An Evaluation of Endangered Resources in the Flambeau River

and

A Supplement to the Environmental Impact Statement for the Flambeau Mine Project

Printed on Recycled Paper

State of Wisconsin
Department of Natural Resources
April 1992

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SUMMARY

The purpose of this report is to document information regarding several state-listed endangered and threatened species recently located in the Flambeau River. It will also supplement information previously provided in the Environmental Impact Statement (EIS) for the Flambeau Mine. The Department has prepared this document to relay its findings to the interested public. The report does not necessarily have any legal status or function.

In May 1987, Kennecott announced that it intended to apply for permits to build a small open pit copper mine along the Flambeau River near Ladysmith. Over the next 3½ years, the project proceeded through the state regulatory review process, which included preparation of draft and final versions of an EIS. The regulatory process was completed in January, 1991, when, after a 3-week hearing, permits for the project where granted.

In spring 1991, Department staff surveying the Flambeau River near the mine site discovered several specimens of purple wartyback mussels (*Cyclonaias tuberculata*), a state-listed endangered species. Subsequent intensive surveys by the Department found two other state-listed endangered species: the bullhead mussel (*Plethobasus cyphyus*) and the pygmy snaketail dragonfly (*Ophiogomphus howei*).

As a result of these findings, the Department conducted a general review of endangered and threatened aquatic species in the river and a specific review of the mine's potential to impact the species. As its first step, the Department compiled information on endangered and threatened species throughout the Flambeau River system. Five additional state-listed species were identified as existing in the river: the gilt darter (*Percina evides*); the river redhorse (*Moxostoma carinatum*); the greater redhorse (*Moxostoma valenciennesi*); the extra-striped snaketail dragonfly (*Ophiogomphus anomalus*); and the wood turtle (*Clemmys imsculpta*). It is likely that additional occurrences or species would be identified with further surveys.

A review of existing water quality data shows the river is generally of high quality, although portions of the river downstream from Park Falls have in the past been significantly degraded by industrial discharges. The major point source dischargers on the river are the Flambeau Paper Corporation, the Pope and Talbot paper making facility, and the cities of Park Falls and Ladysmith. Excessive mercury levels are present in some fish throughout the river. Hydropower operations have a significant impact on the river hydrology and biota.

There are two principal types of impacts from the mine which could affect endangered and threatened aquatic species: discharge of sediments from mine erosion and discharge of wastewater from the mine operation. Sedimentation from the mine would be controlled by techniques described in several documents submitted as part of the regulatory process. These techniques are considered Best

Management Practices under commonly accepted standards for erosion and sedimentation control activities. Proper implementation of these techniques should minimize discharge of sediment to the river.

Wastewater from the mine operation would be comprised of stormwater and groundwater. No chemical processing of the ore would occur at the site.

Potential impacts from the wastewater discharge were first evaluated by reviewing the nationwide database maintained by the Environmental Protection Agency for various metals. No toxicity data were available for freshwater mussels or dragonflies. However, data on taxonomically similar organisms (snails and damselflies) indicated that the species used to established effluent limitations for the mine were more sensitive to metals than were snails and damselflies. These data supported the conclusion that the existing effluent limitations for the mine adequately protected mussels and dragonflies.

Department staff also reviewed other literature not included in the nationwide database. One study, published in 1991, employed a technique currently under development for testing the toxicity of substances to freshwater mussels. This study indicated that mussels may be as sensitive to certain metals as the cladocerans (water fleas) used to determine the mine's effluent limitations. As a result of this study, the Department decided to conduct toxicity testing on a mussel species using this new technique and a synthesized mine effluent.

Toxicity testing was conducted using the paper floater mussel (*Anodonta imbecilis*), the larval fathead minnow (*Pimephales promelas*), and a water flea (*Ceriodaphnia dubia*). No acute toxic effects were observed in any of the test organisms at the expected effluent quality. The tests also showed that the water flea was much more sensitive to the synthesized mine effluent than the mussel species. These tests indicated that, with respect to the mine wastewater, effluent limitations and monitoring designed to protect cladocerans should provide adequate protection to mussel species.

Analysis of data from a single study on metal toxicity to mussels indicates that the mine's effluent limitations for cadmium and nickel may be too high. If this analysis were used as the sole basis for establishing effluent limitations, it would support a reduction in the limitations for these parameters. Concentrations of cadmium and nickel in the mine effluent are projected to be substantially less than the reduced limitations.

INTRODUCTION

PURPOSE OF THE REPORT

This report documents the Department of Natural Resources' ("DNR" or "department") investigations and findings regarding several state-listed threatened or endangered species that were discovered in the Flambeau River since May 1991. The report also serves to supplement the Environmental Impact Statement ("EIS") prepared by the Department on the Flambeau Mine Project near Ladysmith. The DNR has prepared this supplement to provide the public with additional information and documentation regarding potential impacts to these species. The Department does not believe this supplement is legally required by the Wisconsin Environmental Policy Act ("WEPA") or any other law.

WEPA and Wisconsin Administrative Code NR 150 are the state laws which describe when EIS's must be prepared. These laws state that, before any major state action which might significantly affect the quality of the human environment, the Department must prepare an EIS which evaluates the impact of that action. In the case of the Flambeau Mine project, the Department completed its major action with the issuance of the various permits in January, 1991. No judicial review of those decisions was sought by any person or party. The agency action which was the subject of the EIS is therefore completed.

Issuance of the permits does not, however, complete DNR's regulatory responsibilities at the mine site. The Department still has an obligation to protect resources and to ensure compliance with the permit conditions. The Department also may modify existing permits. Any future agency actions on the mine project would be subject to new applications of the requirements of WEPA. While information in this report may be used, in part, to evaluate future actions, it is not intended to serve as a WEPA compliance document for any particular action.

Information in this document is intended to be supplementary to that already provided in a number of project related documents. Readers interested in additional details on the project proposal, the environmental setting, or impact analyses should refer to the source documents which are referenced and incorporated into this report.

HISTORY OF THE FLAMBEAU MINE PROJECT REVIEW

The ore body located along the Flambeau River south of Ladysmith was first discovered in 1968 by Kennecott Copper Corporation. Over the next several years, the company conducted a variety of environmental and engineering studies to support permit applications for a proposed mining operation. The Department also conducted independent studies of the site's physical and biological resources during this period. In 1974, the company submitted its Preliminary Environmental Impact Report to the Department documenting the results of the environmental baseline studies. In February, 1976, the Department issued an EIS on the project proposal describing its analysis of the potential impacts from the mine. A hearing on the EIS was held in March, 1976, and the EIS was subsequently determined to be legally adequate. A hearing on the project permits was initiated in November, 1976, but was adjourned after the Rusk County Board passed a resolution indicating it would not grant the necessary local approvals until the State Legislature passed laws providing economic guarantees and additional local tax revenues. Although the Rusk County Board subsequently passed a resolution indicating its desire that the permit proceeding continue, the permit applications were dismissed by the hearing examiner in September, 1977.

Over the next decade, the project was relatively inactive, although Kennecott continued to collect data on surface water quality, groundwater, air quality, and other environmental parameters.

In May, 1987, Kennecott announced that it, once again, intended to apply for permits to construct a small open pit mine at the site. The company submitted a Notice of Intent (NOI) in July, 1987. This document described the environmental studies and field work the company proposed to conduct in order to support the project's permit applications and Environmental Impact Report (EIR). A public comment period was established for the NOI and a public hearing was held in Ladysmith in September, 1987. About 13 letters were received commenting on the NOI and 13 individuals testified at the public hearing. Comments on the NOI were used to finalize the document into a "Scope of Study" or study plan for the project's environmental data collection.

Over the approximately next 18 months, the company's consultants conducted the studies and surveys described in the NOI. Department staff verified the consultant studies and conducted independent field investigations. The environmental work consisted of a series of studies typically conducted for large or complex projects. A description of the relevant biotic survey work conducted during this period is provided later in this document.

As required by state statutes, the company analyzed the data generated by this field program and compiled it into permit applications and an Environmental Impact Report (EIR) for submittal to the Department. During preparation of these documents, the company's consultant, Foth and Van Dyke, asked the Department several times for any records of state-listed threatened or endangered species in the vicinity of the mine site. Each time, the Department responded that it had no records of threatened or endangered species from the site. Copies of this correspondence are included in Appendix A. The company completed preparation of the EIR and permit applications, and submitted these documents to the Department in April, 1989.

Based on these documents, the Department began preparation of a Draft Environmental Impact Statement (DEIS) on the project. During the process of preparing the DEIS, the Department's Bureau of Environmental Analysis and Review (BEAR) asked the Bureau of Endangered Resources (BER) for records of any occurrences of state-listed, threatened or endangered species from the mine site. BER again responded that there were no threatened or endangered species known to occur on or adjacent to the mine site with the exception of a bald eagle nest located in the general vicinity. This memo went on to note that three species of mussels soon to be listed by the state as endangered were known to exist in the nearby Chippewa River. BER recommended that all areas of potential impact be surveyed for endangered resources, especially with respect to mussels.

The Department decided not to conduct or require any additional survey work for several reasons. First, it was determined that the mine project would have little impact on aquatic organisms. The project would have very minor physical impacts on the river, and would have a small, short-term wastewater discharge regulated by extremely stringent pollution limits. While other bureaus in the agency had reached these technical conclusions, BER had not yet been apprised of these analyses. BER had also not reviewed biological survey work which had been conducted by the company and Department staff during preparation of the EIR and permit applications. These surveys had included sampling of aquatic macroinvertebrates, although not specifically targeted at rare mussels, which had not located any species of mussels planned for addition to the state's threatened and endangered list. In fact, there was, at that time, no record of any of the mussel species from the Flambeau River. The closest known occurrences to the mine site were in the Chippewa River. Finally, BER's survey recommendation was formulated very late in the environmental review process, after the data collection program had been completed.

In September, 1989, the Department issued its DEIS on the mine. A public hearing on the DEIS was held at Ladysmith in October, 1989. The document was revised based on the comments received at the hearing and during the public comment period. The revised document was issued as a Final Environmental Impact Statement (FEIS) in March, 1990. Both the DEIS and FEIS indicated that there were no known state-listed threatened or endangered species on or adjacent to the mine site.

In July, 1990, the final hearing on the project permits and the FEIS began. Approximately 50 expert witnesses provided sworn testimony addressing detailed aspects of the project. Cross examination of these witnesses during the 15 day contested case hearing resulted in one of the most expansive hearing records ever produced by an administrative agency in the history of Wisconsin. After another five months of post hearing legal arguments and review of the record, the hearing examiner concluded that the Department had complied with WEPA and issued permits for the project in January, 1991.

The permits included all of the over 400 special conditions that the Department had proposed. None of the parties to the hearing pursued their option for judicial review of the hearing examiner's decision as provided by state statute.

In May, 1991, Department biologists conducting mussel surveys associated with relicensing of the Thornapple Dam on the Flambeau River discovered two specimens of purple wartyback mussels *(Cyclonaias tuberculata)*, a state-listed endangered species, at a site approximately 0.7 miles downstream from the Flambeau Mine site. As a result of this finding, the Department initiated an extensive mussel survey in the area of the river adjacent to the mine site. Over 2,200 mussels from the area were examined, revealing one additional specimen of a purple wartyback mussel and two specimens of bullhead mussels *(Plethobasus cyphyus)*, also a state endangered species. During these surveys, Department biologists also collected cast skins (exuviae) and nymphs of the pygmy snaketail dragonfly *(Ophiogomphus howei)*, a state endangered species. All of these species were added to the state's endangered and threatened species list in August, 1989, after the field survey work for the project had been completed.

Based on these findings, the Department conducted a review of the mine project to determine if the operation posed any threat to the species. After reviewing the scientific literature and consulting with national experts, staff concluded that:

1. Sedimentation from mine site activities and the wastewater discharge during the mine operations could potentially impact the listed species.

2. Site sedimentation would be adequately controlled by activities required by the surface water management and erosion control plans included in the mining permit.

3. The scientific literature indicated in general that mussels and dragonflies were not highly sensitive to pollutants and should be protected from adverse affects by the regulatory limits imposed on the wastewater discharge, although a single recent study (Keller and Zam, 1991) indicated that mussels might be more sensitive to several pollutants than previously reported. Staff also recommended that the Department conduct laboratory testing on mussels using simulated wastewater from the mine to confirm that the discharge would have no adverse affect and that this testing be conducted before the discharge commenced. This testing program was initiated in July, 1991.

Flambeau Mining Company began construction at the mine site in early July, 1991. Initial construction activities were confined to site clearing and grading, fence building, stripping, and stockpiling of topsoil, and excavation of water retention and handling facilities.

In late July, 1991, the Lac Courte Oreilles band of Lake Superior Chippewa Indians and the Sierra Club filed a suit in Dane County Circuit Court asking that permits for the mine be revoked and that the Department prepare a supplement to the EIS (SEIS) on the project dealing with the endangered and threatened species. At the same time, the Department determined that although an SEIS would have no legal status or function, it would prepare such a document in order to relay its analyses to interested parties and the public. In August, 1991, a one day evidentiary hearing was held to receive evidence regarding the lawsuit. Shortly thereafter, the judge issued a preliminary injunction suspending all permits for the project until 30 days after completion of the SEIS or until the DNR, based upon the SEIS, made a decision regarding any particular project permit. Both the State of Wisconsin and the Flambeau Mining Company have appealed this decision.

SCOPE OF THE DOCUMENT

This report is designed to document information on several state-listed endangered or threatened species recently located in the Lower Flambeau River and to assess the impacts of various human activities on those species. By this definition, the scope of the report is limited to aquatic species in the Flambeau River which are included on the state's endangered and threatened species list.

This document will also serve as a supplement to the FEIS prepared for the Flambeau Mine Project. Since the FEIS and the project permitting process were completed and fully adjudicated in early 1991, information in this document is not applicable to the decision to grant project permits nor is it applicable to the adequacy of the FEIS. This information can, however, be used in evaluating the need to modify any existing project permits. Therefore, the mine-related portions of this document are confined primarily to information which has arisen since the FEIS was completed and to aspects pertinent to the review of existing project permits.

As part of the process of identifying the appropriate scope of the SEIS, the Department solicited public comments on the issues which should be included in the document. This process, known as the issue identification process, is not required by any regulation, but was voluntarily conducted by the Department to provide an opportunity for public participation in formulating the document. The public comment opportunity was announced by a standard news release issued to about 45 media outlets and by direct mailings to federal, state, and local government officials and representatives of environmental groups.

Approximately 150 letters were received during the issue identification process. Almost all of the letters conveyed nearly identical comments suggesting that the Department conduct additional research as part of the SEIS preparation.

Following are the five points most frequently appearing in comment letters and a Department response to each:

Comment The Department should survey for all terrestrial and aquatic endangered species which may be present at or near the mine site.

Response There has been a substantial amount of biological survey work conducted at the mine site since the early 1970's in connection with the two proposals for the mine projects. In addition, intensive mussel surveys were conducted in spring, 1991. The biological survey work is described in further detail in following sections of this report.

It is unclear whether this comment reflects a general position that surveys should be conducted or that, after review of the already completed survey work, commenters felt that additional survey work was merited. The Department believes that the survey work already completed in connection with the mining project adequately characterizes the endangered resources of the site for regulatory purposes. The Department is assuming that species with a reported but unconfirmed presence near the site do, in fact, inhabit the area. While additional survey work could provide further information on species occurrence, distribution and abundance, the existing database is sufficient to assess the potential impacts of the mine operation to endangered and threatened species.

Comment The Department should investigate the "life cycle" of the endangered and threatened species known to exist near the mine site.

Response As a regulatory agency, the Department applies existing scientific knowledge to determine if a project proposal meets legally defined standards and adequately protects natural resources. The very basic level of scientific research, such as investigation of life histories of species, is done by the federal government or in academic institutions. Also, the regulations which limit a mining project's impacts to surface waters are designed to protect various life stages of aquatic life and employ conservative measures in order to account for uncertain or unknown aspects of aquatic organisms' life histories. It is unlikely that additional information on endangered or threatened species' life histories would provide a basis for imposing more stringent conditions in any of the project permits.

Comment The Department should identify existing threats to the endangered and threatened species and should evaluate the potential for synergistic or cumulative impacts from the mine.

Response This document provides a discussion of the existing water quality and hydrologic conditions in the river in the context of potential impacts to the endangered and threatened species. Cumulative impacts are addressed in the process of establishing wastewater effluent limitations which take into account background levels of pollutants; synergism is assessed through bioassay testing. Both effluent limitation calculations and bioassay testing are further described in subsequent sections of this report.

Comment The Department should identify the host species of the endangered mussel and invertebrate species and should evaluate any existing or potential threats to these host species.

Response The purple wartyback and bullhead mussels are the only known invertebrate species from the site which may use a host species during the reproductive cycle. Although the host species for the purple wartyback mussel is not known, it can reasonably be assumed to be a fish species. Only one species of freshwater mussel is known to utilize a vertebrate host species other than a fish. The only known host fish for the bullhead mussel is the sauger. The water quality regulations and other permit requirements applicable to the mine project are designed to protect the sauger and other sensitive fish species. Therefore, while it would be desirable to identify the purple wartyback mussel's host fish as part of an overall species management and recovery program, it is not necessary to do so in order to assess the impacts of the mining project on mussels.

Comment The Department should identify all chemicals presently in the river, their sources and concentrations, and should assess the potential for synergistic or cumulative impacts on known and unknown endangered species.

Response Water quality of the Flambeau River in the vicinity of the mining site has been characterized through extensive monitoring conducted in association with the two mining proposals. The Department believes this monitoring provides an adequate water quality database for assessing impacts from the mine and for establishing permit conditions which would protect aquatic organisms. Synergistic and/or cumulative impacts are addressed in the calculation of permit limitations and through bioassay monitoring and testing.

In addition to the above comments several writers provided comments addressing Department regulatory programs, state policy issues, and other topics not directly pertinent to the scope of this report. Some comments suggested additional studies of other substances or other aspects of the wastewater discharge. A number of commenters expressed opinions about whether mining was a desirable industry. Those comments are not summarized here, but are available in Department files for review by any interested parties.

ENVIRONMENTAL RESOURCES OF THE FLAMBEAU RIVER

HYDROLOGY AND WATER QUALITY

The Flambeau River is contained in the approximately 4500 square mile Upper Chippewa River Basin in northwest Wisconsin. The Basin includes most of Rusk, Sawyer and Price Counties and parts of Bayfield, Ashland, Iron, Vilas, Oneida, Taylor, Chippewa and Washburn Counties. Other major rivers in this basin include the Chippewa, Jump and Manitowish. The Flambeau River is comprised of two branches: the main stem, or North Fork, which originates at the junction of the Bear and Manitowish Rivers in Iron County; and the South Fork, which originates at Round Lake in Price County. The South Fork and main stem join near the Sawyer/Rusk County border and flow downstream to empty into the Chippewa River upstream from Lake Holcombe (Figure 1). The two largest communities within the Upper Chippewa River Basin-- Park Falls and Ladysmith-- are located on the Flambeau River. The river has an overall length of 116 miles with an average gradient of 4.5 feet per mile.

FLAMBEAU RIVER HYDROLOGY

The Flambeau River drains an area of about 838 square miles. Flow in the river is substantially affected by the operation of 9 dams on the mainstem of the river (Table 1). These dams have a combined total head of 253 feet, almost half of the total vertical drop of the river. The most significant effects on streamflows result from manipulations in the river's headwaters at the Turtle-Flambeau Flowage and Rest Lake on the Manitowish River. The effect of these reservoir operations is to dampen natural fluctuations in the river flow. During winter months, the Flambeau River usually has a higher flow than would be expected under unregulated conditions. Summer flows can also be higher at times than would occur under natural conditions. Flow in the South Fork of the Flambeau is unregulated by dams, and may contribute to the somewhat more irregular flow regime that exists in the lower stretches of the main stem. Daily operations of dams operated in a peaking mode can result in substantial short-term fluctuations in flows and probably have significant adverse effects on biota in some stream segments.

Table 1. Characteristics of Dams on the Flambeau River.

Dam	River Mile	Head (feet)	Impoundment Size (acres)	Owner	Power Generation
Turtle-Flambeau Dam	113	27	13,545	Chippewa-Flambeau Improvement Co.	No
Upper Park Falls[1] Dam	94	18	431	Flambeau Paper Corp.	Yes
Lower Park Falls[1] Dam	92	19	71	Flambeau Paper Corp.	Yes
Pixley Dam[1]	88	21	193	Flambeau Paper Corp.	Yes
Crowley Dam[1]	82	20	422	Flambeau Paper Corp.	Yes
Big Falls Dam[1]	30	50	369	Northern States Power Co.	Yes
Dairyland Dam	22	68	1,745	Dairyland Power Cooperative	Yes
Ladysmith Dam	17	17	289	Northern States Power Co.	Yes
Thornapple Dam[1]	6	13	268	Northern States Power Co.	Yes

[1] Currently under review for relicensing.

The Ladysmith Mine site is located about 3.8 river miles downstream of the Ladysmith Dam and about 9 miles upstream of the Thornapple Dam. Before 1969, the river adjacent to the mine site was impounded behind a dam located at Port Arthur, approximately 2.75 miles downstream from the site. When this dam was removed in 1969, average water level of the river dropped about 10 feet and today, the river adjacent to the mine site is essentially free flowing. Streamflows are, however, significantly affected by operations of upstream dams. River levels adjacent to the site fluctuate several feet on a daily basis in response to power generation at the Dairyland and Ladysmith Dams.

The U.S. Geological Survey's gauging station located closest to the mine site is 2.9 miles downstream of the Thornapple Dam. Thirty-six years of river records from this station indicate that the average river discharge is 1,855 cubic feet per second (cfs) with a recorded maximum of 17,600 cfs and a minimum of 100 cfs. The 7-day 10-year low flow (Q7,10) for the Flambeau River in the vicinity of the mine is 435 cfs.

EXISTING WASTEWATER DISCHARGES

The Flambeau River currently receives wastewater from several point source dischargers permitted under the Wisconsin Pollutant Discharge Elimination System (WPDES) program. In addition, the

