The total present-day flow through the area to be occupied by the open pit may be obtained by summing the flows through the till, sandstone, and Precambrian. The total is 6,690 gallons/day (4.6 gallons/minute), of which 18 percent is through the till, 69 percent is through the sandstone, and 13 percent is through the Precambrian. This groundwater ultimately discharges into the Flambeau River, which flows by the site at an average discharge of approximately 1,800 ft^3/sec (1.16×10^9 gallons/day or 808,000 gallons/minute), which is more than 170,000 times greater than the calculated current average groundwater discharge into the river.

3.6.3.3 Groundwater Use

Groundwater is presently being used near the project site area by Kennecott-owned residences along Kennecott Road northwest of the proposed open pit; along Blackberry Lane north of the proposed pit; and along HWY 27 east of the proposed open pit. The wells at these residences tap the glacial-fluvial material, sand and gravel layers within the till, and the Cambrian sandstone. No other groundwater use occurs within the project site area.

3.6.4 Groundwater Quality

This section consists of two parts. The first is a presentation of the data, and the second is a discussion of the data.

3.6.4.1 Baseline Monitoring Program Results

Per the requirements of NR 182.075(1)(d), and as described in the Kennecott Scope of Study document (Foth & Van Dyke, 1987), a baseline groundwater monitoring program was conducted. Samples were collected at the locations and at the frequency described above in Section 3.6.1.2.3.

Appendix No. 3.6-H is a tabulation of the groundwater quality data. The data are presented on three sets of tables in the appendix. On the first set, the data are presented as a series of parameter-oriented tables, with one table for each parameter. On the second set, the data are presented on a series of well-oriented tables, with one table for each well plus blanks. On the third set, the data are presented on a series of sampling event-oriented tables, with one table for each sampling event. In order to protect the confidentiality of the private well owners, the individual private well data sets are not included in the appendix. The data are, however, summarized on Table No. 3.6-12 (see below).

Appendix No. 3.6-H also contains a discussion of the comparison of the split sampling program conducted with the Wisconsin Department of Natural Resources. Overall, the correlation between the Kennecott samples and the WDNR splits was very good, indicating that the data set is accurate and representative of site conditions.

Table No. 3.6-12 is a summary of the data presented in the appendix and also of the private well data. The data are organized first by parameter. For each parameter, the maximum, minimum, median, and mean values, the numbers of samples tested, the numbers of detections made above the detection limit, and the percentage of detections made above the detection limit, were presented for groundwater collected in the overburden wells, the shallow Precambrian wells, the deep Precambrian wells, and the private wells (which are nearly all overburden wells).

Non-detection data points (e.g., values such as <0.05 mg/l) were accounted for in the construction of Table No. 3.6-12 by converting to values equal to one half the detection limit (e.g., 0.05 mg/l converts to a value of 0.025 mg/l). This explains the instances on the table where high, low, mean, and median values appear for parameters which had no detects. For example, thallium was tested for 40 times in the overburden groundwater and was never detected at the 0.005 mg/l detection level. Therefore, all the <0.005 mg/l non-detect values are recorded as 0.0025 mg/l, which then becomes the high, low, mean, and median value for thallium in Table No. 3.6-12.

TABLE NO. 3.6-12

Groundwater Quality Summary

Alkalinity	Overburden	Shallow PC	Deep PC	Pvt. Wells
Maximum	260	340	260	370
Minimum	14	81	150	17
Median	60	170	180	170
Mean	74	172	186	159
# of Tests	126	60	5	97
# of Detects	126	60	5	97
% of Detects	100.0%	100.0%	100.0%	100.0%

Aluminum	Overburden	Shallow PC	Deep PC	Pvt. Wells
Maximum	0.337	0.158	NA	NA
Minimum	0.034	0.034	NA	NA
Median	0.078	0.086	NA	NA
Mean	0.086	0.084	NA	NA
# of Tests	40	20	NA	NA
# of Detects	40	20	NA	NA
% of Detects	100.0%	100.0%	NA	NA

Arsenic	Overburden	Shallow PC	Deep PC	Pvt. Wells
Maximum	0.021	0.003	0.022	0.0015
Minimum	0.003	0.003	0.003	0.0015
Median	0.021	0.003	0.010	0.0015
Mean	0.003	0.003	0.010	0.0015
# of Tests	126	60	5	8
# of Detects	1	0	4	0
% of Detects	0.8%	0.0%	80.0%	0.0%

Barium	Overburden	Shallow PC	Deep PC	Pvt. Wells
Maximum	0.50	0.50	0.25	0.04
Minimum	0.25	0.25	0.25	0.04
Median	0.25	0.25	0.25	0.04
Mean	0.27	0.27	0.25	0.04
# of Tests	126.00	60.00	5.00	8
# of Detects	0	0	0	0
% of Detects	0.0%	0.0%	0.0%	0.0%

Beryllium	Overburden	Shallow PC	Deep PC	Pvt. Wells
Maximum	0.0010	0.0005	NA	NA
Minimum	0.0005	0.0005	NA	NA
Median	0.0005	0.0005	NA	NA
Mean	0.0005	0.0005	NA	NA
# of Tests	40.00	20.00	NA	NA
# of Detects	1	0	NA	NA
% of Detects	2.5%	0.0%	NA	NA

Cadmium	Overburden	Shallow PC	Deep PC	Pvt. Wells
Maximum	0.0170	0.0240	0.0045	0.0002
Minimum	0.0002	0.0002	0.0035	0.0002
Median	0.0010	0.0012	0.0039	0.0002
Mean	0.0016	0.0025	0.0040	0.0002
# of Tests	126	60	5	8
# of Detects	96	37	5	0
% of Detects	76.2%	61.7%	100.0%	0.0%

Calcium	Overburden	Shallow PC	Deep PC	Pvt. Wells
Maximum	95	56	52	47
Minimum	8	17	31	15
Median	13	36	35	35
Mean	25	35	38	32
# of Tests	126	60	5	8
# of Detects	126	60	5	8
% of Detects	100.0%	100.0%	100.0%	100.0%

Chloride	Overburden	Shallow PC	Deep PC	Pvt. Wells
Maximum	230.0	6.0	9.0	81.0
Minimum	0.5	0.5	2.0	1.2
Median	3.0	1.0	3.0	8.0
Mean	24.1	1.8	5.0	16.7
# of Tests	126	60	5	97
# of Detects	83	27	5	83
% of Detects	65.9%	45.0%	100.0%	85.6%

TABLE NO. 3.6-12 (Cont.)

Chromium	Overburden	Shallow PC	Deep PC	Pvt. Wells
Maximum	0.0025	0.0025	0.0025	0.008
Minimum	0.0025	0.0025	0.0025	0.001
Median	0.0025	0.0025	0.0025	0.002
Mean	0.0025	0.0025	0.0025	0.003
# of Tests	126	60	5	8
# of Detects	0	0	0	4
% of Detects	0.0%	0.0%	0.0%	50.0%

Cobalt	Overburden	Shallow PC	Deep PC	Pvt. Wells
Maximum	0.025	0.025	NA	NA
Minimum	0.025	0.025	NA	NA
Median	0.025	0.025	NA	NA
Mean	0.025	0.025	NA	NA
# of Tests	40	20	NA	NA
# of Detects	0	0	NA	NA
% of Detects	0.0%	0.0%	NA	NA

COD	Overburden	Shallow PC	Deep PC	Pvt. Wells
Maximum	90.0	85.0	5.0	130.0
Minimum	2.5	2.5	2.5	2.5
Median	10.0	10.0	2.5	6.0
Mean	13.2	16.1	3.0	10.1
# of Tests	126	60	5	97
# of Detects	84	44	1	52
% of Detects	66.7%	73.3%	20.0%	53.6%

Copper	Overburden	Shallow PC	Deep PC	Pvt. Wells
Maximum	0.046	0.085	0.031	0.068
Minimum	0.003	0.003	0.010	0.005
Median	0.005	0.005	0.011	0.021
Mean	0.009	0.013	0.015	0.026
# of Tests	126	60	5	8
# of Detects	48	22	5	7
% of Detects	38.1%	36.7%	100.0%	87.5%

TABLE NO. 3.6-12 (Cont.)

Fluoride	Overburden	Shallow PC	Deep PC	Pvt. Wells
Maximum	2.50	0.60	0.30	0.2
Minimum	0.05	0.05	0.20	0.1
Median	0.20	0.20	0.30	0.1
Mean	0.35	0.26	0.26	0.1
# of Tests	126	60	5	4
# of Detects	68	51	5	3
% of Detects	54.0%	85.0%	100.0%	75.0%

Hardness	Overburden	Shallow PC	Deep PC	Pvt. Wells
Maximum	400	240	1,137	390
Minimum	2	63	143	1
Median	68	150	150	170
Mean	111	145	369	168
# of Tests	126	60	5	97
# of Detects	126	60	5	96
% of Detects	100.0%	100.0%	100.0%	99.0%

Iron	Overburden	Shallow PC	Deep PC	Pvt. Wells
Maximum	21.00	0.95	0.05	830.00
Minimum	0.05	0.05	0.05	0.03
Median	0.05	0.14	0.05	3.30
Mean	1.43	0.22	0.05	18.82
# of Tests	126	60	5	97
# of Detects	53	35	0	91
% of Detects	42.1%	58.3%	0.0%	93.8%

Lead	Overburden	Shallow PC	Deep PC	Pvt. Wells
Maximum	0.0025	0.0025	0.0025	0.004
Minimum	0.0025	0.0025	0.0025	0.001
Median	0.0025	0.0025	0.0025	0.003
Mean	0.0025	0.0025	0.0025	0.003
# of Tests	126	60	5	8
# of Detects	0	0	0	6
% of Detects	0.0%	0.0%	0.0%	75.0%

TABLE NO. 3.6-12 (Cont.)

Magnesium	Overburden	Shallow PC	Deep PC	Pvt. Wells
Maximum	41.0	24.0	19.0	15.0
Minimum	2.4	5.4	11.0	3.4
Median	5.7	14.0	13.0	10.5
Mean	9.7	13.9	13.8	9.9
# of Tests	126	60	5	8
# of Detects	126	60	5	8
% of Detects	100.0%	100.0%	100.0%	100.0%

Manganese	Overburden	Shallow PC	Deep PC	Pvt. Wells
Maximum	1.40	0.75	0.29	0.6300
Minimum	0.03	0.03	0.03	0.0055
Median	0.09	0.36	0.23	0.2550
Mean	0.25	0.35	0.19	0.2171
# of Tests	126	60	5	8
# of Detects	74	58	4	5
% of Detects	58.7%	96.7%	80.0%	62.5%

Mercury	Overburden	Shallow PC	Deep PC	Pvt. Wells
Maximum	0.00240	0.00025	0.00025	0.00025
Minimum	0.00025	0.00025	0.00025	0.00025
Median	0.00025	0.00025	0.00025	0.00025
Mean	0.00027	0.00025	0.00025	0.00025
# of Tests	126	60	5	8
# of Detects	2	0	0	0
% of Detects	1.6%	0.0%	0.0%	0.0%

Molybdenum	Overburden	Shallow PC	Deep PC	Pvt. Wells
Maximum	0.08	0.06	N/A	N/A
Minimum	0.01	0.01	N/A	N/A
Median	0.01	0.01	N/A	N/A
Mean	0.02	0.03	N/A	N/A
# of Tests	40	20	N/A	N/A
# of Detects	13	8	N/A	N/A
% of Detects	32.5%	40.0%	N/A	N/A

TABLE NO. 3.6-12 (Cont.)

Nickel	Overburden	Shallow PC	Deep PC	Pvt. Wells
Maximum	0.067	0.028	N/A	N/A
Minimum	0.004	0.004	N/A	N/A
Median	0.015	0.015	N/A	N/A
Mean	0.018	0.012	N/A	N/A
# of Tests	94	45	N/A	N/A
# of Detects	29	9	N/A	N/A
% of Detects	30.9%	20.0%	N/A	N/A

NO3+NO2-N	Overburden	Shallow PC	Deep PC	Pvt. Wells
Maximum	2.90	0.42	0.15	3.5
Minimum	0.03	0.03	0.07	0.1
Median	0.30	0.35	0.10	2.0
Mean	0.56	0.08	0.10	1.9
# of Tests	126	60	5	4
# of Detects	105	21	5	4
% of Detects	83.3%	35.0%	100.0%	100.0%

pH	Overburden	Shallow PC	Deep PC	Pvt. Wells
Maximum	7.07	7.38	7.04	6.93
Minimum	5.25	5.78	6.56	4.78
Median	6.21	6.52	6.93	6.16
Mean	6.24	6.58	6.86	6.12
# of Tests	126	60	5	97
# of Detects	126	60	5	97
% of Detects	100.0%	100.0%	100.0%	100.0%

Selenium	Overburden	Shallow PC	Deep PC	Pvt. Wells
Maximum	0.0025	0.0025	0.0025	0.0015
Minimum	0.0025	0.0025	0.0025	0.0015
Median	0.0025	0.0025	0.0025	0.0015
Mean	0.0025	0.0025	0.0025	0.0015
# of Tests	126	60	5	8
# of Detects	0	0	0	0
% of Detects	0.0%	0.0%	0.0%	0.0%

TABLE NO. 3.6-12 (Cont.)

Silver	Overburden	Shallow PC	Deep PC	Pvt. Wells
Maximum	0.0073	0.0070	0.0002	0.0002
Minimum	0.0002	0.0002	0.0002	0.0002
Median	0.0002	0.0002	0.0002	0.0002
Mean	0.0009	0.0009	0.0002	0.0002
# of Tests	126	60	5	8
# of Detects	10	5	0	0
% of Detects	7.9%	8.3%	0.0%	0.0%

Sodium	Overburden	Shallow PC	Deep PC	Pvt. Wells
Maximum	30.0	33.0	14.0	6.6
Minimum	1.2	1.4	9.6	3.0
Median	6.1	14.0	11.0	4.9
Mean	7.7	14.1	11.3	4.8
# of Tests	126	60	5	8
# of Detects	126	60	5	8
% of Detects	100.0%	100.0%	100.0%	100.0%

Spec. Cond.	Overburden	Shallow PC	Deep PC	Pvt. Wells
Maximum	954	876	439	716
Minimum	84	128	298	30
Median	159	315	339	260
Mean	245	324	344	284
# of Tests	126	60	5	97
# of Detects	126	60	5	97
% of Detects	100.0%	100.0%	100.0%	100.0%

Sulfate	Overburden	Shallow PC	Deep PC	Pvt. Wells
Maximum	46.0	48.0	10.0	25.0
Minimum	2.5	2.5	2.5	5.3
Median	11.0	8.0	5.0	6.0
Mean	11.3	9.9	5.8	10.6
# of Tests	126	60	5	4
# of Detects	96	45	3	4
% of Detects	76.2%	75.0%	60.0%	100.0%

TABLE NO. 3.6-12 (Cont.)

TDS	Overburden	Shallow PC	Deep PC	Pvt. Wells
Maximum	1,400	350	280	NA
Minimum	14	67	180	NA
Median	130	200	200	NA
Mean	247	213	210	NA
# of Tests	126	60	5	NA
# of Detects	126	60	5	NA
% of Detects	100.0%	100.0%	100.0%	NA

Thallium	Overburden	Shallow PC	Deep PC	Pvt. Wells
Maximum	0.0025	0.0025	NA	NA
Minimum	0.0025	0.0025	NA	NA
Median	0.0025	0.0025	NA	NA
Mean	0.0025	0.0025	NA	NA
# of Tests	40	20	NA	NA
# of Detects	0	0	NA	NA
% of Detects	0.0%	0.0%	NA	NA

Tin	Overburden	Shallow PC	Deep PC	Pvt. Wells
Maximum	0.136	0.285	NA	NA
Minimum	0.034	0.034	NA	NA
Median	0.034	0.034	NA	NA
Mean	0.042	0.068	NA	NA
# of Tests	40	20	NA	NA
# of Detects	4	7	NA	NA
% of Detects	10.0%	35.0%	NA	NA

Titanium	Overburden	Shallow PC	Deep PC	Pvt. Wells
Maximum	0.028	0.004	NA	NA
Minimum	0.002	0.002	NA	NA
Median	0.002	0.002	NA	NA
Mean	0.004	0.002	NA	NA
# of Tests	40	20	NA	NA
# of Detects	8	1	NA	NA
% of Detects	20.0%	5.0%	NA	NA

TABLE NO. 3.6-12 (Cont.)

Uranium	Overburden	Shallow PC	Deep PC	Pvt. Wells
Maximum	0.017	0.011	0.007	NA
Minimum	0.001	0.001	0.004	NA
Median	0.002	0.003	0.006	NA
Mean	0.002	0.003	0.006	NA
# of Tests	126	60	5	NA
# of Detects	81	45	5	NA
% of Detects	64.3%	75.0%	100.0%	NA

Zinc	Overburden	Shallow PC	Deep PC	Pvt. Wells
Maximum	0.320	1.800	0.070	0.1200
Minimum	0.005	0.005	0.025	0.0055
Median	0.025	0.025	0.025	0.0205
Mean	0.036	0.080	0.039	0.0464
# of Tests	126	60	5	8
# of Detects	31	12	2	6
% of Detects	24.6%	20.0%	40.0%	75.0%

Figure Nos. 3.6-22 through 3.6-29 graphically depict the data on Table No. 3.6-12. For the parameters for which enough detections were available to graph, Figure No. 3.6-22 displays the high, low, median, and mean values for the overburden groundwater quality. Figure Nos. 3.6-23, 3.6-24, and 3.6-25 display the same data for the shallow Precambrian (as sampled monthly in the nested C wells), the deep Precambrian (as sampled in once the R wells) and the private well groundwater (mostly overburden, sampled twice), respectively. Parameters not presented on these figures for lack of enough detections were arsenic, barium, beryllium, chromium, cobalt, lead, mercury, selenium, thallium, tin, and titanium. They were either not detected at all or not detected with sufficient frequency to calculate the pertinent statistics.

3.6.4.2 <u>Discussion of the Data</u>

The groundwater quality of the site area is variable. The data show no significant differences in groundwater upgradient and downgradient of the deposit. The differences, rather, are between the groundwater that occurs in the overburden (till, glacial-fluvial material, and sandstone) and the groundwater that occurs in the Precambrian. In the overburden materials the median data show that the groundwater is relatively soft and low in total dissolved solids (TDS). By contrast, the water in the Precambrian is approximately twice as hard, contains more than 50 percent more TDS, and has higher levels of metals.

The following sections discuss these differences on a parameter-by-parameter basis. Because the mean concentrations usually tend to be skewed upward by a few high values, the discussions below center on median concentrations.

3.6.4.2.1 <u>Primary Drinking Water Standard Compounds</u>

The baseline sampling program included extensive testing for the United State Public Health Service (USPHS) Primary Drinking Water Standard (PDWS) metals compounds arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver, and the non-metal PDWS compounds fluoride and nitrate. Of the PDWS metals, only cadmium was consistently found, albeit at median concentrations well below the PDWS of 0.0100 mg/L (median concentrations of 0.0010 mg/L, 0.0012 mg/L, and 0.0039 mg/L in the overburden, shallow Precambrian, and deep Precambrian, respectively).

Fluoride concentrations were below the 2.2 mg/L standard. The medians were 0.20 mg/L, 0.20 mg/L, and 0.30 mg/L, respectively, in the overburden, shallow Precambrian, and deep Precambrian groundwater.

The nitrate-nitrogen standard of 10 mg/L was not approached in any of groundwaters. The medians were 0.30 mg/L, 0.35 mg/L, and

0.10 mg/L, respectively, in the overburden, shallow Precambrian, and deep Precambrian groundwater.

3.6.4.2.2 Secondary Drinking Water Standard Compounds

The baseline program also included extensive testing for the USPHS Secondary Drinking Water Standard (SDWS) compounds iron, manganese, copper, zinc, chloride, sulfate, and TDS.

Compared to the SDWS of 0.3 mg/L, iron is present in lower concentrations (median=0.14 mg/L) in the shallow Precambrian groundwater, was not detected in the deep Precambrian, and was present in lower concentrations (median=0.05 mg/L) in the overburden. In the private wells, however, it was higher (median=3.3 mg/L). For manganese, all concentration medians were high compared to the SDWS (0.05 mg/L). The median concentrations in the shallow and deep Precambrian, in the overburden, and in the private wells (0.36 mg/L, 0.23 mg/L, 0.09 mg/L, and 0.26 mg/L, respectively) all exceed the SDWS.

