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EXTRACTION AND BENEFICIATION OF ORES AND MINERALS

VOLUME 3

IRON

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DISCLAIMER AND ACKNOWLEDGEMENTS

This document was prepared by the U.S. Environmental Protection Agency (EPA). The mention of company or product names is not to be considered an endorsement by the U.S. Government or the EPA.

This Technical Resource Document consists of two sections. The first section is EPA's Profile of the iron industry; the remaining section is a Site Visit Report from a site visit conducted by EPA. The Profile Section was distributed for review to the U.S. Department of the Interior's (DOI's) Bureau of Mines, the Western Governors' Association, the Interstate Mining Compact Commission, the American Mining Congress (AMC), the Mineral Policy Center, the National Audubon Society, and Public Interest Groups. Summaries of the comments and EPA's responses are presented as an appendix to the Profile Section. The Site Visit Section was reviewed by individual company, state, and Federal representatives who participated in the site visit. Comments and EPA responses are included as Appendices to the specific Site Visit Section. EPA is grateful to all individuals who took the time to review sections of this Technical Resource Document.

The use of the terms "extraction," "beneficiation," and "mineral processing" in this document is not intended to classify any waste streams for the purposes of regulatory interpretation or application. Rather, these terms are used in the context of common industry terminology.

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1.0 MINING INDUSTRY PROFILE: IRON

1.1 INTRODUCTION

This Industry Profile presents the results of the Environmental Protection Agency's (EPA's) research into the domestic iron mining industry and is one of a series of profiles of major mining sectors. Additional profiles describe lead/zinc mining, copper mining, gold mining, and several industrial mineral sectors, as presented in the current literature. EPA prepared these profiles to enhance and update its understanding of the mining industry and to support mining program development by the states. EPA believes the profiles represent current environmental management practices as described in the literature.

Each profile addresses extraction and beneficiation of ores. The scope of RCRA as it applies to mining waste was amended in 1980 when Congress passed the Bevill Amendment, Section 3001(b)(3)(A). The Bevill amendment states that "solid waste from the extraction, beneficiation, and processing of ores and minerals" is excluded from the definition of hazardous waste under Subtitle C of RCRA. The exemption was conditional upon EPA's completion of studies required by RCRA § 8002(f) and (p) on the environmental and health consequences of the disposal and use of these wastes and a subsequent "regulatory determination" that such regulation was necessary. EPA separated their study of extraction and beneficiation wastes from processing wastes. EPA submitted the initial results of these studies in the 1985 *Report to Congress: Wastes from the Extraction and Beneficiation of Metallic Ores, Phosphate Rock, Asbestos, Overburden from Uranium Mining and Oil Shale* (U.S. EPA 1985). In July of 1986, EPA made a regulatory determination that regulation of extraction and beneficiation wastes under Subtitle C was not warranted 51 FR 24496; July 3, 1986). EPA concluded that Subtitle C controls were unnecessary and found that a wide variety of existing Federal and State programs already addressed many of the risks posed by extraction and beneficiation wastes. Instead of regulating extraction and beneficiation wastes as hazardous wastes under Subtitle C, EPA indicated that these wastes should be controlled under Subtitle D of RCRA.

EPA reported their initial findings on wastes from mineral processing from the studies required by the Bevill Amendment in the 1990 *Report to Congress: Special Wastes from Mineral Processing* (U.S. EPA 1990). This report covered 20 specific mineral processing wastes. In June 1991, EPA issued a regulatory determination (56 FR 27300) stating that regulation of these 20 mineral processing wastes as hazardous wastes under RCRA Subtitle C is inappropriate or infeasible. Eighteen of the wastes (including two related to the iron industry, iron blast furnace slag and air pollution control dust/sludge from iron blast furnaces) are now addressed similar to extraction and beneficiation wastes, and are subject to applicable state requirements. The remaining two wastes (phosphogypsum and phosphoric acid process waste water) were evaluated under the authority of the Toxic Substances Control Act (TSCA) to investigate pollution prevention alternatives. The Agency has not yet determined what steps it should take regarding these two wastestreams. Any mineral processing waste not specifically included in this list of 20 wastes no longer qualifies for the exclusion (54 FR 36592). Due to the timing of this decision and the limited number of iron industry wastes at issue, iron processing wastes are not addressed in this profile.

In addition to preparing profiles, EPA has undertaken a variety of activities to support State mine waste programs. These activities include visits to a number of mine sites (including the site described in Section 2 of this document); compilation of data from State regulatory agencies on waste characteristics, releases, and environmental effects; preparing summaries of mining-related sites on the National Priorities List (NPL); and examining specific waste management practices and technologies. EPA has also conducted studies of state mining-related regulatory programs and their implementation.

The purpose of this report is to provide additional information on the domestic iron mining industry. The report describes iron ore extraction and beneficiation operations with specific reference to the wastes and materials associated with these operations. The report is based on literature reviews and on comments received on earlier drafts. This report complements, but was developed independently of, other Agency activities, including those described above.

This report briefly characterizes the geology of iron ores and the economics of the industry. Following this discussion is a review of iron ore extraction and beneficiation methods; this section provides the context for descriptions of wastes and materials managed by the industry, as well as a discussion of the potential environmental effects that may result from iron mining. The report concludes with a description of the current regulatory programs that apply to the iron mining industry as implemented by EPA, Federal land management agencies, and selected States.

1.2 ECONOMIC CHARACTERIZATION OF THE INDUSTRY

The total quantity of usable iron ore product shipped from mines in 1991 is estimated to be 52.8 million lt[1], valued at $1.7 billion. Of the total 1991 domestic production, 1.97 million lt of iron product (4 percent) were exported. The United States imported 12.9 million lt of usable iron ore in 1991 for beneficiation and processing. According to the U.S. Bureau of Mines "usable" iron ore implies that less than 5 percent of the material is made up of manganese (U.S. DOI, Bureau of Mines 1991a).

The total amount of material moved at surface iron ore mines in 1988 was 296 million lt. This was made up of 180 million lt of crude ore and 116 million lt of waste material. Similar information concerning the only operating underground mine, located in Missouri, was withheld by the Bureau of Mines to protect company proprietary data. Typically, approximately 6 lt of material are moved at an iron mine to produce 1 lt of marketable iron product (U.S. DOI, Bureau of Mines 1991c).

In 1991, there were 20 companies operating 22 iron ore mines (21 open pit; 1 underground operation), 16 concentration plants, and 10 pelletizing plants. The primary iron ore producers are located in the States of Minnesota and Michigan, which account for about 99 percent of all domestic crude iron ore. In 1991, 7 mines operated by 4 companies produced approximately 87 percent of the industry's total output (U.S. DOI, Bureau of Mines 1992).

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[1] Industry tends to measure iron ore production in long tons (lt), while the United States Bureau of Mines used short tons (st) before 1989 and now uses metric tons (mt). At the industry's request, all production data in this report are presented in long tons (1 long ton is equivalent to 2,240 lbs).

Table 1-1. Partial List of Active Iron Mines in the United States

State	Mine Name	County	Owner(s) [Operator]	Commodities Produced	Iron Ore Production 1990 (million lt of pellets)	Ore Grade (per ton ore)
MI	Empire Mine	Marquette	Inland Steel (40%) LTV Steel (25%) Cleveland-Cliffs (25%) Wheeling Pittsburgh Steel Corp. (10%) [Empire Iron Mining Partnership]	Iron Ore Pellets	8.0	Fe - 31.5%
MI	Tilden Mine	Marquette	Algoma Steel Corp. (50%) Cleveland-Cliffs (33.3%) Stelco Inc. (16.7%) [Cleveland-Cliffs Iron Co.]	Iron Ore Pellets	2.7	Fe - 33.3%
MN	Cyprus Northshore	St. Louis	Cyprus Minerals Co. (100%) [Cyprus Northshore Mining Corp.]	Iron Ore Pellets	4.1	Magnetic Fe - 24%
MN	Eveleth Mines	St. Louis	Arnco, Inc. (35.1%) Rouge Steel Co. (31.7%) Oglebay Norton Co. (18.5%) Stelco Inc. (14.7%) [Oglebay Norton Taconite Co.]	Iron Ore Pellets	6.1	Magnetic Fe - 24%
MN	Hibbing Taconite	St. Louis	Bethlehem Steel Corp. (70.3%) Cleveland-Cliffs (15%) Stelco Inc. (14.7%) [Hibbing Taconite Co.]	Iron Ore Pellets	9.0	Fe - 30.7%

Source: Gardiner 1990; Michaelis 1990/1991; U.S. DOI, Bureau of Mines 1991b

Table 1-1. Partial List of Active Iron Mines in the United States (continued)

State	Mine Name	County	Owner(s) [Operator]	Commodities Produced	Iron Ore Production 1990 (million lt of pellets)	Ore Grade (per ton ore)
MN	LTV Steel Mine	St. Louis	LTV Steel Company (100%) [LTV Steel Mining Co.]	Iron Ore Pellets	8.0	Fe - 32% Magnetic Fe - 24.5%
MN	Not Specified	St. Louis	Inland Steel Mining Co.	Iron Ore Pellets	greater than 1	Fe - 30.9%
MN	McKinley Extension	St. Louis	LTV Steel Co.	Unagglomerated Concentrate	2.0	N/A
MN	Minntac Mine	St. Louis	USX Corporation (100%) [USS]	Iron Ore Pellets	16.2	Fe - 21%
MN	Minorca Mine	St. Louis	Inland Steel Company (100%) [Inland Steel Mining Company]	Iron Ore Pellets	2.5	Fe - 21%
MN	National Steel Pellet Mine	St. Louis	National Steel Corp. (100%) [National Steel Pellet Company]	Iron Ore Pellets	4.6	Fe - 31%
MO	Pea Ridge	Washington	Big River Minerals Corp. (100%) [Pea Ridge Iron Ore Co. Inc.]	Iron Ore Pellets Unagglomerated Concentrate	1.05 0.15	Fe - 57%
UT	Mountain Lion Mine	Iron	Geneva Steel Corporation [Gilbert Development Inc.]	Iron Ore Pellets	N/A	N/A
WY	Iron Mountain	Albany	[Simons Associates]	Iron Ore Pellets	0.31 (1988)	N/A

Source: Gardiner 1990; Michaelis 1990/1991; U.S. DOI, Bureau of Mines 1991b is partial list of active iron mines in the United States in 1990. Information provided includes mine names, owners, operators, commodities produced, and 1990 iron pellet production data (Gardiner 1990; Michaelis 1990/1991; U.S. DOI, Bureau of Mines 1991b).

Operation capacities tend to be in the range of 1 to 10 million long tons of product per year (ltpy). A few mines, however, produce less than 100,000 ltpy (Weiss 1985).

Employment at iron mines and mills was approximately 7,300 in 1991. Of the total number of workers, about 97 percent are traditionally employed in mines and mills in Minnesota and Michigan alone (U.S. DOI, Bureau of Mines 1988b, 1991a, 1992).

Nearly 98 percent of the demand for iron ore comes from the steel manufacturing industry. Iron is also a component in the manufacture of cement and heavy-media materials. Among the 22 mines producing iron ore, most larger operations produce material for the steel manufacturers. Mines producing for cement plants tend to be smaller operations located outside Michigan and Minnesota (U.S. DOI, Bureau of Mines 1988b, 1991a, 1992).

Approximately 97 percent of all usable ore for the production of iron and steel is now sold in the form of agglomerated pellets. The remaining 3 percent of higher grade usable ore (wash ores) is sold in original form directly to blast furnace operations or in the form of other agglomerated products. On average, pellets are 3/8 inch to 1/2 inch in diameter and are composed of 63.4 percent iron and approximately 5 percent silica (U.S. DOI, Bureau of Mines 1988b, 1992b). Other pellet constituents may include phosphorus, manganese, magnesium, lime, sulfur, and alumina (American Iron Ore Association 1990).

Iron pellets are becoming more widely traded on the open market as world trade affects the industry according to the Iron Mining Association of Minnesota. During the 1980's, global competition made the iron industry more responsive to its market. Foreign competition began to deliver steel products at a lower cost than domestic sources on the Great Lakes. This prompted the domestic iron and steel industries to increase productivity through modernization, produce a higher quality product, and lower overall costs. In the past, each mine produced a standard iron pellet as a product. Now, mines are producing pellet products that fit the individual needs of blast furnace operations.

1.3 ORE CHARACTERIZATION

Iron is an abundant element in the earth's crust averaging from 2 to 3 percent in sedimentary rocks to 8.5 percent in basalt and gabbro. Because iron is present in many areas, it is of relatively low value and thus a deposit must have a high percentage of metal to be considered ore grade. Typically, a deposit must contain at least 25 percent iron to be considered economically recoverable. This percentage can be lower, however, if the ore exists in a large deposit and can be concentrated and transported inexpensively (Weiss 1985).

Over 300 minerals contain iron but five are the primary sources of iron-ore minerals: magnetite (Fe_3O_4), hematite (Fe_2O_3), goethite ($Fe_2O_3H_2O$), siderite ($FeCO_3$), pyrite (FeS_2). The first three are of major importance because of their occurrence in large economically minable deposits (U.S. DOI, Geological Survey 1973).

Iron ore mineral deposits are widely dispersed in the continental United States and form in a wide variety of geologic environments, including sedimentary, metamorphic, and igneous rock formations. Iron ore deposits in the United States are formed by three geologic processes:

- Direct sedimentation forming bedded sedimentary deposits
- Igneous activity forming segregation or replacement deposits
- Enrichment due to surface and near surface weathering (U.S. EPA 1985a).

Table 1-2

Table 2. Geographic Locations and Principal Iron Minerals of Three Types of Iron Ore Deposits

Geological Type	Location	Principal Iron Mineral	Average Iron Content (%)
SEDIMENTARY DEPOSITS			
Banded iron-formation	Lake Superior • Marquette and Menominee, Michigan • Mesabi, Vermillion, Cuyuna, Minnesota	Magnetite Hematite Siderite Iron silicates	33[1]
Ironstones	Central Alabama to Central New York	Limonite Hematite Siderite Chamosite	30
IGNEOUS ACTIVITY			
Magmatic Segregations	New York Missouri	Titaniferous Magnetite Ilmenite Iron silicates	65
Pyrometasomatic	Iron Springs, Utah	Magnetite	45
SURFACE OR NEAR-SURFACE WEATHERING			
Secondary enrichments of low-grade iron deposits	Lake Superior region Texas	Limonite Hematite Siderite	55

[1] Although this figure is cited in the literature, it is significantly different than known ore grades at specific iron ore mines.

Source: U.S. DOI, Geological Survey 1973 indicates the geographic locations of these types of iron ore deposits as well as the principal iron-ore minerals in each (U.S. DOI, Geological Survey 1973). Deposits formed by direct sedimentation may contain significant amounts of manganese; these manganiferous iron ores contain 2 to 10 percent manganese (Ridge 1968). Iron deposits related to igneous activity, surface and near-surface enrichment, and iron-rich placer deposits may contain trace quantities of materials such as aluminum, antimony, arsenic, beryllium, cadmium, chromium, cobalt, copper, lead, manganese, nickel, selenium, silver, sulfur, titanium, and zinc. Historically, gold, silver, copper, and cobalt have been recovered from such iron ore in Pennsylvania, and titanium has been recovered from iron deposits in New York (U.S. DOI, Geological Survey 1973).

1.3.1 Bedded Sedimentary Deposits

Bedded sedimentary iron ore deposits are thought to occur as a result of mineral precipitation from solutions present during the Precambrian period (2.6 to 1.8 billion years ago). The largest bedded sedimentary iron ore deposits in the United States are found in banded iron-formations and ironstones, which are more fully described below. Other historically mined types of bedded deposits, which are not currently mined include bog-iron deposits that are accumulations of iron oxides in swampy areas or shallow lakes; deposits of siderite that occur as thin layers in coal deposits are referred to as "black band" or "clay band"; and "black sands" deposits (U.S. DOI, Geological Survey 1973).

1.3.1.1 Banded Iron-Formations

Banded iron-formations were created when solutions of iron oxides and silica precipitated in alternating layers. The iron oxides form hematite and/or magnetite; the silica forms chert. Iron and silica were supplied by volcanic activity common during the Precambrian period. The deposits accumulated to form distinctive gray (iron oxides) and red bands, hence the name "banded iron." Banded iron deposits constitute the largest source of iron ore now being mined in the United States and the world. Deposits may cover thousands of square kilometers and be hundreds of feet deep. In the United States, banded iron-formations in the Lake Superior region dominate production and hold the largest reserves (U.S. DOI, Geological Survey 1973).

Iron content in these deposits is in the range of 25 to 40 percent. In some formations, the iron is in the form of carbonates (siderite with manganese, magnesium, and calcium) or silicate (greenolite, minnesotaite, and stilpnomelane) and, rarely, in the form of sulfide (pyrite). Chemically, these iron formations are marked by low contents of alumina (Al), sodium (Na), potassium (K), and other less abundant elements. Iron and silica generally dominate, although in the Cuyuna district of Minnesota the manganese content can be several percent (U.S. DOI, Geological Survey 1973; Ridge 1968).

1.3.1.2 Ironstone

Ironstone formed as iron-rich waters permeated shallow, unconsolidated sediments. Iron either occurs with or replaces carbonates in the sediments. The source of the iron is intense weathering of continental crust. Ironstone is much younger (150 to 450 million years) than banded iron deposits, occurs in smaller units, and is not found inter-layered with chert. The primary ironstone deposit in the United States is found in the Appalachian Mountain belt from New York to Alabama (U.S. DOI, Geological Survey 1973).

Ironstones have an iron content from 20 to 40 percent. There is a great variety of ironstones, but the most common type of ironstone mined for iron ore is a thick-bedded rock consisting of small pellets (ooliths) of limonite, hematite, or chamosite in a matrix of chamosite, siderite, or calcite. Grains of quartz and fossil fragments form the cores of the ooliths and are dispersed in the matrix. Phosphate minerals may also be present (U.S. DOI, Geological Survey 1973).

1.3.2 Igneous Activity

Iron ore deposits of igneous origin are formed as a result of magmatic segregation of iron-bearing minerals. Minable deposits of igneous iron ore occur in Missouri at Pea Ridge and Pilot Knob. These deposits occur as veins and tabular replacement bodies of magnetite and hematite in the surrounding Precambrian rocks. Historically, this area was more active; however, only one iron ore mine is currently active in Missouri. The iron content is generally about 20 percent, but it can be as high as 60 percent. Most of the iron ore minerals occur as ilmenite, magnetite, or hematite.

1.3.3 Surface And Near-Surface Weathering

Iron-ore deposits were formed by surface or near surface enrichment as less resistant minerals were removed. This type of deposit occurs in the Lake Superior region. Such deposits were the primary source of iron ore before methods to beneficiate the harder ores were developed. Chemical and physical weathering by soil forming processes of pre-existing iron-bearing minerals (such as siderite or glauconite) resulted in progressive concentration of iron oxides to form iron-rich deposits. Iron contents vary between 50 and 60 percent (U.S. DOI, Geological Survey 1973). Hematite is by far the dominant mineral on the Mesabi Iron Range (Lake Superior District) in Minnesota, other than magnetite, which is the host iron-bearing rock for much of the Mesabi Range (East and Central) according to the Iron Mining Association of Minnesota.

1.4 IRON MINING PRACTICES

Extraction, beneficiation, and processing of iron ore produces iron or steel. "Extraction" is defined as removing ore material from a deposit and encompasses all activities prior to beneficiation. "Beneficiation" of iron includes concentration, generally by physical removal of unwanted gangue; also considered beneficiation is the regulation of product size, or other steps such as agglomeration to improve its chemical or physical characteristics prior to processing. Processing of the concentrated product into iron or steel typically involves the use of pyrometallurgical techniques (U.S. DOI, Bureau of Mines 1968; United States Steel 1973). As discussed in the introduction, processing operations are beyond the purview of this paper.

Historically, most iron ore was simply crushed and shipped directly to a blast furnace. Currently, some ores are high enough in iron content (greater than 50 percent) to be sent directly to furnaces without beneficiation activities other than crushing and washing. Most ores extracted today, however, must undergo a number of beneficiation procedures to upgrade the iron content and prepare the concentrate for the blast furnace. Technological advancements at blast furnace operations require ore feed of a specific size, structure, and chemical make-up for optimum efficiency (Weiss 1985).

1.4.1 Extraction Methods

Iron is mined almost exclusively in surface operations. The most predominant surface mining methods used to extract iron ore are open-pit and open-cut methods. However, there is currently one operating underground iron mine, located in Missouri (five were in operation in Missouri in 1985). The decision to employ underground or surface mining techniques is dependent on the proximity of the ore body to the surface (U.S. DOI, Bureau of Mines 1983).

Historically, underground mining methods, including caving and stopping, were commonly used to extract iron ores. Between 1882 and 1978, approximately 100 underground mines operated in the West Menominee Range of northern Michigan (U.S. DOI, Bureau of Mines 1983).

Surface mining methods are designed to extract ore from surface deposits. Overburden, the soil and rock material that overlies the mine area, is removed to expose the ore deposit. The ore bench is drilled, blasted, and hauled to a plant for beneficiation. Overburden may be continually removed during the life of the mine as the highwall is cut back to permit deepening of the pit. Open-pit and open-cut mining are considered to be the least expensive extraction techniques (United States Steel 1973).

Production drilling is conducted with mechanized drills, specific for each mining method. The chief objective of drilling operations is to create a hole of suitable diameter, depth, and direction in rock for explosives to be placed for blasting activities. At facilities operating in colder environments, salt brine may be added to drilling fluids to prevent freezing of the material in permanently frozen host rock (U.S. EPA 1982).

The main requirement for an explosive to be used in mine blasting is the ability to achieve complete combustion without an external oxygen supply. In the past, explosives used in blasting were comprised of nitroglycerine, carbonaceous material, and an oxidizing agent. Today, the most common explosives used are mixtures of ammonium nitrate fertilizer and fuel oil (called ANFO). The explosive is detonated by a high-explosive blasting cap and/or primer. In other instances, emulsion or gel explosive cartridges may be used. The object of blasting is to expose the ore body for extraction or to create adits (horizontal passages) or shafts in rock formations that can be used to access the ore body during underground mining. Blasting is also used to break up ore in both surface and underground operations (U.S. EPA 1982).