Figure 1. **Main stem (North Fork) of the Flambeau River.**

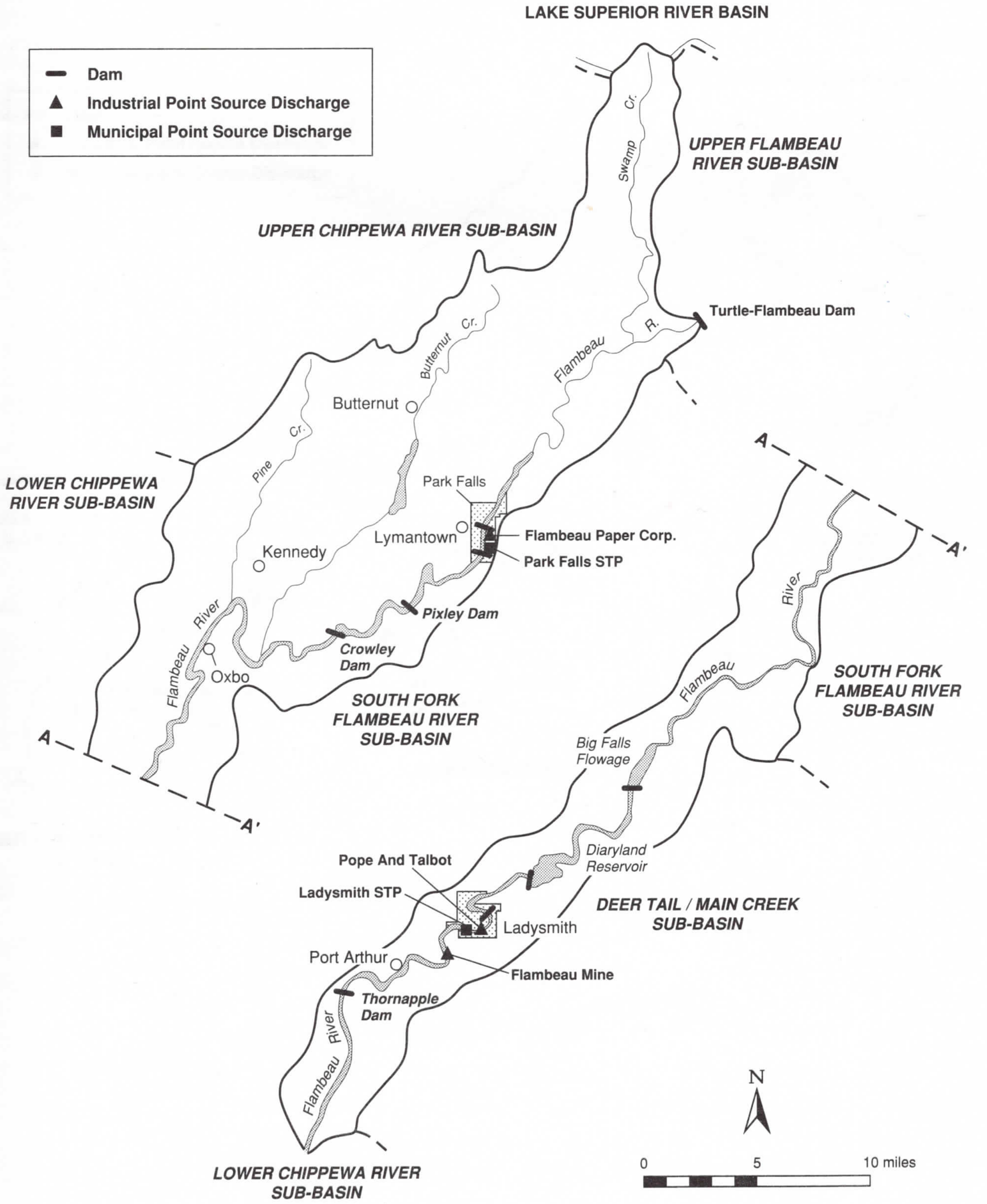

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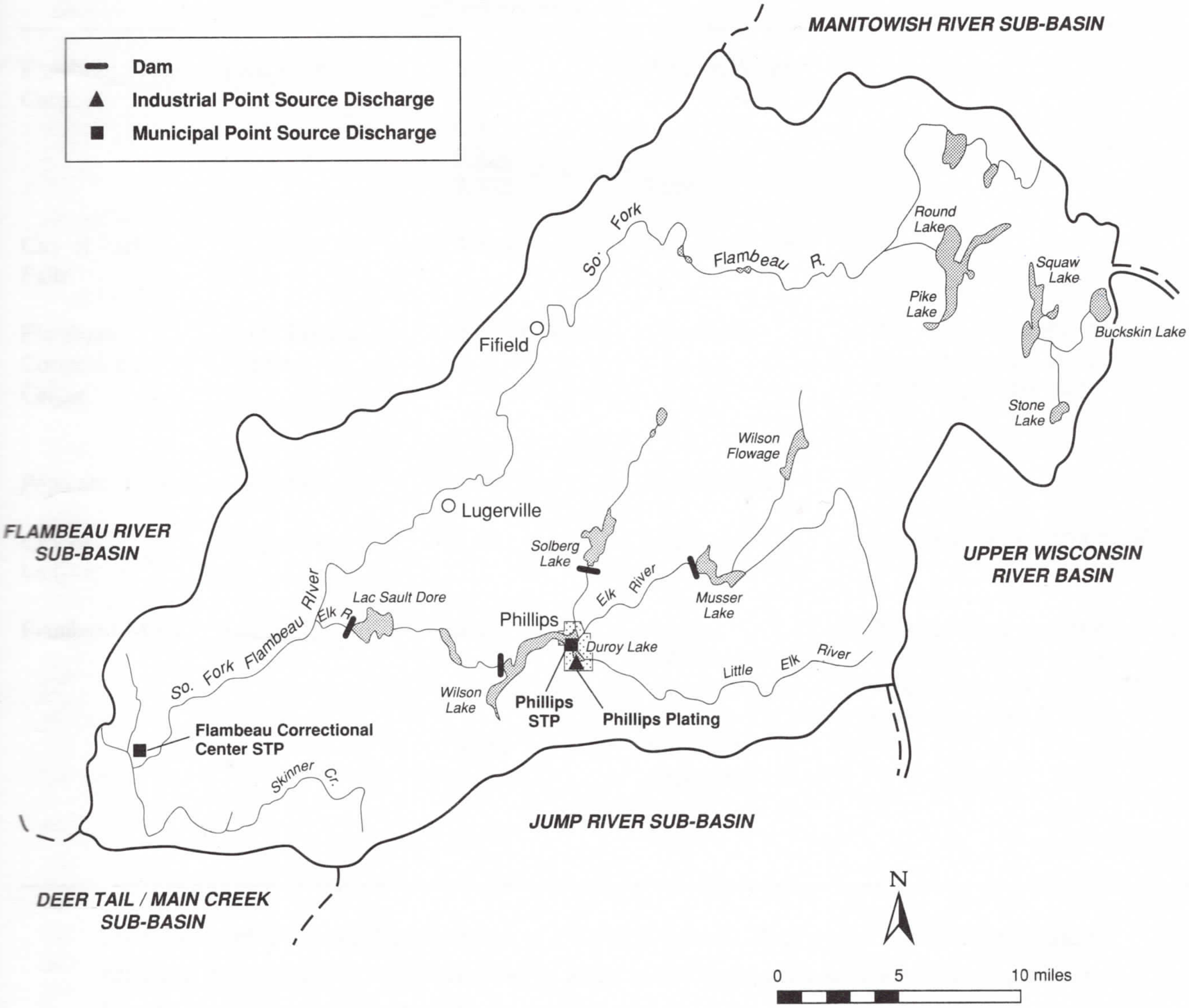
Figure 2. **South Fork of the Flambeau River.**



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Flambeau Mine has received a WPDES permit, but has not yet discharged any wastewater. Table 2 provides a summary of the point source discharges to the Flambeau River.

Table 2. Point Source Discharges to the Flambeau River.

Discharge	Location	Average Discharge Flow (million gallons per day)	Type of Discharge	Comments
Flambeau Paper Corp.	Park Falls	5.673 1.780 0.488 0.824	Process Water	
		8.765	Total	
City of Park Falls	Park Falls	0.523	Municipal	
Flambeau Correctional Center	South Fork at Highway M	0.001-0.006	Municipal	Discharges to wetland adjacent to Hackett Creek. Maximum discharge of .06 MGD
Pope and Talbot	Ladysmith	1.09	Process Water	
City of Ladysmith	Ladysmith	0.450	Municipal	Design flow of 0.778 MGD
Flambeau Mine	Ladysmith	0.327	Contact groundwater inflow and stormwater	Permitted but not yet discharging. Discharge would cease after approximately 8 years. Maximum discharge of 12.8 MGD.
		0.042	Noncontact stormwater runoff	
		0.369	Total	

Each discharge is restricted by the terms of a WPDES permit. Each permit contains limitations for pollutants which could be in the discharge at levels which could cause an environmental problem. Specific requirements for monitoring the quality and flow of the effluent are also included. Permits are issued for terms of five years after which the conditions and effluent limitations are reviewed and revised if appropriate prior to reissuing the permit.

The following is a brief description of each Flambeau River discharge and the significant features of the associated WPDES permit. Each of the permits contains a variety of requirements for monitoring the effluent. However, monitoring conditions have not been included in this discussion in order to simplify the presentation. Readers interested in monitoring requirements for a discharge should refer to the facility's WPDES permit.

Flambeau Paper Corporation

The wastewater discharged from the Flambeau Paper Corporation is the most significant point source discharge to the river system. With an average flow of 8.765 MGD (million gallons per day), the flow of this discharge exceeds the flows of all other point source discharges on the Flambeau River combined. The discharge consists primarily of treated process water from the pulping and paper mill operations, although evaporator waters, vacuum pump seal water, and noncontact cooling water also comprise significant flows. The activated sludge treatment system for the process wastewater consists of primary clarification and aeration followed by secondary and tertiary clarification. The other wastewater flows from this facility are discharged to the river without treatment.

The effluent limitations which are contained in the WPDES permit for the process wastewater are shown in Table 3. The BOD limits are further restricted during the months of May through October based on the streamflow, river water temperature and operation of the upstream dam. Biomonitoring is included as a permit condition. The current WPDES permit for this facility expires June 30, 1995.

Table 3. WPDES Permit Limitations for Flambeau Paper Corp.

	Effluent Limitations		
Effluent Characteristics	Monthly Average	Daily Maximum	Daily Minimum
BOD_5 (lbs/day)	5,308	10,206	--
Total Suspended Solids (lbs/day)	7,846	14,597	--
pH (s.u.)	--	9.0	5.0
Temperature (°F)	--	120	--

City of Park Falls

The City of Park Falls discharges an average of about 0.523 MGD of treated sanitary wastewater to the river. The treatment system consists of two aerated ponds and final chlorination. The treatment system is currently being upgraded to add a dechlorination step to the process. Effluent limitations contained in the WPDES permit for the Park Falls facility are shown in Table 4. The current permit expires June 30, 1994.

Table 4. WPDES Permit Limitations for the City of Park Falls.

	Effluent Limitations			
Effluent Characteristics[1]	Monthly Average	Weekly Average	Daily Minimum	Daily Maximum
BOD_5	30 mg/l	45 mg/l		
Total Suspended Solids	30 mg/l	45 mg/l		
pH (s.u.)			6.0	9.0
Residual Chlorine				0.5 mg/l

[1] Residual chlorine limitation of 0.1 mg/L and fecal coliforms limitation of 400/100 ml effective May 1, 1992.

Flambeau Correctional Center

This discharge consists of the sanitary wastewater from a state prison facility located north of Hawkins. The wastewater is treated in a two cell stabilization pond and discharged without disinfection each spring and fall. The facility is designed to treat 10,000 gallons per day; actual flows range from 5,000 to 11,000 gallons per day. The discharge is directed to a wetland adjacent to Hackett Creek which, in turn, flows into the South Fork of the Flambeau River.

Effluent limitations contained in the WPDES permit for the Flambeau Correctional Center are shown in Table 5. The current permit for this facility expires June 30, 1996.

Table 5. WPDES Permit Limitations for the Flambeau Correctional Center.

	Effluent Limitations			
Effluent Characteristics	Monthly Average	Weekly Average	Daily Minimum	Daily Maximum
Flow	-	-	-	0.06 MGD
BOD_5	30 mg/L	45 mg/l	-	-
Suspended Solids	30 mg/L	45 mg/l	-	-
pH (s.u.)	-	-	6.0	9.0
Dissolved Oxygen	-	-	4.0 mg/l	-

City of Ladysmith

The City of Ladysmith discharges treated sanitary wastewater to the Flambeau River. The City recently completed construction of new wastewater treatment facilities which began operation in July, 1990. The treatment system, which is comprised of three aerated cells followed by ultraviolet disinfection has consistently produced an effluent containing about 12 mg/l BOD and 16 mg/l suspended solids, substantially cleaner than the permitted limits. The plant is designed to treat about 0.78 MGD although current flows average about 0.45 MGD.

The WPDES permit for the Ladysmith treatment plant was recently reissued. Permit effluent limitations are presented in Table 6. The permit for this facility expires December 31, 1996. Acute and chronic biomonitoring requirements are included in the permit.

Table 6. WPDES Permit Limitations for the City of Ladysmith.

	Effluent Limitations			
Effluent Characteristics	Monthly Average	Weekly Average	Daily Minimum	Daily Maximum
BOD_5	30 mg/L	45 mg/l		
Total Suspended Solids	30 mg/L	45 mg/l		
pH (s.u.)			6.0	9.0
Fecal Coliforms	400/100 ml			

Pope & Talbot of Wisconsin, Inc.

The Pope & Talbot facility manufactures tissue paper products. Process wastewater from the operation and roof drain stormwater is treated via polymer addition to aid settling, primary clarification, activated sludge, and secondary clarification. In addition the Norenco cogeneration turbine boiler adds minor flows of softener regeneration water and scrubber wastewater when the boiler is operating. Wastewater flows from the treatment facilities average 1.09 MGD.

Effluent limitations from the WPDES permit are given in Table 7. The permit includes requirements for acute and chronic biomonitoring. The WPDES permit for this facility expires June 30, 1993.

Table 7. WPDES Permit Limitations for Pope and Talbot.

	Effluent Limitations			
	Daily	Annual	Monthly Average	
Effluent Characteristics	Maximum	Mass	Conc.	Mass
BOD_5 (lbs/day)	2004	---	---	1045
Total Suspended Solids (lbs/day)	2588	---	---	1385
Temperature	120°F	---	---	---
Copper	30 μg/L	119 lb/yr	---	---
Cyanide, Free	44 μg/L	174 lb/yr	---	---

Flambeau Mine

The Flambeau Mine has been issued a WPDES permit but not yet discharging. Wastewater from the mine would be comprised entirely of rain water falling on the site and of groundwater flowing into the mine pit. Wastewater would be segregated into two streams. Uncontaminated runoff from the low sulfur waste rock stockpile and other non-contaminating areas of the site would be routed through two settling ponds to remove suspended solids and discharged to the river. Polymers and lime will be added if necessary to assist in settling any colloidal materials. The average flow of this discharge would be 0.042 MGD over the course of the project although flows would be higher during the first stages of pit construction. Some of this water may be used to maintain water levels in a wetland adjacent to the open pit.

The second wastewater stream would consist of water flowing into the open pit and leachate and runoff from the high sulfur waste rock stockpile and runoff from the crusher and ore storage area, haul road and maintenance yard. This water would be directed to the wastewater treatment plant. Treatment would consist of lime addition and sulfide precipitation followed by multi-media filtration. This discharge would average about 0.327 MGD.

Effluent limits for the Flambeau Mine are shown in Table 8. These limits would apply to wastewater from both collection systems. It should be noted that not all of the metals assigned limitations in the permit are expected to be present in the effluent. All metals which were included in the initial baseline monitoring program were also included in the permit. The discharge would cease after the project site is reclaimed, covering a total period of about 8 years. Permit conditions include requirements for biomonitoring. The WPDES permit expires September 30, 1995.

Table 8. WPDES Permit Limitations for the Flambeau Mine.

	Effluent Limitations			
Effluent Characteristics	Weekly Average	Daily Maximum	Monthly Average	Mass Limit
Total Suspended Solids	-	30 mg/l	20 mg/l	-
Aluminum	-	1500 ug/l	-	-
Arsenic	-	730 ug/l	-	-
Beryllium	-	-	0.67 lb/day	-
Cadmium	7.1 ug/l	95 ug/l	50 ug/l	0.046 lb/day
Chromium, Total (or + 3)	980 ug/l	5400 ug/l	-	6.4 lb/day
Chromium (+6)	-	28 ug/l	-	-
Copper	-	50 ug/l	-	-
Lead	140 ug/l	590 ug/l	-	0.89 lb/day
Mercury	-	-	0.002 ug/l	-
Nickel	1200 ug/l	3100 ug/l	-	7.6 lb/day
Selenium	-	120 ug/l	-	-
Silver	-	6.6 ug/l	-	-
Zinc	-	300 ug/l	-	-
pH (s.u.)[1]	-	9.0	-	-
Dissolved Oxygen	5 mg/l			

[1] 6.0 s.u. minimum

EXISTING WATER QUALITY

In addition to the point source discharges described above, several other dischargers exist within the Flambeau River system. Wastewater from the Mercer Sanitary District is discharged to the Little Turtle River, upstream of the Turtle Flambeau Flowage. Sanitary wastewater at Butternut is discharged to the groundwater adjacent to Butternut Creek, which is a tributary to the North Fork of the Flambeau, at a site upstream of Butternut Lake. The Fifield Sanitary District discharges to the groundwater adjacent to the South Fork. In Phillips, sanitary wastewater along with industrial wastewater from Phillips Plating is discharged to Elk Lake located on a tributary to the South Fork. This discharge has, in the past, contained significant levels of metals and poorly or untreated sanitary wastewater. However, the lakes and flowages located downstream from the Mercer, Butternut and Phillips discharges act as pollutant traps preventing contaminants from moving downstream. Therefore, these dischargers probably have little effect on the water quality in the Flambeau River.

The water of the Flambeau River is generally considered to be high quality. The river's watershed is mostly forested, with a relatively low level of population density, agriculture and industry. The exceptions are the cities of Ladysmith and Park Falls, which are the largest cities in the Upper Chippewa River Basin and where various industries comprise a significant component of local economies. Agriculture is a more predominant land use in the lower part of the basin.

The entire Flambeau River is classified as a fish and aquatic life water body capable of supporting a warm water sportfish community under Chapters NR 102, NR 104, and NR 207, of the Wisconsin Administrative Codes. The river is not classified as a public water supply. The water is generally soft, well oxygenated, and nearly neutral in pH.

Historically, point source discharges have caused significant water quality degradation in segments of the Flambeau River. In particular, the water quality of the river downstream from Park Falls has been deteriorated by inadequately treated wastewater, primarily from the Flambeau Paper Corporation. Discharges of wastewater with high levels of BOD (biological oxygen demand) have resulted in suppressed dissolved oxygen concentrations in the water as far downstream as the Big Falls Dam. In addition, solids in the wastewater settled out on the river bottom downstream from the discharge. This material along with bacterial slimes formed a sludge which also exerted an oxygen demand, further depleting dissolved oxygen concentrations. Condensate-sulfite liquor storage lagoons also discharged to the river via surface and groundwater, contributing significant levels of BOD. As a result of this pollution, dissolved oxygen concentrations frequently dropped below the 5 mg/L standard established as necessary to protect aquatic life and regularly dropped below 3 mg/L which was established as an interim standard for this stream segment. In the river below Park Falls, dissolved oxygen concentrations periodically decreased to near zero until the late 1970's.

Upgraded wastewater treatment at the Flambeau Paper Facility and more stringent effluent limitations have improved the quality of the effluent, resulting in an increase in dissolved oxygen concentrations in the river. In 1976, Flambeau Paper Corporation was discharging about 19,000 lbs/day of BOD while the current WPDES permit limits BOD discharges to an average of 5,300 lbs/day during November through April. The BOD discharge is further limited during May through October to levels as low as 1,525 lbs/day under periods of low flow and warm temperatures. The condensate-sulfite liquor lagoons currently in use are lined with a synthetic material and are undergoing an evaluation to determine the liner's effectiveness in containing waste materials. Residual contamination from previously used unlined lagoons appears to be a continuing source of discharge to the river.

As a result of these improvements, dissolved oxygen concentrations have improved substantially over the past years. The interim 3 mg/L standard for this stretch of the river has been removed and the river water normally meets the 5 mg/L standard necessary to protect aquatic life.

In comparison to the dissolved oxygen depletions downstream from Park Falls, other water quality problems on the Flambeau River are relatively minor. The upper stretch of the river above Parks Falls is of excellent quality with no point source dischargers and little development within the drainage area. The South Fork of the river is similarly of good quality with no direct point source dischargers and limited development.

Downstream from the confluent with the South Fork, the Flambeau River continues to have relatively good water quality. It has been reported that, when the Port Arthur Dam was removed in 1968, the exposed river bed in the vicinity of the Flambeau Mine was covered with a black slimy deposit. In the mid 1970s, water quality biologists reported that the river water below the Pope and Talbot discharge had visible levels of paper fibers. However, surveys conducted around this time showed low levels of BOD, adequate dissolved oxygen, and benthic communities indicative of clean water even immediately downstream from the Pope and Talbot outfall. The water downstream from Ladysmith has in the past had occasionally excessive levels of fecal coliform bacteria.

Mercury contamination of fish in the Flambeau River has been a significant concern. In the past, phenyl mercuric acetate was used as a slimicide in the paper industry. Although use of this compound has been banned since 1970, evidence of varying levels of mercury contamination remain. Analysis of fish filets conducted by the DNR since 1985 show mercury levels exceeding 0.5 parts/million (ppm) in some fish samples throughout the Flambeau River. The Department advises only limited consumption of fish with mercury levels over 0.5 ppm and no consumption of fish with levels over 1.0 ppm. All of the walleye filets in a 1985 sample from the Dairyland Flowage exceeded 0.5 ppm mercury as did larger walleye, northern pike and musky from the Lower Park Falls Flowage in 1989 and 1990 samples. One out of four fish analyzed by Flambeau Mining Company from the Thornapple Flowage in 1988 had mercury levels above 0.5 ppm. Twelve of the

42 fish analyzed from the river above the Flambeau Paper discharge and 14 fish from the Turtle-Flambeau Flowage had tissue levels above 0.5 ppm, indicating that mercury contamination in the river may also emanate from sources other than industrial wastewater discharges.

Water Quality Data

Water quality data collected by the Department and other sources are entered into the STORET computer system maintained by the Environmental Protection Agency. A review of the STORET data shows that 978 samples were collected from 31 stations on the Flambeau River between 1973 and 1991. Table 9 provides a summary of these data on relevant water quality parameters.

Table 9. Summary of Flambeau River Water Quality Data 1973-1991[1].

	Number of Samples	Average	Maximum	Minimum
Aluminum	0	-	-	-
Arsenic	25	<0.01	-	-
Barium	0	-	-	-
Beryllium	0	-	-	-
Cadmium	25	0.0002	0.0004	0.0002
Calcium	51	12.1	20.0	6.6
Chloride	199	5.1	28	1
Chromium (+6)	0	-	-	-
Total Chromium	25	0.0003	0.01	0.003
Cobalt	0	-	-	-
Copper	24	0.006	0.029	0.003
Flouride	0	-	-	-
Iron	13	1.01	1.70	0.62
Lead	23	<0.003	-	-
Magnesium	50	3.8	10.0	2.0
Manganese	11	0.078	0.18	0.04
Mercury	25	0.0003	0.0018	<0.0002
Molybdenum	0	-	-	-
Nickel	0	-	-	-
Nitrate/Nitrite-Nitrogen	77	.087	.3	.01
Total Kjeldahl Nitrogen	16	.918	1.60	0.40
Selenium	0	-	-	-
Silver	0	-	-	-
Sodium	9	3.2	6.0	1.0
Sulfate	16	11.2	28	2
Sulfur	0	-	-	-
Thallium	0	-	-	-
Tin	0	-	-	-
Titanium	0	-	-	-
Uranium	0	-	-	-
Zinc	14	0.031	0.160	0.00002
Dissolved Oxygen (field)	547	7.9	13.7	0.4

Total Alkalinity (as $CaCo_3$)	53	33	58	1
Total Hardness	96	48	109	25
Chlorophyll-a	148	0.012	0.041	0.002
C.O.D.	3	31	38.0	23.0
B.O.D.	421	4.0	34.0	0.3
pH (s.u.)(field)	453	7.1	8.2	6.2
Specific Conductivity (micro ohms/cm)	341	108	970	33
Temperature (C°)(field)	556	12.7	28.0	0

[1] Values in mg/L unless otherwise noted. Data quality varies. Users of the data should consult the original sources.

A substantial amount of water quality data was also collected by the Flambeau Mining Company in association with the mine permitting process. Data were collected monthly between October 1987 and September 1988 from two stream monitoring stations; a station located upstream of the mine site at the end of Blackberry Lane, and a station located approximately 2.5 miles downstream at the old Port Arthur Dam site. Results of this sampling as reported in the Environmental Impact Report for the project (Foth and Van Dyke, 1989) are provided in Table 10.

Table 10. Results of Surface Water Quality Sampling Near the Flambeau Mine Site (10/87 - 9/88)[1].

	Average	Range
Aluminum	0.062	0.042-0.111
Arsenic	<0.005	<0.005
Barium	<0.5	<0.5-1
Beryllium	<0.001	<0.001-0.001
Cadmium	<0.003	<0.0003-<0.0010
Calcium	15.0	9.9-19.0
Chloride	6.0	2.0-9.0
Chromium (+6)	<0.05	<0.05
Total Chromium	<0.005	<0.005
Cobalt	<0.005	<0.005
Copper	<0.005	<0.005-0.030
Flouride	0.1	<0.1-0.2
Iron	0.39	0.16-0.54
Lead	<0.0005	<0.0005
Magnesium	3.9	2.7-4.5
Manganese	<0.05	<0.05-0.08
Mercury	<0.0005	<0.0005
Molybdenum	<0.029	<0.029-0.067
Nickel	<0.007	<0.007-0.030
Ammonia Nitrogen	0.28	<0.1-2.2
Nitrate/Nitrite-Nitrogen	0.12	<0.05-<0.35
Total Kjeldahl Nitrogen	<1.0	<1-2
Selenium	<0.005	<0.005
Silver	<0.0004	<0.0004-<0.005
Sodium	6.8	5.1-8.4

Sulfate	10	<5-15
Sulfur	1.7	2.9-4.2
Thallium	<0.005	<0.005
Tin	<0.067	<0.067-0.093
Titanium	<0.004	<0.004-0.004
Uranium	0.003	<0.001-0.011
Zinc	<0.05	<0.05-0.068
Dissolved Oxygen (field)	9.9	6.0-12.0
Total Alkalinity (as $CaCo_3$)	44	27-60
Total Hardness	52	37-71
Total Dissolved Solids	99	21-140
Total Suspended Solids	3	1-15
Total Organic Carbon	11.4	0.26-23.1
Chlorophyll-a	0.004	<0.001-0.012
C.O.D.	26	10-40
B.O.D.	0.9	<0.9-<10
pH (s.u.)(field)	6.8	6.2-8.0
Specific Conductivity (micro ohms/cm)	142	101-179
Temperature (C°)(field)	10.2	1.0-24.5

[1] Values in mg/L unless otherwise noted. Consult original sources for data quality assurance and control information.

The data from the mine site are generally consistent with data collected at other stations on the river. Concentrations for substances are below the water quality criteria established in Chapter NR 105 of the Wisconsin Administrative Code for chronic effects. Two substances, copper and zinc, were each detected at concentrations above the acute toxicity criteria (ATC). Copper concentrations exceeded the ATC of 8.6 ug/L in both upstream and downstream stations in February and April, 1988. All other samples had no detectable levels of copper. Zinc exceeded the ATC of 57.4 ug/L in a single sample in March, 1988. All other monthly samples showed no detectable levels of zinc. These results agreed with sampling from the site in the early 1970s which showed occasionally high levels of zinc and copper (WDNR, 1976). Background stream concentrations in excess of the ATC may have had an adverse impact on some forms of aquatic life.

DESCRIPTION OF KNOWN ENDANGERED RESOURCES IN THE FLAMBEAU RIVER

SURVEY WORK ASSOCIATED WITH THE FLAMBEAU MINE

The biological resources of the Flambeau Mine site have been extensively surveyed during the course of the 1968 through 1977 mine permitting and EIS process, the 1987 through 1991 permitting and EIS process, and additional survey work conducted in the spring of 1991. The following are summaries of the survey work conducted at the mine site during these periods. Readers interested in additional details on biological surveys should refer to the following documents: Preliminary Environmental Impact Report for Mining the Flambeau Copper Deposit, Bear Creek Mining Company, 1974; Environmental Impact Statement for the Flambeau Mining Corporation Proposed Copper Mine, WDNR, 1976; Environmental Impact Report for the Kennecott Flambeau Project, Foth and Van Dyke, 1989; Final Environmental Impact Statement - Flambeau Mining Company - Copper Mine, WDNR, 1990.

Vegetation

Vegetation of approximately 1,000 acres surrounding the mine site was quantitatively and qualitatively surveyed in 1972-1974 (Matson, 1974). Matson identified over 300 species of vascular plants in the area. He identified two plant species from the site, *Asclepia purpurascens* and *Carex lupuliformis* which are now listed as state-endangered species. However, herbarium specimens of these species reviewed by DNR staff in 1989 showed these species had been misidentified and were actually the more common *A. syriaca* and *C. lupulina*.

