Recommendations for Changes to Groundwater, Surface Water, and Biomonitoring Specified in the Stipulation Monitoring Plan at the Flambeau Mine

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In a letter on December 7, 2007, as a result of a Stipulation and Order from a contested case hearing over an application for a Certificate of Completion for closure of the Flambeau Mine, the Flambeau Mining Company implemented a Stipulation Monitoring Plan for additional monitoring at and around the reclaimed mine site. This plan includes groundwater, surface water, sediment, soils, and biomonitoring sites.

The above authors conducted a review of the surface water, groundwater, sediment, and biological monitoring data from the Flambeau Mine.[4,5] These reviews raise questions about actual and/or potential contamination coming from the mine. In order to address the questions about the magnitude and/ or presence of contamination, additional monitoring is needed. Without the additional monitoring recommended below, the extent of groundwater and surface water contamination, and the possibility of impacts to aquatic organisms in the Flambeau River cannot be addressed.

1. Surface Water Monitoring (Chambers)

At the present time the levels of copper in the discharge from the 0.9-acre wetland/biofilter in the Industrial Outlot at the Flambeau Mine site, and from Stream C into the Flambeau River, both exceed Wisconsin water quality standards.[6] 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.

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

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[4] Report on Groundwater and Surface Water Contamination at the Flambeau Mine, David M Chambers, Ph.D, Kendra Zamzow, Ph.D, Center for Science in Public Participation, June 5, 2009
[5] Flambeau River Monitoring at the Flambeau Mine Rusk County, Wisconsin, -- 1. Flambeau River Sediments -- Analysis, Comments and Recommendations, Ken Parejko, Ph.D, April 10, 2009; Flambeau River Monitoring at the Flambeau Mine Rusk County, Wisconsin – 2. Macroinvertebrates -- Analysis, Comments and Recommendations, Ken Parejko, Ph.D, April 10, 2009; Flambeau River Monitoring at the Flambeau Mine Rusk County, Wisconsin, -- 3. Crayfish -- Analysis, Comments and Recommendations, Ken Parejko, Ph.D, April 10, 2009; Flambeau River Monitoring at the Flambeau Mine Rusk County, Wisconsin, -- 4. Walleye Tissue Monitoring -- Analysis, Comments and Recommendations, Ken Parejko, Ph.D, April 10, 2009
[6] Chambers, Zamzow, Table 1: Stream C Water Quality Data, and Table 2: Flambeau River Water Quality Data

contamination, sampling in Stream C at and below the biofilter, at SW-3 in the Flambeau River, and at SW-1 and SW-2 should be done at least quarterly in order to provide background water quality information. 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.

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

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

2. Groundwater Monitoring (Zamzow)

a. Pit Monitoring Wells

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,[7] and that reactions (dissolution and precipitation of metals and ions) are controlled by pH and redox.[8] 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.[9] The pH has remained stable at each well (except alkaline spikes in October 2007 in the MW1014 nest), but 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,[10] 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.

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

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

b. Additional Metals for Groundwater Sampling

The geology of the area and of ore samples suggests nickel,[11] cobalt, aluminum,[12] and uranium[13] could be elevated. Although testing was conducted for all in 1987-1988, no groundwater analysis for these elements has 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. In 2005, nickel was found as high as 440 ug/L (pit well MW-1014B). Effluent limits for nickel were set in the WPDES permit at a maximum discharge of 3100 ug/L daily.[14] The most stringent standard listed in 1992 was 38 ug/L.[15]

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

c. Split Sampling

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

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

d. Background Well

Currently MW-1005 nested wells are utilized for "background" samples. However, this nest lies close to the old high-sulfur waste rock stockpile and Highway 27. We would suggest siting a background well further from the mine site and road. A background well could be sited at the eastern compliance boundary (east of Highway 27) and function as both a location for background samples and a compliance boundary well.

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

e. Migration of Pit 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. To ensure that contaminants are not crossing the compliance boundary, further monitoring wells, particularly in the direction contaminants are known to be traveling, should be installed and monitored.

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

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[11] 2005 data for monitoring wells MW-1014B, MW-1014C, and MW-1013C

[12] Cobalt and aluminum identified in waste rock, Flambeau Mining Company 1997

[13] 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/

[14] 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.

[15] ibid Table 14.

southeast of the wall and would aid in determining groundwater flow direction [16] 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.

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.

3. Sediment and Biological Monitoring (Parejko)

A number of suggested improvements to FMC's Flambeau River sediment and biological monitoring programs can be made. Some of them cannot be implemented retroactively but could still be useful in the design of monitoring programs in the case of future mining activity in other locations. Therefore, two different categories of recommendations are included below: (1) General recommendations, based on perceived shortcomings of monitoring at the Flambeau Mine site, to improve the utility of similar monitoring programs undertaken in the future; and (2) Recommendations for how to continue and augment FMC's monitoring program to better track potential impacts of the Flambeau Mine on the associated ecosystem.