Copper and zinc were detected, but at levels below SDWS levels of 1 mg/L and 5 mg/L, respectively. Copper was detected in approximately one-third of the monitoring well samples tested and in nearly 90 percent of the private well samples tested. Median values were lower than the standard in both the overburden and the shallow Precambrian (0.05 mg/L), in the deep Precambrian (0.11 mg/L) and in the private wells (0.21 mg/L). Zinc was detected less frequently than copper--just over 20 percent of the time. Zinc median values are 0.025 mg/L for all three types of on-site groundwater and 0.020 mg/L for private well groundwater.

Median chloride concentrations were below the standard of 250 mg/L. The medians were 3.0 mg/L, 1.0 mg/L, 3.0 mg/L, and 8.0 mg/L, respectively, in the overburden, shallow Precambrian, deep Precambrian, and private well groundwater. At one well, MW-1005, a reading as high as 230 mg/L was recorded. During the study this well consistently exhibited elevated chloride values, evidently affected by the proximity of the well to State Highway 27 where calcium chloride salt is used for de-icing (calcium readings were also relatively high at this well).

Sulfate concentrations were below the SDWS of 250 mg/L. The medians were 11 mg/L, 8 mg/L, 5 mg/L, and 6 mg/L, respectively, in the overburden, shallow Precambrian, deep Precambrian, and private well groundwater.

TDS concentrations were below the SDWS of 500 mg/L. The medians were 130 mg/L, 200 mg/L, and 200 mg/L, respectively, in the overburden, shallow Precambrian, and deep Precambrian groundwater.

3.6.4.2.3 Other Parameters

Several indicator parameters were monitored during the baseline program. These included the general indicators total alkalinity, field pH, total hardness, field specific conductivity, chemical oxygen demand (COD), and field temperature, and the metals calcium and magnesium.

The overburden groundwaters had a lower pH (median=6.21) and alkalinity (median=60 mg/L) than did the shallow Precambrian groundwater (pH median=6.52, alkalinity median=170 mg/L) or the deep Precambrian groundwater (pH median=6.93, alkalinity median=180 mg/L). For the private wells, the results were mixed. Relative to the other samples, the pH was low (median=6.16), but the alkalinity was high (median=170 mg/L).

The total hardness and field specific conductivity parameters generally parallel TDS. The values in the Precambrian bedrock groundwaters are approximately double those in the overburden groundwaters.

COD is relatively low at the site. It is somewhat higher in both the overburden and shallow Precambrian groundwaters (medians are 10.0 mg/L in both) than in the deep Precambrian groundwaters (median = 2.5 mg/L). In the private wells the median was 6.0 mg/L.

Field temperatures were more variable in water samples taken from shallow wells than from deep wells, fluctuating seasonally with the ambient air temperature.

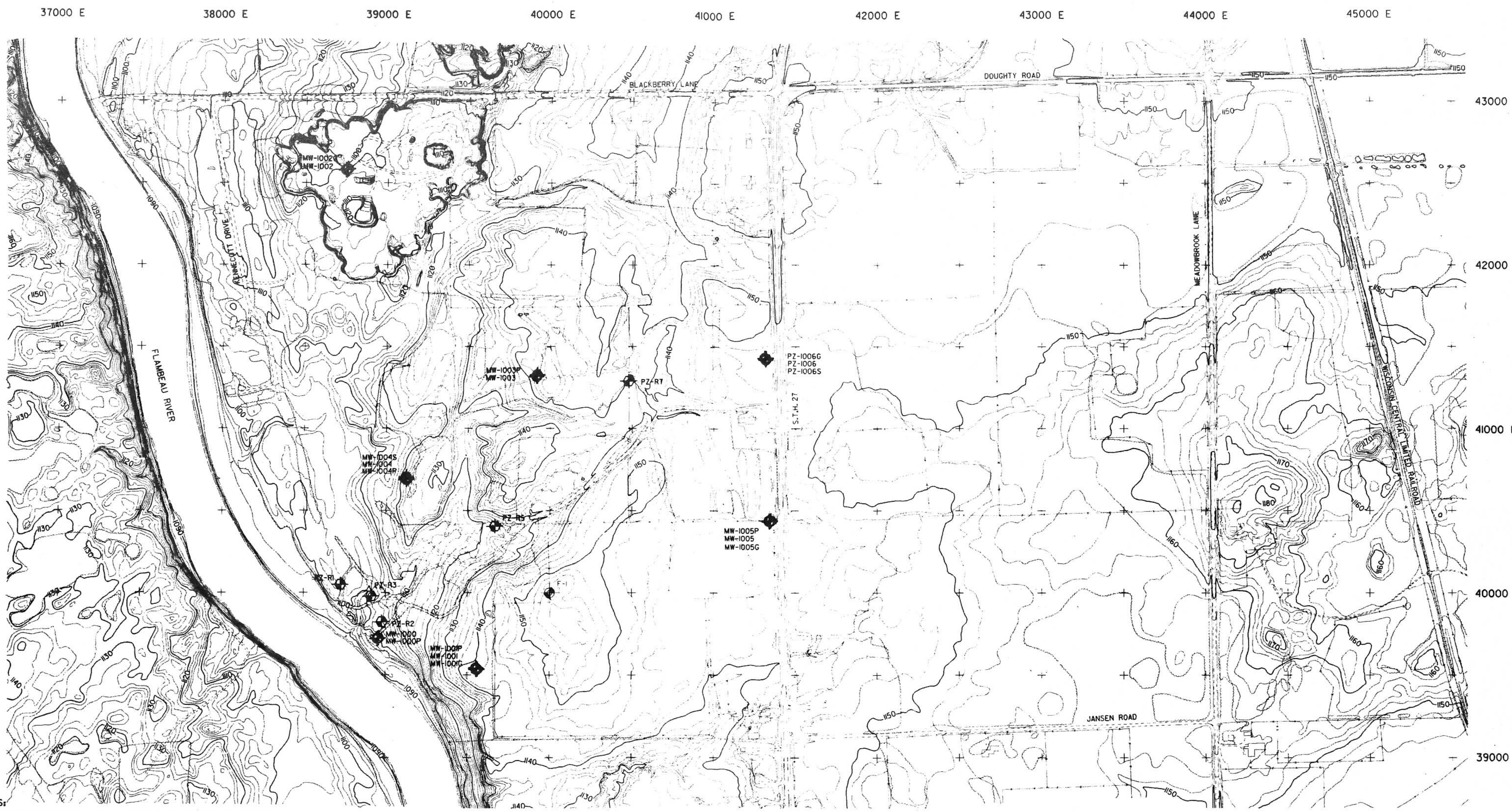
Calcium and magnesium values were higher in the Precambrian groundwaters than in the overburden groundwater. The medians for calcium were 36 mg/L and 35 mg/L and for magnesium were 14 mg/L and 13 mg/L, in the shallow and deep Precambrian groundwaters, respectively, while in the overburden they were 13 mg/L and 5.7 mg/L, respectively. In the private wells the medians for calcium and magnesium were 35 mg/L and 10.5 mg/L, respectively.

A number of metals not included in the drinking water standards or indicator parameter lists were analyzed. These included aluminum, beryllium, cobalt, molybdenum, nickel, thallium, tin, titanium, and uranium. Nickel and uranium were analyzed throughout the investigation. The other metals were run for the first four sampling periods and then dropped for lack of detects at significant concentrations.

Cobalt, selenium, and thallium were not detected in any of the samples tested. Beryllium was detected only once, in an overburden groundwater sample. Molybdenum, nickel, tin and titanium were all detected 10 to 30 percent of the time, generally at levels less than 0.05 mg/L. Uranium was detected in approximately two thirds of the samples tested, with median and mean values in the range of 0.002 to 0.003 mg/L. (The mean value for uranium in groundwaters of the United States is 0.005 mg/L (USEPA, 1975), so the range at the site is low relative to average levels.) Aluminum was detected in all samples tested, at median values of approximately 0.08 mg/L.

No drinking water standards have been set for any of these additional metals. All the measured concentrations, including those for uranium, are quite low and should present no health problems.

Figures for Section 3.6



NOTES:

1. SITE LOCATION: SECTIONS 9, 10, 15 & 16, T34N, R6W, RUSK COUNTY, WISCONSIN.
2. TOPOGRAPHIC BASE MAP PREPARED FROM AERIAL SURVEY BY SURDEX CORPORATION, CHESTERFIELD, MISSOURI. DATE OF PHOTOGRAPHY - APRIL 24, 1970. ROADS, TREES AND BUILDINGS WERE UPDATED AS PER AERIAL PHOTOGRAPH TAKEN BY MARKHURD CORPORATON, MINNEAPOLIS, MINNESOTA. DATE OF PHOTOGRAPHY - SEPTEMBER 14, 1987.
3. ELEVATIONS BASED ON MEAN SEA LEVEL DATUM. CONTOUR INTERVAL IS TWO FEET.
4. HORIZONTAL DATUM BASED ON PROJECT SITE GRID SYSTEM. SITE GRID COORDINATES CORRELATION TO STATE PLANE COORDINATES DERIVED AS FOLLOWS:

SITE GRID COORDINATES CONTROL MONUMENT F-1	STATE PLANE COORDINATES
40000 N =	587,357.8087 N
40000 E =	1,713,516.1229 E

THE ANGULAR ROTATION FROM STATE PLANE BEARINGS TO SITE GRID BEARINGS IS 359°-13'-23" RIGHT WITH CONTROL POINT F-1 AS THE BASE POINT.

LEGEND

- —1100— EXISTING CONTOUR
- EXISTING PAVED ROADWAY
- EXISTING TRAIL/GRAVEL SURFACE
- TREES AND/OR BRUSH
- FENCE
- F-1 CONTROL MONUMENT
- MW-1005 MONITORING WELL
- PZ-R3 PIEZOMETER

0 300' 600'
SCALE

REFERENCES DWG. NO.	DESCRIPTION	REFERENCES DWG. NO.	DESCRIPTION	NO.	DATE	REVISIONS	BY	CHK'D	ENG'R	ENG'R MGR.	NO.	DATE	REVISIONS	BY	CHK'D	ENG'R	ENG'R MGR.

FOTH & VAN DYKE
GEOSCIENCES & ENVIRONMENTAL MANAGEMENT DIVISION
GREEN BAY, WISCONSIN

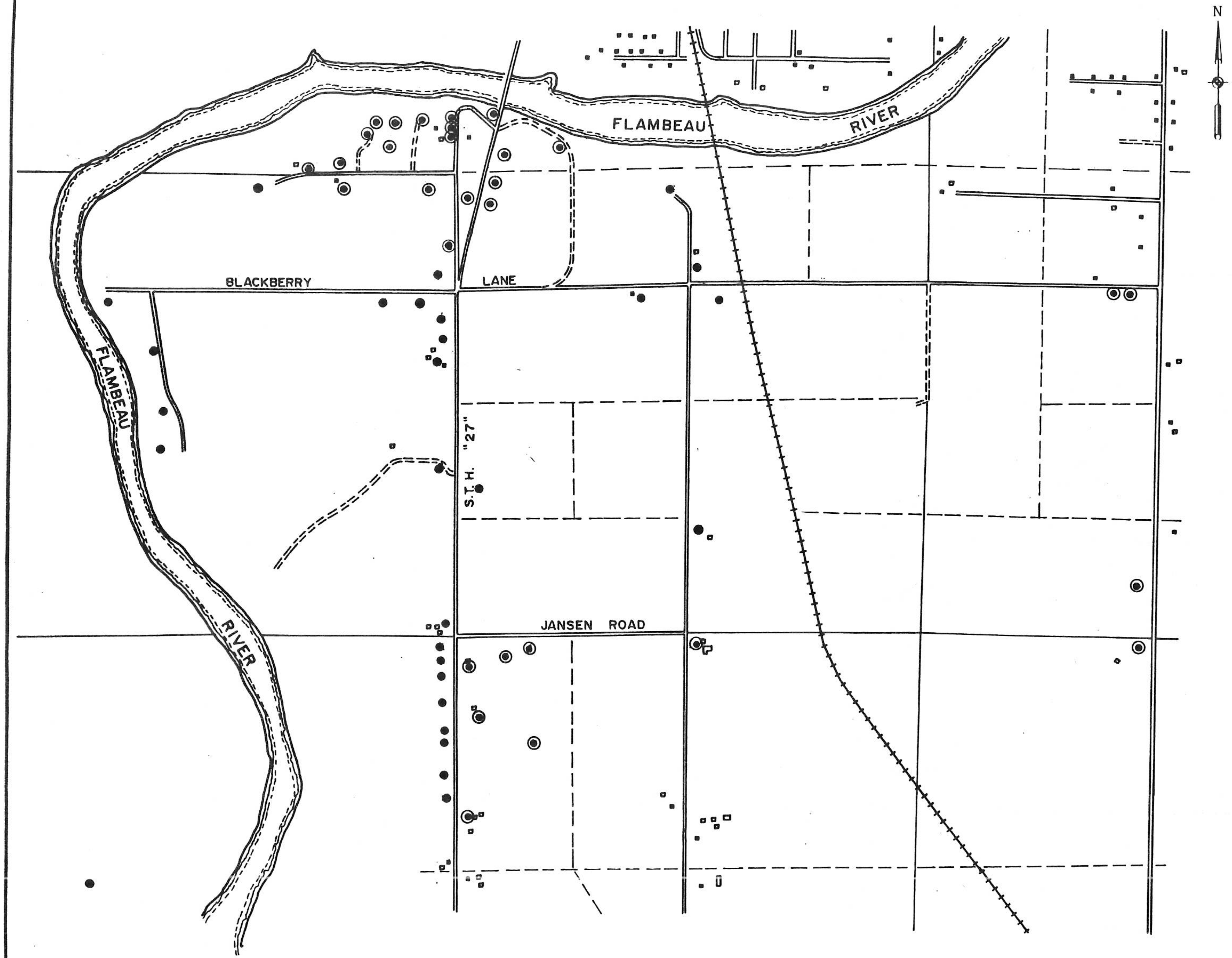
	BY	DATE		BY	DATE
PROJ. ENG'R			DESIGN		
MGR. PROCESS ENG'R			DRAWN	MJO	3/89
ENG'R MGR.			CHK'D	BNP	3/89
			DES. ENG'R		
			SECT ENG'R		