Flambeau Mining Company also surveyed vegetation of the site in 1987-1988. Surveys were conducted along transects and representative plant communities on the mine site. In addition, a Department botanist surveyed the entire site for endangered or threatened plant species. The company's consultant reported locating a threatened species of pondweed (*Potamogeton vaginatus*) from a pond on the site. However, after reviewing the report and investigating the pond, the Department's botanist concluded in 1988 that this habitat was not suitable for *P. vaginatus* and that the specimen was misidentified. Otherwise, no endangered or threatened plant species were identified from the mine site. A complete list of plant species from the site is provided in Appendix 3.9-A of the Environmental Impact Report.

Mammals

Terrestrial wildlife was also surveyed qualitatively and quantitatively during 1972-73 and 1987-88. Terrestrial vertebrate species inhabiting the mine site were identified by surveys employing visual observations of animals, tracks, and other signs, trapping, voice recordings, and review of existing records. Quantitative surveys of small mammals were conducted by trapping during both of the survey periods. A total of 29 species of mammals were observed in the mine site vicinity during these surveys, none of which are listed as endangered or threatened status. A list of terrestrial wildlife species from the mine site is included in Appendix 3.8-c of the Environmental Impact Report.

Birds

Bird species of the site were surveyed quantitatively in 1972-73 and qualitatively in 1987-88. The 1972-73 work was comprised of surveys during the spring, fall, and winter seasons. The quantitative evaluations included transect surveys during all seasons. Flambeau Mining Company's consultants conducted qualitative surveys along five transects on the mine site during the fall of 1987 and spring and summer 1988. In addition, random surveys of the site were conducted. A total of 107 bird species were identified during these surveys. Only the bald eagle (*Haliaeetus leucocephalus*), a state and federally listed threatened species, was located on or near the mine site. An active bald eagle nest was found about one mile downstream from the mine site. No other endangered or threatened bird species were located. A complete list of all bird species found is included in the Environmental Impact Report.

Amphibians and Reptiles

Amphibians and reptiles of the mine site were surveyed in 1973 and again in 1987 and 1988. The surveys were general in nature, and were not targeted at specific endangered or threatened species. The first surveys consisted of searching three transects and hand collecting amphibians and reptiles. Subsequent surveys conducted in fall 1987 and spring 1988 consisted of recording and identifying amphibian calls at five different survey points on the mine site and of incidental observations throughout the site. Eleven species were found on or near the mine site during these surveys. A list of these species is included in the Environmental Impact Report. None of these species are on the state endangered and threatened species list.

Fish

Fish were sampled from the Flambeau River adjacent to the mine site by Bear Creek Mining Company (BCMC) in spring 1973. Sampling with fyke nets occurred at six stations upstream, off shore and downstream of the mine site. The fyke netting was also conducted at several randomly-located supplemental sites. In addition, limited electrofishing was conducting in two tributary streams. In reporting results from these surveys, BCMC also incorporated unpublished DNR data from 1966, 1967, and 1972 surveys of the Thornapple Flowage and a Flambeau River tributary. These latter surveys used fyke netting and electrofishing techniques.

A total of 25 species of fish were located during the 1966 through 1973 surveys. None of the species found were on the state's endangered and threatened species list. One species list in the consultant's report indicated the river redhorse (*Moxostoma carinatum*) as present in the river (Dames and Moore, 1973). The river redhorse is currently listed as threatened in the state. However, the data from individual sampling stations and the report text indicate that only the northern redhorse, a species common in the river, was found during these surveys. While no scientific name for the northern redhorse was given in the report, the northern redhorse is a name commonly used for *Moxostoma macrolepidotum*. The table in this report which shows the river redhorse as present in the samples does not include any mention of the northern redhorse. It appears likely that the northern redhorse was inadvertently replaced with the river redhorse in the species list.

Fish sampling was also conducted in the river during fall 1987 and spring and summer 1988. Flambeau Mining Company consultants sampled using gill netting, electrofishing, hook and line, minnow trapping, and creel censusing. The Department also conducted electroshocking on the Thornapple Flowage in May, 1988.

Results from this series of surveys were reported in the Environmental Impact Report (Foth and Van Dyke, 1989). Seventeen fish species were noted as having been located in the river, including the river redhorse. However, this report exhibits the same discrepancy as the earlier document, that is, the data shows that *Moxostoma macrolepidotum* (termed the shorthead redhorse in this report) was located by the surveys while the species list indicates that it was the river redhorse which was found.

It is apparent that the data, the report texts and general knowledge of the river's fish population would support the conclusion that these reports of the river redhorse were in error. Thus, the reported occurrence of the river redhorse in this stretch of the Flambeau River must be considered tentative and unverified. However, the species does occur downstream in the Chippewa River, and the segment of the Flambeau River between the Ladysmith and Thornapple dams does provide suitable habitats. The Department's fish manager believes it is likely this species occurs in this river stretch. For the purposes of this document and for regulation of the Flambeau Mine Project, the Department assumes that the river redhorse does, in fact, occur in the Flambeau River between the Ladysmith and Thornapple dams.

Fisheries of the Thornapple flowage and the dam tailwaters were also sampled during 1990 as part of the environmental studies conducted in association with licensing the Thornapple Dam (Northern States Power Company, 1991). These surveys identified 33 fish species, one of which was the gilt darter (*Percina evides*), a state-listed threatened species. The single specimen of gilt darter was collected from the tailwaters below the dam. No other threatened or endangered fish species were located during this survey.

It should be noted that darters can be particularly difficult to collect using conventional fish sampling techniques. Darters live close to the river bottom and tend to sink when electroshocked, and can therefore be missed by the individuals collecting the fish. Small fish also are often not identified to species during fish sampling surveys. Although there has been significant fish survey work conducted on this stretch of the Flambeau River, more intensive survey work directed specifically at characterizing the darter populations would be necessary to reach any reasonably definitive conclusion regarding the presence or absence of the gilt darter. The Department's fish manager believes it is likely that this species occurs in this river stretch. Therefore, for the purposes of this document and for regulating the Flambeau Mine Project, the Department is assuming that the gilt darter does actually occur in this segment of the river.

In summary, a total of 41 fish species were identified from the Flambeau River from the Ladysmith Dam to the Thornapple tailwaters during surveys conducted in 1966-67, 1972-73, 1987-88, and 1990. Two of these species are included on the state's threatened species list: the river redhorse and the gilt darter. The reports of the river redhorse are, however, inconsistent with the actual sampling data. The single gilt darter specimen was located downstream of the Thornapple Dam. Both of these species are assumed to exist in the river reach adjacent to the mine site.

Aquatic Macroinvertebrates

Benthic macroinvertebrates were sampled from six different locations in the river adjacent to the mine site in spring, 1973. Three Ponar dredge samples were collected at each station. Surber samplers and drift nets were also used at several stations. In addition to this sampling effort, the Department also collected benthic macroinverterbrates during 1969. The results of both of these sampling efforts were reported in Dames and Moore, 1973.

About 80 different genera or species of invertebrates were identified in the 1969-1973 sampling. Of these, three genera of fingernail clams (Family Sphaeriidae) were located and one Unionid mussel species, identified as *Anodonta marginata* was found. After surveying this stretch of the river, Department biologists believe that the identification of *A. marginata* was either a result of the evolving taxonomy at the time or a misidentification and that the specimen was most likely *Anodonta grandis*, the floater mussel. *A. marginata* is no longer a recognized species name (Turgeon, et al., 1988). A single species of Odonate (dragonflies and damselflies), *Dromogomphus spoliatus*, was identified from the sample. However, this location is out of the species' range and this report was probably a misidentification.

Foth and Van Dyke also surveyed aquatic macroinverterbrates adjacent to the mine site in 1987-88. Invertebrates were collected from five river sampling sites in October and December 1987 and in April and August 1988 using Surber samplers and a net. Seventy-two taxa were identified in this survey. Table 11 lists invertebrate taxa identified from the river near the mine site in the 1973 and 1987-88 surveys.

Table 11. Relative abundance of macroinverterbrates collected from the Flambeau River - 1973 and 1987-88.[1]

		1987										1988										1973
		October					December					April					August					
Taxa	Common Name	M1	M2	M3	M4	M5	M1	M2	M3	M4	M5	M1	M2	M3	M4	M5	M1	M2	M3	M4	M5	
Naididae	Aquatic worm									C												
Tubificidae	Aquatic worm	R	R	R		R				C		R			R	C						
Ferrissia sp.	Limpet	A	A	A		A				C												
Lymnaea sp.	Snail	R																				
Physa sp.	Snail					R				C			R	R	R							
Heliosoma sp.	Snail														C	R			R	R		
Sphaerium sp.	Clam	C	C	C		A				A		R	R	R	A	A			A	R		X
Lampsilis sp.	Clam			R																		
Asellus sp.	Aquatic sowbug									C		R			R							
Hyallella azteca	Scud	R								R												
Orconectes virilis	Crayfish			R										R			R		R			
Baetis sp.	Mayfly																					
Blasturus cupidus	Mayfly																					
Callibaetis sp.	Mayfly																					
Ephemerella sp.	Mayfly	A	A	A		C						A	A	A	A			R		C		X
Isonychia sp.	Mayfly		R	R		R																
Leptophlebia sp.	Mayfly									A												
Stenocron interpunctatum	Mayfly									R												
Ephemera simulans	Mayfly		R	R		A				R				C	C	R						
Hexagenia limbata	Mayfly											R		A	A	A				C	R	
Stenonema sp.	Mayfly	C	C	C		A				R		A	C	C	A	R		R	A			X
Paraleptophlebia sp.	Mayfly												A									
Potamantha sp.	Mayfly		C	A		A				A				A			C					
Taeniopteryx	Stonefly	R																				
Neoperla sp.	Stonefly		R	R						R												
Phasganophora sp.	Stonefly	R	C	C									R	C		R			R		R	
Ophiogomphus sp.	Dragonfly		R	R		R										R						
Micrasema sp.	Caddisfly																					
Brachycentrus sp.	Caddisfly	R																				
Helicopsyche sp.	Caddisfly	C	R	R		C				R		C	A	A	R	R		R			R	X
Cheumatopsyche sp.	Caddisfly	C	C																			
Hydropsyche sp.	Caddisfly	C	C	A		A				R		C	A	A	R	C		R	R	R		X
Macronema zebratum	Caddisfly		C	R																		
Hydroptila sp.	Caddisfly	A	A	A		A																
Lepidostoma sp.	Caddisfly	C	R			R																
Frenesia sp.	Caddisfly	R																				
Neophylax sp.	Caddisfly		R						R			R		R	R							
Pseudostenophylas uniformis	Caddisfly					R			R													
Pycnopsyche sp.	Caddisfly															C						
Molanna sp.	Caddisfly								R													
Chimarra sp.	Caddisfly	R		R		R			R									R				
Polycentropus sp.	Caddisfly	C	C	R					R													

Psychromia flavida	Caddisfly	C	C	R		R											
Paraponyx sp.	Aquatic moth	R															
Coptotomus sp.	Diving beetle									R							
Dineutus sp.	Whirligig beetle																
Berosus sp.	Aquatic beetle									A	R						
Ectopria sp.	Waterpenny beetle	R	R	R		R	R										
Dupiraphia sp.	Riffle beetle						R										
Stenelmis sp.	Riffle beetle	A	A	A		A			R			R			R		
Optioservus sp.	Riffle beetle	A	A	A		A	R										
Albabesmyia sp.	Midge	A		A		A	A										
Cladotanytarsus sp.	Midge	A	A	A			A	R		R		A		R		X	
Chaoborus sp.	Midge			A													
Chironomus sp.	Midge						A										
Dicroptendipes sp.	Midge						A										
Paracladopelma sp.	Midge	A	A		A		A										
Pentaneura monilis	Midge		A														
Stictochironomis sp.	Midge	A	A	A		A	A										R
Cricotopus sp.	Midge	A	A			A											
Orthocladius sp.	Midge					A											
Procladius sp.	Midge	A	A			A	A										
Tribelos sp.	Midge					A	A										
Atherix variegata	Snipefly	R		R		R											
Chrysops sp.	Horsefly									R		R					
Antocha sp.	Cranefly	R	C	R													
Hexatoma sp.	Cranefly		R	R		R	C										
Tipula sp.	Cranefly												R				
Corisella sp.	Water boatman		C				A									R	
Nigronia sp.	Fishfly			R		R											
Sialis sp.	Alderfly						R										

R - 0 to 5
C - 5 to 10
A - 10 or more
X - Present
[1]From Foth and Van Dyke (1989)

In May, 1990, Department biologists conducting mussel surveys of the Flambeau River associated with relicensing of the Thornapple Dam surveyed an area approximately 0.7 miles downstream from the mine site. Two live specimens of the purple wartyback mussel (*Cyclonaias tuberculata*), a state-listed endangered species, were located at this site. The Department subsequently implemented an intensive mussel survey in the river adjacent to and downstream of the mine site. The survey was conducted by SCUBA diving and searching the river bottom. The survey area began about 500 feet below the downstream mine wastewater discharge point and extended to the upstream discharge location. Five main survey stations were established: Station 14 was located at the pipeline crossing 0.7 miles downstream from the mine site; Station 16 was a 30-foot wide section along the bank extending 500 feet downstream from the downstream discharge site; Station 17 extend across the river from Station 16; Station 18 was the 40-foot wide stretch along the mine site between the discharge locations; and Station 19 extended across the river from Station 18. The mussel survey work was conducted over about a 4 week period in May and June, 1991.

Table 12 provides a summary of the state-listed mussel species found during this survey. Approximately 2,200 mussels were examined during the survey of which five were State-listed species. One additional purple wartyback was found in a mid-stream location and two bullhead mussels (*Plethobascus cyphyus*) were found between the discharge sites. All three of the purple wartyback mussels were about 40 years old; the bullhead mussels were 11 and 20 plus years. In addition, a number of old shells of both species were found, indicating that populations had historically existed in the area.

Table 12. Results of 1991 Mussel Surveys Near the Flambeau Mine Site.

Station	14	16	17	18	19
Approx Area (sq. m)	2000	1400	12500	2900	19000
Total mussels	200	643	121	689	536
No. live purple wartybacks	2				1
No. live bullheads				2	

Another 14 stations were also surveyed for mussels by Department staff. One of these stations was upstream of the mine site; the other 13 were downstream from the pipeline crossing located 0.7 miles downstream from the mine. Only 24 mussel specimens were collected from these 14 stations, none of which were endangered or threatened species.

Mussel surveys of the river adjacent to the mine site were also conducted in July, 1991, by Flambeau Mining Company's consultant Dr. Arthur Clarke. A total of 272 specimens were examined, three of which were purple wartybacks. The purple wartybacks were aged at 42, 24, and 24 years old (Clarke, 1991). No live bullhead mussels or other endangered or threatened species were found in this survey.

During the mussel surveys previously described, Department biologists also collected cast skins (*exuviae*) and larvae (*nymphs*) of dragonflies from the river. A preliminary analysis of the samples revealed the presence of the pygmy snaketail dragonfly (*Ophiogomphus howei*), a state-listed endangered species. The full analysis of these samples completed in November 1991, did not indicate the presence of any other state-listed endangered or threatened dragonfly species. Results of these analyses are shown in Table 13.

Table 13. Dragonfly specimens (larvae and exuviae) collected near the Flambeau Mine site.

	Sampling Date (1991)							
Species	5/23	5/31	6/06	6/13	6/19	7/1	9/12	Status[1]
Boyeria vinosa			1	1		1		
Dromogomphus spinosus				1				
Gomphus (Gomphurus) fraternus			1					
Gomphus (Gomphurus) lineatifrons				1				SC
Gomphus (Gomphurus) vastus				1				
Gomphus (Gomphurus) ventricosus			2	3				SC
Gomphus (Gomphus) adelphus (?)					1			
Gomphus (Gomphus) viridifrons				3				SC
Gomphus (Phanogomphus) quadricolor				1				SC
Hagenius brevistylus				2		1		
Macromia illinoiensis				2				
Neurocordulia yamaskanensis				1				SC
Ophiogomphus howei			4	1		1		END
Ophiogomphus rupinsulensis	17		218	34		20	1	
Ophiogomphus sp. nov.				2				SC
Stylurus spiniceps				1				

[1] SC - Species of Special Concern
END - State-Listed Endangered

While no additional endangered or threatened species were found, the June 1991 sample does contain a number of species tracked by the state as species of special concern. Species of Special Concern are those which are suspected to have some problem regarding distribution or abundance. The June 13 sample is notable in that it contains a number of species which had not occurred in any of the other samples from the site. The assemblage of species in this sample is more typical of the St. Croix River than of the Flambeau River. Also, *Ophiogomphus sp. nov.*, which was found in this sample, was recently discovered by Department staff and which is currently being described as a new species. It is likely that this species will be proposed for addition to the state endangered and threatened species list. The only other locations this species has been found are the St. Croix and Chippewa Rivers. DNR Endangered Resources staff indicate that the June 13 sample may have been mislabeled. However, four of the six species indicated as being of special concern have also been located elsewhere in the Flambeau River system. Additional sampling would be necessary to verify that the species do actually exist at this location in the Flambeau River. If all of these species actually occur at this site, it would be considered an unusually diverse dragonfly community which includes several species considered rare or uncommon in the state.

OTHER SURVEYS

Dragonfly sampling was also conducted at other locations throughout the Flambeau River system. Most of the samples were collected by Department staff between 1988 and 1991. Ten other sites were surveyed: seven on the south fork and three on the main stem. A total of about 1,550 specimens were collected throughout the river system, 332 (21%) of which were collected at the Flambeau Mine site. The samples included 39 different species of dragonflies, two of which are listed as state-endangered and ten of which are considered species of special concern. The pygmy snaketail dragonfly, in addition to being found at the Flambeau Mine site, was also located at one other site on the main stem of the river and four sites on the South Fork. A total of 240 specimens of *O. howei* were present in these samples. The extra-striped snaketail dragonfly, (*Ophiogomphus anomalus*), also a state-listed endangered species, was found at two sites on the South Fork and a total of 112 specimens were collected.

Two specimens of the greater redhorse (*Moxostoma valenciennesi*), a state-listed threatened fish species, were collected by the Department in the Upper Park Falls Flowage in April, 1990. Several additional specimens of greater redhorse were also collected in the same area in spring 1991 (Scheirer, 1992).

A single record of a wood turtle (*Clemmys insculpta*) was reported in May, 1990 from a location about a mile north of the mine site on the opposite side of the river.

In summary, the bullhead mussel, the purple wartyback mussel, and the pygmy snaketail dragonfly are known to occur in the river near the mine site. The river redhorse and the gilt darter are suspected to occur in this reach. The greater redhorse occurs in an upstream flowage and a wood turtle has been reported from the area.

No other State-listed endangered or threatened aquatic species are known to exist in the Flambeau River system. However, aquatic endangered and threatened species are difficult to locate, identify, and thoroughly survey. It is possible, that with additional surveys, other occurrences or other listed species could be located elsewhere throughout the Flambeau River system.

DISTRIBUTION AND BIOLOGY OF SPECIES NEAR THE MINE SITE

The following sections provide brief descriptions of the distribution, population status, and aspects of the biology and life history of the five endangered and threatened species known or assumed to exist in the Flambeau River near the mine site. Readers should recognize that there is relatively little known about these species and that the information summarized below is sometimes based upon indirect evidence or other extrapolations. Distribution information from Department files is compiled by the Wisconsin Natural Heritage Inventory Program (WNHIP). Those interested in more detailed background information should refer directly to the referenced sources.

In the following species accounts, the population status of each species is described in terms of global and state ranks. The state ranks are assigned by Department staff: global ranks are taken from The Nature Conservancy. Criteria defining each of the ranks are given below.

Global Rank

G1 - Critically imperilled globally because of extreme rarity (5 or fewer occurrences or very few remaining individuals or acres) or because of some factor making it especially vulnerable to extinction throughout its range.

G2 - Imperilled globally because of extreme rarity (6 to 20 occurrences or few remaining individuals or acres) or because of some factor making it very vulnerable to extinction throughout its range.

G3 - Either very rare and local throughout its range (21 to 100 occurrences) or found locally (even abundantly at some locations) in a restricted range or because of other factors making it vulnerable to extinction throughout its range.

G4 - Apparently secure globally, although it may be quite rare in parts of its range, especially at the periphery.

G5 - Demonstrably secure globally, though it may be quite rare in parts of its range, especially at the periphery.

State Rank

S1 - Critically imperilled in Wisconsin because of extreme rarity (5 or fewer occurrences or very few remaining individuals or acres) or because of some factor making it especially vulnerable to extirpation from the state.

S2 - Imperiled in Wisconsin because of rarity (6 to 20 occurrences or few remaining individuals or acres) or because of some factor making it very vulnerable to extirpation from the state.

S3 - Rare or uncommon in Wisconsin (on the order of 21 to 100 occurrences).

S4 - Apparently secure in Wisconsin with many occurrences.

S5 - Demonstrably secure in Wisconsin.

Mussels

Freshwater mussels belong to the Phylum Mollusca (mollusks) which includes such diverse organisms as chitons, snails, slugs, conchs, squids and octopuses. Within this phylum, clams, oysters, and mussels are placed in the Class Pelecypoda which is a group of animals with a soft body enclosed by a two-part shell (also known as bivalves). Pelecypods of Wisconsin belong to three groups: Family Unionidae and Family Margaritanidae in the Order Unionida, or the fresh water mussels; and Family Sphaeriidae of the Order Veneroida, or the true clams. The term "clam" is commonly used to refer to all of these families. Most of the species of "clams" in Wisconsin and all of the species on the endangered and threatened species list are in the Family Unionidae and are most accurately termed "mussels". Currently there are almost 500 species of mussels known in North America.

Wisconsin has about 50 native species of mussels (WNHIP). Mathiak (1979), in a survey of unionid mussels in Wisconsin, examined almost 9,000 specimens from 641 sites. He found 42 species of mussels, 8 of which were considered "abundant", 9 of which were "common" and 25 of which were "scarce" to "rare". It appears that many of these uncommon species were, in the past, more abundant and more widely distributed throughout the state. Although the precise causes for the population declines of these species are not known, it is likely that impoundment of rivers, siltation from agricultural activities, municipal and industrial water pollution, and perhaps commercial overharvesting were the principal factors. Similar declines in the populations and ranges of many mussel species have occurred across the country.

Adult mussels live their entire lives partially or completely embedded in the bottoms of lakes, ponds and streams. Mussels feed by pumping water through an incurrent siphon past gills where food particles are trapped in mucus. Foods consist of small or microscopic items such as plant and animal debris, algae, protozoans, and mold. Respiration occurs by passing water over and through a pair of internal gills where gas exchange occurs. Mussels move by extending and retracting a muscular foot, pulling the animal forward or down into the substrate. Movement is slow and erratic and most mussels will probably move less than a few hundred yards during a lifetime.

Mussel reproduction is a complicated and intricate process. The sexes are usually distinct. Eggs are produced by ovaries and transported to the female's gills. Egg production is prodigious, with a single female producing perhaps half a million eggs per year. Male sperm is released into the water and taken in by the female via its siphon. Eggs are fertilized and developed within specialized pouches in the female's gills. The fertilized egg turns into a larval stage called *glochidia* which the female discharges into the water. The glochidia attach to a host organism, usually a fish, which they parasitize while developing into the juvenile stage. Glochidia cannot swim and therefore must rely on drifting in the current to encounter a host fish. Many species of mussel require a specific species of fish for their glochidia to successfully develop. Once the glochidium encounters a fish of the appropriate species, it attaches to the fish's gills or fins and imbeds itself into the tissue. There, it metamorphasizes into a juvenile form of the mussel. The juvenile mussel breaks through the tissue of the fish and falls to the river bottom, where it continues its development into an adult. The young mussels must drop onto a suitable substrate in order to successfully mature into an adult.

The required host fish species is not known for several mussel species. Two Wisconsin species, the strange floater (*Strophitus undulatus*) and the paper floater (*Anodonta imbecilis*) are thought not to require a host species for glochidial parasitism. One species, the salamander mussel (*Simpsoniconcha ambigua*) uses an amphibian, the mudpuppy (*Necturus maculosus*), as a host. For some mussel species, impacts to the host species appear to be linked to declines in the associated mussel populations. Declines in the ebony shell mussel (*Fusconaia ebena*) and the elephant ear mussel (*Elliptio crassidens*) in the Mississippi River are probably the result of dams blocking the migration of its principal host fish species, the skipjack herring (*Alosa chroysochloris*). Host fish are thought to have a substantial influence on mussel distribution (Fuller, 1974).

Due to their low level in the food chain and their relative immobility, mussels tend to accumulate certain contaminants at levels far above the ambient concentrations and can serve as biological indicators of environmental contamination. Soft tissues of mussels can accumulate significant concentrations of some metals even when levels in the surrounding water are low or cannot be detected. Even though mussels have long been recognized as potentially valuable for biological monitoring, research demonstrating the relationship between tissue and ambient contaminant levels is sparse, and only a few studies provide sufficient information to relate tissue contaminant levels to ambient concentrations or environmental hazards (Havlik and Marking, 1987). Similarly, very little research has been directed toward determining the effect of high tissue burdens of metals on mussel health or toward evaluating the direct toxicity of metals, either individually or in mixtures (Imlay, 1971; Keller and Zam, 1991).