For a more complete justification for these recommendations, please refer to the separate Sediment, Macroinvertebrate, Crayfish and Walleye Monitoring Reports.

a. Flambeau River and Stream C Sediments

1) The FMC sediment study does not provide adequate baseline data to make any reasonable conclusions about the long-term effect of the Flambeau Mine on the sediment chemistry of the Flambeau River. Samples were taken in 1988, upstream and downstream from the mining site, but were done with a different sampling procedure (PVC cores) than used at later times (sediment traps.) In addition, the 1992 samples, supposedly "background" i.e. before mining began, were actually taken after the failure of erosion-control fences which might have introduced sediment into the river due to on-site pre-mining activity. Gathering useful background information about an ecosystem potentially impacted by human activities is critical to understanding whether those activities have or have not had an effect on that ecosystem. Changing sampling procedures (and sites, see below) greatly reduces our ability to make any inferences about the effect of that human activity on that ecosystem.

Recommendation for similar studies in the future: Sampling protocol should specify that baseline studies be conducted using the same sampling methodology employed in follow-up studies. In addition, baseline studies must be completed before any significant pre-mining activity such as pre-production stripping takes place.

2) In addition to changing sampling procedures from the 1988 to later samples, exposure windows for the sediment jars were not held constant from year to year. Slight changes were also made to the sediment jar procedure between 1994 and subsequent years, to keep larger organisms from disturbing the collected sediments. The admission of the presence of some of these organisms in earlier samples reduces the reliability of those samples, and once again a change in procedure is made "mid-stream" as it were in the sampling period.

[16] In the GEMS database, the MW-1001 nest is listed as "active" but has not had water sampling since 1988. MW-1000R is listed as having been constructed in November 1992, and used only for groundwater elevation information 1997-2008; no information is listed for 1992-1996.

Recommendation for similar studies in the future: Sampling methodology should be thought out ahead of time and remain, as much as humanly possible, unchanged during the sampling regime.

3) The FMC sediment study provided inadequate replication to make inferences with any reasonable degree of confidence vis-à-vis possible mining effects on the sediments of the Flambeau River. As pointed out in the "Sampling & Reporting Issues" section of my Sediment Report, replicate rather than composite samples would greatly improve the procedure.

Recommendation for similar studies in the future: Early on in background sampling, enough replicate samples (I suggest at least five) should be taken to provide a reasonable estimate of variance in metal concentrations at each site. The metal/site combination with highest variance should be used in a power calculation to provide the number of replicates necessary to demonstrate a significant difference, if it exists, at a chosen level of confidence, say 90% or 95%. That number of replicates should then be taken at each sample site for each year and metal sampled. If this procedure is followed, inferences about the presence or absence of significant differences between sample sites will be greatly strengthened.

4) FMC changed its upstream and downstream sediment sampling sites in the Flambeau River when transitioning from baseline (1988) to follow-up (1991-2008) studies. In addition, the downstream sampling site established in 1991 at Port Arthur was changed twice during the period of follow-up sampling. Between 1991 and 1992, the Port Arthur site was moved approximately 120 feet downstream, and starting in 1994 was moved about 9500 feet upstream, to the Sister's Farm site. This unfortunately confounds the ability to make comparisons of year-to-year results.

A separate but related issue regarding sampling site location was the belated addition of Site S-4 to the sampling regime. Site S-4 is located in the Flambeau River, immediately below the Stream C outfall. Despite the fact that Stream C was and is being utilized as a drainage-way from the mine site to the Flambeau River, Site S-4 was not tested until 2008, eleven years after the cessation of mining activities. Additional information related to Stream C is included in Point # 6 below.

Recommendation for similar studies in the future: More thought should be put into carefully choosing sampling sites BEFORE the annual sampling regime is begun. Once those sites are chosen, sampling protocol should specify that the same sampling locations be utilized for the duration of the study (baseline and follow-up).

5) When FMC moved its downstream sediment sampling site from Port Arthur to the Sister's Farm site in 1994, the collection sites for macroinvertebrates and crayfish were not moved to the same location, despite the fact that the monitoring plan referenced in the Flambeau Mine Permit specified that the downstream monitoring site was to "*coincide* with the sediment sampling location near the old Port Arthur Dam"[17] (emphasis added).

Crayfish body copper concentrations were found to be significantly greater downstream than upstream of the Flambeau Mine site (see Crayfish Report), and several macroinvertebrate species appear to have declined (see Macroinvertebrate Report). But having different sampling sites for sediment chemistry and the crayfish and macroinvertebrate communities themselves makes it difficult to draw inferences about the organismal copper concentrations. The sediment microhabitat is an environmental matrix whose chemistry and potential toxicity have a profound influence on these organisms. Events, whether anthropogenic or natural, affecting the sediment chemistry and mineral dynamics, can occur at one

[17] Updated Monitoring Plan for the Flambeau Project (1991)

location while not at another. The sediments are a notoriously heterogeneous matrix, even at relatively small scales. It is therefore difficult to make reasonable inferences about putative effects of mining activities on the macroinvertebrate and crayfish communities when the sediment metal concentrations are not being monitored in situ, but at a site distant from where the organisms are collected.

