Impact of the Steep Rock Iron Mines Operations on Fish Presence

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ABSTRACT Development of the Steep Rock Iron Mines impacted the capacity of the local aquatic system to support fish. The largest undeveloped and richest deposit of hematite iron ore on the North American continent was discovered in 1938 beneath Steep Rock Lake, near Atikokan, Ontario. The iron mines were developed during World War II because of a shortage of iron ore. Since the iron ore was beneath Steep Rock Lake, the development of the open pit mines required a massive water diversion scheme, including the diversion of the Seine River, and drainage and dredging of Steep Rock Lake to expose the iron ore. The mining project, at the time, was the largest project of its type undertaken in Canada. Mining commenced in 1944 and ceased in 1979. The major changes to the environment described above significantly impacted fish. Yet in spite of these environmental challenges, fish managed to survive.

Three specific areas concerning impact on fish presence are considered. The first area concerns the erosion of some of the dredged material into the Seine River, which affected fish. After the problem was solved, the Seine River and the fish recovered. Secondly, the retention basin where 90 million m^3 of dredged silt was deposited was not a fish-friendly environment and yet fish have survived and recovered. Thirdly, the abandoned open-pit mines are slowly filling with water. There are no fish in one open pit, but native fish have become established in the second open pit, along with a successful floating fish farm operation.

Introduction

The richest undeveloped deposit of hematite iron ore on the North American continent at the time was discovered in 1938 beneath Steep Rock Lake, near Atikokan, Ontario, Canada. Atikokan is located as shown on Fig. 1. Stimulus for the development of the mines came during World War II when North American steel mills were facing a critical shortage of iron ore. There was additional interest in the Steep Rock iron ore deposit because the deposit was such a high-grade ore that it could be charged directly into the blast furnaces. Development of the Steep Rock Iron Mines commenced during the war on an accelerated basis, authorized under Canada's *War Measures Act*.

Since the iron ore was located beneath Steep Rock Lake, the development of the open pit mines required a massive water diversion scheme, including the diversion of the Seine River, draining of Steep Rock Lake, construction of various dams, tunnels, and other diversion works, and dredging of a large quantity of very soft lake bottom sediments to expose the iron ore. The mining project at the time was the largest mega-project of its type undertaken in Canada. Mining at the Steep Rock Iron Mines commenced in 1944 and ceased in 1979 after 35 years, and after mining 79 million tonnes of iron ore.

Restoration of the diverted Seine River after mine closure to its original channel was not possible because the Seine River would then be flowing through 90 million m^3 of disposed dredged materials. The resulting increased sediment load could have serious environmental effects on the downstream fish habitat. Consequently, most of the diversion scheme, including the water control structures, will need to operate in perpetuity.

The major changes to the environment required for developing the iron mines significantly impacted fish in three areas. The three areas are; the Seine River, the survival of fish in the West Arm Retention Basin which contains 90 million m^3 of clayey silt dredged spoil, and fish in the abandoned water-filled open pit mines, with a floating fish farm in one open pit.