Purple Wartyback Mussel

The purple wartyback mussel, also known as the purple pimpleback, is a moderately-sized mussel about one to four inches long distinguished by a heavy shell covered with knobby protrusions, or tubercles, and an inner shell (nacre) which is coppery-purple in color. It is the only species within the genus *Cyclonaias*. The purple wartyback mussel occurs throughout the Ohio and Mississippi River Systems, the Lake St. Clair Drainage, and Lake Erie, and is relatively common in the Ohio, Cumberland and Tennessee River Systems and their tributaries. In Wisconsin, the species was historically more widespread than today. Records dating back to the 1820s indicate that this mussel was located in the Rock, Mississippi, St. Croix, Wisconsin Fox, Illinois Fox, Baraboo, Crawfish and possibly the Wisconsin Rivers (Baker, 1928; WNHIP). The purple wartyback has apparently always been uncommon in the Upper Mississippi River (Fuller, 1980). Surveys between 1973-1980 found apparently viable populations only in the St. Croix River, with individual specimens found in the Mississippi and perhaps the Chippewa Rivers (Mathiak, 1979: Thiel, 1981). Mathiak found purple wartyback mussels at 4 out of 641 sites sampled.

Additional survey work conducted by the Department since 1989 has found several specimens at two additional locations: The Flambeau River downstream from Ladysmith, and the Menomonie River in Marinette County. The sizes and viability of these two populations is unknown.

Little is known about the specific habitat or biological requirements of the purple wartyback. It is usually found in medium to large sized rivers in sand, gravel, cobble, or silt substrates. Reproduction is tachytictic, that is, breeding only during the summer months. Females are gravid (bearing fertilized eggs) from June through August. The host fish species for the purple wartyback is not known. In Wisconsin, two of the three occurrences of purple wartybacks coincide with known occurrences of the gilt darter (*Percina evides*), suggesting the possibility that the gilt darter could perform as a host species for purple wartyback glochidia. However, it is at least equally likely that these occurrences are coincidental or a result of other environmental factors. The population status of the purple wartyback is ranked as S1 in Wisconsin and G5 globally.

Bullhead Mussel

The bullhead mussel, also known as a sheepnose, is a brown thick-shelled mussel one to three inches in diameter. It is one of three species within the genus *Plethobasus*, all of which are considered uncommon or rare throughout their ranges.

The bullhead occupies a range very similar to the purple wartyback, i.e., the Ohio, Cumberland, Tennessee and Mississippi River Systems. Historically it is thought to have been widespread but uncommon, and it now occurs sporadically and at low densities throughout its range. It is considered uncommon to rare in Missouri, Illinois, Kansas and Indiana (Buchanan, 1980). In Wisconsin, it once occurred in the Mississippi, Wisconsin, Rock and St. Croix Rivers. Surveys since 1972 indicate that possibly viable populations occur in the lower 110 miles of the Wisconsin River and in the Lower Chippewa River. Mathiak (1979) found bullheads at only 2 of the 641 sites surveyed. Populations believed to be nonviable have recently been located in the Mississippi River near Dakota, Minnesota and the St. Croix River at Prescott (WNHIP). The viability of the population in the Flambeau River is uncertain.

The bullhead is reported as occurring in substrates ranging from mud and silt to boulders, but is most commonly found in gravel and cobble substrates, usually in moderate to swift current in medium to large sized streams. It is tachytictic, bearing fertile eggs between May and July. The only known host fish species for the bullhead is the sauger (*Stizostedion canadense*). The sauger does not occur in the stretch of the Flambeau River adjacent to the mine. The population status of the bullhead is ranked as S1 in Wisconsin and G3 globally.

Dragonflies

Dragonflies are members of the Order Odonata, which is comprised of two suborders: Anisoptera (true dragonflies) and Zygoptera (damselflies). Although very similar, damselflies differ from dragonflies in several ways. Damselflies are small, slower in flight, and have different wing shapes than dragonflies. Whereas dragonflies hold their wings horizontally while resting, damselflies hold them folded over the abdomen. There are more than 150 species of Odonates in Wisconsin, about 108 of which are dragonflies. Of these dragonfly species, about 1/3 are considered common, 1/3 are rare, and the population status of the remaining 1/3 of the species is unknown (WNHIP).

Adult dragonflies mate either while at rest or in flight. The female deposits the fertilized eggs either in or adjacent to water. Depending on the species, eggs can hatch in as little as 5 days or can overwinter before hatching the following year. The newly hatched young, or nymphs, are initially small (less than 1 mm) spider-like organisms which, in Wisconsin, are entirely aquatic. As the nymphs develop, they periodically shed their skin, called an exoskeleton. Stages of the nymphs between sheddings of the exoskeleton are termed *instars* and the majority of the dragonfly species probably have from 11-14 nymphal instars. Eventually, the nymph emerges from the water by crawling on emergent vegetation, rocks, logs, or banks and undergoes the final transformation into the adult. The exoskeleton cast off during each molt (the emergence of the adult) is termed an *exuviae*. Nymphal exuvial remaining from the last molt in which the adult emerges are generally left above the water surface and are collected and identified by biologists as a method of assessing species' distributions. While it is probably typical for the egg-to-adult cycle to take about 1 year, it varies between species and may require more than 4 years for some species.

Dragonfly nymphs are predaceous, feeding on Protozoa and other aquatic insects. Some species' nymphs actively stalk prey; others lie in ambush and may remain concealed and immobile for days at a time. Dragonfly nymphs respire through a highly specialized structure in the rectal chamber containing rows of tracheal gills. The abdomen of the larvae pulsates, pumping oxygenated water into this chamber and past the gills.

Comparatively little is known about the biology and population status of many dragonfly species. About 1/8 of the dragonfly species are only known in the adult stage. Nymphs can be difficult to identify and some can only be identified in advanced instars. Complete life histories are known only for a very few species (Pennak, 1953).

Pygmy Snaketail Dragonfly

The pygmy snaketail dragonfly, also known as Howe's snake darner or the midget snaketail, is a small dragonfly which is a member of the family Gomphidae or the clubtail dragonflies. Species within this family typically inhabit streams or windswept shorelines of large lakes. Nymphs of most Gomphidae species are "burrowers", burying themselves in sand, silt or mud substrates to await prey. In Wisconsin, the *Ophiogomphus* genus includes both species which are common and species which are listed as endangered (*O. howei* and *O. anomalus*) along with several considered as special concern.

As with many insect species, knowledge of the pygmy snaketail dragonfly biology and distribution is limited. The adult of the pygmy snaketail was discovered in 1924 (Bromley, 1924: Calvert, 1924). However, the nymph of the species was not discovered and described until 1979 (Kennedy and White, 1979). The species is known to exist from Maine south to Western Virginia and Eastern Tennessee. In Wisconsin, it has been found in 7 northern rivers, including the Wolf, Peshtigo, Chippewa, St. Croix, North Branch Oconto, Red Cedar and Flambeau.

The nymph of the pygmy snaketail has been reported in several distinct size classes and thus, may require two years to reach the adult stage (Genoways and Brenner, 1985). Adults emerge from the nymph stage from late May to mid June and may live 4-6 weeks. Nymphs occur in riffle areas with sand and gravel substrates usually in medium-sized rivers with higher quality water.

The pygmy snaketail is listed as a Category 2 species by the U.S. Fish and Wildlife Service (being considered for federal listing). It is ranked S2 in Wisconsin and G2, G3 globally.

Fishes

Gilt Darter

The gilt darter, also known as the gilded darter is a member of the Family Percidae which includes perches, walleyes and darters. Darters, which are within the subfamily Etheostomatinae, are primarily stream dwellers and are the smallest fish of the family. Gilt darters average about 66 mm (2.6 inches) in length and the males are brightly colored, especially during the breeding season. The apparent original range of the gilt darter extended from Minnesota, Wisconsin, Iowa, Mississippi, and Arkansas, east to New York, Pennsylvania, West Virginia, Virginia and North Carolina and south to Northern Alabama, Mississippi and Georgia. Now, it exists in widely scattered populations which are diminishing in numbers and has been extirpated from many states. This is particularly evident in northern parts of its range where it apparently no longer exists in Iowa, Illinois, and Ohio (Becker, 1983). In Wisconsin, apparently isolated populations of the gilt darter are found in the Mississippi Drainage from the Lower Black River to the Upper Chippewa River and the Jump River to the St. Croix-Namekagon Rivers, where it reaches the northern-most extent of its continental range. Populations are difficult to assess at these sites, although Becker reported that populations may range from uncommon to common in parts of the St. Croix and Black Rivers.

The gilt darter occurs in small to large sized streams with silt-free bottoms and strong currents. It inhabits deep ripples and pools in areas of gravel, rubble and small boulder substrates. The gilt darter probably spawns in mid-June over sandy or gravelly riffles. Adults feed primarily on small aquatic insects. Schwartz (1965) reported that gilt darters moved to deeper pools in the winter, returning to riffle areas in spring. Gilt darters are difficult to collect because of the high currents and irregular substrates in their preferred habitats. The gilt darter status is ranked as S2 in Wisconsin and G4 globally. Its decline in population is probably linked to the impounding of rivers and the inundation and siltation of riffle areas.

River Redhorse

The river redhorse is a member of the Sucker Family (Catostomidae). This family, which is closely related to the minnow family, is comprised of about 100 species in North America. Species in this family are bottom-grubbing fish which feed on plants, mollusks, and other bottom dwelling organisms.

The river redhorse is one of six redhorse species in Wisconsin. Becker (1983) reports an adult length of about 300 mm (12 inches) although a specimen over 11 pounds was taken from the Chippewa River. The river redhorse is difficult to identify and can be confused with the shorthead redhorse or the greater redhorse. The most diagnostic feature of the species are very large, molar-like pharyngeal teeth; however, specimens must be sacrificed and dissected to examine these structures.

The river redhorse occurs throughout the Mississippi River, Lower Great Lakes, and St. Lawrence River Basins. Becker (1983) reported that it has declined in populations over much of its range including Illinois, Kansas, Iowa, Pennsylvania and Alabama, and that it was probably extirpated in Michigan and Indiana. However, Seegert (1991) indicated that it is more common within its range than previously thought and noted that the species had been found at several sites in Michigan and Indiana. Robison and Buchanan (1988) reported that, although building of reservoirs undoubtedly reduced river redhorse populations in Arkansas, several new records for the species were recently identified.

In Wisconsin, the river redhorse has been reported from the Rock, Sugar, Wisconsin, Mississippi, Black, Chippewa, Yellow and St. Croix Rivers (Becker, 1983). It prefers larger rivers, inhabiting reservoirs, pools and areas of moderate to fast current over clean gravel and rubble bottoms. It is normally not found in deeper water with silt, mud or sand bottoms. The river redhorse spawns late, probably mid-May, over gravel and rubble shoals. Its primary food is apparently mollusks and its enlarged pharyngeal arch and molariform teeth are adapted for crushing mollusk shells.

The population status of the river redhorse is ranked as S2, S3 in Wisconsin and G4 globally. Impoundment construction, siltation and water quality degradation are thought to be responsible for the decline in river redhorse populations. Jenkins (1970) pointed to the decline in species of suckers which are primarily mollusk feeders, suggesting that these species' status could be linked to declines in mussel populations and ranges.

Wood Turtle

The wood turtle is a medium-sized semiterrestrial turtle with distinctive concentric markings on its shell, giving it the appearance of wood grain. It is considered a very intelligent turtle and is a popular species for pets.

Wood turtles are found in an area ranging from Nova Scotia south through New York and Pennsylvania to northern Virginia and west to northeastern Ohio, Michigan, Wisconsin, eastern Minnesota, and northeastern Iowa. They occur throughout Wisconsin except for the extreme southwestern corner of the state.

Wood turtles require forested areas along moderate to fast moving streams. They are known from the Black, Wisconsin, St. Croix, Brule, Baraboo and many other rivers. They are diurnal and omnivorous, feeding both in the water and on land on a wide variety of plants and animals. Alder (*Alnus*) may be a critical habitat for basking during spring and early summer and for juvenile and hatchings as critical microhobitats. Wood turtles are communal nesters, utilizing the same nesting areas year after year. Preferred nesting sites are usually in a disturbed, open area, often with a southerly exposure. Wood turtles overwinter in rivers, respiring via specialized structures in their tails.

The population status of the wood turtle is ranked as S3 in the state and G4 globally. In Wisconsin, it is listed as threatened. Due to its communal nesting behavior, heavy predation on nest sites may limit the species' reproductive success. In the past, habitat destruction and commercial collections for pets and biological supply houses contributed to a decline in populations (Vogt, 1981).

IMPACTS TO ENDANGERED RESOURCES AT THE MINE SITE

There are two principal types of impacts with potential to affect endangered and threatened aquatic species near the mine: discharge of sediments from mine site erosion, and discharge of wastewater and associated water quality changes in the Flambeau River. Both of these categories of impacts were described in the Final Environmental Impact Statement prepared on the project. The following sections provide additional analyses of sedimentation, water quality and other impacts in light of the endangered and threatened species known or suspected to exist in the river near the mine. Readers should refer to the FEIS, the Mine Permit Application, and other referenced materials for more in-depth descriptions of the proposed design and engineering details related to the sediment control and water quality components of the project.

SEDIMENTATION

Sedimentation is the transportation of soil particles from an upland site via overland or channelized water flow into a surface water. There, soil particles can remain suspended in the water column or settle to the bottom. Sedimentation can have a variety of adverse affects on aquatic ecosystems, including clogging of organisms' gills, smothering of larva or eggs, decreased light penetration and primary production, and burying of critical habitats. While all streams and rivers carry a certain amount of sediment load naturally, land uses such as agriculture, forestry, and construction activities contribute significant additional sediment loads to surface waters. Impoundments on rivers and streams slow the water velocity, causing soil particles to settle and sediment to accumulate upstream of the dams. Excessive sedimentation has and continues to cause significant destruction of aquatic habitats throughout North America.

Control of sedimentation from construction sites can be accomplished by implementing measures which prevent water from eroding soil or which settle or filter sediment from water before it leaves the site. Common techniques employed to control construction site erosion include diverting flow around active areas, use of filter fabric fences, straw bale fences and straw bale barriers, sediment traps and basins, mulching, seeding, and establishment of stabilized drainageways. The optimum combination of erosion control techniques is unique to each construction site. Detailed planning along with proper installation and maintenance of erosion control devices is necessary to minimize sedimentation and avoid significant surface water impacts.

EROSION CONTROL AND SEDIMENTATION AT THE MINE SITE

Erosion control activities required at the mine site are described in two documents: the Erosion Control Plan included in the Mine Permit Application (Foth and Van Dyke, 1989), and the Surface Water Management Plan (Foth and Van Dyke, 1991). These plans call for sequencing of construction to minimize exposed soils and for implementation of a wide variety of erosion control measures. Temporary erosion control measures are designed to function only until permanent control facilities are constructed or become operative. Temporary facilities required by the plan are described for each of ten zones within the mine site and include silt fences, straw bale barriers, mulch, perimeter dikes, diversion channels and sediment basins. Interested readers should refer directly to the Surface Water Management Plan for more detailed descriptions of the erosion control measures within each of the construction zones.

Permanent erosion control features are designed to minimize erosion and manage storm water flows during the later stages of construction and throughout the mine operation. The permanent erosion control system consists of perimeter diversions to prevent water from flowing onto the mine site, grading the interior of the mine site to direct all water to a collection system, and routing the collected water to either the settling ponds, the surge pond or the runoff pond. The permanent erosion control facilities are designed to accommodate the highest 24-hour rainfall that would, on the average, occur once every 25 years (a 25-year storm event).

It was widely and erroneously reported last fall that erosion control facilities on the site that were designed to control a 25-year storm failed during a series of moderate to heavy rain falls. At the time of the rainfalls, the permanent erosion control facilities, which are designed for a 25-year storm event, were in the process of being constructed. The temporary control facilities, which do not have any storm-based design standard, were the operative erosion control measures at this time. While there were two failures of structures during these storms (one straw bale barrier and a short segment of filter fabric fence), these failures represent a very small fraction of the site's overall erosion control system. The straw bale barrier failure resulted in a minor discharge of sediment to the river.

During and immediately after these storms, storm water containing suspended sediment was discharged via natural drainageways to the river, creating a visible plume extending 10 to 30 feet into the river. This discharge was not related to any erosion control device failure, but rather resulted from the large volume of rainwater received at the site over several days. The temporary erosion control structures functioned as designed, although several straw bale barriers were overtopped due to the volume of the storm water. These structures did impound the storm water allowing larger soil particles to settle. Some very fine, lightly colored soil particles remained in suspension in the decanted water, creating the visible plume.

Currently, the site has been rough graded so that all project facilities within the fenced area, with the exception of the pit, are sloped to drain into the permanent erosion control system. The approximately 40 acre area over the pit has not yet been cleared and graded. When this area is constructed, runoff would be controlled with silt fences and straw bales and routed through the settling ponds.

The other remaining construction activities with potential for sediment discharge to the river include construction of the flood control dike and slurry wall. These facilities are located between the pit edge and the river. The flood control dike would fill in a small drainage way from the pit area and would serve to impound any storm water normally discharging through this channel. Impounded storm water would be pumped to the settling ponds. The area of the slurry wall construction corridor would be graded away from the river and runoff would be directed into the mine pit or a temporary retention basin.

The Department has compiled a publication which defines the erosion control practices necessary to adequately control sediment produced at construction sites (WDNR, 1989). This document describes the erosion control measures, termed Best Management Practices, which are necessary to minimize sediment production and prevent significant sediment discharges to surface waters. The erosion control practices required in the Erosion Control Plan and the Surface Water Management Plan for the mine site meet or exceed the Best Management Practices as defined in this document.

SEDIMENT IMPACT TO ENDANGERED RESOURCES

Any gill-breathing aquatic organism is susceptible to adverse impacts from sedimentation. Sediments suspended in the water column can interfere with feeding and clog gills, interfering with respiration and causing stress or even death of the organism. Relatively immobile organisms such as mussels and dragonfly larva are particularly vulnerable to sediment impacts since they are less able to avoid areas of high suspended sediment concentrations or sediment deposition.

The response of mussels to sediment appears to be somewhat variable, perhaps due to physiological differences between species. Ellis (1936) demonstrated mortality could occur with as little as one-quarter inch of silt deposition and that suspended sediment could increase by 50 percent the amount of time that mussels remained closed. Other investigators reported reduced growth rates (Stansbery, 1970) and significantly altered physiological energetics (Payne et al, 1987) in response to high concentrations of suspended sediments. On the other hand, some species of mussels are known to thrive in turbid waters and some can survive extremely high levels of sediment deposition. Marking and Bills (1980) found that over 50 percent of fat mucket (*Lampsilis radiata*) and pocketbook mussels (*L. ventricosa*) could emerge and survive after being buried by about 5 inches of sand or silt.

Long-term light exposures to siltation are likely to be more harmful to mussels than short-term heavy exposures. Mussels have the ability to close their shells to avoid temporary periods of adverse environmental conditions. A consistent increase in the suspended solids concentration in the water column would be more detrimental than infrequent episodes of sediment discharge.

Dragonfly nymphs are probably somewhat less sensitive to sediment suspended in the water column. The respiratory system which actively pumps water past tracheal gills is likely less susceptible to clogging with suspended particles. Nymphs within the family Gomphidae mostly burrow into substrates of sand, mud or gravel, occupying a microhabitat which is largely comprised of small soil particles. Fuller (1974) compiled data from numerous reports of turbidity levels where species of the Gomphidae family were found. Over one-half of the species reported occurred in water with suspended solids levels more than 100 mg/l. However, the Gomphidae species recently found in the Flambeau River are known primarily from rivers with faster flowing, higher quality water. Dragonfly nymphs also have some ability to move to escape unfavorable conditions and to burrow or hide in substrate interstices during transient adverse events.

The most significant impact to dragonfly larva from sedimentation probably occurs from deposition of sediment onto the gravel cobble and rubble substrates which are the preferred habitats of several species. This deposition can fill the spaces between the rocks eliminating the habitats necessary for the development of both the dragonfly larva and their food organisms.

Adult fish generally are not highly sensitive to short-term increases of suspended sediments (Mackenthun, 1969). Longer-term increases can have indirect impacts on adults by decreasing light penetration, primary production, and populations of fish food organisms. Although adult fish are generally not harmed by sediment in normal concentrations (Hynes, 1960), exceptionally high silt levels can kill fish by clogging the opercular cavities and gills (Smith, 1966).

The most significant impact of sedimentation on fish is probably the effect deposition of sediment can have on incubating fish eggs. Sediment can decrease the flow of oxygenated water through gravel and rock beds harboring eggs, causing high mortality. Long-term or heavy discharges of sediment can permanently smother spawning areas, resulting in a long-term or permanent reduction in reproduction.

The permanent erosion control system now installed on the site is expected to effectively control sediment production and discharge during the period of the mine operation. Some discharge of sediment could occur during construction and stabilization of the flood control dike and slurry wall. Due to the limited area of this construction and the required best management practice erosion control measures, any discharge from this activity is expected to be short-term and minor.

Sediment discharge could also occur if a storm event in excess of the 25-year 24-hour storm design occurred. There is less than a 40% chance that a single storm of this magnitude would occur any time during the eight to nine year mine operation. If it did occur, the water handling facilities at the mine do have capacities in excess of the 25-year 24-hour design. If all of the water retention ponds become full, they are designed to direct any overflow to the open pit.

If discharges of sediment did occur from the mine site, any impacts to mussel and dragonfly habitat would be expected to be short-term. The regularly reoccurring periods of high water velocity in this stretch of the river would tend to suspend sediment and transport it downstream to a location where the current slows, most likely the Thornapple Flowage. It is this hydrologic regime which is probably responsible for the existing sediment-free condition of the river substrate.

The wastewater discharged through the treatment systems would contain minor amounts of suspended sediments. The WPDES permits for the discharges impose a daily maximum limit of 30 mg/L and an average concentration limit of 20 mg/L. These concentrations are only slightly over background levels and are not expected to adversely impact aquatic life.

OTHER CONSTRUCTION IMPACTS

Dragonflies and many other aquatic insects spend a relatively short period of their life cycle in a terrestrial stage. It is therefore possible that terrestrial alterations could impact these species. However, there is no known critical habitat for the adult pygmy snaketail dragonfly. Also, streamside vegetation, which is the zone used by emerging dragonflies, would be largely unaffected. The stream side vegetation would remain in a strip which is a minimum of about 100 feet wide for a short distance and is 300 feet or more wide over most of the site. In addition, the site vegetation is very typical of the area and is widely available at alternate sites. Therefore, it is not expected that alteration of terrestrial environments would adversely affect the pygmy snaketail dragonfly.

Construction of the wastewater outfalls would involve placing riprap over two approximately 10 by 20 foot areas on the stream bottom. It is possible, although unlikely, that individuals of the listed mussel and dragonfly species could occur within these riprap zones and could be injured or killed by this activity. The Department intends to survey these areas prior to riprap placement, and to move any specimens found. Due to the small areal extent of the riprap, no significant impacts to the populations of these species would occur from placing the riprap.

The wood turtle could use the habitat which still remains over the pit area. An open canopy providing sunlight to the ground provides basking sites. Alder is preferred in spring before foliage appears. There is a small amount of alder in this area which could serve as basking habitat. However, alder is common in the area and mine construction would not significantly affect the available habitat. It is possible, although unlikely, that wood turtles could nest somewhere on the approximately 40 acres of the site which have not yet been cleared. No nesting sites were located during the biological survey work conducted on the site. If a communal nesting site existed in this area, mine construction could adversely affect recruitment to the local wood turtle population.

IMPACTS FROM THE WASTEWATER DISCHARGE

Impacts to aquatic resources from wastewater discharges are controlled by a series of regulations which describe the water quality necessary to protect aquatic life and which establish procedures to determine the allowable level of pollutants in wastewater discharges. The same regulations that apply to the mine discharge also apply to approximately 2,300 other wastewater dischargers across the state. The underlying authorities for these regulations are derived from the Federal Clean Water Act and the program is administered by the Department with the approval and under the supervision of the U. S. Environmental Protection Agency.

The principal regulations which control the impacts of wastewater discharges are contained in the following Administrative Codes:

NR 102	Water Quality Standards for Wisconsin Surface Waters
NR 103	Water Quality Standards for Wetlands
NR 104	Uses and Designated Standards
NR 105	Surface Water Quality Criteria for Toxic Substances
NR 106	Procedures for Calculating Water Quality Based Effluent Limitations for Toxic and Organoleptic Substances Discharged to Surface Waters
NR 207	Water Quality Antidegradation

CALCULATION OF EFFLUENT LIMITATIONS

Effluent limitations are numerical or other limits on the amounts of pollutants allowed in wastewater discharges. The calculation of effluent limitations for toxic substances for any particular discharge is based on a complicated sequence of equations and database analyses which are described in Chapter NR 106. Effluent limitations are imposed by a Wisconsin Pollutant Discharge Elimination System Permit (WPDES) permit and are calculated in a manner so that the receiving water will continue to meet water quality standards.

Water quality standards are established in Chapters NR 102 through 105 and describe the minimum conditions all surface waters must meet in order to maintain existing and future uses. Water quality standards are required by law to protect the public interest, which includes the protection of public health and welfare, protection of water supplies, propagation of fish and other aquatic life and wild and domestic animals, domestic and recreational purposes, and agricultural, commercial, industrial and other legitimate uses.

In order to meet the water quality standards, the Department establishes numerical *water quality criteria* which must be maintained in the receiving water to protect aquatic life and other uses of surface waters. For the Flambeau Mine discharge, the following water quality criteria were applied:

Acute Toxicity Criteria (ATC)	The maximum daily concentration of a substance which ensures protection of sensitive aquatic species from acute (short-term) toxic effects.
Chronic Toxicity Criteria (CTC)	The maximum 4-day concentration of a substance which ensures protection of sensitive aquatic species from chronic (long-term) toxic effects.
Wild and Domestic Animal Criteria (WDAC)	The maximum concentration of a substance which protects wild and domestic animals from adverse effects resulting from ingestion of surface waters or ingestion of aquatic organisms.
Human Threshold Criteria (HTC)	The maximum concentration of a substance which protects humans from adverse effects resulting from contact with or ingestion of surface waters or from ingestion of aquatic organisms.
Human Cancer Criteria (HCC)	The maximum concentration of a substance which protects humans from an unreasonable incremental risk of cancer resulting from contact with ingestion of surface waters or from ingestion of aquatic organisms.