Recommendation to augment FMC's sediment monitoring program: In my Macroinvertebrate Report a recommendation is made for an additional six to ten years of sampling, perhaps done every other year. In my Crayfish Report a recommendation is also made that monitoring continue on a regular basis for at least 10 years. The historic downstream sampling site for macroinvertebrates and crayfish coincides with Site S-4 in the Flambeau River, where sediment was sampled as a one-time event in 2008. It is recommended that sediments at Site S-4 continue to be sampled in conjunction with the recommended macroinvertebrate and crayfish studies. Sediment sampling should also continue at Site S-1 (Blackberry Lane), which coincides with the upstream macroinvertebrate and crayfish sampling location, and Site S-3 at Sister's Farm.

6) Stream C is an intermittent stream that drains the southeast corner of the Flambeau Mine site and receives overflow from a 0.9-acre biofilter/detention basin constructed by FMC in 1998. Stream C, classified as navigable, enters the Flambeau River about 0.3 miles downstream of the project area. Discussions indicated the possibility of water and sediments being carried through this intermittent stream, some possibly with high levels of potential toxins, into the Flambeau River. Consequently for 2008 FMC agreed to sample sediment within the bed of Stream C and in the Flambeau River, immediately below the mouth of this stream. Elevated levels of copper and zinc were detected. The belated testing of the sediment in a navigable stream used as a drainage-way from the mine site to the Flambeau River, as well as the belated testing of the sediment in the Flambeau River immediately below the stream's outfall, suggest that choice of sediment sampling sites for the entire period of monitoring was not as carefully done as one would expect.

Recommendation to augment FMC's sediment monitoring program: Sediment sampling at Site S-4 in the Flambeau River, immediately below the Stream C outfall, should continue for at least ten years. This sampling should be coordinated with sediment testing at sites S-1 and S-3 and the macroinvertebrate and crayfish sampling indicated above. If significant changes are detected during the expanded monitoring period, an additional five years sampling beyond the ten years recommended should be required. These changes could be triggered statistically (the precautionary principle suggests using $p = 0.10$) by the monitoring results, or even if not exactly statistically significant, by apparent unexplained spikes in metal concentrations in the sediment.

Additional sediment sampling within Stream C could also provide useful information, especially should relatively high sediment metal concentrations be encountered within the river during the extended sediment sampling period.

7) The measured level of metal concentrations in biota and sediments during monitoring are to an important degree affected by surface water metal concentrations. The interplay of sediment and surface water toxins on the biotic community is complex and differs for particular metals, species, and ecotypes. In case continued monitoring of the biota and sediments discloses unforeseen changes in the community structure or metal concentrations, it would be useful in attempting to explain those changes to have as much information on hand as possible vis-à-vis all possible causal mechanisms. It would therefore be amiss to not continue surface water monitoring of the Flambeau River.

Recommendation to augment FMC's sediment monitoring program: Surface water monitoring of the Flambeau River should continue for as long as sediment studies are being conducted in the river (at least ten years), drawing on water quality data collected as part of the expanded monitoring programs recommended for macroinvertebrates, crayfish and walleye (see other reports). Additional surface water sampling should be undertaken co-located temporally and spatially with sediment monitoring if significant increases in sediment metal concentrations (statistically significant at p = 0.10 or notable spikes which may or may not result in statistical significance) are observed.

b. Macroinvertebrates

1) Flambeau Mining Company failed to gather adequate baseline data regarding macroinvertebrate populations upstream and downstream from the mine site prior to commencement of the mine project. Although some macroinvertebrate sampling occurred previous to October, 1991, the procedures used varied and were not those later adopted, disallowing comparisons with later data. Standardized sampling of the kind later used ought to have occurred previous to October 1991, since nearly 90 acres of land had already been cleared of vegetation and topsoil by that time during the pre-production stripping phase of the mine project and the mine's erosion control system had failed six weeks earlier. Given the natural variability of populations due to intrinsic and extrinsic non-human factors, making reliable inferences about the pre-mining populations requires several years' sampling – the more, the better. The paucity of baseline data in this case makes questionable any statements about whether the mine either has or has not impacted the aquatic biota.

Recommendation for similar monitoring programs in the future: Sampling protocol should specify that baseline studies be conducted using the same sampling methodology employed in follow-up studies. In addition, baseline studies should entail several years' sampling and must be completed before any significant pre-mining activity such as pre-production stripping takes place.

2) FMC changed one of its two downstream macroinvertebrate sampling sites in the Flambeau River when transitioning from baseline to follow-up studies. Hence, no baseline data exists for that site (Port Arthur).

