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"Technical Support for Grassroots Public Interest Groups"

Report on
Groundwater and Surface Water Contamination
at the Flambeau Mine

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SURFACE WATER

The Flambeau Mine, an open-pit copper-gold-silver mine located near Ladysmith, Wisconsin was permitted in January 1991 and began production in 1993. The ore body, characterized as a "Precambrian supergene enriched massive sulfide deposit," [1] yielded 181,000 tons of copper, 334,000 ounces of gold and 3.3 million ounces of silver over the mine's brief four-year lifespan.[2] Approximately 4.5 million tons of waste rock characterized as "high sulfur" and 4 million tons of "low sulfur" waste were generated and stockpiled on site for eventual return to the pit.[3]

When mine operations ceased in 1997, the open pit was 220 feet deep, a half mile long and 32 acres in size. Backfill operations commenced promptly, and over 30,000 tons of limestone was blended into the sulfide-bearing waste rock on relocation.[4] In addition, a layer of non-acid generating waste was placed on top of the acid-generating waste backfilled into the pit. Although groundwater has infiltrated the backfilled pit, the combination of neutralizing limestone and submergence of the acid-generating material in water, which limits the availability of oxygen, is meant to slow the generation of acid and dissolution of metals in this material to an acceptable amount.

Backfill operations were completed by early 1998, at which time surface reclamation began. This entailed recontouring the surface, spreading topsoil and establishing plant communities. In late 2001 a Notice of Completion for reclamation activities was submitted to the state regulatory agency, followed by a mandatory four-year monitoring period.

A partial Certificate of Completion for reclamation activities was granted in May 2007 subsequent to an agreement negotiated between opposing parties at a contested case hearing. Groundwater contamination within the backfilled pit, exceedances of applicable groundwater standards at the mine's legally-

[1] "Flambeau – A Precambrian Supergene Enriched Massive Sulfide Deposit," *Geoscience Wisconsin*, July 1977
[2] Flambeau Mining Company, 2007 Annual Report, January 2008, pg 3
[3] Flambeau Mining Company, 1997 Backfilling Plan for Stockpiled Type II Material, March 1997, pg ii-iii
[4] Flambeau Mining Company, 2007 Annual Report, January 2008, pg 3

established intervention boundary, and data related to potential impacts of the mine on macroinvertebrates, sediment, crayfish, and walleye in the Flambeau River were not assessed as part of the certification process and therefore did not factor into the decision. Rather, partial certification for the site was based upon completion of backfill operations according to plan and successful revegetation of the surface. Due to ongoing problems with surface water pollution in a small creek that receives runoff from the mine site, certification was withheld for a 32-acre section of the mine site known as the Industrial Outlot. The Industrial Outlot includes the area where the mine's rail spur, runoff and surge ponds, water treatment plant and administrative building were located during the mining years, as well as a portion of the high sulfur waste rock stockpile**.**

During mining, water was pumped from the pit to keep it relatively dry. This pumping caused a groundwater cone of depression to form around the pit, directing all groundwater flow during mining toward the pit. At mine closure the pumping ceased and natural groundwater flow patterns were restored. The southwestern edge of the pit is 140 feet from the Flambeau River. The pit is separated from the Flambeau River by a slurry cutoff wall designed to limit groundwater flow to/from the river both during and after mining. The post-mining groundwater hydrology is described as flow from the pit towards the Flambeau River (see Figure A and Figure B).

Ore from the mine received only minimal processing at the mine site. An ore crusher was positioned close to a mine site rail terminal, and from there the ore was shipped to Canada for further processing. During mining, water pumped from the pit that came in contact with acid-generating rock and contaminated water from the mine's high sulfur waste rock stockpile was routed to a surge pond and from there to an onsite water treatment plant. After mining ceased, the reclamation plan was modified to allow the surge pond to stay in place, and the pond was modified to facilitate its use as a biofilter for treating water collected from the southeast corner of the mine site where the Industrial Outlot is located (see Figure C). This wetland, the "Outlot (0.9 acre) Biofilter," now discharges into Stream C, which flows into the Flambeau River (See Figure D).

There are presently two areas of concern with regard to contamination of water coming from the reclaimed mine site.

First: Water discharged from the Outlot Biofilter wetland into Stream C does not meet Wisconsin surface water quality standards. This water flows into the Flambeau River.

Second: Groundwater in a monitoring well between the pit and the Flambeau River (on the Flambeau River side of the slurry wall separating the pit from the river) does not meet Wisconsin groundwater quality standards.

Stream C

Stream C originates in an area just northeast of where the rail spur was located during mining, and then flows through the eastern portion of the Industrial Outlot where the discharge from the Outlot Biofilter joins it. Stream C flows southwest for approximately one half mile and discharges directly into the Flambeau River. Today the stream is relatively small and has little aquatic life. The pre-mining data is insufficient to document the flow or extent of aquatic life.

Stream C is classified as "navigable" and "intermittent." Presence of aquatic life in Stream C has been documented when it is flowing, and observation of unimpacted streams in the vicinity suggests that aquatic life was probably present before mining. Flow in Stream C is not likely to have been increased by mining activity and reclamation, since the backfilled pit constitutes a preferential flow path away from Stream C, and the industrial activities at the present site (roads, parking lots, buildings, etc.) would enhance stormwater runoff and lessen stream base flow related to groundwater recharge.

Stream C Water Quality

There appears to be no quantitative or qualitative pre-mining water quality data for Stream C, but there is nothing to indicate that the pre-mining background levels of copper in Stream C were at the levels measured post-mining. All indications appear to be that Stream C was much like other streams in this area – relatively clean water with low copper content. It is interesting to note that the discharge from the wetland/biofilter is a direct point discharge into a water of the State/US, hence could or should be governed by the discharge permit requirements of the Clean Water Act.

Water quality data for Stream C has been recorded only sporadically. In 2004-2005 Foth & Van Dyke of Green Bay, Wisconsin, recorded data from multiple Stream C locations on four different days. Although this may not be a true synoptic sample, it is probably as close as can be had to synoptic data for this site. Of the analytes recorded in the data for Stream C it appears that copper is a contaminant of significant concern. This is potentially significant since aquatic organisms are not only very sensitive to copper,[5] but also sensitive to changes in copper over background levels.[6]

At the present time the levels of copper in the discharge from the wetland/biofilter, and from Stream C into the Flambeau River, both exceed Wisconsin water quality standards.

The data in Table 1 is taken from the report "Stream C - 2005 Analysis of Collected Data," Foth & Van Dyke, October 10, 2005, Figure 2; and, "2008 Monitoring Results and Copper Park Lane Work Plan," Foth Infrastructure & Environment, Table 1 – 2008 Monitoring Results. The full Foth & Van Dyke Figure 2, which contains most of the reported surface water data from Stream C, is attached as Figure E. The data for two of these sites is presented in Table 1 – station BFSW-C2, the outlet from the wetland/biofilter, and station SW-C6, Stream C just before it flows into the Flambeau River.

Table 1: Stream C Water Quality Data

	Date						
***from WAC NR 105.06 (Nov08)**	**15Sep04**	**23Oct04**	**26Apr05**	**09Jun05**	**25Apr08**	**8Jun08**	**27Oct08**
Biofilter Outlet BFSW-C2							
Copper (Cu) (µg/L)	67	28	27	46	22	8.8	16
Hardness (mg/L)	24	24	29	32	27	19	17
pH, Lab (s.u.)	6.37	6.64	6.82	6.85	7.63	7.31	6.83
Chronic Copper Water Quality Standard based on Hardness (µg/L)*	3.1	3.1	3.6	3.9	3.4	2.5	2.3
Acute Copper Water Quality Standard based on Hardness (µg/L)*	4.0	4.0	4.8	5.3	4.5	3.2	2.9
Stream C Outlet SW-C6							
Copper (Cu) (µg/L)	34	15	14	36	no data	no data	no data
Hardness (mg/L)	35	82	39	31	no data	no data	no data
pH, Lab (s.u.)	6.20	6.52	7.19	6.67	no data	no data	no data
Chronic Copper Water Quality Standard based on Hardness (µg/L)*	4.2	8.7	4.6	3.8	no data	no data	no data
Acute Copper Water Quality Standard based on Hardness (µg/L)*	5.8	12.9	6.4	5.1	no data	no data	no data

[5] Hall et al. 1988, Eisler 2000, Baldwin et al. 2003
[6] Baldwin et al. 2003

It can be seen that the copper level in the water entering Stream C from the wetland/biofilter is approximately a factor of two higher than the copper level in the discharge from Stream C as it entered the Flambeau River. It would be expected that some dilution would occur as water in Stream C gets closer to the Flambeau River because of the diluting effect of the unnamed stream that enters Stream C approximately half way between the wetland/biofilter discharge point to Stream C and where Stream C enters the Flambeau River. It is also probable that there is some groundwater recharge to Stream C.

It should be noted that copper in Stream C, as shown in Table 1, exceeds Wisconsin water quality standards both at the discharge from the wetland/biofilter and from Stream C as it flows into the Flambeau River.

The water quality standard for copper is a function of the hardness of the water. Since hardness data was available, the calculated hardness-dependent values for the chronic and acute copper standard are also listed in Table 1. As can be seen from this table, both the chronic and acute standard for copper was exceeded on each day for which data was recorded.

In the 2008 Foth report a proposal to remove and replace soil from the Copper Park Lane drainage ditch is discussed. It is clear from the monitoring data that copper is coming from the drainage ditch and is loading Stream C downstream of the biofilter. The removal of the surface material in the Copper Park Lane drainage ditch should help lower the level of copper in Stream C. However, it is also clear that the level of copper coming from the biofilter itself is still enough to cause an exceedance of Wisconsin water quality standards at Stream C at the mine boundary.

It was noted in the Foth & Van Dyke report:

> "The stream appears to be very limited in biota in all aspects including aquatic vegetation, macroinvertebrate populations, and fish."[7]

A slight increase in the level of copper can form a barrier to the migration of fish.[8] Stream C flows into the Flambeau River immediately upstream of Meadowbrook Creek. Copper could potentially impact the migration of fish into and out of Meadowbrook Creek.

With copper levels significantly exceeding both chronic and acute water quality criteria, it is likely that these high metal levels are contributing to the lack of aquatic life in Stream C. These levels also suggest that better monitoring of Stream C and the Flambeau River below Stream C should be done.

The discharge from the outlet of the wetland treatment system should meet Wisconsin water quality standards at that point. There is not enough dilution in Stream C to effectively dilute contaminants, so any contaminant will impact aquatic organisms along most or all of the length of Stream C. Because of this fact, Stream C is being presently used as a conduit for contaminated water from the mine site to the Flambeau River, where dilution by the large volume of water in the river occurs.

Surface water data from 2008 shows that at SW-C5 (below the biofilter discharge to Stream C, but above the contribution from the Copper Park Lane ditch) the copper level is approximately 10 times the hardness-based acute water quality standard, and the zinc level is approximately twice the hardness-based acute water quality standard.[9] Copper and zinc are synergistic metals, so their combined impact on aquatic organisms is greater than that of either by itself.

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[7] Foth & Van Dyke, 2005, p.4
[8] Baldwin et al. 2003, van Aardt et al. 2007
[9] Foth Infrastructure & Environment, 2008, Table 1 – 2008 Monitoring Results

Surface water data has been simultaneously sampled only three times at SW-2 (Flambeau River below the mine site) and SW-3 (Flambeau River just below Stream C, and below SW-2). On all three sampling dates the copper level is greater at SW-3, below the outlet of Stream C, than at SW-2. On April 25, 2008, the sample data for SW-3 show the copper level is approximately double the Wisconsin chronic water quality standard, while the copper level at SW-2 is below the standard.[10] The measured level for copper at SW-3 in the Flambeau River was 5.6 ug/L, while the hardness-based copper water quality standard is 3.2 µg/L for chronic effects, and 4.2 µg/L for acute effects. The copper level measured exceeds both the chronic and acute standards. If the copper is coming from Stream C, as would be likely, then it is probably being diluted to below the water quality standard as it enters the Flambeau River just above SW-3. Dilution of water from Stream C would constitute a "mixing zone" under a discharge permit which would extend below SW-3. At present no permit or authorized mixing zone exist.