Most water quality criteria are derived from documents published by the U. S. EPA containing the nationwide database for each substance. These documents contain the results of chemical-specific testing on various organisms from across the country. The Department utilizes this database to calculate water quality criteria for each substance which might be in a wastewater discharge. Briefly, this process involves analyzing the database to find the lowest concentrations of each substance which have been shown to be harmful to aquatic life, wildlife or humans. For fish and aquatic life, the process first determines the three or four species which are most sensitive to each substance in the discharge. Toxicity data for the most sensitive group of species is then used to calculate acute and chronic toxicity criteria for each substance. These criteria are designated to protect 95% of the species for which data are available on a nationwide basis. The term acute toxicity refers to the ability of a substance to cause mortality or some other adverse effect in an organism from a single or short-term exposure. Chronic toxicity refers to the ability of a substance to cause an adverse effect in an organism from an exposure for a time period which represents a substantial portion of the natural life expectancy of that organism. The toxicity of some substances varies in relation to other water quality parameters such as hardness. For these substances, a formula is used in calculating criteria to reflect the actual characteristics of the receiving water. Sufficient data on chronic toxicities of many substances is not available. In these cases, an acute-chronic toxicity ratio is used to generate chronic toxicity criteria.

Conceptually similar processes are used to develop the Wild and Domestic Animal, Human Threshold, and Human Cancer criteria. The processes used for calculating all water quality criteria for substances which may be toxic are defined in Chapter NR 105 of the Wisconsin Administrative Code. The water quality criteria used for the Flambeau River under these guidelines are designed to provide protection to aquatic organisms and the health of humans and animals ingesting organisms from the river.

Effluent limitations establish the maximum concentrations of substances which can occur in a wastewater effluent without violating the water quality standards of the receiving water. Three variables are involved in the effluent limitation calculation: The flow (volume) of the effluent, the flow of the receiving water, and the existing background concentrations of substances in the river.

For the Flambeau Mine, the effluent flow used for calculating the limitations was 0.57 cfs (256 gpm). Background water quality data were taken from the database generated by the project monitoring program (Table 10).

Stream flow values used varied depending on the criterion that was used as the basis for the limitation. Acute toxicity criteria are applied at the point of discharge and therefore, background stream flows are not used in calculating the related effluent limitations. Acute toxicity limits are applied as daily maximums. Chronic toxicity criteria are applied in the stream after the effluent has mixed with the background flows. In calculating the effluent limitations related to chronic criteria, the volume of background stream flow allowed for dilution is one-quarter of the lowest flow occurring for a seven day period once every ten years ($\frac{1}{4}\,{}_7Q_{10}$). In the case of the Flambeau Mine, provisions of Chapter NR 207 (Water Quality Antidegradation) further reduced the stream flow allowed for dilution to one-third of the above flow. As a result, of the 1,855 cfs average stream flow adjacent to the mine site, only 36 cfs were considered as available for diluting the effluent when calculating limitations related to chronic toxicity. This is a conservative approach to calculating these limitations which provides a substantial safety margin in protecting organisms from chronic toxic affects. Chronic limitations are applied as weekly average limits.

Effluent limitations designed to protect wild and domestic animals from adverse effects utilize 85 percent of the $_7Q_2$ (7-day 2-year low flow) in the calculations. The river flow used in calculating limits based on the human threshold and human cancer criteria is the mean annual river flow. The flows allowed for dilution to meet these criteria were also adjusted by the one-third factor in accordance with the antidegradation provisions. Effluent limitations within both of these categories are imposed as a monthly average limit.

The effluent limitations applied to the Flambeau Mine discharge are given in Table 8. For most substances the limitation calculated for acute toxicity is the most stringent and therefore is the controlling limit. This is due to the low average flow of the Flambeau Mine discharge (0.57 cfs) in relation to the high average flow of the river and the resulting dilution of the effluent. This high rate of dilution rapidly reduces concentrations for most substances in the effluent below the chronic toxicity criterion. As a result, limitations based upon preventing acute toxicity are lower and, for these substances, are the limitations which control the effluent quality. In the cases of cadmium, total chromium, lead and nickel, limitations based on chronic toxicity criterion could be the most stringent and therefore are included in the permit.

The processes described above incorporate the available scientific information and chemical-specific testing on organisms. However, combinations of substances can have different, often-higher, toxicities than the individual components of the mixture. The best way to assess the toxicity of an effluent is to subject the effluent to <u>whole effluent toxicity testing</u> or <u>bioassays</u>. In this type of testing, sensitive organisms are exposed to the actual wastewater in varying concentrations and evaluated to determine if the effluent causes any adverse effects. For proposed discharges, a synthesized effluent must be produced which can only approximate the composition of the actual discharge. For this reason, bioassay tests are of limited usefulness for assessing proposed discharges and are most applicable to existing discharges. Bioassay testing done to assess the proposed discharge at the Flambeau Mine is described in subsequent sections.

The WPDES permit for the Flambeau Mine requires whole effluent toxicity testing on a regular basis. The permit further specifies immediate retesting upon failure of any test. If the follow-up tests are failed, the Department has the options, under both the wastewater law and terms of the WPDES permit, of modifying the permit to require additional testing, imposing a schedule to reduce the effluent toxicity, and/or imposing an effluent toxicity limitation in the permit. Under the mining law, the legislature has provided that, for any aspect of mining, the Department has the ability to require an immediate cessation of mining if continuance of mining constitutes an immediate and substantial threat to public health and safety or the environment.

The process of determining effluent limitations and the conditions of the WPDES permit for the Flambeau Mine was identical to that used for discharges throughout the state. To put the mine discharge into some perspective, it can be compared to other state discharges. The mine discharge would average about 0.369 MGD (million gallons per day). The largest dischargers in the state, which include utilities and the Milwaukee sewerage discharge, are each in excess of 100 million gallons per day. The smallest discharges in the state are in the neighborhood of several hundred gallons per day. There are about 115 municipal sewage treatment plants which are designed for discharges equal to or greater than that for the Flambeau Mine. Of the 37 pulp and paper mills with permitted wastewater discharges to surface waters in Wisconsin, 33 have existing discharges greater than the Flambeau Mine's proposed flow rate. In terms of concentrations of pollutants, it is likely that the stormwater runoff from the City of Ladysmith contains higher concentrations of metals than would the wastewater from the Flambeau Mine.

IMPACTS FROM WATER QUALITY CHANGES

A general assessment of the impact of water quality changes from the Flambeau Mine discharge can be made by comparing the projected river water quality after mixing with the wastewater with its predischarge quality and applicable water quality criteria. To address concerns with potential chronic toxicity and addition of metals to the water column and sediment, it is most useful to look at average stream flow conditions and discharge rates. Table 14 provides background levels, instream concentrations with the discharge at the maximum allowable levels (effluent limitations), instream concentrations with the discharge at the projected levels, and the most stringent water quality standard for each substance. It should be noted that, for these calculations, it was assumed that the river was flowing at 1/3 of its average annual flow. Therefore, the concentrations of these substances at average stream flows after complete mixing with a stream would actually be lower than indicated in the table.

Table 14. Water Quality Impacts to the Flambeau River from the Wastewater Discharge[1]

		INSTREAM CONCENTRATION[2]		
Substance	Existing	With Discharge at Effluent Limits	With Discharge (at Projected) Quality)[4]	Most Stringent Water Quality Standard
Arsenic	<5.0	0.7	0.005	50.0
Beryllium	<1.0	0.2[3]	no data	0.2
Cadmium	<1.0	0.01	0.005	0.23
Chromium (total)	<5.0	1.9	0.046	31.6
Chromium (+6)	<50.0	0.03	no data	9.7
Copper	3.7	3.7	3.7	6.2
Lead	<5.0	0.27	0.09	4.39
Mercury	<0.5	0.0007	NA[5]	0.0002
Nickel	0.4	2.7	0.44	38.0

Selenium	<5.0	0.11	0.09	7.07
Silver	<0.4	0.0006	0.0006	0.93
Zinc	5.1	5.4	5.1	28.5
Aluminum	62.5	63.8	63.4	87

[1] All values in ug/L (parts per billion)

[2] Based on a stream flow of 1/3 of the average annual flow (618.3 cfs) and a total effluent flow of 0.57 cfs.

[3] Background data indicates beryllium concentrations in the discharge would be substantially less than the effluent limit.

[4] Assumes substances not detected are present at the detection limit.

[5] Detection limit for pilot plant testing was above the effluent limit.

It can be seen from this table that, after mixing, the wastewater from the mine would have very little measurable effect on the river water quality. Assuming that substances not detected in the river were in fact not present, the addition of the Flambeau Mine effluent at the maximum allowable concentrations would not result in any appreciable change in the river water quality. With the exception of aluminum, the discharge would not result in any detectable change in the river water quality using commonly accepted laboratory detection levels. Although the calculations indicate that aluminum would increase slightly, this is the result of the high concentration (1,500 ug/L) allowed by the effluent limitations which is substantially higher than the concentrations expected to be in the effluent. Calculations using the maximum concentrations predicted to be in the effluent show that, other than for aluminum, no detectable change in water quality would occur and that the theoretical (calculated) resultant water quality would be several orders of magnitude below the most stringent water quality standard. No pilot plant data were generated for aluminum, and therefore, a relatively high concentration (1,000 ug/L) was assumed to occur in the effluent. Even at this concentration, aluminum concentrations in the river would increase by less than 1.5% (0.9 ug/L).

The lack of any significant impacts to water quality under average flow conditions is attributable to three factors. First, no chemical processing of ore will occur at the site. The wastewater will consist solely of rainwater falling on the site and groundwater flowing into the pit. Second, the proposed treatment system is effective in removing metals from the effluent. Pilot studies of the wastewater treatment system, while of limited reliability, indicate that most metals would not be detectable in the effluent. Third, the high dilution ratios previously mentioned act to quickly reduce concentrations of substances in the effluent to background or nondetectable levels. For these reasons, no significant change in water quality under average flow conditions in the Flambeau River is expected from the mine discharge.

It is possible that water quality impacts could be more pronounced under conditions of low stream flows and high wastewater flows. Uncontaminated runoff would be collected and routed to the settling ponds where suspended solids would be allowed to settle. If these ponds were emptied over a short period of time, discharge flows could temporarily be as high as 11.6 MGD. Under these conditions, water quality impacts to the river could be different than those shown in Table 14.

The process of calculating effluent limitations as defined in Chapter NR 106 of the Wisconsin Administrative Code allows for mixing the effluent with a portion of the river flow before chronic toxicity criteria are applied. As a result, chronic toxicity criteria could be exceeded within this mixing zone if pollutants are discharged at or near the effluent limitations. Sensitive organisms which would normally spend a substantial portion of their life cycle within the mixing zone area could be adversely affected by chronic toxicity.

The mixing zone associated with the mine discharge would probably be a narrow, shore-hugging zone extending a variable distance downstream. The actual geometry of the zone would depend on the hydrodynamics of the river and would vary along with the substantial flow fluctuations which occur in this area. It is possible that mussels and/or dragonflies which spent a sufficient portion of their life cycle within the mixing zone area could experience chronically toxic effects. The net effect of such toxicity, if it occurred, would likely be a small area within the river where the organisms would not reproduce, grow or reach maturity.

Metals in the effluent would tend to adsorb to suspended sediment particles and eventually settle in a downstream depositional zone. Metals not attached to particles would remain in a soluble form or be taken up by aquatic biota. Although metals adsorbed to sediments are generally less biologically available than those in solution, they can accumulate over time. Deposition of metal-bearing sediment over long periods of time can result in contaminated sediments potentially injurious to benthic and other aquatic life. Although sediment quality criteria are currently being developed on a national basis, there are no existing standards which establish the maximum sediment contaminant levels which would protect aquatic life. It is likely, however, that water quality-based criteria will be at least as stringent as sediment quality-based criteria and therefore will protect both water quality and sediment quality. While it is not possible to definitively predict the partitioning of metals from the mine discharge amongst the various phases, or the effect of contaminated sediment on biota, two factors indicate that significant biological impacts from metal-containing sediments would not be expected as a result of the mine discharge. First, the mass loading of metals to the river from the mine would be insignificant compared to the existing loading. As previously described, even at the maximum allowable concentrations, the mine discharge would not result in an analytically detectable change in water quality for most substances. Second, the mine discharge would exist less than ten years, limiting its ability to affect sediment characteristics. Other long-term sources of metals contributions to the river would be the predominant factors influencing sediment quality.

After the mine closes, groundwater would flow through the backfilled pit and discharge into the river. This groundwater could contain substances from the backfilled material. However, the very low rate of groundwater flow through the pit would limit the potential impact to surface water. Groundwater modeling indicates that only about 2 gallons per minute (gpm) of groundwater would flow through the pit and discharge into the river. Since the average river flow in the mine vicinity is over 800,000 gpm, this groundwater, even if carrying the maximum possible concentrations of substances, would not significantly effect water quality in the river.

Bioassay Testing

Acute and chronic bioassay tests were conducted in 1989 on synthesized mine effluent by a private laboratory under contract with Flambeau Mining Company. Standard bioassay test organisms, the fathead minnow (*Pimephales promelas*) and a water flea (*Ceriodaphnia dubia*) were exposed to various concentrations of synthetic effluent ranging from 1% to 100% effluent. Results of these tests were reported in Hunter/ESE (1989). These tests showed that the synthetic effluent was not acutely toxic at 100% concentrations or chronically toxic at the expected instream concentration (1%). Chronic toxicity was observed at 100% effluent concentration for an effluent produced from a lime precipitation wastewater treatment, and at 30% concentration for a lime/sulfide precipitation treatment, which is the treatment system proposed for the mine project. This chronic toxicity at 30% concentration may be anomalous since testing at 100% concentration did not show any chronic effects. The 30% concentration is about 30 times the concentration which would occur after mixing with ¼ of the stream at low flow conditions ($_7Q_{10}$) and about 1,000 times the concentration which would occur with full mixing under average stream flow conditions.

Water Quality Impacts to Endangered and Threatened Species

After finding evidence that the purple wartyback mussel, the bullhead mussel and the pygmy snaketail dragonfly existed in the Flambeau River near the mine site, the Department initiated a process to review the wastewater discharge from the Flambeau Mine to determine if it had the potential to adversely affect these species. This process was comprised of two components: A review of the available scientific information to determine if any additional toxicological information on these species existed, and bioassay testing of a synthesized mine effluent.

As the first step in this review, documents published by the U.S. EPA containing the water quality criteria were evaluated to determine if the available data indicated that fresh water mussels or dragonflies were more sensitive to heavy metals than the species which were used to establish the fish and aquatic life acute criteria for the Flambeau Mine discharge. This review concluded that toxicological data for mussels and dragonflies were nearly nonexistent in the national database for cadmium, hexavalent chromium, copper, nickel and zinc, the metals which could be present in the mine effluent. Because there were no data in the criteria documents on mussel or dragonfly species, Department staff evaluated toxicological data for species that were taxonomically similar, or closely related. Data on snails (Phylum Mollusca: Class Gastropoda) were substituted for mussels (Phylum Mollusca: Class Pelecypoda). Data on damselflies (Phylum Arthropoda; Class Insecta: Order

Odonata: Suborder Zygoptera) were substituted for dragonflies (Phylum Arthropoda; Class Insecta: Order Odonata: Suborder Anisoptera).

Table 15 provides a summary of the species with data in the water quality criteria documents and a ranking of their sensitivity to the five metals. The table includes data from the most sensitive aquatic species in the entire national data base, the four most sensitive warmwater species, and all insect and mollusk species. The four most sensitive warmwater species are those used directly to establish the NR 105 criteria for the Flambeau River.

Table 15. Relative Rank of Species Mean Acute Value (SMAV) for Toxicity Test Species Represented in the U.S. EPA Water Quality Criteria Documents. [NOTE: Dataset condensed to include the four most sensitive species, the four most sensitive warmwater species denoted by an asterisk (*), and all remaining insect and mollusk species.]

Substance	# of Species Tested	Common Name	[Class] or Order (Sub-order)	Genus species	Rank of SMAV
Cadmium	52	Brown Trout	--	*Salmo trutta*	1
		Rainbow Trout	--	*Oncorhynchus mykiss*	2
		Chinook Salmon	--	*Oncorhynchus tshawytscha*	3
		Coho Salmon	--	*Oncorhynchus kisutch*	4
		Water Flea	[Cladocera]	*Daphnia magna*	5*
		Fathead Minnow	--	*Pimephales promelas*	6*
		Bryozoan	Ctenostomata	*Lophopodella carteri*	7*
		Water Flea	[Cladocera]	*Moina macrocopa*	8*
		Snail	[Gastropoda]	*Aplexa hypnorum*	17
		Snail	[Gastropoda]	*Physa gyrina*	19
		Mayfly	Ephemeroptera	*Paraleptophlebia praepedita*	23
		Midge	Diptera	*Chironomus sp.*	26
		Caddisfly	Trichoptera	Unidentified	33
		Snail	[Gastropoda]	*Amnicola* sp.	39
		Damselfly	Odonata (Zygoptera)	Unidentified	51
Chromium^{+6}	32	Water Flea	[Cladocera]	*Daphnia pulex*	1*
		Water Flea	[Cladocera]	*Daphnia magna*	2*
		Water Flea	[Cladocera]	*Simocephalus vetulatus*	3*
		Water Flea	[Cladocera]	*Simocephalus serrulatus*	4*
		Snail	[Gastropoda]	*Physa heterostropha*	11
		Midge	Diptera	*Tanytarsus dissimilis*	20
		Midge	Diptera	*Chironomus tentans*	22
		Damselfly	Odonata (Zygoptera)	*Enallagama aspersum*	30
		Stonefly	Plecoptera	*Neophasganophora capitata*	32
Copper	53	N. Squawfish	--	*Hychochelius oregonensis*	1*
		Water Flea	[Cladocera]	*Daphnia pulicaria*	2*
		Water Flea	[Cladocera]	*Daphnia pulex*	3*
		Water Flea	[Cladocera]	*Daphnia magna*	4*
		Snail	[Gastropoda]	*Physa integra*	10
		Snail	[Gastropoda]	*Physa heterostropha*	11
		Snail	[Gastropoda]	*Gyraulas circumstriatus*	13
		Midge	Diptera	*Chironomus sp.*	14
		Midge	Diptera	*Chironomus tentans*	15
		Snail	[Gastropoda]	*Goniobasis livescens*	33
		Snail	[Gastropoda]	*Amnicola* sp.	44
		Snail	[Gastropoda]	*Campeloma decisum*	47
		Damselfly	Odonata (Zygoptera)	Unidentified	50

		Caddisfly	Trichoptera	Unidentified	52
		Stonefly	Plecoptera	*Acroneuria lycorias*	53
Nickel	21	Water Flea	[Cladocera]	*Daphnia magna*	1*
		Water Flea	[Cladocera]	*Daphnia pulicaria*	2*
		Rock Bass	--	*Ambioplites rupestris*	3*
		Mayfly	Ephemeroptera	*Ephemerella subvaria*	4*
		Snail	[Gastropoda]	*Amnicola* sp.	13
		Damselfly	Odonata (Zygoptera)	Unidentified	17
		Caddisfly	Trichoptera	Unidentified	19
		Stonefly	Plecoptera	*Acroneuria lycorias*	20
Zinc	41	Water Flea	[Cladocera]	*Ceriodaphnia reticulata*	1*
		Water Flea	[Cladocera]	*Ceriodaphnia dubia*	2*
		Striped Bass	--	*Morone saxatilis*	3*
		Longfin Dace	--	*Agoxia chrysogaster*	4*
		Snail	[Gastropoda]	*Physa heterstropha*	15
		Snail	[Gastropoda]	*Physa gyrina*	16
		Snail	[Gastropoda]	*Helisoma campanulatum*	17
		Mussel	[Pelecypoda]	*Corbicula fluminea*	25
		Snail	[Gastropoda]	*Amnicola* sp.	39
		Damselfly	Odonata (Zygoptera)	*Argla sp.*	41

As shown in Table 15, damselflies and snails for which data are available are far less sensitive to these metals than the species which were used to establish acute water quality criteria and the associated WPDES permit limitations for the Flambeau Mine. For three of the metals (Cr^{+6}, Ni, Zn), a cladoceran test organism in the family Daphnidae was the most sensitive of all of the species tested. In the case of cadmium (Cd), a cladoceran was the fifth most sensitive test organism ranking only behind four cold water trout and salmon species. The northern squawfish was the most sensitive species to copper (Cu), followed by four different species of cladocerans. In general, the cladocerans (water fleas) were amongst the most sensitive species, snails tend to be intermediate in their sensitivities, and damselflies were amongst the least sensitive of all species tested. It should be noted that most of the species for which toxicology data is available are relatively common. It is possible that rarer species might be more sensitive to metals than closely related, abundant species. However, if, with regards to sensitivities to metals, mussels are similar to snails and dragonflies are similar to damselflies, this review supports the conclusion that the water quality based effluent limitations currently contained in the WPDES permit for the Flambeau Mine adequately protect mussels and dragonflies in the river.

Department staff also conducted a literature review of toxicological data published or otherwise becoming available after the NR 105 water quality criteria were promulgated. No new information was located which provided any toxicity data for dragonfly nymphs. However, a new study from the University of Florida published in 1991 provided useful data on the acute toxicity of certain metals and metal mixtures to mussels. This study (Keller and Zam, 1991) utilized a laboratory protocol still in the developmental stage to test the acute toxicity of metals to the paper floater mussel (*Anodonta imbecilis*). The paper floater is in the same taxonomic family (Unionidae) as the bullhead and purple wartyback mussels, making it a useful species for comparison of potential toxic responses. However, the paper floater is a very common and widespread mussel, and is thought to be tolerant of adverse environmental conditions. These studies utilized 1 to 2 day-old juveniles as test organisms. Glochidia of the mussels were cultured in the laboratory during their transformation into free living juveniles. The methodologies employed were not approved by the EPA or the American Society for Testing Materials (ASTM); no such approved methodology for toxicity testing of juvenile mussels exists. Keller and Zam also performed simultaneous toxicity tests with the cladoceran (water flea) *Ceriodaphnia dubia* using standard methods like those required in the WPDES permit for the mine.

The study measured toxicity of five metals to juvenile mussels. Results are reported as the concentration (Lethal Concentration or LC) of the metal which produced a 50% mortality (LC_{50}) over a 48 hour (48-h LC_{50}) or 96 hour (96-h LC_{50} period). The tests were conducted in both soft water (hardness = 40-48 mg/L) and moderately hard water (hardness = 80-100 mg/L). Water hardness is important since the toxicity of most of the metals limited in the WPDES permit for the mine are inversely related to water hardness (i.e., higher hardness yields lower toxicity). Since the estimated hardness of the mine effluent is 155 mg/L, the toxicity of these metals would be less in the effluent than the 96-h LC_{50}s reported by the study.

In order to apply the Keller and Zam results to the Flambeau Mine effluent, the data were transformed with a regression analysis to generate 96-h LC_{50} values at a hardness of 155 mg/L. The regression analysis was performed two different ways: (1) assuming a straight linear regression with respect to hardness utilizing the 96-h LC_{50}s for soft and moderately hard water, and (2) calculating the geometric mean of the 96-h LC_{50}s for soft and moderately hard water and fitting it to a line using the slope described in NR 105 for each of the metals. Table 16 provides the 96-h LC_{50} values from these analyses along with those reported by Keller and Zam.

Table 16. Actual and estimated 96-h LC_{50} values for *A. imbecilis*. (Data Source: Keller and Zam (1991)).

	96-h LC_{50} ($\mu g/L$) @ Hardness (as $CaCO_3$) of:			Using Slope of (A) & (B)	Using NR 105 Slope and Data Point (C)
Substance	40-48 mg/L (A)	80-100 mg/L (B)	67 mg/L (C)	155 mg/L (D)	155 mg/L (E)
Cadmium	9	107	31	702	79.8
Chromium^{+6}	39	618	155	5041	155
Copper	86	199	131	376	289
Mercury	147	171	159	192	159
Nickel	190	252	219	312	445
Zinc	268	438	343	636	698

(A) = 96-h LC_{50} ($\mu g/L$) as reported by Keller & Zam (1991) in soft water.
(B) = 96-h LC_{50} ($\mu g/L$) as reported by Keller & Zam (1991) in moderately hard water.
(C) = Estimated 96-h LC_{50} ($\mu g/L$) in water with hardness = 67 mg/L (as $CaCO_3$). Hardness was calculated as the arithmetic mean of values used for soft (40-48) and moderately hard (80-100) water. LC_{50}s are reported as geometric mean of (A) and (B).
(D) = Estimated 96-h LC_{50} ($\mu g/L$) in water with hardness = 155 mg/L (as $CaCO_3$) as extrapolated using the data from (A) and (B).
(E) = Estimated 96-h LC_{50} ($\mu g/L$) in water with hardness = 155 mg/L (as $CaCO_3$) using the slope of the line reported in Ch. NR 105 (Wis. Adm. Code) and the data point generated by (C).

The two regression analyses provided similar results for each of the metals except Cd and Cr^{+6}. The differences in the results for these two metals are attributable to two factors. First, the LC_{50}/hardness relationship for *A. imbecilis* is different than the combined LC_{50}/hardness relationship for all species tested. Second, the two hardness ranges from the Keller and Zam study were fairly close when compared to the hardness range of data used to generate the criteria listed in Chapter NR 105. The results shown in Column E of Table 16 are more statistically appropriate since the regression analysis using the NR 105 LC_{50}/hardness relationship was based on a much larger data base with a larger range of hardness.