Recommendation for similar monitoring programs in the future: More thought should be put into carefully choosing sampling sites BEFORE the annual sampling regime is begun (also see point # 3 and point # 4 below). Once those sites are chosen, sampling protocol should specify that the same sampling locations be utilized for the duration of the study (baseline and follow-up).

3) Throughout most of the study at hand, FMC failed to appropriately co-locate its downstream macroinvertebrate sampling sites (Port Arthur and Meadowbrook Creek) with sites being utilized for sediment testing. With regard to the Port Arthur site, FMC tested sediment there for three years (1991-1993) and then moved the sediment sampling site to Sister's Farm (see Sediments Report). At that time the collection site for macroinvertebrates (including crayfish) was not moved to the same location, despite the fact that the monitoring plan referenced in the Flambeau Mine Permit specified that the downstream monitoring site for macroinvertebrates was to "*coincide* with the sediment sampling location near the old Port Arthur Dam"[18] (emphasis added).

With regard to the Meadowbrook Creek macroinvertebrate sampling site, sediment was not tested there until 2008, seventeen years after the macroinvertebrate study commenced.

[18] Updated Monitoring Plan for the Flambeau Project (1991)

Having different sampling sites for sediment chemistry and macroinvertebrates makes it difficult to draw inferences about organismal metal concentrations. The sediment microhabitat is an environmental matrix whose chemistry and potential toxicity have a profound influence on these organisms. Events, whether anthropogenic or natural, affecting the sediment chemistry and mineral dynamics, can occur at one location while not at another. The sediments are a notoriously heterogeneous matrix, even at small scales. It is therefore difficult to make reasonable inferences about putative effects of mining activities on the macroinvertebrate and crayfish communities when the sediment metal concentrations are not being monitored in situ, but at a site distant from where the organisms are collected.

Recommendation to augment FMC's macroinvertebrate monitoring program: One of the two historic downstream sampling sites for macroinvertebrates and crayfish (Meadowbrook Creek) coincides with Site S-4 in the Flambeau River, where sediment was sampled as a one-time event in 2008 (See Sediments Report). It is recommended that sediments at Site S-4 continue to be sampled for at least ten years in conjunction with additional macroinvertebrate and crayfish studies as recommended under point # 8 below. Sediment sampling should also continue at Site S-1 (Blackberry Lane), which coincides with the upstream macroinvertebrate and crayfish sampling location, and Site S-3 at Sister's Farm.

An additional five years of sediment sampling beyond the ten years recommended above should be required if significant changes are detected in the continuing monitoring of the biota or the sediment. These changes could be triggered statistically (the precautionary principle suggests using p = 0.10) by the biotic or sediment monitoring results, or even if not exactly statistically significant, by apparent unexplained spikes in metal concentrations in biota or sediment or notable declines in biota toward the end of the ten-year monitoring period.

Recommendation for similar monitoring programs in the future: In the future, choice of sampling sites should be done more carefully. In particular, sampling sites for macroinvertebrates and sediment need to be co-located physically and temporally whenever possible to reduce the influence of potentially confounding factors.

4) Throughout most of the study at hand, FMC failed to appropriately co-locate its downstream macroinvertebrate sampling sites (Meadowbrook Creek and Port Arthur) with sites being utilized for surface water testing. With regard to the Meadowbrook Creek site, surface water was not tested there until 2007, sixteen years after the macroinvertebrate study commenced. Surface water has never been tested at the Port Arthur site.

An additional problem with FMC's surface water quality monitoring program is that the historic surface water sampling site utilized by FMC for "downstream" testing (SW-2) is actually upstream of the river's confluence with Stream C, which originates at the mine site and may be conveying potential toxins to the river. This problem was corrected in 2007 with the addition of a new surface water sampling site to the study regime (SW-3), located immediately below the mouth of Stream C. But it is not possible to determine if, historically, there was a causal relationship between metal levels in the river's surface water and the observed trends in macroinvertebrate populations in the Flambeau River.

The measured level of metal concentrations in biota and sediments during monitoring are to an important degree affected by surface water metal concentrations. The interplay of sediment and surface water toxins on the biotic community is complex and differs for particular metals, species, and ecotypes. In case continued monitoring of the biota and sediments discloses unforeseen changes in the community structure or metal concentrations, it would be useful in attempting to explain those changes to have as much

information on hand as possible vis-à-vis all possible causal mechanisms. It would therefore be amiss to not continue surface water monitoring of the Flambeau River.

Recommendation to augment FMC's macroinvertebrate monitoring program: Surface water monitoring of the Flambeau River should: (1) continue for as long as sediment and biota are being monitored in the river (at least ten years); and (2) due to concerns over spatial co-location, be expanded to include not only the surface water sampling sites identified in the December 2007 Stipulation Monitoring Plan (SW-1, SW-2 and SW-3), but also the Port Arthur biota sampling site. In addition, due to concerns over temporal co-location, surface water sampling should be timed so that samples are collected on the same days as biota are sampled.