Table 2: Flambeau River Water Quality Data

	Date		
***from WAC NR 105.06 (Nov08)**	**21Sep07**	**25Apr08**	**27Oct08**
SW-2 (Flambeau River at Mine Boundary)			
Copper (Cu) (µg/L)	<1.3	2.8	1.8
Hardness (mg/L)	60	27	57
pH, Lab (s.u.)	7.94	7.54	8.26
Chronic Copper Water Quality Standard based on Hardness (µg/L)*	6.7	3.4	6.4
Acute Copper Water Quality Standard based on Hardness (µg/L)*	9.6	4.5	9.1
SW-3 (Flambeau River below Stream C)			
Copper (Cu) (µg/L)	4.2	5.6	2.7
Hardness (mg/L)	53	25	56
pH, Lab (s.u.)	7.83	7.46	8.25
Chronic Copper Water Quality Standard based on Hardness (µg/L)*	6.0	3.2	6.3
Acute Copper Water Quality Standard based on Hardness (µg/L)*	8.5	4.2	9.0

In order to address the question of whether the increase in copper at SW-3 is coming from Stream C, water quality samples should be taken in Stream C just prior to its discharge point into the Flambeau River. This could be easily accomplished by reactivating sampling station SW-C6, which was sampled from September, 2004 to June, 2005.

At the present time the levels of copper in the discharge from the wetland/biofilter, and from Stream C into the Flambeau River, both exceed Wisconsin water quality standards. This discharge of copper appears to be impacting the water in the Flambeau River, as measured at SW-3 just downstream of the junction of Stream C with the river.

Recommendation:* *In order to address the question of the amount of copper contamination entering the Flambeau River from Stream C, and the increase in copper at SW-3, water quality samples should be taken in Stream C just prior to its discharge point into the Flambeau River. This should be done by reactivating sampling station SW-C6, which was sampled from September, 2004 to June, 2005.

[10] Foth Infrastructure & Environment, 2008, Table 1 – 2008 Monitoring Results

An increase in monitoring frequency would better establish the risk presently being posed to aquatic organisms in the Flambeau River. Presently surface water sampling is being done twice per year.

Recommendation: Until it can be demonstrated that the water quality in Stream C, and in the Flambeau River below Stream C, is not being impacted by mine-related contamination, sampling in Stream C and at SW-3 in the Flambeau River, and at SW-1 and SW-2 in order to provide background water quality information, should be done at least quarterly. This frequency should be maintained for at least 5 years after water quality exceedances cease.

Copper is demonstrably the contaminant of concern. The monitoring recommendation above is the minimum necessary to adequately monitor water quality to determine the presence/absence of copper contamination. A more thorough monitoring program would also look for the presence of other potential contaminants, since it is rare that only one metal is present at elevated levels.

Recommendation: It is also recommended that once per year, in the spring sampling event, a full suite of metals and their associated indicator parameters be sampled, until water quality exceedances cease. These parameters should include Conductivity (field), pH (field), Total Suspended Solids, Total Dissolved Solids, Aluminum, Arsenic, Cadmium, Chromium, Cobalt, Copper, Lead, Mercury, Nickel, Selenium, Silver, Uranium/Radioactivity, Zinc, Hardness, Iron, Manganese, and Sulfate.

Potential Mitigation Measures for Stream C

In reviewing the Foth & Van Dyke data for Stream C it is also evident that the portion of Stream C above the junction with the wetland/biofilter also carries significant copper, and possibly some zinc contamination (See Figure E, station SW-C8). In general the data also indicates the pH is normal, with some fluctuations, and the sulfate level is low. These would all suggest that metals are being sequestered in the wetland/biofilter, but that copper may be attached to suspended sediment or organic particles flowing from the wetland/biofilter. It could also be that there is just too much copper to be effectively filtered by the existing wetland. There is little data available on total suspended solids to correlate with the available water quality data.

In either case an expanded wetland/biofilter could be constructed to give more residence/treatment time to remove copper not only from the mine site drainage, but also to include water from the upper portion of Stream C above the Lot, which also shows indications of contamination.

GROUNDWATER

The long term closure plans of the Flambeau Mining Company included backfilling the open pit with waste rock, sludge, and limestone and allowing the pit to fill with groundwater. This will submerge the rock to limit oxygen and oxidative reactions. However, this placement of reactive rock surfaces in contact with water will result in long term reactions within the pit that are unlikely to stabilize in the near future. Rock surfaces are reactive in terms of redox chemistry and solubility, resulting in localized reactions that form acid, dissolved metals, and secondary mineral oxides. To date it appears that backfilling has not resulted in additional acid production, but metal leaching is occurring and complex pit chemistry is difficult to predict over the long term. Some current and future issues include

- Solubility/precipitation reactions within the pit
- Depletion/passivation of limestone
- Dissolution and flushing of material out of the pit

Reactions within pit

To monitor pit chemistry, two pit monitoring well nests (MW-1013 and MW-1014) were constructed in September 1998 after the backfill had roughly a year to settle (see Figure F for well positions in pit). Wells were nested in order to sample water at different depths (24', 47', 86', 202' for MW-1013; 34', 64', 105', and 157' for MW-1014).

Groundwater only fully rebounded in pit wells (MW-1013, MW-1013A, MW-1014) in 2005, therefore some wells have only three years worth of water quality data. It has been recognized by FMC that pit reactions have not stabilized,[11] and that reactions (dissolution and precipitation of metals and ions) are controlled by pH and redox.[12] The long term stable condition of the pit will not be determined until redox and pH are stable. Redox continues to fluctuate in pit wells, particularly in the more shallow screens.[13] The pH is controlled by dissolution of limestone intentionally mixed with waste rock to control acid. It may take hundreds of years for the limestone to completely dissolve as FMC states,[14] but limestone could become ineffective much sooner if secondary minerals (hydroxides and carbonates) precipitate and coat limestone. If/when limestone stops going into solution, pH may drop and significantly affect the concentrations of minerals in solution.

Pit Chemistry

Sampling has indicated and continues to indicate that pit chemistry reactions have not stabilized. Manganese, copper, iron, zinc and redox remain in flux within the pit wells. This is likely due in part to localized oxidation reactions between waste rock and sludge: ferric iron (Fe^{3+}) that precipitated during mine-water treatment remains in sludge, and is available to oxidize the pyrite present in waste rock. This results in the release of ferrous iron (Fe^{2+}) and acid in localized pockets even under anoxic conditions:

$$FeS_2 + 8\,H_2O + 14\,Fe^{3+} \rightarrow 15\,Fe^{2+} + 2\,SO_4^{2-} + 16\,H^+$$

Where acid (H^+) is generated, dissolution of minerals – particularly of copper and manganese from sulfidic waste rock – will occur. To date, reactions continue to occur within the pit, as demonstrated by

- Increase of copper in MW-1013B
- Increases in manganese and iron in MW-1013C

[11] Flambeau Mining Company. 2007 Annual Report.
[12] Foth and Van Dyke/SRK Consulting memorandum. Oct 12 2000. In Flambeau Mining Company 2000 Annual Report.
[13] SRK Consulting memorandum Jan 25 2008 in Flambeau Mining Company 2007 Annual Report, Figures 14-15.
[14] Flambeau Mining Company 2000 Annual Report

- Manganese decreases in MW-1014A and MW-1014B
- Iron decreases and loss of gypsum in MW-1014C
- Increasing redox in MW-1014A and decreasing redox in MW-1013A

Because the mixture within the pit is not homogenous, different reactions can be expected to occur and at different rates, making it quite difficult to develop accurate models.[15] Models for the Flambeau mine pit groundwater were generated in 1989, when the Mining Permit Application was submitted to the state regulatory agency for review. Specifically, the application included a data table entitled "Predicted Parameter Concentrations of Contact Groundwater Leaving the Backfilled Pit"[16] that is reproduced here for review (see Table 3). The table has utility from two viewpoints: (1) it summarizes projected water quality for pit water; and (2) per the terms of the Flambeau Mine Permit, it defines the applicable groundwater enforcement standards for monitoring wells MW-1000 and MW-1010 located between the backfilled pit and the Flambeau River.[17]

Table 3: Predicted Concentrations of Groundwater Contaminants[18]

TABLE NO. 2-5

Predicted Parameter Concentrations of Contact Groundwater Leaving the Backfilled Pit

Parameter	Concentration, mg/L	Years
Sulfate	1,360	0-8.42
	1,100	8.42-132
	832	132-2,850
	317	2,850-3,010
	9.9	3,010+
Manganese	0.550	0-3,920
	0.445	3,920-4,000
	0.350	4,000+
Iron	0.320	>4,000
Copper	0.014	>4,000

[15] Kuipers et al 2006
[16] Foth and Van Dyke, 1989
[17] Decision, Findings of Fact, Conclusions of Law and Permits [for the Flambeau Mine], State of Wisconsin Division of Hearings and Appeals, 1991, pp. 87-93.
[18] Table 2-5 from Appendix L of Flambeau Mine Permit Application, 1989

Column testing by the Flambeau Mining Company in 1997 was not able to produce the manganese concentrations predicted, but it was thought that "with an extended time manganese levels would decrease to those predicted in Table 4-23"[19]; i.e. 2 mg/L (2,000 µg/L) at 1% carbon dioxide.[20] However, ten years after backfilling, manganese concentrations in pit pore water remain underestimated by more than an order of magnitude in four of the eight pit monitoring wells (MW-1013, 1013B, 1013C, and 1014B), and fluctuate strongly in three of the remaining four (MW-1013A, 1014, 1014A) (Table 4 and Figure G).

Gypsum and metal hydroxides present in buried water treatment sludge can be expected to dissolve over time and flush down-gradient, making their way into or under the Flambeau River. Metals and mineral oxides that dissolve as a result of localized oxidation reactions within backfill can also be expected to flush down-gradient. Flushing will remain a concern for decades to come.

The most likely fate of manganese will be to flush out of the pit. It is unlikely to precipitate at neutral pH in the presence of iron. Dissolution reactions, in addition to influx of groundwater high in manganese, have likely contributed to the high manganese concentrations observed in the pit that were not predicted by modeling.

The fate of copper in the pore water within the backfilled mine pit depends on ion concentrations, pH, and redox conditions.

Copper may

- flush in the dissolved form
- precipitate as an oxide/carbonate
- sorb to surfaces

To date copper concentrations in pit pore water have generally reached concentrations expected from company modeling, but exceed expected concentrations by more than an order of magnitude at pit wells MW-1013B (86') and MW-1014B (105'), with no apparent trends (Table 5).

Similarly, iron levels reached expected concentrations in pit pore water measured at MW-1013A, 1013B, 1014, 1014A and 1014B, but were underestimated by more than an order of magnitude in pit wells MW-1013, 1013C, and 1014C (Table 6). No trends in iron are evident; while MW-1014C has generally declined in iron concentrations, MW-1013 and MW-1013C fluctuate.

The unpredictability observed in copper, iron, and manganese concentrations indicates that important assumptions were missing in original modeling or that more time is needed for complex dissolution and precipitation reactions to stabilize.

Limestone performance

Limestone is being relied on to neutralize acidity present at the time of backfill as well as any acidity produced after backfilling by reactions between ferric iron and waste rock. Ferric iron oxidation reactions may continue for some time, and until they stop, limestone will be required to neutralize acidity and precipitate resulting metal dissolution. Precipitation products such as aluminum hydroxide can be expected to settle on the limestone surface, and may render it less effective. It is not known how limestone will perform over the long term. If the limestone loses effectiveness, intervention wells along with pit wells will be important in tracking potential changes in pit water quality.