Data resulting from these analyses can be compared to the effluent limitations in the WPDES permit for the Flambeau Mine to determine if those limitations provide adequate protection for mussels with sensitivities comparable to *A. imbecilis* (Table 17). It can be seen that the effluent limits for Cr^{+6}, Cu, Hg, and Zn are all below the 96-h LC_{50} values reported, and therefore should provide adequate protection from acute toxicity. However, the permit limitations for both Ni and Cd exceed the calculated 96-h LC_{50} values, indicating a potential that the water quality based effluent limitations would not adequately protect mussels from toxic effects from these metals. It should be noted that wastewater permit limitations are calculated without regard to the expected level of pollutants in a discharge. Consequently, effluent limitations for nickel and cadmium were included in the WPDES permit even though pilot testing of the wastewater treatment design did not detect any nickel or cadmium in the effluent at detection limits of 30 ug/L and 0.3 ug/L respectively.

Table 17. Comparison of estimated 96-h LC_{50}s at hardness = 155 mg/L (as $CaCO_3$) and WPDES permit limitations for the Flambeau Mine.

Substance	Keller & Zam 155 mg/L (A)	Ch. NR 105 155 mg/L (B)	Current WPDES Permit Limitations		
			Daily Max.	Weekly Avg.	Monthly Avg.
Cadmium	702	79.8	**95**[c]	7.1	---
$Chromium^{+6}$	5041	155	28	--	---
Copper	376	289	50	--	---
Mercury	192	159	---	--	0.002
Nickel	312	445	**3100**[d]	**1200**[d]	---
Zinc	636	698	300	--	---

(A) = Extrapolated 96-h LC_{50} ($\mu g/L$) for the mussel *A. imbecilis* using data reported by Keller & Zam (1991) and hardness = 155 mg/L (as $CaCO_3$).

(B) = Extrapolated 96-h LC_{50} ($\mu g/L$) for the mussel *A. imbecilis* using geometric mean of soft and moderately hard water data reported by Keller & Zam (1991), slope described in Ch. NR 105 (Wis. Adm. Code) and hardness = 155 mg/L (as $CaCO_3$).

c = Daily Max. for cadmium exceeds the 96-h LC_{50} estimated for the mussel *A. imbecilis* generated using methods described in Ch. NR 105 (Wis. Adm. Code).

d = Both Daily Max. and Weekly Avg. exceed the 96-h LC_{50} estimated for the mussel *A. imbecilis* generated using the methods described in Ch. NR 105 (Wis. Adm. Code).

After reviewing the analyses described above, Department staff determined that it would be desirable to attempt to conduct toxicity testing on mussels using a synthesized mine effluent. Department staff along with staff from the State Laboratory of Hygiene consulted with national experts to determine the most appropriate test design and protocol. Staff from the State Lab of Hygiene received specialized training necessary to accurately evaluate any effects on the juvenile mussels.

The tests were designed to provide three different assessments: (1) the sensitivity of mussels to an effluent with all metals at the maximum concentrations allowed by the WPDES permit, (2) the sensitivity of mussels to an effluent with metals at the projected concentrations, and (3) a comparison of the sensitivities to metals of mussels, water fleas and larval fathead minnows. Testing methodologies followed those utilized by Dr. Don Wade of the Tennessee Valley Authority, who is currently refining methods for acute and chronic toxicity testing with *A. imbecilis*.

The following is a brief description of the testing parameters and results. A more complete discussion of the tests is provided in a report prepared by Department and State Laboratory of Hygiene staff which is attached as Appendix B.

Toxicity testing was conducted in August and September, 1991 with the mussel *A. imbecilis*, the water flea (*C. dubia*), and larval fathead minnows (*P. promelas*). Testing of the purple wartyback and bullhead mussels or the pygmy snaketail dragonfly was not possible due to the absence of accepted laboratory techniques for testing these species. All tests were performed with several controlled treatments and the following four test treatments:

- **Treatment F-50-HIGH**: Flambeau River water (Hardness ≈ 50 mg/L) was spiked with Cd, Cr^{+6}, Cu, Ni, and Zn at concentrations equal to the effluent limitations proposed for the WPDES permit (Table 18). This treatment reflected the worst case condition for two reasons: (1) the extremely low hardness increases the bioavailability of metals; and (2) the metals concentrations were as high as the WPDES permit allows and any exceedance of those limitations would be deemed a permit violation.

- **Treatment L-90-HIGH**: SLH Laboratory water (Hardness ≈ 90 mg/L) was spiked with Cd, Cr^{+6}, Cu, Ni, and Zn at concentrations equal to the effluent limitations proposed for the WPDES permit (Table 18). This treatment was included to demonstrate the effect of a moderately hard water on the toxicity of heavy metals.

- **Treatment F-155-HIGH**: Flambeau River water with adjusted hardness (Hardness ≈ 155 mg/L) was spiked with Cd, Cr^{+6}, Cu, Ni, and Zn at concentrations equal to the effluent limitations proposed for the WPDES permit (Table 18). This treatment reflected the discharge of the maximum allowable concentration of metals under conditions of projected effluent hardness.

- **Treatment F-155-LOW**: Flambeau River water with adjusted hardness (Hardness ≈ 155 mg/L) was spiked with Cd, Cr^{+6}, Cu, Ni, and Zn at concentrations equal to projected treated effluent concentrations (Table 19). This treatment was designed to reflect the expected "real world" discharge situation with effluent having the estimated water quality projected by the wastewater facility design engineers.

Table 18. Heavy metal concentrations in test treatments F-50-High, L-90-High, and F-155-High. (NOTE: Cr^{t6}, Cu, Ni and Zn concentrations equal to Daily Maximum limitations recommended for the WPDES permit. Cd concentrations equal to recommended weekly average limitation.

Metal Species	Spike Concentration	Compound Used
Cadmium	7.1 $\mu g/L$	$CdCl_2$
Chromium^{+6}	28 $\mu g/L$	$K_2Cr_2O_7$
Copper	50 $\mu g/L$	$CuSO_4 \circ 5H_2O$
Nickel	445 $\mu g/L$	$NiSO_4 \circ 6H_2O$
Zinc	300 $\mu g/L$	$ZnSO_4 \circ 7H_2O$

Table 19. Heavy metal concentrations in test treatments F-155-Low. (NOTE: Concentrations equal effluent concentrations projected by wastewater treatment plant design engineers at Foth & Van Dyke - Green Bay.).

Metal Species	Spike Concentration	Compound Used
Cadmium	7.1 $\mu g/L$	$CdCl_2$
Chromium^{+6}	2 $\mu g/L$	$K_2Cr_2O_7$
Copper	31 $\mu g/L$	$CuSO_4 \circ 5H_2O$
Nickel	30 $\mu g/L$	$NiSO_4 \circ 6H_2O$
Zinc	19 $\mu g/L$	$ZnSO_4 \circ 7H_2O$

The mussels were exposed for 9 days in a static, renewal system to all test controls and treatments. The standard U.S. EPA 7 day static, renewal chronic toxicity tests were used for the evaluation of *C. dubia* and larval fathead minnows. This latter testing methodology provides both acute and chronic toxicity data. It should be noted however, that the chronic toxicity testing utilized the equivalent of 100% effluent; no allowances were made for dilution by the receiving stream as provided by Chapter NR 106 procedures.

Significant acute toxicity, demonstrated by a survival rate of less than 50%, was observed in all three of the test treatments spiked with the high metals concentration, although the species affected differed amongst the treatments (Table 20). Responses observed for each test species were as follows:

- *Anodonta imbecilis*

  The mussels were significantly affected in the treatment with the lowest hardness (F-50-High) as demonstrated by only 9% survival. The remaining treatments spiked with the high metals concentration did not result in significant mortality as demonstrated by survival rates of 78%, and 93% for treatments L-90-High and F-155-High, respectively.

  The treatment representing expected effluent quality (F-155-Low) did not result in any significant mortality as the observed survival rate was 89%.

- *Ceriodaphnia dubia*

  None of the cladocerans survived in any of the synthetic effluent treatments spiked at the high concentration of metals (i.e., F-50-High, L-90-High, and F-155-High). Upon review of the survival data for the three treatments, it appears that a trend exists between hardness and time lapsed to total mortality. More clearly, the treatment with the lowest hardness (F-50-High) resulted in total population mortality in less than 24-hours while it was between 24-hours and 48-hours for the same mortality rate to occur in the treatment with the highest hardness (F-155-High). Since the synthetic effluents were lethal to all of the adult organisms prior to production of any neonates, the potential for chronic toxicity could not be determined.

  Similar to the results for *A. imbecilis*, the treatment representing expected effluent quality (F-155-Low) did not result in significant mortality as all test organisms survived for the duration of the test. However, the undiluted synthetic effluent (F-155-Low) did demonstrate a potential for sub-lethal impact as noted by a statistically significant ($\underline{P}<0.05$) decrease in fecundity rate when compared to the Flambeau River control.

- Larval Fathead Minnows (LFHM)

  Excessive LFHM mortality was not observed in any of the synthetic effluent treatments where Flambeau River water was the medium. Specifically, survival rates were 90%, 93%, and 93%, for F-50-High, F-155-High, and F-155-Low, respectively. Significant mortality was observed in the treatment where reconstituted laboratory water was the medium (L-90-High). The LFHM survival rate was only 8% for this treatment. There is no clear explanation for this response, although it is likely that it was related to exposure to the metals mixture since the reconstituted laboratory water control (no spiked metals) did not result in any mortality.

When comparing 7-day growth against the control response, a sub-lethal impact was observed for the L-90-High and F-50-High treatments. The L-90-High response was due to the low survival of the test organisms mentioned in the previous paragraph. The F-50-High response is likely to be indicative of stress induced by the exposure to heavy metals. No sub-lethal response was observed for the two treatments with the high hardness, F-155-High and F-155-Low.

Table 20. Summary of observed toxicity test responses for three freshwater species exposed to synthetic mine effluents. (NOTE: Number of + symbols relates to relative degree of acute impact (i.e., + = Toxic, +++++ = Extremely Toxic).

Treatment I.D.	*Anodonta imbecilis*	*Ceriodaphnia dubia*	Larval Fathead Minnow
F-50-High	+	+++++	--
L-90-High	--	+++	+
F-155-High	--	++	--
F-155-Low	--	--	--

\+ = Toxic: Population mortality >50%.
-- = Non-toxic: Population mortality ≤50%

In summary, there is no direct toxicity data available on the purple wartyback mussel, the bullhead mussel or the pygmy snaketail dragonfly. Toxicity testing on related species indicates that the effluent limitations established for the Flambeau Mine should adequately protect mussels and dragonflies. However, a single study showed that a mussel species was as sensitive to some metals as were zooplankton and more sensitive than fish and aquatic insect species commonly used for toxicity testing. This study also provided data which, when extrapolated indicates that the effluent limitations for cadmium and nickel may be too high. However, the concentrations of cadmium and nickel in the mine effluent are projected to be substantially lower than the effluent limitations. Toxicity testing of a synthesized mine effluent shows that the effluent would be acutely toxic to mussels and zooplankton at the maximum permitted concentrations in soft water, but would not be acutely toxic to any of the test species at the expected concentrations and water hardness. The tests also showed that the cladoceron *C. dubia* was more sensitive to the mine effluent than the mussel species, indicating that *C. dubia* is an appropriate species to use for setting effluent limitations and for toxicity testing related to the mine.

ALTERNATIVES

Typically, an EIS describes alternatives to the proposed action which is the subject of the document. In this case, there is no proposed action and therefore no alternatives to the proposed action which can be described and analyzed in this section. There are however, alternative approaches the Department can take with respect to the endangered and threatened species in the river both in regard to the mining project and other activities which affect water quality and quantity in the river. This section describes the range of those alternatives and provides information which can be used in future actions affecting the river.

Alternatives Related to the Flambeau Mine

Alternative Department actions on the Flambeau Mine Project are defined in the statutes and administrative codes which provide the authorities for the various project permits. These laws describe the processes and criteria for modifying, suspending, canceling, or revoking existing permits. For example, ss. 144.83(6), Wisconsin Statutes, authorizes the Department to cancel a mining permit for a site which does not comply with the mining laws. Similarly, the Department may cancel a mining permit if the proper reports are not submitted (ss. 144.89(2), Wisconsin Statutes) or revoke the permit for violations described in s. 144.93, Wisconsin Statutes. Section 144.87(3), Wisconsin Statutes, enables the Department to require an amended mining and reclamation plan if the existing plans would not result in adequate reclamation of the site. Under s. 144.91, Wisconsin Statutes, the Department may issue a stop order requiring an immediate cessation of mining if it determines that the continuance of mining constitutes an immediate and substantial threat to public health and safety or the environment.

Similar provisions apply to other permits for the mine. Section 147.03, Wisconsin Statutes, authorizes modification, suspension, or revocation of WPDES permits for cause. Section 144.04, Wisconsin Statutes, allows modification of plan approvals. Section 30.07(2), Wisconsin Statutes, authorizes the Department to modify or rescind for good cause, permits issued for activities in navigable waters, and s. 30.03, Wisconsin Statutes, allows the Department to order a hearing and request an order from the hearing examiner requiring abatement of any violation of statute or infringement of public rights related to navigable waters.

The principal regulatory alternative related to the endangered and threatened species would be modification of the WPDES permit to incorporate data from the Keller and Zam (1991) study. If data from this study was included along with the entire toxicological database, it is unlikely that the water quality criteria or the effluent limitations resulting from the calculations prescribed in Ch. NR 106 would be significantly different from those currently reflected in the permit. If this data was the only data used in the calculations, and information from the toxicological database was ignored, the resultant effluent limitations would be slightly reduced for cadmium and substantially reduced for nickel. This later process would be a conservative approach, affording an additional level of protection to aquatic species over that provided by the standard process for calculating effluent limitations.

Wastewater monitoring requirements in the WPDES permit could be modified to include more frequent or different types of biological monitoring. The current permit requires effluent toxicity testing twice a year using standard test organisms (a cladoceran and fathead minnow larvae) and laboratory testing protocols approved by the EPA for acute and chronic toxicity testing (EPA, 1991; EPA, 1989). Testing frequencies, particularly for acute toxicity, could be increased to provide more assurance that the effluent was not exhibiting toxic characteristics. Mussels could be included as test species, providing direct information on the effluent's effect on mussels. However, since no approved testing protocol exists for mussels, the tests may be less reliable than those using standardized techniques. Both the EPA Water Quality Criteria Documents and the Keller and Zam study indicate that cladocerans are likely to be as or more sensitive to metals than mussels and that cladocerans should be an acceptable surrogate species for toxicity testing. This conclusion is strongly supported by the Department's bioassay testing, which showed that a cladoceran species was much more sensitive to the mine effluent than the mussel species.

Alternative physical facilities for the wastewater treatment and discharge system could be employed. Other treatment technologies such as reverse osmosis, ion exchange, or vapor compression evaporation could produce effluents with lower concentrations of some substances. However, most metal concentrations in the projected effluent quality are approaching or are below levels of detection and alternate treatment technologies would only provide relatively minor improvements in the effluent quality. A diffuser could be added to the discharge structure to inject the wastewater into the river at a velocity which results in rapid mixing with the river and/or which discourages aquatic organisms from inhabiting the immediate discharge locale. Construction activities required for some types of diffusers on the river bottom could have adverse effects on aquatic organisms.

Other Alternatives

The Department could take a variety of other actions related to the endangered and threatened species in the Flambeau River. For example, the Department could review and possibly modify WPDES permits for other dischargers to the Flambeau River. Currently, most of the WPDES permits for discharges to the river do not contain limitations for metals, although the Pope and Talbot permit does impose limitations for cadmium and cyanide. These discharges and permits could be reviewed to evaluate the need for metal limitations. The permits for Flambeau Paper Corporation, the City of Ladysmith and Pope and Talbot do however require the dischargers to conduct toxicity testing of the effluent using standard test organisms. Toxicity testing similar to that performed for the Flambeau Mine could be done using effluents from these facilities and a mussel species. This type of testing would help to determine if these effluents exhibited any toxic characteristics to mussels and whether the standard test organisms are suitable surrogates for mussels with regard to these effluents.

The Department could also conduct or participate in research on the life histories, chemical sensitivities, or other biological or physiological characteristics of the endangered or threatened species in the river. This research could include attempting to determine the host fish species for the purple wartyback mussel, developing laboratory testing protocols for the endangered mussel and dragonfly species, conducting chemical-specific testing on these species, and investigating Flambeau River populations to evaluate factors inhibiting reproduction and/or survival. Determining the host fish species for the purple wartyback could enable more effective management and recovery efforts. Developing techniques for conducting toxicity testing of the endangered mussel species would provide better information upon which to base wastewater effluent limitations. There is no assurance, however, that an effort to develop these techniques would be successful. It is unlikely that chemical-specific testing on the dragonfly species would indicate they are more sensitive to metals than the species currently used to establish limitations. Additional surveys would yield further information on the status and distribution of the endangered and threatened species in the river, and may reveal the presence of other listed species. Additional survey information could also aid in management efforts for these species.

Additional research could also be directed at determining the effect hydropower operations have on the listed species. With the substantial impact that dam operations have on water levels and flows over much of the river, these operations have the potential to exert a significant influence on the distribution and abundance of aquatic populations. Additional surveys near existing dams along with evaluation of the dams' impacts on endangered and threatened species would provide information on how hydropower project operations could be improved to lessen adverse impacts on these species.

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APPENDIX A

BUREAU OF ENDANGERED RESOURCES CORRESPONDENCE

Engineers
Architects
Planners
Scientists
Economists

Foth & Van Dyke

8528 West Lisbon Avenue
Milwaukee, WI 53222-3799
414/463-9160

March 9, 1988

Ms. Diane Hills
Wisconsin Department of Natural Resources
Bureau of Endangered Resources
P. O. Box 7921
Madison, WI 53707

87K10

Dear Ms. Hill:

RE: KENNECOTT FLAMBEAU PROJECT
RUSK COUNTY, WISCONSIN

We are currently preparing an EIR for a proposed copper mine in Rusk County, Wisconsin and would like to receive the available information the Department has on file for endangered resources in the project area. Information of interest to us includes the following:

1. A current list of endangered or threatened resources for the state of Wisconsin.
2. Known distributions, life histories, preferred habitats, and current status of those species occurring in Rusk County.
3. Historical information on occurrences of endangered or threatened resources in Rusk County.
4. Other data you may have that would assist us in preparing the EIR.1

The site is in the Town of Grant just south of Ladysmith on the Flambeau River.

Thank you for your help. Please call me at 414-463-9160 if you have questions or require additional information.

Sincerely,

FOTH & VAN DYKE

Tim J Weyenberg

Tim J. Weyenberg
Director of Operations

TJW:kll

cc: L. Mercando, Kennecott
G. Sevick, Foth & Van Dyke
✓R. Ramharter, DNR

50 years

State of Wisconsin \ DEPARTMENT OF NATURAL RESOURCES

Carroll D Besad
Secretar

BOX 792
MADISON, WISCONSIN 5370

APR - 8 1988

March 29, 1988

File Ref 1650

Mr. Tim J. Weyenberg
FOTH & VAN DYKE
8528 West Lisbon Avenue
Milwaukee, Wisconsin 53222-3799

Dear Mr. Weyenberg:

The Bureau of Endangered Resources has reviewed the project area described in your letter of March 9, 1988 for the proposed copper mine, Rusk County.

We have no occurrence records of endangered or threatened animal or plant species, nor of any Natural Areas or communities on the project area, in Sections 2 - 5, 8 - 11, 14 - 16, T34N R6W.

Please be sure to include a legal description of the area for which you are requesting information in any future requests.

Your concern for endangered resources is greatly appreciated.

Sincerely,

Ronald F Nicotera

Ronald F. Nicotera
Director, Bureau of Endangered Resources

cc: Gary Birch - BEAR/6
~~Michael Neuman - BEAR/6~~
William Clark - NWD
Bruce Moss - NWD

Foth & Van Dyke

Engineers
Architects
Planners
Scientists
Economists

2737 S. Ridge Road
P. O. Box 19012
Green Bay, WI 54307-9012
414/497-2500

October 19, 1988

OCT 20 1988

87K10-47

Ms. Diane Hills
Bureau of Endangered Resources
Wisconsin Department of Natural Resources
P. O. Box 7921
Madison, WI 53707-7921

Dear Ms. Hills:

Re: Kennecott Flambeau Project
Rusk County, Wisconsin

Reference is made to our telephone conversation on October 18th, during which we discussed the Wisconsin Natural Heritage Inventory.

Please send me the descriptive site information you have on file for the rare communities in Rusk County that are designated on the attachment.

Your prompt attention is greatly appreciated. Please call me if you have any questions.

Thank you.

Sincerely,

FOTH & VAN DYKE

Tim J. Weyenberg

Tim J. Weyenberg
Senior Project Manager

TJW:psl

cc: Robert Ramharter, WDNR ✓

State of Wisconsin \ **DEPARTMENT OF NATURAL RESOURCES**

Carroll D. Besadny
Secretary

BOX 7921
MADISON, WISCONSIN 53707

November 11, 1988

File Ref: 1650

Mr. Tim J. Weyenberg
Foth & Van Dyke
2737 S. Ridge Road
P.O. Box 19012
Green Bay, WI 54307-9012

Dear Mr. Weyenberg:

Per your October 19, 1988 request for descriptive site information on the Rusk County natural communities: Enclosed are brief summary abstracts for the Natural Areas (encompassing those natural communities that you've highlighted in yellow), except for Tenmile Creek Marsh Natural Area. An abstract for Tenmile Creek Marsh could not be located, so a Natural Area (NA) data sheet for this NA has been supplemented. These abstracts identify the NA location by a legal description. However, if you want to locate the specific natural community within the NA, you may have to consult us again or use a USGS topographic map.

Also enclosed is a section of Wisconsin's Natural Heritage Inventory Working List, "Natural Community Element List," listing all the natural community types that we track throughout Wisconsin. A key and definition sheet have been included to aid in your interpretation of this list. Please reference John T. Curtis' <u>Vegetation of Wisconsin</u> for the explanation/definition of the specific community types in the state. The Bureau of Endangered Resources tracks these natural community types expounded by Curtis.

Please call if you have questions or need any further information regarding these Rusk County Natural Areas.

Sincerely,

Ronald F. Nicotera (DMH)

Ronald F. Nicotera
Director, Bureau of Endangered Resources

cc: Gary Birch - EA/6
William Clark - NWD
Bruce Moss - NWD

RECEIVED

NOV 28 1988

NORTHWEST DISTRICT
HEADQUARTERS

P.C. Ramharter-EA
11/28/88
BC

SPR EI

Foth & Van Dyke

Engineers
Architects
Planners
Scientists
Economists

2737 S. Ridge Road
P. O. Box 19012
Green Bay, WI 54307-9012
414/497-2500

87K10-53

January 18, 1989

Mr. William A. Smith
Bureau of Endangered Species
Wisconsin Department of Natural Resources
P. O. Box 7921
Madison, WI 53707-7921

Dear Mr. Smith:

As stated in our telephone conversation on January 17, 1989, we are interested in documented occurences of the wood turtle (<u>Clemmy's insculpta</u>) in Rusk County. Our interest in the wood turtle was derived from conversations with Gary Casper, Milwaukee Public Museum Vertebrate Zoologist, who suggested its range may include Rusk County. More specifically, does your office have any documented occurrences of wood turtles within our study area, which includes Sec. 9, T34N, R6W?

High priority

To further the scope of this request, I have included our list of amphibian and reptile species we have encountered on the study area and ask if you have any other amphibian or reptile occurrences in your records.

<u>Chelydra serpentina</u> - snapping turtle
<u>Chrysemys picta</u> - painted turtle
<u>Thamnophis sirtalis</u> - eastern garter snake
SC <u>Ambystoma tigrinun</u> - tiger salamander
<u>Plethodon cinereus</u> - red-backed salamander — low
<u>Ambystoma laterale</u> - blue-spotted salamander
<u>Hyla crucifer</u> - spring peeper
<u>Hyla versicolor</u> - grey tree frog
<u>Rana septentrionalus</u> - mink frog
SC <u>Rana palustris</u> - pickerel frog
<u>Bufo terrestris</u> - american toad

Regarding another subject, I have been informed by the media that bald eagles are being changed from an endangered species to threatened in Wisconsin. Could you please elaborate on this pertaining to when this may occur and why it is being changed.

Get copy of memo E/T list change

Sincerely,

FOTH & VAN DYKE

Jon H. Gumtow

Jon H. Gumtow
Project Scientist

JHG:psl

50 years

State of Wisconsin \ **DEPARTMENT OF NATURAL RESOURCES**

Carroll D. Besad
Secreta

BOX 792
MADISON, WISCONSIN 5370

April 3, 1989

File Ref: 1650

RECEIVED - DNR
APR 19 1989
ENVIRONMENTAL ANALYSIS

Mr. Jon Gumtow
Foth & Van Dyke
2737 S. Ridge Road
Green Bay, WI 54307-9012

Dear Mr. Gumtow:

The Bureau of Endangered Resources has reviewed the Kennecott Copper Mine project area described in your letter of January 16, 1989 for any occurrences of endangered and threatened amphibians or reptiles in Section9 of T34N R6W, Rusk County.

Of those species identified in your letter, the Natural Heritage Inventory currently tracks only the <u>Clemmys insculpta</u> (State-threatened), <u>Ambystoma tigrinum</u> and <u>Rana palustris</u> (both Special Concern species).

We hope you take notice of the species on our Special Concern (Watch) List. They are species about which some problem of abundance or distribution is suspected but not yet proved. The main purpose of this category is to focus attention on certain species <u>before</u> they become Endangered or Threatened.

We have no occurrence records for the aforementioned species in our data files. However, other than your encounters with these amphibians and reptiles, comprehensive surveys for these species may not have been completed for this project area in Section 9 of T34N R6W. Our data files may be incomplete as a result and does not preclude their presence.