Recommendation for similar monitoring programs in the future: In the future, choice of sampling sites should be done more carefully. In particular, sampling sites for macroinvertebrates and surface water need to be co-located physically and temporally whenever possible to reduce the influence of potentially confounding factors.

5) Since number of individuals and taxa encountered in biotic sampling depends so intimately on sampling effort, it is critical that each year's and site's sampling be as identical as possible. The standard methodology of sampling utilized by FMC subsequent to 1991 is not clear. It is described (e.g. in the *FMC 2004 Annual Report: Appendix D*) as "using a net with an 8 by 18-inch opening and an 800 to 900 micron mesh size." To the present author this sounds like an aquatic kick-net. The methodology is further described as "Instream sampling methods consisted of kick-seining." But kick-seining, again to the present author, involves a much larger net than one with an 8 by 18-inch opening – usually about 4 by 4 feet – and stirring up a meter square of river-bottom at each sampling effort. The area sampled by disturbing the river-bottom in front of each kick-net or kick-seine sampling, an important sampling parameter, is not described. Sampling effort for 2004 is described as: "At each of the three sites, instream sampling was conducted for approximately two man-hours." The *FMC 1992 Annual Report* says only that "Aquatic invertebrate collections were conducted using kick sampling techniques with both Surber sampler and D-frame nets."

These descriptions of sampling effort are inappropriately vague. On the one hand it's not clear exactly what the sampling methodology for any given year was – kick-net, Surber or kick-seining – and on the other it is not possible to verify that between sites and years, sampling effort was equivalent. "Approximately two-hours sampling effort" is quite vague, especially as the amount of sampling accomplished in two hours can vary depending on the individual. The purpose of benthic macroinvertebrate sampling is to gather information adequately reflecting the range of taxa and populations sizes of the macroinvertebrates in the river. The protocol used by FMC is a time-based protocol, which includes sorting of individual organisms from sediments. In addition to depending on the expertise, etc. of the individual doing the sampling another problem with time-based protocols is that they can underestimate large populations and over-estimate small populations. This is because the actual number of subsamples taken in the river is reduced when a large number of individual organisms needs to be sorted in a given time-frame, while when populations are low, more subsamples can be taken. The number (and total area sampled) of subsamples taken therefore more accurately represents the biota in the river than a time-based protocol.

A much more clearly-described and carefully-chosen sampling protocol would assure that data across sites and years is in fact comparable, and more reliably represents populations within the river. Such a protocol might include e.g. using the same number and size of subsamples (Surber, kick-net or kick-seine samples) for each site, and a description of the method used to locate subsamples – e.g. random within a site, equally or randomly spaced along a cross-river transect, etc. Collecting subsamples (e.g. kick-net

samples) into separate containers, and identifying and recording them separately would also increase the statistical usefulness of the collection.

Recommendation for similar monitoring programs in the future: A sampling protocol needs to be defined. The protocol should include number and size of subsamples for each site, and a description of the method used to locate subsamples.

6) Consistency in sampling and data presentation is critical. Although it is not always feasible because of lack of taxonomic knowledge or expertise and due to time constraints, whenever possible specimens should be identified to the species level. This is especially important for the Ephemeroptera, Plecoptera, and Tricoptera, which are used in the calculation of the EPT index. As mentioned in my Macroinvertebrate Report, some species of these orders are much more tolerant of pollutants than others, and without knowing the community structure to the level of species it's difficult to make inferences about possible human impacts on the macroinvertebrates. In other words, without proper species-level identification for these taxa, these indices have considerably less usefulness.

I also found it necessary to not use the results from FMC's 2006 survey in some of my analyses because identification of specimens was not done in the same manner as in previous years. Longitudinal (cross-year) sampling consistency is essential! As an example, if you are trying to determine trends in traffic on a highway, and for eight years you count all traffic, but discover that in the last year of the study, motorcycles & buses weren't counted, that makes that year's data useless for most analyses. If taxa are ID'd to species (or genus) level in one year, they should be in all years.

Recommendation for similar monitoring programs in the future: Specimens should be identified to the species level. If this is not possible, then the reasons for foregoing species level identification should be clearly recorded. Once a particular level of taxa identification has been established (e.g., species vs. genus), that same level of identification should be maintained throughout the survey.

7) Changing daylengths and water temperatures affect macroinvertebrate behavior in ways which might make them less susceptible to capture. It is therefore important that the principle of temporal co-location be applied to macroinvertebrate studies. This was not always done by FMC. For example, macroinvertebrate sampling was conducted in late October 1991, late September 1992 and mid-August 2004.

Recommendation for similar monitoring programs in the future: Sampling protocol should specify that sampling be conducted at the same date (except for extenuating circumstances, within a 2- week window each year) and day-time (again, except for extenuating circumstances, within a 2-hour time window of the day).

