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MINING LAND USE

LEVEL I REPORT

May 9, 1978

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Minnesota Environmental Quality Board
Regional Copper-Nickel Study

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ABSTRACT

Past, present, and potential mining land uses in the Regional Copper-Nickel Study Area were examined as part of an investigation of potential copper-nickel mining impacts in northeastern Minnesota. The objective of this report is to characterize the land used by natural iron ore and taconite ore extraction and related mining activities. Estimations of future land consumed by taconite, iron ore, and copper-nickel and associated minerals extraction are formulated based on the most current calculation of potential reserves.

Taconite and natural iron ore mining consume, at present, six percent of all the land area in the Study Area. If all known mining potentials were utilized, total land area covered by extraction and mining-related activities could reach well over 14 percent.

INTRODUCTION TO THE REGIONAL COPPER-NICKEL STUDY

The Regional Copper-Nickel Environmental Impact Study is a comprehensive examination of the potential cumulative environmental, social, and economic impacts of copper-nickel mineral development in northeastern Minnesota. This study is being conducted for the Minnesota Legislature and state Executive Branch agencies, under the direction of the Minnesota Environmental Quality Board (MEQB) and with the funding, review, and concurrence of the Legislative Commission on Minnesota Resources.

A region along the surface contact of the Duluth Complex in St. Louis and Lake counties in northeastern Minnesota contains a major domestic resource of copper-nickel sulfide mineralization. This region has been explored by several mineral resource development companies for more than twenty years, and recently two firms, AMAX and International Nickel Company, have considered commercial operations. These exploration and mine planning activities indicate the potential establishment of a new mining and processing industry in Minnesota. In addition, these activities indicate the need for a comprehensive environmental, social, and economic analysis by the state in order to consider the cumulative regional implications of this new industry and to provide adequate information for future state policy review and development. In January, 1976, the MEQB organized and initiated the Regional Copper-Nickel Study.

The major objectives of the Regional Copper-Nickel Study are: 1) to characterize the region in its pre-copper-nickel development state; 2) to identify and describe the probable technologies which may be used to exploit the mineral resource and to convert it into salable commodities; 3) to identify and assess the impacts of primary copper-nickel development and secondary regional growth; 4) to conceptualize alternative degrees of regional copper-nickel development; and 5) to assess the cumulative environmental, social, and economic impacts of such hypothetical developments. The Regional Study is a scientific information gathering and analysis effort and will not present subjective social judgements on whether, where, when, or how copper-nickel development should or should not proceed. In addition, the Study will not make or propose state policy pertaining to copper-nickel development.

The Minnesota Environmental Quality Board is a state agency responsible for the implementation of the Minnesota Environmental Policy Act and promotes cooperation between state agencies on environmental matters. The Regional Copper-Nickel Study is an ad hoc effort of the MEQB and future regulatory and site specific environmental impact studies will most likely be the responsibility of the Minnesota Department of Natural Resources and the Minnesota Pollution Control Agency.

FIGURE 1.

THE REGIONAL COPPER-NICKEL
STUDY AREA IN RELATION TO THE
MESABI IRON RANGE

Source: William Treathewey, University of Minnesota
Bulletin, Mining Directory Issue, 1974

MINING LAND USE IN THE REGIONAL COPPER-NICKEL STUDY AREA

INTRODUCTION

In exploring the potential of copper-nickel mining the Regional Copper-Nickel Study Area, it is necessary to examine all mining-related land uses in the area to forecast future land use, impacts, and conflicts.

In the Study Area, six percent or 29,506 hectares of land support some type of activity related to the production of natural ore and taconite (Figure 2). Extraction, waste rock stockpiles, reservoirs, processing facilities, tailings basins, and transportation routes cover a wide band of land from the cities of Mountain Iron to Babbitt in the Study Area (Table 1). Plans have been expressed by many mining companies to expand existing operations or develop new mines and facilities. These plans include only the identified reserves of iron ore and taconite, but do not consider, yet, the more than 20 billion metric tons of iron ore and taconite potential not economically recoverable today (Marsden 1977).

NATURAL IRON ORE OPERATIONS

From the 1880s until the late 1950s, the Vermilion and Mesabi Iron Ranges were mined exclusively for natural or high grade iron ore. The advent of taconite[1] mining in Minnesota brought more mines and new technology

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[1] Natural ore is defined as "all hematitic and geothitic iron rich material that can be mined and beneficiated to a saleable product by simple methods, i.e., crushing and sizing." (Marsden 1977)

Taconite ore is defined as "magnetite taconite ore and oxidized banded iron-formation ore. Commercially, the term "taconite" is often used to mean any magnetite-bearing iron-formation that can be economically mined and processed by fine grinding and magnetic separation to yield a saleable iron ore concentrate or pellets." (Marsden 1977)

Table Land use comparison.

LAND USE	ST. LOUIS COUNTY % of total land	LAKE COUNTY % of total land	REGIONAL COPPER-NICKEL STUDY AREA % of total land
Water	8.0	15.9	8.4
Marsh/Swamps/Bogs	1.1	0.3	18.2
Open Pasture/Vacant	4.2	0.4	5.8
Forest	81.4	82.5	59.6
Farmland	1.8	0.1	2.1
Rural Residential	0.9	0.2	1.0
Urban Residential	1.4	0.5	0.7
Mining	1.0[b]	.07[b]	3.6
Transportation	0.1	---	0.1
	99.9[a]	100.6	99.5

SOURCE: Barton-Ashman Assoc. Draft EIS--Reserve Mining Company, 1975, and Land Use Map of the Regional Copper-Nickel Study Area, Socio-Economic Studies, 1977.

[a] Due to rounding, the percentages and totals do not equal 100.

[b] The calculation of these figures does not include all tailings basins, stockpiles, and mine structures.

to the Study Area. Though there were as many as 50 operating natural ore mines in what is now the Study Area, at one time, they cover a relatively small amount of land when compared to the five expansive taconite operations now in the Study Area. Mining and producing taconite has become more profitable than natural ore mining. Today, there are only a handful of natural iron ore operations still shipping ore out of the Study Area.

Methodology

Data for exploring present and possible mining-related land use were gathered through many sources. The "University of Minnesota Bulletin, 1974, Mining Directory Issue," compiled by William Treatheway, was the prime data source. The "Bulletin" supplied the most current listings and descriptions of natural ore exhausted, abandoned, inactive and active mines. The University of Minnesota will publish an update of the Bulletin in June, 1977.

The Minnesota Department of Natural Resources (MDNR), Minerals Division, at the Hibbing and St. Paul offices, supplied information as did MDNR-Reclamation; George Wheaton, a University of Minnesota geological research associate; and Marvin Lamppa, an iron range historian.