The mining of taconite, a tough and abrasive low-grade ore (ranging from 40 to 60 percent silica and 17 to 30 percent iron) common to Minnesota and Michigan, is especially difficult because of the extreme hardness of the ore. Because of this hardness, additional drilling, blasting, crushing, and grinding are often required to extract the ore.

Overburden and stripping ratios are important in determining whether a deposit will be mined. The stripping ratio describes the unit of overburden that must be removed for each unit of crude ore mined. Stripping ratios increase with the quality of the ore being mined and cost factors related to beneficiation and transportation. These ratios may be as high as 7:1 (for high-grade wash ores) or as low as 0.5:1 (for low-grade taconite ores) (United States Steel 1973). A summary of quantities of material handled, ore treated, and marketable product generated at iron mines in 1988 is presented in Table 1-3.

Other earthen materials associated with mining may include mine development rock. "Mine

Table 1-3. Ore Treated to Product Ratios and Material Handled to Product Ratios for U.S. Surface Iron Ore Mines, in Thousand Long Tons, 1988

Material/Ratio	Quantity (in thousand long tons)/Ratio
Material Handled	331,000
Ore Treated	218,000
Marketable Product	55,100
Ore Treated to Marketable Product Ratio	4.0:1
Material Handled to Marketable Product Ratio	6.0:1

Source: U.S. DOI, Bureau of Mines 1991c

development rock" is the material removed while exploiting the ore body through underground mining. Typically, the term "mine development rock" excludes material removed at surface operations (U.S. DOI, Bureau of Mines 1968). Therefore, waste in the form of mine development rock is associated with historic underground iron mines.

Materials generated as a result of open-pit mining include overburden, waste rock, and mine water containing suspended solids and dissolved materials. Other wastes may include small quantities of oil and grease spilled during extraction. Mine water will contain dissolved or suspended constituents similar to those found in the ore body itself. These may include traces of aluminum, antimony, arsenic, beryllium, cadmium, chromium, copper, manganese, nickel, selenium, silver, sulfur, titanium, and zinc (U.S. DOI, Geological Survey 1973).

1.4.2 Beneficiation Methods

"Beneficiation," defined by 40 Code of Federal Regulations (CFR) 261.4, means the following as applied to iron ore: milling (crushing and grinding); washing; filtration; sorting; sizing; gravity concentration; magnetic separation; flotation; and agglomeration (pelletizing, sintering, briquetting, or nodulizing). Although the literature suggests that all these methods have been used to beneficiate iron ore, information provided by members of the American Iron Ore Association indicates that milling and magnetic separation are the most common methods used. Gravity concentration is seldom used at existing U.S. facilities. Flotation is primarily used to upgrade concentrates from magnetic separation by reducing the silica content of the concentrate.

Most beneficiation operations will result in the production of three materials: a concentrate; a middling or very low-grade concentrate, which is either reprocessed (in modern plants) or stockpiled; and a tailing (waste), which is discarded. Table 1-4 compares the percentage of total domestic ore treated by each iron ore beneficiation method in 1990 (Ryan 1991). A more detailed description of each follows.

Table 1-4. Beneficiation Methods Commonly Associated With Iron Ores and the Percentage of Ore Treated by Each Method, 1990

Beneficiation Method	Percentage of Iron Ore Treated
Magnetic Separation	41.6
Flotation following Magnetic Separation	51.2
Subtotal	92.8
Flotation	6.3
Gravity Concentration	< 1[1]
Total	100

[1] This operation was to be shut down in 1992.

Source: Ryan 1991

Table 1-5. Water Usage of Selected Iron Ore Operations and the Sources of the Water Used

Facility Name	Average Water Usage	Percent From Tailings Thickener Overflow	Percent From Tailings Basin	Percent From Mine Water Pumpout	Percent From Outside Sources
LTV Steel Mining Co.	150,000 gpm	75	20	0	5
Eveleth Mines	174,000 gpm	94	4	0	2
Minntac Mine	360,000 gpm	90	7	0	3
Minorca Mine	90,000 gpm	80	N/A	3	7

Source: Learmont 1985

Before describing beneficiation methods/practices, it should be noted that the iron ore industry uses large amounts of water. The beneficiation of iron ore typically occurs in a liquid medium. In addition, many pollution abatement devices use water to control dust emissions. At a given facility, these techniques may require between 600 and 7,000 gallons of water per ton of iron concentrate produced, depending on the specific beneficiation methods used. Table 1-5 presents a summary of the average water usage at four iron ore operations. The table also includes a breakdown of the sources of the water used; much of the water is recycled from plant operations (Learmont 1985). Industry has indicated that an average of 95 percent of the water appropriated by iron ore facilities is recirculated and reused according to the Iron Mining Association of Minnesota.

In 1984, the iron ore industry used a total of 652 billion gallons of water, down from a high of 849 billion gallons in 1973. Of the total water usage in 1984, approximately 584 billion gallons (90 percent) were recirculated water; 68 billion gallons were from new water sources. Sources of recycled water included tailings thickener overflow and tailings impoundments. New water was taken primarily from lakes and reservoirs (77 percent), rivers and streams (12 percent), mine water (10 percent), and ground water (<1 percent). New water replaces 11 billion gallons of water (2 percent) consumed in beneficiation processes and 57 billion gallons (8 percent) discharged offsite (U.S. DOI, Bureau of Mines 1988c).

The amount of water used to produce one unit (one lt of crude ore) has increased considerably. In 1954, approximately 500 gallons of water were employed to produce 1 unit; in 1973, 3,480 gallons of water were needed per unit. By 1984, this number had risen to 3,700 gallons per unit (U.S. DOI, Bureau of Mines 1988c). This increase was due to the industry's changeover from "natural" direct shipping ores to taconite mining. Additional water is needed in milling and magnetic separation of taconite ore according to the Iron Mining Association of Minnesota and the American Iron Ore Association.

1.4.2.1 Milling

Beneficiation begins with the milling of extracted ore in preparation for further activities to recover iron values. Milling operations are designed to produce uniform size particles by crushing, grinding, and wet or dry classification. The capital investment and operation costs of milling equipment are high. For this reason, economics plays a large part in determining the use of comminution equipment and the degree of crushing and grinding performed to prepare ore for further beneficiation. Other factors considered in determining the degree of milling include the value concentration of the ore, its mineralogy, hardness, and moisture content. Milling procedures vary widely both between mills and within individual mills depending on these variables.

Milling is a multistaged process and may use dry or wet ore feed. Typically, primary crushing and screening take place at the mine site. Primary crushing is accomplished by using gyratory and cone crushers (Weiss 1985). Primary crushing yields chunks of ore ranging in size from 6 to 10 inches. Oversize material is passed through additional crushers and classifiers to achieve the desired particle size. The ore is then crushed and sized at a secondary milling facility (Weiss 1985).

Secondary milling (comminution) further reduces particle size and prepares the ore for beneficiation processes that require finely ground ore feed. The product resulting from this additional crushing is usually less than 1 inch (1/2 to 3/4 inches). Secondary crushing, if necessary and economical, is accomplished by using standard cone crushers followed by short head cone crushers. Gyratory crushers may also be used (Weiss 1985).

Subsequent fine grinding further reduces the ore particles to the consistency of fine powder (325 mesh, 0.0017 inches, 0.44 microns). The choice of grinding circuit is based on the density and hardness of the ore to be ground. Although most taconite operations employ rod and/or mill grinding, a few facilities use autogenous or semi-autogenous grinding systems. Autogenous grinding uses coarse pieces of the ore itself as the grinding media in the mill. Semi-autogenous operations use metallic balls and/or rods to supplement the grinding action of the ore pieces. Autogenous grinding is best suited to weakly cemented ores containing some hard material (e.g., labrador specularite). The benefit of autogenous grinding is that it is less labor- and capital-intensive. Semi-autogenous grinding eliminates the need for a secondary crushing circuit. Rod and ball wear, the principal maintenance cost of traditional grinders, is also eliminated with this method (Weiss 1985).

Between each grinding unit, operation hydrocyclones are used to classify coarse and fine particles. Coarse particles are returned to the mill for further size reduction. Milled ore in the form of a slurry is pumped to the next beneficiation step. If the ore being milled is destined for flotation activities, chemical reagents used during the process may be added to the slurry at this time. To obtain a uniform product, many operations blend ores of several different grades, compositions, and sizes. The mixing of ore materials is typically accomplished through selective mining and hauling of ore.

1.4.2.2 Magnetic Separation

Magnetic separation is most commonly used to separate natural magnetic iron ore (magnetite) from a variety of less-magnetic or nonmagnetic material. Today, magnetic separation techniques are used to beneficiate over 90 percent of all domestic iron ore (See Table 1-4) (Ryan 1991). Between 20 and 35 percent of all the iron units being beneficiated in the United States today are lost to tailings because hematite is only weakly magnetic. According to the Bureau of Mines, techniques used-to-date to try to recover the hematite have proven uneconomic.

Magnetic separation may be conducted in either a dry or wet environment, although wet systems are more common. Magnetic separation operations can also be categorized as either low or high intensity. Low intensity separators use magnetic fields between 1,000 and 3,000 gauss. Low intensity techniques are normally used on magnetite ore as an inexpensive and effective separation method. This method is used to capture only highly magnetic material, such as magnetite. High intensity separators employ fields as strong as 20,000 gauss. This method is used to separate weakly magnetic iron minerals, such as hematite, from nonmagnetic or less magnetic gangue material. Other factors important in determining which type of magnetic separator system is used include particle size and the solids content of the ore slurry feed (Weiss 1985; United States Steel 1973).

Typically, magnetic separation involves three stages of separation: cobbing, cleaning/roughing, and finishing. Each stage may employ several drums in a series to increase separation efficiency. Each successive stage works on finer particles as a result of the removal of oversized particles in earlier separations. Cobbers work on larger particles (3/8 inch) and reject about 40 percent of the feed as tails.

Cleaners or scavengers work on particles in the range of 48 mesh and remove only 10 to 15 percent of the feed as tails. Finally, finishers work on ore particles less than 100 mesh and remove the remaining 5 percent of gangue (because of the highly concentrated nature of the feed at this point) (Weiss 1985).

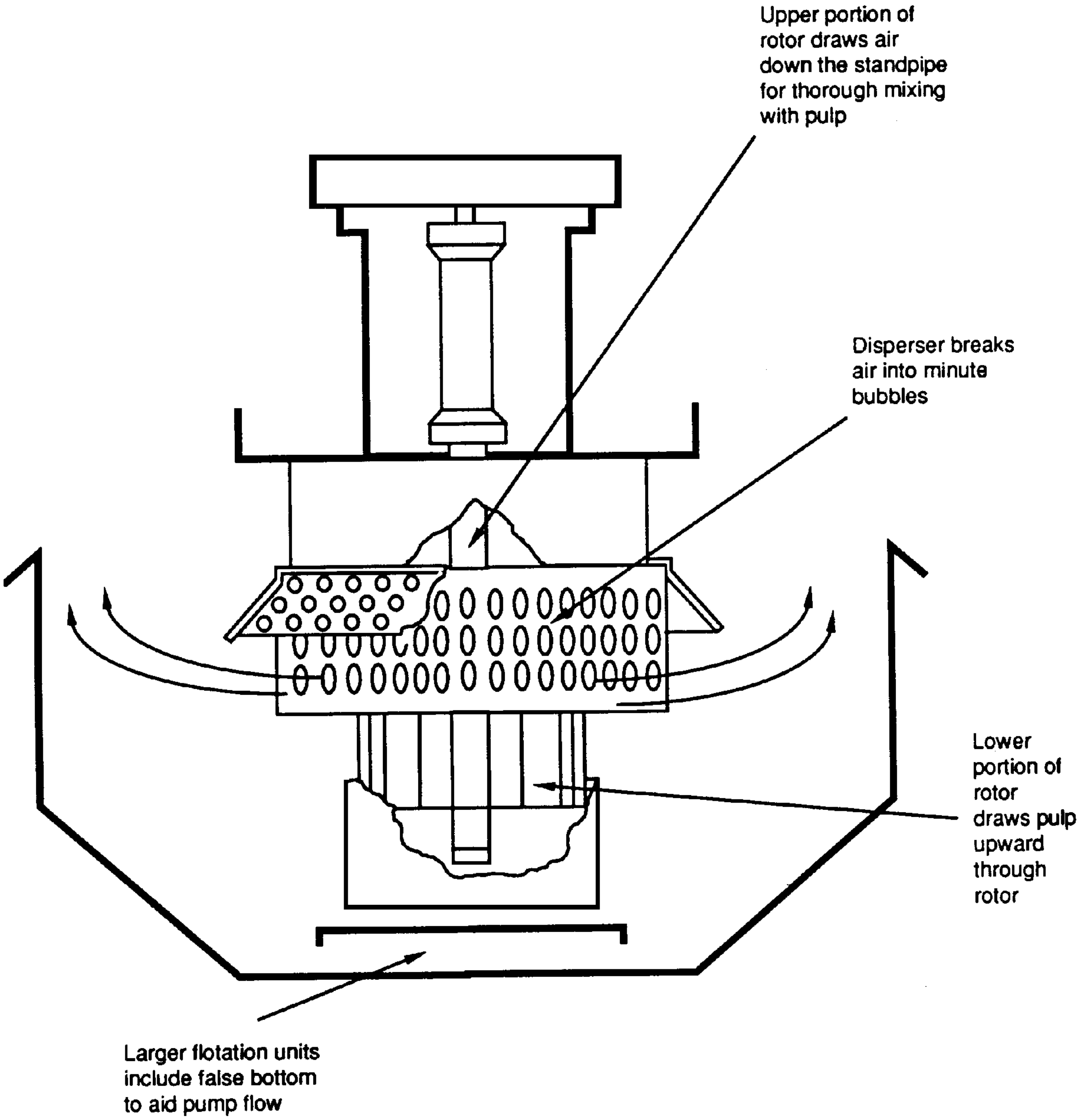


Figure 1-1. Cross-Section of a Typical Flotation Cell

(Source: Envirotech 1974)

Low intensity wet processes typically involve conveyors and rotary drum separators using permanent magnets and are primarily used on ore particles 3/8 inch in diameter or less. In this process, ore is fed by conveyor into the separator where magnetite particles are attracted and held to sides of the drum until they are carried out of the magnetic field and transferred to an appropriate concentrate receiver (see Figure 1-1). The nonmagnetic or less magnetic gangue material remains and is sent to a tailings pond. In some operations, several drums may be set up in series to obtain maximum recovery (United States Steel, 1973). Other mechanisms used include magnetic pulleys, induced roll separators, cross-belt separators, and ring-type separators. Low intensity dry separation is sometimes used in the cobbing stage of the separation process (Weiss 1985). A detailed description of these separator systems is provided in the Society of Mining Engineers' "Mineral Processing Handbook" (Weiss 1985).

High intensity wet separators produce high magnetic field gradients by using a matrix of shaped iron pieces that act as collection sites for paramagnetic particles. These shapes may include balls, rods, grooved plates, expanded metal, and fibers. A detailed description of several types of high intensity wet separators is provided by the Society of Mining Engineers' "Mineral Processing Handbook" (Weiss 1985).

The primary wastes from this type of operation are tailings made up of gangue in the form of coarse- and fine-grained particles, and waste water slurry in the case of wet separation. Particulate wastes from dry separation may also be slurried. Following separation of solids in a thickener or settling pond, solids are sent to a tailings impoundment and the liquid component can be recycled to the mill or discharged if water quality criteria are met.

1.4.2.3 Flotation

Flotation is a technique where particles of one mineral or group of minerals are made to adhere preferentially to air bubbles in the presence of a chemical reagent. This is achieved by using chemical reagents that preferentially react with the desired mineral. Several factors are important to the success of flotation activities. These include uniformity of particle size, use of reagents compatible with the mineral, and water conditions that will not interfere with the attachment of the reagents to the mineral or air bubbles (U.S. EPA 1982).

Today, flotation is primarily used to upgrade concentrates resulting from magnetic separation. Over 50 percent of all domestic iron ore is upgraded using this technique. Flotation, when used alone as a beneficiation method, accounts for approximately 6 percent of all ore treated (see Table 1-4) (Ryan 1991).

Chemical reagents of three main groups may be used in flotation. A description of the function of each group follows (Weiss 1985; U.S. EPA 1982):

- Collectors/Amines—Cause adherence between solid particles and air bubbles in a flotation cell.
- Frothers—Are used to stabilize air bubbles by reducing surface tension, thus allowing collection of valuable material by skimming from the top of the cell.
- Antifoams—React with particle surfaces in the flotation cell to keep materials from remaining in the froth. Instead, materials fall to the bottom as tailings.

Several factors are important when conditioning ore for flotation with chemical reagents. These include thorough mixing and dispersal of reagents through the pulp, repeated contact between the reagents and all of the relevant ore particles, and time for the development of contacts with the reagents and ore particles to produce the desired reactions (Fuerstenau 1970).

Reagents may be added in a number of forms including solid, immiscible liquid, emulsion, and solution in water. The concentration of reagents must be closely controlled during conditioning; adding more reagent than is required may retard the reaction and reduce efficiency (Fuerstenau 1970).

Figure 1-1 presents a cross section of a typical flotation cell. The current trend is toward the development of larger, more energy efficient flotation cells. A pulp containing milled ore, flotation reagents, and water is fed to flotation cells. Typically, 10 to 14 cells are arranged in a series from roughers to scavengers. Roughers are used to make a coarse separation of iron-bearing metallic minerals (values) from the gangue. Scavengers recover smaller quantities of remaining values from the pulp. The pulp moves from the rougher cells to the scavengers as values are removed. Concentrates recovered from the froth in the roughing and scavenging cells are sent to cleaning cells to produce the final iron-bearing metallic mineral concentrate (Fuerstenau 1970).

Iron-bearing metallic mineral flotation operations are of two main types: anionic and cationic. The difference between the two methods is related to which material (values or gangue) is floated and which sinks. This is determined by preliminary test results, weight relationships of the values and gangue, and the type of reagents used. In anionic flotation, fine-sized crystalline iron oxides, such as hematite or siderite, are floated away from siliceous gangue material such as quartz or chert. In cationic flotation, the silica material is floated and the value-bearing minerals are removed as underflow (Nummela and Iwasaki 1986).

Today, anionic flotation is not commonly used in North American operations. Three plants in Michigan (the Humboldt Mine, the Groveland Mine, and the Republic Mine) used anionic flotation techniques before shutting down because of the depletion of reserves or the reduction of demand for iron products (Nummela and Iwasaki 1986).

The Tilden Mine operation owned by the Cleveland-Cliffs Company is one of many facilities currently using cationic flotation as part of its iron ore beneficiation process (Nummela and Iwasaki 1986). Some of the reagents commonly used in the cationic flotation process are listed in Table 1-6 (Ryan 1991). The resulting upgraded concentrate may be reground and magnetically reconcentrated before agglomeration activities commence (Weiss 1985).

Table 1-6. Reagents Commonly Used In Iron Ore Flotation Activities [1]

Reagent Type	Chemical Composition	Producing Company
Frothers		
Methyl isobutyl Carbinol	Methyl isobutyl Carbinol	Shell
TX-4733	C4-18 alcohols, aldehydes, and esters; butyric acid; 2-ethylhexane	Nalco
DP-SC-79-139	Mixed aldehydes, alcohols, and esters	Sherex
Collectors/Amines		
Arosurf MG83A	1,3-propendiamine, N-[3-branched tridecyloxyl propyl] derivatives; acetic acid	Sherex
MG-580	1,3-propendiamine, N-[3-branched tridecyloxyl propyl] derivatives	Sherex
Antifoams		
7810	Polyglycol esters in hydrocarbon solvent	Nalco

[1] This list is not meant to be a full representation of all reagents used in the industry.

Source: Ryan 1991

The use of flotation techniques by operations such as the Minntac Mine has enabled the facility to produce pellets containing less than 4 percent silica (Strukell 1991). Lower silica content and higher iron concentrations in the pellets being produced result in an improved productivity and energy efficiency at blast furnaces (Iwasaki 1989). This may be particularly true at newly developed direct-reduction electric furnaces should the economics become favorable in the future. Such furnaces produce a direct-reduced iron product that can then be used as a feed to a steel producing electric furnace according to the American Iron Ore Association and the Iron Mining Association of Minnesota.

Wastes from the flotation cell are collected from the tailings overflow weir. Depending on the grade of the froth, it is recycled for further recovery of iron units or discharged as tails. Tailings contain remaining gangue, unrecovered iron minerals, chemical reagents, and process waste water. Generally, tailings proceed to a thickener prior to going to a tailings impoundment. The solids content of the slurry varies with each operation, ranging between 30 and 60 percent. After thickening, tailings may be pumped to an impoundment, solids may be recycled for further beneficiation to collect remaining values, and clarified water may be returned to the milling process. In the tailings pond, solids are settled out of the suspension and the liquid component may be recycled to the mill. It should be noted that the chemical reagents used in flotation generally adhere to the tailings particles and remain in the tailings impoundment.