8) It is important to continue macroinvertebrate monitoring at the Flambeau Mine site to determine if the apparent trends in decreased macroinvertebrate biodiversity downstream from the mine (discussed in my Macroinvertebrate Report) are real. Plecopterans (stoneflies), Tricopterans (caddisflies) and Gastropods (mollusks) show evidence of downstream declines over the course of sampling, although Tricopterans appear to have declined upstream as well. Ephemeropta (mayflies) showed an apparent decrease in taxa encountered in 2006, upstream and downstream. These trends are potentially important. Problems with the 2006 data for total taxa sampled (discussed in my Macroinvertebrate Report) make inferences about future trends especially difficult.

There appears to be no good explanation vis-à-vis human activities to explain the observed decline in some macroinvertebrate fauna downstream from the mine. The observed changes may or may not be completely unrelated to the mining activity. The greatest change in the macroinvertebrates, as noted above, seems to have been at the Port Arthur Dam site, far enough downstream from the mine that other,

e.g. agriculture-related impacts may have caused those changes. However, the changes may in some causal way be connected to mining activities, as suggested by the observation of similar though perhaps not as profound changes at the Meadowbrook Creek site, near the mine.

To clarify these issues and because of the sensitivity of these organisms to metallic toxins, additional monitoring of macroinvertebrates in the Flambeau River is warranted.

Recommendation to augment FMC's macroinvertebrate monitoring program: It is recommended that an additional six to ten years of macroinvertebrate sampling be done at the Blackberry Lane, Meadowbrook Creek and Port Arthur sampling sites, perhaps done every other year. If significant changes are detected in taxon richness or the EPT index during the expanded monitoring period, an additional five years sampling beyond that already recommended should be required. These changes could be triggered statistically (the precautionary principle suggests using p = 0.10) by the monitoring results, or even if not exactly statistically significant, by apparent unexplained declines in either taxon richness or the EPT index.

9) Because of the ability of macroinvertebrates to bioaccumulate metals, regular analysis of a select set of macroinvertebrates (instead of only crayfish) for total body metal concentrations should be done, upstream and downstream from the potentially impacting activity. Copper or other metals in the macroinvertebrates will likely make their way into the higher food chain. In some streams near Yellowstone Park copper concentrations in macroinvertebrates reached levels which killed half of trout fed food with the same copper concentration.[19] Chemical analyses of macroinvertebrates in addition to crayfish were not done by FMC.

Recommendation for similar monitoring programs in the future: Based on macroinvertebrate taxa present and their relative abundance, it is recommended that a select set of macroinvertebrates be identified for total body metal analysis.

10) A number of endangered and threatened species were found in potentially-impacted reaches of the Flambeau River, previous to mining activity. As far as can be ascertained, no special effort was made to determine the location and numbers of these endangered populations either during the years of ore production or after mining ceased. Without such monitoring, it is not possible to make any reasonable statements vis-à-vis the effect of FMC's mining operation on these species of concern.

Recommendation to augment FMC's macroinvertebrate monitoring program: It is recommended that FMC conduct follow-up surveys to determine the fate of the following endangered or threatened species identified in the Supplement to the Environmental Impact Statement for the Flambeau Mine Project, April 1992: the purple wartyback mussel, the bullhead mussel, and three species of dragonflies (the pygmy snaketail, extra-striped snaketail, and St. Croix snaketail).

Recommendation for similar monitoring programs in the future: It is recommended that specific monitoring for endangered or threatened species be undertaken whenever a new mining operation is under consideration, and that additional monitoring specifically targeting any such species identified be required if the mine is permitted.

[19] Nimmo, et al (1998) Environmental Management 22(6): 913-926

c. Crayfish

1) Though some preliminary crayfish monitoring was undertaken by FMC in1988, ambiguous recording made the results uninterpretable. In addition, "background" data from 1991 and 1992 may have been affected by preliminary work at the mine site already underway in 1991 (see my individual reports).

Recommendation for similar monitoring programs in the future: It is recommended that several years' true background monitoring be gathered before initiating pre-mining or mining activity and that care be taken to avoid ambiguous recording of data. It is also recommended that the protocols used for these baseline studies, including sampling locations, remain constant during the pre-mining, mining and post-mining period.

2) Iron and manganese were not added to the crayfish test panel until 2007. As a result, interpretation of current test results showing measureable concentrations of these metals in crayfish specimens has been impeded.

Recommendation for similar monitoring programs in the future: Test panels should be thoroughly reviewed at the onset of any monitoring program such as that undertaken by FMC so that important data sets are not overlooked.

3) The availability of only one composite sample/site/year limited the ability to do statistical analysis and draw meaningful conclusions on a timely basis for a given year. It was only after a number of years' data was collected that it became possible to make statistically-significant inferences vis-à-vis metal concentrations in the crayfish.

