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# PROGRESS REPORT ON FEASIBILITY OF DEVELOPING A MUNICIPAL WATER SUPPLY FROM ABANDONED IRON MINES IN MONTREAL, WISCONSIN

by

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## INTRODUCTION

The Montreal and Hurley area is water poor from both the quanity and quality standpoint. The area is underlain by up to about 50 feet of glacial drift mapped as ground moraine (Thwaites, 1956). Test drilling and geophysical exploration have shown the drift consists largely of silty sand, clay, and boulders with poor water yielding characteristics. Only small amounts of high water-yielding sand and gravel are present. The glacial drift is underlain by bedrock made up of slate, basic lava flows, granite, quartzite and other crystalline rock types which do not yield water. The poorly permeable nature of the drift and the non-waterbearing character of the bedrock precludes development of adequate, shallow ground water supplies.

The abundance of swamps and marshes in the area, which is drained by the Montreal and West Fork Montreal rivers, is the source of organic materials that impart a deep brown color to both surface and shallow ground water. Surface and ground water also are high in iron and much of the ground water contains hydrogen sulfide which is typical of swampy areas. The poor quality of shallow ground water has made it an undesirable source for municipal supply in both the presently used wells and in areas where test drilling has shown potentially good yields.

Surface water is available from the Gile flowage and the Montreal and West Fork Montreal rivers. Lake Lavina is presently used as a source of water by the city of Hurley. However, color, high cost of treatment, and need of the river water for power generation limit surface water use for municipal supply.

The Cary and Montreal iron mines, now abandoned, underlie the Montreal-Hurley area and represent a huge underground reservoir that may provide a suitable source of water for municipal and/or industrial supply. The Geological and Natural History Survey, The University of Wisconsin-Extension with the aid of several City of Montreal officials and interested citizens began a project in 1966 to assess the quantity and quality of the mine water and determine its suitability as a source of supply.

The purpose of this paper is to report on the progress of the study and present data collected to date for use in planning for possible development of the water supply. The physical problem of collecting data on the mine water, which is presently more than 1600 feet below land surface, has limited the study to date to monitoring of water level rise in the mine and changes in chemical quality.

## THE RESERVOIR

Workings of the abandoned Montreal and Cary Iron mines that honeycomb the rocks underlying the Montreal-Hurley area reach to a depth of over 4100 feet below land surface and have a maximum lateral extent of 3½ to 4 miles. They form a large reservoir for storage of water. The Montreal mine is approximately

$2\frac{1}{2}$ times the size of the Cary mine as estimated from total gross tons of ore produced. In the approximately 77 years of mining the two mines shipped a total of 64,089,344 gross tons of ore (Skillings Mining Review, August, 1967, P. 7). Assuming an additional 10 percent waste rock was removed from the mines and estimating rock volume at 10 cubic feet per ton; this volume would provide storage for over 5 billion gallons of water.

The two mines are interconnected through numerous openings down to the Montreal 35th level which is about 2,870 feet below land surface. There is no interconnection below the 35th level. Water level measurements at the Montreal Number 5 shaft and the New Cary Mine shaft on September 30, 1968 showed water level in both mines were at the same elevation and established that there is hydraulic connection between the mines.

According to former mine officials, the Montreal mine received its principal inflow of water from the west, especially from zones overlying northeastward dipping dikes that traverse the area. Projection of the dikes places their surface outcrop location near Pence about 3 to 4 miles to the southwest. Water from the surface also enters the mines through communicating fractures and especially along fault zones. The Cary mine probably received its principal inflow from the east and north. Pumpage to keep the 2 mines dewatered during operation averaged an estimated 1,500 gpm (gallons per minute). This water was probably largely from inflow from the land surface but included some water in the ore bodies and rock fractures encountered as the mines enlarged.