1.4.2.4 Gravity Concentration

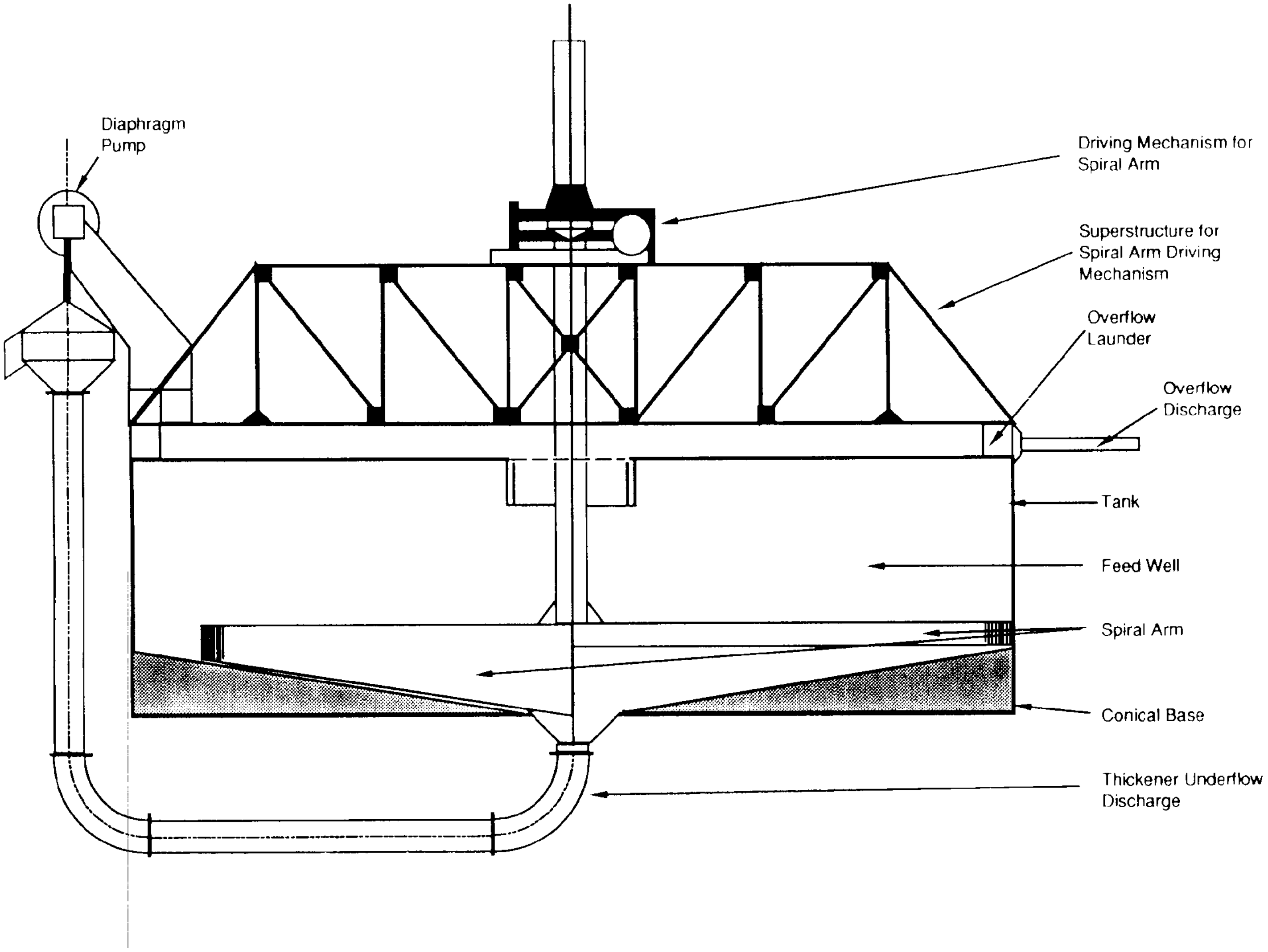
Although gravity concentration was once widely used in the beneficiation of iron ores, less than 1 percent of total domestic iron ore was beneficiated using this method by the early 1990s (see Table 1-4). The decline of this method is chiefly due to the low cost of employing modern magnetic separation techniques and the exhaustion of high-grade hematite iron ores of the Mesabi Range.

Gravity concentration is used to suspend and transport lighter gangue (nonmetallic or nonvaluable rock) away from the heavier valuable mineral. This separation process is based primarily on differences in the specific gravities of the materials and the size of the particles being separated. Values may be removed along with the gangue material (tailings) despite differences in density if the particle sizes vary. Because of this potential problem, particle sizes must be kept uniform with the use of classifiers (such as screens and hydrocyclones). Three gravity separation methods have historically been used for iron ore: washers, jigs, and heavy-media separators (Weiss 1985).

Wastes from gravity concentration are tailings made up of gangue in the form of coarse- and fine-grained particles and process water. This material is pumped as a slurry to a tailings pond. The solid content of the slurry varies with each operation, ranging between 30 and 60 percent. Following separation of solids in a tailings pond, tailings water can be recycled to the mill or discharged.

1.4.2.5 Thickening/Filtering

Thickeners (see Figure 1-2


Diaphragm Pump
Driving Mechanism for Spiral Arm
Superstructure for Spiral Arm Driving Mechanism
Overflow Launder
Overflow Discharge
Tank
Feed Well
Spiral Arm
Conical Base
Thickener Underflow Discharge

) are used to remove most of the liquid from slurried concentrates and waste slurries (tailings). Thickening techniques may be employed in two phases of iron ore production: concentrates are thickened to reduce moisture content and reclaim water before agglomeration, and slurried tailings are thickened to reclaim water. Facilities usually employ a number of thickeners concurrently.

Typically, iron ore operations use continuous thickeners equipped with a raking mechanism to remove solids. Several variations of rakes are commonly used in thickeners. When concentrates are being thickened, underflow from the thickener (concentrate) is collected and may be further treated in a vacuum filter. The filter removes most of the remaining water from the concentrate (Weiss 1985).

The liquid component removed during the thickening process may contain flotation reagents, and/or dissolved and suspended mineral products. The liquid is usually recycled to a holding pond to be reused at the mill. When concentrates are thickened, the solid material resulting from these operations is collected as a final concentrate for agglomeration and processing (Fuerstenau 1970). Thickened tailings are discharged to a tailings impoundment.

1.4.2.6 Agglomeration

After concentration activities, agglomeration is used to combine the resulting fine particles into durable clusters. The iron concentrate is balled in drums and heated to create a hardened agglomerate. Agglomerates may be in the form of pellets, sinter, briquettes, or nodules. The purpose of agglomerating iron ore is to improve the permeability of blast furnace feed leading to faster gas-solid contact in the furnace (Weiss 1985). Agglomerating the ore prior to being sent to blast furnaces reduces the amount of coke consumed in the furnace by increasing the reduction rate. It also reduces the amount of material blown out of the furnace into the gas-recovery system (United States Steel 1973).

Historically, the four types of agglomerate products mentioned have been produced in varying amounts. Today, however, pellets account for more than 97 percent of all agglomeration products. Because of this, only the pelletizing technique will be discussed in this report. It should be noted, however, that the other agglomerates mentioned above are produced by similar high-temperature operations.

Pelletizing operations produce a "green" (moist and unfired) pellet or ball, which is then hardened through heat treatment. These pellets are normally relatively large (3/8 to 1/2 inch) and usually contain at least 60 percent iron. Pellets must be strong enough to withstand abrasion during handling, transport, and high temperature treatment within the furnace. It is also important for the material to be amenable to relatively rapid reduction (removal of oxygen) in the blast furnace. Bentonite is often added as a binder to form green pellets prior to agglomeration (Weiss 1985).

In addition to iron, pellet constituents can include silica, alumina, magnesia, manganese, phosphorus, and sulfur. Additives such as limestone or dolomite may also be added to the concentrate in a process known as "fluxing," prior to balling to improve blast furnace recovery (Weiss 1985). In the past, these constituents were added in the blast furnace. However, the development of fluxed pellets, which incorporate the flux in the pellet material, has been shown to increase furnace efficiency (Nigro 1991). The composition of pellets produced by five taconite facilities is compared in Table 1-7

Table 1-7. Chemical Composition of Average 1990 Standard and Fluxed Pellets and Pellets From Five Iron Ore Operations, 1990

Constituent	1990 Avg. Standard Pellets	1990 Avg. Fluxed Pellets	LTV Steel Co.	Eveleth Mines	National Steel Pellet Co.	Minntac (Fluxed)	Minorca
Total Fe	64.43 %	61.35 %	63.71 %	64.54 %	65.10 %	62.26 %	61.35 %
Silica	4.91 %	4.25 %	4.94 %	5.03 %	4.93 %	3.93 %	4.13 %
AlO_3	0.23 %	0.12 %	0.33 %	0.08 %	0.19 %	. . .	N/A
Mn	0.05 %	0.03 %	. . .	0.07 %	0.09 %	N/A	N/A
P	0.013 %	0.06 %	0.016 %	0.015 %	0.010 %	N/A	N/A
MgO	N/A	N/A	0.43 %	0.31 %	0.31 %	. . .	N/A
S	N/A	N/A	. . .	0.003 %	0.002 %	N/A	N/A
Lime	N/A	N/A	0.45 %	0.75 %	0.20 %	. . .	N/A
Moisture	1.91 %	2.14 %	2.77 %	1.47 %	1.25 %	2.43 %	2.00 %
Pellet Capacity (in million long tons/year)	33.1	20.8	8.0	6.1	4.6	16.2 (including acid pellets)	2.5

N/A Not Available

Sources: American Iron Ore Association 1991; U.S. DOI, Bureau of Mines 1991b

(American Iron Ore Association 1991; U.S. DOI, Bureau of Mines 1991b). Since their development in the late 1980's, fluxed pellets have gained in popularity. In 1989, standard pellets accounted for 73 percent of total pellet production, while fluxed pellets accounted for 24 percent. By 1990, about 40 percent of Minnesota pellet output was fluxed. According to the Bureau of Mines, North American iron industry pellet production was about 38 percent fluxed in 1990.

The first step in pelletizing iron concentrates is forming the pellets. This is usually accomplished in a series of balling drums or discs. The pellets are formed by the rotating of the drums, which act to roll the iron concentrate into balls. One of three different systems may then be used to produce hardened pellets:

- Travelling-Grate—Is used to produce pellets from magnetite concentrates obtained from taconite ores. Green pellets are fed to a travelling grate, dried, and preheated. The pellets then proceed to the ignition section of the grate where nearly all the magnetite is oxidized to hematite. An updraft of air is then used to cool the pellets.

- Shaft-Furnace—Green pellets are distributed across the top of a furnace by a moving conveyor belt, then pass vertically down the length of the furnace. In the furnace, the pellets are dried and heated to 2400°F. The bottom 2/3 of the furnace is used to cool the pellets using an upward-rising air stream. The pellets are discharged from the bottom of the system through a chunkbreaker.

- Grate-Kiln—Combines the grate technique with a rotary kiln. No fuel material is incorporated into or applied to the pellets in this process. The pellets are dried and preheated on a travelling grate before being hardened by high-temperature heating in the kiln. The heated gas discharge from the kiln is recycled for drying and preheating (United States Steel 1973).

Agglomeration generates byproducts in the form of particulates and gases, including compounds such as carbon dioxide, sulfur compounds, chlorides, and fluorides that are driven off during the production process. These are usually treated using cyclones, electrostatic precipitators (wet and dry), and scrubbing equipment. These treatment technologies generate either a wet or a dry effluent, which contains valuable iron units and is commonly recycled back into the operation according to the American Iron Ore Association and the Iron Mining Association of Minnesota.

1.5 WASTES AND OTHER MATERIALS ASSOCIATED WITH IRON ORE EXTRACTION AND BENEFICIATION

This section describes several of the wastes and materials that are generated and/or managed at iron ore extraction and beneficiation operations and the means by which they are managed. As is noted in the previous section, a variety of wastes and other materials are generated and managed by iron mining operations.

Some, such as waste rock and tailings, are generally considered to be wastes and are managed as such, typically in on-site management units. Even these materials, however, may be used for various purposes (either on- or off-site) in lieu of disposal. Some quantities of waste rock and tailings, for example, may be used as construction or foundation materials at times during a mine's life. Many other materials that are generated and/or used at mine sites may only occasionally or periodically be managed as wastes. These include mine water removed from underground workings or open pits, which can be recirculated for on-site use (e.g., as mill makeup water) but also can be discharged to surface waters.

The issue of whether a particular material is a waste clearly depends on the specific circumstances surrounding its generation and management at the time. In addition, some materials that are wastes within the plain meaning of the word are not "solid wastes" as defined under RCRA and thus are not subject to regulation under RCRA. These include, for example, mine water or process wastewater that is discharged pursuant to an NPDES permit. It is emphasized that any questions as to whether a particular material is a waste at a given time should be directed to the appropriate EPA Regional office.

Facilities also store and use a variety of chemicals required by mine and mill operations. A list of chemicals used at iron mines, compiled from data collected by the National Institute for Occupational Safety and Health (NIOSH) and supplemented by the U.S. DOI, Bureau of Mines is presented below (National Institute for Occupational Safety and Health 1990):

Acetylene
Argon
Calcium oxide
Carbon dioxide
Diesel fuel
Hydrogen chloride
Hydrogen fluoride
Mercuric chloride
Methyl alcohol
Nitric acid
Nitrogen
Oxalic acid
Phosphoric acid
Propane
Sodium hydroxide
Sulfuric acid
Titanium dioxide
Toluene
Xylene

The first subsection below describes several of the more important wastes (as defined under RCRA or otherwise) and nonwastes alike, since either can have important implications for environmental performance of a facility. The next subsection describes the major types of waste units and mine structures that may present environmental concerns during and after the active life of an operation.

1.5.1 Extraction and Beneficiation Wastes and Materials

The subsections below describe many of the wastes and materials generated and managed at iron sites. Notwithstanding the status of a particular waste or material, it should be noted that a number of factors determine whether that waste or material poses any risk to human health or the environment. Perhaps the most important are the inherent nature of the material (which is generally determined by its origin and the processes by which it is generated), the manner in which the material is managed, and the environment in which it is managed and to which it could be released. As noted above, questions concerning the actual status of any particular material or waste should be directed to the appropriate EPA Region.

1.5.1.1 Waste Rock

The solid material generated in the largest quantities by iron ore extraction is the material that overlies the ore body (the overburden) and the other rock that has to be removed to gain access to the ore (the mine development rock and waste rock). The quantity and composition of waste rock vary greatly between sites. These wastes contain minerals associated with the ore body and host rock. The materials can occur in a wide range of particle sizes owing to variations in ore formations and differences in mining methods. In many operations, waste rock is disposed of in piles located near the mine (Van Ness 1980). It also can be used in dams or other on- or off-site construction.

1.5.1.2 Milling Dust Control Materials

Most mills use a wet milling operation and employ water to control dust from crushing and grinding. Slurried value-bearing process water from dust control contains both suspended and dissolved solids. The solid content of the slurry varies with each operation, ranging between 30 and 60 percent. The dust control slurry is typically pumped to a ball mill overflow/hydrocyclone feed sump for further beneficiation (U.S. EPA 1976).

1.5.1.3 Magnetic Separation Wastes and Materials

The primary wastes from magnetic separation (either wet or dry operations) are tailings made up of gangue in the form of coarse- and fine-grained particles, and waste water slurry in the case of wet separation. Particulate wastes from dry separation may also be slurried. Following separation of solids in a thickener or settling pond, solids are sent to a tailings impoundment and most of the liquid component can be recycled to the mill or discharged if water quality criteria are met.

1.5.1.4 Flotation Wastes and Materials

Discharge from a typical floatation cell system is made up of 25 to 50 percent solids, mostly gangue material and small quantities of unrecovered iron minerals. The liquid component of flotation waste is usually water, along with any remaining reagents not consumed in the flotation process. Most operations send these wastes to tailings impoundments where solids settle out of the suspension. The liquid component may then be used in other mining activities as needed or discharged if water quality criteria are met. The characteristics of tailings from the flotation process vary, depending on the ore, reagents, and processes used.

1.5.1.5 Gravity Concentration Wastes and Materials

Waste from gravity concentration is mainly tailings (made up of coarse- and fine-grained particles and process water). These tailings are pumped as a slurry to a tailings impoundment. The solid content of the slurry varies with each operation, ranging between 30 and 60 percent. Following the separation of solids, process water may be recycled to the mill or discharged if water quality criteria are met.

1.5.1.6 Agglomeration Wastes and Materials

The agglomeration process may generate carbon dioxide, sulfur compounds, chlorides, and fluorides, which are driven off during the pellet production process. Large amounts of dust, containing metals and other ore and additive constituents, may also be generated. These wastes are usually collected using cyclones, electrostatic precipitators, and scrubbing equipment and create both dry and slurry forms of waste. The waste water is commonly combined with waste water generated during other production operations for treatment (typically settling and/or thickening). Solids are returned for recycling through the process, and the liquid component can be recycled to the mill or discharged (U.S. EPA 1985b).

1.5.1.7 Mine Water

Because mine water that is discharged or otherwise released to the environment can be a source of contamination, it is addressed in this section although it is not always a RCRA-defined waste. Mine water consists of water that collects in mine workings, both surface and underground, as a result of inflow from rain or surface water, and ground water seepage. As discussed previously, mine water may be used and recycled to the beneficiation circuit, pumped to tailings impoundments for storage prior to recycling or for disposal, or discharged to surface water under an NPDES permit.

During the life of the mine, if necessary, water is pumped to keep the mine dry and allow access to the ore body. This water may be pumped from sumps within the mine pit or from interceptor wells. Interceptor wells are used to withdraw ground water and create a cone of depression in the water table around the mine, thus dewatering the mine. Surface water contributions to the volume of mine water are generally controlled using engineering techniques to prevent water from flowing into the mine, typically by diverting it around pits or underground openings.

The quantity and chemical composition of mine water generated at mines vary by site. The chemistry of mine water is dependent on the geochemistry of the ore body and surrounding area. After the mine is closed and pumping stops, the potential exists for mines to fill with water. Water exposed to sulfur-bearing minerals in an oxidizing environment, such as open pits or underground workings, may become acidified.

Sampling conducted by EPA at several iron operations in 1982 for the "Development Document for Effluent Limitations Guidelines and Standards for the Ore Mining and Dressing Point Source Category" (U.S. EPA 1982) noted that, in general, mine water associated with iron operations is characterized by low pollutant levels. In some cases, detectable concentrations of arsenic [0.005 milligrams per liter (mg/l)], copper (0.90 and 120 mg/l), and zinc (0.018 and 0.030 mg/l) were found in discharges from active iron mines. Non-asbestiform amphibole mineral fibers were also detected, but in relatively small amounts (U.S. EPA 1982). It should be noted, however, that relatively few samples were analyzed. Relevant treatment requirements are summarized in the Current Regulatory and Statutory Framework Section of this report.

1.5.2 Waste and Materials Management

Wastes and materials that are generated as a result of extraction and beneficiation of iron ore are managed (treated, stored, or disposed of) in discrete units. For the purposes of this report, these units are divided into two groups: waste rock and ore piles; and tailings impoundments. These units may be exposed to the environment, presenting the potential for contaminant transport. In addition, mine structures such as pits and underground workings are described in this section as they may expose constituents to the environment and increase the potential for transport.

1.5.2.1 Waste Rock and Ore Piles

Overburden and waste rock removed from the mine are stored or disposed of in unlined piles onsite. These piles may also be referred to as mine rock dumps or mine dumps. As appropriate, topsoil may be segregated from overburden and mine development rock, and stored for later use in reclamation and revegetation. These dumps are generally unsaturated and provide an environment that can foster acid generation if sulfide minerals, oxygen, and water are present. However, in Minnesota and Michigan, where most crude iron ore is produced, sulfide-bearing minerals are present in only one unique geologic environment (see below), according to the American Iron Ore Association (Guilbert 1986), so acid generation should not be a problem elsewhere. Ore is also stored in piles at the mine or mill before beneficiation.

1.5.2.2 Tailings Impoundments

Tailings are the discarded material resulting from the concentration of ore during beneficiation operations. Tailings are characterized by fine particle size and varying mineralogical and chemical composition (Aleshin 1978). Tailings typically take the form of a slurry consisting of water, with solids from flotation, magnetic separation, and/or agglomeration. This material has minimal value at present but is produced in extremely large quantities.

Typically, tailings slurries initially contain 65 percent water and 35 percent solids. At the tailings impoundment, solids settle out of solution and water is reused, evaporated, or discharged if water quality criteria are met. Over time, the solid component of the tailings impoundment increases, eventually leaving damp or dry tailings material (Van Ness 1980).

Chemical analyses performed by the IIT Research Institute in 1970 found that tailings from taconite ore beneficiation were composed of a variety of constituents, such as metal oxides. A summary of the constituents found in taconite tailings, along with their associated concentrations, is listed in Table 1-8 (Aleshin 1978; Schwartz 1970).

Table 1-8. Chemical Analysis of Taconite Ore Tailings, in Percentage of Total Weight

Constituent	Percentage of Total Weight
SiO_2	59
Fe_xO_y	15
Al_2O_3	2.7
MgO	3.7
CaO	2.7
NaO	-
K2O	-
LOI	7.4
Minor Constituents	
Ni	-
Ti	-
Cu	-
Mn	0.73
Zn	-
S	0.012
P	0.047

Sources: Aleshin 1978; Schwartz 1970

Mill tailings samples taken by EPA during the development of Clean Water Act effluent limitation guidelines (U.S. EPA 1982) noted the trace amounts of several toxic metals in raw mill tailings effluents. These metals included antimony, arsenic, beryllium, cadmium, chromium, copper, lead, nickel, selenium, silver, and zinc. In some instances (Silver Bay, Minnesota and Groveland Mine, Michigan), amphibole minerals with fibrous characteristics may be a constituent in the tailings. While amphibole minerals (cummington-grunerite) are present in some Eastern Mesabi Range taconite formations, asbestos has not been identified as such (U.S. EPA 1976). Most of these contaminants can be removed or reduced as a result of effluent treatments, such as settling in tailings impoundments (U.S. EPA 1982). This will be discussed further in the Environmental Effects Section of this report.

The disposal of tailings requires a permanent site with adequate capacity for the life of the mine. Tailings ponds or impoundments are created to dispose of these wastes. Literature consulted for this report suggests that only impoundments are used in the iron ore industry. As an example, the tailings impoundment at LTV Steel Mining Company's facility at Hoyt Lakes is approximately 3,000 acres and contains about 500 million tons of tailings (LTV Steel Mining Company 1991).

Two general classes of impounding structures may be used to construct a tailings impoundment: water-retention dams and raised embankments. Dikes associated with impoundments are commonly constructed of tailings material. The choice of impounding structure is influenced by the characteristics of the mill tailings and effluent, as well as the site.

1.5.2.3 Mine Pits and Underground Workings

In addition to wastes generated during active operations, pits and underground workings may be allowed to fill with water when the mine closes or stops operation, since the need for dewatering is over. At one site in Minnesota, the Dunka Mine, accumulated water, or mine drainage, has acidified through contact with sulfide minerals in an oxidizing environment and become contaminated with heavy metals, as well as suspended solids.

At abandoned underground mines, deficiencies in mine shaft protection and mine subsidence may be a problem. However, these problems do not exist at open-pit operations, where the bulk of iron ore is currently mined. Although there is only one underground iron mine currently operating in the United States, abandoned underground iron mines have contributed to the creation of subsidence features. For example, West Iron County, Michigan, subsidence features caused by abandoned iron mines have grown into large pits and caused interruptions in utility service, damage to roadways, and loss of life (Michigan State, Geological Survey Division 1983).