FLAMBEAU PROJECT
LADYSMITH, WISCONSIN

KENNECOTT MINERALS COMPANY
155 MINERAL SQUARE
SALT LAKE CITY, UTAH
84112

FIGURE NO. 3.6-1
GROUNDWATER QUALITY
SAMPLING LOCATIONS

MICROFILM	JOB
DRAWING NO.	REV.
DIVISION DRAWING NO.	
SCALE	SEE BAR SCALE



LEGEND

● KENNECOTT OWNED PROPERTY WITH ACTIVE WELL AND PROPERTY NUMBER

◉ PRIVATELY OWNED PROPERTY WITH ACTIVE WELL

REPRODUCED FROM USGS LADYSMITH AND THORNAPPLE 7.5 MINUTE SERIES TOPOGRAPHIC MAPS

FOTH & VAN DYKE
GEOSCIENCES & ENVIRONMENTAL MANAGEMENT DIVISION
GREEN BAY, WISCONSIN

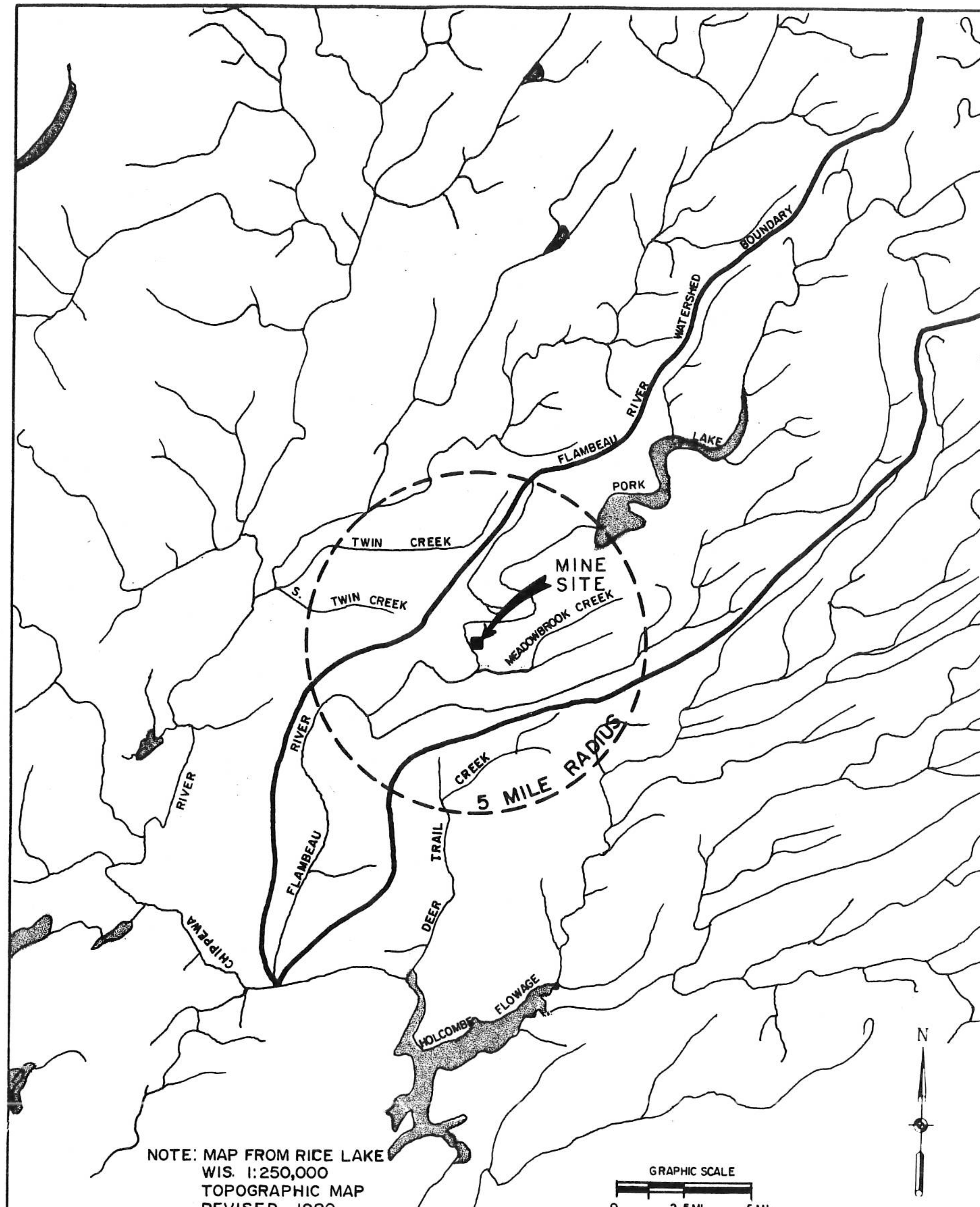
FLAMBEAU PROJECT
LADYSMITH, WISCONSIN

KENNECOTT MINERALS COMPANY
1515 MINERAL SQUARE
SALT LAKE CITY, UTAH
84112

FIGURE NO. 3.6-2
PRIVATE WATER SUPPLY
WELL LOCATION MAP

	BY	DATE
DESIGN		
DRAWN	RDM	3/89
CHK'D	BNP	3/89
DES. ENG'R		
SECT ENG'R		

SCALE NTS



FOTH & VAN DYKE
GEOSCIENCES & ENVIRONMENTAL MANAGEMENT DIVISION
GREEN BAY, WISCONSIN

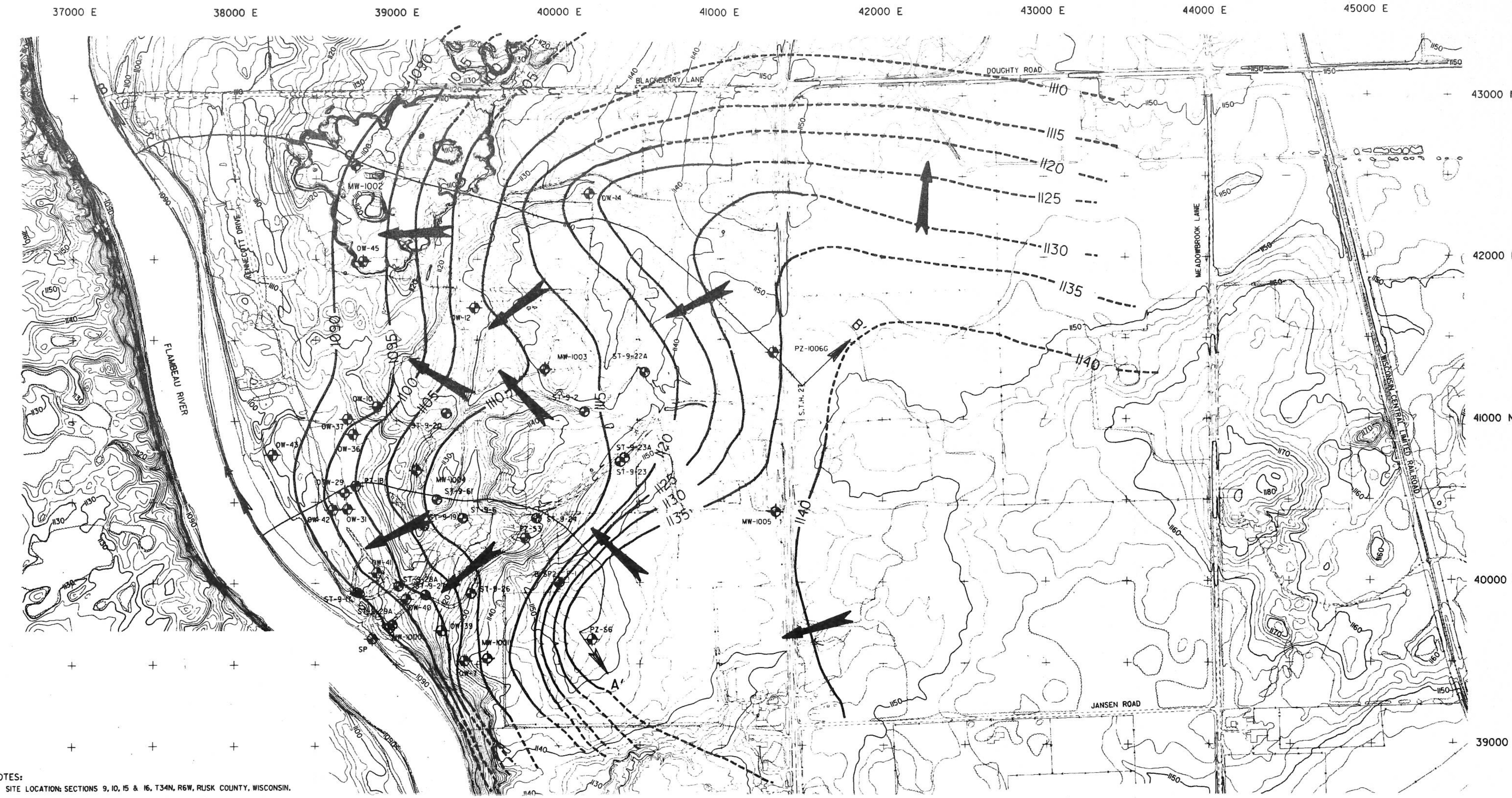
NOTES	APPROVAL		DATE
	DESIGNED BY		
	DRAWN BY	R.M.H.	3/89
	CHECKED BY	B.N.P.	3/89
	APPROVED BY		
	CAD No.	SCALE	

KENNECOTT MINERALS COMPANY

FLAMBEAU PROJECT
LADYSMITH, WISCONSIN

FIGURE NO. 3.6-3
REGIONAL GROUNDWATER FLOW SYSTEM DISTRIBUTION

Job No	Dwg No	REV



NOTES:

1. SITE LOCATION: SECTIONS 9, 10, 15 & 16, T34N, R6W, RUSK COUNTY, WISCONSIN.
2. TOPOGRAPHIC BASE MAP PREPARED FROM AERIAL SURVEY BY SURDEX CORPORATION, CHESTERFIELD, MISSOURI. DATE OF PHOTOGRAPHY - APRIL 24, 1970. ROADS, TREES AND BUILDINGS WERE UPDATED AS PER AERIAL PHOTOGRAPH TAKEN BY MARKHURD CORPORATON, MINNEAPOLIS, MINNESOTA. DATE OF PHOTOGRAPHY - SEPTEMBER 14, 1987.
3. ELEVATIONS BASED ON MEAN SEA LEVEL DATUM. CONTOUR INTERVAL IS TWO FEET.
4. HORIZONTAL DATUM BASED ON PROJECT SITE GRID SYSTEM. SITE GRID COORDINATES CORRELATION TO STATE PLANE COORDINATES DERIVED AS FOLLOWS:

SITE GRID COORDINATES CONTROL MONUMENT F-1	STATE PLANE COORDINATES
40000 N =	587,357.8087 N
40000 E =	1,713,516.1229 E

THE ANGULAR ROTATION FROM STATE PLANE BEARINGS TO SITE GRID BEARINGS IS 359°-13′-23″ RIGHT WITH CONTROL POINT F-1 AS THE BASE POINT.

5. SEE FIGURE NO.'S 3.6-8 AND 3.6-9 FOR HYDRO GEOLOGIC CROSS SECTIONS.

LEGEND

- —1100— EXISTING CONTOUR
- EXISTING PAVED ROADWAY
- EXISTING TRAIL/GRAVEL SURFACE
- TREES AND/OR BRUSH
- FENCE
- F-1 CONTROL MONUMENT
- MW-1005 MONITORING WELL
- PZ-54 OW-43 PIEZOMETER
- ST-9-2 SOIL BORING
- —1120— HIGH GROUNDWATER CONTOUR
- INFERRED GROUNDWATER CONTOUR
- GROUNDWATER FLOW DIRECTION

WELL	GROUNDWATER ELEVATION	WELL	GROUNDWATER ELEVATION	WELL	GROUNDWATER ELEVATION
MW-1000	1091.06	ST-9-23	1115.45	OW-36	1096.57
MW-1001	1112.83	ST-9-26	1108.92	OW-37	DRY
MW-1002	1090.72	ST-9-27A	DRY	OW-39	1099.26
MW-1003	1110.37	ST-9-28A	1099.75	OW-40	1096.85
MW-1004	1109.69	ST-9-29A	1094.99	OW-41	1097.50
MW-1005	1139.10	OW-7	1105.97	OW-42	1096.10
ST-9-2	1114.87	OW-10	1094.81	OW-43	1088.65
ST-9-19A	1109.77	OW-12	1109.14	OW-45	1093.63
ST-9-22A	DRY	OW-14	1124.84	SAND POINT (SP)	1086.84

N

0 300′ 600′
SCALE

FOTH & VAN DYKE
GEOSCIENCES & ENVIRONMENTAL MANAGEMENT DIVISION
GREEN BAY, WISCONSIN

FLAMBEAU PROJECT
LADYSMITH, WISCONSIN

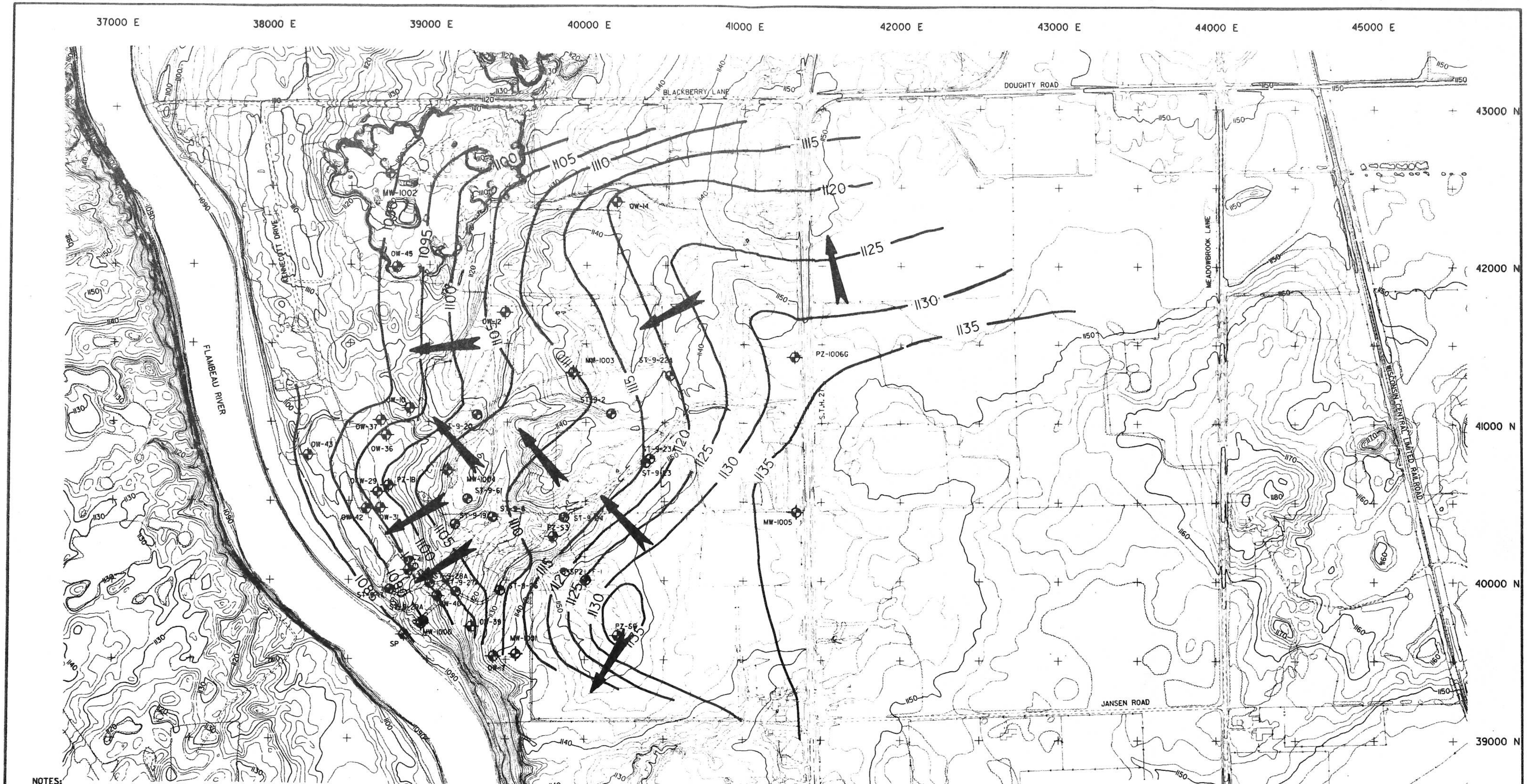
KENNECOTT MINERALS COMPANY
1515 MINERAL SQUARE
SALT LAKE CITY, UTAH
84112

FIGURE NO. 3.6-4
HIGH WATER TABLE
CONTOUR MAP
APRIL 6, 1988

	BY	DATE
DESIGN		
DRAWN	M.J.O.	3/89
CHK'D	B.N.P.	3/89
DES. ENG'R		
SECT ENG'R		

MICROFILM | JOB | DRAWING NO. | REV. | DIVISION DRAWING NO. | SCALE | SEE BAR SCALE

REFERENCES: DWG. NO. | DESCRIPTION | NO. | DATE | REVISIONS | BY | CHK'D | ENG'R | ENG'R MGR. | PROJ. ENG'R | MGR. PROCESS ENG'R | ENG'R MGR.



NOTES:

1. SITE LOCATION: SECTIONS 9, 10, 15 & 16, T34N, R6W, RUSK COUNTY, WISCONSIN.
2. TOPOGRAPHIC BASE MAP PREPARED FROM AERIAL SURVEY BY SURDEX CORPORATION, CHESTERFIELD, MISSOURI. DATE OF PHOTOGRAPHY - APRIL 24, 1970. ROADS, TREES AND BUILDINGS WERE UPDATED AS PER AERIAL PHOTOGRAPH TAKEN BY MARKHURD CORPORATON, MINNEAPOLIS, MINNESOTA. DATE OF PHOTOGRAPHY - SEPTEMBER 14, 1987.
3. ELEVATIONS BASED ON MEAN SEA LEVEL DATUM. CONTOUR INTERVAL IS TWO FEET.
4. HORIZONTAL DATUM BASED ON PROJECT SITE GRID SYSTEM. SITE GRID COORDINATES CORRELATION TO STATE PLANE COORDINATES DERIVED AS FOLLOWS:

SITE GRID COORDINATES CONTROL MONUMENT F-1	STATE PLANE COORDINATES
40000 N =	587,357.8087 N
40000 E =	1,713,516.1229 E

THE ANGULAR ROTATION FROM STATE PLANE BEARINGS TO SITE GRID BEARINGS IS 359°-13'-23" RIGHT WITH CONTROL POINT F-1 AS THE BASE POINT.

LEGEND

- —1100— EXISTING CONTOUR
- EXISTING PAVED ROADWAY
- EXISTING TRAIL/GRAVEL SURFACE
- TREES AND/OR BRUSH
- FENCE
- F-1 CONTROL MONUMENT
- MW-1005 MONITORING WELL
- PZ-S4 PIEZOMETER
- ST-9-2 SOIL BORING
- —1120— LOW GROUNDWATER CONTOUR
- GROUNDWATER FLOW DIRECTION

N

WELL	GROUNDWATER ELEVATION	WELL	GROUNDWATER ELEVATION	WELL	GROUNDWATER ELEVATION
MW-1000	1087.96	ST-9-23	1115.15	OW-36	1095.74
MW-1001	1110.94	ST-9-26	1108.38	OW-37	DRY
MW-1002	1089.44	ST-9-27A	DRY	OW-39	1098.50
MW-1003	1109.91	ST-9-28A	1095.52	OW-40	1094.35
MW-1004	1107.70	ST-9-29A	DRY	OW-41	1094.12
MW-1005	1136.71	OW-7	1109.13	OW-42	1092.67
ST-9-2	1111.79	OW-10	1093.01	OW-43	1086.85
ST-9-19A	1107.71	OW-12	1108.04	OW-45	1091.14
ST-9-22A	DRY	OW-14	1121.41	SANDPOINT (SP)	1084.71

0 300' 600'
SCALE

REFERENCES DWG. NO.	DESCRIPTION	REFERENCES DWG. NO.	DESCRIPTION

NO.	DATE	REVISIONS	BY	CHK'D	ENG'R	ENG'R MGR.

NO.	DATE	REVISIONS	BY	CHK'D	ENG'R	ENG'R MGR.

FOTH & VAN DYKE
GEOSCIENCES & ENVIRONMENTAL MANAGEMENT DIVISION
GREEN BAY, WISCONSIN

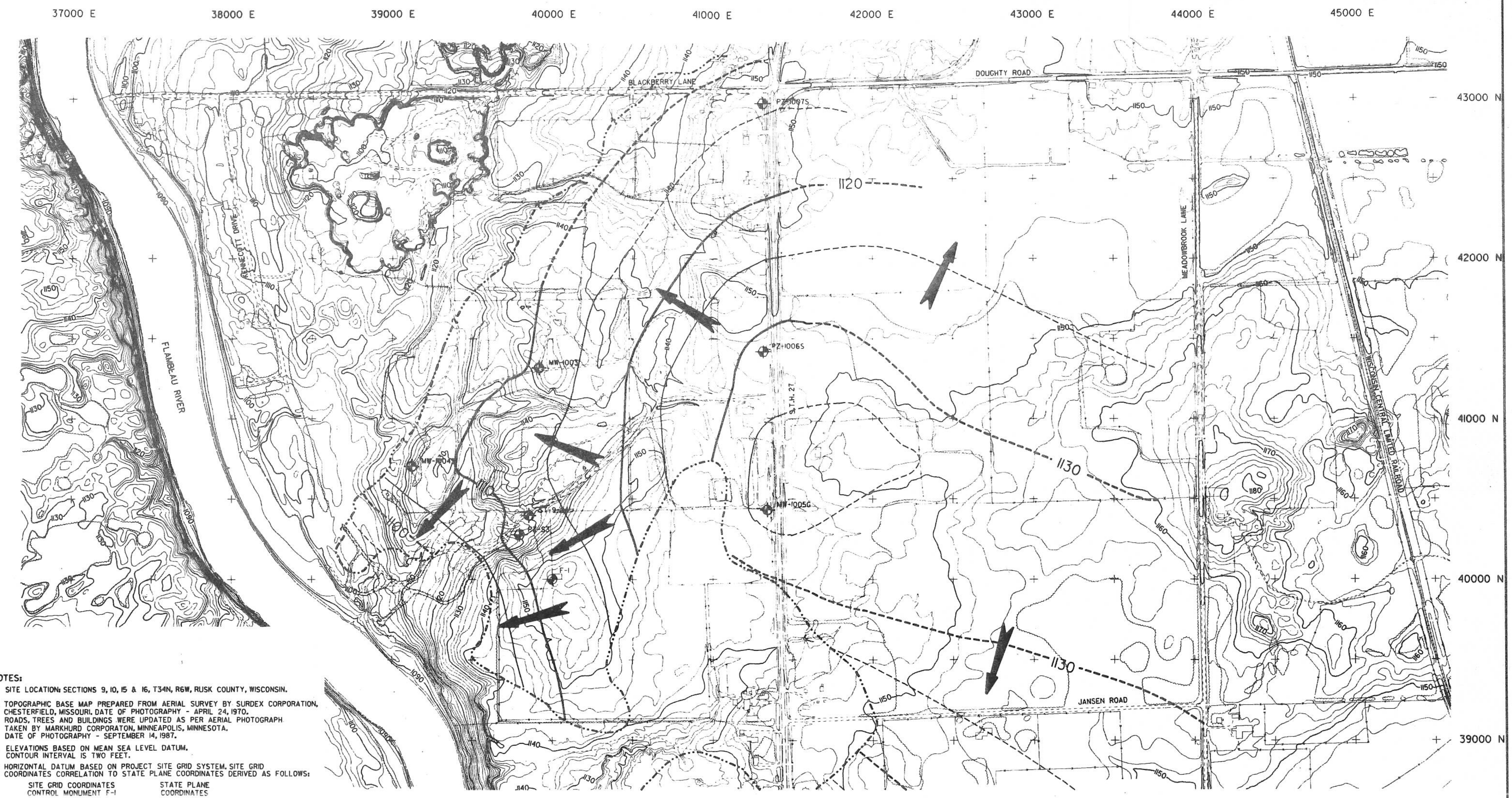
	BY	DATE		BY	DATE
PROJ. ENG'R			DESIGN		
MGR. PROCESS ENG'R			DRAWN	M.J.O.	3/89
ENG'R MGR.			CHK'D	B.N.P.	3/89
			DES. ENG'R		
			SECT ENG'R		

FLAMBEAU PROJECT
LADYSMITH, WISCONSIN

KENNECOTT MINERALS COMPANY
156 MINERAL SQUARE
SALT LAKE CITY, UTAH
84112

FIGURE NO. 3.6-5
LOW WATER TABLE CONTOUR MAP
SEPTEMBER 6, 1988

MICROFILM	JOB
DRAWING NO.	REV.
DIVISION DRAWING NO.	
SCALE	SEE BAR SCALE



NOTES:

1. SITE LOCATION: SECTIONS 9, 10, 15 & 16, T34N, R6W, RUSK COUNTY, WISCONSIN.
2. TOPOGRAPHIC BASE MAP PREPARED FROM AERIAL SURVEY BY SURDEX CORPORATION, CHESTERFIELD, MISSOURI. DATE OF PHOTOGRAPHY - APRIL 24, 1970. ROADS, TREES AND BUILDINGS WERE UPDATED AS PER AERIAL PHOTOGRAPH TAKEN BY MARKHURD CORPORATON, MINNEAPOLIS, MINNESOTA. DATE OF PHOTOGRAPHY - SEPTEMBER 14, 1987.
3. ELEVATIONS BASED ON MEAN SEA LEVEL DATUM. CONTOUR INTERVAL IS TWO FEET.
4. HORIZONTAL DATUM BASED ON PROJECT SITE GRID SYSTEM. SITE GRID COORDINATES CORRELATION TO STATE PLANE COORDINATES DERIVED AS FOLLOWS:

SITE GRID COORDINATES CONTROL MONUMENT F-1	STATE PLANE COORDINATES
40000 N =	587, 357. 8087 N
40000 E =	1, 713, 516. 1229 E

THE ANGULAR ROTATION FROM STATE PLANE BEARINGS TO SITE GRID BEARINGS IS 359°-13'-23" RIGHT WITH CONTROL POINT F-1 AS THE BASE POINT.