## WATER LEVEL RISE IN THE MINES

Pumpage from the Montreal mine was discontinued in August 1962 and from the Cary mine in about March 1964. With cessation of pumpage, seepage from the land surface proceeded to flood the mines. A water level measurement in March 1963, made by the mine company, placed water level in the Montreal mine at 2,855 geet below the collar of the Number 5 shaft or about 1,250 feet above the lowest level of the mine. However, the Cary mine was still in operation at that time which undoubtly slowed the rate of water level rise in the Montreal.

Water level rise has been monitored in the Montreal Number 5 shaft since September, 1966. Water level on that date was 2,625 feet below the collar or about 1480 feet above the lowest level of the mine. Water level data to date are shown in the hydrograph in figure 1 and in table 1.

Measurements show the rate of water level rise was erratic in 1966-67. Water level rose rapidly between the September and November 1966 measurements but then declined by June 1967. Although it is possible that an error was made in measurement, it is assumed that a temporary damming of water in the mine which later broke through was responsible for this anomaly. Discounting the November 1966 measurement, the rate of rise between September 1966 and June 1967 was about .33 feet per day.

Rates of water level rise in the Montreal mine after June 1967 (Table 1)

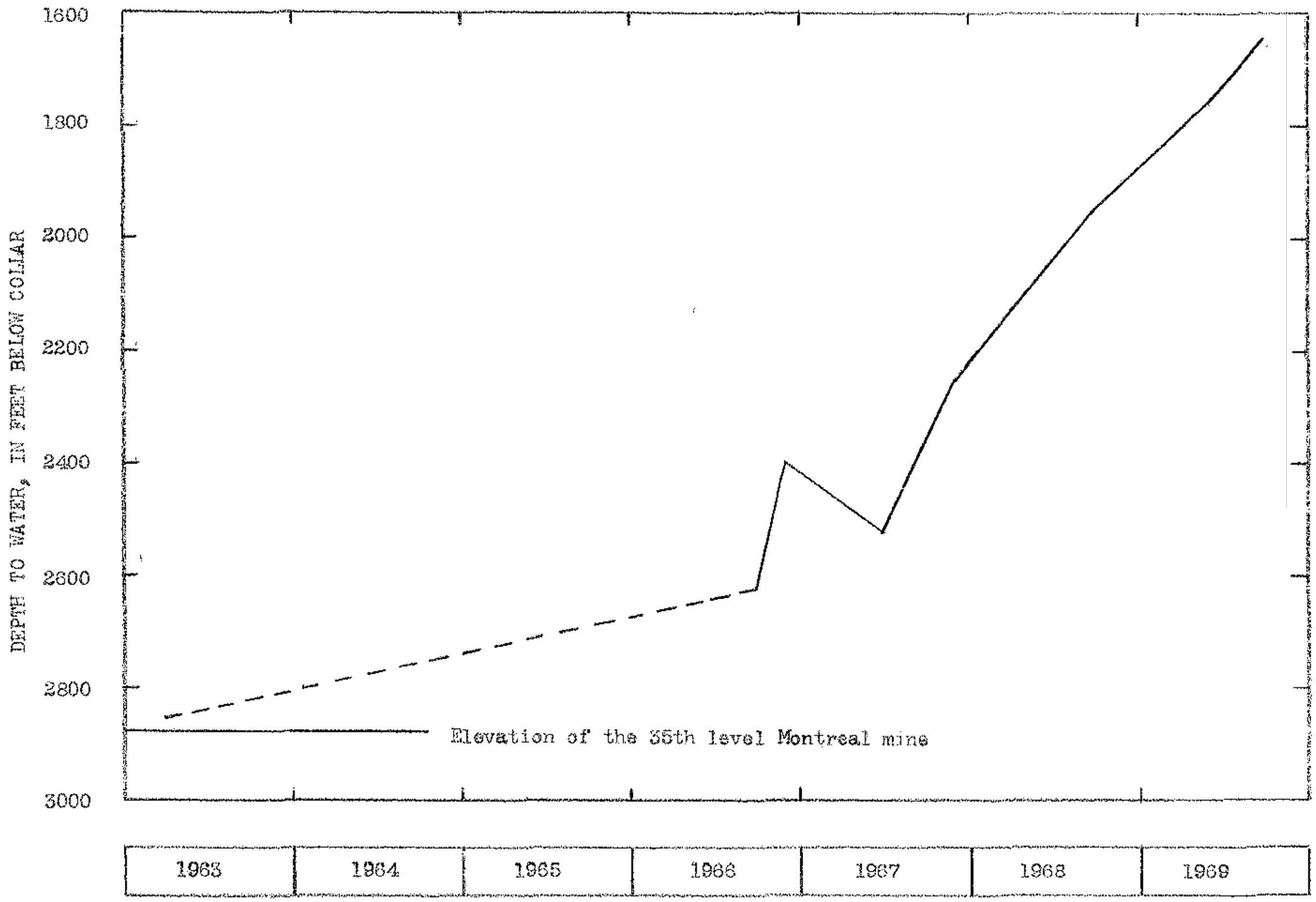


Figure 1.-- Water level in the Number 5 shaft, Montreal Mine in Montreal, Wisconsin.

Table 1. Water level measurements and rate of rise in the Montreal Mine Number 5 shaft.

| Date | Measurement below collar (feet) | Days from Previous Measurement | Rise of water level (feet) | Rate of water level rise (ft/day) |
|---|---|---|---|---|
| March 1963 | 2855 | | | |
| | | -- | -- | -- |
| Sept. 2, 1966 | 2625 | | | |
| | | 68 | 225 | 3.3 |
| Nov. 9, 1966 | 2400 | | | |
| | | 232 | 126 | -- |
| June 29, 1967 | 2526 | | | |