1.6 ENVIRONMENTAL EFFECTS

Since wastes and other materials at active mines are managed on land, there is a potential for environmental contamination from various parts of the mining operation. Mine pits and underground workings, overburden and waste rock piles, ore piles, and tailings impoundments in the iron ore mining industry are of particular note, since these are the areas in which toxic contaminants are most commonly found. A discussion of the potential environmental effects associated with iron ore mining is presented in the following sections. Specific examples from industry are included in this section, as appropriate. Actual environmental damages at iron mine sites are described in the Damage Case Section of this report.

This section does not purport to be a comprehensive examination of environmental damages that can occur or that actually occur at mining operations. Rather, it is a brief overview of some of the potential problems that may occur under certain conditions. The extent and magnitude of contamination depends on highly variable site-specific factors that require a flexible approach to mitigation. EPA is aware that many of the potential problems can be, and generally are, substantially mitigated or avoided by proper engineering practices, environmental controls, and regulatory requirements.

1.6.1 Ground Water/Surface Water

The primary concerns for ground water and surface water at mine sites are chemical and physical contamination associated with mine operation. Exposed ore, overburden piles, waste rock and ore piles, tailings impoundments, and other disturbed areas can contribute sediment and increase the total solids load to surface water bodies. Other potential sources of surface and ground water contamination include fuel spills, flotation reagents, cleaning solutions, and other chemicals used or stored at the site.

For iron recovered from sulfide-bearing ores, acid generation due to the oxidation of sulfides (e.g., pyrite and pyrrhotite) in the ore body, host rock, and waste material may be of concern. Trace elements and minerals often associated with iron deposits includes aluminum, antimony, arsenic, beryllium, cadmium, chromium, copper, lead, manganese, nickel, selenium, silver, sulfur, titanium, and zinc (U.S. DOI, Geological Survey 1973). Lowering of pH increases the solubility of these constituents, and may make them available for transport in both surface water and ground water. However, acid drainage from iron ore mines is known to occur only at the Dunka Mine in Minnesota and at abandoned underground mines.

Surface and underground mines may need to be dewatered to allow extraction of ore. This can be accomplished in one of two ways: pumping from ground water wells to lower the water table, or pumping directly from the mine workings. After a mine is abandoned, pumping is usually stopped, allowing the pit or underground workings to fill with water. Over time, this may lead to uncontrolled releases of mine water. Mine water from iron mines generally has a pH of seven or higher and presents no known problems. However, mine water at the Dunka Mine site in Minnesota is acidic and contaminated with metals as well as dissolved and suspended solids.

1.6.2 Soil

Environmental impacts to soils as a result of mining activities are most commonly associated with erosion and contamination. Erosion may be caused by land disturbances and removal of vegetation related to mining activities. Under these conditions, precipitation events, such as snowmelt, may lead to erosion of soils.

Contamination of soils may result from water discharge, runoff, seepage from tailings impoundments, pits and mine workings, as well as from the overburden, waste rock, and ore piles directly to soils. In addition, deposition of windblown particulates from piles and dry tailings impoundments may also be a source of soil contamination. Other sources of soils contamination include spills of fuels, flotation reagents, cleaning solutions, as well as other chemicals used or stored at the site.

1.6.3 Air

The primary sources of air contamination at mine sites are fugitive dust from dry surfaces of dry tailings impoundments, as well as overburden, waste rock, and ore piles. Blasting generally produces relatively large particles that settle rapidly and have little effect on ambient air quality. In addition, fugitive dust from milling is limited because 99 percent of iron ore milling in Michigan and Minnesota is wet according to the American Iron Ore Association.

Often, tailings impoundments are not completely covered by pooled water; thus, dry tailings may be available for windblown transport. Deposition of windblown tailings provides exposure routes for contamination of ground water, surface water, and soil.

A 1982 NIOSH study of asbestos control at mines and mills sampled several surface and underground iron mines. The amphibole silicate mineral cummington-grunerite is present in some iron ore deposits. Although this silicate is not naturally found in a fibrous state, milling activities may lead to fibrous cleavage fragments that resemble asbestos. The study examined several iron mine production areas, including blasting, drilling, extraction, ore transportation, milling, and concentrating. The results from these analyses included the following (National Institute of Occupational Safety and Health 1982):

- Blasting—22 percent of samples exceeded the low PEL and 100 percent were less than medium PEL.
- Surface Operation Drilling—23 percent of samples exceeded low PEL, 5 percent exceeded medium PEL, and 100 percent were less than high PEL.
- Surface Operation Extraction—16 percent of samples exceeded all PEL standards.

- Surface Operation Ore Transportation—10 percent of samples exceeded low PEL, 4 percent exceeded medium PEL, and 2 percent exceeded high PEL.
- Milling—33 percent of samples exceeded low PEL, 22 percent exceeded medium PEL, and 16 percent exceeded high PEL.
- Concentrating—11 percent of samples exceeded low PEL, 7 percent exceeded medium PEL, and 4 percent exceeded high PEL.

The actual impact, if any, of these conditions on taconite miners is not known. The American Iron Ore Association sponsored studies of health impacts on taconite miners and millers beginning in 1979. The most recent study, "An Updated Analysis of Mortality in a Cohort of Minnesota Taconite Miners and Millers," concluded that considering the minimum potential latency period of 30 years, there was "no evidence to support any association between low level exposures to nonasbestiform amphibole particles or quartz with either lung cancer, nonmalignant respiratory disease or any other specific cause" (Cooper, et al. 1991).

1.6.4 Damage Cases

Damages resulting from the management of wastes from the mining of iron and associated minerals have been documented. Minnesota and Michigan have verified three sites where environmental contamination has resulted from iron mining. They are the Reserve Mining Company site and the Dunka Mine, both in Minnesota, and the Iron River District in Michigan.

1.6.4.1 Reserve Mining Company; Silver Bay, Minnesota

In 1971, EPA conducted a study of taconite tailings disposal into Lake Superior by the Reserve Mining Company operation in Silver Bay, Minnesota. The report notes that 67,000 tons of taconite tailings slurried with 500 million gallons of water were discharged into Lake Superior per day during plant operations. Particle sizes in the tailings ranged from 3/8 inch to less than one micron. Coarse particles contained in the slurry settled on the bottom of the lake as sediment; fines particles either settled out or were dispersed because of temperature differences between the wastewater and thermoclines in the lake. When dispersion occurred, water currents acted to keep the particles in suspension and transport them over a wider area of the lake. In 1971, the tailings were estimated to cover 160 square miles of the bottom of Lake Superior along the coast southwest of Silver Bay. Tailings discharges into the lake have been associated with increased concentrations of iron and manganese both in the lake itself and in surrounding waterways (U.S. EPA 1971).

EPA studies have also noted the presence of asbestiform-type amphiboles (over 20 percent) within the Reserve Mining Company taconite beds at Babbitt, Minnesota. These minerals remained in the ore as acicular or needle-like grains, even during milling activities. The grains were discharged through emission stacks of the facility's agglomeration plant and as a waste slurry into Lake Superior.

Several environmental impacts have been associated with tailings discharge (U.S. EPA 1971):

- Algal growth in the lake was stimulated because of nutrient increases
- Growth of iron-fixing bacteria in the lake increased
- Populations of benthic fauna (such as shrimp) decreased by as much as 50 percent.

Tailings from the mine were also thought to have contaminated local ground water supplies (U.S. EPA 1971).

It should be noted that, according to the Iron Mining Association of Minnesota, the Reserve operation has since changed its method of tailings disposal, converting to on-land disposal subject to specific permits issued and monitored by the Minnesota Pollution Control Agency and the Minnesota Department of Natural Resources.

1.6.4.2 Dunka Site: Babbitt, Minnesota

The Dunka Site, owned by LTV Steel Mining Company, is a full-scale open-pit taconite operation near Babbitt, Minnesota. Piles of waste rock, generated during open-pit taconite mining, are stored onsite. These piles exceed 50 million tons, cover 320 acres, and contain metal sulfide minerals. (It should be noted that the Dunka Mine is a unique geological situation, not found elsewhere in Minnesota or Michigan and is not typical to iron mining.) The Duluth Gabbro, a mafic formation that contacts the iron formation at this point, has been subject to several exploratory operations for its copper and nickel values. The mine waste rock may be, therefore, more analogous to a copper-nickel mine, rather than an iron ore mine. An extensive remediation process is under way at the Dunka site, which includes an experimental wetland treatment system, plus testing of two, more technically advanced systems, one of which has been selected for permanent installation. Further, closure notice has been given for this property according to the American Iron Ore Association.

The Minnesota Department of Natural Resources (DNR) found that more than 95 percent of all leachate samples taken from the mine site between 1976 and 1980 had pH values between 6.0 and 8.5, but values as low as 4.5 were reported. Specific information regarding sampling procedures was not provided. Concentrations of trace metals (copper, nickel, cobalt, zinc) exceeded ambient levels by 10 to 10,000 times. Toxicity testing showed that copper and nickel concentrations exceeded the 48-hour lethal concentration (LC50) for Daphnia pulicaria, while nickel concentrations also exceeded the 96-hour LC50 for fathead minnow. Concentrations of calcium, magnesium, and sulfate in the stockpile drainage were also elevated, but these heightened concentrations were of less environmental concern than the metals (Minnesota Department of Natural Resources 1981).

Total discharge from the watershed into Bob Bay on Birch Lake was estimated to be 500 million gallons per year. The annual flow contained a mass load of over one ton of nickel, presumably in solution. Nickel contributed more than 90 percent of the trace metal load, and less than 40 percent was removed through natural lake processes (Minnesota Department of Natural Resources 1981).

Studies of waste rock pile drainage flowing through a white cedar swamp prior to entering Unnamed Creek between July 1976 and August 1977 indicated average nickel and copper concentrations in solution were 17.9 and 0.62 mg/l, respectively. Analysis of water quality and peat samples indicated that at least 30 percent of the nickel and essentially 100 percent of the copper were being removed from the drainage by peat sequestration (U.S. DOI, Bureau of Mines 1986). Subsequently, a pilot-scale wetland treatment project was initiated in cooperation with the MDNR and MPCA to determine the capability of an enhanced wetland to remove heavy metals waste rock pile seepage. The system currently consists of four enhanced wetland test cells constructed of peat from the surrounding area. The dimensions of the area are approximately 80 feet by 240 feet; a collection pipe at the end provides for outflow. This project is currently only a temporary system, but may be expanded if it proves effective in treating leachate (Department of the Army 1990).

Pre-mining sediment samples from Bob Bay showed appreciable concentrations of the same metals reported in 1981. According to the American Iron Ore Association, the transport of metals to Bob Bay was occurring naturally before mining began in that area. In the study of trace metals in Bob Bay reported in 1981, which had been conducted in 1976-1977, it was found that concentrations of sulfate, nickel, cadmium, magnesium, chlorine, copper, and the alkalinity in the waters of the bay were higher than the regional average concentrations and decreased with distance from the point of input at the mouth of Unnamed Creek. Elevated metal concentrations were also observed in the sediments, as well as in plant and clam tissue (Minnesota State Department of Natural Resources 1981). When the Bob Bay study was repeated in 1983, metal concentrations were higher than those observed previously. This was thought to be due to higher input concentrations from the mining watershed (Minnesota State Department of Natural Resources 1984).

1.6.4.3 Iron River District: Iron County, Michigan

Acid drainage in the Iron River District is caused by the presence of sulfur-bearing black slate associated with the Riverton Iron Formation. The sulfur is in the form of fine grained pyrite that rapidly oxidizes to form sulfuric acid when combined with water. Sulfuric acid leaching mobilizes other minerals present in the host rock, such as iron, calcium, magnesium, manganese, and aluminum. Upon entering the Iron River, the acid drainage is rapidly neutralized and precipitates "yellow-boy," a finely divided yellow-brown iron hydroxide. The yellow-boy clouds the river water and covers any objects in the river or sediment. Sampling conducted by the Michigan Geological Survey Division between 1975 and 1977 identified two sources of acid mine drainage in the area: the abandoned Dober and Buck Mines (Michigan State, Geological Survey 1978).

At the Dober Mine, highly acidic ground water seepages fill the abandoned pit and drain into the Iron River. Between 50 and 100 gallons of contaminated water were reported to enter the river per minute.

In 1975, the mine drainage contained the following contaminants: pH: 4.1; iron: 1,125 mg/l; manganese: 121 mg/l; sulfate: 5,130 mg/l; lead: 0.05 mg/l; and cadmium: 0.02 mg/l (Michigan State, Geological Survey 1978).

Acid drainage from the Buck Mine results from waste rock piles located along the Iron River. The waste rock piles cover about 19 acres and contain pyrite-bearing rock and approximately 10.2 million pounds of sulfur. The sulfur has the potential to generate as much as 31.1 million pounds of sulfuric acid. The combined flow from these piles in 1976 and 1977 was approximately 441 gallons per minute and deposited 117 pounds of iron, 56 pounds of manganese, and 9,750 pounds of sulfate per day (Michigan State, Geological Survey 1978).

1.7 CURRENT REGULATORY AND STATUTORY FRAMEWORK

Iron ore mining activities must meet the requirements of both Federal and State regulations. Environmental statutes administered by EPA or the states, such as the Clean Water Act (CWA) and the Clean Air Act (CAA), apply to mining sites regardless of the status of the land on which they are located. The extent to which other Federal regulations apply depends on whether a mining operation is located on federally owned land. Federal regulations exist for operations on Federal lands managed by the U.S. Forest Service (FS), the U.S. Fish and Wildlife Service (FWS), the National Park Service (NPS), and other land management agencies. In addition, the U.S. Army Corps of Engineers has promulgated rules for construction and mining activities that have the potential to affect wetlands and navigable waters. Finally, operations must comply with a variety of state requirements, some of which may be more stringent than Federal requirements.

Federal air quality regulations do not specifically address iron ore extraction and beneficiation, but they do regulate certain types of air pollution. Federal water quality regulations, on the other hand, include effluent discharge standards for specific types of point-source discharges to surface waters from iron mining operations. Federal land management agencies have regulations that, in some cases, target particular types of extraction and beneficiation methods, but generally are not specific to individual, nonfuel mineral types. State regulations similarly address operations types, but less frequently target specific minerals. In Minnesota, however, State reclamation regulations are specific to ferrous mining operations.

This section summarizes the existing Federal regulations that may apply to iron ore mining operations. Because little or no iron mining occurs on Federal lands, programs and regulations that govern iron ore mining and that are implemented by the Departments of Agriculture and Interior are not described. It also provides an overview of the operational permitting, water quality, air quality, waste management, reclamation, and wetlands protection regulations in the two predominant iron-producing States (Minnesota and Michigan).

1.7.1 Federal Environmental Protection Agency Regulations

1.7.1.1 Resource Conservation and Recovery Act

The EPA implements the Solid Waste Disposal Act of 1978 (SWDA), as amended by RCRA, as amended by the Hazardous and Solid Waste Amendments (HSWA) of 1984 (collectively referred to as RCRA) to protect human health and the environment from problems associated with solid and hazardous wastes. Mining wastes are included in RCRA's definition of solid waste, and in 1978, when EPA proposed regulations for the Subtitle C hazardous waste program, special management standards were proposed for mining wastes. However, in 1980, RCRA was amended to include what is known as the Bevill Amendment (RCRA §3001(b)(3)(A)). The Bevill Amendment provides a conditional exclusion from RCRA Subtitle C hazardous waste requirements for wastes from the extraction, beneficiation, and processing of ores and minerals.

The exemption was conditioned upon EPA's preparation of a report to Congress on the wastes and a subsequent regulatory determination that regulation under Subtitle C was appropriate. EPA met its statutory obligation with regard to extraction and beneficiation wastes with the 1985 *Report to Congress, Wastes from the Extraction and Beneficiation of Metallic Ores, Phosphate Rock, Asbestos, Overburden from Uranium Mining and Oil Shale.* In the subsequent regulatory determination (51 FR 24496; July 3, 1986), EPA indicated that extraction and beneficiation wastes (including iron mining wastes) should not be regulated as hazardous but should be regulated under a Subtitle D program specific to mining wastes.

As discussed above, wastes from the extraction and beneficiation of ores and minerals are generally excluded from RCRA Subtitle C requirements by the Bevill Amendment. EPA interprets this exclusion to encompass only those wastes uniquely associated with extraction and beneficiation activities; the exclusion does not apply to wastes that may be generated at a facility but are not uniquely related to mineral extraction or beneficiation. For example, waste solvents that meet the listing requirement as a hazardous waste under 40 CFR 261.31 and are generated at an extraction or beneficiation facility by cleaning metal parts (i.e., activities not uniquely related to extraction and beneficiation) are considered hazardous wastes and regulated as such. These wastes must be managed as any other hazardous waste, subject to the Federal requirements in 40 CFR Parts 260 through 271 (or State requirements if the State is authorized to implement the RCRA Subtitle C program), including those for manifesting and disposal in a permitted facility.

1.7.1.2 Clean Water Act

Under Section 402 of the CWA (33 USC § 1342), all point-source discharges to waters of the United States from industrial and municipal sources must be permitted under the National Pollutant Discharge Elimination System (NPDES). A point source is defined as any discrete natural or manmade conveyance, including pipes, ditches, and channels. NPDES permits are issued by EPA or authorized States.

Effluent limits imposed on an NPDES permittee are either technology-based or water quality-based. National technology-based effluent guideline limitations have been established for discharges from active iron ore mines under the Iron Ore Mining and Dressing Point-Source Category (40 CFR Part 440, Subpart A). These regulations govern discharges from surface (open-pit) and underground mining operations related to the extraction, removal, or recovery of iron ore and waste water discharges from mills beneficiating iron ore by physical separation (both magnetic and nonmagnetic) and/or chemical separation. Discharges from these operations must meet Best Available Technology/ Best Practicable Technology (BAT/BPT) standards for iron, total suspended solids, and pH. The

Table 9. BPT and BAT Standards for the Ore Mining and Dressing Point Source Category: Iron Ore Subcategory. Concentration of Pollutants Discharged in Mine Drainage (milligrams per liter)

POLLUTANT	BPT Maximum for 1 Day	BPT Average of Daily Values for 30 Consecutive Days	BAT Maximum for 1 Day	BAT Average of Daily Values for 30 Consecutive Days
Iron	2.0	1.0	2.0	1.0
Total Suspended Solids	30	20	N/A	N/A
pH	6.0 - 9.0	6.0 - 9.0	N/A	N/A

Source: 40 CFR Part 440 Subpart A

BPT and BAT Standards for the Ore Mining and Dressing Point Source Category: Iron Ore Subcategory. Concentration of Pollutants Discharged from Mills That Use Physical (Magnetic and Nonmagnetic) and/or Chemical Separation for Beneficiation (milligrams per liter)

POLLUTANT	BPT Maximum for 1 Day	BPT Average of Daily Values for 30 Consecutive Days	BAT Maximum for 1 Day	BAT Average of Daily Values for 30 Consecutive Days
Iron	2.0	1.0	2.0	1.0
Total Suspended Solids	30	20	N/A	N/A
pH	6.0 - 9.0	6.0 - 9.0	N/A	N/A

Source: 40 CFR Part 440 Subpart A

specific effluent standards are summarized in Table 1-9. In addition, the Ore Mining and Dressing regulations establish a "no discharge of process waste water to navigable waters" for mills in the Mesabi Range. Permit writers can establish additional limitations at a specific facility based on Best Professional Judgment (BPJ). For pollutants not addressed by these guidelines, effluent limits are based on BPJ.

The NPDES permit writer also must ensure that the NPDES permit will protect water quality. Table 1-10 identifies the Federal surface water quality criteria for pollutants that may be associated with iron ore mining activities established by EPA's Office of Water. Individual states are required to adopt water quality criteria at least as stringent as the Federal levels. The application of these criteria is based on the designated use of a specific receiving water (e.g., drinking water supply, aquatic life, and/or recreational use). Also, each State has been required to develop instream water quality standards to protect the designated uses of receiving waters.

Table 1-10. Federal Water Quality Criteria and Drinking Water MCL (in mg/l)

Constituent	Fresh Acute[1]	Fresh Chronic[1]	Marine Acute[1]	Marine Chronic[1]	Maximum Contamination Limit (MCL)
Beryllium	130	5.3	N/S	N/S	N/S
Chromium (hex)	16	11	1,100	50	0.05 mg
Chromium (tot)	1700*	210*	10,300	N/S	0.05 mg
Copper	18*	12*	2.9	2.9	N/S
Nickel	1400*	160*	75	8.3	N/S
Silver	4.1*	0.12	2.3	N/S	0.05 mg
Zinc	120*	110*	96	96	N/S

[1] Standards are relative to water hardness. Standards shown are for hardness 100.

N/S = No Standard

Source: U.S. EPA, 1986

NPDES permit writers must determine whether technology-based effluent limitations are adequate to ensure that applicable water quality standards are met. Where technology-based limits are not sufficiently stringent, water quality-based effluent limitations must be developed. As a result, an NPDES permit may include technology-based effluent limitations for some pollutants and water quality-based effluent limitations for other pollutants.

Contaminated storm water discharges from some mining operations have been documented as causing water quality degradation. These regulations require NPDES permits for all point source discharges of contaminated storm water from mines. Storm water requirements are applied to mine sites either individually (i.e., through individual NPDES permits) or in larger groups (i.e., through general NPDES permits applicable to similar operations).

Some discharges from mine sites do not meet the traditional definition of a point source discharge. Under Section 319 of the CWA, States have been required to prepare nonpoint-source assessment reports and to develop programs to address nonpoint sources on a watershed-by-watershed basis. Each State must report to EPA annually on program implementation and resulting water quality improvements.

1.7.1.3 Clean Air Act

Under the CAA (42 USC § 4209, Section 109), EPA established national primary and secondary ambient air quality standards for six "criteria" pollutants. These are known as the National Ambient Air Quality Standards (NAAQS). The NAAQS sets maximum concentration limits for lead, nitrogen oxides, sulfur dioxide, carbon monoxide, and suspended particulate matter of less than 10 microns in diameter, and ozone. To attain the air quality goals set by the CAA, States and local authorities are given the responsibility of bringing their regions into compliance with NAAQS. In addition, states may promulgate more stringent ambient air quality standards.