Fig. 1 – Location of Steep Rock Lake

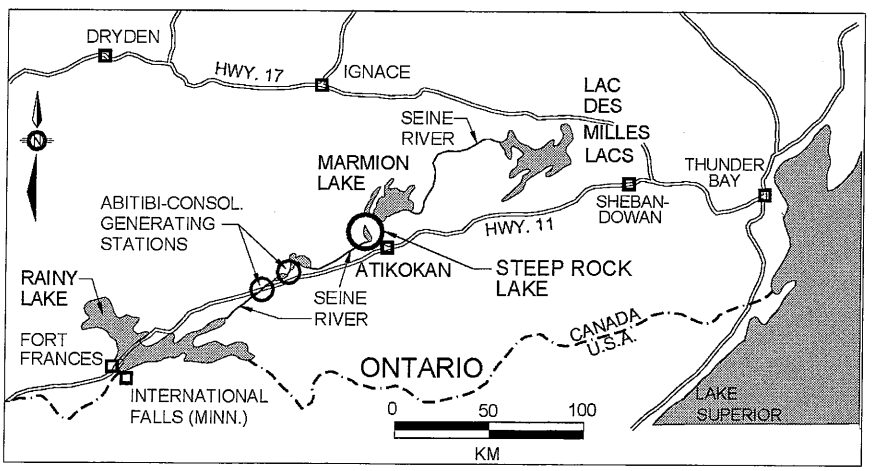
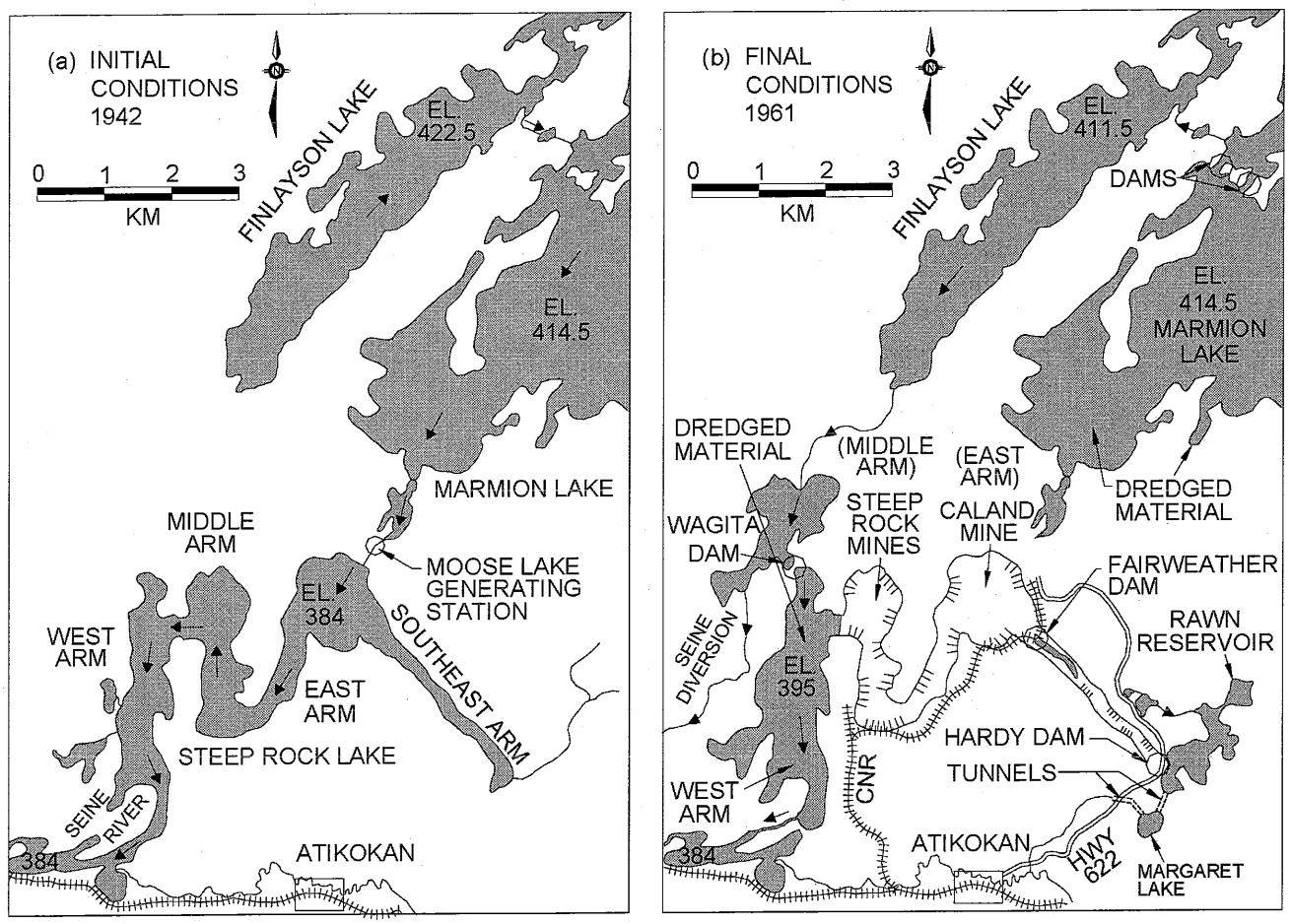


Fig. 2 – History of mine development



In order to understand the development of the Steep Rock Iron Mines and its various components, and the impact on fish habitat, it is necessary to view the mine development, construction of the water control structures, and the environmental changes in a chronological historical perspective. For this reason, a brief description of both a historical review of the mine development, and the geology of the iron ore deposit, are described below.