| | | 132 | 272 | 2.06 |
| Nov. 8, 1967 | 2254 | | | |
| | | 214 | 195 | .91 |
| June 10, 1968 | 2059 | | | |
| | | 112 | 112 | 1.0 |
| Sept. 30, 1968 | 1947 | | | |
| | | 233 | 198 | .85 |
| May 21, 1969 | 1749 | | | |
| | | 124 | 104 | .84 |
| Sept. 22, 1969 | 1645 | | | |
| Sept. 2, 1966 | 2625 | | | |
| | | 1115 | 980 | .88 |
| Sept. 22, 1969 | 1645 | | | |

dropped from about 2 feet per day in the latter part of 1967 to stabilize between about .8 and 1.0 feet per day in 1968-69. The relatively small changes in rate in the latter 2 years can probably be accounted for by differences in mine workings volume between various levels in the mine and differences in precipitation and therefore recharge to the mine. The overall rate of water level rise in the mines from September 2, 1966 to September 22, 1969 was about .88 feet per day (Table 1).

Assuming an average rate of water level rise of .88 feet per day, the mines will fill to an elevation of about 1460 feet above mean sea level, the elevation of the West Fork Montreal River at Montreal, in about 1,733 days or 4.7 years. However, the rate may decrease due to lowering of hydraulic gradients toward the mines as they fill. In which case the time for filling will be considerably extended. Water, of course, can be recovered from the mine before it fills to the river level.

## CHEMICAL QUALITY OF WATER IN THE MINES

Chemical quality of water in the Montreal mine is improving with rise in water level and all constitutents tested for, except iron and manganese, are presently (October, 1969) within limits recommended for drinking water by the U. S. Public Health Service (1962). The water is clear with no trace of color and is a very hard calcium magnesium bicarbonate type which is slightly alkaline. Chemical analyses of water samples from the Montreal Number 5 shaft and an analysis of water from the New Cary Mine shaft are shown in Table 2 along with U. S. Public Health Service drinking water standards.