Natural Iron Ore Resources

Available ore resources[2] in the Study Area include 33 million metric tons of natural iron ore. These reserves are actually insignificant to future

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[2] Reserves are defined as "known identified deposits of mineral-bearing rock from which the mineral or minerals can be extracted profitably with existing technology and under present economic conditions. Resources are defined to include not only reserves but also other mineral deposits that may eventually become available--either known deposits that are not economically or technologically recoverable at present, or unknown deposits, rich or lean, that may be inferred to exist but have not yet been discovered (Meineke-Listerud 1977).

Table 2 Estimated reserves of natural ore. Natural ore reserves based on information from the State of Minnesota covering 1976-1977 reserves. Only iron ore reported as mines or mine groups on the tax roll, containing 510,204 metric tons of reserves are included.

RANGE	MINE	RESERVES (metric tons)
15	Donora	9,252,444
	Embarrass	1,566,222
	Meadow Reserve	1,008,000
	0-47 Reserve	1,152,888
	Stephens, Perkins, Perkins Annex	1,648,888
	U.S.S. Reserve #40	1,658,666
	Subtotal	16,287,108
16	Bangor, 043 Reserve, Roy	4,449,777
	Corsica	431,111
	J & L #45 (Welton)	922,666
	J & L #47 Reserve	1,526,222
	McKinley	2,195,555
	Subtotal	9,525,331
17	Auburn, Great Western	3,506,666
	Cloquet and Annex	1,196,444
	Rouchleau and Annex	953,777
	Security	516,444
	Subtotal	6,173,331
18	Brunt	1,533,333
	Subtotal	1,533,333
	TOTAL	33,516,444

SOURCE: State of Minnesota, Office of Ore Estimation, Eveleth, Minnesota, 1977.

ore production because of steel companies' preference to use taconite in the steel-making process. It is doubtful, however, that mining companies controlling these reserves would sell or exchange them for uses other than mining (Marsden 1977) (Table 2).

Exhausted Mines

In 1870, a representative of the Ontonagan Syndicate, a mining company from Michigan, drove a drift into a hillside near the townsite of present-day Babbitt with hand tools and black powder. This established the first iron ore mine on either the Vermilion or the Mesabi Ranges. The venture was eventually condemned due to banded ore and hard rock (Lamppa 1976).

By 1884, shipments were being made from seven mines: the Stone, Lee, Breitung, Tower, Armstrong, Stuntz, and Montant on the Vermilion Range (Lamppa 1976). Within ten years, there were at least twelve mines in the Study Area, including long-running operations such as the Biwabik, Chandler, Canton, Minnewas, and Ohio mines. Some of these mines remained active into the 1960s. Today, there are 76 mines that were mined for natural iron ore at one time or another in the Study Area (Treathewey 1974) (Figure 3). An exhausted mine has been mined until all reserves are depleted. The mines in this case have no available natural ore, but many of them are mined today for taconite ore.

Leases

There are 29 state and private leases for taconite reserves in exhausted natural iron ore mines (Treathewey 1974). A number of companies still hold natural ore leases for fifteen of the mines designated as exhausted (Appendix A).

Abandoned Mineland

Production-related buildings and land were often abandoned when a mine became exhausted. Old production facilities and mines are often purchased or leased by other companies, but many operations are left to deteriorate (e.g., the odl Peter Mitchell Plant southeast of Babbitt, or the rigs of the Pioneer Mine in Ely). The Longyear mine site has been reconstructed to represent its original working state. This site is designated as a Minnesota Inventory Historic Site. The underground Soudan Mine became a state park in 1974. All surface and subsurface operations remain in working condition as a tourist attraction. The last shipment from the Soudan Mine was made in 1963, but the mine is not yet exhausted.

Inactive Mines

Inactive mines are defined as mines still containing iron ore. Owners and operators have halted extraction from such mines to await a more profitable time or means of extraction to mine the remaining ore. There are 43 inactive mines within the Study Area (Treathewey 1974). The Embarrass Mine, for example, contains approximately 1.75 million metric tons of natural iron ore, but it is water filled to its top edges. The possibility still exists, however, to drain the pit and extract the remaining ore (Appendix B).

Flooded Pits

Flooding is a common consequence for many exhausted and inactive mines. The pits are flooded by underground springs and run-off

from the Biwabik Iron Formation. Flooded pits are often stocked with fish. Three of the larger water-silled pits are the Knox, Belgrade, and St. James. The city of Aurora uses the water from the St. James Pit Lake, as it is now called, for their city supply. The city of Eveleth is planning to dewater small flooded pits near their city limits to enhance the water supply. Many mining companies also dewater pits to add to their reservoirs for taconite processing.

Reclamation

Waste rock stockpiles and surrounding ancillary land have been left to revegetate naturally in the past. Now techniques to speed the revegetation process are being explored by mining companies and MDNR-Reclamation Division. Because of shifting and settling, building construction on waste rock stockpiles has not been feasible in the past. Many houses built on stockpiles in Hibbing have experienced foundation cracks and shifting. In most cases, exhausted mines, abandoned mining facilites, and surrounding land have not been reclaimed to any recreational or economical value, but are often leased by other mining companies for use as dumps or other related facilites.

Present Natural Ore Operations

Natural iron ore operations are relatively small in comparison to neighboring taconite mining facilities. Shipments are still made from the Gross-Nelson, Gauntry, McKinley, Rouchleau, and Weltan Reserve mines. Active natural ore mines within the

Study Area cover approximately 210.12 hectares or only three percent of all mining-related land within the Study Area. These mines are not creating many new stockpiles, but are adding negligible amounts of waste rock to old stockpiles. At least one mining company, Pittsburgh Pacific, makes stockpile shipments from exhausted or inactive mines. The stockpile shown in Figure 2 includes waste rock stockpiles, lean ore stockpiles, and mine dumps. Very few stockpiles will be depleted by any measurable amount through ore shipments. These stockpiles, therefore, should be considered as relatively permanent topographical features.

Processing and Transportation

Natural ore must be crushed, screened, and washed before leaving the Mesabi Iron Range. These are only minor production activities. This processed natural ore is then shipped by rail to Duluth and Two Harbors where it is shipped to Great Lakes port sites for processing.

TACONITE OPERATIONS

Taconite is now the dominant source of iron ore. Approximately 65 percent of the land devoted to mining-related activities in the Study Area is used for taconite extraction, stockpiles, tailings basins, reservoirs, crushers, and concentration facilities. Knowledge of taconite operations and resources is essential to calculate present and future land use in the Study Area.

Table 3 Total taconite ore reserves of the Mesabi Range by range unit.