Historical background of mine development

Initial conditions

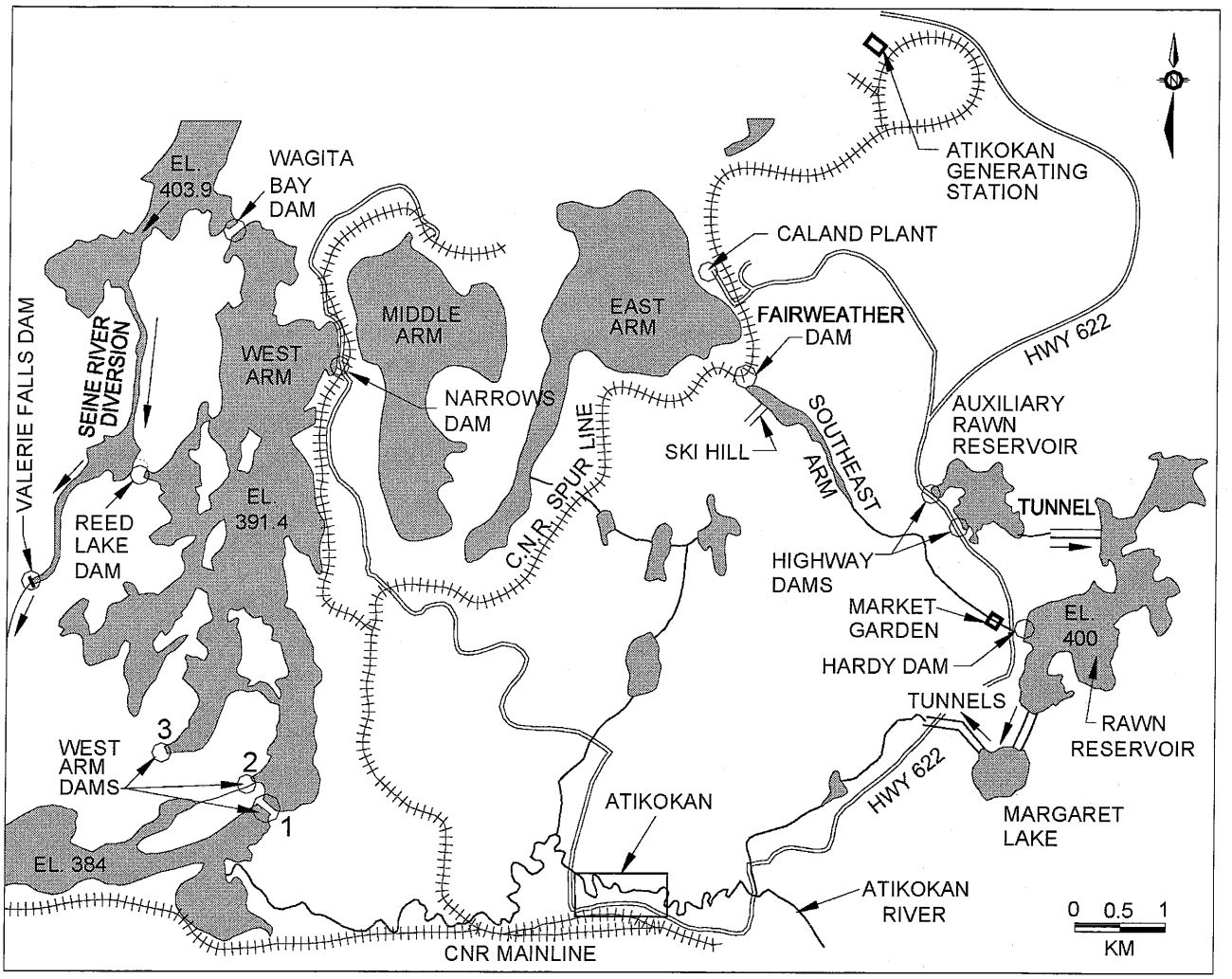
The initial pre-development conditions in the mine area in 1942 are shown on Fig. 2a. The Seine River flows from Lac Des Mille Lacs to Marmion Lake, as shown on Fig. 1, then to Steep Rock Lake and to Rainy Lake. In 1929 Boise Cascade (now Abitibi-Consolidated Inc.) constructed power dams on the Seine River, Fig. 1, including the Moose Lake Generation Station, (Fig. 2a). Steep Rock Lake forms roughly an "M" shape, as shown on Fig. 2a, with the following names assigned to each leg; West Arm, Middle Arm, East Arm, and Southeast Arm.