[19] Flambeau Mining Company, 1997, pg 68
[20] Flambeau Mining Company, 1997, Table 4-23 and Table 4-24

Unexamined Contaminants

Consideration should also be given to expanding the groundwater monitoring program at the Flambeau mine site to include more parameters. The geology of the area and of ore samples suggests nickel,[21] cobalt, aluminum,[22] and uranium[23] could be elevated. Although testing was conducted for all in 1987-1988, no groundwater analysis for these elements have been conducted since then, with the exception that samples were analyzed for nickel in July 2005. Shallow wells not recovered from groundwater drawdown did not yet have water and were therefore not sampled for nickel.

Monitoring wells MW-1014B, MW-1014C, and MW-1013C in the pit all had significant levels of nickel for the one reported nickel measurement taken in 2005, with MW-1014B as high as 440 ug/L. MW-1000PR was also sampled for nickel in 2005 and a level of 94 µg/L recorded. Effluent limits for nickel were set in the WPDES permit at a maximum discharge of 3100 ug/L daily.[24] The most stringent standard listed in 1992 was 38 ug/L.[25] The EPA water quality standard for nickel is hardness-dependant. A typical hardness for the Flambeau River is 60 mg/L (2007). At a hardness of 60 mg/L, the water quality limit for nickel would be 34 µg/L. Therefore, if well water from MW-1000PR was entering the Flambeau River at the measured level of 94 µg/L, it is possible that the water quality standard is being violated.

Other parameters that should be added to the list include cobalt and aluminum, since both were identified in measurable quantities in pore water obtained from leach extraction tests performed by the company on waste rock samples in 1997.[26] It is also recommended that groundwater and stream sediment be tested for radioactivity, since Rusk County has been identified by the United States Department of Energy in 1980 as "favorable for uranium deposits"[27] and enforcement standards specific to radioactivity were included in the Flambeau Mine Permit. Adding nickel, cobalt, aluminum, uranium and radioactivity to the list of parameters will not have a significant impact to the collection or analytical monitoring costs.

Pit Monitoring Wells

Monitoring of pit wells and downgradient intervention wells should be continued until the pit chemistry has stabilized. Original modeling predicted concentrations of manganese, iron, and copper exiting the pit would be near background concentrations early on.[28] In the case of manganese, and occasionally iron and copper, this has not proved to be the case (Table 4 to 7). In addition, sulfate was expected to be, and is, high in concentration in the pit.

Since chemistry in pit wells, intervention wells, and at the compliance well has not stabilized, and since it is not known how limestone will perform over the long term, monitoring should continue. Also, a measure of confidence would be added if samples collected by FMC were available for independent analysis, if this is not already being done.

Recommendation: Monitoring should be continued in the pit until redox stabilizes.

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[21] 2005 data for monitoring wells MW-1014B, MW-1014C, and MW-1013C
[22] Cobalt and aluminum identified in waste rock, Flambeau Mining Company 1997
[23] Cannon, WF and LG Woodruff. 2003. The Geochemical Landscape of Northwestern Wisconsin and adjacent parts of Northern Michigan and Minnesota (Geochemical Data Files). US Geological Survey Open File Report 03-259 http://pubs.usgs.gov/of/2003/of03-259/
[24] WDNR. 1992. An evaluation of endangered resources in the Flambeau River and a supplement to the Environmental Impact Statement for the Flambeau Mine project. Table 8.
[25] ibid Table 14.
[26] Flambeau Mining Company 1997
[27] Cannon, WF and LG Woodruff. 2003. The Geochemical Landscape of Northwestern Wisconsin and adjacent parts of Northern Michigan and Minnesota (Geochemical Data Files). US Geological Survey Open File Report 03-259 http://pubs.usgs.gov/of/2003/of03-259/
[28] Foth and Van Dyke, 1989, Appendix L

Recommendation: Add nickel, cobalt, aluminum, and uranium/radioactivity to parameters being measured.

Recommendation: Split groundwater samples with WDNR or the public, if requested.

Migration of Contaminants

Pit contaminants are moving out of the pit, as evidenced by concentrations of elements in the intervention boundary well MW1000PR, located on the Flambeau River side of the pit slurry wall. It is possible that contaminants may be moving around the ends of the slurry wall and/or under the bed of the Flambeau River. In addition, elevated copper has been consistently found in surface water near the Industrial Outlot, but there are no intervention or compliance wells between the Outlot and the western or southern compliance boundaries. Currently there is only one monitoring well (MW-1015) on the compliance boundary, which surrounds approximately 180 acres of the mine footprint.

If bedrock is permeable, then what occurs within the pit is relevant in that constituents move out of the pit. The bedrock forming the wall between the pit and the Flambeau River has been described as a “natural impermeable barrier”[29] but other statements referred to the river pillar of this area as “relatively highly permeable”,[30] "fractured",[31] and that blasting during mining had the potential to increase fractures.[32]

The fractured bedrock forms a conduit from the pit to the River, allowing water movement in both directions. During operations, “water from the Flambeau River was drawn into the dewatered pit through fractured Precambrian bedrock that formed the western wall”.[33] After closure, modeling in 1989 indicated that

> “groundwater flowing through the….pit will exit….through the Precambrian rock in the river pillar and flow directly into the bed of the Flambeau river…..Since there will be no dispersion, dilution or retardation in the river pillar, the concentrations of these constituents in the groundwater leaving the pit will be the same as the concentrations entering the river bed”[34]

Some of these constituents, as observed at MW-1000PR, fail to comply with Flambeau Mine groundwater enforcement standards.

Between the pit and the River, a bentonite slurry cutoff wall was built to limit water exiting from the pit. Whether pit water is moving around, under or through the slurry cutoff wall is not known. It is presumed that groundwater moves from the pit into the Flambeau River (see Figure A in this paper), but potentially groundwater could move under the river. MW-1000PR, which appears to be receiving groundwater from the pit, is located west of the slurry wall and below the bed of the Flambeau River.[35] It is not evident whether the bedrock itself under the river is impermeable, or contains fractures that could carry pit constituents to the west side of the river. The draft EIS refers to “groundwater movement to the

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[29] Preliminary Environmental Report, 1975, pg 29 and Figure 16 http://digital.library.wisc.edu/1711.dl/EcoNatRes.PreEnvRepAug75

[30] Foth and Van Dyke, 1989, Appendix L pg L4

[31] Foth and Van Dyke, 1989, Appendix L pg L32 says "…all of the groundwater flowing through the …reclaimed pit will exit through the Precambrian rock in the river pillar and flow directly into the bed of the Flambeau River….Since this flow path is very short and occurs entirely within fractured crystalline rock….". Also see Environmental Impact Report for the Kennecott Flambeau Project (Report Narrative), 1989, pg. 3.6-33 and Foth & Van Dyke Memorandum to Jana Murphy, Flambeau Mining Company, October 12, 2000, p.13-14

[32] Final Environmental Impact Statement 1990, pg 76 http://digital.library.wisc.edu/1711.dl/EcoNatRes.FinEnvImpMar90

[33] Foth & Van Dyke, 2000, p.13-14

[34] Foth and Van Dyke, 1989, Appendix L pg L29

[35] Well begins at land elevation 1100.5' and ends 57' down at 1043.5'. The river bed is at 1080' elevation.

southwest along the strike of the ore body"[36] and the ore body is shown to extend under the river to the west side[37] although mining stopped just short of the river.

Flambeau Mine Management

Wisconsin law requires the establishment of two different boundaries at mine sites for enforcement of groundwater quality standards. The first, known as the compliance boundary, is located 1,200 feet from the outer perimeter of the mining waste facility (NR 182.075). The term "compliance boundary" was changed to "design management zone" when the statute was amended in 1998; it is referred to in the present document as the "compliance boundary". In the case of the Flambeau Mine, the unlined backfilled pit constitutes the mining waste facility. See Figure A for the location of the Flambeau Mine compliance boundary.

The compliance boundary marks the point where groundwater quality must be in compliance with the state's groundwater protection law. In particular, drinking water standards established in Chapter NR 140 of the *Wisconsin Administrative Code* cannot be exceeded at or beyond the boundary. These standards, known as Maximum Contaminant Levels (MCLs), were specifically listed in the 1991 Flambeau Mine Permit as the applicable groundwater enforcement standards for the mine's compliance boundary, with the exception of manganese.[38] Since baseline manganese levels at the mine site already exceeded the NR 140 MCL of 50 µg/L, the Flambeau-specific enforcement standards were set at 90 µg/L (overburden), 360 µg/L (shallow Precambrian) and 230 µg /L (deep Precambrian).

In addition to the 1,200-foot compliance boundary, an intervention boundary was established for the Flambeau Mine between the mine pit and compliance boundary, as required by law (NR 182.075). Monitoring groundwater quality at the intervention boundary is designed to help identify emerging pollution problems before they have a chance to reach the compliance boundary. As such, the applicable groundwater enforcement standards, known as Preventive Action Limits (PALs) and listed in Chapter NR 140 of the *Wisconsin Administrative Code*, are typically 10-20% of the corresponding MCLs, with some as high as 50%.

Intervention Boundary Wells

Five different monitoring wells (MW-1000, 1002, 1004, 1005 and 1010) constitute the intervention boundary established for the Flambeau Mine site when permits were granted in January 1991 (Figure A). Per the terms of the permit, two different sets of enforcement standards for groundwater pollution apply to the wells: (1) MW-1002, 1004 and 1005 are subject to PAL standards; and (2) MW-1000 and 1010 are subject to the same, except in the case of copper, iron, manganese and sulfate, where enforcement standards are based upon water quality projections for the backfilled pit as set forth in Appendix L of the Mining Permit Application.[39]

Intervention well MW-1002 in the northwest quadrant of the mine site is nested (16', 52'), as is MW-1004 at the northwest edge of the pit (13', 30', 76') and MW-1005 east of the former high sulfide rock stockpile (19', 52', 92'). Pit water is not expected to move towards these wells. Water sampling indicates these wells are stable with regards to redox, contain low concentrations of iron and manganese, and constituents do not exceed the baseline measurements. However, monitoring well MW-1004, listed as an active well in the Wisconsin DNR Groundwater Environmental Monitoring System (GEMS) database, has not since

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[36] Draft Environmental Impact Statement, 1976, pg 35 http://digital.library.wisc.edu/1711.dl/EcoNatRes.DraftEnvImpSep89
[37] Schwenk 1977, Figure 14
[38] Decision, Findings of Fact, Conclusions of Law and Permits [for the Flambeau Mine], State of Wisconsin Division of Hearings and Appeals, 1991, pp. 87-93.
[39] Foth & Van Dyke 1989, pg L27-L31.

1989 had the yearly sampling that other intervention wells are subjected to for a wide range of elements (arsenic, barium, cadmium, chromium, lead, mercury, silver, selenium, and zinc).

Pit water is expected to move to the southwestern end of the pit, near the slurry wall. The monitoring well MW-1001 is located just south of the west end of the pit. It appears that water is not being collected from MW-1001 (nested at 33', 52', and 95'), although the wells are listed as "active" in the WDNR GEMS database.[40] If possible, data should be collected from this nest in order to assist in characterizing groundwater quality and flow.

Between the pit and the river is a slurry cutoff wall. Intervention boundary wells MW-1000PR, MW-1000R and MW-1010P sit about 125' from the Flambeau River, directly between the backfilled pit and river, on the west side of the slurry cutoff wall. They are well-situated to indicate the quality of groundwater entering the river.

It appears that water is not being collected from MW-1000R (24.5', not nested). It is noteworthy that this well has not had water testing since 1988 when baseline data was reported, although it appears to remain an active well. If the well is operational, water samples should be collected.