	RANGE	TACONITE RESERVES (metric tons)
Study Area	12	981,397,333
	13	3,435,128,889
	14	5,521,702,222
	15	339,302,222
	16	2,429,000,000
	17	8,540,204,444
	18	7,263,644,444
	TOTAL	28,510,379,560
Remainder of Mesabi Iron Range	19	1,596,961,333
	20	785,920,888
	21	1,680,040,000
	22	3,976,177,778
	23	1,924,080,000
	24	1,831,804,444
	25	1,895,235,556
	26	0
	TOTAL	13,777,105,780

SOURCE: State of Minnesota Office of Ore Estimation, Eveleth, Minnesota. 1977.

Table 4 Estimated area devoted to taconite mining by activity and company within the Study Area.

COMPANY	ACTIVITY	AREA (square hectares)
Erie-Hoyt Lakes Operation	Reservoir	1619.4
	Tailings Basin	680.0
	Mines	1165.9
	Stockpiles	708.5
	Plant	64.8
	Related Land[b]	1668.0
		5906.6
Erie-Dunka	Mine	226.7
	Stockpile	129.5
	Related Land	291.5
		647.0
	ERIE TOTAL	6991.0
U.S. Steel-Minntac[a]	Reservoir	404.9
	Tailings Basin	404.9
	Mines	275.0
	Stockpiles	291.0
	Plant	81.0
	Related Land	987.9
	U.S. STEEL TOTAL	2445.0
Eveleth Taconite Expansion Company	Tailings Basin	161.9
	Mine	275.0
	Stockpiles	939.3
	Plant	81.0
	Realted Land	664.0
	EV. TAC.& EXP. TOTAL	2121.5
Reserve Mining Company	Mine	1473.7
	Stockpiles	809.7
	Plant	81.0
	Related Land	2433.2
	RESERVE TOTAL	4793.1

Table (contd.)

COMPANY	ACTIVITY	AREA (square hectares)
Inland Steel Company Minorca	Reservoir	421.0
	Tailings Basin	485.8
	Mine	518.2
	Stockpiles	1036.4
	Plant	81.0
	Related Land	793.5
	INLAND TOTAL	3336.0

SOURCE: Direct Mining Land Use Map. MEQB Regional Copper-Nickel Study, 1977.

[a]Calculations for U.S. Steel's Minntac plant included only activities or parts of activities on land within the Study Area.

[b]Related land is defined as the auxiliary land around plant and pit areas used for storage or transportation, or vacant land.

Methodology

Information pertaining to taconite reserves, operations, and expansion was supplied in plans published by mining companies, aerial photo interpretation, field checking, direct communication with mining companies in the Regional Copper-Nickel Study Area, the "University of Minnesota Bulletin, 1974, Mining Directory Issue," and MDNR in St. Paul and Hibbing. Many facts and conceptual plans were taken from the transcripts of the Reserve Mining Company hearings and various environmental impact statements published by Erie Mining and Reserve Mining.

Production and Reserves

In 1975, Erie, Reserve, U. S. Steel, and Eveleth Taconite and Expansion Company (Ev. Tac.) produced a combined total of 23.7 million metric tons of taconite pellets. Taconite reserves in the Study Area[3] hold approximately 28.5 billion metric tons of merchantable ore, as compared to 13.7 billion metric tons in the remainder of the Mesabi Iron Range (Table 3).

Land Use

Processing taconite to extract iron from the hard rock consumes more acres than the open pit extraction process. Inland Steel, Erie Mining, U. S. Steel, and Eveleth Taconite have processing facilities covering approximately 14,000 square hectares (Table 4).

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[3] The official Copper-Nickel Study Area covers only the two eastern sections of range 18, west. The entire range 18, west, was used to calculate taconite reserves.

Reserve Mining Company ships taconite to their processing facilities at Silver Bay. Crushers, mines, roads, railroads, and switching yards crisscrossing the area adjacent to Reserve's Peter Mitchell mine cover 3,300 square hectares without processing facilities (Figure 4).

Erie's Hinsdale operation north of Hoyt Lakes covers more land than any other mining operation in the Study Area. Erie also ships crude taconite over 15 miles by rail from their Dunka pit operation near Babbitt to the Hinsdale plant. Eveleth Taconite and Expansion Company's processing plant and tailings basin are just south of the Study Area near Forbes. Eveleth Taconite has maintenance buildings just north of Eveleth. The crude taconite from the Thunderbird Mine at Eveleth is shipped by rail six miles to the processing plant.

Water Use and Tailings Basins

Water consumption is integral to taconite production. Reserve Mining has alleviated their water supply problem by drawing water from Laker Superior for processing at their Silver Bay facilities. Eveleth Taconite and Expansion Company use the St. Louis River as their water source. Erie Mining and U. S. Steel are located on the Laurentian Divide which enables them to mine and process in the same area because of water flow. These locations, however, do result in a water supply problem solved by the use of constructed reservoirs. Erie pumps water from Colby and Whitewater Lakes to smaller reservoirs at the Hinsdale operation. U. S. Steel has a reservoir and also dewaters the Stephens Mine for its water supply (Jerry Johnson, MDNR 1975).

Water is used during taconite production to wash away non-ore particles. Tailings, or the sludge-like by-product of taconite processing, is disposed of in the Study Area by pumping the tailings into a basin. The basin is a large area encompassed by a double-walled earthen and sand dike. In general, tailings basins are constructed for a 35 to 40 year life.

Erie's basin covers approximately 680 square hectares, while Eveleth Taconite and Expansion Company's basin covers only 162 square hectares. Only Erie, Inland, and U. S. Steel have tailings basins within the Study Area. Erie expressed interest in a new tailings site extending north and east from their present tailings basin to ultimately consume another 4,200 square hectares (Figure 4). Reserve had been dumping their tailings into Lake Superior and will begin dumping at a nearby on-land disposal site.

Auxiliary Land Use

Total mining operations also include land used for the plant buildings themselves, transportation, and vacant land adjacent to mines or the plant. Most of the mining companies own or lease land around their present operations or have land available for land exchange.

TRANSPORTATION

Methodology

Mining company transportation was compiled primarily from Minnesota Department of Transportation and United States Geological Survey

maps. Aerial photo interpretation followed by field-checking in the Study Area was also used.

Railroads

Mining company transportation routes lace the entire Mesabi Iron Range. There are five major railroads running through the Study Area. These are: the Duluth Missabe and Iron Range Railroad (DM and IR), the heaviest ore-carrying railroad in the Study Area; the Duluth, Winnipeg Railroad, primarily a grain carrier; Burlington Northern; and two private lines owned by Erie and Reserve. Inland, U. S. Steel and Eveleth Taconite use the DM and IR to transport ore out of the Mesabi Iron Range area. Erie and Reserve have extensive road and rail arteries for transport from mine-to-plant and plant-to-shipping ports on Lake Superior (Figure 5).