Saline water and brines, water with total dissolved solids in excess of 1000 ppm and 35,000 ppm, respectively, were encountered at depth in both the Cary and Montreal mines. However, there is little available data to determine accurately the original quality of water progressively encountered as the mines were deepened. Three mine company analyses each from the 32nd and 34th levels of the Cary mine and 4 analyses from the 37th level of the Cary mine, all from sumps, were made. Dissolved solids and pH values from those analyses are reproduced below.

| | Dissolved Solids (PPM) | pH |
|---|---|---|
| 32nd level | 808 | 8.1 |
| | 556 | 8.1 |
| | 944 | 7.9 |
| 34th level | | |
| | 78,500 | 6.7 |
| | 80,000 | 7.0 |
| | 80,000 | 6.6 |
| 37th level | | |
| | 110,000 | 5.6 |
| | 114,000 | 5.7 |
| | 117,000 | 5.9 |
| | 114,000 | 6.1 |

Table 2. Chemical analyses of mine waters and drinking water standards

Analyses of water from the Montreal Number 5 Shaft

| Date | Water Level (Feet) | Silica ($SiO_2$) | Iron (fe) | Manganese (Mn) | Calcium (Ca) | Magnesium (Mg) | Sodium (Na) | Potassium (K) | Bicarbonate ($HCO_3$) | Sulfate ($SO_4$) | Chloride (Cl) | Flouride (F) | Nitrate ($NO_3$) | Dissolved Solids | Hardness (as $CaCO_3$) | Specific Conductance (Micromhos at 25°C) | pH | Analysis by* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 11/9/66 | 2,400 | 18 | -- | -- | 249 | 63 | 99 | 22 | 182 | 27 | 670 | .3 | 3.1 | 1,360 | 881 | 2,450 | 7.0 | USGS |
| 6/29/67 | 2,526 | -- | 1.1 | .19 | 214 | 49 | 108 | 18 | 176 | 32 | 560 | -- | 2.1 | 1,250 | 736 | 2,080 | 7.2 | USGS |
| 11/8/67 | 2,254 | -- | 3.4 | .00 | 175 | 41 | 74 | 22 | 186 | 35 | 435 | .2 | 2.8 | 876 | 606 | 1,680 | 7.8 | USGS |
| 6/10/68 | 2,059 | 17 | 2.8 | .22 | 114 | 26 | 44 | 11 | 182 | 33 | 220 | .4 | 1.6 | 652 | 392 | 1,020 | 8.2 | USGS |
| 9/30/68 | 1,947 | -- | 1.8 | .60 | 150 | 29 | 64 | -- | 178 | 33 | 310 | .6 | .5 | -- | 492 | -- | 7.1 | WSLH |
| 5/21/69 | 1,749 | -- | 1.9 | .07 | 86 | 15 | 30 | -- | 171 | 24 | 120 | .4 | .2 | 496 | 288 | -- | 7.55 | WSLH |
| **Analyses of water from the new Cary Mine Shaft** | | | | | | | | | | | | | | | | | | |
| 9/30/68 | 1,929 | -- | 21 | 2.0 | 106 | 31 | 50 | -- | 275 | 2 | 180 | 1.35 | .5 | -- | 392 | -- | 7.1 | WSLH |
| **U.S. Public Health Service Drinking Water Standards, 1962** | | | | | | | | | | | | | | | | | | |
| | | | .3 | .05 | | | | | | 250 | 250 | 1.7 | 45 | 500 | | | | |

*USGS, U.S. Geological Survey; WSLH, Wisconsin State Laboratory of Hygiene.
The Analyses by the USGS are in Milligrams per liter while those of the WSLH are in parts per million.
The units are essentially equivalent.

It appears from this limited data and conversation with mine officials that water in the crystalline rocks was fresh with relatively low dissolved solids content and alkaline pH above the 31st level (about 2000 feet below land surface). Below the 31st level water rapidly became saline and acidic with depth and brines of up to 117,000 parts per million dissolved solids were found at the 37th level (about 3200 feet below land surface). The brines were of the calcium and sodium chloride type.

The brines result from entrapment of ground water in the rock openings at depth where little or no circulation occurs. The stagnant water dissolves minerals from the rock and becomes progressively more saline. Because water above the 31st level of the Cary mine was reasonably fresh, there is an indication that ground water circulation does take place down to that depth. However, the mine itself increases water circulation and naturally occurring saline water may have been flushed out of the rock during the long history of mining.