An additional problem with composite samples is that they mask any individual organisms which might, because of their particular physiology, microhabitats, or diet have accumulated metals to potentially toxic or otherwise harmful levels. The uncertainties around potential hazards to individual crayfish from copper in the Flambeau River are succinctly summarized in a December 12, 2001 memo written by Elisabeth Harrahy, an environmental toxicologist with the Wisconsin Department of Natural Resources (DNR). In that memo Ms. Harrahy, in an analysis of metals in Flambeau River crayfish reported by FMC up to that date, states that "Without more in-depth monitoring, it is difficult to draw any conclusions on the effects of this Cu on these crayfish."

Recommendation to augment FMC's crayfish monitoring program: To allow more timely management decisions to be made, it is recommended that the total composite crayfish sample be divided into replicate subsamples of say 5 each, and analyses be done on these subsamples. If only 2 or 3 crayfish provide enough tissue for the analyses, then smaller composites should be used, the principle being to provide as many subsamples per site/year as possible, to improve the ability to do statistical analyses comparing sites and years. In addition, FMC should include in its reporting a current literature assessment of toxicological thresholds for the metals being monitored in order to facilitate interpretation of the data.

Recommendation for similar monitoring programs in the future: Crayfish or other chosen macroinvertebrate sampled for metal analyses should be done in such a way as to provide as many subsamples per site as possible, and include a current literature assessment of toxicological thresholds for the metals being monitored.

4) To strengthen inferences about the possible effect of mining on the metal concentrations in Flambeau River invertebrates, it is recommended the monitoring of crayfish metals continue on a regular

basis for at least 10 years. These analyses could be limited to only the five elements historically present at regularly detectable levels, i.e. zinc, aluminum, manganese, iron and copper.

The need for continued monitoring of the crayfish receives further support from a statement in the memo mentioned in #3 above, written by the Wisconsin DNR's Elisabeth Harrahy. In that letter Ms. Harrahy states: "However, because metals are expected to continue moving from the mine pit to the river, and because metals can build up in sediments over time and bioaccumulate in organisms (with potential for cascading up the food chain), continued monitoring could yield much important information."

Recommendation to augment FMC's crayfish monitoring program: It is recommended that crayfish analysis, using protocols discussed above, continue for an additional 10 years. If significant changes are detected during the expanded monitoring period, an additional five years sampling beyond the ten years recommended should be required. These changes could be triggered statistically (the precautionary principle suggests using p = 0.10) by the biotic monitoring results, or even if not exactly statistically significant, by apparent unexplained spikes in metal concentrations in the crayfish.

5) Chemical analyses of macroinvertebrates in addition to crayfish were not done by FMC. As mentioned in my Macroinvertebrate Report, because of the ability of macroinvertebrates to bioaccumulate metals, regular analysis of a select set of macroinvertebrates (in addition to crayfish) for total body metal concentrations could provide much useful information with regard to tracking potential toxins that might be making their way into the higher food chain.

Recommendation for similar monitoring programs in the future: It is recommended that monitoring programs such as those undertaken by FMC include whole-body elemental analyses of invertebrates in addition to crayfish – e.g. mayflies, stoneflies, mussels, etc.

6) Inferences regarding the possible effects of human activities on river or stream ecosystems are strengthened when sampling sites for specimens such as crayfish, macroinvertebrates, sediment and surface water are spatially and temporally co-located. In particular, the measured level of metal concentrations in biota and sediments during monitoring is to an important degree affected by surface water metal concentrations. In case continued monitoring of crayfish by FMC discloses unforeseen changes in metal concentrations, it would be useful in attempting to explain those changes to have as much information on hand as possible vis-à-vis all possible causal mechanisms. It would therefore be amiss to not continue surface water monitoring of the Flambeau River per existing protocols.

Recommendation to augment FMC's crayfish monitoring program: Surface water monitoring of the Flambeau River should: (1) continue for as long as crayfish are being monitored in the river (at least ten years); and (2) due to concerns over spatial co-location, be expanded to include not only the surface water sampling sites identified in the December 2007 Stipulation Monitoring Plan (SW-1, SW-2 and SW-3), but the crayfish sampling site at Port Arthur. Due to concerns over temporal co-location, surface water sampling should be timed so that samples are collected on the same days as crayfish are sampled, in addition to other scheduled dates.

Recommendation for similar monitoring programs in the future: Whenever possible, the various studies (e.g., metals analyses of crayfish, walleye, sediment and surface waters and/or biota surveys) implemented by an industry or agency to assess potential impacts of human activity on the riverine community should be spatially and temporally co-located.

d. Walleye

1) Though some preliminary walleye monitoring was undertaken by FMC in 1988, data collection was insufficient to draw meaningful conclusions regarding baseline metal levels in walleye tissue. "Background" data from 1991 and 1992 may have been affected by preliminary work at the mine-site already underway in 1991. Several years' true background monitoring – before any on-site human disturbance – should always be gathered, and the procedures and protocols of that background sampling should be the same as subsequent procedures.