Roads

Mining company roads are usually restricted, for example, the restricted road from the Hinsdale operation to the Dunka Pit. This road is the shortest route from the Hoyt Lakes area to the Babbitt area but is for Erie use only. Abandoned company roads to pits and stockpiles are often blocked by gates or piles of waste rock.

TACONITE EXTRACTION POTENTIAL

After 80 years of iron mining, the landscape of the Mesabi Iron Range is characterized by man-made canyons and mountains as the consequence, for the most part, of natural high-grade iron ore mining. The advent

of taconite mining in 1956 brought the need for mining operations to consume an even larger percent of the land than had previously been devoted to mining. Today, large mine pits and expansive facilities sprawl along the Biwabik Iron Formation with the expection of more expansion. As was shown in Table 3, taconite reserves within the Study Area are twice that of the rest of the Mesabi Iron Range.

Methodology

To project the availability of extractable taconite, Dr. Ralph Marsden, a geologist with the University of Minnesota-Duluth, conducted a study of iron ore reserves in the Mesabi Iron Range (Marsden 1977).

Ultimate Pit Limit

Marsden used calculations of reserves to predict an Ultimate Pit Limit (Figure 6). He defines the Ultimate Pit Limit (UPL) as "the break-even cost situation with all available funds after recognition of all production costs used for stripping" (Marsden 1977). Constant 1974 dollars were used in the calculations.

Data used to calculate the UPL ranged from reliable to scanty with ore test results dating back as far as 30 years. Different methods of testing in different laboratories over the years also added to the questionable reliability of the data. Since the data used by Marsden was the most reliable data available, the calculations are accepted as an estimation of iron ore reserves. To show the varying levels of reliability of input data, a "Probabilistic Grade-Quality Matrix"

was included in the estimation. Calculations and estimations were initially made through the United States Bureau of Mines, Minerals Availability System. The calculated tonnages then "include all material that can be produced at a break-even or on a profitable basis using cost and mineral value information available to the evaluator for 1974" (Marsden 1977).

Ore Classifications

For calculation purposes, iron ore in the Mesabi Range was grouped by class of iron ore material content. The classifications included: 1) Natural Iron Ore; 2) Magnetite Taconite Ore; 3) Magnetite Taconite Lean Ore; 4) Bottom Magnetite Taconite Lean Ore; 5) Siliceous Magnetite Taconite Ore; 6) Siliceous Magnetite Taconite Lean Ore; and 7) OXIBIF (Oxidized Banded Iron Formation Ore). Ore from all of these groups is present in the Study Area.

Ore Reserve Estimate

Since the major factor in determining the UPL for material that can be economically mined is the quantity of stripping that can be removed to meet a no-profit, no-loss situation, the only tonnages included in the taconite ore reserve estimate are related directly to the cost of producing taconite pellets. The taconite production costs used were calculated as a range-wide average taken from data submitted to the Minnesota Department of Revenue from seven taconite plants across the range. The amount of stripping

Table 5 Summary of Mesabi Range iron ore reserves by ore class and range unit.[a]

RANGES	MAGNETITE TACONITE ORE	[illegible]MAGNETITE TACONITE LEAN ORE	BOTTOM MAGNETITE TACONITE LEAN ORE	SILICEOUS [illegible] TACONITE
12	645.86			335.9
13	2,120.52			1,314.6
14	3,228.77			2,248.4
15	281.52			
16	1,780.87	180.86		
17	6,735.62	230.93	110.53	
18	4,270.12	1,342.27	1.145.53	
Subtotal	19,063.28	1,754.06	1,256.06	3,898.5
19	868.42	13.84	271.6	
20	381.48	56.17	12.0	
21	1,122.80	11.51	306.36	
22	2,141.51			
23	518.74			
24				
25				
26				
Subtotal	2,366.31	81.52	589.96	0
TOTAL	24,096.28	1,835.58	1,846.02	3,898.5

SOURCE: Dr. R.W. Marsden, 1977. Iron ore reserves of the Mesabi Range, Minnesota, A Minerals Availability Report, 1977.

[a]Data recorded in millions of metric tons.

SILICEOUS MAGNETITE TACONITE ORE	SILICEOUS MAGNETITE TACONITE LEAN ORE	OXIBIF	NATURAL ORE MINES PLUS 450,000 TONS	TOTAL
335.52				981.39
1,314.60				3,435.12
2,248.41	44.5			5,521.69
		57.77	16.28	355.58
		459.26	9.52	2,430.51
		1,463.11	6.16	8,546.37
		505.69	1.52	7,265.17
3,898.53	44.5	2,485.83	33.48	28,535.83
		352.64	5.60	1,511.66
		336.44	52.75	838.86
		236.68	10.25	1,690.29
		1,834.66	5.90	3,982.08
		1,405.33	9.04	1,933.12
		1,831.80	7.91	1,839.66
		1,895.23	7.71	1,902.95
			9.54	9.54
0	0	7,892.78	108.70	13,708.16
3,898.53	44.5	10,378.61	142.28	42,243.99

to the UPL was calculated using the average stripping cost. A summary of the estimated iron ore reserve tonnage for the Study Area[4] is listed in Table 5 by ore classification. Designated taconite reserves are shown by location and company as compiled by William Treathewey in Figure 7 (University of Minnesota Bulletin, Mining Directory Issue 1974).

Prediction

Marsden predicts that mining up to the UPL in the Study Area may be met by several obstacles. As mining nears the UPL, pits will become deeper due to the deepening slope of the ore deposits. Haul costs and quantities of stripping to be removed may increase. The availability of dump areas may become a problem as mining moves into densely-populated areas. This is also complicated by the occurrence of Bottom Taconite Lean Ore, which prohibits stockpiling in existing pits due to the feasibility of mining the Bottom Taconite in the future.

Tonnages along the Biwabik Iron Formation may be reclassified from iron ore resources to ore reserves before all the currently estimated iron ore reserves are mined. The possibility also exists that ore included in this estimate may not be mined due to environmental concerns or costs. Proposed mine pits can also expand

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[4] The official Copper-Nickel Study Area covers only the two eastern sections of range 18, west. The entire range 18, west, was used to calculate taconite reserves.

beyond the UPL set by Marsden's study when and if economics allow production at higher stripping ratios, or if technological advances present methods of processing ore materials not included in this estimate.

Underground Potential

Areas along the Biwabik Iron Formation that are not currently being mined will almost certainly be mined in the future (MDNR 1977). The MDNR expects that in the distant future, when all available ore has been removed by open pit mining, underground mining may become a viable means of extracting ore from the Biwabik Iron Formation beneath the Virginia Formation. The overall recovery of taconite ore by underground methods would be less than 35 percent (Yardley 1975).