Water samples are collected from MW-1010P (115', not nested). Although this well is not generally exceeding mine permit water quality standards, redox is not stable, indicating that water chemistry has not stabilized, and it has exceeded the PAL for arsenic (5 ug/L) in 21 out of 28 samples taken between 1999 and June 2008, with one of the highest concentrations detected in June 2008 (23 ug/L). It also has not been tested for uranium, thorium, or other radioactive material.

The intervention monitoring well MW-1000PR (57', not nested) may be a good indicator of the water quality entering the Flambeau River, in that it is located

> "within a weathered and highly fractured schist …. (and) pore water has begun migrating through this fracture zone from the backfill toward the Flambeau River and MW-1000PR"[41]

Water quality at MW-1000PR consistently exceeds 1991 baseline measurements in sulfate, total dissolved solids (TDS), conductivity, manganese, zinc and calcium; baseline iron and copper levels have also been exceeded on occasion.

There have been consistent and statistically significant exceedances of 1991 Flambeau mine permit standards at MW-1000PR for manganese, calcium, conductance and TDS; manganese exceeds standards by nearly an order of magnitude. In addition, although the PAL standard of 2500 µg/L for zinc has not been exceeded in MW-1000PR, the well often contains 600-800 µg/L, significantly elevated above the <70 µg/L baseline. Similarly sulfate has not exceeded the 1100 mg/L site-specific permit application standard, but has consistently been at or above 300 mg/L, greatly elevated above the baseline of <31 µg/L, and would exceed the NR 140 PAL of 125 µg/L had that standard been specified in the mine permit (Table 7).

It is possible that pit water could be moving around the ends of the slurry wall. Inspection of the projected groundwater flow directions in Figure A and the groundwater potentiometric surface lines in Figure B both support this hypothesis. It appears that both MW-1000PR[42] and MW-1010P are screened in bedrock. Since it is apparent from the MW-1000PR data that groundwater contamination is exiting the pit toward the river, two nested wells should be placed at the northwest and southeast ends of the slurry wall separating the pit from the Flambeau River. These wells would either confirm that no groundwater

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[40] http://prodoasext.dnr.wi.gov/inter1/gemsfac$points.startup?P_LIC_NUMBER=3180&P_0=3180&Z_CHK=57753
[41] Foth & Van Dyke, 2000, p.13
[42] Foth & Van Dyke Memorandum to Jana Murphy, Flambeau Mining Company, October 12, 2000, p.13

leakage is going around the slurry wall, or would provide a means to measure the amount and water quality of this leakage.

Recommendation: Place nested wells at either end of the slurry wall; if MW-1000R (25' deep) is active, this could serve as one of the new monitoring wells; a deeper well should be constructed next to it. In addition, samples should be taken from MW-1001 which, although not located at the slurry wall, is nested (33', 52', 95') and located just to the southeast of the wall and would aid in determining groundwater flow direction. A monitoring well on the southern compliance boundary would ensure no contaminants are moving in that direction.

Recommendation: Site a monitoring well for "background" groundwater samples away from the mine site, Industrial Outlot, and roads.

Compliance Boundary Well

Only one well is currently sited at a compliance boundary. This well, MW-1015A/B (64', 148') is located northwest of the former pit and about 320 feet from the Flambeau River. It was drilled in January 2001, three years after the mine pit was backfilled, so no pre-mine baseline water quality data exists.

The company's groundwater modeling suggests that MW-1015 is not likely to receive a substantial influx of groundwater from the backfilled pit.[43] However, the well remains unstable with regards to redox, and MW-1015B has shown exceedances of the applicable groundwater enforcement standard for manganese (2002-2004) and had an exceedance of the 1991 permit standard for iron in at least one sample in every year from 2002-2007[44] (Table 8).

Given that exceedances have occurred in the one compliance well, and given the movement of contaminants out of the pit towards MW-1000PR, and since it is theoretically possible that contaminated groundwater could move under the Flambeau River toward the compliance boundary located west of the mine site, it would be prudent to provide a nested monitoring well at the compliance boundary to the west of the Flambeau River to ensure that any residential or agricultural well water quality is not being impacted, and to provide a point of measurement for ensuring groundwater meets Wisconsin drinking water standards.

Recommendation: Place a nested well on the compliance boundary on the western side of the Flambeau River to determine if contaminated groundwater is moving under the River.

[43] Final Environmental Impact Statement. 1990. Figure 3-7
[44] Flambeau Mining Company 2007 Annual Report, Appendix B, Attachment 1 "Historical Groundwater Results"

Monitoring Mine Management Wells

Long term monitoring will determine whether permit violations continue to occur at the Flambeau Mine intervention boundary (MW-1000PR and MW-1010) and compliance boundary (MW-1015). Since 1999, measured concentrations of manganese and iron in MW-1000PR (125' from the Flambeau River) have repeatedly been greater than the enforcement standards cited in the 1991 mine permit, and manganese significantly greater. MW-1015, 320' from the Flambeau River exceeded 1991 groundwater enforcement standards for iron at least once every year between 2002 and 2007, and remains unstable in redox, warranting continued monitoring.

A measure of confidence would be added if samples collected by FMC were available for independent analysis.

Recommendation: Monitoring should be continued at intervention and compliance wells until metal concentrations consistently remain below Wisconsin water quality standards and redox stabilizes.

Recommendation: Split groundwater samples with WDNR or the public, if requested.

MONITORING FLAMBEAU RIVER BIOTA

In 1991, Flambeau Mining Company initiated monitoring programs in the Flambeau River to assess potential accumulation of heavy metals in crayfish, walleye and sediment downstream from the mine site. Macroinvertebrate studies were also initiated to assess potential impacts of the mine on river health. Studies were performed on an annual basis through 1998 (macroinvertebrates), 2000 (walleye and sediment) and 2001 (crayfish). Additional studies were conducted in 2004 (crayfish and macroinvertebrates), 2005 (walleye), 2006 (crayfish, walleye, sediment and macroinvertebrates) and 2007 - 2008 (crayfish, walleye, and sediment). Additional crayfish and walleye studies are scheduled to be conducted on an annual basis through 2011.

Despite the assemblage of data, it is unclear how the monitoring programs for crayfish and walleye will provide statistically significant data regarding mine impacts to the Flambeau River and biota, or lack thereof. As discussed below, flaws may exist in the study design, methods, and/or presentation of information. This makes it difficult for the public to ascertain whether contaminants are moving into biota and sediment, or whether natural macroinvertebrate populations have been impacted downstream from the mine site.

Crayfish and Walleye

The current monitoring program for crayfish does not outline a determinate number of specimens to be collected at each sample site to ensure consistency, nor how a determination would provide statistically relevant information. Moreover, even though the walleye monitoring plan calls for sampling a set number of fish at each of two sampling sites in the river, the sample sizes are quite small – one to three fish each of 5 different sizes. The plan does not explain how the collected data of such a small sample set will be statistically relevant.

Monitoring plans do not provide information regarding the natural ranging and foraging habits of crayfish and walleye to determine if these species are likely to provide information on contaminant movement specifically from the mine site. Possibly shellfish located near mine site discharges would be better indicators, if shellfish are present. The choice of species lies primarily in what question is being answered. Is the question "Are bioavailable contaminants moving out of the mine area?" or is the question "Is aquatic life safe to eat?" It would be helpful for the Stipulation Monitoring Plan to state the question they want answered.

Macroinvertebrates

A common method for assessing stream health is bioassessment using macroinvertebrates. Bioassessments were conducted 1991-1998, 2004 and 2006. Although the full data is presented, it is not clear what the data indicates. Abundance of taxa, which is presented, does not necessarily imply stream health. Rather, it is the ratio of taxa that are sensitive to pollution (generally species within Ephemeroptera, Plecoptera, Trichoptera, or EPT) and those that are tolerant to pollution (such as Diptera) that provides information. Presentation of ratios and trends in ratios over time would allow the public to better understand impacts to aquatic life in the Flambeau River.

While it is essential and useful to provide raw numbers of species in order to allow independent experts the ability to analyze the data, the utility of the macroinvertebrate data would be enhanced by reporting summary information such as percent EPT of total abundance; richness of each of Ephemeroptera, Plecoptera, Trichoptera, and Diptera; percent taxa intolerant to pollution and percent taxa tolerant to pollution in a manner that allows the general public to understand trends.

CONCLUSIONS

Copper contamination in excess of Wisconsin water quality standards is reaching the Flambeau River from the Flambeau mine site and the Flambeau pit is leaching contaminants that exceed Wisconsin groundwater quality standards to beyond the slurry wall designed to separate pit water from the Flambeau River. It appears that the state is allowing these unpermitted discharges to continue under the assumptions that (1) dilution in the Flambeau River is such that no impact is occurring, and that (2) no contaminated groundwater from the pit is flowing under the Flambeau River toward the groundwater compliance boundary.

If all, or part of the groundwater contamination is not entering the Flambeau River, as is presently assumed, then it is going under the river towards the 1200 foot compliance boundary. There appears to be insufficient monitoring to determine either the quantity of groundwater movement, the quantity of contamination entering the Flambeau River, and/or the groundwater contamination migrating toward the southwest groundwater compliance boundary.

As discussed in this report, it is not clear from the monitoring data that there is no impact from the surface water discharge both into Stream C, and from Stream C into the Flambeau River, as it crosses Meadowbrook Creek. Since this is an ongoing discharge from an industrial facility, the discharge should be more carefully monitored, and should either be cleaned up before it leaves the mine site, or the discharge should be regulated under a Clean Water Act discharge permit which would place limits on the amount of contamination discharged, and the “mixing zone” which is currently being utilized in the Flambeau River.

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Figure A: Plan View Groundwater Flow