5. AVERAGE POTENTIOMETRIC SURFACE DEVELOPED BY KRIGING AVERAGE GROUNDWATER ELEVATIONS (DECEMBER TO NOVEMBER 1988) FOR THE FOLLOWING WELLS:

WELL	AVERAGE GROUNDWATER ELEVATION
MW-1003	1110.28
MW-1004S	1108.41
MW-1005	1137.51
MW-1006S	1131.92
MW-1007S	1114.72
ST-9-24	1112.94
PZ-S3	1112.84

LEGEND

- —1100— EXISTING CONTOUR
- EXISTING PAVED ROADWAY
- EXISTING TRAIL/GRAVEL SURFACE
- TREES AND/OR BRUSH
- FENCE
- F-1 CONTROL MONUMENT
- MW-1005 MONITORING WELL
- PZ-S4 PIEZOMETER
- —1090— POTENTIOMETRIC SURFACE CONTOUR
- INFERRED POTENTIOMETRIC SURFACE CONTOUR
- LIMIT OF SANDSTONE
- GROUNDWATER FLOW DIRECTION

FOTH & VAN DYKE
GEOSCIENCES & ENVIRONMENTAL MANAGEMENT DIVISION
GREEN BAY, WISCONSIN

FLAMBEAU PROJECT
LADYSMITH, WISCONSIN

KENNECOTT MINERALS COMPANY
155 MINERAL SQUARE
SALT LAKE CITY, UTAH
84112

FIGURE NO. 3.6-6
AVERAGE POTENTIOMETRIC SURFACE
CAMBRIAN SANDSTONE

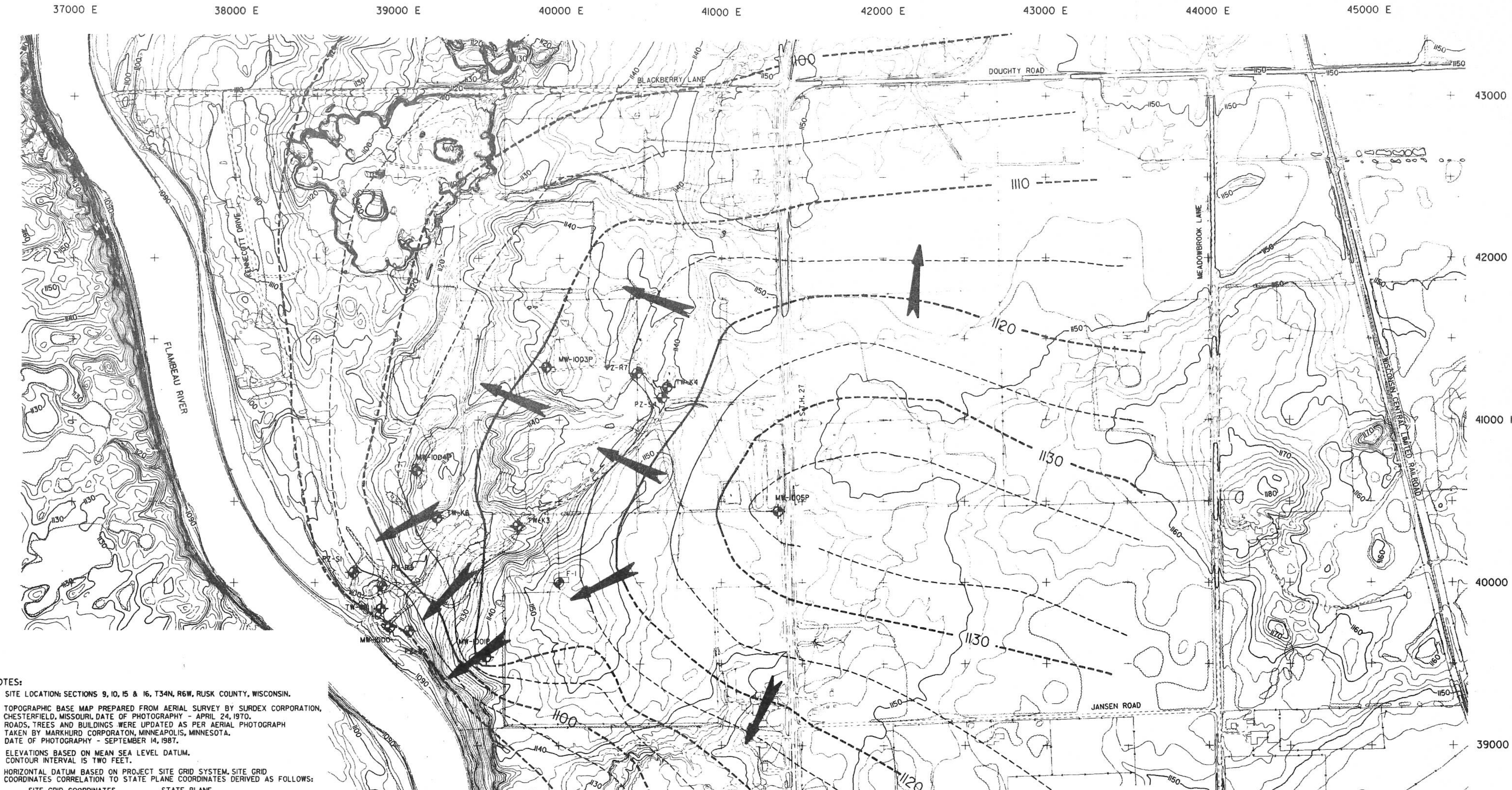
	BY	DATE
DESIGN		
DRAWN	MJS	3/89
CHK'D	BNP	3/89
RES. ENG'R		
SECT ENG'R		

PROJ. ENG'R / MGR. PROCESS ENG'R / ENG'R MGR.

MICROFILM | JOB | DRAWING NO. | REV. | DIVISION DRAWING NO. | SCALE SEE BAR SCALE

REFERENCES: DWG. NO. | DESCRIPTION

REVISIONS: NO. | DATE | REVISIONS | BY | CHK'D | ENG'R | ENG'R MGR.



NOTES:

1. SITE LOCATION: SECTIONS 9, 10, 15 & 16, T34N, R6W, RUSK COUNTY, WISCONSIN.
2. TOPOGRAPHIC BASE MAP PREPARED FROM AERIAL SURVEY BY SURDEX CORPORATION, CHESTERFIELD, MISSOURI. DATE OF PHOTOGRAPHY - APRIL 24, 1970. ROADS, TREES AND BUILDINGS WERE UPDATED AS PER AERIAL PHOTOGRAPH TAKEN BY MARKHURD CORPORATON, MINNEAPOLIS, MINNESOTA. DATE OF PHOTOGRAPHY - SEPTEMBER 14, 1987.
3. ELEVATIONS BASED ON MEAN SEA LEVEL DATUM. CONTOUR INTERVAL IS TWO FEET.
4. HORIZONTAL DATUM BASED ON PROJECT SITE GRID SYSTEM. SITE GRID COORDINATES CORRELATION TO STATE PLANE COORDINATES DERIVED AS FOLLOWS:

SITE GRID COORDINATES CONTROL MONUMENT F-1	STATE PLANE COORDINATES
40000 N =	587,357.8087 N
40000 E =	1,713,516.1229 E

THE ANGULAR ROTATION FROM STATE PLANE BEARINGS TO SITE GRID BEARINGS IS 359°-13'-23" RIGHT WITH CONTROL POINT F-1 AS THE BASE POINT.

5. AVERAGE POTENTIOMETRIC SURFACE DEVELOPED BY KRIGING AVERAGE GROUNDWATER ELEVATIONS (DECEMBER TO NOVEMBER 1988) FOR THE FOLLOWING WELLS:

WELL	AVERAGE GROUNDWATER ELEVATION	WELL	AVERAGE GROUNDWATER ELEVATION
MW-1000	1088.91	PZ-S4	1116.17
MW-1001P	1112.53	PZ-R3	1093.30
MW-1003P	1110.34	PZ-R7	1115.41
MW-1004P	1106.17	TW-K3	1111.67
MW-1005P	1137.91	TW-K4	1116.34
PZ-S1	1094.95	TW-K6	1107.88
PZ-S2	1091.41	TW-K8	1092.09

LEGEND

- 1100 EXISTING CONTOUR
- EXISTING PAVED ROADWAY
- EXISTING TRAIL/GRAVEL SURFACE
- TREES AND/OR BRUSH
- FENCE
- F-1 CONTROL MONUMENT
- MW-1005 TW-K4 MONITORING WELL
- PZ-S4 PIEZOMETER
- 1090 POTENTIOMETRIC SURFACE CONTOUR
- INFERRED POTENTIOMETRIC SURFACE CONTOUR
- GROUNDWATER FLOW DIRECTION

N

0 300' 600'
SCALE

FOTH & VAN DYKE
GEOSCIENCES & ENVIRONMENTAL MANAGEMENT DIVISION
GREEN BAY, WISCONSIN

FLAMBEAU PROJECT
LADYSMITH, WISCONSIN

KENNECOTT MINERALS COMPANY
1515 MINERAL SQUARE
SALT LAKE CITY, UTAH
[illegible]

FIGURE NO. 3.6-7
AVERAGE POTENTIOMETRIC SURFACE
TOP OF PRECAMBRIAN ROCK

	BY	DATE
PROJ. ENG'R		
MGR. PROCESS ENG'R		
ENG'R MGR.		

	BY	DATE
DESIGN		
DRAWN	M.J.O.	3/89
CHK'D	B.N.P.	3/89
DES. ENG'R		
SECT ENG'R		

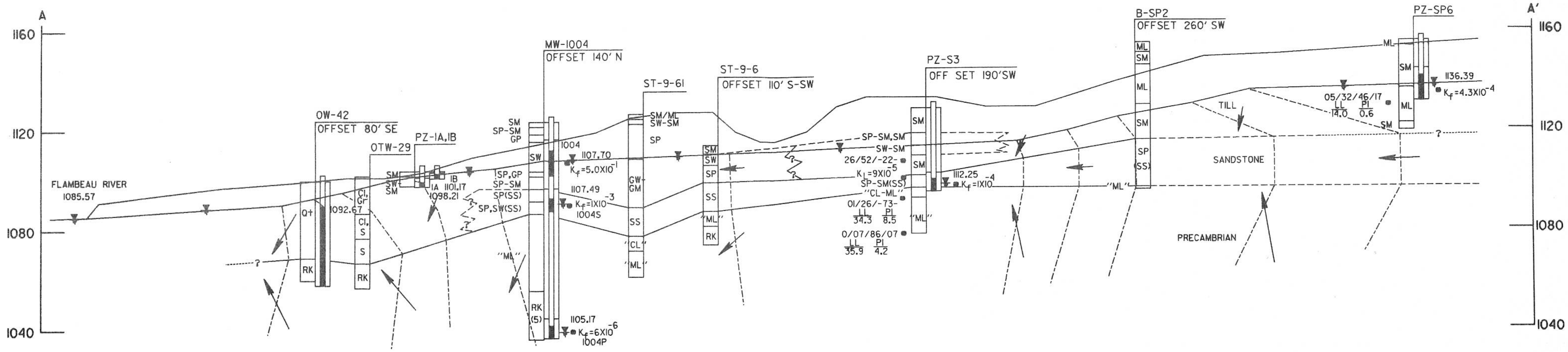
MICROFILM | JOB
DRAWING NO. | REV.
DIVISION DRAWING NO.
SCALE: SEE BAR SCALE

REFERENCES DWG. NO.	DESCRIPTION	REFERENCES DWG. NO.	DESCRIPTION

NO.	DATE	REVISIONS	BY	CHK'D	ENG'R	ENG'R MGR.	NO.	DATE	REVISIONS	BY	CHK'D	ENG'R	ENG'R MGR.

SECTION A-A'

(LINE OF SECTION SHOWN ON FIGURE NO. 3.6-4)



LEGEND

QUATERNARY

Qt	TILL, AND SAND AND GRAVEL (MAY CONTAIN SOME CAMBRIAN SANDSTONE)
SM	SILTY SAND
SW-SM	WELL GRADED SAND WITH SILT
SP	POORLY GRADED SAND
SP-SM	POORLY GRADED SAND WITH SILT
SW	WELL GRADED SAND
SP-SM, SW	POORLY GRADED SAND WITH SILT INTERBEDDED WITH WELL-GRADED SAND
SM,SP	SILTY SAND INTERBEDDED WITH POORLY GRADED SAND
SW,SM	WELL GRADED SAND INTERBEDDED WITH SILTY SAND
SM/ML	SILTY SAND/SILT
SC/SM	CLAYEY SAND/SILTY SAND
SC	CLAYEY SAND
SC-SM	SILTY-CLAYEY SAND
GW	WELL GRADED GRAVEL
GW-GM	WELL GRADED GRAVEL WITH SILT
GP	POORLY GRADED GRAVEL
GM	SILTY GRAVEL
SP,GP	POORLY GRADED SAND INTERBEDDED WITH POORLY GRADED GRAVEL
SM/GM	SILTY SAND/SILTY GRAVEL
SM,GW-GM	SILTY SAND INTERBEDDED WITH POORLY GRADED GRAVEL WITH SILT
GM/SM	SILTY GRAVEL/SILTY SAND

ML	SILT
Cl,S	CLAY AND SAND
Cl,Gr	CLAY AND GRAVEL
S	SAND

CAMBRIAN

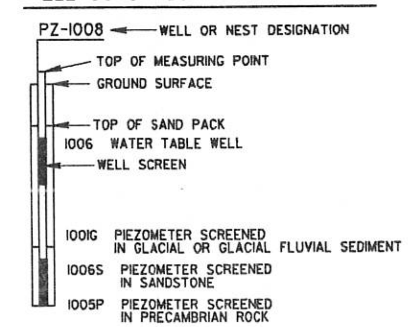
SS	SANDSTONE

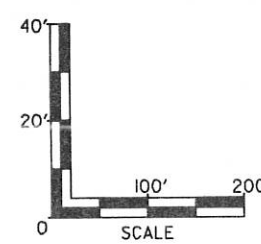
PRECAMBRIAN

RK	ROCK
Qtz	QUARTZ
(1a)	SERICITE-QUARTZ SCHIST
(2)	BIOTITE SCHIST
(3)	AUGEN SCHIST
(5)	METADACITE (VOLCANIC FLOW ROCK)
"ML"	ROCK THAT DISAGGREGATES TO SILT
"SM"	ROCK THAT DISAGGREGATES TO SILTY SAND
"GM"	ROCK THAT DISAGGREGATES TO SILTY GRAVEL
"CL/ML"	ROCK THAT DISAGGREGATES TO LEAN CLAY/SILT
"SM/ML"	ROCK THAT DISAGGREGATES TO SILTY SAND/SILT
"SM,ML"	ROCK THAT DISAGGREGATES TO INTERBEDS OF SILTY SAND AND SILT

•	SAMPLING POINT
LL 26 PI 13	ATTERBERG LIMITS
K_f=7.9X10^{-5}	IN-FIELD PERMEABILITY VALUE (CM/SEC)
K_L=4.0X10^{-9}	LABORATORY PERMEABILITY VALUE (CM/SEC)
01/50/41/08	GRAVEL/SAND/SILT/CLAY PERCENTAGES
0/93/-7-	GRAVEL/SAND/P200 PERCENTAGES
▼ 1113.27	LOW WATER LEVEL SEPTEMBER 6, 1988
———	CONTACTS-REASONABLY CERTAIN
- - - -	UNCERTAIN
········	VERY UNCERTAIN
— — —	ESTIMATED GROUNDWATER CONTOUR
←	GROUNDWATER FLOW DIRECTION

WELL CONSTRUCTION INFORMATION





FOTH & VAN DYKE
GEOSCIENCES & ENVIRONMENTAL MANAGEMENT DIVISION
GREEN BAY, WISCONSIN

	BY	DATE
DESIGN		
DRAWN	M.J.O.	3/89
CHK'D	B.N.P.	3/89
DES. ENG'R		
SECT ENG'R		

FLAMBEAU PROJECT
LADYSMITH, WISCONSIN

KENNECOTT MINERALS COMPANY
155 MINERAL SQUARE
SALT LAKE CITY, UTAH
84112

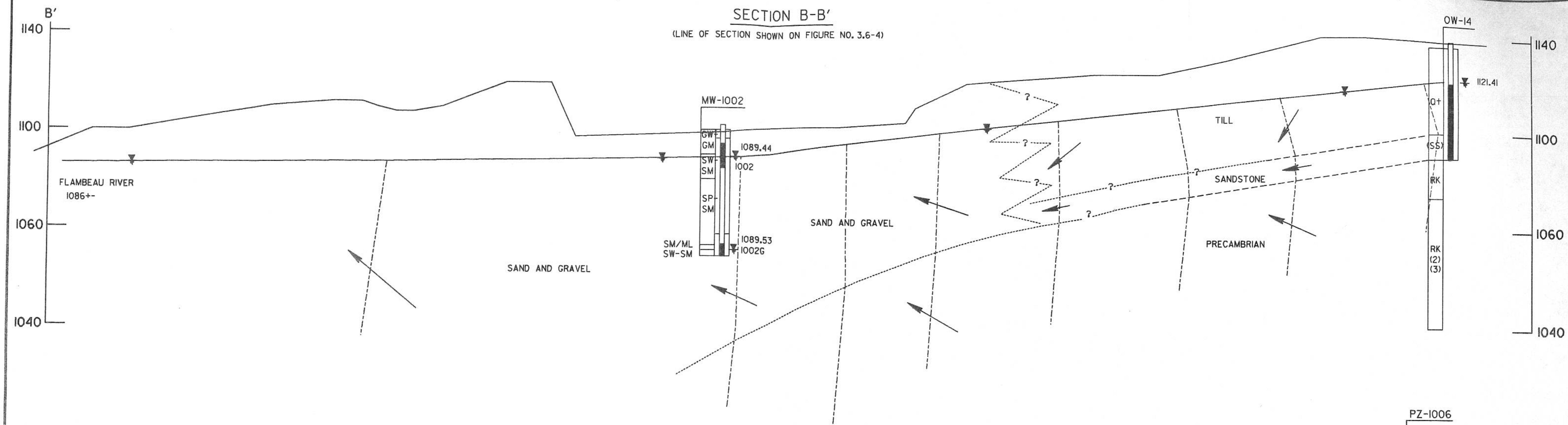
FIGURE NO. 3.6-8
HYDRO GEOLOGIC CROSS SECTION
A-A'

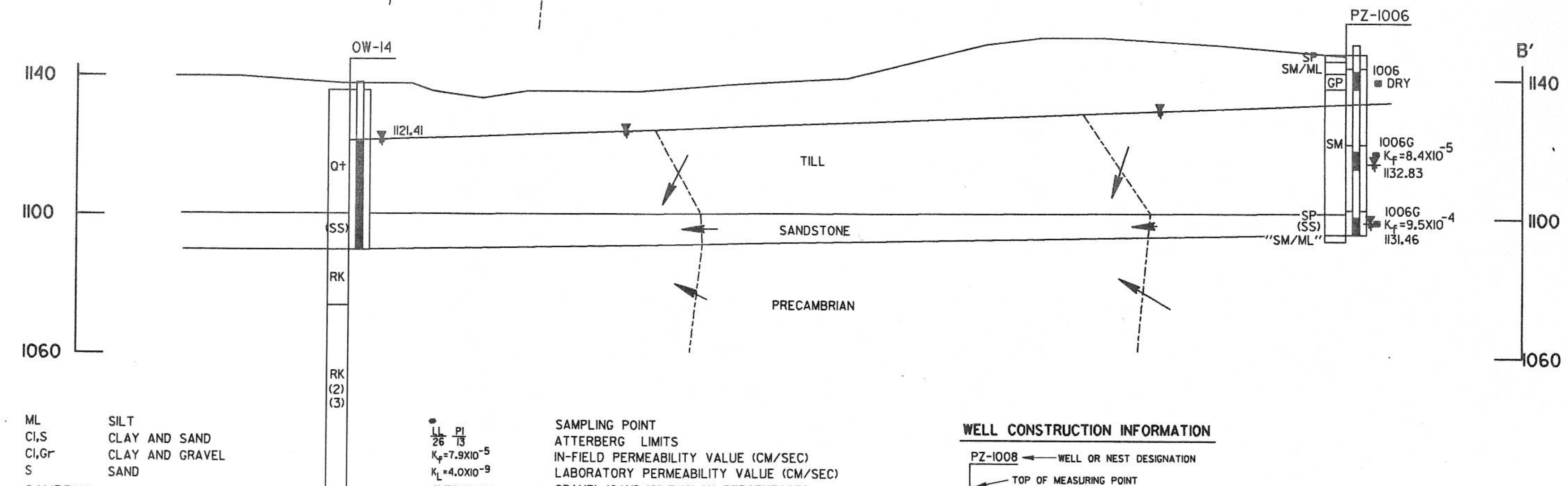
MICROFILM | JOB
DRAWING NO. | REV.
DIVISION DRAWING NO.
SCALE: SEE BAR SCALE

DWG. NO.	DESCRIPTION	DWG. NO.	DESCRIPTION	NO.	DATE	REVISIONS	BY	CHK'D	ENG'R	ENG'R MGR.	NO.	DATE	REVISIONS	BY	CHK'D	ENG'R	ENG'R MGR.