Final conditions

The final configuration after the Seine River was diverted, Steep Rock Lake was drained, the soft lakebed overburden was dredged, and the various mines were developed is shown on Fig. 2b. To begin open pit mining in 1943 in the Middle Arm of Steep Rock Lake, it was necessary to isolate the Middle Arm and divert the Seine River around it. The Seine River diversion route chosen was through the channel flowing northwest from Marmion Lake, through to Finlayson Lake, then south through the West Arm of Steep Rock Lake, as shown on Fig. 2b. Two control dams were constructed, one dam to regulate Marmion Lake, and the Wagita Bay Concrete Dam to control flow into the West Arm. A third dam, the Narrows Dam, (Fig. 3), was constructed in the Steep Rock Lake to separate the Middle Arm from the West Arm, Fig. 2b. The Moose Lake power generating station, Fig. 2a, was closed.

Isolation of the Middle, East and Southeast Arms from the Seine River allowed draining Steep Rock Lake by pumping and subsequent dredging. The clayey silt lakebed overburden material was dredged from the Middle Arm and dumped into the West Arm. The Errington Mine in the Middle Arm was opened and the first ore was shipped on October 3, 1944.

Fig. 3 - General arrangement of the Steep Rock Iron Mines area



Steep Rock Iron Mines Limited developed the Hogarth and Roberts open pit mines in the Middle Arm next, Fig. 2b. Dredging of the soft clayey silt overburden from the Middle Arm for these mines began in December 1950 and the dredged material was dumped on the ice of the West Arm during the winter of 1950-51. A significant amount of the dredged clayey silt that was dumped on the ice was eroded during the spring melt of 1951 into the Seine River, and transported downstream as far as Rainy Lake. Both the Canadian and American residents along the Seine River and Rainy Lake were upset by the damaging effect of the dredged silt on the domestic water supplies and on fish.

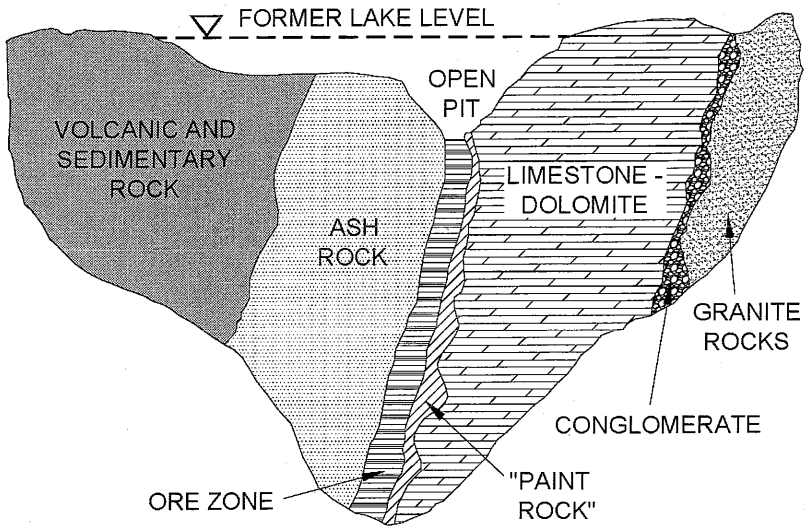
The solution to the dredge pollution problem was to isolate the West Arm of Steep Rock Lake to create the West Arm Retention Basin to allow settlement of the dredged clayey silt. Isolation of the West Arm was achieved in 1952 by constructing a series of dams to divert the Seine River further to the west of the West Arm as shown on Fig 2b, and also on Fig. 3. The Reed Lake Concrete Dam was constructed and the Wagita Bay Concrete Dam was raised. Three earthfill dams, West Arm Dams No. 1, 2, and 3, were constructed to retain the dredged clayey silt overburden deposits, and to regulate the water levels. A tunnel was bored through the bedrock at the abutment of West Arm Dam No. 2 to provide an outlet from the West Arm. The terms West Arm Retention Basin or West Arm are used interchangeably in this paper.