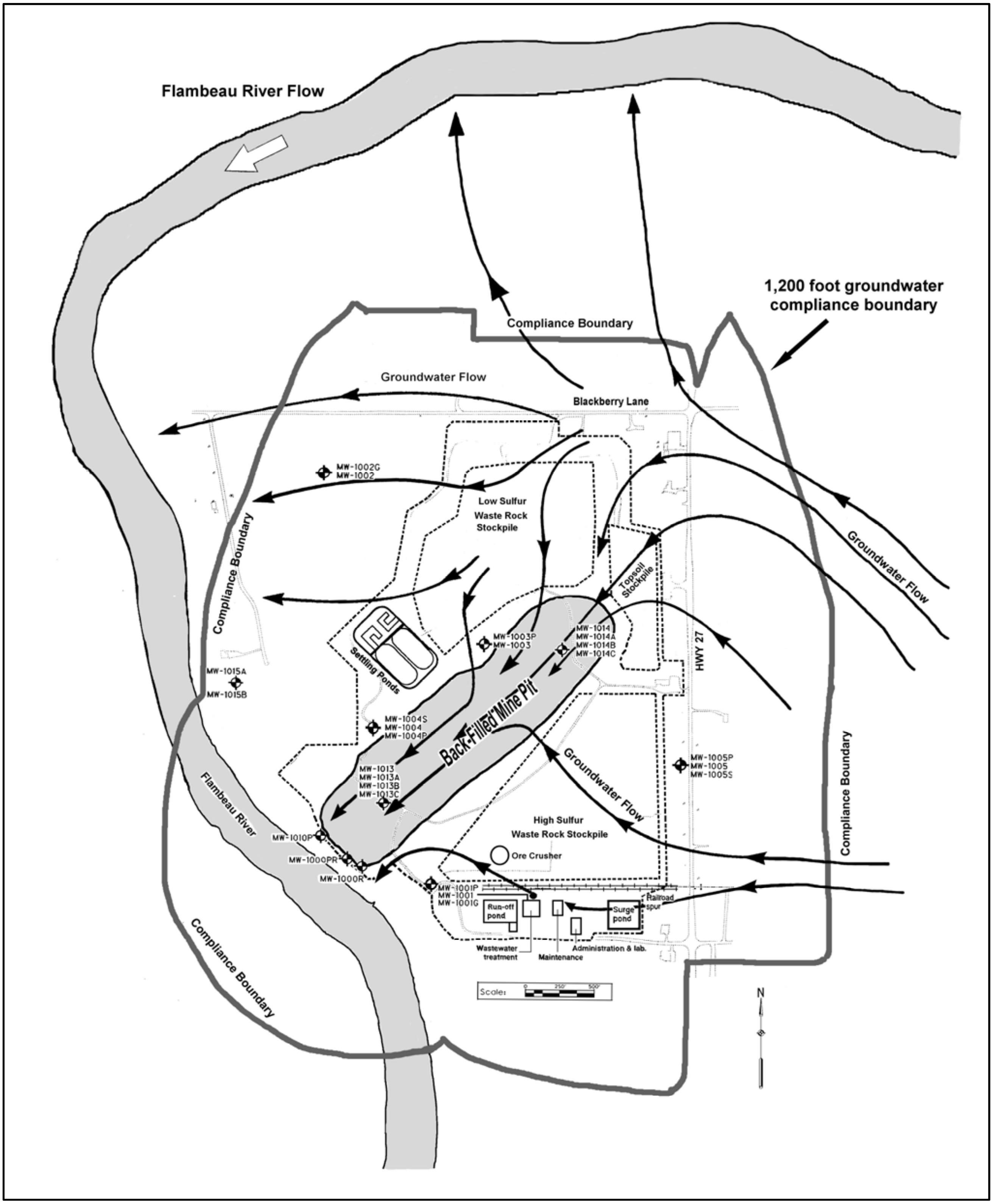


Figure B: Groundwater Potentiometric Surface

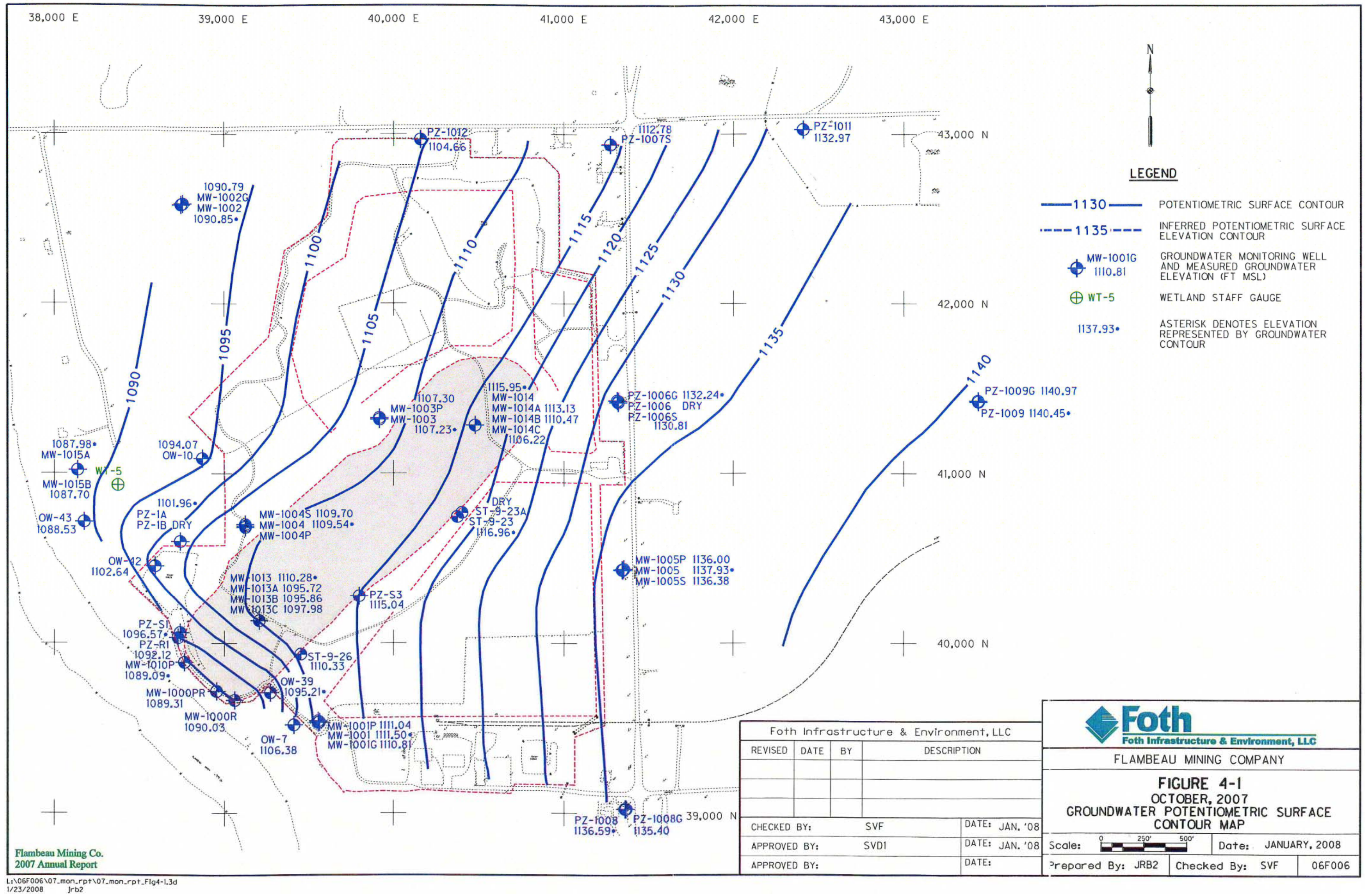


Figure C: Outlot Biofilter Drainage Area

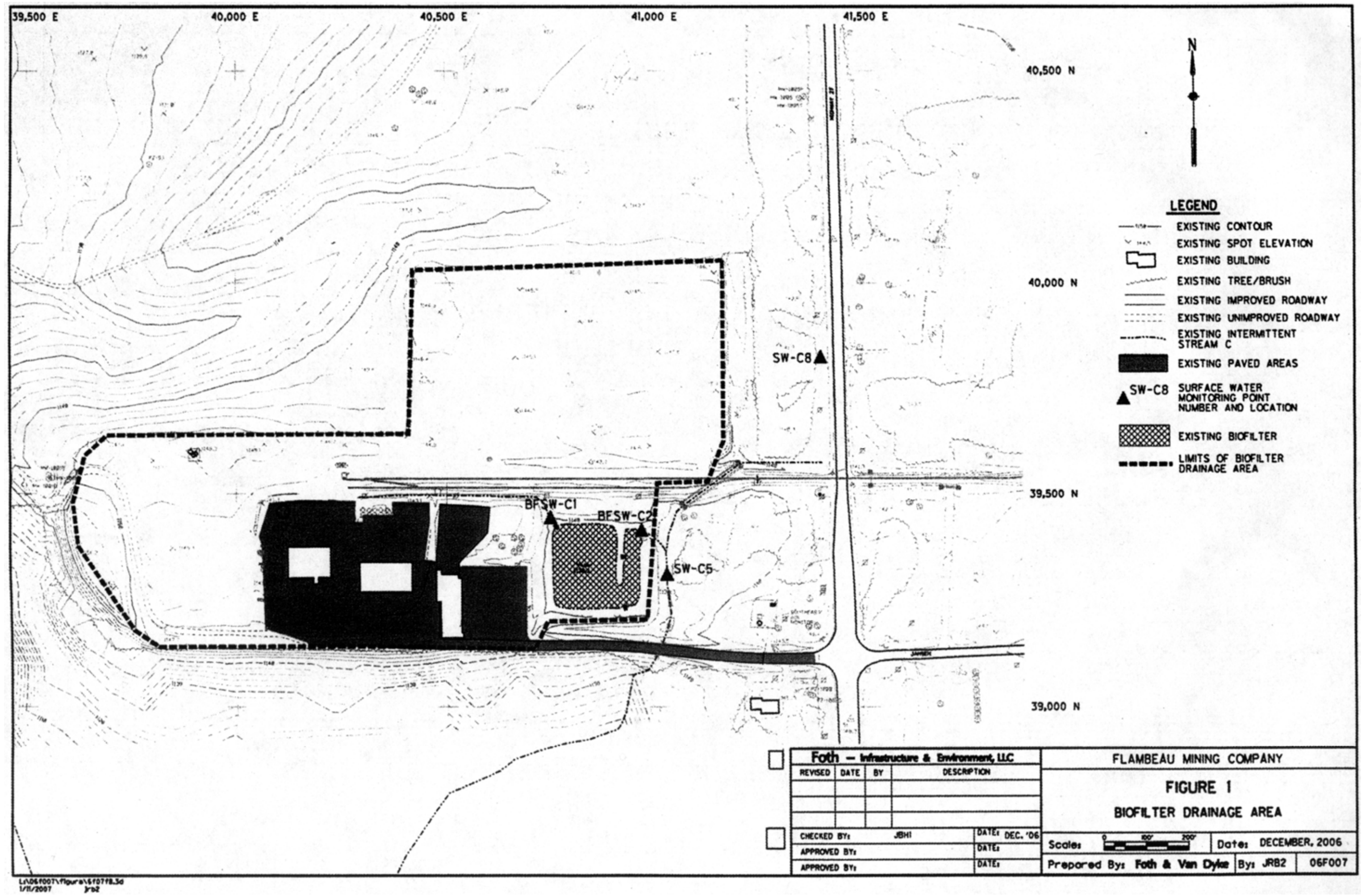
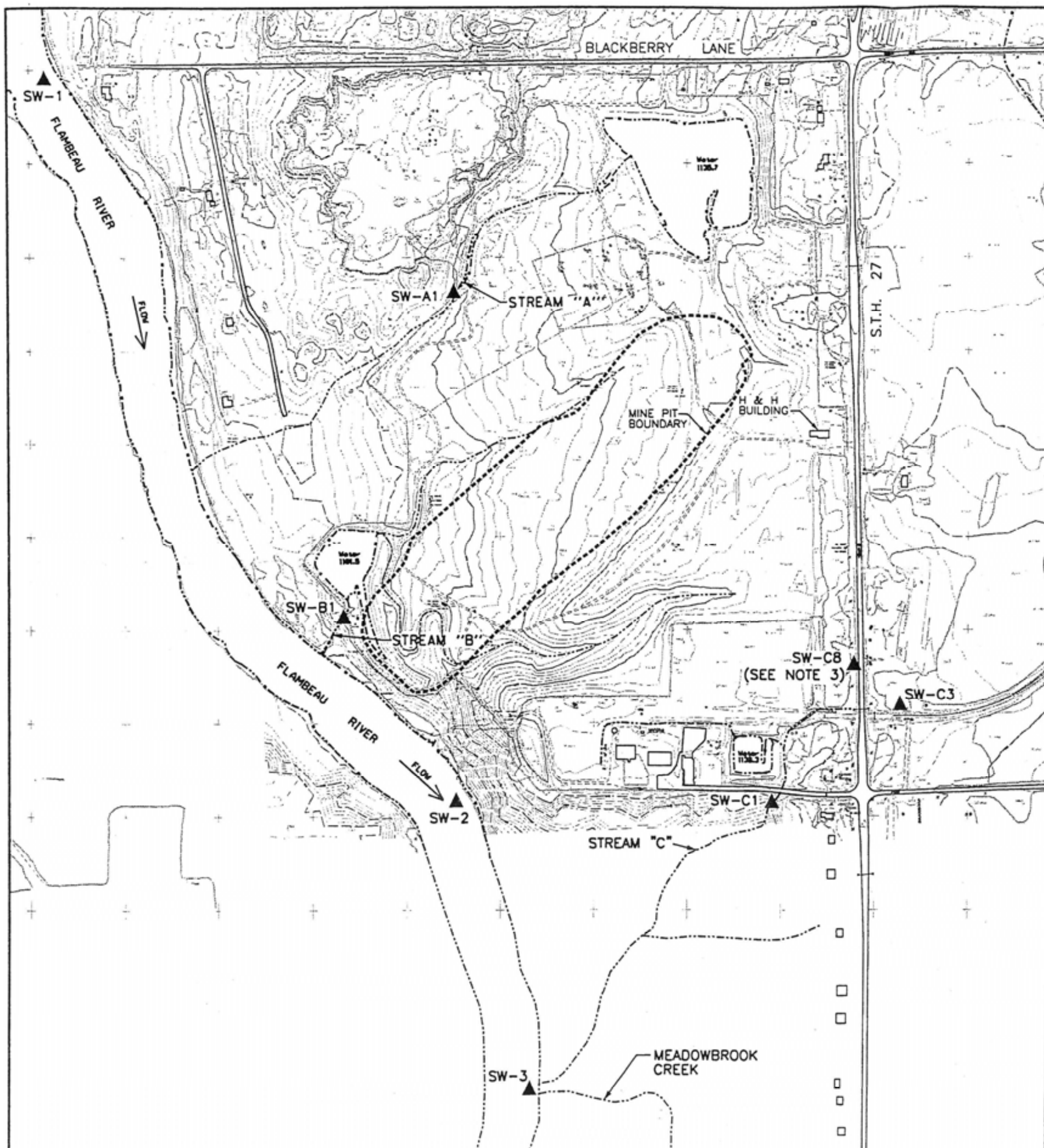