Recommendation for similar monitoring programs in the future: It is recommended that adequate baseline studies be completed before initiating pre-mining or mining activity, and the protocols used for these baseline studies, including sampling locations, should be continued into the period of monitoring during pre-mining, mining or post-mining activity.

2) It may not physically be realistic to require fish sampling directly above and directly below activities such as those undertaken by the FMC along the Flambeau River. However, fish collected as far upstream as the Ladysmith Flowage (3.8 miles) and downstream as the Thornapple Flowage (7.6 miles), as was the case in the FMC study, are subject to environmental variability which may readily not be related to the mining activity. Whether walleyes collected nearer the mine, upstream or downstream, would have elemental compositions regularly differing from those collected farther afield is difficult to say. They might, depending on random, sporadic or regular events, or they might not. However, whenever possible – and this might require choosing a different species of fish as biomonitor – samples should be collected as near to upstream and as near to downstream of the potentially impacting human activity as possible.

Recommendation for similar monitoring programs in the future: It is recommended that sampling locations for fish species being monitored be located as near to upstream and downstream of the potentially-impacting human activity as possible.

3) Because the majority of the FMC data were from composited samples (one composite sample/year/location), there was no measure of variability. This lack of replication and data on variability among individual samples makes it difficult to interpret what the metal concentrations measured in liver tissue mean from a toxicological viewpoint. Although earlier sampling can not be redone at this location, having information on current levels of variability for each of the trace elements would allow for a fuller assessment of potential risk to fish. Therefore it is recommended that walleye livers be analyzed individually, especially for copper but for the other elements as well, for some portion of the monitoring period. That will provide approximately 9 replicates per location upon which to calculate variability. It would be desirable to have a measure of variability for two or more years of data given the level of inter-annual variation seen in the Hg fillet data set. All of the other caveats for sampling would need to be considered, such as collecting the same species, same size or range of sizes, same timeframe, same habitat, etc. In addition, it would be helpful for FMC to include in its reporting a current literature assessment of toxicological thresholds for metals of concern (copper, iron, zinc, manganese and aluminum), in order to facilitate interpretation of the data.

Statistical reliability of comparisons of upstream and downstream walleye liver metal concentrations would be greatly enhanced if samples were tested individually. This is yet one more reason that individual as opposed to composite testing of walleye liver specimens is recommended for at least two years of the monitoring period.

Recommendation to augment FMC's walleye monitoring program: It is recommended that walleye livers be analyzed individually, especially for copper but for the other elements as

well, for two or more years of the monitoring period. FMC should also include a current assessment of toxicological thresholds for metals of concern in its report.

Recommendation for similar monitoring programs in the future: It is recommended that all specimen tissues extracted for metals analysis – fillet, liver or other – be analyzed on an individual rather than composite basis, for at least some portion (two or more years) of the monitoring period, in order to establish an estimate of variation among individuals. The entity initiating mining activity should include a current assessment of toxicological thresholds for metals of concern in its report.

4) To strengthen inferences about the possible effect of mining on the metal concentrations in Flambeau River walleye, and to clarify if the recent declining trend in copper levels in downstream fish is real or not, it is recommended the monitoring of metals in walleye liver tissue continue on a regular basis for at least 10 years. These analyses could be limited to the five elements historically present at regularly detectable levels, i.e. copper, zinc, iron, manganese and aluminum.

Recommendation to augment FMC's walleye monitoring program: It is recommended that walleye liver tissue analysis, using protocols discussed above, continue for an additional 10 years. If significant changes are detected during the expanded monitoring period, an additional five years sampling beyond the ten years recommended should be required. These changes could be triggered statistically (the precautionary principle suggests using p = 0.10) by the biotic monitoring results, or even if not exactly statistically significant, by apparent unexplained spikes in metal concentrations in the walleye liver tissue.

5) The measured level of metal concentrations in biota and sediments during monitoring is to an important degree affected by surface water metal concentrations. In case continued monitoring of walleye discloses unforeseen changes in metal concentrations, it would be useful in attempting to explain those changes to have as much information on hand as possible vis-à-vis all possible causal mechanisms. It would therefore be amiss to not continue surface water monitoring of the Flambeau River per existing protocols.

Recommendation to augment FMC's walleye monitoring program: Surface water monitoring of the Flambeau River should: (1) continue for as long as walleye are being monitored in the river (at least ten years); and (2) due to concerns over spatial co-location, be expanded to include not only the surface water sampling sites identified in the December 2007 Stipulation Monitoring Plan (SW-1, SW-2 and SW-3), but the walleye sampling sites at the Ladysmith Flowage and Thornapple Flowage. Due to concerns over temporal co-location, surface water sampling should be timed so that samples are collected on the same days as walleye are sampled, in addition to other scheduled dates.

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