TACONITE INDUSTRY EXPANSION PLANS

Methodology

It is essential to examine expansion plans for the taconite industry in the Study Area to predict future land use. Companies may undergo expansion at their present operations or on land that they control away from their operations. For purposes of expansion prediction, any location listed as a taconite reserve (Figure 7) or land controlled by mining concerns may be considered as devoted exclusively to mining in the future.

Information for mining company expansion plans was taken from transcripts from the Reserve Mining Company hearings and published plans by individual mining companies. The MDNR-Hibbing was also used as a source.

Development Scenario

Mining companies are developing plans for expansion or new production facilities. Some of these plans are speculative and others are more

Table 6 Existing and possible expansion in taconite production

COMPANY	PROBABLE OPERATION DATE	PRODUCTION (millions of metric tons)
U.S. Steel (incl. Phase III)**	existing	16.4
Reserve**	existing	9.6
Erie**	existing	9.4
Hanna (Butler & National)	existing	7.6
Hibbing Taconite	existing	4.8
Eveleth Taconite & Expansion**	existing	5.3
Inland**	existing	2.3
Hibbing Taconite	1979	1.4
Hibbing Taconite	1980	1.0
Oglebay-Norton	1980	0.5
Hanna	1981-82	1.0
Hanna	1983-84	2.5
U.S. Steel (Phase IV)	1983-84	5.4
Jones and Laughlin	1984-85	3.7
Hanna	1985-87	2.3
Hibbing Taconite	1985-87	4.5
Oglebay-Norton	1982-87	2.7
Hanna	1988-92	3.7
Erie (Biwabik)*	1995-2000	4.5
Inland	1980-2000	2.3
EXISTING		56.6
ADDITIONAL		36.2
TOTAL		92.8

SOURCE: Direct Testimony and Hearing Transcripts from Rehearing on Certificate of Need for MP&L/UPA, 1977.

*CuNi staff assumption that this operation may be feasible after 1990.
**Companies with taconite processing facilities in the Study Area.

definite. Table 6 lists possible expansion by company, the probable date of operation, and possible production amounts.

By 1995-2000, annual taconite production could reach 12.8 million metric tons (Regional Copper-Nickel Study and Minnesota Energy Agency 1977). This projection is based on testimony and hearing transcripts (1977) provided by representatives of each taconite mining company operating in northeastern Minnesota. Taconite production capabilities are, today, approximately 63.8 million metric tons (Table 6).

Specific Expansion Plans

Figure 8 illustrates the approximate location of each operation described in the development scenario. Hanna Mining Company owns 161 hectares of surface along the Biwabik Iron Formation in the Study Area, but does not own any taconite reserves in the area. The figures quoted for Hanna in the development scenario do not include any plans for taconite production in the Study Area at this time. Hibbing Taconite does not own any surface area along the Biwabik Formation in the Study Area. Like Hanna, the expansion figures quoted for Hibbing Taconite in the development scenario do not include plans for taconite production in the Study Area.

Jones and Laughlin Steel Corporation

Jones and Laughlin (J & L) currently operate a natural ore-producing facility at McKinley and have been proposing a large taconite project just north of Gilbert and McKinley. This proposed facility will cover approximately 3,903 square hectares (Figure 2). The

proposed Jones and Laughlin project has been discussed by J & L for at least fifteen years (Meineke 1977), and no definite plans have yet been announced. The MDNR, Minerals Division at Hibbing does not foresee a major development for Jones and Laughlin within the next 25 years (Meineke 1977).

Reserve Mining Company

Reserve Mining Company has no plans for expansion away from their present operation. The Peter Mitchell Mine Pit south of Babbitt is a large operation, and it is believed to contain ample reserves in and around the pit. As is shown in Figure 2, there are 2,429 square hectares surrounding the pit to support stockpiles, plant, and transportation facilities. Reserve ships all taconite ore extracted from the Peter Mitchell mine to Silver Bay for processing.

Erie Mining Company

Erie Mining Company owns considerable acreage in the Study Area. The final environmental impact statement for a land exchange in preparation for Erie to construct a reservoir is now undergoing final reviewal. Lake Forest Enterprises, Incorporated, a land agent for Erie Minnig Company, has requested a land-for-land exchange for acreage in the Superior National Forest. Erie needs the lands for a clearwater reservoir to supplement existing water supplies in times of insufficient precipitation. Erie presently draws water for processing from Colby Lake, but the water level in Colby is not sufficient at all times to supply Erie with the great

amount of water needed for processing taconite at the Hoyt Lakes operation.[5] The proposal calls for damming a portion of the Upper Partridge River and holding water from the Patridge River, Colvin, Wetlegs, and Cranberry Creeks, and Bannor Brook. When the taconite plant requires supplemental water, the water will be let out of the reservoir to flow downstream to Colby Lake where it will be pumped to the plant site. The National Forest Service is expected to recommend that Erie be allowed to go ahead with the land exchange. This exchange will enable the Forest Service to consolidate many hectares of National Forest lands. Erie is then expected to proceed with necessary steps towards the construction of the reservoir. The MDNR, however, has indicated that the reservoir may cause management problems with future land uses in the area (Meineke 1978).

Pickands-Mather, managing agents for Erie Mining Company, has apparently abandoned previously-announced plans to mine taconite reserves beneath the city of Biwabik. These plans, which included the relocation of Biwabik by 1980 to a new site approximately three miles south of the present townsite, were reportedly abandoned due to dim market projections for taconite. The Regional Copper-Nickel Study staff continues, however, to include a Biwabik operation in future taconite development scenarios.

Eveleth Taconite and Expansion Company

Oglebay-Norton, managing agent for Eveleth Taconite, owns 275 hectares of surface area along the Biwabik Iron Formation in the Study Area. This figure includes the area now mined as the Thunderbird Mine near Eveleth. Oglebay-Norton projects .55 million metric tons of produced ore for 1980 to account for adjustments at their Forbes operation.

United States Steel Corporation

U. S. Steel has set their expansion possibilities in terms of phases. Their large Minntac facility at Mountain Iron is now operating at Phase III capacity. Phase III expansion should begin in 1983 and is expected to boost U. S. Steel's taconite production by one-third (U. S. Steel 1978). Only one-half of U. S. Steel's Minntac operation lies within the Study Area.

Inland Steel Company

Inland Steel's Minorca operation northeast of Virginia is expected to double taconite production from the present 2.4 million metric tons between 1980 and 2000.

CONCLUSION

For the purpose of estimating future expansion areas for non-mining surface development, the calculated Ultimate Pit Limit line south of the Biwabik Iron Formation and the Northern Limits of the Ore Formation may prove to be the most reliable boundaries. Roughly 2,672 square hectares are included between the northern limits and the Ultimate Pit

Limit. Added waste-rock stockpiles, new or expanded tailings basins, and other facilities would necessitate land consumption outside of these boundaries. A rational one and one-half miles north and south of the boundaries has been proposed by the Copper-Nickel Study staff to accommodate expansion of surface facilities (Figure 9). This will cover a total 76,356 square hectares compared to the 29,506 square hectares presently consumed by mining in the Study Area. The possibility exists that mining may never reach this maximum operation level; or mining may extend beyond the boundaries of this arbitary exclusion area.