Figure D: Active Surface Water Monitoring Locations



(SEE NOTE 3) → SW-C8

Location	ug/L Copper.tot	mg/L Iron.tot	ug/L Mn	mg/L Sulfate	ug/L Zinc
SW-C8	86	2.5	140	5.3	41
SW-A1	[3.1]	0.37	61	<2.5	10
SW-B1	[2.7]	0.44	13	<2.5	[7.8]
SW-B1(DUP)	[2.9]	0.45	13	<2.5	[7.1]
SW-C1	47	1.3	23	5.8	52
SW-1	<1.3	0.57	130	10	[6.0]
SW-2	<1.3	0.50	130	11	[5.4]
SW-3	4.2	0.60	100	10	[8.6]

NOTES:

- < NOT DETECTED ABOVE THE LOD
- [ ] RESULTS ≥ THE LOD BUT < THE LOQ AND ARE WITHIN A REGION OF "LESS-CERTAIN QUANTITATION"
- LOD LIMIT OF DETECTION
- LOQ LIMIT OF QUANTITATION
- DUP DUPLICATE
- ug/L MICROGRAMS/LITER
- mg/L MILLIGRAMS/LITER

LEGEND

- SW-A1 ▲ SURFACE WATER SAMPLE NUMBER AND LOCATION
- EXISTING CONTOUR
- EXISTING SPOT ELEVATION
- EXISTING BUILDING
- EXISTING TREE/BRUSH
- EXISTING IMPROVED ROADWAY
- EXISTING UNIMPROVED ROADWAY

NOTES:

1. RESULTS POSTED FROM SEPTEMBER 2007.
2. SW-C3 WAS ADDED TO THE SAMPLING PLAN IN NOVEMBER 2007 AND WAS NOT SAMPLED IN SEPTEMBER 2007.
3. SW-C8 COC AND DATA SHEET SUBMITTED WITH THE BIOFILTER SUBMITTAL DATED 9/27/07

Foth – Infrastructure & Environment, LLC

REVISED	DATE	BY	DESCRIPTION

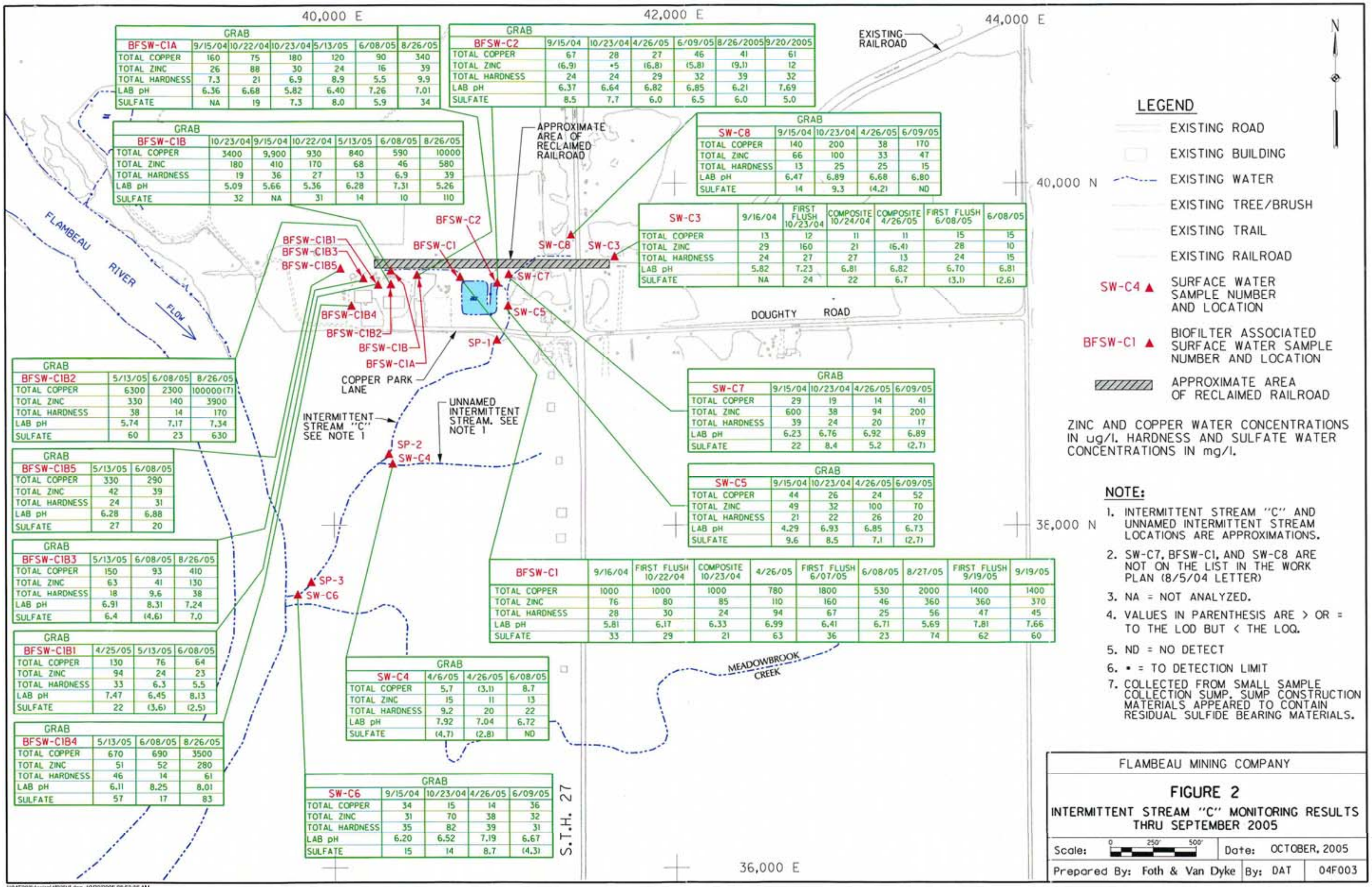
CHECKED BY: DATE:
APPROVED BY: DATE:
APPROVED BY: DATE:

FLAMBEAU MINING COMPANY

FIGURE 1
STIPULATED MONITORING
SURFACE WATER SAMPLE LOCATIONS
AND SEPTEMBER 2007 RESULTS

Scale: 0 300' 600' Date: DECEMBER, 2007
Prepared By: BLK Checked By: SVF 06F006

Figure E: Stream C Water Quality Data



	GRAB					
BFSW-C1A	9/15/04	10/22/04	10/23/04	5/13/05	6/08/05	8/26/05
TOTAL COPPER	160	75	180	120	90	340
TOTAL ZINC	26	88	30	24	16	39
TOTAL HARDNESS	7.3	21	6.9	8.9	5.5	9.9
LAB pH	6.36	6.68	5.82	6.40	7.26	7.01
SULFATE	NA	19	7.3	8.0	5.9	34

GRAB						
BFSW-C1B	10/23/04	9/15/04	10/22/04	5/13/05	6/08/05	8/26/05
TOTAL COPPER	3400	9,900	930	840	590	10000
TOTAL ZINC	180	410	170	68	46	580
TOTAL HARDNESS	19	36	27	13	6.9	39
LAB pH	5.09	5.66	5.36	6.28	7.31	5.26
SULFATE	32	NA	31	14	10	110

	GRAB					
BFSW-C2	9/15/04	10/23/04	4/26/05	6/09/05	8/26/2005	9/20/2005
TOTAL COPPER	67	28	27	46	41	61
TOTAL ZINC	(6.9)	•5	(6.8)	(5.8)	(9.1)	12
TOTAL HARDNESS	24	24	29	32	39	32
LAB pH	6.37	6.64	6.82	6.85	6.21	7.69
SULFATE	8.5	7.7	6.0	6.5	6.0	5.0

	GRAB			
SW-C8	9/15/04	10/23/04	4/26/05	6/09/05
TOTAL COPPER	140	200	38	170
TOTAL ZINC	66	100	33	47
TOTAL HARDNESS	13	25	25	15
LAB pH	6.47	6.89	6.68	6.80
SULFATE	14	9.3	(4.2)	ND

SW-C3	9/16/04	FIRST FLUSH 10/23/04	COMPOSITE 10/24/04	COMPOSITE 4/26/05	FIRST FLUSH 6/08/05	6/08/05
TOTAL COPPER	13	12	11	11	15	15
TOTAL ZINC	29	160	21	(6.4)	28	10
TOTAL HARDNESS	24	27	27	13	24	15
LAB pH	5.82	7.23	6.81	6.82	6.70	6.81
SULFATE	NA	24	22	6.7	(3.1)	(2.6)

GRAB			
BFSW-C1B2	5/13/05	6/08/05	8/26/05
TOTAL COPPER	6300	2300	100000(7)
TOTAL ZINC	330	140	3900
TOTAL HARDNESS	38	14	170
LAB pH	5.74	7.17	7.34
SULFATE	60	23	630

GRAB		
BFSW-C1B5	5/13/05	6/08/05
TOTAL COPPER	330	290
TOTAL ZINC	42	39
TOTAL HARDNESS	24	31
LAB pH	6.28	6.88
SULFATE	27	20

GRAB			
BFSW-C1B3	5/13/05	6/08/05	8/26/05
TOTAL COPPER	150	93	410
TOTAL ZINC	63	41	130
TOTAL HARDNESS	18	9.6	38
LAB pH	6.91	8.31	7.24
SULFATE	6.4	(4.6)	7.0

GRAB			
BFSW-C1B1	4/25/05	5/13/05	6/08/05
TOTAL COPPER	130	76	64
TOTAL ZINC	94	24	23
TOTAL HARDNESS	33	6.3	5.5
LAB pH	7.47	6.45	8.13
SULFATE	22	(3.6)	(2.5)

GRAB			
BFSW-C1B4	5/13/05	6/08/05	8/26/05
TOTAL COPPER	670	690	3500
TOTAL ZINC	51	52	280
TOTAL HARDNESS	46	14	61
LAB pH	6.11	8.25	8.01
SULFATE	57	17	83

	GRAB			
SW-C7	9/15/04	10/23/04	4/26/05	6/09/05
TOTAL COPPER	29	19	14	41
TOTAL ZINC	600	38	94	200
TOTAL HARDNESS	39	24	20	17
LAB pH	6.23	6.76	6.92	6.89
SULFATE	22	8.4	5.2	(2.7)