In 1953 Steep Rock Iron Mines Limited entered into an agreement with Caland Ore Limited to develop an open pit mine in the East Arm of Steep Rock Lake. Caland Ore erected their plant facilities on the east shore of the East Arm, located as shown on Fig. 3. Caland Ore also dredged the lakebed overburden material from the East Arm. The southern part of Marmion Lake was converted into a retention basin and 120 million m^3 of the dredged clayey silt lakebed overburden material was deposited into the Marmion Lake retention basin.

Draining and dredging of Steep Rock Lake

Draining and dredging of Steep Rock Lake was required to provide access to the iron ore in order to develop the open

Fig. 4 – Simplified geological section through the Steep Rock Lake iron ore deposit. Adapted from E. G. Pye, 1968.



pit mines. The drainage of Steep Rock Lake required installation of large capacity electrically-powered water pumps. The overall electrical power requirements for the mining project were so large that Ontario Power Generation constructed a 110 KV electric transmission line, 193 km long, from Thunder Bay to Atikokan.

Pumping commenced on December 16, 1943, and dredging commenced six months later. After sufficient dredging was completed to expose the first mine, mining of the iron ore commenced in September 1944, and the first trainload of 20 rail cars was loaded on October 3, 1944.

Dredging at Steep Rock Lake was a massive operation that required four large ocean-going all-electric dredges that were specifically transported to the mine site. The four large dredges, two operated by Steep Rock Iron Mines, and two operated by Caland Ore, were undertaking the largest earth-moving project in history at that time. The combined electric power required for operating both the four dredges and the water pumps simultaneously made the two mining companies, jointly, Ontario Power Generation's largest industrial user of electrical power at the time. Further details on the lake drainage and dredging are described elsewhere, (Sowa et al. 2002).

Drainage of the lake water and dredging continued for many years until 1962. After 1962, pumping of seepage and runoff water accumulating in the bottom of the open pit mines continued until 1979 when mining operations ceased. Since that time, the abandoned open pit mines, originally as deep as 300 m below the original lake level, continue to slowly fill with water.

Geological description of the iron ore deposit

A brief geological description of the iron ore deposit is warranted. The iron ore mine site is located at the southern margin of the granite-greenstone Wabigoon subprovince of the superior province of the Canadian Shield, (Ontario Ministry of Northern Development and Mines 1994). The area around Steep Rock Lake contains Archean metavolcanic, metasedimentary and intrusive rocks which have been displaced by a series of faults, (Shklanka 1972).

The iron ore deposit is bordered on one side by "Ash Rock" formed from volcanic ash, and is bordered on the other side by "Paint Rock", a soft clay-like material eroded from the limestone which is adjacent to the Paint Rock. A simplified geological cross-section is illustrated on Fig. 4 (Pye 1968). The displacement of the granitic masses along the faults caused folding, and tilted the ore body and associated rocks to a nearly vertical position. The iron ore extended to a depth of 760 m, with a width of 50 m, and over a length of 4 km.

The iron ore consisted mostly of geothite and hematite, and averaged, Fe = 56.5%, Si = 3.42%, P = 0.17%, Al = 8%, and Mn = 0.21%, (Steep Rock Mines, 1943). While it possible that the iron originated from volcanic action, the most accepted theory is that the iron was precipitated as oxides in the shallow waters of a Precambrian sea when oxygen became abundant (Ojakangas and Matsch 1982).

Impact of the Steep Rock Mines operations on fish presence

General

The major changes to the environment during the development and operation of the Steep Rock Iron Mines significantly impacted fish. Yet in spite of these environmental challenges, fish managed to survive. Three specific areas where fish were impacted are described in the following.

Fish in the Seine River

As noted previously, a significant amount of suspended silt from the dredge spoil in the West Arm entered the Seine River, Fig. 1, 2a, and 2b, during spring thaw in 1951, and

was transported 145 km downstream as far as Rainy Lake. The suspended colloidal clayey silt particles did not settle out readily and the river water turned muddy grey in colour. The residents along the Seine River and Rainy Lake became quite upset about the discolouration and the possible effects it might have on fish and domestic water supplies. The residents on the American side of Rainy Lake were more vocal than the Canadians, and the State of Minnesota threatened various actions. Requests were made to the International Joint Commission for an inquiry.