New Source Performance Standards (NSPS), authorized by Section 111 of the CAA, have been promulgated for metallic mineral processing plants and can be found in 40 CFR Part 60, Subpart II. Processing plants are defined as "any combination of equipment that produces metallic mineral concentrates from ore; metallic mineral processing commences with the mining of the ore." (All underground processing facilities are exempt from NSPS.) Also, NSPS particulate emission controls on concentration standards apply only to stack emissions. NSPS require controls on particulates emitted from stacks in excess of 0.005 grams per dry standard cubic meter (dscm). In addition, stack emissions must not exhibit greater than 7 percent opacity, unless the facility uses a wet scrubbing emission control device. However, on or after 60 days following the achievement of the maximum production rate (but no later than 180 days after initial startup), operations must limit all process fugitive emissions (meaning fugitive dust created during a processing operation though not released through a stack) to 10 percent opacity.

Prevention of Significant Deterioration (PSD) provisions of the CAA are intended to ensure that NAAQS are not exceeded. Under this program, new plants, additions, and major modifications are subject to extensive study requirements if they will emit (after controls are applied) specified quantities of certain pollutants. At least four taconite mines in Minnesota and Michigan have had to go through PSD review.

State ambient air standards promulgated to meet or exceed Federal NAAQS are generally maintained through permit programs that limit the release of airborne pollutants from industrial and land-disturbing activities. Fugitive dust emissions from mining activities may be regulated through these permit programs (usually by requiring dust suppression management activities).

Currently, only the six criteria pollutants are regulated by NAAQS. Several other pollutants are regulated under National Emission Standards for Hazardous Air Pollutants (NESHAPs). NESHAPs address health concerns that are considered too localized to be included under the scope of NAAQS. No NESHAP standards apply to iron-ore mining operations.

Under the 1990 Amendments to the CAA, Congress required EPA to establish technology-based standards for a variety of hazardous air pollutants, including many metal compounds associated with iron-ore mining including manganese and nickel. In November 1993, EPA published a list of source categories and a schedule for setting standards for the selected sources. Furthermore, if a source emits more than 10 tons per year of a single hazardous air pollutant or more than 25 tons per year of a combination of hazardous air pollutants, the source is considered a "major source." Major sources are required to use the maximum available control technology to control the release of the pollutants (CAA Section 112).

1.7.2 State Regulations

1.7.2.1 Minnesota

Minnesota's regulatory requirements for iron-ore mining activities include Federal water and air regulations and other State-specific requirements. Two State agencies are responsible for regulating mining activities. An Interagency Coordinating Committee coordinates programs of the Minnesota Pollution Control Agency and the Department of Natural Resources (DNR) as they relate to mining and, in addition, works with other Federal, State, and local regulatory agencies.

The Minnesota Pollution Control Agency (MPCA) is the lead agency for regulating the following:

- Air quality
- Solid and hazardous waste
- Noise control/abatement
- Ground and surface water quality.

The DNR is responsible for the regulation of mining operations, including the following:

- Sitting, design, construction, operation, and deactivation, including reclamation of lands disturbed after August 1980

- Water appropriations (i.e., taking or disposing of water)

- Dam safety (including location, materials, and operation)
- Activities affecting alteration of protected waters.

Operation and Reclamation

Minnesota's Mineland Reclamation Act and its implementing rules require a "permit to mine," which is issued for the life of the mine. The rules, specific to iron-ore mines, establish design standards for buffers and barriers, sloping and landform, open pits, stockpiles, tailings disposal areas, management of runoff, and vegetation. In-mine disposal of mining waste is allowed. The permittee is required to submit environmental setting maps, mining and reclamation maps, mine operating plan details of ground water conditions, and a reclamation plan. An annual mining report must be submitted that includes a report on reclamation activities. A performance bond may also be required at any time. Mining is prohibited or restricted in specific areas. (Minnesota Mineland Reclamation Act, Chapter 93, Minnesota Mineland Reclamation Rules, Chapter 6130.) Mining areas must be inspected periodically for compliance with design and operating standards, and permits may be modified or revoked and fines imposed for failure to achieve compliance. In addition, the State maintains authority over mine water in open pits and can require owner/operators to monitor water quality and treat discharges after closure.

Water Quality

Minnesota is authorized to implement the NPDES program and regulates point-source discharges accordingly. The State discharge limits are the same as the Federal guidelines. Pursuant to Clean Water Act requirements, Minnesota has established numeric standards to protect designated uses of surface waters and, thus, permit limits may be based on water quality as well as BAT/BPT. State Disposal System (SDS) permits are required for land application of sludge and waste waters. (Minnesota Water Pollution Control Laws, Chapter 115; Minnesota Permit Rules).

Minnesota has no ground water classification system, but has defined all ground water as potentially potable, with a policy of nondegradation. As necessary, site-specific requirements are applied based on Maximum Contaminant Levels established by EPA under the Safe Drinking Water Act or State Recommended Allowable Levels.

Air Quality

The Air Pollution Control Rules and Regulations stipulate that any emission source must not interfere with the attainment or maintenance of the National ambient air quality standards, must comply with NESHAPs (as noted, some apply to iron ore operations), and any applicable Federal standards of performance for new stationary sources. (Minnesota Waste Management Act, Chapter 116 of the Minnesota Statutes Annotated; Minnesota Air Pollution Control Rules and Regulations, Chapter 7005). In addition, Minnesota rules require that "mining shall be managed to control avoidable dust."

Solid Waste

Under Minnesota's General Technical Requirements for Solid Waste Facilities, mining wastes are excluded from these regulations provided the facility is permitted under the mine reclamation rules (Minnesota Waste Management Act, Chapter 115A of the Minnesota Statutes Annotated; Minnesota General Technical Requirements for Solid Waste Facilities, Chapter 7035.2525).

1.7.2.2 Michigan

Michigan has various regulatory requirements controlling iron-ore mining activities. Some of the regulations are the result of Federal program delegation while others were developed under State statutes. Major programs are described below. In addition to these, solid waste requirements and dam safety requirements may apply to mining activities. The State's solid waste laws require that a license must be obtained from either the State's Waste Management Division or a certified county health department to construct a solid waste disposal facility. The permit application process includes hydrogeological monitoring and reporting and a surety bond.

Reclamation

Michigan's Mine Reclamation Act and its administrative rules apply to open-pit mining. The rules require reclamation activities relating to control of erosion and air and water pollution to be conducted concurrently (where feasible) with the mining operation and initiated "at the earliest possible time" after abandonment. Any portion of a mining area that has been inactive for more than 1 year is deemed abandoned. Reclamation must be completed within 2 years of abandonment, although this timeframe can be extended if approved by the Michigan Department of Natural Resources. The rules stipulate that all worthless debris and rubbish must be removed from the mining area within 1 year of abandonment. Required reclamation of open pits, stockpiles, tailings basins, dikes, borrow pits, and roads includes sloping and grading, stabilization, and vegetation. (Michigan Mine Reclamation Act, Act No. 92 of the Public Acts of 1970; Michigan Mine Reclamation Act Administrative Rules, Chapter 123).

The rules require written notice to DNR prior to commencement of mining, the submission of an annual plan map showing location and boundary of the mining area, plants, open pits, stockpiles, surface water bodies, tailings basins, roads, active and abandoned portions of the mining area, drainage, and discharges from mining operations. The rules also require written notice to DNR of abandonment of any portion of the mining area and a report of reclamation activities must be submitted annually until reclamation is completed and approved by DNR. The DNR may require submission of a reclamation plan and a surety or security bond in an amount equal to the cost of reclamation.

Water Quality

Michigan regulates the discharge of waste into the State's surface waters under a federally approved NPDES program. Any waste discharges onto the ground or into the ground water are regulated by a State permit. The Water Resources Commission (within DNR) administers both the NPDES permit and State permit systems under the authority of the Michigan Water Resources Commissions Act and through the Water Resources Commission General Rules. Both the State and NPDES permits require that discharges meet all applicable effluent limitations authorized under the Federal Clean Water Act; there are no additional State-wide standards for mining industry discharges. However, the Water Resources Commissions Act and its rules do not apply to iron ore mining operations that affect surface waters owned by or under the control of the mining company. Waters from the mining site that are permitted to escape into public waters are also not regulated if the water contains a minimal amount (not defined in the rules) of residue from the mining operations. The Act and its rules also do not apply to the discharge of water from underground mining operations subject to a determination by the Water Resources Commission (Michigan Water Resources Commission Act, Chapter 323 of the Michigan Compiled Laws; Michigan Water Resources Commission General Rules; Michigan Water Quality Standards).

Air Quality

The State's ambient air quality standards are the same as the Federal requirements. Operators of all sources of air contamination (including mining and beneficiation/mill operations) are required to obtain a "permit to install" the equipment or process that will be the source of air contamination and a "permit to operate" the air emission source. These operations may also be required to develop and implement a fugitive dust control operating program. Any emission source must not interfere with the attainment or maintenance of the national ambient air quality standards, must comply with the national emission standards for hazardous air pollutants (none are iron ore mining applicable), and any applicable Federal standards of performance for new stationary sources. Permits must be obtained for the construction and operation of any new sources. An evaluation must be submitted by the applicant that includes an estimate of air quality after construction of the proposed facility to ensure that ambient air quality will be maintained. (Michigan Air Pollution Laws, Chapter 336 of the Michigan Compiled Laws; Michigan Administrative Rules for Air Pollution Control.)

In addition, Michigan's Administrative Rules for Air Pollution Control contain particulate matter emissions and opacity limits for specific mining operations.

Hazardous Waste

Michigan's Hazardous Waste Management Act has the same mining waste exclusions found in the Federal hazardous waste regulations. Mining overburden returned to the mine site and solid waste from the extraction, beneficiation, and processing of ores and minerals are exempt from the State's hazardous waste regulations. (Michigan Hazardous Waste Management Act, Chapter 229 of the Michigan Compiled Laws; Michigan Hazardous Waste Management Rules.)

Wetlands Protection

The State's Goemaere-Anderson Wetland Protection Act, and its implementing rules, prohibits the use or development of wetlands unless by permit. However, permits are not required for the construction or maintenance of temporary roads for moving mining equipment through a wetland area or the construction of iron mining tailings basins and water storage areas. Permits that allow iron-ore mining activity in a wetland area may contain conditions designed to mitigate the impact upon or impairment to the wetland. (Goemaere-Anderson Wetland Protection Act, Act No. 203 of the Public Acts of 1979, Chapter 281.7 of the Michigan Compiled Laws.)

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APPENDIX 1-A

COMMENTS AND RESPONSES

APPENDIX 1-A: COMMENTS AND RESPONSES

A draft of the *Industry Profile: Iron* was provided to the U.S DOI, Bureau of Mines, the Western Governors' Association, the Interstate Mining Compact Commission, the American Mining Congress (AMC), the Mineral Policy Center, the National Audubon Society, and Public Interest Groups for their review and comment. Approximately 165 comments were submitted to EPA by the following three reviewers: the Bureau of Mines, the American Iron Ore Association, and the Iron Mining Association of Minnesota. The comments included technical and editorial changes, as well as comments on the scope of the Profile and how it relates to authorities provided under RCRA Subtitle D.

Because several general concerns were raised by a number of commenters, EPA has grouped the comments into two categories. The first includes seven general concerns that were raised by all commenters. These are addressed in the first section below. The second category of comments includes technical comments on this Profile, which were raised by specific reviewers, rather than the group as a whole. These are addressed in the second section below. All other comments, including minor technical and marginal notes, have been incorporated into the revised Profile; EPA believes they have served to improve the document's accuracy and clarity. EPA would like to thank all the agencies, companies, and individuals for their time and effort spent reviewing and preparing comments on the Profile.

General Issues Pertaining to All Profiles

1. Comment: Several commenters objected to the use of hypothetical phrases like "may cause" or "may occur." Their use was characterized as misleading and inappropriate in describing environmental impacts in an Industry Profile of this type.

   Response: We believe that the descriptions of conditions and impacts that may occur regarding potential effects is appropriate in many cases, since the intent of the relevant sections of the profiles is to describe potential impacts that may occur as a result of extracting and beneficiating ores and minerals. As noted in the responses to related comments below, EPA has extensively revised the sections of the profiles addressing environmental effects. They are now more focussed and direct; they describe, in general terms, a number of specific types of impacts that can occur under particular conditions or in particular environments.

2. Comment: A related issue raised by commenters was that EPA did not balance the profile by describing environmental protection practices currently followed by the mining industry. Instead, the commenters were critical that EPA selected the worst sites to describe, which represent only a small number of mines and even a few clandestine operations.

   Response: We believe the Profile represents current environmental management practices as described in the current literature. EPA also collected information on current waste management practices at an iron mine (see Section 2.0).

3. Comment: Commenters were concerned that the sites described in the discussion of environmental effects were under some other regulatory authority (e.g., CERCLA).

Response: As noted above, the relevant sections of the profiles have been revised extensively. However, EPA believes that, with proper qualification, sites under other regulatory authorities, including CERCLA, are relevant to any examination of actual or potential environmental effects.

4. Comment: Commenters were concerned that the Profile considered materials other than those considered "wastes" under RCRA.

   Response: EPA believes it is proper to consider all facets of the industry that have some potential to pose risks to human health and the environment. Since this document is a technical resource for States and others, it is very much appropriate to describe areas of concern so they may be properly controlled by States.

5. Comment: Many commenters recommended that the mitigating effects of site-specific factors on potential environmental effects be discussed.

   Response: As noted above, we have revised the relevant sections of the profiles, including the addition of language that emphasizes the site-specific nature of potential environmental effects.

6. Comment: Many commenters recommended that the effectiveness of State regulatory actions in preventing adverse environmental effects be integrated into any discussion of potential effects.

   Response: The Profile has been amended to reflect the fact that State requirements can substantially reduce or eliminate many adverse environmental effects.

7. Comment: A number of comments were received on the table in the draft profile that cited NIOSH data on the quantities of certain chemicals found on mine property and that included worker exposure limits. Commenters questioned the data's accuracy and relevance.

   Response: The original table has been replaced with a simple list of chemicals typically found on sites.

Technical Issues Pertaining to the Iron Profile

9. Findings of the 1985 Report to Congress should be presented in the profile, specifically the finding that no hazardous waste was produced by the iron ore industry.

   Response: We have not included this language from the 1985 Report to Congress because, in light of the 1990 Report to Congress, this language is too vague.

10. The environmental effects data reflects only two sites (Dunka and Reserve Mine sites) and are thus misleading.

    Response: In keeping with changes to the environmental effects sections noted above, the discussion of the Dunka and Reserve sites have been revised.

11. Much of the mine production, process, and tailings impoundment capacity data are inaccurate and out of date.

Response: Where possible, we have updated statistics with data from the Bureau of Mines and the American Iron Ore Association. When up-to-date data were not available, specific statistics were deleted.

12. Commenters expressed concern about terminology use in asbestos discussions (e.g., need to distinguish between asbestiform and non-asbestiform minerals).

    Response: We have revised the terminology used in the discussions about asbestos and edited the appropriate sections. However, the 1971 EPA Report identified in the text documents the presence of asbestiform-type amphibole minerals in the Reserve Mining Taconite beds.

13. Discussion of the Cimmaron Mine site should be deleted because environmental degradation was a result of precious metals mining, not iron ore.

    Response: We have deleted the discussion of the Cimmaron site.

14. Any discussion of 1990 RTC on Mineral Processing is unwarranted as iron ore mining ends at agglomeration and does not include processing.

    Response: We discuss the 1990 *Report To Congress on Special Wastes from Mineral Processing* in the introduction to the profile. This is done to present an overview of all aspects of the mining industry and EPA's actions. The body of the report is confined to topics and materials associated with extraction and beneficiation, not processing.

15. Delete the discussion of BLM management because 99 percent of iron ore is mined in states where this has no application.

    Response: We have deleted the discussion of BLM management.

16. The Profile should include a description of Michigan solid waste laws and regulations which apply to non-mining wastes in the mining industry and Michigan's dam safety laws and regulations.

    Response: We have noted the existence of these programs in the revised profile, although they are not discussed in detail.

17. Since the Profile was commissioned as part of the ongoing Subtitle D regulatory process, abandoned mine lands should not be included in this report, except insofar as they reflect current or future mining operations.

    Response: We feel that inclusion of abandoned mine sites is appropriate in providing useful information regarding potential environmental impacts.

APPENDIX 1-B

ACRONYM LIST
Acronym List

AMC	American Mining Congress
AMD	Acid Mine Drainage
ARD	Acid Rock Drainage
BAT	Best Available Technology
BPJ	Best Professional Judgment
BPT	Best Practicable Technology
CAA	Clean Air Act
CFR	Code of Federal Regulations
CWA	Clean Water Act
DNR	Department of Natural Resources
DOI	Department of the Interior
dscm	dry standard cubic meter
FS	Forest Service
FWS	Fish and Wildlife Service
HHS	Health and Human Services
HSWA	Hazardous and Solid Waste Amendments
LC50	lethal concentration
lt	long ton
ltpy	long tons per year
MCLs	Maximum Contaminant Levels
mg/l	milligrams per liter
mg/m^3	milligrams per cubic meter
mt	metric ton
NESHAPs	National Emissions Standards for Hazardous Air Pollutants
NIOSH	National Institute of Occupational Safety and Health
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
NPS	National Park Service
NSPS	New Source Performance Standards
PELs	Permissible Exposure Limits
PSD	Prevention of Significant Deterioration
RCRA	Resource Conservation and Recovery Act
SAIC	Science Applications International Corporation
SDS	State Disposal System
SDWA	Safe Drinking Water Act
st	short tons
SWDA	Solid Waste Disposal Act
TSCA	Toxic Substances Control Act
U.S.	United States
USC	United States Code
EPA	U.S. Environmental Protection Agency

MINE SITE VISIT:

LTV STEEL MINING COMPANY

U.S. Environmental Protection Agency
Office of Solid Waste
401 M Street SW
Washington, DC 20460

2.0 SITE VISIT REPORT: LTV STEEL

2.1 INTRODUCTION

2.1.1 Background

The Environmental Protection Agency (EPA) has initiated several information gathering activities to characterize mining wastes and management practices. As part of these ongoing efforts, EPA is gathering data by conducting visits to mine sites to study waste generation and management practices. As one of several site visits, EPA visited LTV SMCo.'s facilities near Hoyt Lakes, Minnesota on September 11 and 12, 1991.

Sites to be visited were selected to represent both an array of mining industry sectors and different regional geographies. All sites visits have been conducted pursuant to RCRA Sections 3001 and 3007 information collection authorities. When sites have been on Federal land, EPA has invited representatives of the land management agencies (Forest Service/Bureau of Land Management). State agency representatives and EPA regional personnel also have been invited to participate in each site visit.

For each site, EPA has collected information using a three-step approach: (1) contacting the facility by telephone to get initial information, (2) contacting state regulatory agencies by telephone to get further information, and (3) conducting the actual site visit. To assist in these efforts, EPA developed an informal guide for information collection prior to the site visit. Information collected prior to the visit was then reviewed to ensure accuracy during the initial meeting and the closing meeting of the site visit.

In preparing this report, EPA collected information from a variety of sources including the LTV SMCo. facility, the Minnesota Department of Natural Resources, the Minnesota Pollution Control Agency, and other published sources. The following individuals participated in the LTV SMCo. site visit on September 11 and 12, 1991:

<u>LTV SMCo.</u>	
Dennis Koschak, Technical Services Superintendent	(218) 225-4219
Jim Stanhope, Environmental Engineer	(218) 225-4373
Dave Youngman, Forester	(218) 225-4223
<u>Cleveland-Cliffs, Inc.</u>	
Phil Brick, Manager, Environmental Affairs	(216) 694-5414
Chuck Hoffman, Director, Environmental Affairs	(218) 722-0566
<u>U.S. EPA</u>	
Stephen Hoffman, Chief, Mining Waste Section	(202) 308-8413
<u>Minnesota Department of Natural Resources</u>	

Paul Pojar, Geological Engineer	(612) 296-4807
Minnesota Pollution Control Agency	
Richard Clark, Hydrogeologist, Industrial Section, Water Quality Division	(612) 296-8828
Science Applications International Corporation	
Ron Rimelman, Chemical Engineer	(703) 821-4861
Jonathan Passe, Regulatory Analyst	(703) 821-4831

2.1.2 General Facility Description

The LTV Steel Mining Company (LTV SMCo.) mines magnetite iron ore (primarily taconite) from open pit mines located near Hoyt Lakes and Aurora, Minnesota and from the Dunka Pit, located 20 miles northeast of the primary site. Due to the unique characteristics of the Dunka site, this operation is discussed in a separate section of this report. LTV SMCo. currently extracts ore from 5 pit areas (Areas 2E, 2WX, 5 South, and 6 at Hoyt Lakes and Area 8 at the Dunka Site). Extracted ore is hauled by truck to rail cars, which transport the ore to the beneficiation facility at Hoyt Lakes (see Erie Plant in Figure 2-1) for crushing, grinding, concentration of magnetic iron minerals, and agglomeration into a pellet product. Surficial materials (identified as glacial till), waste rock, and lean taconite ore are stored in stockpiles in and around the mine pits. Tailings generated through beneficiation of the ore are disposed of in a tailings impoundment located north of the beneficiation facility. Pellets are transported approximately 74 miles by rail to LTV SMCo.'s Taconite Harbor dock facility on Lake

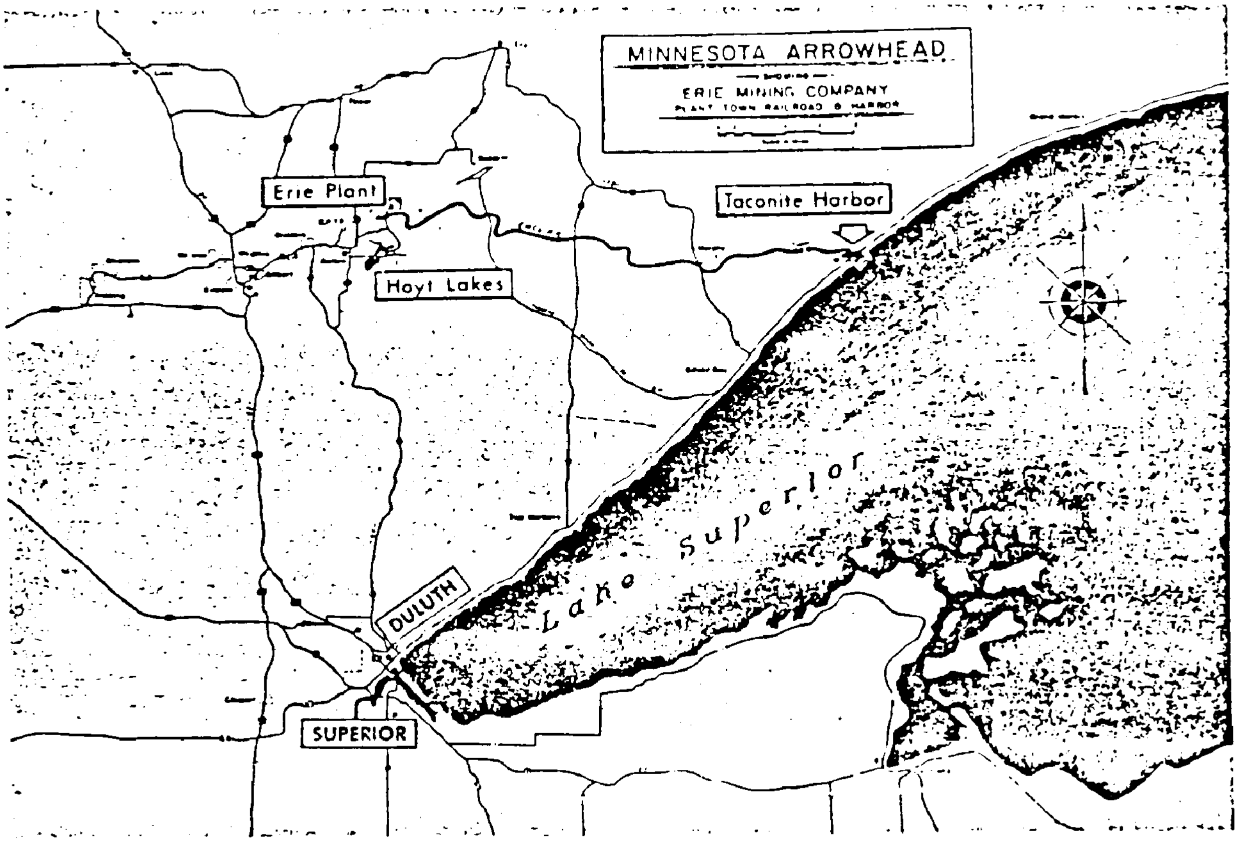

Figure 2-1. Location of LTV Steel Mining Company Facilities

(Source: Erie Mining Company, 1969)

Superior, where they are shipped to blast furnaces in other States. Figure 2-1 shows the location of LTV

SMCo. facilities.