For your information regarding the verification of the <u>Asclepias purpurascens</u> and <u>Carex lupuliformis</u> specimens identified in R. A. Matson's M.S. thesis from UW-Eau Claire: Our office received the specimens March 3, 1989. The <u>C. lupuliformis</u> (State-endangered) identified by Master (8-14-74) from a river bank south of Ladysmith in Section 9 of T34N R6W has been re-identified as <u>Carex lupulina</u>. The <u>A. purpurascens</u> collected by Master in 7-25-74 has been identified as <u>A. syriaca</u>, the common milkweed.

However, again please note that comprehensive endangered resource surveys may not have been completed for the Kennecott project area. As a result, our data files may be incomplete. The absence of known occurrences does not preclude the possibility of their presence.

Sincerely,

Ronald F. Nicotera

Ronald F. Nicotera
Director, Bureau of Endangered Resources

cc: Gary Birch - EA/6
Bob Ramharter - EA/6
William Clark - NWD
Bruce Moss - NWD

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GE

INSTRUCTIONS TO SENDER:
REMOVE YELLOW COPY FOR YOUR FILE.
SEND REMAINDER OF FORM INTACT WITH CARBONS TO PERSON ADDRESSED.

Diane Hills Machon ER/4

FROM: Ed Jepsen EA/6

SUBJECT–MESSAGE

Inquiry as to Records concerning Rare, Threatened or Endangered Species use ~~of~~ the Flambeau River Adjacent to the Kennecott mine Site

Please provide information by 7-7-89 on the presence or use ~~of~~ by endangered, threatened or rare plant and animal species of the Flambeau River in the Town of Grant (Rusk Co.) T34N R6W (Sections 4, 7, 8, 9, 16, 17, 18). If you have any questions please call me (6-5386). ~~[illegible]~~ Please check your records for terrestrial species ~~[illegible]~~ in Sections 9 and 10 also. Thanks.

SIGNED Ed Jepsen DATE 6-29-89

REPLY

(AD 75)

CORRESPONDENCE/MEMORANDUM

STATE OF WISCONSIN

Date: July 5, 1989

File Ref: 1650

To: Ed Jepsen - EA/6

From: Ronald F. Nicotera - ER/4

RECEIVED - DNR
JUL 11 1989
ENVIRONMENTAL ANALYSIS

Subject: Endangered Resources Information Review

The Bureau of Endangered Resources has reviewed the project area described in your memo of June 29, 1989 for the Flambeau River adjacent to the Kennecott Mine site, Rusk County.

Our data files contain the following information for this site, in T34N R6W:
A **Haliaeetus leucocephalus** (bald eagle) nest, Federally and State-endangered species, (#RU-5) occurs in a white pine on the south side of the river in the SW 1/4 of the NW1/4 of Section 17. Another nest (#RU-5a) is located in an aspen on the south side of the river in the NE1/4 of the SE1/4 of Section 17.
Refer to the enclosed portion of the "Endangered and Nongame Species Handbook" regarding management guidelines for bald eagle and osprey nests.

Comprehensive endangered resource surveys may not have been completed for this project area. As a result, our data files may be incomplete. The absence of known occurrences does not preclude the possibility of their presence.

Specifically, no mussel surveys have ever been performed for this part of the Flambeau River. The following mussels occur in the Chippewa River near Ladysmith, **close to, but not on**, the project area:
Quadrula metanvra (monkeyface mussel), proposed State-threatened.
Simpsonaias ambigua (salamander mussel), proposed State-threatened.
Cyclonaias tuberculata (purple wartyback mussel), proposed State-endangered.
Please note that these species will be officially listed as endangered and threatened, effective Fall of 1989.

Due to the lack of existing aquatic species information, especially with respect to mussels, we **recommend** that all areas of potential impact be surveyed for endangered resources.

The specific occurrence location of endangered resources is sensitive information and has been provided for the analysis and review of the Kennecot Flambeau project. Exact locations should **not** be reprinted in any publicly disseminated documents.

Please be sure to include any available maps of the area for which you are requesting information in any future requests.

cc: Gary Birch - EA/6
William Clark - NWD
Bruce Moss - NWD

MANAGEMENT

Bald Eagle and Osprey Nests

Investigations show that bald eagle and osprey populations have declined rapidly throughout the country. To help slow down this process and perhaps save the two species from extinction, the following guidelines will be adhered to on Department lands:

1. Report active nests to the unit which manages the land involved so that buffer zones can be established.

2. 0-5 chain zone (330 feet). Land use activity will not be permitted at any time of year within five chains of any eagle or osprey nest. In cases of exceptional circumstances and need, and where prolonged inactivity of a particular nest has been documented, the district director may permit an exemption.

3. 5-20 chain zone (1,320 feet; 1/4 mile). Land use activity is permitted in this zone from August 1 to February 15 for eagles, March 15 for osprey. This seasonally restricted zone may be extended by the district director if justified. Timber harvests or other construction activity in this zone should be cleared with the district endangered species coordinator. If timber cutting is allowed, several supercanopy pine trees should be left for future nest and roost sites within the 1/4 mile zone. In addition, for long-range management, some medium- and small-sized pine should be left for nest tree replacements as the old mature trees disappear. In osprey territories, dead-topped supercanopy pine should be maintained.

4. Roads and trails, existing or planned for management purposes, that occur within 20 chains (1/4 mile) of a nest site should be closed to vehicular traffic or relocated. This does not apply to travelways over which the DNR has no jurisdiction and where obvious public needs are involved without feasible alternatives. Road closures must be decided on a case-by-case basis, using information on past nesting success, visual buffers and other special circumstances.

* 5. Guard against the use of pesticide sprays and fish toxicants which may affect the birds. *

As Wisconsin lies within the primary breeding range of bald eagles and ospreys, it is appropriate that we take steps to protect the nesting sites of both species on Department lands. It is our intent also to protect the rookeries of herons, as these may be destroyed through cutting or other disturbances.

APPENDIX B

REPORT ON COMPARATIVE ACUTE TOXICITY TESTING

COMPARATIVE ACUTE TOXICITY OF A SYNTHETIC MINE EFFLUENT TO *CERIODAPHNIA DUBIA*, LARVAL FATHEAD MINNOW, AND THE FRESHWATER MUSSEL, *ANODONTA IMBECILIS*.

ROBERT G. MASNADO
Bureau of Water Resources Management
Wisconsin Department of Natural Resources
101 S. Webster Street, Madison, Wisconsin 53707

and

STEVEN W. GEIS
Aquatic Life Toxicity Testing Laboratory
Wisconsin State Laboratory of Hygiene
977 Jonathon Drive, Madison, Wisconsin 53713

March 1992

CONTENTS

EXECUTIVE SUMMARY

Site-specific acute toxicity tests were performed using synthetic effluent representing a wide spectrum of water quality characteristics in an effort to determine if water quality-based effluent limitations recommended for the Flambeau Mine would provide adequate protection for fish and aquatic life species in the Flambeau River, especially endangered freshwater mussels. The toxicity tests were performed with three physiologically different species representing a diversity of ecological niches in the freshwater community. The study design incorporated two primary objectives. The first objective was to compare the difference in species sensitivity for the three species to a complex five-metal mixture. The second objective was to evaluate the potential for the mine effluent to result in an adverse impact to the fish and aquatic life community of the Flambeau River near the proposed discharge site.

The cladoceran, *Ceriodaphnia dubia*, clearly exhibited a much greater sensitivity to various mixtures of cadmium, hexavalent chromium, copper, nickel, and zinc than either larval fathead minnows (*Pimephales promelas*) or the freshwater mussel, *Anodonta imbecilis*. Further, the results of this study suggest that wastewater discharged from the Flambeau Mine which is consistently non-toxic to *C. dubia*, as demonstrated by frequent toxicity tests, should also be non-toxic to fish and aquatic life indigenous to the Flambeau River, including any freshwater mussels species which are equally or less sensitive to heavy metals than the freshwater mussel, *A. imbecilis*.

INTRODUCTION

Due to the toxic nature of many heavy metals, their presence in wastewater effluents may adversely impact local water quality and present a serious threat to ecologically important aquatic life communities. Historically, regulatory agencies have attempted to protect water quality from adverse impacts by imposing effluent limitations in National Pollutant Discharge Elimination System (NPDES) permits for individual metals based on national water quality criteria. Since 1985, however, an increasing number of state regulatory agencies have also required NPDES permitted dischargers to meet effluent limitations based on whole effluent toxicity tests performed with aquatic organisms.

In Wisconsin, many NPDES permitted dischargers are required to perform acute whole effluent toxicity tests with a combination of three freshwater species, including; (1) the fathead minnow (*Pimephales promelas*); (2) the cladoceran *Ceriodaphnia dubia*; and (3) the cladoceran *Daphnia magna*. Acute test methods closely follow those recommended by U.S. Environmental Protection Agency (1991) with receiving water collected upstream of the discharge point serving as the diluent. The U.S. EPA 3-brood *C. dubia* survival and reproduction test and 7-day larval fathead minnow survival and growth test (U.S. EPA 1989) are required in those cases where chronic toxicity testing is warranted.

In 1989, the Flambeau Mining Company, a subsidiary of the Kennecott Corporation, submitted a mining permit application to the Wisconsin Department of Natural Resources (WDNR). Additionally, an environmental impact report, and various wastewater, air pollution, groundwater, and surface water permit applications were submitted. The company proposed to use open pit mining techniques to remove copper ore from the Flambeau deposit in northwestern Wisconsin. The orebody is located 1.6 miles south of Ladysmith in the Town of Grant, Rusk County (Figure 1.)

The proposed open pit at its maximum extent would be 32 acres in size and involves removing the enriched, upper 150-200 feet of the orebody. Groundwater from the pit and stormwater runoff collected from the site would be treated in a three stage treatment process and discharged to the Flambeau River; a relatively fast flowing (7-Q_{10} = 435 cfs), unpolluted river which supports a diverse, high quality fish and aquatic life community. The three stage wastewater treatment plant would utilize lime treatment for acid neutralization, followed by sulfide precipitation of metals and finally, filtration (Foth & Van Dyke 1989).

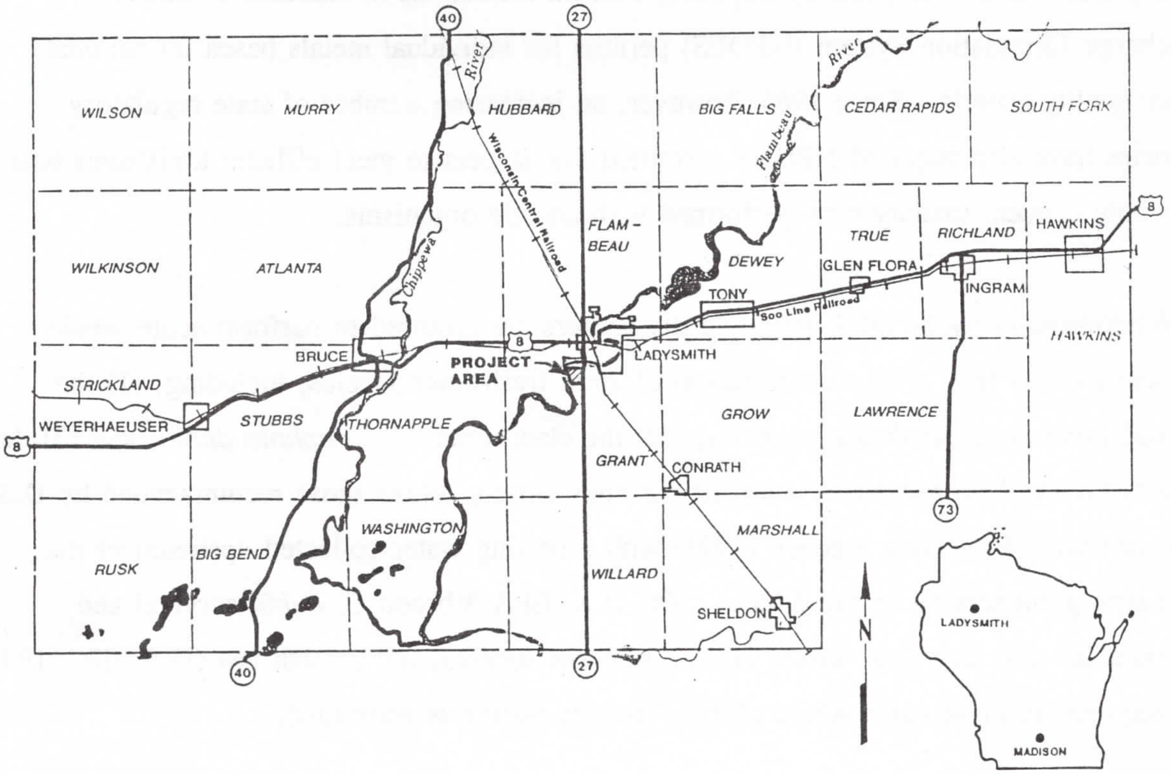

Figure 1
Project Location in Rusk County

After a series of highly controversial public hearings, a hearing examiner granted all permits in January 1991. The NPDES permit issued to the mining company contained chemical-specific water quality-based limitations for cadmium, hexavalent chromium, copper, nickel, and zinc. Further, acute whole effluent toxicity testing with the test species noted above was recommended as a "safety net" for the chemical-specific limitations. Although chronic toxicity testing was required in the NPDES permit, the potential for chronic impacts was deemed low since the Flambeau River provided substantial dilution even under critical streamflow conditions.

In May 1991, WDNR staff performed a biosurvey in the area downstream of the proposed mine discharge. The biosurvey, conducted in support of a Federal Energy Regulatory Commission relicensing effort for a nearby hydropower dam, resulted in the discovery of two freshwater mussels and a dragonfly nymph on the State's endangered species list. The mussels were identified as the purple wartyback mussel (*Cyclonaias tuberculata*) and the bullhead mussel (*Plethobasus cyphyus*); both from the family Unionidae. The dragonfly nymph was identified as that of the pygmy snaketail (*Ophiogomphus howeii*). Soon after the discovery of the endangered species, a lawsuit was filed on behalf of the Sierra Club and the Lac Courte Oreilles Band of the Lake Superior Chippewa Indians asking for a halt to the mine and a revocation of all permits. In August 1991, a circuit court judge levied an injunction on all mining operations at the site until WDNR could complete a supplemental environmental impact statement (SEIS) to determine the potential for impact to the endangered species. The study described in this document was performed in support of the SEIS.

Upon reviewing EPA water quality criteria documents (U.S.EPA 1985a,b,c; 1986; and 1987), WDNR staff concluded that there was a relative absence of representative data to determine the adequacy of numerical chemical-specific limitations to freshwater mussels or dragonflies (WDNR 1991). Utilizing data from taxonomically similar species represented in the criteria documents (e.g., snails and damselflies), staff concluded that the water quality criteria used to establish numerical NPDES permit limitations were derived from species that were much more sensitive to metals than mussels or dragonflies. Specifically, cladocerans such as *C. dubia* and *D. magna* were typically the most sensitive warmwater species to the metals evaluated.

WDNR staff also performed a review of literature that was published since the promulgation of the State's numerical water quality criteria in March 1989 (Wis. Adm. Code 1989). Staff located a recent study by Keller and Zam (1991) which presented data that indicated that certain freshwater mussels may be as sensitive to metals as the cladoceran, *C. dubia*. The Keller and Zam study suggested that the paper floater mussel (*Anodonta imbecilis*) is equally sensitive to certain metals as *C. dubia* and more sensitive than *Chironomus* sp., an insect species. Additional information has been generated which suggests that *A. imbecilis* may be more sensitive to certain complex effluents than *C. dubia* (Wade et al. 1989).

As a result of these findings, WDNR staff concluded that conducting site-specific comparative toxicity tests with synthetic effluent would yield the best available evaluation regarding the adequacy of water quality-based effluent limitations for the mine permit. While laboratory-based toxicity tests cannot reproduce all interactions between an effluent and the physical, chemical, and biological components of the receiving water, they can be more representative than single chemical bioassays which are used to set water quality criteria. Toxicity tests are a useful tool when predicting complex interactions between effluents and natural receiving waters since they can account for physical or chemical characteristics of water which may ameliorate or enhance the bioavailability and/or toxicity of contaminants (Le Du et al. 1990; Livens 1991). Toxicity tests are particularly useful in evaluation of heavy metal mixtures since the potential for toxicity may be effected by phenomena such as additivity, synergism, and antagonism (Enserink et al. 1991).

Research in recent years has led to the successful laboratory culture of certain freshwater mussel species (Isom and Hudson 1982; Isom and Hudson 1984; Hudson and Isom 1984; Isom 1987). This success has allowed advances to be made in performing toxicity tests on the early life stages of certain freshwater mussel species under controlled laboratory conditions (Wade 1989; Wade et al. 1989; Wade 1990; Keller and Zam 1991). The advantage to using free-living juveniles (transformed from parasitic glochidia) is that they are believed to be the most sensitive life stage of the freshwater mussels to environmental pollution (Teresa Naimo, U.S. Fish & Wildlife Service, LaCrosse, Wisconsin, personal communication).

There are no functional toxicity test methods for the endangered mussel species indigenous to the Flambeau River, however. Therefore, WDNR staff, in conjunction with State Laboratory of Hygiene (SLH) staff decided to utilize a test protocol being refined by researchers at the Tennessee Valley Authority's (TVA) Aquatic Research Laboratory in Decatur, Alabama (Wade et al. 1989). The method of choice was a 9-day acute toxicity test with juveniles of the freshwater mussel *A. imbecilis*, a mussel belonging to the same taxonomic family as *C. tuberculata* and *P. cyphyus*. Consequently, the results of the toxicity tests and any interpretations made from them must be qualified as follows:

> The freshwater mussels *A. imbecilis*, *C. tuberculata*, and *P. cyphyus* are all listed in the same taxonomic family (Uniondae). While the physiology of these species may differ, their sensitivity to heavy metals is assumed to be similar barring any definitive ecotoxicological data which may indicate otherwise.

Two primary objectives were established for the study. The first was to compare the difference in species sensitivity for *C. dubia*, larval fathead minnows, and *A. imbecilis* to a complex five-metal mixture. The second objective was to evaluate the potential for whole effluent toxicity of a complex five-metal mixture representative of either "worst case" or "real world" discharge conditions.

MATERIALS AND METHODS

Sediment Collection & Preparation

Juvenile mussels must be maintained on a silt substrate. Accordingly, silt from Tennessee River sediments was prepared in the TVA laboratory and used to maintain cultures prior to testing. The Tennessee River silt (TRS) was also used as a negative test control as it is known to support healthy populations of *A. imbecilis*. TRS was prepared by sieving field collected sediment through 100 μm Nitex® screen and shipped to the SLH laboratory in a 1 Liter polyethylene Cubitainer® where it was stored in the dark at 4°C until use. An aliquot of TRS was removed for metals analysis.

Flambeau River silt (FRS) was also used as a site control. FRS was prepared from Flambeau River sediment that was collected approximately 20 meters downstream and 30 meters offshore from the proposed outfall location. Sediment was removed from the streambed with a No. 2 steel shovel and transferred to an acid-washed 5-g polyethylene bucket and capped with a polyethylene cover. The sediment sample was transported directly to the SLH and stored in the dark at 4°C until processing. Prior to test initiation, aliquots of sediment were sieved through 100 μm Nitex® screen to separate silt from larger particles. An aliquot of FRS was removed for metals analysis.

Dilution Water Collection & Preparation

Synthetic and natural waters were used for culture maintenance and preparation of test solutions. Synthetic moderately hard laboratory water (SMHW) with a hardness of $\approx$90 mg/L as $CaCO_3$ was used as a negative control. SMHW was prepared according the U.S. EPA (1991) guidance by spiking Type I (reagent grade) water with the following salts: (1) potassium chloride (KCl); (2) sodium bicarbonate ($NaHCO_3$); (3) magnesium sulfate ($MgSO_4$); and (4) calcium sulfate ($CaSO_4 \circ 2H_2O$).

Flambeau River (FR) water was also used as a test control and diluent. Flambeau River water was collected immediately upstream from the proposed outfall location by submerging new polyethylene Cubitainers® under the surface of the water. To account for ambient water quality fluctuations, four river samples were collected over an 8-day period, each being used for no more than 72-h after initial use. All Cubitainers® were placed in ice-filled coolers and shipped to the SLH laboratory via overnight courier. All water samples were stored in the dark at 4°C until use. Prior to use, each sample was sieved through a 5 μm filter to remove debris and indigenous, competitive organisms.

Flambeau River water exhibited a hardness ranging from 32-51 mg/L as $CaCO_3$ (Table 1). To represent estimated effluent quality, the hardness of the Flambeau River water was also adjusted to a hardness of $\approx$155 mg/L following U.S. EPA (1991) guidance. Adjustments were made by spiking subsamples of river water with the salts mentioned above.

Test Organisms

Culture of *C. dubia* and fathead minnows followed methods described by U.S. EPA (1989). Toxicity tests were performed with *C. dubia* neonates (<24-h old) that were obtained from brood stock acclimated to Flambeau River water for one generation and reared on a combined diet of yeast/Cerophyll™/Biokyowa™ 400 Fish Food (YCF) and a mixture of the green algae *Selenastrum capricornutum* and *Chlamydomonas reinhardtii* (SLH 1991). Fathead minnow (*P. promelas*) toxicity tests were initiated with freshly hatched larvae that were less than 24-h old.

Table 1. Water Quality for Test Dilution Waters.

Water Type	Batch	Dissolved Oxygen (mg/L)	pH (S.U.)	Conductivity (μmhos·cm^{-1})	Alkalinity (mg/L as CaCO$_3$)	Hardness (mg/L as CaCO$_3$)
FR-50	A	8.2	8.04	97	38	42
	B	7.9	7.91	96	28	32
	C	8.0	8.01	98	36	51
	D	8.0	8.11	103	41	43
SMHW-90	A	8.0	8.26	288	61	91
	B	7.9	8.34	289	61	85
FR-155	A	8.2	8.39	436	112	152
	B	7.9	8.32	425	109	149
	C	8.0	8.46	438	112	158
	D	8.1	8.49	441	112	156

FR-50 = Flambeau River Water w/ Hardness ≈50 mg/L (as CaCO$_3$)
SMHW-90 = Synthetic Moderately Hard Water w/ Hardness ≈90 mg/L (as CaCO$_3$)
FR-155 = Moderately Hard Synthetic Water w/ Hardness ≈155 mg/L (as CaCO$_3$)

Juveniles of the freshwater mussel *A. imbecilis* were transformed *in vitro* from glochidia obtained from gravid females at the TVA Aquatic Research Laboratory following the protocol described by Hudson and Isom (1984). Live, juvenile mussels were transported in Tennessee River water to the SLH Aquatic Life Toxicity Testing Laboratory where they were gradually acclimated to Flambeau River water over a period of 4-days. Juvenile mussel cultures were maintained under static conditions and were fed daily with a suspension of algae indigenous to the Tennessee River provided by TVA. Culture water was renewed daily to avoid stress due to deteriorating water quality caused by an accumulation of metabolic wastes or unconsumed food.

Heavy Metal Stock Solutions

Stock solutions were prepared using the following metals: $CdCl_2$, $K_2Cr_2O_7$, $CuSO_4{\circ}5H_2O$, $NiSO_4{\circ}6H_2O$, and $ZiSO_4{\circ}7H_2O$. The Cr^{+6} stock solution was prepared by dissolving $K_2Cr_2O_7$ in Type I Reagent grade water. To reduce the possibility for oxidation to the +3 valance state, the Cr^{+6} stock was stored in the dark at 4°C in a Nalgene® bottle and was not preserved by chemical addition. The remaining metals were mixed together and dissolved in Type I Reagent grade water. The mixed metal stock solution (Cd, Cu, Ni, and Zn) was preserved with 0.5% HNO_3 to maintain solubility and stored in the dark at 4°C in a Nalgene® bottle.

Control Solutions

The *C. dubia* and larval fathead minnow toxicity tests were performed with a SMHW control as well as adjusted (FR-155) and unadjusted (FR-50) Flambeau River controls (Table 2). To ensure that the silt substrate was not responsible for observed mussel mortality, additional controls were included in the *A. imbecilis* toxicity test. Accordingly, the *A. imbecilis* tests were performed with a total of five negative controls (Table 3).

Table 2. Description of Negative Test Controls for *C. dubia* and Larval Fathead Minnow Toxicity Tests.

Control	Description
SMHW	Synthetic Moderately Hard water (Hardness ≈90 mg/L as $CaCO_3$)
FR-50	Flambeau River water (Hardness ≈50 mg/L as $CaCO_3$)
FR-155	Flambeau River water with hardness adjusted to ≈155 mg/L as $CaCO_3$

Synthetic Effluent Solutions

Synthetic effluent treatments were created by spiking the appropriate dilution water with the stock solutions to obtain one of two effluent quality matrices. The first synthetic effluent matrix - designated as "High" - consisted of dilution water spiked with the metals at concentrations equal to expected NPDES permit limitations (Table 4). Target concentrations for Cr^{+6}, Cu, and Zn were equivalent to the daily maximum (acute) limitations established in the existing WPDES permit. The target concentration for Cd was equivalent to the weekly average (chronic) limitation established in the existing WPDES permit since the wastewater treatment facility will be designed to meet that limitation. The target concentration for Ni was equivalent to the revised daily maximum limitation after consideration of the Keller and Zam (1991) data. The second synthetic effluent matrix - designated as "Low" - consisted of dilution water spiked with the metals equal to the concentrations expected in the effluent after treatment (Table 4).

Table 3. Description of Negative Test Controls for *A. imbecilis* Acute Toxicity Tests.