The initial development of the Steep Rock Iron Mines was accelerated by the shortage of iron ore during World War II. At the time of the dredge spoil contamination of the Seine River in 1951, the Korean War was then in progress, and again there was a critical shortage of iron ore. As a result, the governments of both United States and Canada were keen to maintain production of the iron ore. They encouraged cooperation of the mining company and the residents, and for the mining company to resolve the problem of dredge spoil entering the Seine River.

The problem of suspended silt in the dredge spoil was studied by the Ontario Research Council, and the Ontario Department of Health. Several laboratory methods of eliminating the suspended silt were devised. However, none of the methods were practical and it was obvious that drastic measures had to be taken (Taylor 1978). In the end, the solution was to create the West Arm Retention Basin, as described previously, to store and contain the dredge spoil. This proved to be successful since soon after the creation of the retention basin in 1952, the quality of the river water improved, and the Seine River returned to being one of the best sport-fishing rivers in Northwestern Ontario (Taylor 1978).

Fish in the West Arm Retention Basin

The West Arm of Steep Rock Lake, Fig. 3, was transformed into the West Arm Retention Basin for storing the silty lakebed material dredged from the Middle Arm of Steep Rock Lake. The West Arm, which once was up to 60 m deep, is now filled with the deposition of 90 million m^3 of the dredged silty lakebed material. In fact, sufficient dredged material was deposited into the West Arm to raise the level of the West Arm Lake about 7.3 m.

Today the West Arm Retention Basin supports a diverse fish population in spite of 90 million m^3 of dredged material that has been deposited into the West Arm. The most commonly found fish in the West Arm are bass, walleye, pike, white fish, and lake herring, and the local residents routinely catch and consume fish from the West Arm, (Nash 2002, private communication).

The fact that the fish were able to survive in the West Arm is perhaps surprising since dredging and deposition of the fine-gained clayey silt dredged material into the West Arm Retention Basin continued for 18 years from 1944 to 1962. In the early years, dredging was a continuous year-round operation, 24 hours a day, 7 days a week. Such circumstances are a particularly severe assault on fish which leads to speculation concerning the reasons for fish being able to survive. Several factors which could have been instrumental in assisting survival of fish are considered next.

There has been a suggestion that possibly, after the dredging was completed that the West Arm was artificially re-stocked with fish. While this is possible, the local long-time Ontario Ministry of Natural Resources staff is not aware of any past program of this type. Furthermore, the range of fish species found in the West Arm is the same as that found in the natural lakes environment in the area, (Nash 2002, private communication). This would not usually be the case if the West Arm was re-stocked, since normally only the most desirable fish species would have been introduced.

Some fresh water seeps continuously through small gaps between adjacent wooden stop logs installed in the spillway of the Wagita Bay Concrete Dam located at the north end of the West Arm, Fig. 3. This seepage aids, to some extent, in refreshing the water in the West Arm. The concept of fry passing through the gaps in the stop logs with the seepage was considered as a possible natural source of re-stocking. While it is uncertain whether the gaps are large enough, (Nash 2002, private communication) this possibility can not be excluded.

The water that seeps between the stop logs of the Wagita Dam passes through a small channel prior to entering the main body of the West Arm Lake. Some fish, particularly walleye, take advantage of the clearer and fresher water in the channel for spawning, (Nash 2002, private communication).

Perhaps the more likely reason that fish were able to survive in the West Arm may be due to the particular geographic shape of the lake. The West Arm is a relatively long body of water with numerous long inlets, as shown on Fig. 3. There is a strong possibility that in spite of the continuous deposition of dredged spoil into the West Arm, that the dredged material never reached the distant ends of all the more remote inlets along the shore of the lake. The water in some of the more remote inlets is noticeably clearer compared, even now, to the more visually turbid water in the main West Arm Lake, (Nash 2002, private communication). It is believed that the clearer water in the more remote inlets could have provided a safe refuge for fish.