	GRAB			
SW-C5	9/15/04	10/23/04	4/26/05	6/09/05
TOTAL COPPER	44	26	24	52
TOTAL ZINC	49	32	100	70
TOTAL HARDNESS	21	22	26	20
LAB pH	4.29	6.93	6.85	6.73
SULFATE	9.6	8.5	7.1	(2.7)

BFSW-C1	9/16/04	FIRST FLUSH 10/22/04	COMPOSITE 10/23/04	4/26/05	FIRST FLUSH 6/07/05	6/08/05	8/27/05	FIRST FLUSH 9/19/05	9/19/05
TOTAL COPPER	1000	1000	1000	780	1800	530	2000	1400	1400
TOTAL ZINC	76	80	85	110	160	46	360	360	370
TOTAL HARDNESS	28	30	24	94	67	25	56	47	45
LAB pH	5.81	6.17	6.33	6.99	6.41	6.71	5.69	7.81	7.66
SULFATE	33	29	21	63	36	23	74	62	60

	GRAB		
SW-C4	4/6/05	4/26/05	6/08/05
TOTAL COPPER	5.7	(3.1)	8.7
TOTAL ZINC	15	11	13
TOTAL HARDNESS	9.2	20	22
LAB pH	7.92	7.04	6.72
SULFATE	(4.7)	(2.8)	ND

	GRAB			
SW-C6	9/15/04	10/23/04	4/26/05	6/09/05
TOTAL COPPER	34	15	14	36
TOTAL ZINC	31	70	38	32
TOTAL HARDNESS	35	82	39	31
LAB pH	6.20	6.52	7.19	6.67
SULFATE	15	14	8.7	(4.3)

Figure F: Location of pit monitoring wells (Flambeau Mine Company Annual Report 2007)

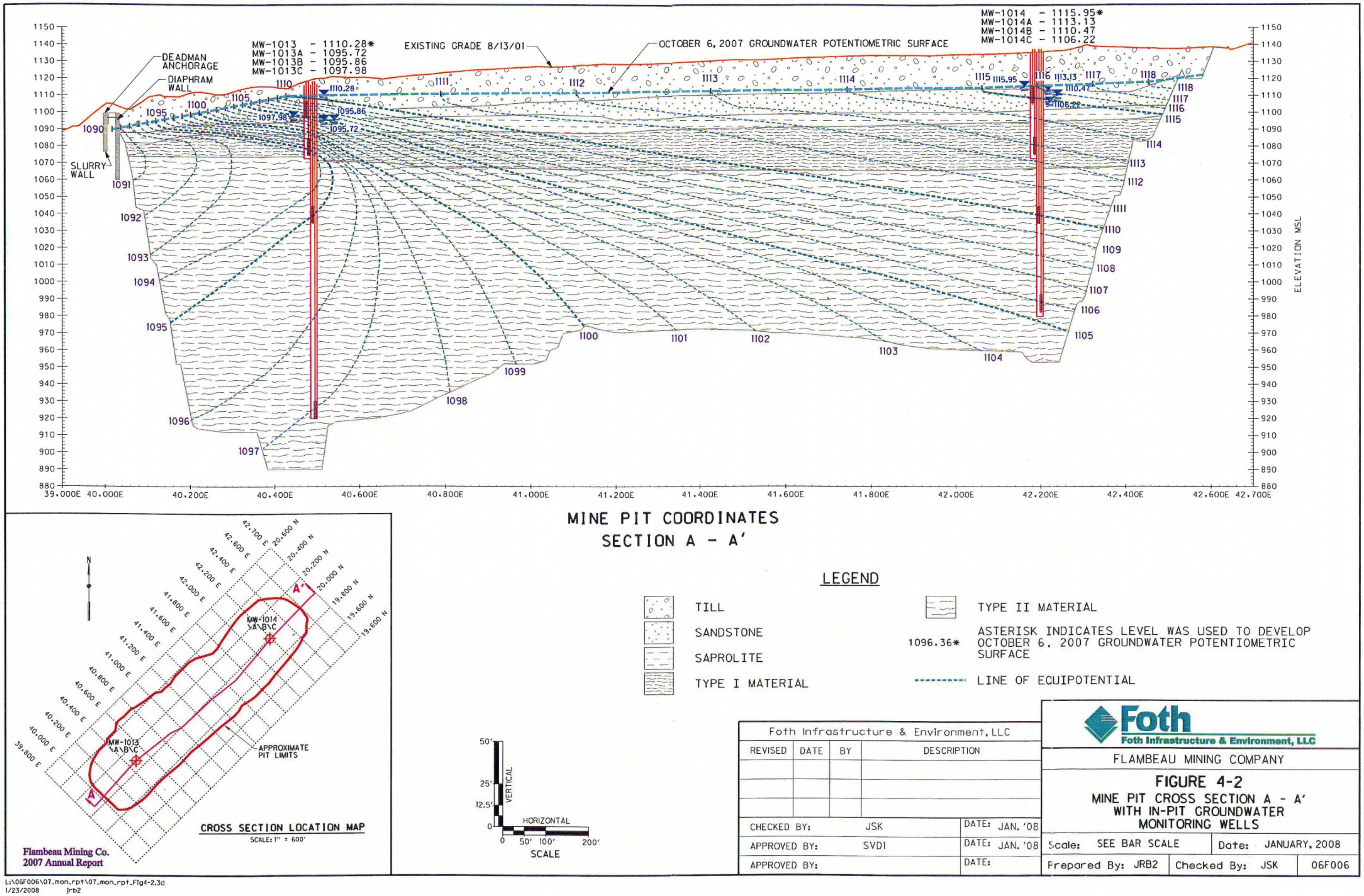


Figure G: Manganese Levels in Monitoring Well 1013-B at Reclaimed Flambeau Mine Site (1999-2007) (raw data obtained from Flambeau Mining Company, 2007 Annual Report, Appendix B – Groundwater Quality & Elevation/Surface Water Quality Trend and Flambeau Mining Company, Environmental Monitoring Results (Groundwater), First Quarter 2008, Second Quarter 2008, and Third Quarter 2008 reports)

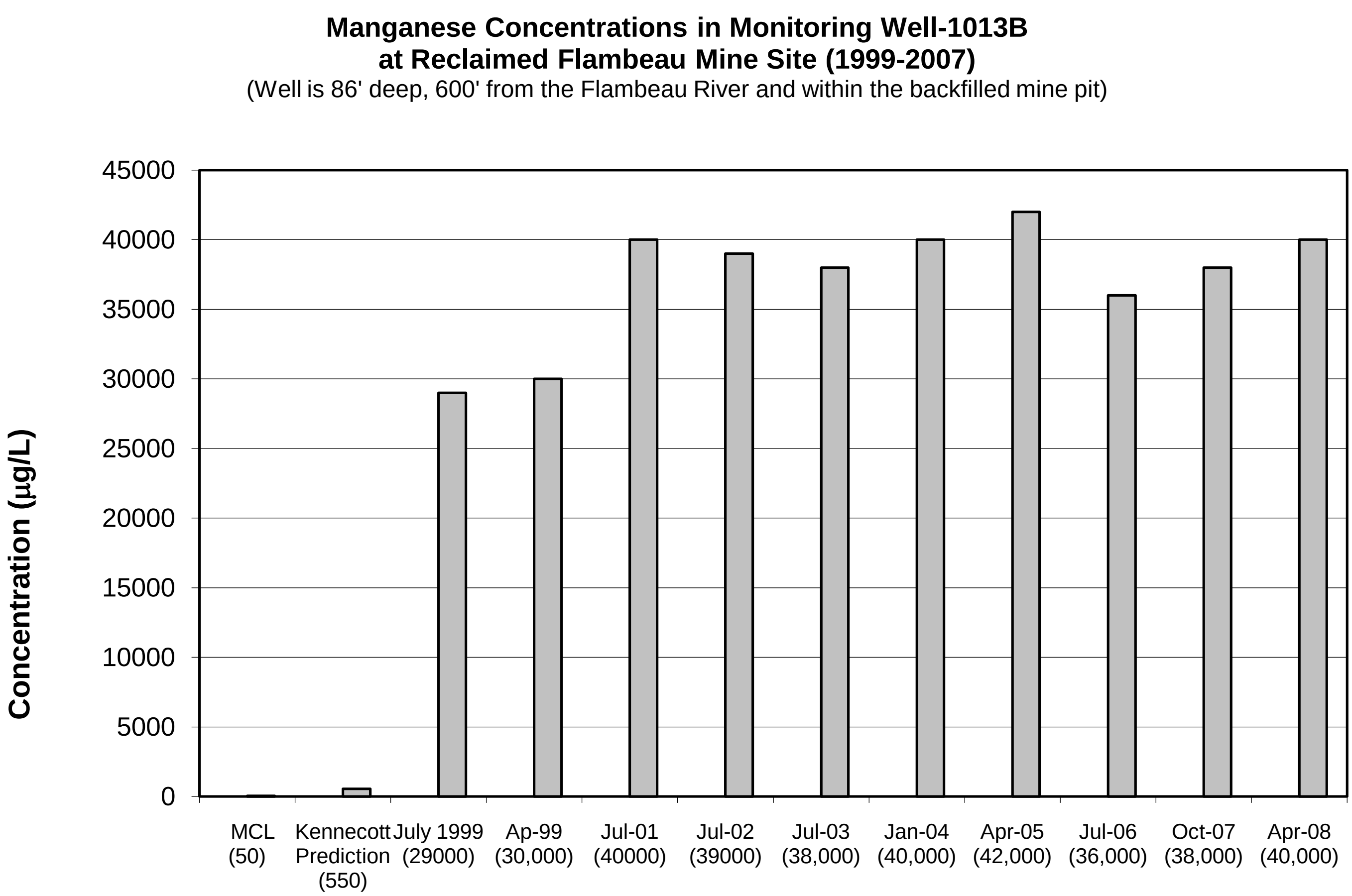


Table 4. Manganese Levels in Pore Water within Backfilled Flambeau Mine Pit Reported by Flambeau Mining Company (FMC) to the Wisconsin Department of Natural Resources (μg/L)[45]

	MW 1013	MW 1013A	MW 1013B	MW 1013C	MW 1014	MW 1014A	MW 1014B	MW 1014C
Depth	24'	47'	86'	202'	34'	64'	105'	157'
FMC Prediction [46]	550	550	550	550	550	550	550	550
Feb 99	Dry	Dry	25,000	7,200	Dry	Dry	23,000	4,300
Apr 99	Dry	Dry	30,000	7,700	Dry	Dry	23,000	4,500
Jul 99	Dry	Dry	29,000	7,300	Dry	Dry	23,000	4,000
Apr 00	Dry	Dry	32,000	7,800	Dry	7,200	22,000	3,600
Oct 00	Dry	Dry	35,000	8,200	Dry	6,700	21,000	3,200
Jul 01	Dry	Dry	40,000	9,000	Dry	6,500	20,000	3,000
Oct 01	Dry	Dry	34,000	8,500	Dry	6,000	18,000	2,900
Jul 02	Dry	Dry	39,000	10,000	Dry	6,100	19,000	2,700
Jan 03	Dry	Dry	33,000	9,500	Dry	5,300	17,000	2,400
Jul 03	Dry	Dry	38,000	9,600	Dry	4,200	16,000	2,500
Oct 03	Dry	Dry	37,000	9,800	Dry	3,000	19,000	2,400
Jan 04	Dry	Dry	40,000	9,100	Dry	3,100	17,000	2,300
Apr 04	Dry	Dry	32,000	9,700	Dry	3,100	14,000	2,300
Oct 04	Dry	Dry	34,000	9,800	Dry	2,000	17,000	2,100
Jan 05	Dry	Dry	24,000	9,500	Dry	2,000	16,000	2,000
Apr 05	Dry	Dry	42,000	10,000	Dry	2,000	16,000	2,300
Jul 05	Dry	Dry	39,000	11,000	Dry	1,400	17,000	2,200
Oct 05	25,000	4,500	30,000	11,000	1,300	1,500	15,000	2,200
Apr 06	21,000	3,900	25,000	11,000	1,200	2,100	14,000	2,100
Jul 06	20,000	1,700	36,000	9,800	940	1,400	12,000	1,900
Oct 06	24,000	2,400	23,000	11,000	880	820	13,000	2,000
Jan 07	24,000	1,700	24,000	11,000	1,300	780	15,000	1,900
Apr 07	24,000	1,700	23,000	11,000	610	920	14,000	2,000
Oct 07	24,000	2,600	38,000	11,000	580	890	13,000	2,000
Jan 08	24,000	2,100	31,000	10,000	800	940	14,000	1,800
Apr 08	23,000	2,800	40,000	11,000	260	1,100	14,000	1,900
Jun 08	22,000	3,500	21,000	10,000	830	410	14,000	1,800

[45] Unless otherwise indicated, data was obtained from: (1) Flambeau Mining Company, 2007 Annual Report, Appendix B – Groundwater Quality & Elevation/Surface Water Quality Trends; or (2) Flambeau Mining Company, Environmental Monitoring Results (Groundwater), First Quarter 2008, Second Quarter 2008, and Third Quarter 2008 reports.