SECTION B-B'

(LINE OF SECTION SHOWN ON FIGURE NO. 3.6-4)





LEGEND

QUATERNARY

Q+	TILL, AND SAND AND GRAVEL (MAY CONTAIN SOME CAMBRIAN SANDSTONE)
SM	SILTY SAND
SW-SM	WELL GRADED SAND WITH SILT
SP	POORLY GRADED SAND
SP-SM	POORLY GRADED SAND WITH SILT
SW	WELL GRADED SAND
SP-SM, SW	POORLY GRADED SAND WITH SILT INTERBEDDED WITH WELL-GRADED SAND
SM,SP	SILTY SAND INTERBEDDED WITH POORLY GRADED SAND
SW,SM	WELL GRADED SAND INTERBEDDED WITH SILTY SAND
SM/ML	SILTY SAND/SILT
SC/SM	CLAYEY SAND/SILTY SAND
SC	CLAYEY SAND
SC-SM	SILTY-CLAYEY SAND
GW	WELL GRADED GRAVEL
GW-GM	WELL GRADED GRAVEL WITH SILT
GP	POORLY GRADED GRAVEL
GM	SILTY GRAVEL
SP,GP	POORLY GRADED SAND INTERBEDDED WITH POORLY GRADED GRAVEL
SM/GM	SILTY SAND/SILTY GRAVEL
SM,GW-GM	SILTY SAND INTERBEDDED WITH POORLY GRADED GRAVEL WITH SILT
GM/SM	SILTY GRAVEL/SILTY SAND

ML	SILT
Cl,S	CLAY AND SAND
Cl,Gr	CLAY AND GRAVEL
S	SAND

CAMBRIAN

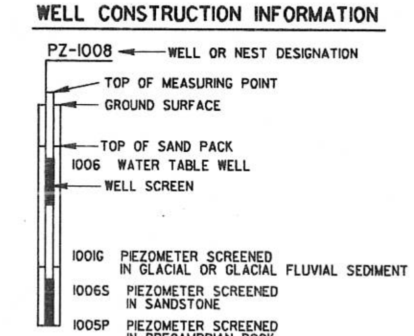
SS	SANDSTONE

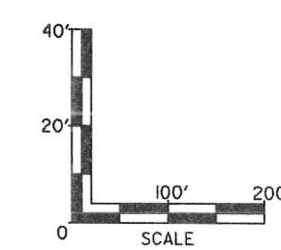
PRECAMBRIAN

RK	ROCK
Q+z	QUARTZ
(Ia)	SERICITE-QUARTZ SCHIST
(2)	BIOTITE SCHIST
(3)	AUGEN SCHIST
(5)	METADACITE (VOLCANIC FLOW ROCK)
"ML"	ROCK THAT DISAGGREGATES TO SILT
"SM"	ROCK THAT DISAGGREGATES TO SILTY SAND
"GM"	ROCK THAT DISAGGREGATES TO SILTY GRAVEL
"CL/ML"	ROCK THAT DISAGGREGATES TO LEAN CLAY/SILT
"SM/ML"	ROCK THAT DISAGGREGATES TO SILTY SAND/SILT
"SM,ML"	ROCK THAT DISAGGREGATES TO INTERBEDS OF SILTY SAND AND SILT

•	SAMPLING POINT
LL 26 PI 13	ATTERBERG LIMITS
K_f=7.9X10^{-5}	IN-FIELD PERMEABILITY VALUE (CM/SEC)
K_L=4.0X10^{-9}	LABORATORY PERMEABILITY VALUE (CM/SEC)
01/50/41/08	GRAVEL/SAND/SILT/CLAY PERCENTAGES
0/93/-7-	GRAVEL/SAND/P200 PERCENTAGES
▼ 1113.27	LOW WATER LEVEL SEPTEMBER 6, 1988
———	CONTACTS-REASONABLY CERTAIN
– – –	UNCERTAIN
········	VERY UNCERTAIN
–·–·–	ESTIMATED GROUNDWATER CONTOUR
←	GROUNDWATER FLOW DIRECTION

WELL CONSTRUCTION INFORMATION





FOTH & VAN DYKE
GEOSCIENCES & ENVIRONMENTAL MANAGEMENT DIVISION
GREEN BAY, WISCONSIN

FLAMBEAU PROJECT
LADYSMITH, WISCONSIN

KENNECOTT MINERALS COMPANY
1515 MINERAL SQUARE
SALT LAKE CITY, UTAH
84112

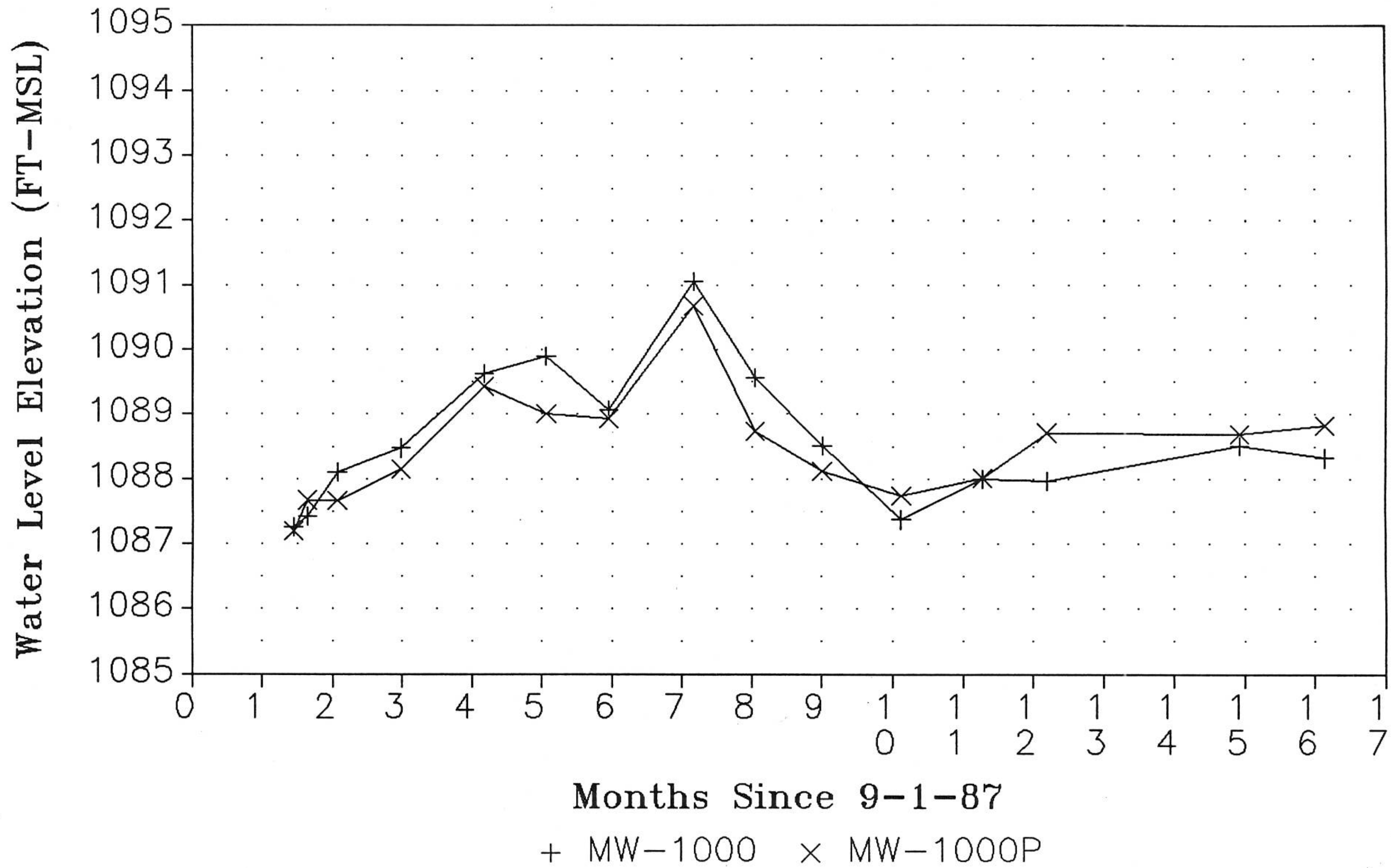
FIGURE NO. 3.6-9
HYDRO GEOLOGIC CROSS SECTION
B-B'

	BY	DATE
DESIGN		
DRAWN	M.J.O.	3/89
CHK'D	B.N.P.	3/89
DES. ENG'R		
SECT ENG'R		

PROJ. ENG'R / MGR. PROCESS ENGR. / ENG'R MGR. — BY — DATE

MICROFILM — JOB — DRAWING NO. — REV. — DIVISION DRAWING NO. — SCALE

REFERENCES DWG. NO.	DESCRIPTION	REFERENCES DWG. NO.	DESCRIPTION	NO.	DATE	REVISIONS	BY	CHK'D	ENG'R	ENG'R MGR.	NO.	DATE	REVISIONS	BY	CHK'D	ENG'R	ENG'R MGR.

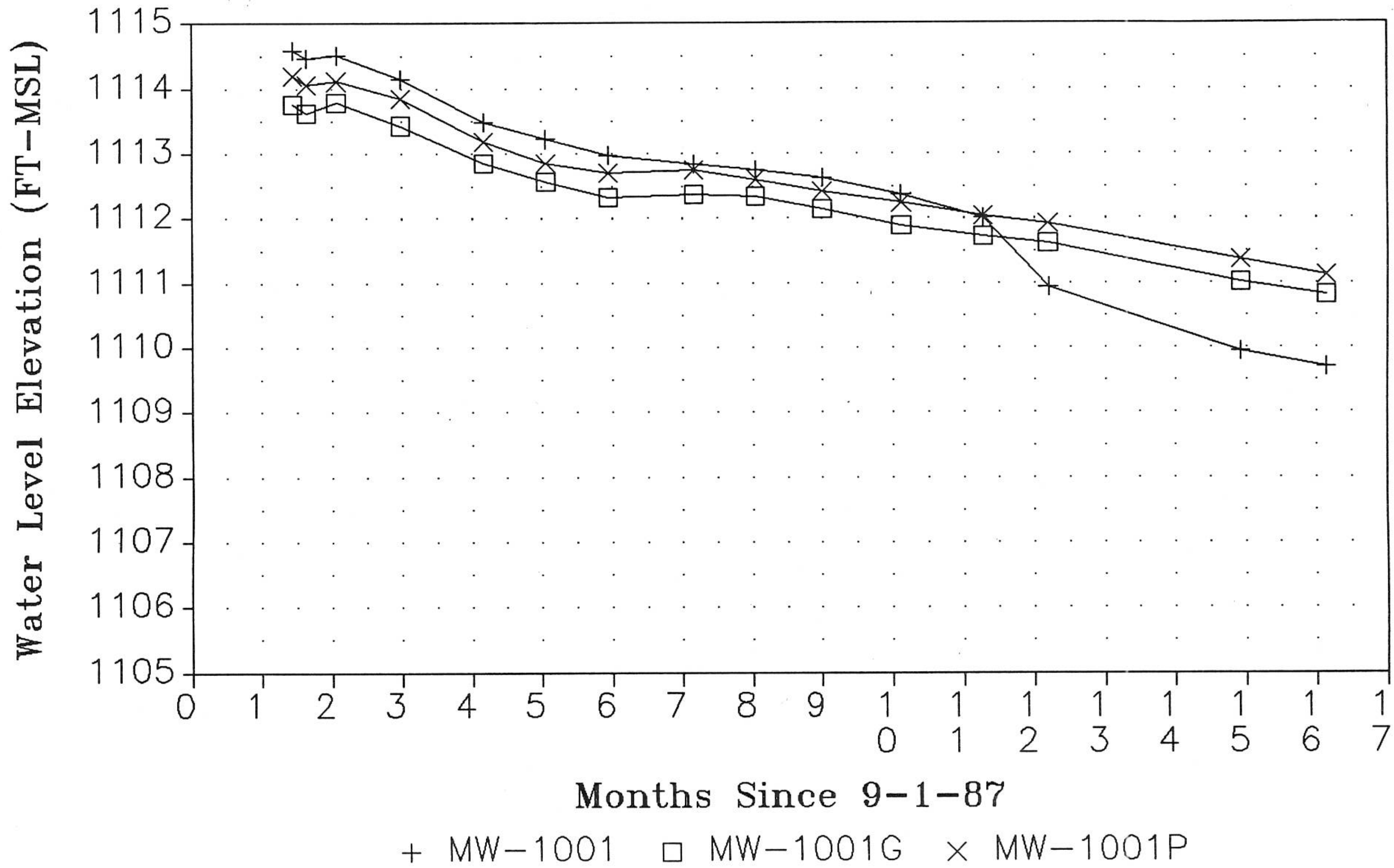


FOTH & VAN DYKE GEOSCIENCES & ENVIRONMENTAL MANAGEMENT DIVISION GREEN BAY, WISCONSIN	KENNECOTT MINERALS COMPANY FLAMBEAU PROJECT LADYSMITH, WISCONSIN	

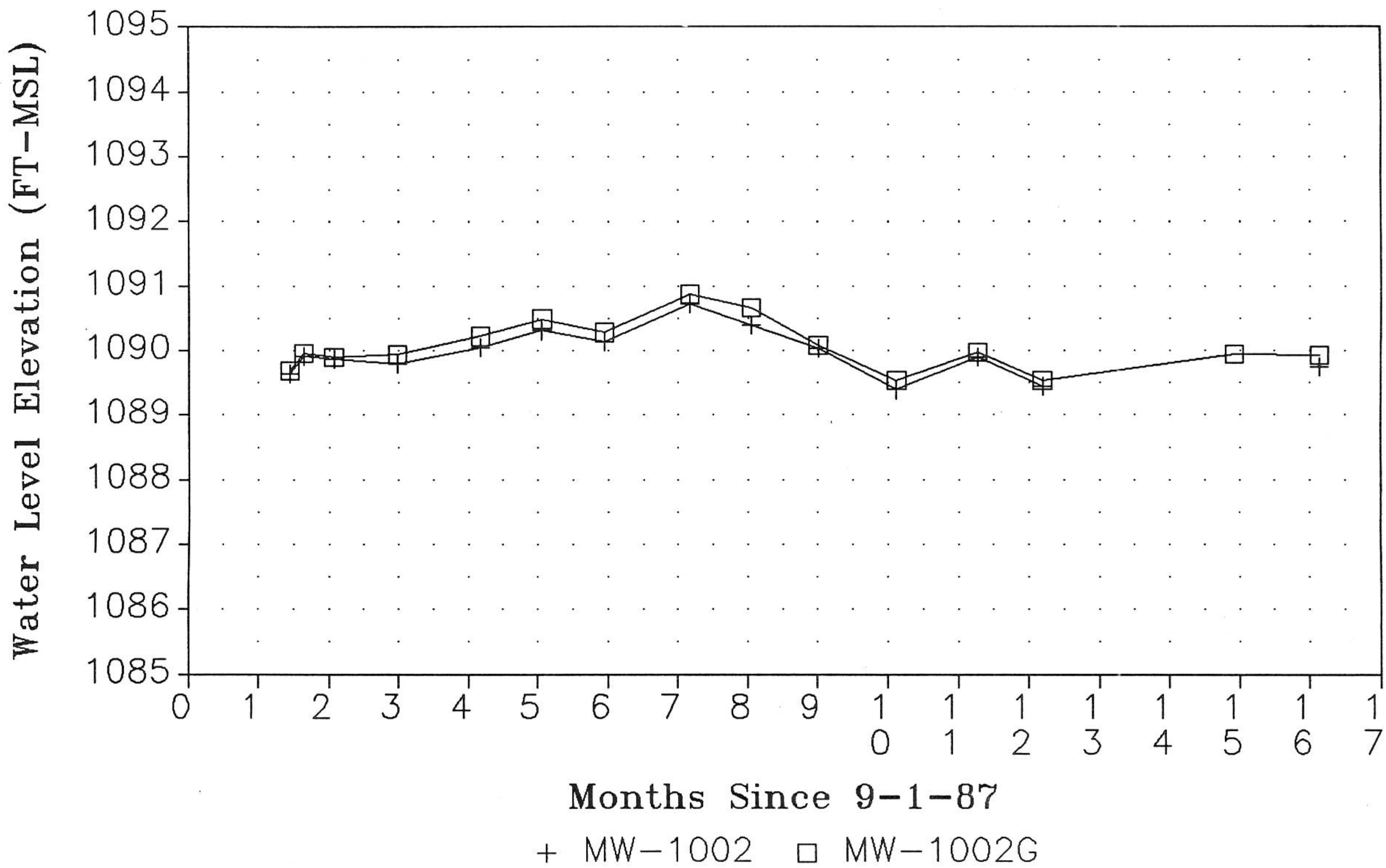
No	REVISIONS	NOTES	APPROVAL	DATE
△			DESIGNED BY	
△			DRAWN BY	
△			CHECKED BY	
△			APPROVED BY	
△			CAD No.	SCALE

FIGURE NO 3.6-10
HYDROGRAPH
WELL NEST 1000

Job No	Dwg No	REV



			FOTH & VAN DYKE GEOSCIENCES & ENVIRONMENTAL MANAGEMENT DIVISION GREEN BAY, WISCONSIN		KENNECOTT MINERALS COMPANY FLAMBEAU PROJECT LADYSMITH, WISCONSIN
No	REVISIONS	NOTES	APPROVAL	DATE	FIGURE NO 3.6-11 HYDROGRAPH PIEZOMETER NEST 1001
△			DESIGNED BY		
△			DRAWN BY RDM	3/89	
△			CHECKED BY BNP	3/89	
△			APPROVED BY		
△			CAD No. / SCALE		Job No / Dwg No / REV



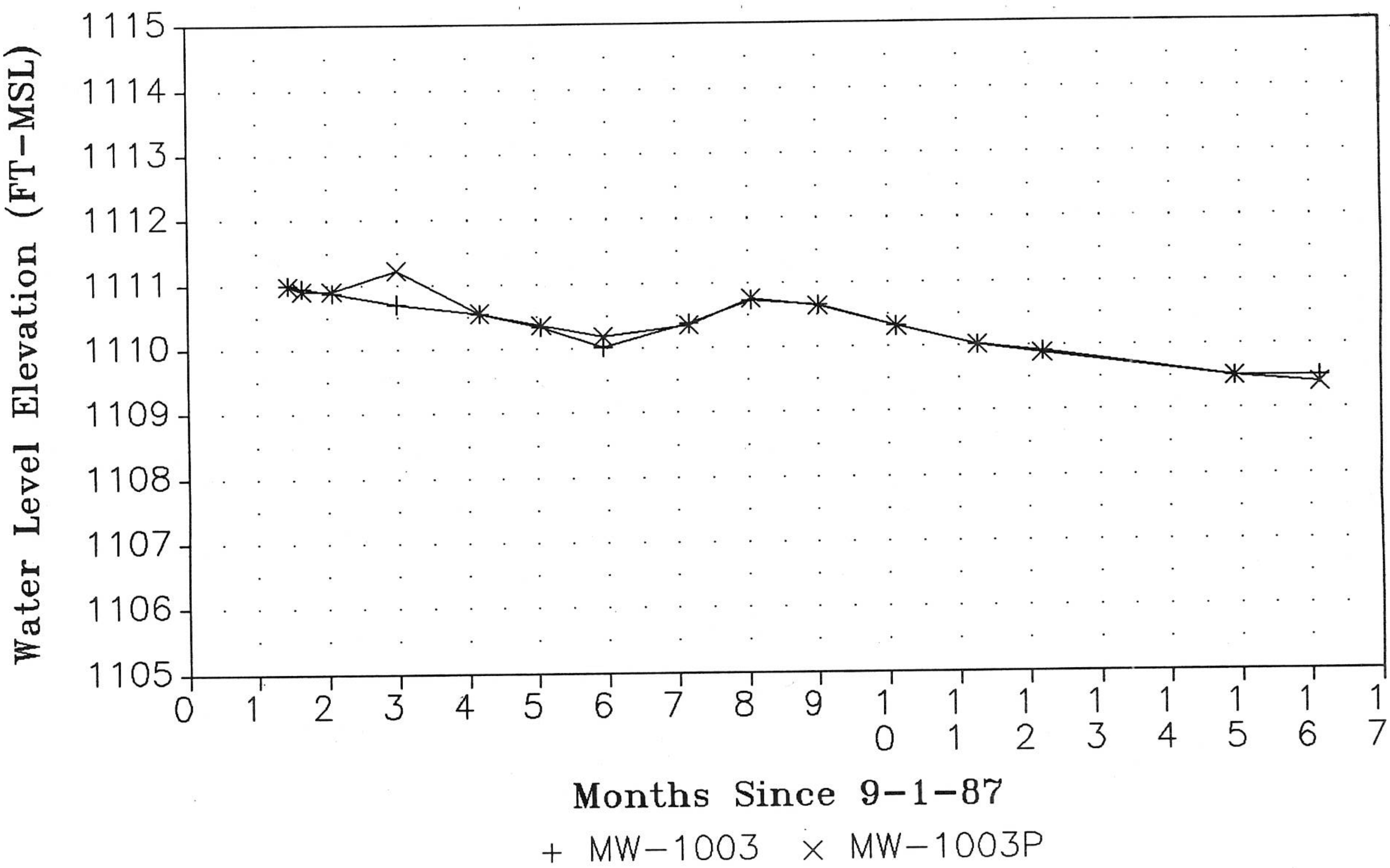
FOTH & VAN DYKE
GEOSCIENCES & ENVIRONMENTAL MANAGEMENT DIVISION
GREEN BAY, WISCONSIN