The total LTV SMCo. site area is 61,600 acres; of this, 7,720 acres are currently associated with active operations. The facility is sited on privately owned lands, Federal lands (Forest Service and Bureau of Land Management), and State lands located in St. Louis, Lake, and Cook Counties of Minnesota. The land around the perimeter of the facility is predominantly undeveloped multiple use forest land. The land is used for hunting, fishing, logging, snowmobiling, hiking, and skiing. A minor amount of agriculture is also practiced. The nearest towns are Hoyt Lakes (population 2,348) and Aurora (population 1,965), located 4.4 and 5.5 miles from the site, respectively. The distances from an active mine pit to the nearest dwelling and school are 2 miles and 2.5 miles, respectively. The distance from the Taconite Harbor site to the nearest dwelling is approximately 200 to 300 feet.

In 1990, the LTV SMCo. Hoyt Lakes operations manufactured a total of 8,014,402 tons[2] of pellets (wet) from 25,353,159 tons of crude taconite ore. The facility also stripped 9,114,201 and 9,573,902 tons of rock and surficial materials in 1990, respectively. Approximately 17,200,000 tons of tailings were generated by beneficiation activities in 1990 (LTV SMCo., Undated a).

2.1.3 Environmental Setting

The LTV SMCo. site has an interior continental climate. The average local temperature ranges from 8.3° F in January (recorded minimum, -45° F) to 68.1° F in July (recorded maximum 103° F). Local average annual precipitation is 26.91 inches per year with nearly half (49 percent) falling during the growing season. Average annual snowfall is approximately 70 inches; an inch or more of snow covers the ground for approximately 140 days during the winter. On average, the first fall freeze occurs in mid-September, the last in late-May. No permafrost occurs in the area.

Endangered, threatened, and/or State-protected species present on or within 1 mile of the facility include the Eastern Timber Wolf (Canis lupus), Bald Eagle (Haliaeetus leucocephalus), Peregrine Falcon (Falco peregrinus), and Lady Slipper (Cypripedium orchid). The facility has cooperatively participated with the Minnesota DNR in wildlife management/enhancement programs on the site to benefit moose, deer, and ruffed grouse. Walleye and other fish species live in the facility's tailings impoundment. Hunting is prohibited on all of the facility's 61,600 acres. The facility also participates in timber and fire management programs and has a fire-fighting equipment and manpower agreement with the Forest Service.

2.1.3.1 Surface Water

The LTV SMCo. Hoyt Lakes site is within the Lake Superior drainage basin. First Creek, Second Creek (Knox Creek), Longnose Creek, Wyman Creek, and Colby Lake are the immediate receiving waters for the Hoyt Lakes plant site and mine drainage. These creeks are all tributaries of the Partridge

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[2] In this report, the term "tons" is used to refer to long tons (2,240 pounds), which is the standard unit of measure in the iron industry.

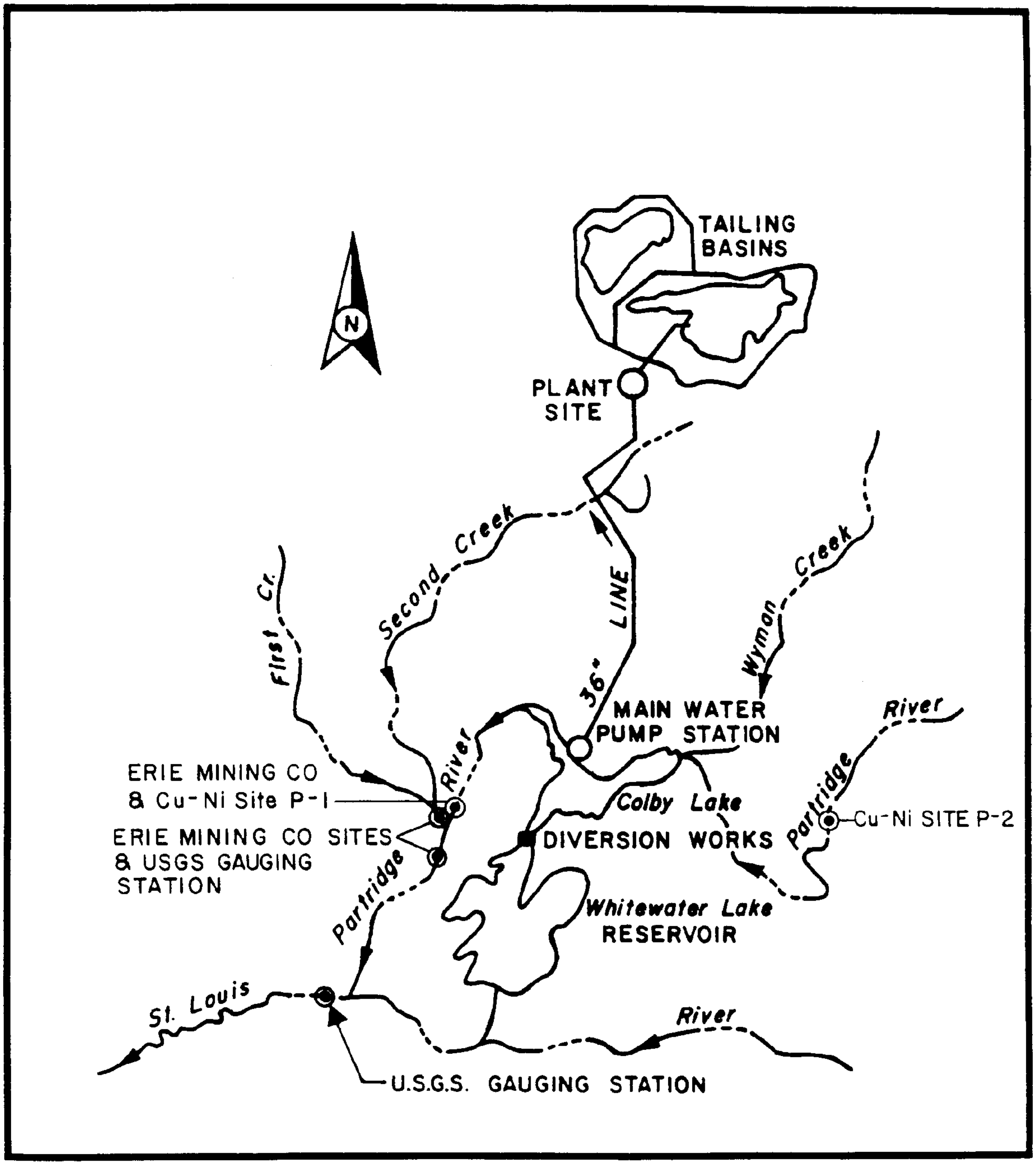


Figure 2-2. U.S.G.S. Gauging Stations, Erie Mining Company Sampling Sites, and Copper Nickel Task Force Sampling Locations

(Source: St. Paul District Corps of Engineers, 1976)

River which flows into the St. Louis River southwest of Hoyt Lakes (see Figure 2-2). The St. Louis

River ultimately discharges into Lake Superior near the city of Duluth (MPCA, 1991c).

Gauging stations installed by USGS at Second Creek, Partridge River, and the St. Louis River (see Figure 2-2) have recorded the following flow measurements (flow measurements for the other water bodies were not available):

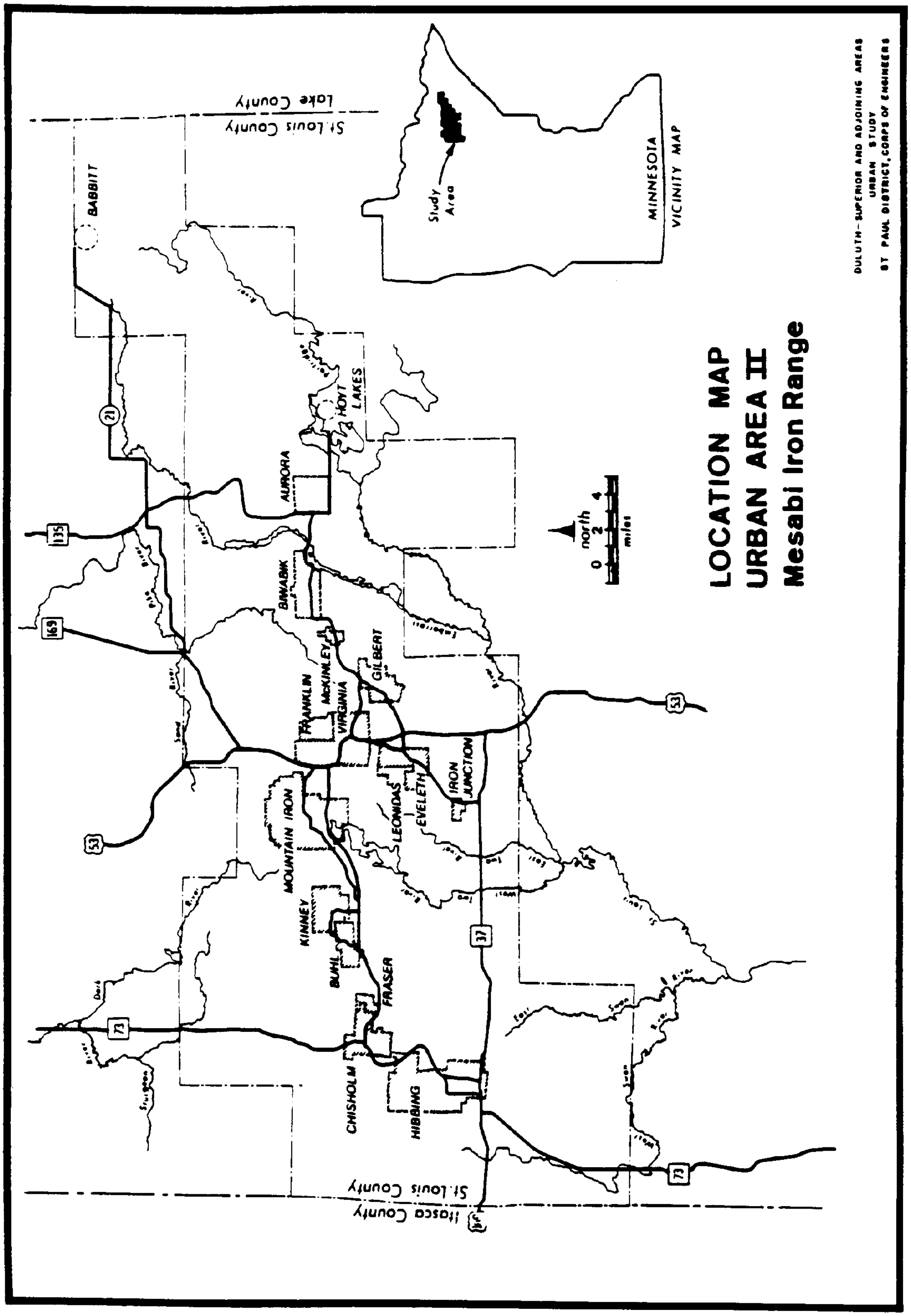
Waterway	Period of Record	Maximum Discharge (cfs)	Minimum Discharge (cfs)	Average Discharge (cfs)
Second Creek	March, 1955 to present	254	1.5	22.8
Partridge River	August, 1942 to present	3,230	2.2	128
St. Louis River	August, 1942 to present	5,380	4.0	247

The Minnesota Pollution Control Agency's (MPCA) Rules 7050.0040-.0470, "Classification of Waters of the State", designate the LTV SMCo. receiving waters, except for Wyman Creek and Colby Lake, as class 2B, 3B, 4A, 4B, 5, and 6 waters. These classifications designate these waters as suitable for fisheries, recreation, industrial consumption, agriculture, wildlife, navigation, and waste disposal. Wyman Creek is classified as 1B, 2A, 3B, 3C, 4A, 4B, 5, and 6 water. Colby Lake is classified as 1B, 2Bd, 3B, 3C, 4A, 5, and 6 water. These classifications designate these waters as suitable for domestic consumption, fisheries, recreation, industrial consumption, agriculture, wildlife, navigation, waste disposal, and all other uses (MPCA, 1991c).

LTV SMCo.'s Dunka mine site is located within the Hudson Bay watershed. The mine water and runoff from the site are discharged into the following surface-water bodies: Dunka River, and Unnamed Creek and its tributary, Billiken Creek, and Flamingo Creek. Unnamed Creek and Flamingo Creek flow into Bob Bay, which is part of Birch Lake. The Dunka river flows into Dunka Bay, a part of Birch Lake. Each of these water bodies is classified as 2B, 3B, 4A, 4B, 5, and 6 waters. These classifications designate the waters as suitable for fisheries, recreation, industrial consumption, agriculture, wildlife, navigation, and waste disposal (MPCA, 1991a; MPCA, 1991b).

The LTV SMCo. Taconite Harbor site is in the Lake Superior drainage basin. The Taconite Harbor power plant cooling water discharges into Lake Superior (MPCA, 1991d).

2.1.3.2 Geology



The principal iron-bearing formation in Northern Minnesota, known as the Biwabik iron formation, extends from Grand Rapids eastward to Birch Lake (see Figure 2-3). Much of the Biwabik is overlain by unconsolidated glacial drift. The width of the outcrop averages about 1.25 miles, but ranges between 1/4 mile to 3 miles. The total subcrop area is approximately 135 square miles. From the northern limit of the subcrop area at the boundary formed by exposure of the underlying Pokegama quartzite, the formation slopes gently to the south at a dip of 5 to 10 degrees from the horizontal. The southern limit of the exposure is defined by the overlying Virginia slate (Argillite),except near the eastern end of the Range where an intrusion of dark colored gabbro (or Duluth Complex material) lapped up over the iron formation and pinched it out at the eastern extremity, greatly affectingthe iron formation by its "cooking action" in the process (see Figure 2-4) (St. Paul District Corps of Engineers, 1976). While LTV SMCo.'s Hoyt Lakes facility is located where the Biwabik formation is overlain with Virginia slate, the Dunka site is located in the area of gabbro intrusion.

The sedimentary rocks of the Biwabik iron formation are called taconite. The essential minerals in order of their abundance are quartz (or chert) and other silicates, magnetite, carbonates, and hematite, which occur together in varying proportions. Local chemical weathering and leaching by the infiltration of surface waters has removed the silica and caused a relative increase in iron concentration. This process has locally altered the taconite to magnetite and hematite, to yield the red natural ore deposits of the Mesabi Range. These deposits are described as occurring like "raisins in a cake" for a 70 to 80 mile length of the Range (St. Paul District Corps of Engineers, 1976).

The LTV SMCo. Hoyt Lakes facility is located in a "Zone 1" seismic area. Seismic classifications are based on the distribution of historical, damaging earthquakes, their intensities, evidence of strain release, and distributions of geological structures related to earthquake activity. Zone 1 indicates expected minor damage to structures due to distant earthquakes (Cargo and Mallory, 1977). According to LTV SMCo. personnel, there are no holocene faults at the site and no karst or fractured terrain can be found in the area.

2.1.3.3 Hydrogeology

Dominance of Precambrian bedrock, glacial till, and lake deposits has limited the occurrence of high-yielding, permeable aquifers in the area. The Biwabik Iron formation is the only significant bedrock aquifer in the area. The thickness of this surficial aquifer is commonly greater than 50 feet, and it exceeds 100 feet in the general vicinity of four bedrock valleys along the formation. The depth to the water table is generally no more than 25 feet below land surface at any place in the range. Although the surficial aquifer generally yields low volumes of water, the bedrock aquifer is in the sedimentary formation. This formation is also the source of the iron ore deposits. The bedrock has been locally altered by weathering so that its permeability and porosity have increased. Excavations that extend below the water table fill unless water is removed by pumping or other means. Although well yields of up to 1,000 gpm have been reported, average yields range from 100 to 200 gpm (St. Paul District Corps of Engineers, 1976).

2.1.3.4 Wetlands

There are hundreds of acres of wetlands along the Mesabi Iron Range. Wetlands are found within the facility boundaries of each of the mining companies along the Range. The State of Minnesota has based its program of wetland protection on the classification system presented in Wetlands of the United States, U.S. Department of the Interior, Fish and Wildlife Circular No. 39, 1971 Edition. This circular classifies wetlands into 8 types, from seasonal flooded areas to permanently flooded areas such as open water wetlands and bogs. Activities in Type 3, 4, and 5 wetlands are directly regulated by the Minnesota DNR, Division of Waters. In addition, all wetlands across the Range are subject to regulation by the Minnesota DNR, Division of Waters and Minerals.

The Minnesota Wetlands Conservation Act of 1991 provides for protection and/or replacement of all other wetland types. Executive Order 91-3 directs state departments and agencies to follow a No-Net-Loss policy in regard to the wetlands they impact or regulate. Replacement of drained or filles wetlands will be guided by new regulations to be developed for the Wetland Conservation Act.

Wetlands located at LTV SMCo.'s operation are dominated by bogs, Type 8 wetlands. In addition, a small area of wetlands at Hoyt Lakes is composed of open water and flora typically associated with shallow marsh (Type 3 wetlands) and shrub swamp (Type 6 wetlands).

2.2 FACILITY OPERATIONS

The LTV SMCo. Hoyt Lakes Taconite Operation (formerly Erie Mining Company) is located 65 miles north of Duluth, Minnesota, near the eastern end of the Mesabi Iron Range. The operation's surface mines are located generally east and west of the processing plant. At the plant, taconite ores are crushed, milled, concentrated, and agglomerated into pellets. The pellets are transported by rail east to LTV SMCo.'s Taconite Harbor docking and shipping facility on Lake Superior for shipment to out-of-state steel manufacturers. LTV SMCo. also operates a power plant at the Taconite Harbor site.

Mining on the Mesabi Range originally centered around open pit and underground mining of natural ore. In the 1950s, the modern taconite pellet process was developed. By the 1960s, as the reserves of natural ore decreased, mining activities began to focus on taconite ore. Although some natural ore (as opposed to taconite) is still produced near the LTV SMCo. facility, it is being phased out as reserves are mined to economic limits.

The Hoyt Lakes operation began in 1931 when Pickands Mather & Co., in conjunction with Bethlehem Steel Corporation and the Youngstown Sheet and Tube Company first became interested in processing lean taconite ores in Northern Minnesota. The Erie Mining Company was formed in 1940 after initial studies and exploration confirmed both the extent of reserves at the site and the potential for economic utilization of those reserves. A pilot-scale laboratory was established in 1942 and by 1946, Erie began testing the laboratory flowsheet with commercial-size equipment. Erie ownership expanded to include Interlake Steel Corporation (formerly Interlake Iron Corporation) and the Steel Company of Canada, Ltd. In 1954, Pickands Mather & Co., retained as the managing agent, began construction of a commercial plant with an annual pellet production capacity of 7.5 million tons (which was later increased to 10.3 million tons). Construction of the facility was completed in September 1957 (Erie Mining Company, 1969).

In April 1986, LTV SMCo. took over sole ownership of the Erie Mining Company and the facility name officially changed to LTV Steel Mining Company Hoyt Lakes in 1987. Pickands Mather & Co. was retained as the facility managing agent. Cleveland-Cliffs, Inc. bought Pickands Mather & Co. in 1986 and, after internal reorganization, Cliffs Mining Co. became the managing agent.

The LTV SMCo. facility currently generates 20,000 tons of 1/4-inch pellets per day. These pellets contain 67.5 percent iron, 4.9 percent silica, and trace amounts of alumina, manganese, phosphorus, magnesium, sulfur, and oxygen. The plant also generates 200,000 tons of broken pellets (chips) per year. The chips may be consumed internally, reground and used as concentrate, or sold to blast furnaces for use as sinter feed.

2.2.1 Mining Operations

The LTV SMCo. Hoyt Lakes operation consists of several open pit mines; however, only a few areas of each pit are mined at any given time. At the time of EPA's site visit, LTV SMCo. was mining five pit areas (Areas 2E, 2WX, 5 South, 6, and 8). The operating area of the Hoyt Lakes site is 7,720 acres. The average or maximum depth of the pits was not specified.