COPPER-NICKEL RESOURCES

Methodology

The Study Area is known to contain significant quantities of copper-nickel and titanium mineralization (MDNR 1977). The Regional Copper-Nickel Study has produced two major products leading to copper-nickel resource estimates in the Study Area. The Regional Copper-Nickel Study, through the efforts of the Minnesota Geological Survey and the MDNR, Minerals Division, have produced new maps and reports compiling all prior resource data. Reports, maps and other recent investigations have been put together as a final report for the MDNR. The MDNR, Minerals Division, has also produced a report on the mineral resources and potential of the Study Area. This report is based on data from about 500 drill holes which was collected by the Minerals Division for this purpose. Data for these reports was also made available by individual mining companies.

Location

In the Study Area, the major portion of known mineralization occurs in the "basal zone," or lower most several hundred feet of the Duluth Complex.

The Duluth Complex is thought of as a "series of sheet-like intrusions into and beneath the Keweenawan volcanics" (Figure 10).

Potential Mineralization

Data available from the International Nickel Company (INCO) bulk sample tests on the Spruce Road site also indicate the presence of recoverable grades of silver, gold, platinum, and palladium in varying quantities. Cobalt was also found at this site but was not mentioned as a recoverable metal by INCO in 1975. With a 50 percent recovery of cobalt through smelting and with the current market price, cobalt should be economical to recover.

Other resources occurring in economically interesting quantities include vanadium, chromium, aluminum, graphite, and asbestos. Titanium and copper-nickel occur together in the Water Hen ultramatic rocks in the south central part of the Study Area. Graphite is also abundant in the Water Hen Creek area of T.57N, R.14W.

COPPER-NICKEL RESERVES

Figure 10 shows the results of the MDNR-Minerals Division's mineral resource study. The percentages of $\geq$ 0.25 percent copper and $\geq$ 0.5 percent copper illustrate the copper mineralization with regard to thickness and distance above the basal contact. Tonnage estimates were made using data from 324 of the 500 drill holes used in the study. A standard polygon method was implemented to calculate the area of influence of each hole. (See Meineke-Listerud Report for a more detailed explanation of this methodology.) The estimate of material $\geq$ 0.5 percent copper in units $\geq$ 15.24 meters thick is four billion metric tons. Material found to be $\geq$ 0.25 percent copper

persists from the top of the core to the base of the complex or at least 30.48 meters. Material at $\geq$ 0.25 percent copper is estimated at over 900 million metric tons. The tonnage estimate for material $\geq$ 10 percent titanium and $\geq$ 50 feet or 15.24 meters thick is 195.5 million metric tons.

Amax Mineralization Estimates

American Metals Climax, Inc. (AMAX) released information at a public meeting in August, 1977, that indicated significantly higher grade mineralization existing in the AMAX area. AMAX has estimated 293-333 million metric tons averaging about 0.8 percent copper and 0.2 percent nickel as their underground potential. They also reported the discovery of 2.8 to 5.3 million metric tons of semi-massive sulfides averaging about three percent copper and 0.6 percent nickel. Tonnage estimates in the MDNR report are based on certain assumptions and are, therefore, insured as conservative estimates. Data presented in the MDNR report shows that basal zone mineralization is not the only mineralization that occurs in the Duluth Complex. The mineralized zones that are known to occur above the basal zone may and should be explored for possible extraction.

Plans and Activities

Should extraction of any of the local mineralization occur, land on and around the Duluth Complex may be used for mining-related activities. The type and extent of mines and facilities for the extraction of known copper-nickel or any of the economically interesting mineralization near the Duluth Complex will depend on environmental, economic, and management factors. Few companies have made comprehensive mining and production plans available to the public.

INCO

INCO has published plans for a plant, a stockpile, an open pit, and a tailings basin covering approximately 2,332 square hectares (INCO 1975). Since publication of these plans, INCO has suspended operations in Minnesota.

AMAX

AMAX has conducted extensive exploration in Sections 29 and 32, T.60N, R.12W. At present, AMAX is discussing operating plans and feasibility studies publicly within their corporation and have released a conceptual plan for a copper-nickel operation covering approximately 372 square hectares.

Leases

As of May, 1978, Duval Corporation and Exxon Corporation are the only concerns still holding federal prospecting permits. More federal prospecting permits are pending for AMAX, Exxon, Erie, Lloyd K. Johnson, Eileen Scully, Paul Beaird and Leon F. Scully, INCO, and Hanna. INCO has been granted two federal leases for their Spruce Road site. AMAX, Exxon, and Duval are prospecting also under state leases. A number of the companies mentioned also control non-public land and mineral rights in the potential copper-nickel mining area.

CONCLUSION

A great deal of marketable mineral resources lie beneath the surface of the Regional Copper-Nickel Study Area. Enough taconite and natural iron ore material exist so that mining at the present economy and scale could possibly

continue for at least 50 years (Marsden 1977). Projected natural ore and taconite operations could conceivably cover a total 76,356 square hectares if allowed to expand to the Ultimate Pit Limit.

Copper-nickel and titanium mining could consume at least another 9,312 square hectares or 1.7 percent of the land area in the Study Area. This figure does not include any mining-related land uses, such as plants, stockpiles, reservoirs. Combined iron ore, taconite, and copper-nickel mining land use could consume 85,668 square hectares or 14 percent of the land area in the Regional Copper-Nickel Study Area, as compared to the present-day six percent.

Appendix A. Exhausted mines and types of leases within the Study Area.