KENNECOTT MINERALS COMPANY
FLAMBEAU PROJECT
LADYSMITH, WISCONSIN

FIGURE NO 3.6-12
HYDROGRAPH
WELL NEST 1002

No	REVISIONS	NOTES	APPROVAL	DATE
△			DESIGNED BY	
△			DRAWN BY RDM	3/89
△			CHECKED BY BNP	3/89
△			APPROVED BY	
△			CAD No.	SCALE

Job No	Dwg No	REV



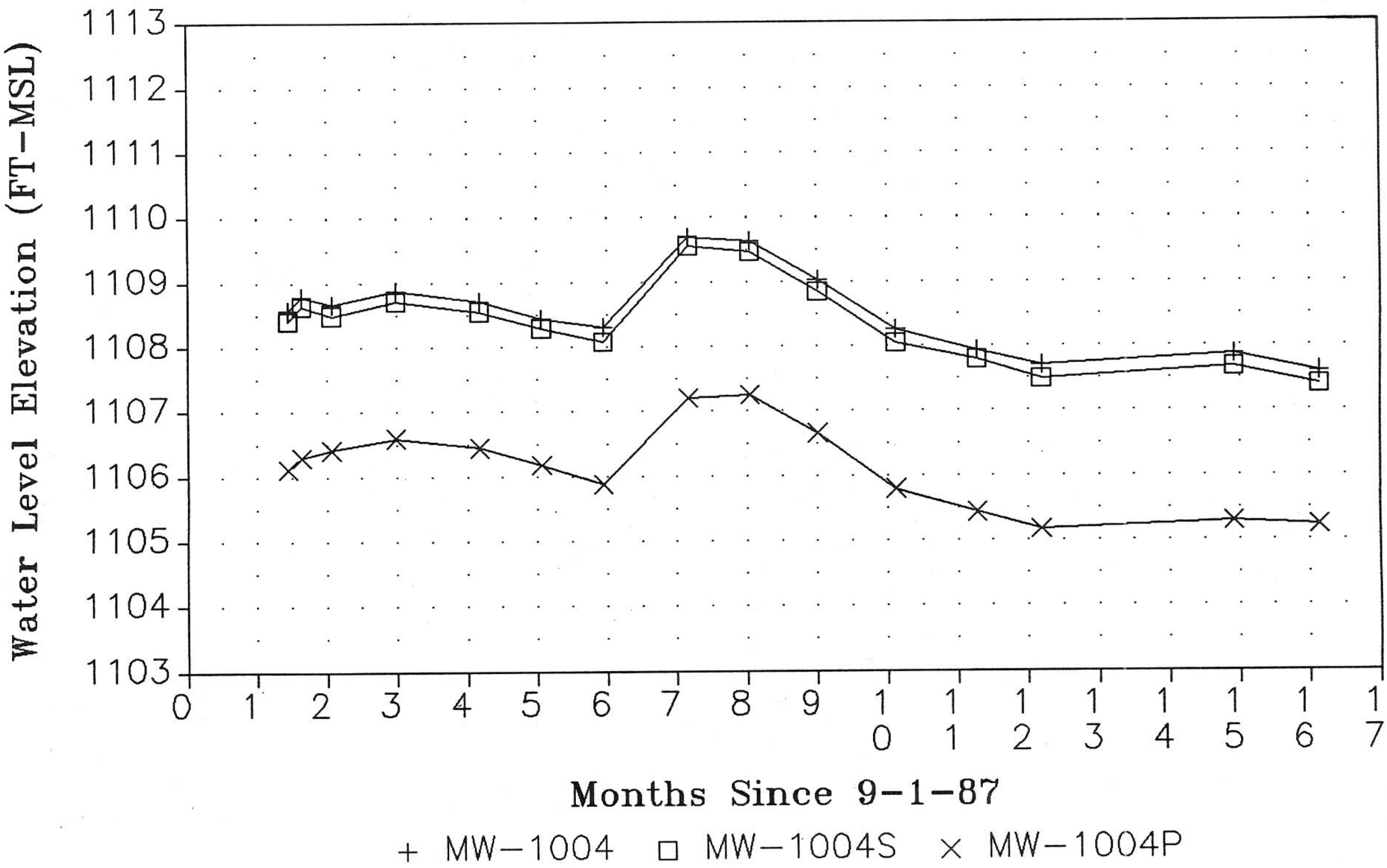
FOTH & VAN DYKE
GEOSCIENCES & ENVIRONMENTAL MANAGEMENT DIVISION
GREEN BAY, WISCONSIN

KENNECOTT MINERALS COMPANY
FLAMBEAU PROJECT
LADYSMITH, WISCONSIN

FIGURE NO 3.6-13
HYDROGRAPH
WELL NEST 1003

No	REVISIONS	NOTES	APPROVAL		DATE
△			DESIGNED BY		
△			DRAWN BY	RDM	3/89
△			CHECKED BY	BNP	3/89
△			APPROVED BY		
△			CAD No.	SCALE	

Job No | Dwg No | REV



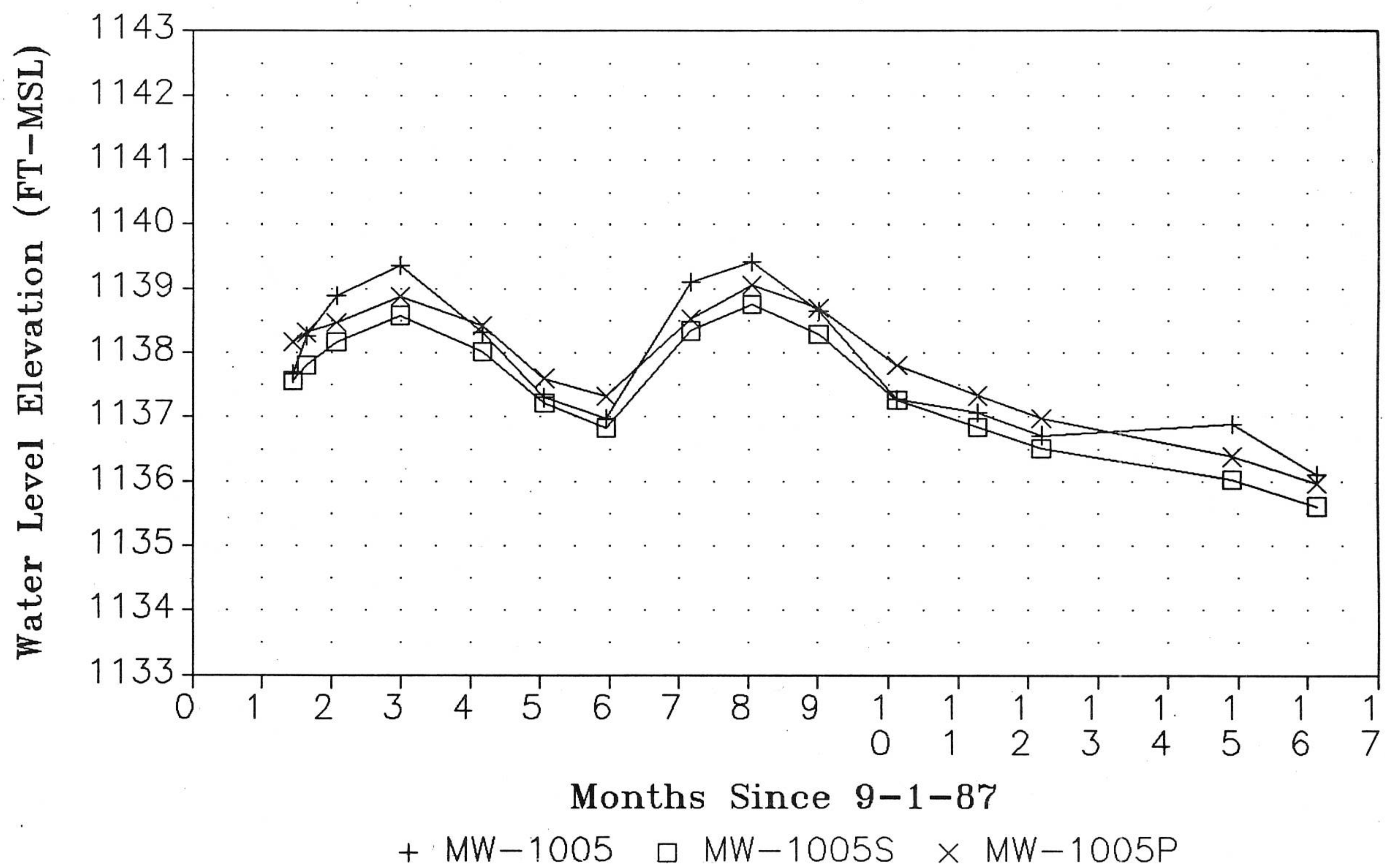
FOTH & VAN DYKE
GEOSCIENCES & ENVIRONMENTAL MANAGEMENT DIVISION
GREEN BAY, WISCONSIN

KENNECOTT MINERALS COMPANY
FLAMBEAU PROJECT
LADYSMITH, WISCONSIN

FIGURE NO 3.6-14
HYDROGRAPH
WELL NEST 1004

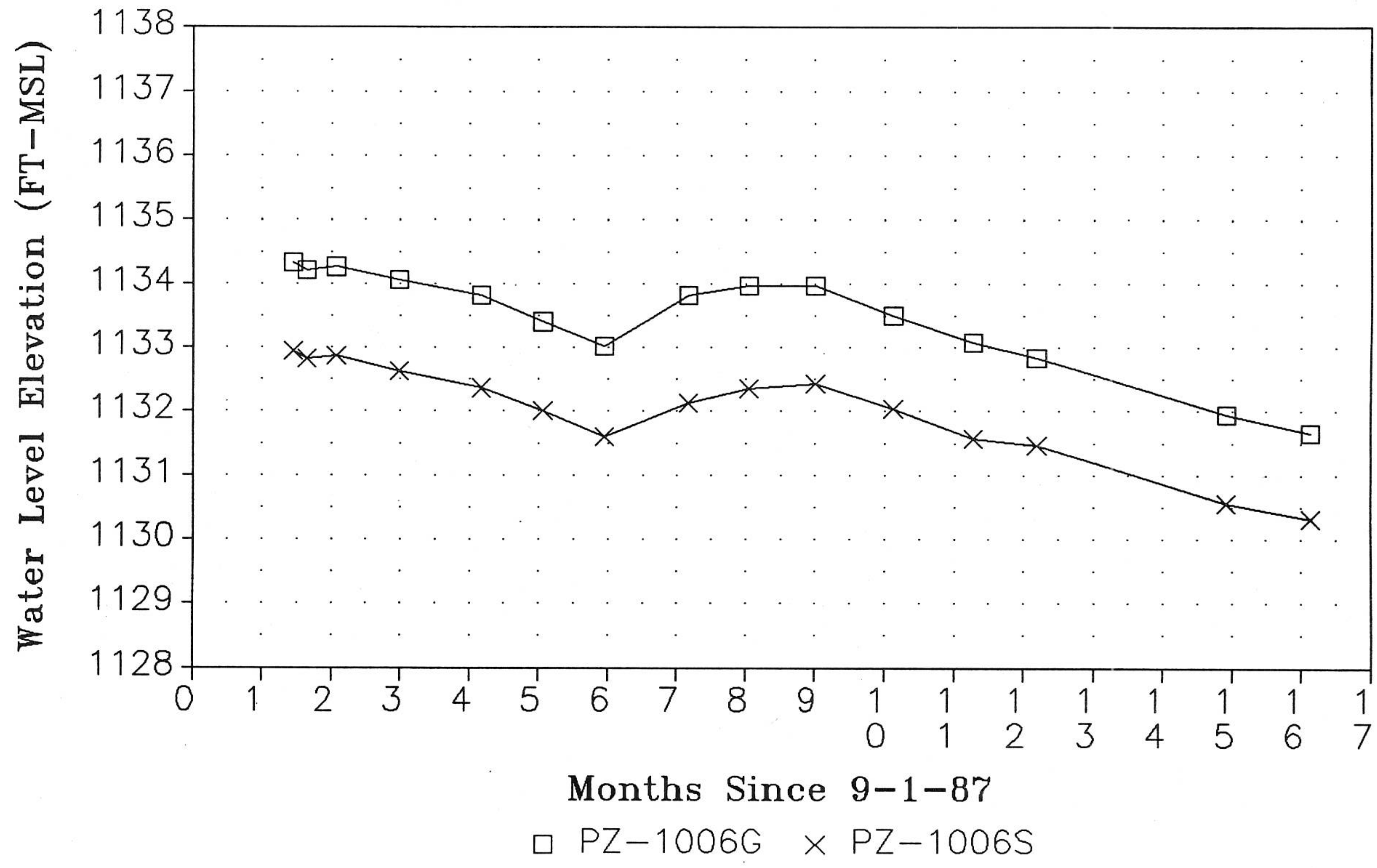
No	REVISIONS	NOTES	APPROVAL		DATE
△			DESIGNED BY		
△			DRAWN BY	RDM	3/89
△			CHECKED BY	BNP	3/89
△			APPROVED BY		
△			CAD No.	SCALE	

Job No	Dwg No	REV



FOTH & VAN DYKE GEOSCIENCES & ENVIRONMENTAL MANAGEMENT DIVISION GREEN BAY, WISCONSIN		KENNECOTT MINERALS COMPANY FLAMBEAU PROJECT LADYSMITH, WISCONSIN
APPROVAL	DATE	FIGURE NO 3.6-15 HYDROGRAPH WELL NEST 1005
DESIGNED BY		
DRAWN BY RDM	3/89	
CHECKED BY BNP	3/89	
APPROVED BY		
CAD No.	SCALE	Job No. / Dwg No. / REV

No	REVISIONS	NOTES
△		
△		
△		
△		
△		



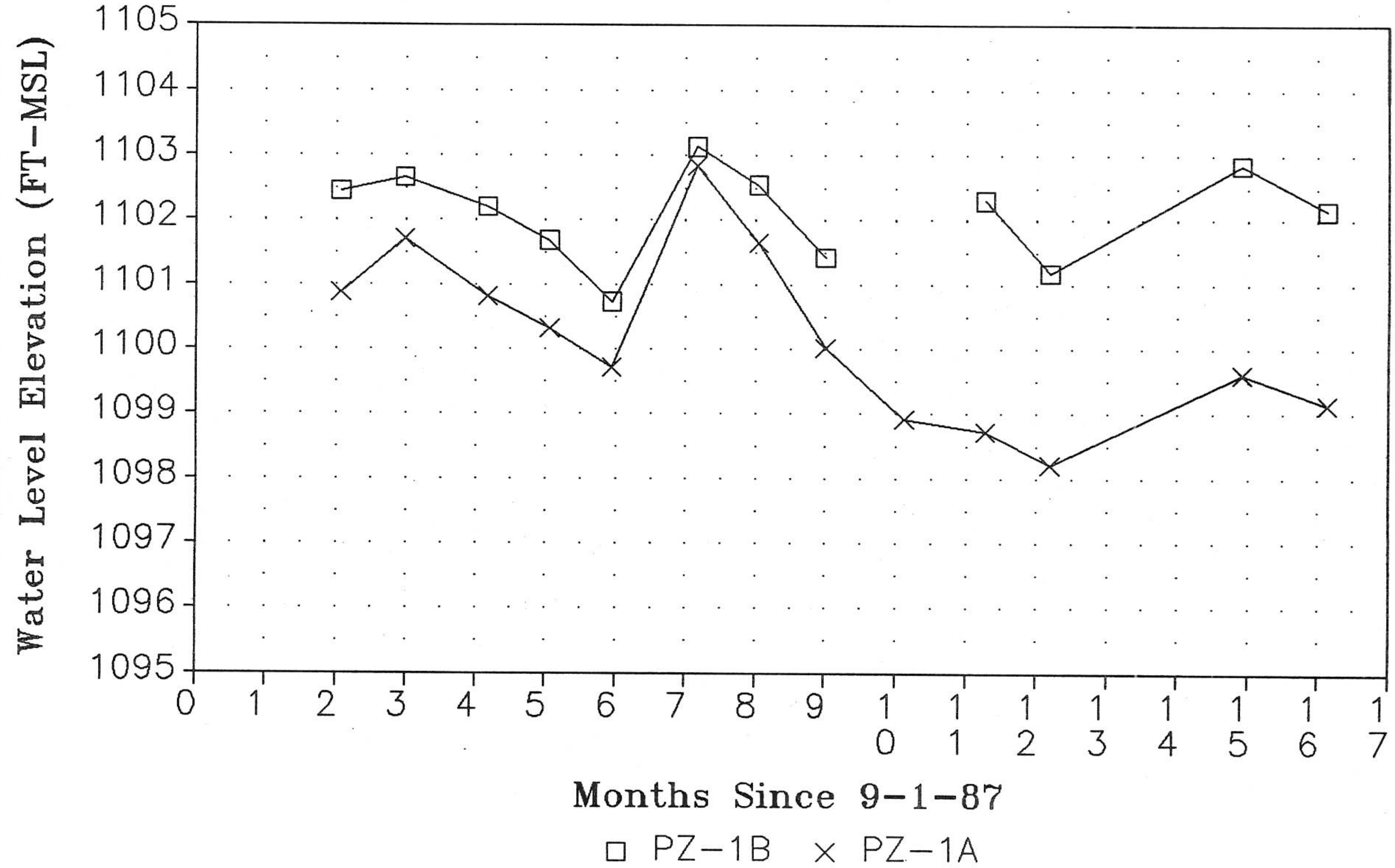
FOTH & VAN DYKE
GEOSCIENCES & ENVIRONMENTAL MANAGEMENT DIVISION
GREEN BAY, WISCONSIN

KENNECOTT MINERALS COMPANY
FLAMBEAU PROJECT
LADYSMITH, WISCONSIN

FIGURE NO. 3.6-16
HYDROGRAPH
PIEZOMETER NEST 1006

No	REVISIONS	NOTES	APPROVAL	DATE
△			DESIGNED BY	
△			DRAWN BY RDM	3/89
△			CHECKED BY BNP	3/89
△			APPROVED BY	
△			CAD No. / SCALE	