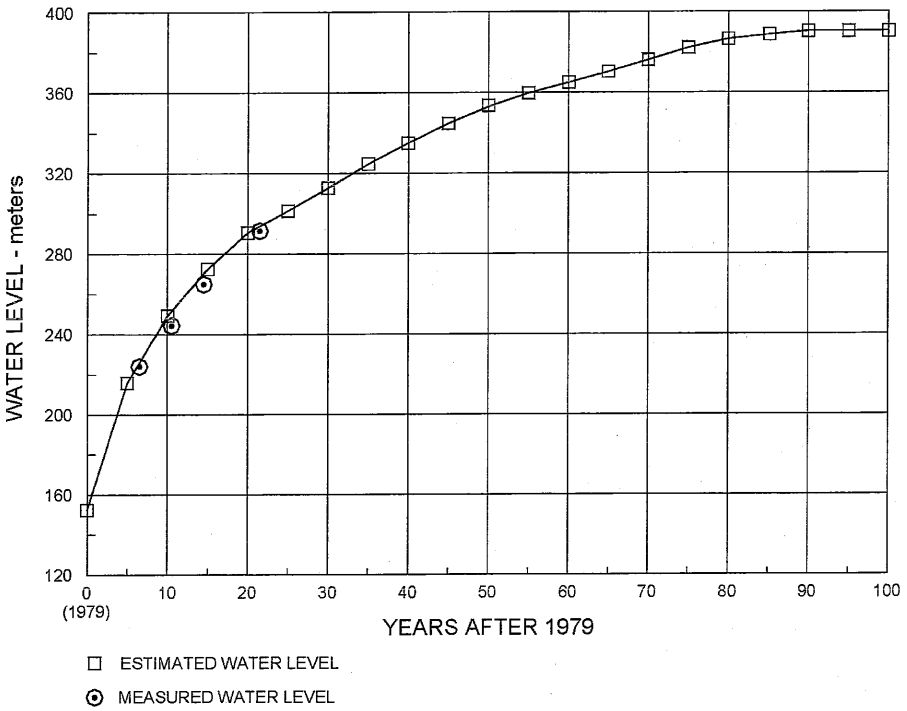
Finally, local residents, including a former dredging operator, have reported that throughout the dredging operation, fish were observed in the West Arm. Also, poaching in the West Arm was occurring during the early 1960's when disposal of dredging was still on-going (Nash 2002, private communication). Both of these observations indicate the strong will of fish to survive, and perhaps the remote inlets in the West Arm were the reason for the survival of fish during these times.

Fish farm in abandoned open pit mine

The open pit iron ore mines were located in the Middle and the East Arms, Fig. 3, and after the pumps were turned off in 1979, the pits are slowly filling with water (Sowa et al. 2001). The source of water is mainly precipitation and some seepage from the bedrock slopes of the pits. The precipitation accumulating in the pits is that which falls directly into the pits and runoff from the immediate drainage basin surrounding the pits. The Middle and East Arms are self-contained bodies of water and there is no other source of fresh water.

The volume of water accumulating in the East Arm open pit mine is about one million m^3 per year. The estimated rate and the actual rate at which the East Arm open pit is filling with water are shown on Fig. 5. Fig. 5 shows the elevation of the water rising in the pit with time after pumping stopped. As can be seen, the estimated rate of filling compares well with the actual measured rate. Also, as can be seen, it will take about 75 years after the pumping stopped in 1979, that is, to about the Year 2054 for the water level in the open pit to reach the original level of Steep Rock Lake (elevation 384 m) before the lake was drained.

Fig. 5 – Rate of water level rise in the abandoned East Arm open pit mine



Fish have colonized the abandoned open pit mine in the East Arm, but not in the open pit mine in the Middle Arm. Some possible reasons for this difference are considered later. Because of suitable conditions for fish in the East Arm open pit, a floating fish farm has been established since 1988, (McNaughton et al. 1999). Over the years, the fish farm operator has tried and been successful with various species of fish, but has been most successful with rainbow trout.

The fish farm uses cage culture to raise rainbow trout, (McNaughton et al. 1999). The cages are extended in the water column to a depth of 20 m. The fish are raised throughout the year but growth occurs primarily in the summer. The usual procedure is to place trout fingerlings in smaller 7.6 m diameter cages in the spring where they remain until they are 10 cm in length. The fish are then transferred first into cages 15 m in diameter and finally to 23 m diameter cages where they grow to market size of 1 to 2 kg. The larger cages have a capacity of 20,000 kg in the summer and 40,000 kg in the winter. The maximum production was 52,000 kg per year until 1998. In 1998 a major expansion was undertaken to increase the production gradually to 225,000 kg per year, (McNaughton et al. 1999). The fish have been marketed in various cities, including Toronto and Chicago.