Control	Description
SMHW-TRS	Synthetic Moderately Hard water (Hardness ≈90 mg/L as $CaCO_3$) with Tennessee River silt used as mussel substrate.
SMHW-FRS	Synthetic Moderately Hard water (Hardness ≈90 mg/L as $CaCO_3$) with Flambeau River silt used as mussel substrate.
FR-50-TRS	Flambeau River water (Hardness ≈50 mg/L as $CaCO_3$) with Tennessee River silt used as mussel substrate.
FR-50-FRS	Flambeau River water (Hardness ≈50 mg/L as $CaCO_3$) with Flambeau River silt used as mussel substrate.
FR-155-FRS	Flambeau River water (Hardness ≈155 mg/L as $CaCO_3$) with Flambeau River silt used as mussel substrate.

Four synthetic effluent treatments were included in the tests for all three species (Table 5). Treatment FR-50-High was included to evaluate the effect of low hardness on the potential for metal induced toxicity. Treatment SMHW-90-High served as laboratory performance control in addition to providing information on the effect of a moderately hard water on the potential for metal induced toxicity. Treatment FR-155-High was included to evaluate the potential for metal induced toxicity if metals were discharged at the maximum allowable concentrations under expected effluent hardness conditions. Treatment FR-155-Low was included to represent the potential for metal induced toxicity if metals were discharged at expected concentrations following wastewater treatment.

Table 4. Synthetic Effluent Quality Matrix Metals Concentrations (All values reported as $\mu g/L$).

Metal	Compound Used	"High" Concentration	"Low" Concentration
Cadmium	$CdCl_2$	7.1	7.1
Chromium^{+6}	$K_2Cr_2O_7$	28	2
Copper	$CuSO_4 \circ 5H_2O$	50	31
Nickel	$NiSO_4 \circ 6H_2O$	445	30
Zinc	$ZnSO_4 \circ 7H_2O$	300	19

Table 5. Description of Synthetic Effluent Treatments for Comparative Toxicity Tests.

Treatment	Description
SMHW-90-High	Synthetic Moderately Hard water (Hardness ≈90 mg/L as $CaCO_3$) with metals spiked equal to NPDES permit daily maximum limitations.
FR-50-High	Flambeau River water (Hardness ≈50 mg/L as $CaCO_3$) with metals spiked equal to NPDES permit daily maximum limitations.
FR-155-High	Flambeau River water with hardness adjusted to ≈155 mg/L as $CaCO_3$ and spiked with metals equal to NPDES permit daily maximum limitations.
FR-155-Low	Flambeau River water with hardness adjusted to ≈155 mg/L as $CaCO_3$ and spiked with metals equal to projected effluent quality following wastewater treatment.

Toxicity Test Methods

All tests with *C. dubia* and larval fathead minnows were performed following SLH (1991) modifications to EPA (1989) protocols. Mussel toxicity tests were completed following methods described by Wade et al. (1989). Test highlights are described below and summarized in Appendixes A-C.

Test controls and treatments were prepared daily. Prior to dispensing solutions to test chambers, an aliquot of each control and synthetic effluent treatment was removed daily for determination of dissolved oxygen, pH, and conductivity. Additional aliquots were removed prior to introducing the mussels to test chambers for metals and ammonia determination. Metal concentrations were measured according to U.S. EPA Method 200.7 using a Perkin-Elmer Model 5100-Z or 5100-ZL equipped with Zeeman background correction and reported as total recoverable metals.

***C. dubia*:** Individual neonates (<24-h old) were exposed to each control and synthetic effluent treatment in 30 mL disposable polystyrene cups containing 15 mL of test solution. Ten replicate cups were used for each control and synthetic effluent treatment which was renewed with fresh solution daily. Each living test organism was fed once daily with a suspension consisting of 7 mL/L of mixed algae (*Selenastrum capricornutum* and *Chlamydomonas reinhardtii*) and 7 mL/L of YCF. At the conclusion of each 24-hour exposure period, the condition of each individual test organism and the number of neonates released was noted. Live adult organisms were transferred to new polystyrene cups containing fresh test solution and food suspension. Spent test solution was composited for all replicates within a treatment and analyzed for dissolved oxygen, pH, and conductivity (Appendix D). The test was terminated when a minimum of 60% of control organisms released three broods of neonates (7-days).

Larval Fathead Minnows: Larvae (<24-h old) were exposed to each control and synthetic effluent treatment in a 600 mL borosilicate glass beaker containing 250 mL of test solution. Ten individual larvae were placed in each of four replicate beakers used for each control and synthetic effluent treatment. Larvae were fed freshly-hatched brine shrimp three times daily at 4-hour intervals. At the conclusion of each 24-hour exposure period, the condition of the larvae was noted. Spent solution and excess food were siphoned and renewed with fresh solution daily. Spent solution was composited for all replicates within a treatment and analyzed for dissolved oxygen, pH, and conductivity (Appendix D). The exposures were terminated after 7-days and surviving larvae were enumerated, sacrificed, and preserved in ethanol. Mean individual dry weight was determined after drying the larvae from each replicate for 2-h at 100°C.

***A. imbecilis*:** Juvenile mussels (11-days post-transformation) were exposed to each control and synthetic effluent treatment in 250 mL crystallizing dishes containing 200 mL of test solution, 0.6 mL of silt (≈ 10 mg/L), and 1.2 mL TVA algal concentrate. Fifteen juvenile mussels were placed in each of three replicates vessels for each control and synthetic effluent treatment. To expedite daily renewal and microscopic examination, and to allow for unrestricted water/silt exchange, the mussels were enclosed within each test vessel by a vertical glass tube (50 mm O.D.) slightly taller than the crystallizing dish. At the conclusion of each 24-h exposure period, the glass tubes were removed from the crystallizing dish with the juvenile mussels remaining on the mesh and submerged in a petri dish of fresh dilution water. The tubes were swirled to rinse away most of the silt. The mussels were examined microscopically and the condition was recorded. Immediately after examination, the glass tubes were placed in crystallizing dishes with fresh test solution, silt, and algae. Spent solution was composited for all replicates within a treatment and analyzed for dissolved oxygen, pH, conductivity, and ammonia (Appendix D). Additional aliquots of the spent solution were removed for metals analysis. The exposures were terminated after 9-days and surviving mussels were enumerated.

Data Analysis

Due to the absence of multiple concentrations for each synthetic effluent treatment, statistical methods were not used to estimate LC_{50}s. Consequently, for *C. dubia* and larval fathead minnows, survival data were pooled for each replicate within a treatment and reported as a percentage of live test organisms upon test termination. Using this method, a toxic response was demonstrated by any treatment yielding a pooled survival rate of less than 50%. Further, *C. dubia* reproduction and larval fathead minnow growth data were evaluated using Student's *t*-test to determine the potential for sub-lethal impacts.

Proportions of mussels surviving for each replicate were subjected to an arc sine square root transformation using the TOXSTAT (Version 3.2) computer program. All transformed data were evaluated with a one-way analysis of variance and Dunnett's Procedure to differentiate between toxic and non-toxic treatments.

RESULTS

Initial water column concentrations of all metals except Cr^{+6} were within 10% of target concentrations for all of the synthetic effluent treatments with the "High" concentration matrix (Table 6). Initial Cr^{+6} concentrations in the "High" synthetic effluent matrix ranged from 17.0 μg/L to 24.1 μg/L which was less than the target concentration of 28 μg/L.

Initial water column concentrations for Cd, Cr^{+6}, and Cu were within 10% of target concentrations for the FR-155-Low treatment. The initial Zn concentration was higher than expected in the FR-155-Low treatment with an average concentration of 35.7 μg/L compared with the target concentration of 19 μg/L. Conversely, the initial Ni concentration was lower (26.6 μg/L) than the targeted 30 μg/L concentration.

Table 6. Average Pre-Exposure and Post-Exposure Water Column Concentrations of Heavy Metals in Controls and Synthetic Mine Effluent Treatments. (All values reported as μg/L with standard deviation in parentheses.)

Treatment	Exp.	Cadmium		Chromium^{+6}		Copper		Nickel		Zinc	
SMHW-90-TRS	Pre	<0.2	(0.0)	<4	(0.0)	<3	(0.0)	ND	--	29.4	(9.66)
	Post	<0.2	(0.0)	<4	(0.0)	6.2	(1.33)	ND	--	71.5	(10.24)
SMHW-90-FRS	Pre	<0.2	(0.0)	<4	(0.0)	<3	(0.0)	ND	--	ND	--
	Post	<0.2	(0.0)	<4	(0.0)	9.3	(3.14)	ND	--	56.0	(11.52)
SMHW-90-FRS-High	Pre	7.0	(0.37)	24.1	(0.63)	50	(4.12)	442.0	(13.02)	306.7	(22.91)
	Post	3.8	(0.58)	18.9	(1.54)	38.8	(8.08)	253.3	(31.41)	223.3	(32.66)
FR-50-TRS	Pre	<0.2	(0.0)	<4	(0.0)	<3	(0.0)	ND	--	12.3	(3.21)
	Post	<0.2	(0.0)	<4	(0.0)	5.4	(1.34)	ND	--	40.5	(14.49)
FR-50-FRS	Pre	<0.2	(0.0)	<4	(0.0)	<3	(0.0)	ND	--	ND	--
	Post	<0.2	(0.0)	<4	(0.0)	11.2	(7.14)	ND	--	92.5	(47.98)
FR-50-FRS-High	Pre	6.8	(0.28)	17.3	(2.75)	51.3	(3.54)	442.5	(22.52)	307.5	(12.82)
	Post	3.7	(0.62)	13.0	(3.30)	41.2	(7.25)	291.7	(44.46)	205.0	(35.64)
FR-155-FRS	Pre	<0.2	(0.0)	<4	(0.0)	<3	(0.0)	ND	--	13.0	(7.97)
	Post	<0.2	(0.0)	<4	(0.0)	13.7	(3.78)	ND	--	67.2	(22.32)
FR-155-FRS-High	Pre	7.1	(0.35)	17.0	(3.15)	51.8	(3.49)	437.8	(18.56)	315.6	(19.44)
	Pre	4.0	(0.45)	15.1	(4.06)	44.3	(6.19)	280.0	(35.21)	250.0	(36.88)
FR-155-FRS-Low	Pre	7.0	(0.52)	<4	(0.0)	32.9	(1.36)	26.6	(3.89)	35.7	(12.00)
	Post	3.6	(0.68)	<4	(0.0)	29.2	(6.40)	21.2	(10.92)	66.6	(16.21)

Final (i.e., post 24-h exposure) concentrations of the metals were lower than initial concentrations in the synthetic effluent treatments except for the FR-155-Low treatment where Zn was measured at 66.6 μg/L, well above the target concentration of 19 μg/L (Table 6). Elevated concentrations of Cu and Zn were observed in several of the post-exposure analyses of the control treatments. Cu and Zn analyses of Tennessee River silt resulted in dry weight concentrations of 14.7 mg/kg and 140 mg/kg, respectively. Similarly, Flambeau River silt contained 52.3 mg/kg and 250 mg/kg of Cu and Zn, respectively.

Test organisms were not adversely effected by exposure to any controls as demonstrated by acceptable survival rates for each test species. *C. dubia* survival was 100% in each control treatment. Furthermore, mean 3-brood reproduction ranged from 33.9 - 37.7 neonates per female which exceeds the U.S. EPA recommended mean of 15. Seven-day survival rates for fathead minnow larvae ranged from 85% in the FR-50 control to 100% in SMHW. Mean individual larval weight ranged from 0.302 mg - 0.332 mg which exceeds the U.S. EPA recommended mean of 0.250 mg. Nine-day survival rates for *A. imbecilis* ranged from 86.7% in the FR-50-TRS control to 97.7% in the FR-155-FRS control.

***C. dubia*:** Total mortality (100%) was exhibited by all test organisms exposed to synthetic effluent with the "High" metals concentration (Table 7). Elapsed time to 100% mortality was different among the three treatments. All mortalities observed in the FR-50-High treatment occurred within 24-h. Ninety percent (90%) mortality occurred in the SMHW-

Table 7. Summary Data for 3-Brood *Ceriodaphnia dubia* Survival and Reproduction Test (N = 10).

		# of Neonates/Surviving Female	
Treatment I.D.	Mean % Survival	Mean	Std. Dev.
SMHW-90	100	36.7	2.00
SMHW-90-High	0	0	0.00
FR-50	100	33.9	6.30
FR-50-High	0	0	0.00
FR-155	100	37.7	2.00
FR-155-High	0	0	0.00
FR-155-Low	100	24.0	3.16

90-High treatment within 24-h with the remaining 10% occurring prior to 48-h. Forty percent (40%) mortality occurred in the FR-155-High treatment within 24-h with the remaining 60% occurring prior to 48-h. All test organisms survived in the FR-155-Low treatment although significant (α=0.01) reduction in mean neonate production (24.0 per ♀) was observed when compared to the upstream FR-50 control (33.9 per ♀).

Larval Fathead Minnows: Significant mortality (92.5%) was observed in the SMHW-90-High treatment (Table 8). Elapsed time to mortality was variable among replicates, however, as total mortality (100%) was observed within 24-h for one replicate and gradual mortality was observed for the remaining three. A sub-lethal impact was observed in those test organisms that survived in the SMHW-90-High exposure as noted by a significant difference in weight. Survival in the FR-50-High, FR-155-High, and FR-155-Low treatments was acceptable as noted by survival rates of 90%, 93%, and 93%, respectively. Sub-lethal impacts were not observed in the FR-155-High or FR-155-Low treatments. However, a significant difference (α=0.01) in larval weight was observed between the FR-50-High (mean = 0.220 mg) and FR-50 control treatment (mean = 0.302 mg).

Table 8. Summary Data for 7-Day Larval Fathead Minnow Survival and Growth Test (N = 4).

Treatment I.D.	Mean % Survival	Dry Weight (mg.) Per Larva Mean	Std. Dev.
SMHW-90	100.0	0.332	0.018
SMHW-90-High	7.5	0.004	0.005
FR-50	85.0	0.302	0.057
FR-50-High	90.0	0.220	0.046
FR-155	92.5	0.317	0.072
FR-155-High	92.5	0.321	0.043
FR-155-Low	92.5	0.319	0.044

***A. imbecilis*:** The FR-50-High treatment exhibited significant mortality (α=0.05) since the observed survival rate was only 8.9% (Table 9). In general, 96-h elapsed before the mussels began to exhibit stress in the FR-50-FRS-High treatment. No significant adverse effects were observed for all other synthetic effluent treatments as noted by survival rates of

77.7%, 93.3%, and 88.9% for SMHW-90-FRS-High, FR-155-FRS-High, and FR-155-FRS-Low, respectively.

Table 9. Summary Data for 9-Day Juvenile *A. imbecilis* Survival Test (N = 3).

Treatment I.D.	Mean % Survival	Arc Sine Square Root Transformed Survival Mean	Std. Dev.
SMHW-90-TRS	93.0	1.303	0.000
SMHW-90-FRS	95.5	1.349	0.080
SMHW-90-FRS-High	77.7	1.084	0.103
FR-50-TRS	86.7	1.204	0.098
FR-50-FRS	88.9	1.256	0.212
FR-50-FRS-High	8.9	0.287	0.168
FR-155-FRS	97.7	1.395	0.080
FR-155-FRS-High	93.3	1.315	0.120
FR-155-FRS-Low	88.9	1.238	0.133

DISCUSSION

This study was performed with synthetic effluent treatments employing different water quality matrices since the proposed Flambeau Mine has not initiated discharge to the Flambeau River. The spectrum of spiked metals concentrations and hardness characteristics of the synthetic effluent ranged from "worst case" to "real world." With the exception of Cr^{+6}, actual pre-exposure metals concentrations in each synthetic effluent treatment were within 10% of target concentrations. Pre-exposure concentrations of Cr^{+6} were lower than target concentrations; probably due to the rapid reduction of Cr^{+6} to Cr^{+3} in natural waters. The fate of the metals in the static test system was not evaluated in this study. However, post-exposure concentrations of the metals were observed to be generally lower than pre-exposure concentrations which was probably due to differences in the sorptive behavior of the metals involved.

With the exception of Zn, the metals were not detected in the pre-exposure control treatment aliquots. Measurable pre-exposure concentrations of Zn (Range = 12.3 μg/L - 29.4 μg/L) were observed in three of the five controls. The behavior of Cu and Zn during the 24-h exposure period was noteworthy since post-exposure water column concentrations were significantly higher than pre-exposure concentrations. While this study cannot provide a definitive explanation for the increased Cu and Zn concentrations in the water column, it is likely that partitioning between the solid/liquid phase was critical in the behavior of the metals.

Species sensitivity to individual metals cannot be determined by the results of this study since single chemical toxicity tests were not performed. However, the synthetic effluent toxicity tests suggest that the cladoceran, *Ceriodaphnia dubia*, is more sensitive to the five-metal mixture than larval fathead minnows or the freshwater mussel, *Anodonta imbecilis* (Table 10). Total mortality to *C. dubia* was observed for each synthetic effluent treatment spiked with the "High" metals matrix. Further, it appears that the difference between elapsed time to 100% mortality is related to the hardness of the dilution water used in each treatment. This observation is consistent with the phenomenon discussed by Sprague (1985) that the toxicity for each of the heavy metals used in the mixture is inversely proportional to hardness.

The correlation between hardness and toxicity also appears to be consistent for *A. imbecilis* as the survival rates increased with increasing hardness in all "worst case" exposures. The only toxic response observed for the mussels occurred in the FR-50-High treatment which represents a discharge of undiluted metals to the Flambeau River; a situation which will not occur due to the high rate of mixing expected at the proposed discharge site of the mine.

Table 10. Toxicity of a Five-Metal Mixture to *C. dubia*, Larval Fathead Minnow, and *A. imbecilis*. (NOTE: + = Toxic and — = Non-Toxic.) Number of + symbols depicts relative severity of response as determined by elapsed time to observed impact.

Treatment I.D.	*C. dubia*	Larval FHM	*A. imbecilis*
FR-50-High	+++++	—	+
SMHW-90-High	+++	+	—
FR-155-High	++	—	—
FR-155-Low	—	—	—

With the exception of the SMHW-90-High treatment, there were no acute effects observed for the larval fathead minnows tested. There is no clear explanation for the observed mortality in the SMHW-90-High treatment since water quality was acceptable throughout the exposure period and survival in all controls and remaining synthetic effluent treatments exceeded 85%.

Based on the significant mortality exhibited by *C. dubia*, it is likely that the Flambeau Mine effluent may be toxic to zooplankton exposed to an undiluted effluent with metals concentrations approaching the daily maximum limitations, regardless of effluent hardness. Conversely, if the hardness of the effluent is relatively close to the estimated 155 mg/L (as $CaCO_3$), the effluent should be non-toxic to fish and other aquatic life with sensitivities similar to those demonstrated by larval fathead minnows and the freshwater mussel *A. imbecilis*. Lastly, there should not be any observed toxicity to fish and aquatic life if the Flambeau Mine effluent contains metals at or below the projected concentrations following wastewater treatment.

CONCLUSION

Many physical, chemical, and biological components of natural receiving waters may affect the toxicity of complex effluents such that water quality criteria for the individual chemical constituents may not always be adequate for the protection of fish and aquatic life. Accordingly, water quality-based chemical-specific limitations should be complemented with whole effluent toxicity testing requirements to ensure that bioavailability of toxic effluent constituents is adequately addressed.

Every effort was made in this study to generate site-specific acute toxicity data for the Flambeau Mine that would enable WDNR staff to determine if water quality-based effluent limitations and monitoring recommendations would protect all fish and aquatic life in the Flambeau River. Three physiologically different organisms from different ecological niches were represented in the study. Widely accepted test methods were used for two of the organisms, *C. dubia* and larval fathead minnow. On the other hand, there have been very few published studies based on the *A. imbecilis* test method described by Wade et al. (1989). Based on the performance of the negative controls and the response observed in the "worst case" treatment, the *A. imbecilis* test method was a success in this study. While methods for the same genus or species as the Flambeau River endangered species would have been preferred, the use of *A. imbecilis* as a surrogate does not set a precedent as it is accepted practice to use data from taxonomically similar organisms when setting water quality criteria (Stephan et al. 1985).

Keller and Zam (1991) concluded that setting water quality standards with zooplankton may adequately protect freshwater mussel fauna and that *C. dubia* may serve as an acceptable surrogate for mussels in heavy metal toxicity tests. This study supports that conclusion as it has shown that an effluent discharged from the proposed Flambeau Mine which is consistently non-toxic to the cladoceran *Ceriodaphnia dubia* should also be non-toxic to other fish and aquatic life in the Flambeau River, including any freshwater mussel species that are equally or less sensitive to heavy metals than the freshwater mussel, *Anodonta imbecilis*.

ACKNOWLEDGEMENTS

The authors are extremely grateful to Dr. Don Wade of the Tennessee Valley Authority for providing guidance and supplying the SLH laboratory with juvenile mussels. Additionally, without the assistance of the following people, this project would not have been successful:

Study Design: Bob Schuknecht and George Bowman
Sample Collection: Frank Koshere, Larry Prenn, and Alan Christian
Toxicity Tests: Wyatt Repavich and Karen Ammerman
Metals Analyses: Al Clary, Sue Hill, JoAnne Wilken, Duane Kennedy-Parker, Jim Thorye, and Roger Schultz
Contract Management: Russ Dunst and Jon Standridge

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Appendix A. Summary of Conditions for 3-Brood *Ceriodaphnia dubia* Survival and Reproduction Test.

1. Test type:	Static renewal
2. Temperature:	25 ± 1°C
3. Photoperiod:	16-h light, 8-h dark
4. Test chamber volume:	30 mL
5. Test solution volume:	15 mL
6. Renewal frequency:	Daily
7. Age of test organisms:	Less than 24-h
8. Individuals per replicate:	1
9. Replicates per treatment:	10
10. Feeding regime:	7 mL/L Mixed Algae, 7 mL/L YCF
11. Test duration:	Until 60% of females in test control release 3 broods
12. Effect measured:	Survival and reproduction

Appendix B. Summary of Conditions for 7-day Larval Fathead Minnow (*Pimephales promelas*) Survival and Growth Test.

1. Test type:	Static renewal
2. Temperature:	25 ± 1°C
3. Photoperiod:	16-h light, 8-h dark
4. Test chamber volume:	600 mL
5. Test solution volume:	250 mL
6. Renewal frequency:	Daily
7. Age of test organisms:	Less than 24-h
8. Individuals per replicate:	10
9. Replicates per treatment:	4
10. Feeding regime:	0.1 mL freshly hatched *Artemia* sp. nauplii 3 times daily at 4-h intervals
11. Test duration:	7 Days
12. Effect measured:	Survival and growth (weight)

Appendix C. Summary of Conditions for 9-day Acute Toxicity Test with the Freshwater Mussel, *Anodonta imbecilis*.

1. Test type: Static renewal
2. Temperature: 24 ± 1°C
3. Photoperiod: 24-h darkness
4. Test chamber volume: 250 mL
5. Test solution volume: 200 mL
6. Renewal frequency: Daily
7. Age of test organisms: 11-days post-transformation
8. Individuals per replicate: 15
9. Replicates per treatment: 3
10. Feeding regime: 6 mLs/L daily of concentrated mixed algae from Tennessee River and 3 mLs/L Tennessee River or Flambeau River silt (< 100 μm)
11. Test duration: 9-days
12. Effect measured: Mortality

Appendix D. Summary of Water Chemistry Conditions for *A. imbecilis* Acute Toxicity Tests. (NOTE: Average pre-exposure (Initial) and post-exposure (Final) values are reported. Ranges are reported in parentheses.)

Treatment	Total NH_3-N (mg/L)		Dissolved Oxygen (mg/L)		pH		Conductivity (μmhos/cm)	
	Initial	Final	Initial	Final	Initial	Final	Initial	Final
SMHW-90-TRS	0.008 (<0.005-0.227)	0.135 (0.043-0.227)	8.0 (7.9-8.2)	7.8 (7.5-7.9)	8.19 (8.09-8.34)	7.99 (7.89-8.04)	293 (286-304)	296 (285-301)
SMHW-90-FRS	-----	0.082 (0.005-0.185)	8.0 (7.8-8.1)	7.6 (7.3-7.8)	8.22 (8.11-8.35)	7.99 (7.88-8.05)	297 (291-305)	300 (292-304)
SMHW-90-FRS-High	0.007 (<0.005-0.014)	0.071 (<0.005-0.160)	8.0 (7.9-8.1)	7.6 (7.2-7.8)	8.00 (7.83-8.18)	7.99 (7.86-8.04)	297 (291-305)	297 (289-301)
FR-50-TRS	0.016 (0.005-0.035)	0.141 (0.028-0.246)	8.0 (7.9-8.2)	7.6 (7.2-7.8)	8.05 (7.91-8.28)	7.74 (7.63-7.83)	98 (96-103)	101 (97-106)
FR-50-FRS	-----	0.093 (0.013-0.194)	8.0 (7.8-8.2)	7.6 (7.2-7.8)	8.01 (7.91-8.16)	7.72 (7.59-7.79)	96 (92-101)	99 (94-104)
FR-50-FRS-High	0.015 (0.006-0.032)	0.091 (0.010-0.183)	8.0 (7.8-8.3)	7.6 (7.2-7.8)	7.75 (7.64-7.84)	7.69 (7.55-7.76)	97 (92-102)	99 (94-105)
FR-155-FRS	0.013 (0.005-0.023)	0.073 (0.020-0.152)	8.1 (7.9-8.2)	7.6 (7.2-7.8)	8.44 (8.32-8.50)	8.24 (8.09-8.32)	440 (425-455)	443 (431-459)
FR-155-FRS-High	0.028 (0.007-0.140)	0.075 (0.009-0.150)	8.0 (7.9-8.2)	7.6 (7.1-7.8)	8.39 (8.25-8.46)	8.23 (8.08-8.29)	442 (427-454)	446 (434-460)
FR-155-FRS-Low	0.012 (<0.005-0.022)	0.078 (0.022-0.145)	8.0 (7.9-8.3)	7.6 (7.2-7.9)	8.44 (8.33-8.51)	8.24 (8.10-8.30)	446 (431-459)	451 (437-463)