Job No | Dwg No | REV



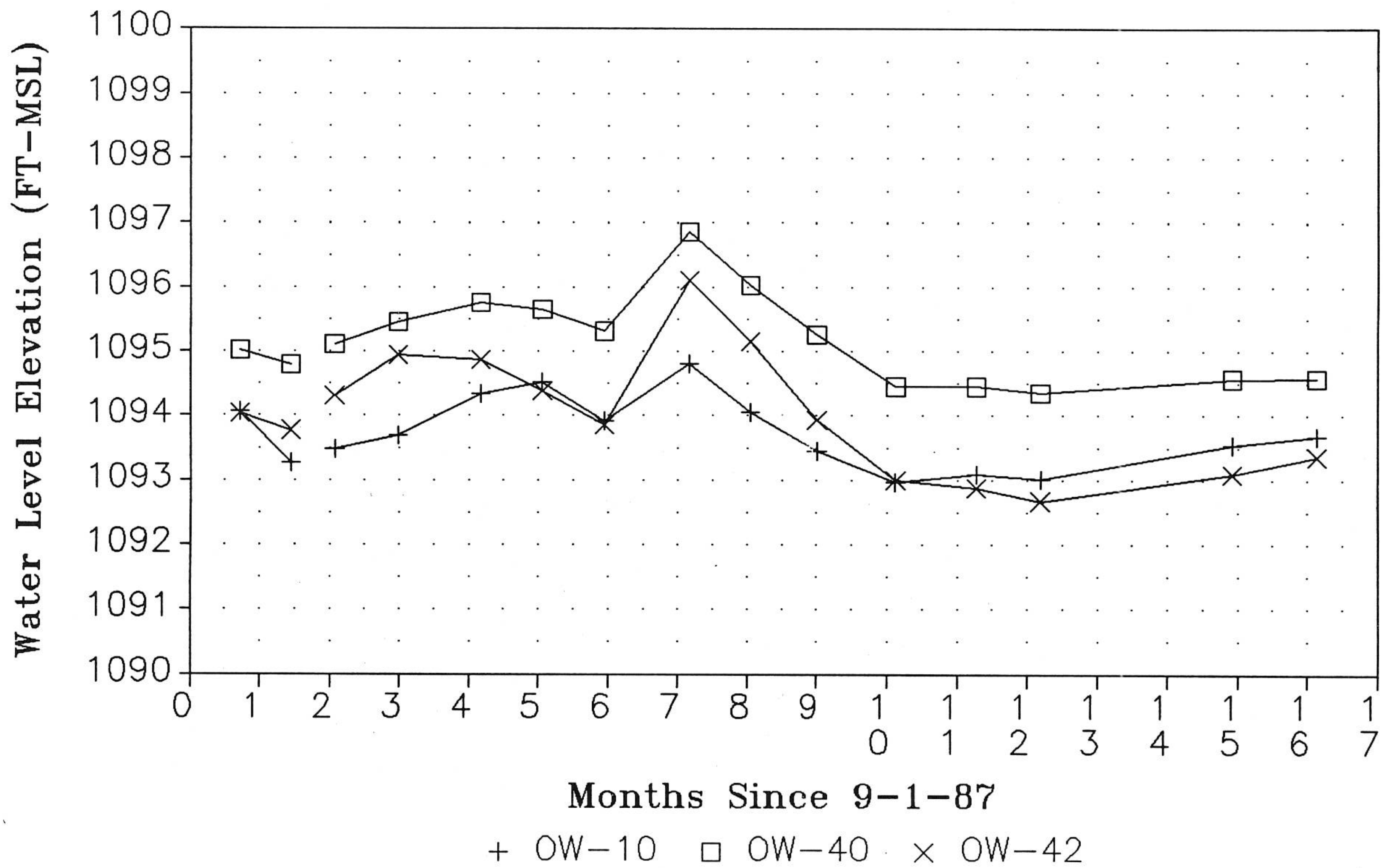
FOTH & VAN DYKE
GEOSCIENCES & ENVIRONMENTAL MANAGEMENT DIVISION
GREEN BAY, WISCONSIN

KENNECOTT MINERALS COMPANY
FLAMBEAU PROJECT
LADYSMITH, WISCONSIN

FIGURE NO 3.6-17
HYDROGRAPH
PIEZOMETER NEST PZ-I

No	REVISIONS	NOTES	APPROVAL	DATE
△			DESIGNED BY	
△			DRAWN BY RDM	3/89
△			CHECKED BY BNP	3/89
△			APPROVED BY	
△			CAD No. / SCALE	

Job No | Dwg No | REV



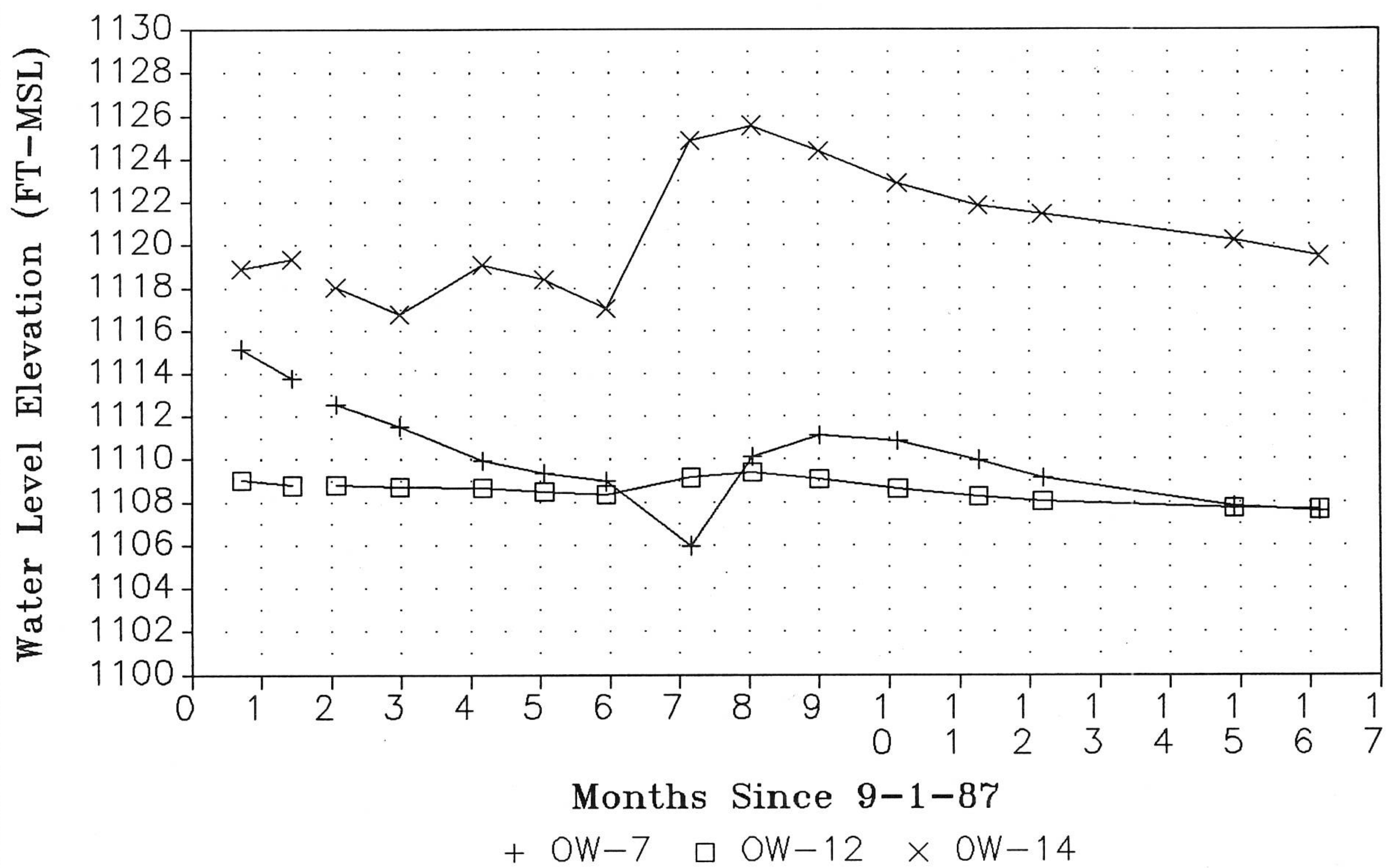
FOTH & VAN DYKE
GEOSCIENCES & ENVIRONMENTAL MANAGEMENT DIVISION
GREEN BAY, WISCONSIN

KENNECOTT MINERALS COMPANY
FLAMBEAU PROJECT
LADYSMITH, WISCONSIN

No	REVISIONS	NOTES	APPROVAL		DATE
△			DESIGNED BY		
△			DRAWN BY	RDM	3/89
△			CHECKED BY	BNP	3/89
△			APPROVED BY		
△			CAD No.	SCALE	

FIGURE NO 3.6-18
HYDROGRAPH
OW 10, 40, AND 42

Job No | Dwg No | REV



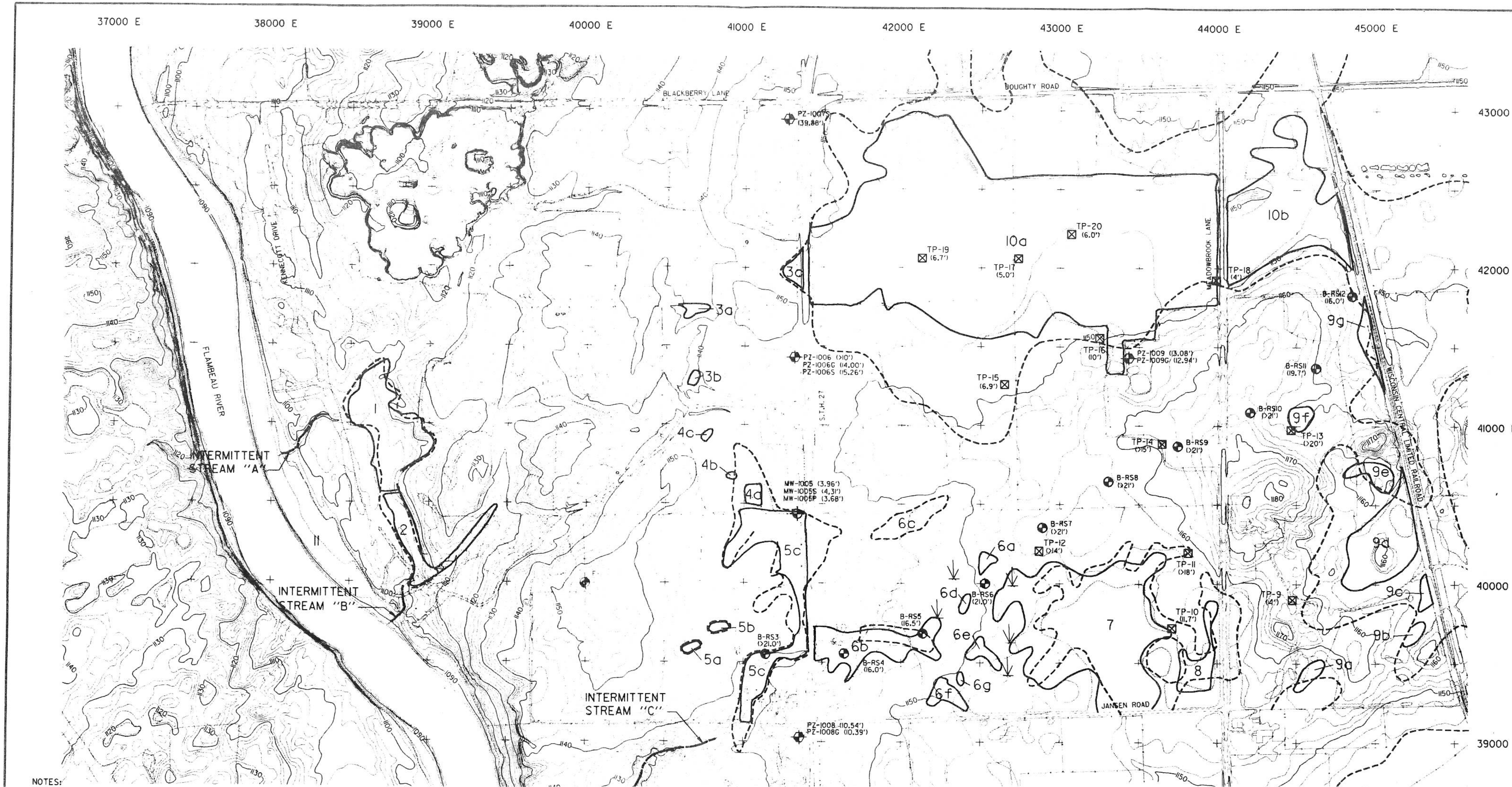
FOTH & VAN DYKE
GEOSCIENCES & ENVIRONMENTAL MANAGEMENT DIVISION
GREEN BAY, WISCONSIN

KENNECOTT MINERALS COMPANY
FLAMBEAU PROJECT
LADYSMITH, WISCONSIN

No	REVISIONS	NOTES	APPROVAL		DATE
△			DESIGNED BY		
△			DRAWN BY	RDM	3/89
△			CHECKED BY	BNP	3/89
△			APPROVED BY		
△			CAD No.	SCALE	

FIGURE NO 3.6-19
HYDROGRAPH
OW 7, 12, AND 14

Job No.	Dwg No	REV



NOTES:

1. SITE LOCATION: SECTIONS 9, 10, 15 & 16, T34N, R6W, RUSK COUNTY, WISCONSIN.
2. TOPOGRAPHIC BASE MAP PREPARED FROM AERIAL SURVEY BY SURDEX CORPORATION, CHESTERFIELD, MISSOURI. DATE OF PHOTOGRAPHY - APRIL 24, 1970.
   ROADS, TREES AND BUILDINGS WERE UPDATED AS PER AERIAL PHOTOGRAPH TAKEN BY MARKHURD CORPORATON, MINNEAPOLIS, MINNESOTA.
   DATE OF PHOTOGRAPHY - SEPTEMBER 14, 1987.
3. ELEVATIONS BASED ON MEAN SEA LEVEL DATUM.
   CONTOUR INTERVAL IS TWO FEET.
4. HORIZONTAL DATUM BASED ON PROJECT SITE GRID SYSTEM. SITE GRID COORDINATES CORRELATION TO STATE PLANE COORDINATES DERIVED AS FOLLOWS:

SITE GRID COORDINATES CONTROL MONUMENT F-1	STATE PLANE COORDINATES
40000 N =	587, 357. 8087 N
40000 E =	1, 713, 516. 1229 E

THE ANGULAR ROTATION FROM STATE PLANE BEARINGS TO SITE GRID BEARINGS IS 359°-13'-23" RIGHT WITH CONTROL POINT F-1 AS THE BASE POINT.

LEGEND

- —1100— EXISTING CONTOUR
- EXISTING PAVED ROADWAY
- EXISTING TRAIL/GRAVEL SURFACE
- TREES AND/OR BRUSH
- FENCE
- F-1 CONTROL MONUMENT
- TP-10 (10.3') TEST PIT LOCATION AND DEPTH TO GROUNDWATER
- PZ-R3 (12.3') PIEZOMETER LOCATION AND DEPTH TO GROUNDWATER
- B-RS3 (18.7') SOIL BORING LOCATION AND DEPTH TO GROUNDWATER
- HYDRIC SOILS
- HYDROPHYTIC VEGETATION
- 7 WETLAND AREA DESIGNATION

0 300' 600'
SCALE

REFERENCES DWG. NO.	DESCRIPTION	REFERENCES DWG. NO.	DESCRIPTION	NO.	DATE	REVISIONS	BY	CHK'D	ENG'R	ENG'R MGR.	NO.	DATE	REVISIONS	BY	CHK'D	ENG'R	ENG'R MGR.

FOTH & VAN DYKE
GEOSCIENCES & ENVIRONMENTAL MANAGEMENT DIVISION
GREEN BAY, WISCONSIN

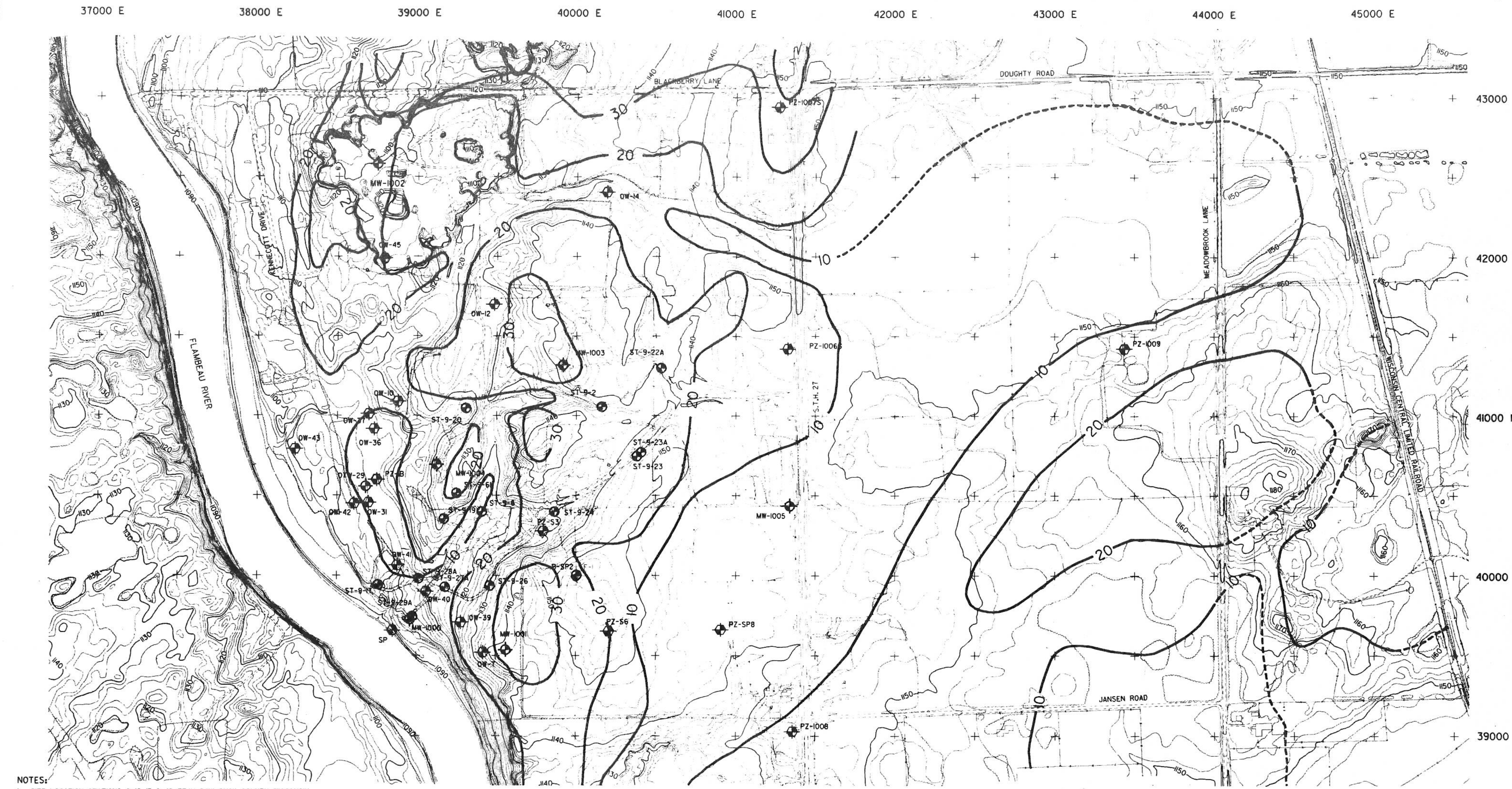
	BY	DATE		BY	DATE
PROJ. ENG'R			DESIGN		
MGR. PROCESS ENG'R			DRAWN	M.J.O.	3/89
ENG'R MGR.			CHK'D	B.N.P.	3/89
			DES. ENG'R		
			SECT ENG'R		

FLAMBEAU PROJECT
LADYSMITH, WISCONSIN

KENNECOTT MINERALS COMPANY
1515 MINERAL SQUARE
SALT LAKE CITY, UTAH
84112

FIGURE NO. 3.6-20
LOCATION OF WETLANDS, TEST PITS, AND BORINGS IN SECTIONS 9 & 10

MICROFILM | JOB
DRAWING NO. | REV.
DIVISION DRAWING NO.
SCALE | SEE BAR SCALE



NOTES:

1. SITE LOCATION: SECTIONS 9, 10, 15 & 16, T34N, R6W, RUSK COUNTY, WISCONSIN.
2. TOPOGRAPHIC BASE MAP PREPARED FROM AERIAL SURVEY BY SURDEX CORPORATION, CHESTERFIELD, MISSOURI. DATE OF PHOTOGRAPHY - APRIL 24, 1970. ROADS, TREES AND BUILDINGS WERE UPDATED AS PER AERIAL PHOTOGRAPH TAKEN BY MARKHURD CORPORATON, MINNEAPOLIS, MINNESOTA. DATE OF PHOTOGRAPHY - SEPTEMBER 14, 1987.
3. ELEVATIONS BASED ON MEAN SEA LEVEL DATUM. CONTOUR INTERVAL IS TWO FEET.
4. HORIZONTAL DATUM BASED ON PROJECT SITE GRID SYSTEM. SITE GRID COORDINATES CORRELATION TO STATE PLANE COORDINATES DERIVED AS FOLLOWS:

SITE GRID COORDINATES CONTROL MONUMENT F-1	STATE PLANE COORDINATES
40000 N =	587, 357. 8087 N
40000 E =	1, 713, 516. 1229 E

THE ANGULAR ROTATION FROM STATE PLANE BEARINGS TO SITE GRID BEARINGS IS 359°-13'-23" RIGHT WITH CONTROL POINT F-1 AS THE BASE POINT.