Water samples for analysis were collected from the Montreal Number 5 and New Cary mine shafts with an improvised bailer attached to the cable used for water level measurements. The water samples are from the top 10-20 feet of water and may be only generally representative of water in the mines.

The initial water sample, collected from the Montreal mine in November 1966 with water level at 2400 feet below the surface,contained 1,360 ppm dissolved solids. The water was high in calcium and magnesium which caused excessive hardness and chlorides and sodium were high. Bicarbonate, sulfate, and nitrates were within normal limits of local ground water and pH was 7 or neutral.

The gradual decrease in concentration of several constituents with the rise of water level in the Montreal mine is shown in figure 2. The anmalous jump in concentration of the several parameters in the September 30, 1968 analysis is unexplained but may have resulted from short term changes in recharge to the mine or local conditions in the mine at that particular level. Bicarbonate and sulfate have been fairly consistant with water level rise but nitrate has shown a gradual decrease (table 2). Iron and manganese have remained high and have been inconsistant through the monitoring period. The water has remained alkaline but with varying values of pH.

The analysis of water from the New Cary Mine shaft (Table 2) compares fairly closely to analysis of water from the Montreal shaft taken on the same date, indicating that chemical quality of water throughout the lateral extent of the mines is reasonably consistant. Bicarbonate and flouride were considerably higher in the Cary mine and sulfate was much lower than in the Montreal. The excessive iron and higher manganese in Cary mine waters are probably erroneous, resulting from precipitated iron and manganese in the unstrained sample that was scraped from the shaft as the sample was collected.

Rock temperatures in the Montreal mine were determined by a mine company survey when the mine was in operation. Rock temperatures ranged from about 52°F at 50 feet below land surface to 75°F at 2600 feet below land surface and showed an average temperature gradient of 1°F increase in temperature with each 110 feet of depth. Water temperatures in the mines when they are full should show approximately the same temperature gradient.