[46] Foth & Van Dyke, 1989, pg L27-L31.

Table 5. Copper Levels in Pore Water within Backfilled Flambeau Mine Pit Reported by Flambeau Mining Company (FMC) to Wisconsin Department of Natural Resources (μg/l)[a]

	MW 1013	MW 1013A	MW 1013B	MW 1013C	MW 1014	MW 1014A	MW 1014B	MW 1014C
Depth	24'	47'	86'	202'	34'	64'	105'	157'
FMC Prediction[b]	14	14	14	14	14	14	14	14
Feb 99	Dry	Dry	36	100	Dry	Dry	810	<4.7
Jul 99	Dry	Dry	33	50	Dry	Dry	520	16
Oct 00	Dry	Dry	<12	<12	Dry	<12	430	<12
Oct 01	Dry	Dry	69	<13	Dry	<13	490	<13
Jul 02	Dry	Dry	150	<13	Dry	<13	550	<13
Jan 03	Dry	Dry	92	<13	Dry	<13	590	<13
Jul 03	Dry	Dry	120	<13	Dry	<13	500	<13
Oct 03	Dry	Dry	110	<13	Dry	<13	640	<1.3
Apr 04	Dry	Dry	230	<13	Dry	<13	440	<13
Oct 04	Dry	Dry	380	<13	Dry	<13	550	<13
Jan 05	Dry	Dry	180	<13	Dry	<13	520	<13
Apr 05	Dry	Dry	450	<13	Dry	<13	460	<13
Jul 05	Dry	Dry	400	<13	Dry	<13	560	<13
Oct 05	<13	<13	230	<13	<13	<13	400	<13
Apr 06	23	17	280	<13	36	22	530	<13
Jul 06	24	16	470	14	26	31	510	16
Oct 06	<13	<13	200	<13	<13	<13	460	<13
Jan 07	<13	<13	290	<13	39	<13	600	<13
Apr 07	<13	<13	230	<13	17	<13	470	<13
Jun 07	<13	<13	240	<13	<13	<13	600	<13
Oct 07	<13	<13	500	<13	33	<13	490	<13
Jan 08	<13	<13	400	<13	<13	<13	500	<13
Apr 08	<13	<13	530	<13	<13	<13	570	<13
June 08	[22]	<13	270	<13	22	<13	580	<13

[a] Unless otherwise indicated, data was obtained from: (1) Flambeau Mining Company, 2007 Annual Report, Appendix B – Groundwater Quality & Elevation/Surface Water Quality Trends; (2) Flambeau Mining Company, Environmental Monitoring Results (Groundwater), First Quarter 2008, Second Quarter 2008, and Third Quarter 2008 reports.

[b] Foth & Van Dyke, 1989, pg L27-L31.

Table 6. Iron Levels in Pore Water within Backfilled Flambeau Mine Pit Reported by Flambeau Mining Company (FMC) to Wisconsin Department of Natural Resources (μg/l)[a]

	MW 1013	MW 1013A	MW 1013B	MW 1013C	MW 1014	MW 1014A	MW 1014B	MW 1014C
Depth	24'	47'	86'	202'	34'	64'	105'	157'
FMC Prediction[b]	320	320	320	320	320	320	320	320
Feb 99	Dry	Dry	45	920	Dry	Dry	62	14,000
Jul 99	Dry	Dry	760	1,300	Dry	Dry	72	14,000
Oct 00	Dry	Dry	840	1,600	Dry	960	<360	12,000
Oct 01	Dry	Dry	660	2,700	Dry	1,500	<150	9,600
Jul 02	Dry	Dry	700	4,100	Dry	380	<150	9,400
Jan 03	Dry	Dry	150	5,400	Dry	540	<150	8,300
Jul 03	Dry	Dry	610	4,200	Dry	320	<290	8,200
Oct 03	Dry	Dry	<290	6,200	Dry	1,000	<290	7,800
Apr 04	Dry	Dry	<330	7,800	Dry	130	<330	7,500
Oct 04	Dry	Dry	<330	7,000	Dry	<330	<330	6,600
Jan 05	Dry	Dry	<330	7,200	Dry	<330	<330	6,400
Apr 05	Dry	Dry	<330	8,200	Dry	<330	<330	7,000
Jul 05	Dry	Dry	<330	8,500	Dry	<330	<330	6,900
Oct 05	22,000	<330	<330	8,300	<330	<330	<330	7,000
Apr 06	2,200	<330	<220	8,900	<330	<330	<330	6,400
Jul 06	3,200	<330	<330	7,000	<330	<330	<330	5,900
Oct 06	11,000	<330	<330	9,100	<330	<660	<330	6,100
Jan 07	12,000	<330	<330	9,500	<330	<330	<330	6,000
Apr 07	3,300	<330	<330	9,300	<33	530	<330	6,100
Jun 07	9,600	<330	<330	11,000	<330	<330	<330	5,800
Oct 07	15,000	<330	<330	9,700	<330	<330	<330	5,800
Jan 08	14,000	<330	<330	9,100	<330	<330	<330	5,400
Apr 08	4,100	<330	<330	9,600	<330	<330	<330	5,600
Jun 08	3,600	<330	<330	10,000	<330	<330	<330	5,400

[a] Unless otherwise indicated, data was obtained from: (1) Flambeau Mining Company, 2007 Annual Report, Appendix B – Groundwater Quality & Elevation/Surface Water Quality Trends; or (2) (2) Flambeau Mining Company, Environmental Monitoring Results (Groundwater), First Quarter 2008, Second Quarter 2008, and Third Quarter 2008 reports.

[b] Foth & Van Dyke, 1989, pg L27-L31.

Table 7. Groundwater Quality in Intervention Boundary Well MW-1000PR[a]

	Parameter							
	Calcium (mg/L)	Conductance, field (μmhos/cm)	Copper (μg/L)	Iron (μg/L)	Manganese (μg/L)	Sulfate (mg/L)	Total Diss. Solids (mg/L)	Zinc (μg/L)
1987-88 EIS Baseline (Prior to mining) [b]	9-26	98-251	< 66	< 620	260-590	16-31	100-350	<110
Flambeau Mine Permit Standard [c]	25 over baseline	200 over baseline	14	320	550	1100	200 over baseline	2500
Jul 1991 (Repeat Baseline)	20[d]	225	<14	650	850	<10	190	Not Done
Apr 96 (Prior to backfilling)	11[d]	150	31	18	64	16	130	Not Done
Apr 97 (During backfilling)	12[d]	133	32	43	190	10	160	Not Done
Jul 98 (After backfilling)	130[d]	1097	66	76	1800	350	250	42[d]
Apr 99	Not Done	1319	55	1300	5300	340	1200	Not Done
Jul 99	220	1310	97	3200	5600	350	1300	880
Oct 99	210	1400	17	3600	5200	680	1100	730
Oct 00	200[d]	1189	<2.6	6600	4200	460	1100	900
Oct 01	160	1109	<13	2800	3300	450	940	440
Jul 02	170	1093	<13	6200	3600	380	1000	640
Jan 03	170	1080	<13	6700	3200	390	990	700
Jul 03	170	1027	<6.7	6600	3200	360	810	730
Apr 04	151	1025	<6.7	7000	2900	330	720	623
Jul 04	150	998	28	2300	2800	310	690	830
Jul 05	160	962	27	1500	2900	330	680	650
Oct 05	Not Done	955	25	730	2900	330	730	Not Done
Apr 06	150	926	30	460	2600	300	620	560
Jul 06	130	928	21	620	2400	310	660	500
Oct 06	Not Done	948	12	490	2700	290	600	Not Done
Jan 07	Not Done	959	29	260	2600	290	570	Not Done
Apr 07	Not Done	929	13	380	2600	300	630	Not Done
Jul 07	140	887	12	660	2600	300	660	490
Oct 07	Not Done	933	<2.7	4700	2800	300	650	Not Done
Jan 08	Not Done	921	13	310	2400	310	690	Not Done
Apr 08	Not Done	880	7.8	330	2500	280	710	Not Done
Jun 08	140	932	21	460	2500	240	640	450

a Unless otherwise indicated, data was obtained from: (1) Flambeau Mining Company, 2007 Annual Report, Appendix B – Groundwater Quality & Elevation/Surface Water Quality Trends; or (2) Flambeau Mining Company, 2008 Environmental Monitoring Results (Groundwater) First Quarter, Second Quarter, and Third Quarter reports
b Data on file with Wisconsin Department of Natural Resources, Madison, WI
c Decision, Findings of Fact, Conclusions of Law and Permits [for the Flambeau Mine], State of Wisconsin Division of Hearings and Appeals, 1991, pp. 87-93.
d Since FMC did not report test results for the parameter in question, the indicated value is from split sample test results reported by the Wisconsin Department of Natural Resources and on file at Department headquarters in Madison, WI.

Table 8. Iron and Manganese Concentrations in Compliance Boundary Well MW-1015B [a]

	Parameter	
	Iron (µg/L)	**Manganese (µg/L)**
Pre-Mine Baseline[b]	Not Done	Not Done
Flambeau Mine Enforcement Standard[c]	300	230
Apr 01	69	140
Jul 01	<5	19
Oct 01	<5	8.6
Jan 02	<5	25
Apr 02	<5	73
Jul 02	69	53
Oct 02	420	380
Jan 03	120	440
Apr 03	210	250
Jul 03	450	170
Oct 03	670	290
Jan 04	440	240
Apr 04	380	120
Jul 04	450	190
Oct 04	300	140
Jan 05	220	120
Apr 05	290	130
Jul 05	400	140
Oct 05	300	140
Jan 06	320	110
Apr 06	440	100
Jul 06	52	97
Oct 06	320	110
Jan 07	350	120
Apr 07	160	81
Jul 07	340	100
Oct 07	330	100
Jan 08	290	94
Apr 08	300	86
Jun 08	200	89

[a] Unless otherwise indicated, data was obtained from: (1) Flambeau Mining Company, 2007 Annual Report, Appendix B – Groundwater Quality & Elevation/Surface Water Quality Trends; or (2) Flambeau Mining Company, 2008 Environmental Monitoring Results (Groundwater) First Quarter, Second Quarter, and Third Quarter reports

[b] The MW-1015 nest was not drilled until January 2001. Since the mine operated from 1993-1997 and the pit was backfilled in 1997, this means there are no pre-mine baseline measurements. The MW-1015 nest was first sampled in April 2001.

[c] Decision, Findings of Fact, Conclusions of Law and Permits [for the Flambeau Mine], State of Wisconsin Division of Hearings and Appeals, 1991, pp. 87-93.