LEGEND

—1100—	EXISTING CONTOUR
	EXISTING PAVED ROADWAY
	EXISTING TRAIL/GRAVEL SURFACE
	TREES AND/OR BRUSH
	FENCE
F-1	CONTROL MONUMENT
MW-1005	MONITORING WELL
PZ-S4	PIEZOMETER
ST-9-2	SOIL BORING
— 20 —	DEPTH TO WATER ISOPACH CONTOUR

REFERENCES DWG. NO.	DESCRIPTION	REFERENCES DWG. NO.	DESCRIPTION	NO.	DATE	REVISIONS	BY	CHK'D	ENG'R	ENG'R MGR.	NO.	DATE	REVISIONS	BY	CHK'D	ENG'R	ENG'R MGR.

FOTH & VAN DYKE
GEOSCIENCES & ENVIRONMENTAL MANAGEMENT DIVISION
GREEN BAY, WISCONSIN

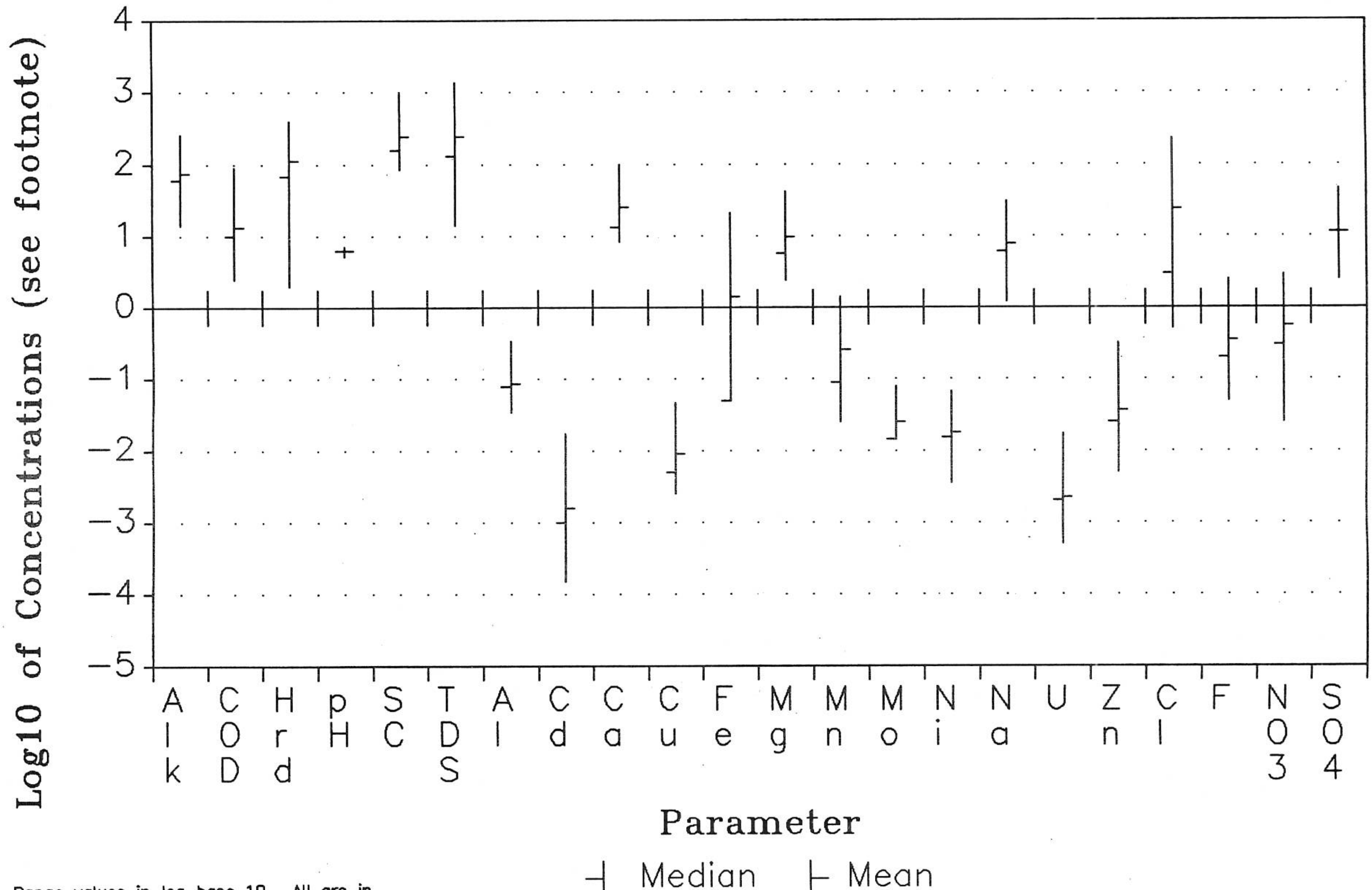
	BY	DATE		BY	DATE
PROJ. ENG'R			DESIGN		
MGR. PROCESS ENG'R			DRAWN	M.J.O.	3/89
ENG'R MGR.			CHK'D	B.N.P.	3/89
			DES. ENG'R		
			SECT ENG'R		

FLAMBEAU PROJECT
LADYSMITH, WISCONSIN

KENNECOTT MINERALS COMPANY
155 MINERAL SQUARE
SALT LAKE CITY, UTAH
84112

FIGURE NO. 3.6-21
DEPTH TO WATER
ISOPACH MAP

MICROFILM	JOB
DRAWING NO.	REV.
DIVISION DRAWING NO.	
SCALE	SEE BAR SCALE



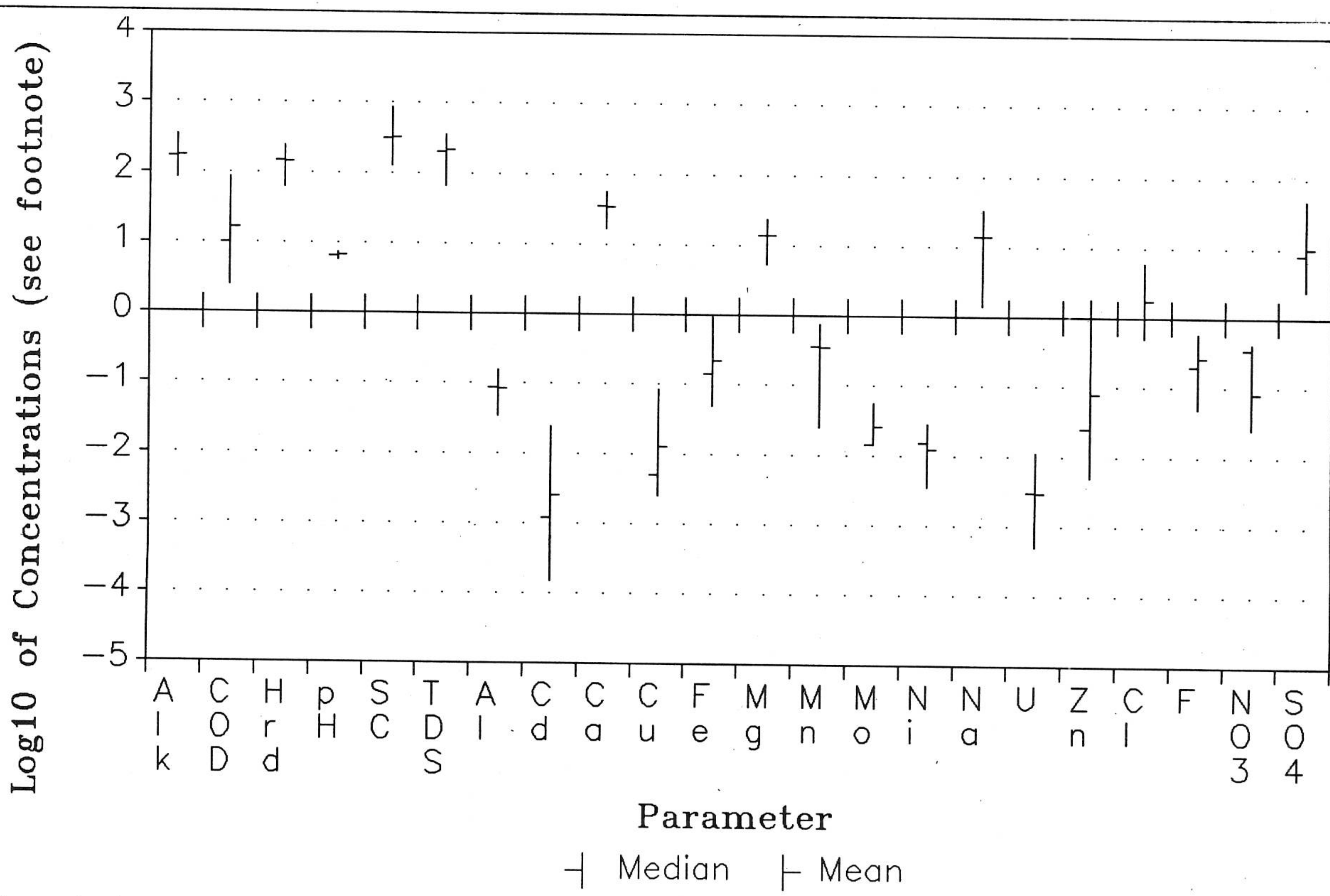
Range values in log base 10. All are in mg/l except specific conductivity (umho/cm) and pH (Standard Units).

FOTH & VAN DYKE GEOSCIENCES & ENVIRONMENTAL MANAGEMENT DIVISION GREEN BAY, WISCONSIN	KENNECOTT MINERALS COMPANY FLAMBEAU PROJECT LADYSMITH, WISCONSIN

No	REVISIONS	NOTES	APPROVAL		DATE
△			DESIGNED BY		
△			DRAWN BY	RDM	3/89
△			CHECKED BY	BNP	3/89
△			APPROVED BY		
△			CAD No.	SCALE	

FIGURE NO 3.6-22
OVERBURDEN
GROUNDWATER QUALITY RANGES

Job No	Dwg No	REV



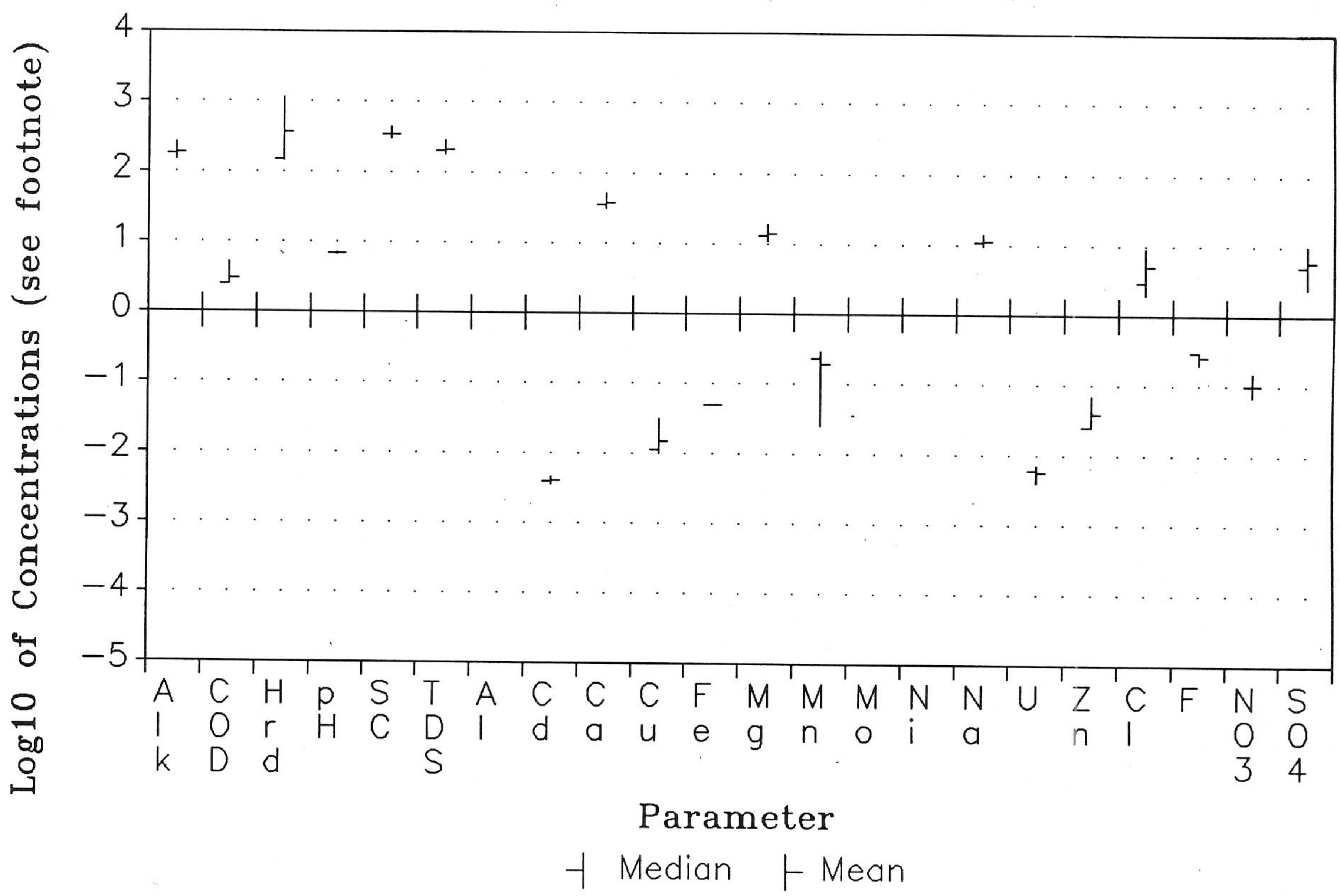
Range values in log base 10. All are in mg/l except specific conductivity (umho/cm) and pH (Standard Units).

FOTH & VAN DYKE GEOSCIENCES & ENVIRONMENTAL MANAGEMENT DIVISION GREEN BAY, WISCONSIN	KENNECOTT MINERALS COMPANY FLAMBEAU PROJECT LADYSMITH, WISCONSIN

No	REVISIONS	NOTES	APPROVAL		DATE
△			DESIGNED BY		
△			DRAWN BY	RDM	3/89
△			CHECKED BY	BNP	3/89
△			APPROVED BY		
△			CAD No.	SCALE	

FIGURE NO 3.6-23
SHALLOW PRECAMBRIAN
GROUNDWATER QUALITY RANGES

Job No	Dwg No	REV



Range values in log base 10. All are in mg/l except specific conductivity (umho/cm) and pH (Standard Units).

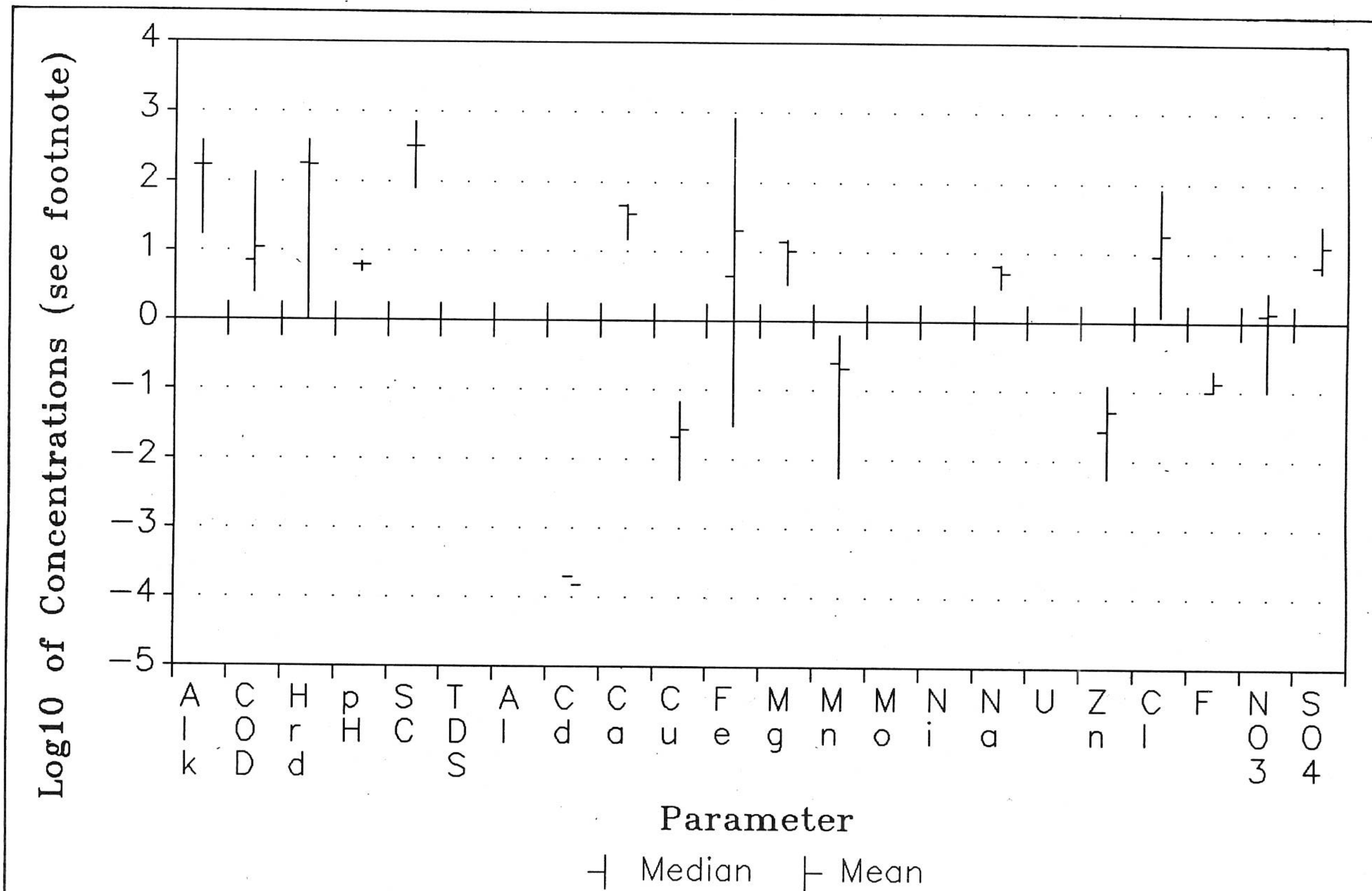
FOTH & VAN DYKE
GEOSCIENCES & ENVIRONMENTAL MANAGEMENT DIVISION
GREEN BAY, WISCONSIN

KENNECOTT MINERALS COMPANY
FLAMBEAU PROJECT
LADYSMITH, WISCONSIN

FIGURE NO 3.6–24
DEEP PRECAMBRIAN
GROUNDWATER QUALITY RANGES

No	REVISIONS	NOTES	APPROVAL		DATE
△			DESIGNED BY		
△			DRAWN BY	RDM	3/89
△			CHECKED BY	BNP	3/89
△			APPROVED BY		
△			CAD No.	SCALE	

Job No	Dwg No	REV



Range values in log base 10. All are in mg/l except specific conductivity (umho/cm) and pH (Standard Units).

FOTH & VAN DYKE
GEOSCIENCES & ENVIRONMENTAL MANAGEMENT DIVISION
GREEN BAY, WISCONSIN

KENNECOTT MINERALS COMPANY
FLAMBEAU PROJECT
LADYSMITH, WISCONSIN

FIGURE NO 3.6-25
PRIVATE WELL
GROUNDWATER QUALITY RANGES

No	REVISIONS	NOTES	APPROVAL	DATE
△			DESIGNED BY	
△			DRAWN BY RDM	3/89
△			CHECKED BY BNP	3/89
△			APPROVED BY	

CAD No. SCALE Job No. Dwg No. REV