As part of its Permit to Mine (discussed in greater detail later in this report), LTV SMCo. prepares an annual Mine Plan summarizing estimated material movement at each mining area for the upcoming year. LTV SMCo.'s anticipated mining activities in each area for 1992 are presented below (LTV SMCo., Undated c):

Area	Active Excavation Area (acres)	Taconite (1,000 long tons)	Rock (1,000 long tons)	Surface Material (1,000 long tons)
2E	100	4,967	5,520	250
2WX	144	5,280	6,300	1,760
5 South	53	3,378	2,103	1,883
6	107	7,390	6,250	850
8	12	3,862	500	N/A
Total Tons		25,416	20,673	4,743

Although each of the facility's mining areas have similar geological features (with the exception of the Dunka site), there are differences in the ore qualities (percent of iron and liberating characteristics). However, a consistent uniform grade ore feed is required due to the limited flexibility at the taconite processing plant to adjust to ore feed changes. Therefore, the LTV SMCo. facility has developed a computerized blending system where in-field ore characteristic analyses are fed to a computer that coordinates ore transfers to the crusher. Ores from different mining areas with different iron content and liberating characteristics are blended to produce an ore feed that will result in a concentrate containing 67.5 percent magnetic iron and 4.6 percent silica after concentration activities. Another determining factor for blending is that concentrates containing greater than 0.2 percent phosphorus hinder the steel-making process. The computer system was brought on line in the late 1980s; prior to this, blending was performed manually.

All of the ore and waste rock are drilled using rotary drill rigs. The LTV SMCo. facility uses ammonium nitrate fuel oil (ANFO) as a blasting agent in low water areas. In wet holes, an ammonium nitrate emulsion is used with aluminum additives to enhance energy as required. Approximately 80 percent of the usage is the emulsion type. Between 250,000 and 1,000,000 tons of material (750,000 tons on average) are broken per blast (Erie Mining Company, 1969).

Overall, approximately 60,000 tons of surface material and waste rock are stripped at the LTV SMCo. mine pits per day. This is accomplished using 28-yard and 15-yard electric shovels to load 170-ton trucks. Additional activities employ smaller mechanical shovels, front-end loaders, and tractor dozers. Non-ore material removed from the mine is classified as glacial till, waste rock, and lean taconite and stored in segregated stockpiles located on like material (e.g., surface material on surface material, not lean taconite ore on waste rock). Stockpiles are sited based on convenience and need. Lean ore stockpiles are specifically located near rail lines to facilitate transport to the mill should economic conditions justify its use. Most waste rock is placed back into the pits (Erie Mining Company, 1969).

As of January 1, 1992, there were 47 lean taconite ore stockpiles at LTV SMCo (14 piles in Area 1, 10 piles in Area 2, 3 piles in Area 2WX, 1 pile in Area 5N, 6 piles in Area 5S, 1 pile in Area 6, 7 piles in Area 8, and 5 piles in Area 9). The range and average quantity of lean taconite stored in stockpiles and the range and average size of stockpiles in each area are summarized below (LTV SMCo., 1992a):

- Area 1: average quantity = 167,000 long tons (range = 9,000 - 470,000 long tons); average size = 68,000 cubic yards (range = 3,500 - 192,000 cubic yards)

- Area 2: average quantity = 13,100,000 long tons (range = 48,000 - 10,350,000 long tons); average size = 1,066,000 cubic yards (range = 19,000 - 4,216,000 cubic yards)

- Area 2WX: average quantity = 1,335,000 long tons (range = 88,000 - 3,542,000 long tons); average size = 544,000 cubic yards (range = 36,000 - 1,443,000 cubic yards)

- Area 2N: quantity = 496,000 long tons; size = 202,000 cubic yards

- Area 5S: average quantity = 457,000 long tons (range = 16,000 - 1,321,000 long tons); average size = 186,000 cubic yards (range = 6,600 - 538,000 cubic yards)

- Area 6: quantity = 97,000 long tons; size = 39,000 cubic yards

- Area 8: average quantity = 267,000 long tons (range = 18,000 - 692,000 long tons); average size = 108,000 cubic yards (range = 7,500 - 282,000 cubic yards)

- Area 9: average quantity = 81,600 long tons (range = 12,000 - 208,000 long tons); average size = 33,000 cubic yards (range = 5,000 - 85,000 cubic yards)

The mined ore is loaded by 8- and 15-yard shovels onto 170- and 240-ton trucks that transport the ore to rail loading pockets equipped with vibrating feeders. The facility's trains are diesel powered and are typically comprised of 8 to 16 cars, depending on area haulage and processing plant feed requirements. The trains transport ore directly to one of the beneficiation facility's 2 primary crushers. Diesel fuel for the facility's trucks and trains is stored in above-ground 12,000 gallon stationary main tanks and distributed by "mobile units" (Erie Mining Company, 1969).

The Hoyt Lakes mine facility uses lignonsulfate as a chemical dust suppressant at a rate of 1.2 million gallons per year on roads, in the pits, and in loading areas. Calcium chloride and/or a calcium chloride-sodium chloride mixture are also applied to the facility's roads at rates of approximately 12.5 and 110 tons per year, respectively (Erie Mining Company, 1969).

2.2.2 Beneficiation Operations

LTV SMCo.'s beneficiation operation consists of crushing, grinding, magnetic separation, and flotation. The ore entering beneficiation operations typically has a magnetic iron content of 23 percent. The milling, magnetic separation, and flotation processes (prior to agglomeration) result in a

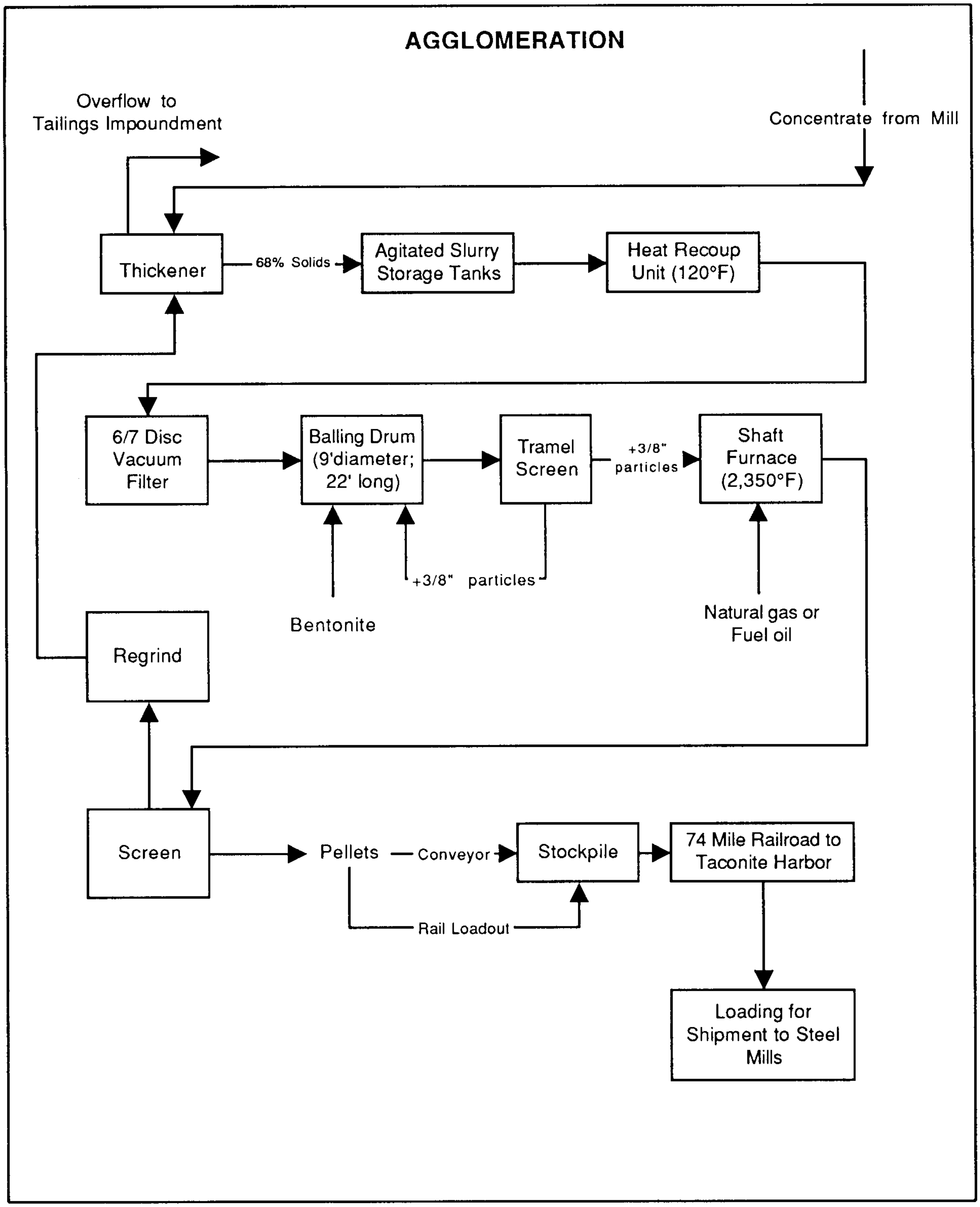


Figure 2-6. LTV Steel Mining Company Ore Agglomeration Flow Diagram

(Source: USEPA Field Notes)

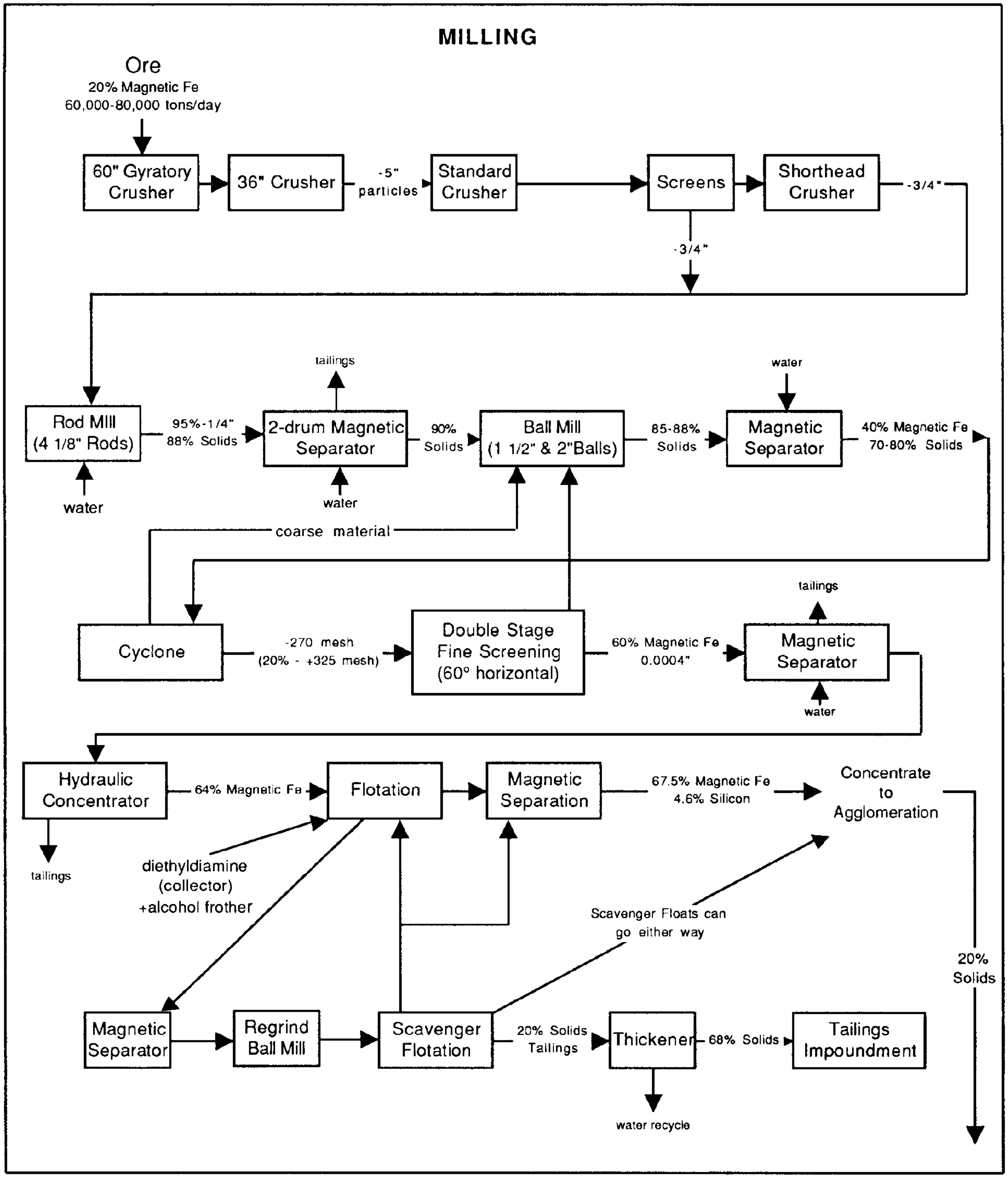


Figure 2-5. LTV Steel Mining Company Milling Operation Flow Diagram

(Source: USEPA Field Notes)

concentrate with a magnetic iron content of 67.5 percent (see Figures 2-5 and 2-6).

Ore is fed from the rail cars into one of two 60-inch gyratory crushers for primary crushing. Each of the 60-inch crushers feeds directly into four 36-inch crushers (8 total), which crush the ore into -5 inch particles. These crushing operations are dry processes where baghouse collectors are used to control fugitive dust. Collected dust is reintroduced to the crusher system.

The eight 36-inch crushers feed seven fine crusher systems. Each fine crusher system consists of one 7-foot standard cone crusher and two 7-foot shorthead crushers. The -2 inch ore that leaves the standard crushers is classified on a vibrating screen before entering the shorthead crushers. Ore leaving the shorthead crushers is -3/4-inch with 1/2 to 1 percent natural moisture. Although this is a dry process, water is used for fugitive dust control. In addition, soda ash is added to the ore to reduce water hardness in the mill. Approximately 60,000 to 80,000 tons of fine crushed ore are produced per day and held in surge bins prior to further beneficiation (Erie Mining Company, 1969).

Fine ore is fed from the surge bins to one of 34 mill lines, each of which consists of a rod mill, a ball mill, and several separation and classification stages. The nominal ore feed to each of these lines is approximately 100 tons per hour. LTV SMCo. typically operates 25 to 30 of their 34 mill lines at any one time to allow for maintenance on individual units without needing to shut down whole sections of the plant.

In each line, ore is first fed into a rod mill containing 4 1/8-inch rods. Each rod mill is 12.2-feet in diameter by 14-feet in length and powered by an 800 horsepower (hp) motor. At this point in the process, water is added to the ore to produce a slurry of 88 percent solids. The ore particles resulting from the rod mill are 5 percent +1/4-inch and 95 percent -1/4-inch.

This ore is then fed, along with additional water, into a two-drum magnetic separator. Varying quantities of water are used to wash gangue away from the magnetic values. The gangue flows to a tailings thickener and is ultimately disposed of in the facility's tailings impoundment.

The ore slurry, now approximately 80-85 percent solids, is further ground in a ball mill containing 1 1/2- and 2-inch balls. Each ball mill is 12.2-feet in diameter by 14-feet in length and powered by a 1,250 hp motor. The ore leaving the ball mill, which is in a slurry of 85 to 88 percent solids, flows to a magnetic rougher.

The magnetic rougher increases the magnetic iron content of the ore to approximately 40 percent. The ore slurry leaving the rougher contains between 70 and 80 percent solids; water is then added, decreasing the solids content to about 35 percent. The ore slurry is then cycloned and coarse material is sent back to the ball mill and the fine material product (80 percent -270 mesh or 0.0021 inches, 20 percent +325 mesh or 0.0017 inches) is sent to fine screening.

Fine material from cyclones is fed to a double-force 0.004-inch opening fine screen that is mounted at a 60° angle and which provides an ore particle size of minus 270 mesh; coarser ore particles are sent back to the ball mill. The ore particles passing through the fine screen (approximately 35 to 40 tons of ore per line per hour) are then sent to a three-drum magnetic separator which further concentrates the iron content to 60 percent. Tailings from the separator are sent to a thickener and ultimately to the tailings impoundment for disposal.

The ore resulting from magnetic separation then enters a hydraulic concentrator that separates magnetic material (product) and gangue by gravity or magnetic properties (no chemicals are added). In the concentrator, magnetic ore material, now 64 percent iron, settles to the bottom of the tank at a rate of 34 tons per hour. Gangue overflows the tank and is thickened and disposed of in the tailings impoundment.

Ore is drawn off the bottom of the concentrator in each line and sent to one of the facility's four central flotation lines. Dimethyl diamine, a flotation reagent, is added to the cells at a rate of 0.1 pounds per ton of ore. A 10 to 12 carbon chain alcohol frother is also added, at a rate of 0.001 pounds per ton of ore. At the time of the site visit LTV SMCo. was experimenting with the addition of froth suppressants as well. The flotation cells float silica material away from the iron values, which sink to the bottom of the cell. Between 2 and 3 percent of the ore feed is rejected in the flotation cells.

The product from the flotation cells is then magnetically separated. Concentrate from the magnetic separator is sent to the agglomeration plant, while the rejects are reground in one of three ball mills. The reground ore leaves the ball mills and enters scavenger flotation cells that remove any additional iron-bearing values. Tailings are thickened and sent to the impoundment for disposal, while values may be sent back to the flotation cells or directly to magnetic separation and the agglomeration plant.

According to LTV SMCo. personnel, beneficiation activities generate a nominal average of 20,000 tons of concentrate per day (or 833.33 tons per hour). As noted above, the resulting concentrate contains approximately 67.5 percent total iron.

Prior to agglomeration, concentrate is sent to one of 12 gravity thickeners (each 40-feet in diameter). The thickeners increase the solids content of the concentrate from 20 to 68 percent; the liquid overflow is sent to the facility's tailings impoundment. The site visit team observed that the water in the LTV SMCo. fines recovery thickener was reddish in color. The water in the 12 concentrate thickeners is essentially clear.

From the thickeners, the concentrate is sent to one of five slurry storage tanks. Each tank has a 1,000-ton capacity and is equipped with an agitator. Prior to filtering and agglomeration in LTV SMCo.'s furnaces, the concentrate flows from the slurry tanks through a heat recoup unit that uses heated off-gases from the agglomerating furnace to pre-heat the concentrate to a temperature of 120° F. After pre-heating, the concentrate is sent through a series of two disk vacuum filters (6 or 7 disks each). These filters reduce the moisture content of the concentrate from 60 to 10 percent. The flow rate of concentrate through the filters is dictated by the needs of the agglomerating furnace, but is typically in the range of 55 tons per hour for each of the two sets of filters. The water removed from the concentrate passes into a fines recovery thickener, from which solids are recovered and water is reused.

Filtered concentrate is then sent to one of 24 balling drums (9-feet in diameter by 22-feet long). Prior to the balling drums, bentonite (stored in silos) is added to the concentrate at a nominal rate of 25 pounds per ton of concentrate to aid in the forming of pellets. The facility was experimenting with the use of organic binders as a substitute for bentonite; they had been found to be less effective and not cost effective.

Upon leaving the balling drum, the pellets pass over a trammel screen that removes +3/8-inch material. Smaller particles are sent back to the balling drums to be re-balled. Typically, 52 tons of pellets leave each balling drum per hour.

The green (unfired) pellets are then transported to one of 24 shaft furnaces. The furnaces are fueled by natural gas and/or fuel oil to heat the pellets to a temperature of 2,350° F. All of the furnaces at the facility are equipped with mechanical air pollution control units. As discussed above, half of the furnaces have heat recoup units, which serve to scrub emissions and feed the concentrate pre-heaters. Pellets enter at the top of the furnace and pass down the shaft with an average residence time of four hours. Magnetite in the iron pellets is converted into hematite. Between 500,000 and 525,000 BTU of energy are applied per ton of pellet product fired. The use of shaft furnaces is atypical in the iron industry; most facilities employ natural gas-fueled grate or grate-kiln furnaces to heat pellets. Fuel oil is the main substitute fuel, with the use of coal or wood chips as alternative fuels. In addition, while many iron industry facilities have begun to produce flux pellets, the LTV SMCo. facility has not because of problems associated with making flux pellets in shaft furnaces.

According to LTV SMCo. personnel, water from the furnace operation (including the wet emissions scrubber system) is sent through fines recovery. Recovered fines are returned to the balling mills as concentrate.

The fired pellets leave the bottom of the furnace and are transported along a water-cooled conveyer across a screen to a pellet stockpile, where water is used in dust control. The pellet stockyard has a capacity of 5 million tons. From there, pellets are moved by two 10-yard shovels for rail transport to the Taconite Harbor facility for shipment.

The LTV SMCo. Hoyt Lakes facility was generating (in September 1991) 20,000 tons of plus 1/4-inch pellets per day. These pellets contain 67.5 percent iron, 4.9 percent silica, as well as oxygen and other minor constituents. The plant also generates 200,000 tons of broken pellets (chips) per year. The chips may be consumed internally, reground and used as concentrate, or sold to blast furnaces for use as sinter feed.

2.2.3 Taconite Harbor/Power Plant

The LTV SMCo. Taconite Harbor docking and shipping facility is located 74 miles from the main Hoyt Lakes plant. EPA did not visit these facilities. Pellets are transported from the agglomerating plant or a pellet stockpile to Taconite Harbor by rail. The rail cars are 85-ton capacity bottom-dump type with mechanisms that allow the car to be automatically dumped while still in motion. Typically, a 96-car train containing 8,000 tons of pellets is dumped in approximately 6.5 minutes while the train is moving at 10 miles per hour or slower to control fugitive dust emissions (Erie Mining Company, 1969).

The Taconite Harbor dock is approximately 2,500 feet in length; the pellet storage and boat loading facility is about 1,200 feet in length with a storage capacity of 100,000 tons of pellets. Ships are loaded by positioning the hatches underneath retractable belt conveyors that move pellets from the storage bins to the ship's hold. Coal to feed the power plant is also unloaded from incoming ships at the dock (Erie Mining Company, 1969).

The LTV SMCo. power plant at Taconite Harbor provides power to both the Harbor and the Hoyt Lakes facility. The Hoyt Lakes facility also has the capacity to draw electricity from the local power company when necessary. LTV SMCo.'s power plant is a 225,000 kilowatt (kw) capacity steam plant capable of generating power at 13,800 volts. The steam for the plant's three 75,000 kw turbines is supplied by three pulverized coal-fired boilers. The initial voltage is stepped-up by transformers to 138,000 volts and transmitted over double-circuit lines to Hoyt Lakes (Erie Mining Company, 1969).