MINE	DATES OF SHIPMENT	LOCATION	LEASE
Aad	1904-1928	E½-NE, Sec. 31, T. 58, R. 17	
Adriatic	1906-1918	W½-NE, Sec. 30, T. 59, R. 14	taconite
Ajax	1899-1953	NW¼, Sec. 1, T. 58, R. 16	
Alberta	1907-1913	NE¼, Sec. 16, T. 58, R. 17	
Allan	1913-1914	SW-NW & NW-SW, Sec. 32, T. 59, R. 17	taconite
Alpena Mine W.	1955-1960	Lot 4, Sec. 5, T. 58, R. 17	
Armstrong Bay	1923-Exploration	S½-SE, Sec. 7 & S½-SW, Sec. 8, T. 62, R. 14	
Arne	1965-1969	SW-NW, SE-NW, Lot 3, Sec. 4, T. 58, R. 15	
Belgrade	1908-1923	NW-NE, Sec. 9, T. 58, R. 16	taconite
Biwabik	1893-1955	Lot 4 & SW-NW, Sec. 2 & Lot 1 & SE-NE, Sec. 3, T. 58, R. 16	taconite
Burns	1895-1951	Lots 6, 7, 12 & parts of 11, 13, 14, Sec. 4, T. 57, R. 17	taconite
Canton	1893-1954	SW-NE, NW-SE & NW¼, Sec. 3, T. 58, R. 16	taconite
Cass	1903-1955	SW-NE & SE-NW, Sec. 2, T. 58, R. 16	
Chandler No.	1891-1942	NE-SE, Sec. 28, T. 63, R. 12	
Chandler So.	1888-1942	SE-SE, Sec. 28, T. 63, R. 12	
Consolidated Vermilion & Extension	1916-1920	S½-NW, SW-NE & NW-SE, Sec. 5, T. 62, R. 14	
Coons	1940-1970	NE-NW, SE-NW, Sec. 16, T. 58, R. 16	
Duluth	1893-1951	Lot 2, Sec. 3, T. 58, R. 16	taconite
Elba Mine	1898-1926	NE-SE & S½-SE, Sec. 13, T. 58, R. 17	taconite
Emmett	1897-1956	W½-SW & SW-NW, Sec. 8, T. 58, R. 16	taconite
Ernie	1953-1958	SW-SE, Sec. 32, T. 59, R. 17	

Appendix A (cont'd.)

MINE	DATES OF SHIPMENT	LOCATION	LEASE
Fay	1911-1953	Lot 1,Sec.6,T.58,R.17	taconite
Fayal No. 1	1919-1924	Lot 4,Sec.5 & Lot 1,Sec.6,T.57,R.17	taconite
Franklin	1893-1919	SE-NW,Sec.9,T.58,R.17	natural ore
Genoa Fee	1896-1951	NW-SW & SW-NW,Sec.34,T.58,R.17	
Genoa-Sparta	1896-1956	NE-SW,S½-SW,S½-SE,Sec.34,T.58,R.17	
Gilbert Sliver	1954-1957	NE-SE,Sec.23,T.58,R.17	taconite
Hanna Mine	1909-1955	NW-SW,Sec.2 & N½-SE,Sec.3,T.58,R.18	taconite
Higgins No. 1	1914-1957	E½-SW,Sec.3,T.58,R.16	taconite
Holland	1905-1957	N½-SE,Sec.4,T.58,R.16	taconite
Hudson	1910-1918	NW-NW,Sec.4,T.58,R.17	taconite
Jean	1916-1919	NE-SE,Sec.31,T.58,R.17	
Julia	1895-1955	SW-NE & NW-SE,Sec.9,T.58,R.17	natural ore
Knox	1909-1955	SE-SW,Sec.19,T.59,R.14	taconite
LaBelle	1902-1920	N½-NE,Sec.24,T.58,R.17	taconite
Larkin	1906-1948	NE-NE,Sec.4,T.58,R.17	natural ore
Lone Jack	1895-1962	SW-NW,Sec.9,T.58,R.17	
Malta and Malta Annex	1899-1937	W½-NW,Sec.35,T.58,R.17	
Mariska	1907-1963	W½-SE,Sec.24,T.58,R.17	taconite
Mayas	1906-1938	NW-SW,Sec.15,T.59,R.14	taconite
McComber	1917-1919	Lots 3 & 4,Sec.13 & Lots 2,3,4, Sec.14,T.62,R.14	
Meadow	1910-1963	Lots 3 & 4,Sec.3,T.58,R.15	taconite
Meadow Extn.	1958-1961	SW-SE & SE-SW,Sec.34,T.59,R.15	
McEwen	1905-1974	NE-SW & E.15A,NW-SW,Sec.4,T.58,R.17	

Appendix A (cont'd.)

MINE	DATES OF SHIPMENT	LOCATION	LEASE
Mill	1958	Lots 4 & 5,Sec.6,T.58,R.17	taconite
Minnewas	1893-1966	W½-NW,W½-SW & E½-SW,Sec.16,T.58,R17	
Morrow Extension	1927-1929	Lots 2 & 3,Sec.4,T.57,R.17	
Moose	1926-1967	E½-SE,Sec.8,T.58,R.17	
Ohio	1895-1962	W½-SW,Sec.9,T.58,R.17	
Onondaga	1907-1913	W-25A,NW-SW,Sec.4,T.58,R.17	natural ore
Ordean	1916-1919	E½-SE,Sec.31, & SW-SW,Sec.32,T.59,R.17	natural ore
Pacific	1937-1958	SW-SE,Sec.23,T.59,R.15	taconite
Park Lot No. 1	1899-1917	5.12A,SE-SE,Sec.31,T.58,R.17	
Perkins	1909-1919	NE-SW,Sec.26,T.59,R.15	natural ore
Pilot	1919-1955	SW-NE & NW-SE,Sec.2,T.58,R.18	natural ore
Pilot Annex	1951-1956	E½-SW & SW-SE,Sec.2,T.58,R.18	natural ore
Prindle	1914-1960	S½-NE & W½-SE,Sec.36,T.59,R.18	natural ore
Reed	1940-1941	NE-SE,Sec.9,T.58,R.17	
Ruddy	1911-1955	NW-SW,Sec.3,T.58,R.16	taconite
St. James	1916-1963	NE-SW & S½-SW,Sec.3,T.58,R.15	
Savoy	1899-1916	E½-NW,Sec.26,T.63,R.12	
Section 30	1910-1923	Lots 1,2,3,5,6,SW-NE,SE-NW & NW-SE, Sec.30,T.63,R.11	
Sibley	1899-1954	SW-NW & NW-SW,Sec.26 & Lot 1,Sec.27, T.63,R.12	
Sidney	1937-1960	N½-SE,Sec.32,T.59,R.17	natural ore
Siphon	1907-1929	NE¼,Sec.11,T.59,R.14	taconite
Sliver	1909-1917	Lot 1,Sec.6,T.58½,R.17	taconite
Snively	1905-1955	W½-NE,Sec.3,T.58,R.18	
Sparta	1897-1906	NE¼,Sec.34,T.58,R.17	

Appendix A (cont'd.)