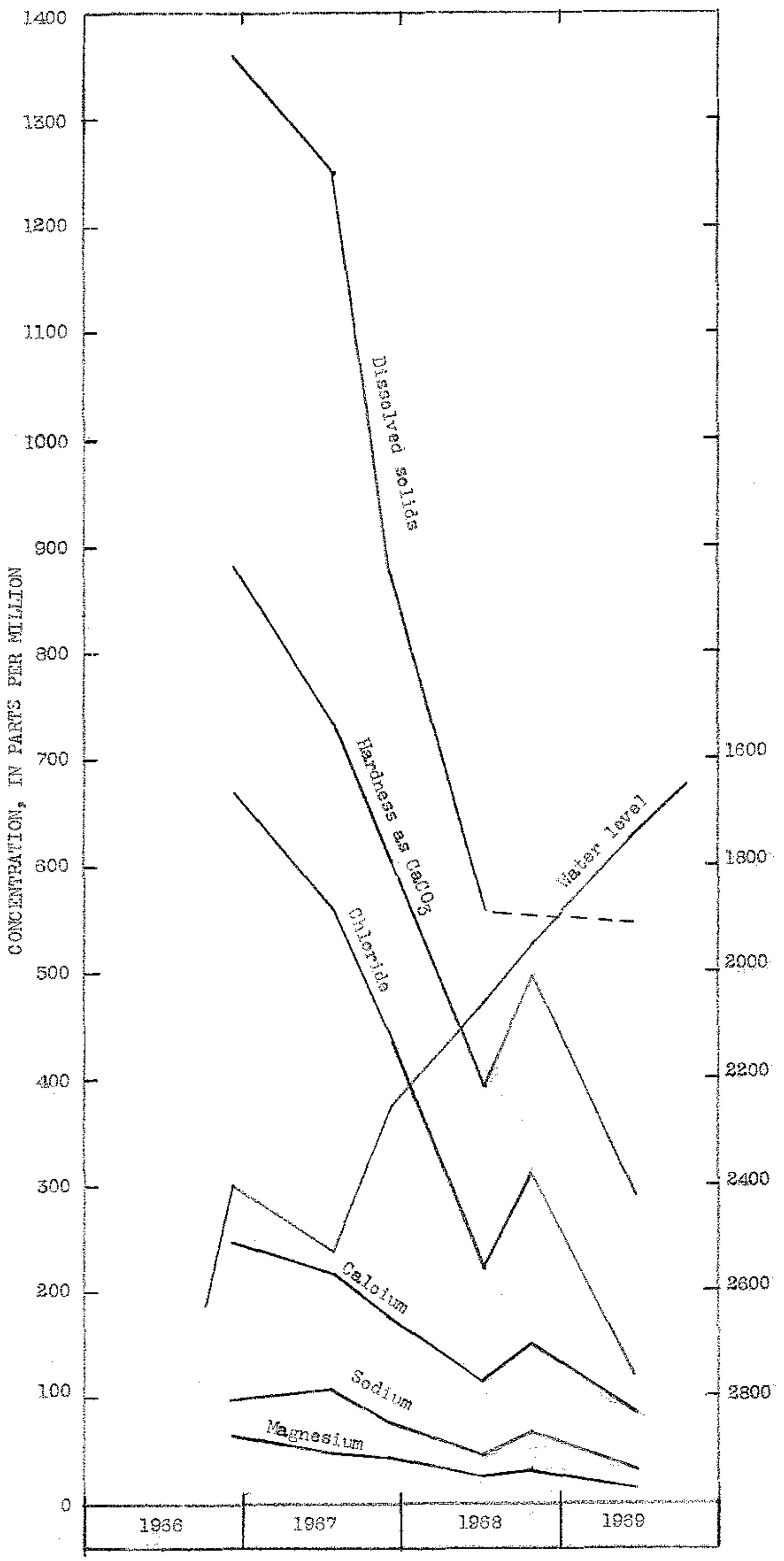


Figure 2.-- Change in concentration of selected chemical constituents in mine water with rise in water level, Montreal mine, Number 5 Shaft.

It appears from the chemical analyses that the saline water found at depth in the mines is not mixing to any great extent with fresh water presently entering the mines. Presumably, the fresh water, which is less dense than saline water, is floating on the saline water and mixing is minimal.

Because chemical quality has improved rapidly with the rise of water level in the mines and is now essentially within drinking water standards, there is every indication that the mine water will provide a potable source when the water reachs a level where pumping to the surface is economically feasible. Bacterial quality of the mine water has not been tested because the only access is through mine shafts which undoubtedly would show unsafe water.

## FUTURE PROJECT PLANS

Monitoring of both chemical quality and water levels will continue in the mine through the water level recovery period. When water levels are sufficiently near land surface for ease in access, water samples will be collected at several depths with a grab sampler to determine any changes of quality with depth. Additional samples will also be collected from the New Cary mine shaft and other points of access to the mines to define quality of water latterly in the mines. Water samples will be analysed for trace elements that may affect water potability. Bacterial quality will have to be tested in the well drilled into the mine workings for municipal supply.

## MANAGEMENT CONSIDERATIONS

Present information on chemical quality of the water indicate that development of a supply from the mines will require treatment for iron and manganese. The water may also be quite hard. Treatment for bacterial control will also be necessary.

Water probably can be best recovered from the mines through a drilled well that taps the mine workings. It is suggested that surface openings to the mines such as the shafts should be avoided to help in bacterial control and possible pollution from the surface. The well should be located where it will be least effected by land subsidence which is a problem in the area. A submersable pump may be the best type to use in the event that subsidence does change alignment of the well.

Pumping rates that can be sustained from the mine are difficult to assess at this point but probably will be slightly less than the average rates of pumping during mine operations. If this is true, a sustained yield of about 1000 gpm can probably be obtained from the mines with little drawdown of water level. Additional water can be withdrawn from storage in the mine.