While fish have colonized the abandoned open pit East Arm mine, no fish are present in the open pit mine in the Middle Arm. The reason for this difference is in the process of being studied and some of the results have been published, (McNaughton et al. 1999). A detailed evaluation of their study is beyond the scope of this paper. However, it is worthwhile to mention some of the observations and factors noted in that study which could have a bearing on the reason for fish presence in one open pit, and not in the other.

At the time of the study, the water-filled open pit in the East Arm had a depth of 180 m with a surface area of 1.5 km^2, while the open pit in the Middle Arm was approximately 155 m deep with a surface area of 1.6 km^2. Both small lakes in the open pit mines have a bowl/cone shaped basin morphology with a very low surface area to depth ratio. These lakes are steep sided and are well sheltered from winds.

The presence of limestone and dolomite deposits at the site adjacent to the iron ore deposit, as shown on Fig. 4, counters the production of acid from the waste rock, and the water in the pits remains above neutrality, (McNaughton et al. 1999). The analysis of water samples from each open pit showed that the water chemistry was found to be largely dependent on the type of adjacent waste rock and surficial geology. The water in the pits differed in the metal, anion, cation, conductivity, hardness and dissolved oxygen concentrations.

There is evidence that some of the local drainage runoff into the Middle Arm open pit is more acidic, with a pH range of 2 to 5 compared to the runoff into the East Arm open pit with a pH of 7 to 8, (McNaughton et al. 1999). The lower pH increases leaching from the waste rock and tailings, and consequently increases concentrations of certain elements in the water column.

From plankton tows, the Middle Arm open pit lake appears to be devoid of aquatic organisms even though a high concentration of oxygen extended to the sediment/water interface at a depth of greater the 150 m. Various explanations were given (McNaughton et al. 1999) for the lack of life in the Middle Arm, including elevated magnesium salt concentrations and increasing salinity. There is also the possibility of toxic substances. Others have found that one of the many minor constituents commonly found in iron ores is arsenic. Of interest relative to this matter, studies undertaken by the Hydro Generating Station at the nearby Marmion Lake found that there were high levels of arsenic in the lichen and the conifer needles. Another possible explanation may the presence of buried toxicants, such as PCB's left behind by Steep Rock after closure, (McNaughton et al. 1999).

Further studies are required to provide additional information to explain the reason for fish surviving in the East Arm, and not in the Middle Arm.

Summary

A deposit of iron ore at Atikokan was located below Steep Rock Lake. Development of the iron ore mine required the diversion of the Seine River, draining of Steep Rock Lake, dredging of a large quantity of overburden material to expose the iron ore, and the construction of many water control and water diversion structures, mainly dams and tunnels. The entire project was a massive undertaking.

The environment was affected considerably during mine construction and mine development, including the impact on fish habitat. Yet, in spite of these environmental challenges, fish managed to survive, and three specific areas were examined. The first area considered is the Seine River. The Seine River, which was once affected by eroded dredge spoil that impacted the river water supply and fish, recovered and now is still one of the best sport-fishing rivers in the area. Secondly, the West Arm retains 90 million m^3 of dredge spoil, and yet supports a diverse fish population. Thirdly, fish are established in the East Arm mine pit, which also includes a successful floating fish farm. No fish are currently present in the Middle Arm mine pit, and further studies are required to explain the reason for the difference between the two open pit mines.

Acknowledgements

The author appreciated being involved with this project and is grateful for the opportunity to prepare this paper. The author wishes to acknowledge the assistance received from Jacques Whitford with the production of the paper.

The information presented in this paper regarding fish is anecdotal, supplemented with information from historical records, and also the results of a study reported by McNaughton et al. (1999), all of which have been acknowledged in the references. The author specifically wishes to acknowledge Mr. Tom J. Nash for his contribution of local knowledge concerning fish in the Steep Rock Iron Mines area, particularly in the West Arm. The author also wishes to acknowledge Mr. Ward Prystay, M.Sc., R.P.Bio., Jacques Whitford, who provided a critical review of the aquatic aspects of this paper and made many helpful suggestions for improvement. Since the author is not a fish biologist he is particularly grateful to Messrs. Nash and Prystay, and a most helpful anonymous reviewer for saving him from potential embarrassments in dealing with aquatic matters. Any embarrassments, however, that remain, and the interpretations and opinions expressed in this paper, are solely those of the author.

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