MINE	DATES OF SHIPMENT	LOCATION	LEASE
Sullivan	1915-1948	NW-NE,Sec.4,T.58,R.17	natural ore
Syracuse	1966-1968	Lot 12,Sec.6,T.58,R.15	
Union	1900-1957	NE-NW,Sec.9,T.58,R.17	
Victoria	1906-1957	S½-SE,Sec.9,T.58,R.17	natural ore
Vivian	1913-1947	SW-SE,Sec.20,T.59,R.14	taconite
Weed	1915-1918	NE-NW,Sec.25,T.59,R.15	
Wheeling	1931-1956	Lot 4 & SW-NW,Sec.1 & SE-NE,Sec.2, T.58,R.16	taconite
Williams	1895-1955	Lots 2 & 3,Sec.2,T.58,R.16	taconite
Yawkey	1907-1963	SE-SW,Sec.9,T.58,R.17	
Zenith	1892-1964	N½-SE,Sec.27,T.63,R.12	

SOURCE: University of Minnesota, Bulletin, Mining Directory Issue Wm. Tretheway. Minnesota. 1974.

Appendix B. Inactive Mines and Types of Leases Within the Study Area.

MINE	DATES OF SHIPMENT[a]	LOCATION	AVAILABLE ORE (metric tons)	LEASE
Alice	1928-1957	Lot 2,Sec.6,T.57,R.17	5,589	
Bangor	1910-1918	Lot 5,Sec.1,T.58,R.16 Lot 6,Sec.6,T.58,R.15	2,297,147	
Brunt	1905-1964	N½-NE,SW-NE,NW-SE,Sec.10,T.58,R.18	1,533,294	
Corsica	1901-1967	S½-NE,NE-SW,N½-SE,SW-SW,Sec.18,T.58,R.16	431,077	
Donora	no shipments	S½-NW,W½-SW,NE¼SW,Sec.27,S½-NE,NE-SE,Sec.28,T.59,R.15	716,808	
Embarrass	1944-1967	Lot 4,5,6,NE-SW,Sec.5,Lot 1,10,11,12,Sec.6,T.58,R.15	1,749,891	
Enterprise	1952-1961	SW-NW,Sec.5,T.58,R.17	23,417	
Fayal	1897-1965	SW-NE,Lot 3,S½-NW,E½-SW,NW-SW,NW-SE,Sec.5,S½-NE,Sec.6,T.57,R.17	149,900	taconite
Fowler	1907-1922	Lot 2,Sec.3,T.58,R.15	62,136	
Gilbert	1907-1973	S½,NE¼ & SE,diag½ of SE-NW,Sec.26,T.58,R.17	141,333	
Graham	1913-1957	NE-SW,SW-SW,Sec.21,T.59,R.14	19,090	
Hector	1893-1953	SW-NE,Sec.1,T.58,R.16	44,444	
Higgins No. 2	1904-1973	SW-NE,S½-NW,Sec.4,T.58,R.17	144,853	
Hobart	1906-1969	SE-NW,Sec.25,T.58,R.17	70,800	
Hull-Nelson	1901-1969	Lots 1 & 2,Sec.31,T.58,R.17	48,177	taconite
Iroquois	1903-1964	E½-NW,Sec.10,T.58,R.18	75,081	
Leonidas	1908-1969	E½,Sec.36,T.58,R.18	774,053	

Appendix B (cont'd.)

MINE	DATES OF SHIPMENT[a]	LOCATION	AVAILABLE ORE (metric tons)	LEASE
Lincoln	1902-1974	NW-SE, S½-SW, Sec.4, SE-SE, Sec.5, T.58, R.17	20,151	
Madrid	1912-1922	SE-NW, Sec.8, T.58, R.17	29,586	
Mary Ellen	1924-1962	E½-NE, N½-SE, Sec.9, T.58, R.16, NW-NW, N½-SW-NW, NE-NW, Sec.10, T.58, R.16	375,005	taconite
Miller-Mohawk	1905-1953	N½-SE, SW-SE, N½-SW, SE-SW, Sec.4, T.58, R.15	unknown	
Minorca	1902-1953	Lots 3 & 4, Sec.4, SE-NE, Lots 1 & 2, Sec.5, T.58, R.17	2,149	
Missabe Mt.	1893-1974	NE¼, Sec.8, T.58, R.17	454,664	
Monica	1909-1915	NE-NW, Sec.9, T.58, R.16	24,658	taconite
Morrow	1913-1938	Lot 8, Sec.4, T.57, R.17	16,000	
Mountain Iron	1892-1956	Lots 3, 4, S½-NW, N½-SW, SW-SW, Sec.3, SE-NE, NE-SE, Sec.4, T.58, R.18	20,811	
Norman	1894-1963	NE-SW, Sec.9, T.58, R.17.	9,066	
Pearsall	1958-1962	W½-NE, Sec.7, T.57, R.17	68,068	taconite
Perkins Annex	1941	SW-NW, Sec.26, T.59, R.15	93,422	
Petit	1902-1969	NW-NW, Sec.25, T.58, R.17	121,925	
Pioneer	1888-1967	SW½, Sec.27, T.63, R.12	5,544,156	
Schley	1910-1969	SW-NW, Sec.25, T.58, R.17	302,888	
Security	1961-1965	SW-SW, Sec.5, NW-NW, Sec.8, S.800 ft. SE-SE, Sec.6, T.57, R.17	705,879	
Sliver	1908-1960	Lot 2, Sec.5, T.58½, R.17	6,685	

Appendix B (cont'd.)

MINE	DATES OF SHIPMENT[a]	LOCATION	AVAILABLE ORE (metric tons)	LEASE
Spruce	1894-1965	W½-NE, E½-NW, SW¼, W½-SE, Sec. 31, T. 58, R. 17 and W½-NW, Sec. 6, T. 57, R. 17	825,372	
Stephars	1903-1972	S½-SW, SE-SE, Sec. 23, S½-NE-SW, S½-SW, Sec. 24, W½-NW, NW-SW, Sec. 25, N½-NW, SE-NW, NE¼, N½-SE, Sec. 26, T. 59, R. 15	2,923,683	
Troy	1903-1962	E½-NE, Sec. 7, T. 57, R. 17	55,208	
Wacootah	1906-1964	SW-SW, Sec. 2, SE-SW, S½-SE, Sec. 3, NW-NW, Sec. 11, T. 58, R. 18	37,414	
Wentworth No. 1	1956-1915	SE-SW, Sec. 21, T. 59, R. 14	5,706	
Wentworth No. 2	1953-1956	SW-NE, NW-SE, Sec. 21, T. 59, R. 14	12,793	
Wills	1902-1918	W½-NW, Sec. 17, NE-NE, Sec. 18, T. 58, R. 16	35,775	taconite
Wisstar	1918-1960	NE-NW, Sec. 17, T. 58, R. 16	2,808	taconite
Wyoming	1943-1973	S½-SW-SE, Sec. 4, N½-NE, Sec. 9, T. 58, R. 17	103,244	

SOURCE: University of Minnesota Bulletin, Mining Directory Issue Wm. Tretheway. Minnesota, 1974.

[a]Dates of operation indicate life of mine but do not necessarily indicate that the shipments were made consecutively from date of opening to date of last shipment.

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