2.2.4 Water Supply

The LTV SMCo. facility circulates approximately 142,000 gallons of water per minute (gpm). Of this, 96 percent is water reclaimed from the facility's tailings basin and thickeners. Only 4 percent (8,000 - 12,000 gpm) of the facility's water consumption comes from an outside source, the man-made Colby Lake reservoir. Colby Lake water is pumped 5.5 miles to LTV SMCo.'s Plant Reservoir through a 36-inch diameter steel pipeline. Colby Lake is also a drinking water source for the LTV SMCo. facility and the town of Hoyt Lakes (LTV SMCo., 1991b).

In addition, Colby Lake is located adjacent to Whitewater Lake, a man-made reservoir which can hold up to 6.5 billion gallons (at an elevation of 1,440 feet). LTV SMCo.'s Colby Lake pumping station, which has three 5,000 gpm pumps, is used to transfer water between the two lakes, as needed. One of three pumps is operated continuously, while the other two pumps are used as required, depending on levels in the Plant Reservoir and the two lakes. A State water permit issued in 1950, and still in effect, requires that LTV SMCo.: (1) maintain the elevation in Whitewater Reservoir at 1,410 to 1,440 feet, (2) "pay back" gallon for gallon water taken from Colby Lake when the water level in Colby Lake drops below 1,439 feet, and (3) limit Colby Lake pumping to the Plant Reservoir to 15,000 gpm. LTV SMCo. has installed an emergency power supply for the Colby Lake pump station (LTV SMCo., 1990).

The LTV SMCo. Plant Reservoir holds approximately 10 million gallons when filled to the normal level of 1,775 feet. The reservoir bottom is divided so that approximately 1 million gallons are segregated in a sump to provide fire protection if the reservoir is empty (LTV SMCo., 1991b).

Two barges are used to pump water from the tailings basin to the Return Water Station. Barge #2 has three 12,000 gpm manually controlled pumps. Barge #1 has three 10,000 gpm and three 5,000 gpm pumps, which are remotely controlled from the facility's Central Control Room (LTV SMCo., 1991b).

Four 22,500 gpm vertical turbine and eleven 7,500 gpm horizontal pumps are used to move reclaimed water from the Return Water Station to the concentrator water loop via two 42-inch water headers. Flow rate to the concentrator is regulated manually from the Central Control Center to maintain a 6.5-foot level in the concentrator sump (LTV SMCo., 1991b).

2.3 WASTE AND MATERIAL MANAGEMENT

2.3.1 Types of Wastes and Materials

2.3.1.1 Surficial Material and Waste Rock

The term surface material, which is identified by LTV SMCo. as "glacial till," refers to all materials removed in accessing an ore body prior to blasting. Glacial till may be composed of top soil, rock, and boulders. In 1990, over 9.5 million tons of surficial material were stripped (LTV SMCo., Undated a).

Waste rock refers to all material that has been excavated by blasting but will not be beneficiated in the future (i.e., contains less than 10 percent magnetic iron). In 1990, more than 9.1 million tons of waste rock were stripped.

In addition, lean taconite is removed during mine operation. This is material that has more than 10 percent magnetic iron, but not enough to be economically beneficiated using current technologies under current market conditions. However, changes in technologies or market conditions may make it economically feasible to beneficiate this material at a later date; thus, the facility does not consider the lean taconite as a waste material.

2.3.1.2 Mine Water

Water can accumulate in mine pits through precipitation, runoff from surrounding areas, and ground-water infiltration. Mine pits at LTV SMCo. are typically de-watered using sumps installed at the bottom of the pits. Water is pumped from these sumps intermittently. According to LTV SMCo. personnel, mine pumpout is analyzed for both quantity and chemical composition and then discharged to local creeks, including several that are drinking water sources, under NPDES permitted discharges (see Section 2.4.2). LTV SMCo. must specifically sample and analyze NPDES outfalls that discharge mine water for flow, turbidity, total suspended solids (TSS), asbestos, pH level, temperature, un-ionized ammonia, chloride, nitrate, and nitrite, oil, dissolved iron, and physical attributes (color, floating solids, foam, and films) (MPCA, 1991a; MPCA 1991b; MPCA, 1991c). Several communities along the Mesabi Range rely on surface water that receives mine water from abandoned pits as a source of drinking water. Other communities use abandoned water-filled mine pits as their source of domestic water.

2.3.1.3 Tailings

Non-magnetic materials (including gangue and process water) that are removed from crude taconite in the beneficiation process are discharged from the mill to tailings thickeners where the excess water is recovered before sumping to the tailings basin. Tailings also may contain iron values lost with gangue material as a result of concentration.

According to LTV SMCo. personnel, the facility has generated an estimated total of 500 million tons of tailings. The generation rate in September 1991 was approximately 40,000 tons of solid tailings material per day.

Tailings at the LTV SMCo. facility typically have a pH of approximately 8. LTV SMCo. monitors the turbidity of the tailings water, but chemical analyses are not generally conducted on the tailings. Facility personnel did indicate, however, that several years ago testing was performed to quantify nitrogen, phosphorus, and potassium levels in the tailings due to algal bloom in the tailings impoundment. Data from these analyses were not available for review by the site visit team.

2.3.1.4 Fly Ash/Coal Mill Rejects

Fly ash, coal mill rejects, and other utility wastes are generated at the Taconite Harbor Power Plant. The facility generates between 101,700 tons per year (tpy) (for eastern coal) and 153,000 tpy (for western coal) of the ash/water mixture waste. The ash chemistry of the coal purchased by LTV SMCo. to be used at the Taconite Harbor facility in 1991 is summarized below (MPCA, 1991d):

Constituent	% By Weight
Silica (SiO_2)	55.97
Alumina (Al_2O_3)	22.09
Titanium Dioxide (TiO_2)	0.86
Ferris Oxide (Fe_2O_3)	6.27
Lime (CaO)	1.03
Magnesia (MgO)	0.99
Potassium Oxide (K_2O)	3.23
Sodium Oxide (Na_2O)	0.66
Phos. Pentoxide (P_2O_5)	0.25
Sulfur Trioxide (SO_3)	1.65
	100.00

2.3.1.5 Other Wastes

Other wastes generated at the LTV SMCo. Hoyt Lakes facility include the following:

- Waste Oils
- Spent Solvents (unspecified)
- PCBs (transformers)
- Sewage/Sanitary Wastewaters and Sludge
- Solid Wastes (i.e., garbage)
- Laboratory Wastes.

Although quantitative information concerning these wastes was not obtained, management practices are summarized in Section 2.3.2 below.

2.3.2 Process and Waste Management Units

For the purposes of this discussion, materials management practices at LTV SMCo. are divided into process and waste management units. Process units are those units whose contained materials not considered to be wastes until after facility closure. Examples of these include mine pits and lean taconite ore stockpiles. Waste units are those that contain materials disposed of prior to facility closure. Examples of these include waste rock stockpiles and the tailings impoundment.

2.3.2.1 Mine Pits

As stated previously, LTV SMCo. conducts mining operations in nine pit areas, although only five pits were active at the time of the site visit. Also, as indicated, during active operations, mine water is intermittently pumped and discharged into nearby surface waters through NPDES permitted outfalls. LTV SMCo. has not found it necessary to reduce potential infiltration to ground water or to monitor ground water since ground-water flow is generally into the pits and discharges of mine water meet NPDES limits. However, according to facility staff, the formation is relatively inert. As indicated earlier, water from Mesabi Range abandoned mines provides drinking water to several towns in the area.

After mining operations have ceased, the State requires that the facility conduct reclamation of pit slopes from the top of the pit down to the lowest level of the glacial till (surficial materials). Reclamation requirements include sloping to 2.5:1, maximum 60-foot lifts, and introduction of vegetative cover. The pits are expected to fill with water up to this level and submerge all rock/formation surfaces. However, according to LTV SMCo. personnel, this may not always occur in practice due to variations in elevation within the large pits at the site.

2.3.2.2 Glacial Till (Surface Materials) and Waste Rock Stockpiles

Glacial till, waste rock, and lean taconite ore are hauled and stockpiled in segregated piles in and around the mine pits. Stockpiles created after 1980 must be sited in accordance with general State siting criteria, but the facility maintains discretion as to specific placement. The MDNR is informed of changes in stockpile locations and construction of new stockpiles in the facility's annual report. (The total number of pre- and post-1980 glacial till and waste rock stockpiles and the total quantity of material stored at the LTV SMCo. site were not readily available from LTV SMCo.).

Under the State law, stockpiles constructed after 1980 must generally be designed and constructed to complement nearby natural terrain, minimize adverse water quality and quantity effects on receiving waters, enhance the survival and propagation of vegetation, be structurally sound, control erosion, promote early completion and progressive reclamation, and encourage the prompt conversion from mining to an approved subsequent use.

Specifically, the final exterior slopes of post-1980 waste rock (and lean ore) stockpiles shall consist of benches and lifts as follows:

- No lift shall exceed 30 feet in height. However, when surface veneer is used, 40 foot lifts are allowable.
- No bench width shall be less than 30 feet wide, measured from the crest of the lower lift to the toe of the next lift.
- The sloped area between the benches shall be no steeper than the angle of repose.
- Benches shall be designed and constructed to control runoff.
- When vegetation is required by the statute, the sloped area between the benches shall be prepared to support vegetation. LTV SMCo. is required to vegetate benches and tops, but not slope surfaces.

Under the State law, the final exterior slopes of glacial till (surface material) stockpiles are required to consist of benches and lifts as follows:

- No lift shall exceed 40 feet in height
- No bench width shall be less than 30 feet wide, measured from the crest of the lower lift to the toe of the next lift
- The sloped area between the benches shall be no steeper than 2.5:1.

Runoff from glacial till and waste rock stockpiles located within LTV SMCo.'s mine pits is collected with mine water and discharged under the facility's NPDES permit. LTV SMCo. does not collect and manage runoff from glacial till piles and waste rock piles located outside of the mine pits.

For glacial till stockpiles constructed after the passage of the State's mining laws in 1980, reclamation is required both on sloped surfaces and benches. For post-1980 waste rock piles, reclamation is only required on the benches and top surfaces of the piles. No requirements apply to glacial till or waste rock stockpiles constructed before 1980. However, MDNR can authorize reclamation "tradeoffs" in which the facility agrees to reclaim a pre-1980 stockpile in lieu of reclaiming a post-1980 stockpile, when the MDNR considers it more important to reclaim the older stockpile.

2.3.2.3 Tailings Impoundment

Tailings Thickener

Mill tailings generated during the beneficiation process are sent to one of five AMCO tailings thickeners. Cationic flocculants, such as Calgon 502 or equivalent, are added to the tailings to aid the gravity separation process which yields a slurry of 40 to 42 percent solids. Tailing solids settle in the thickeners at a rate of 40,000 tons per day. Liquid overflow from the thickeners is recycled to the mill for use as process water (without treatment) at a rate of 140,000 gpm.

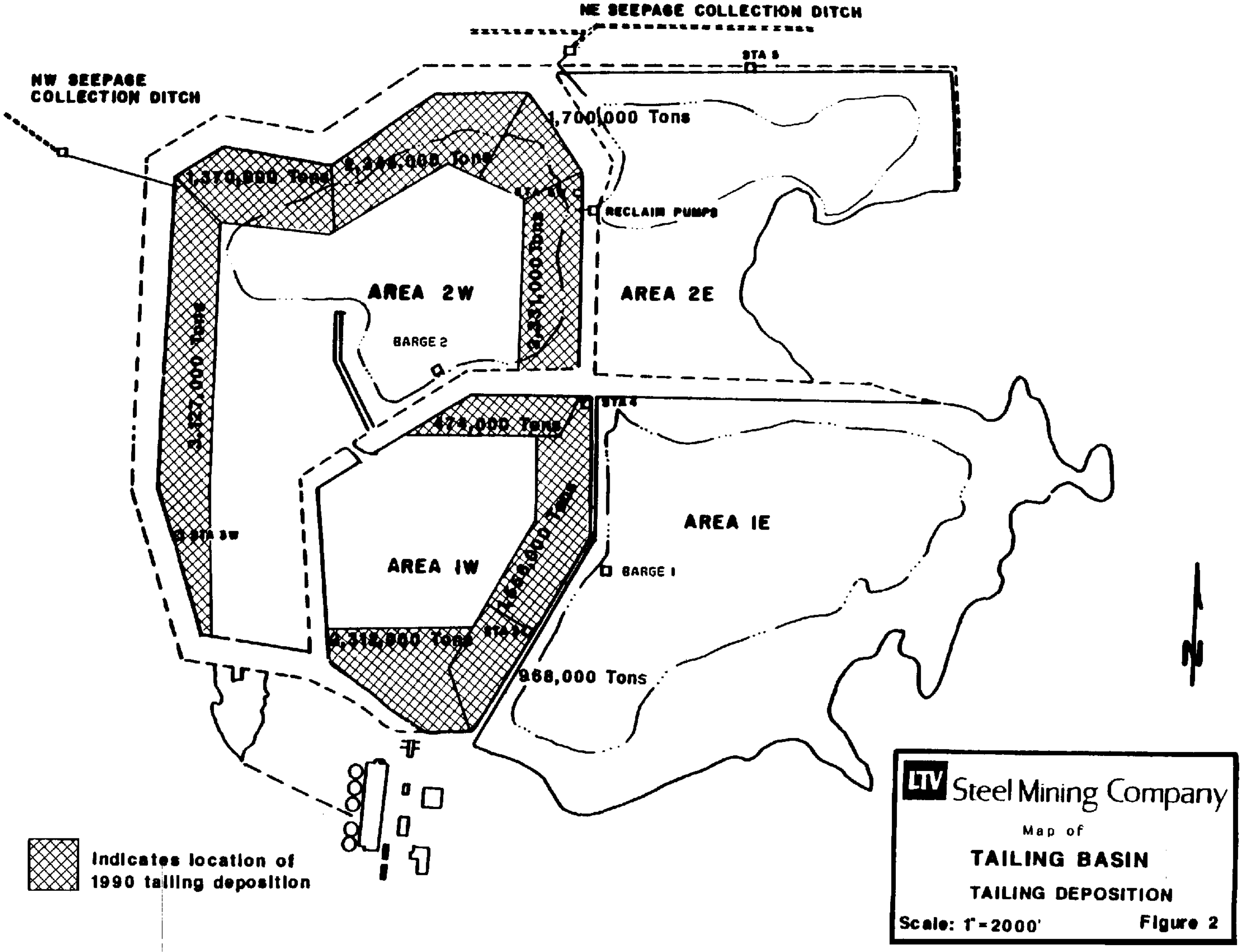
Tailings Pipelines and Emergency Basin

Tailings are transported from the tailings thickeners to the tailings impoundment via steel pipelines with rubber coated inner walls. The pipelines are contained in blowout/spill control ditches that flow into a 25-acre emergency basin. This basin also receives plant site runoff, plant floor washings, wastewater treatment plant discharge, and other spilled materials. Finally, the tailings thickeners also can be emptied to the basin in emergency situations. Solids are dredged from the basin by an outside contractor and recycled to the mill. Liquid in the basin is also recycled to the mill.

Pipelines used to transport tailings in the impoundment were previously sited along the crest of the embankments where a pipe break could result in tailings flowing down the outside slopes of the impoundment. These transport pipelines are now located inside the embankment to ensure that any spills will be contained.

Tailings Impoundment

The 3,000 acre LTV SMCo. Hoyt Lakes facility tailings impoundment is actually comprised of 4 individual ponds (or cells) designated as Areas 1 West (1W), 2 West (2W), 1 East (1E), and 2 East(2E)(See Figure 2-7). In 1990, Areas 1W, 2E, and 2W were utilized for tailings disposal with Area 2W as the primary deposition area (LTV SMCo., 1991h).



▨ Indicates location of 1990 tailing deposition

LTV Steel Mining Company

Map of

TAILING BASIN

TAILING DEPOSITION

Scale: 1" = 2000' **Figure 2**

The LTV SMCo. Hoyt Lakes impoundment was opened in 1957 (along with the plant) and has since been expanded three times (to add new cells). The construction of the last cell was begun in 1982. As stated above, approximately 40,000 tons of tailings are generated and disposed of each day, depending on production rates. The total volume of tailings in the impoundment is approximately 500 million tons (LTV SMCo., 1991h).

Impoundment starter dams are composed of crushed rock and then covered by slimes. Coarse tailings are discharged directly into a specific area of the basin or are spigotted and pushed with rubber-tired dozers to form the dams enclosing the basin using an upstream construction method (see Figure 2-8). Raises of the dams are constructed in separate 5-foot lifts and the backslopes are shaped after 4 lifts are completed. The liquid component of the tailings slurry is clarified in a series of ponds and is reclaimed by barges for reuse in the plant (LTV SMCo., 1991h).

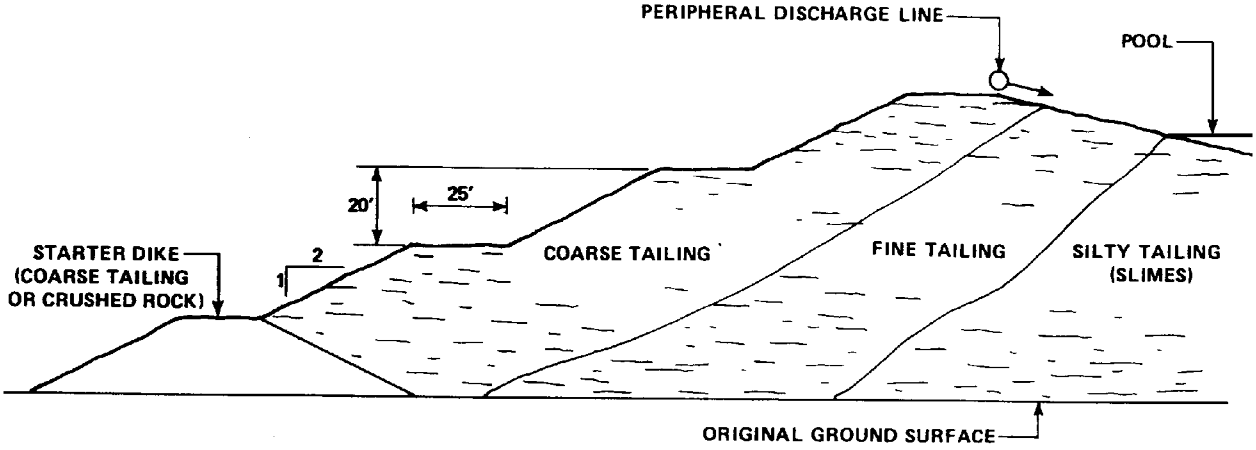


Figure 2-8. Typical Upstream Method of Construction

(Source: EBASCO Services Inc., 1977)

In the late 1970s, LTV SMCo. commissioned an independent firm, EBASCO, to conduct a stability analysis on the tailings impoundment. As a result, LTV SMCo. operates 11 well point piezometers at 6 locations within the tailings basin to monitor phreatic levels (i.e., ground-water saturation) within the embankments and to assess stability. Based on EBASCO's studies, the present Factor of Safety is considered to be higher than satisfactory (LTV SMCo., 1991h). Due to the nature of the impoundment dams, LTV SMCo. personnel believe there is little, if any, ground-water infiltration into the tailings impoundment.

Seepage and runoff flow from the slope of the impoundment is collected in unlined drainage ditches and seepage ponds. The total flow of seepage is measured and is highly variable, ranging from no flow in the winter to 800 to 1,000 gpm during the 4-month growing season. Seepage collected in the ponds is returned to the tailings impoundment and used as process make-up water at the plant (LTV SMCo., 1991h). The EPA site visit team observed a significant algal bloom and aquatic plant life in one of the tailings seepage ponds at the site.

The facility operates one ground-water monitoring well to assess water quality downgradient of the tailings impoundment. As required by the State, samples from the monitoring well are collected and analyzed quarterly and the results are reported in quarterly and annual monitoring reports.

Reclamation of the tailings impoundment includes sloping, grooming, seeding, and planting of the basin perimeter dams (LTV SMCo., 1991h). It should be noted that State reclamation requirements, issued in 1980, apply to all areas of the tailings impoundment regardless of their age because all of the impoundment is considered a single unit. LTV SMCo.'s 1990 tailings impoundment reclamation activities included the reclamation of 33 acres of the 2W basin with permanent plantings. Specifically, basin backslopes were shaped to a 2:1 slope and 500 pounds of 11-55-0 fertilizer and 100 pounds of 0-46-0 fertilizer were applied on the backslopes by hydroseeder and worked into the tailing with a klodbuster. A perennial mixture of grasses and legumes (including Smooth Brome, Red Fescue, Perennial Ryegrass, Alfalfa, and Birds Foot Trefoil) was spread on the reclamation area using a hydroseeder at rates between 10 and 20 pounds per acre, with a total planting rate of 70 pounds per acre. The seed mix was then lightly covered with tailings and approximately 2 tons per acre of hay mulch were blown on the slopes and "tacked down" with 250 gallons of asphalt per acre (LTV SMCo., Undated a).

Other recent tailings impoundment reclamation activities (not observed by the site visit team) included (LTV SMCo., Undated a):

- Area 2E - reseeding 65 acres and seeding 27 acres;
- Area 1E - sloping and seeding 3.7 acres; and
- Area 1W - sloping and seeding 1.8 acres.

LTV SMCo.'s 1991 Operating Plan called for approximately 10 acres of backslope planting (including 4 acres of maintenance work) and 120 acres of temporary interior plantings (for dust control). All interior planting was planned to be completed in early spring 1991. Most permanent reclamation was scheduled for dormant seeding in late fall (LTV SMCo., Undated a). The EPA site visit team observed both hydroseeding and the placement of hay mulch at the impoundment. The results of previous reclamation activities observed by the site visit team included areas covered with grasses.

2.3.2.4 Fly Ash/Coal Mill Rejects Disposal Area

LTV SMCo. maintains a 30-acre ash/rejects disposal area at the Taconite Harbor site (see Figure 2-9). All of the areas surrounding the site, as well as the rail line that connects Taconite Harbor and the Hoyt Lakes facility, are owned by LTV SMCo. Ash and power plant coal rejects are transported to the disposal area via truck and deposited in lifts. The disposal pile is comprised of three lifts, each of

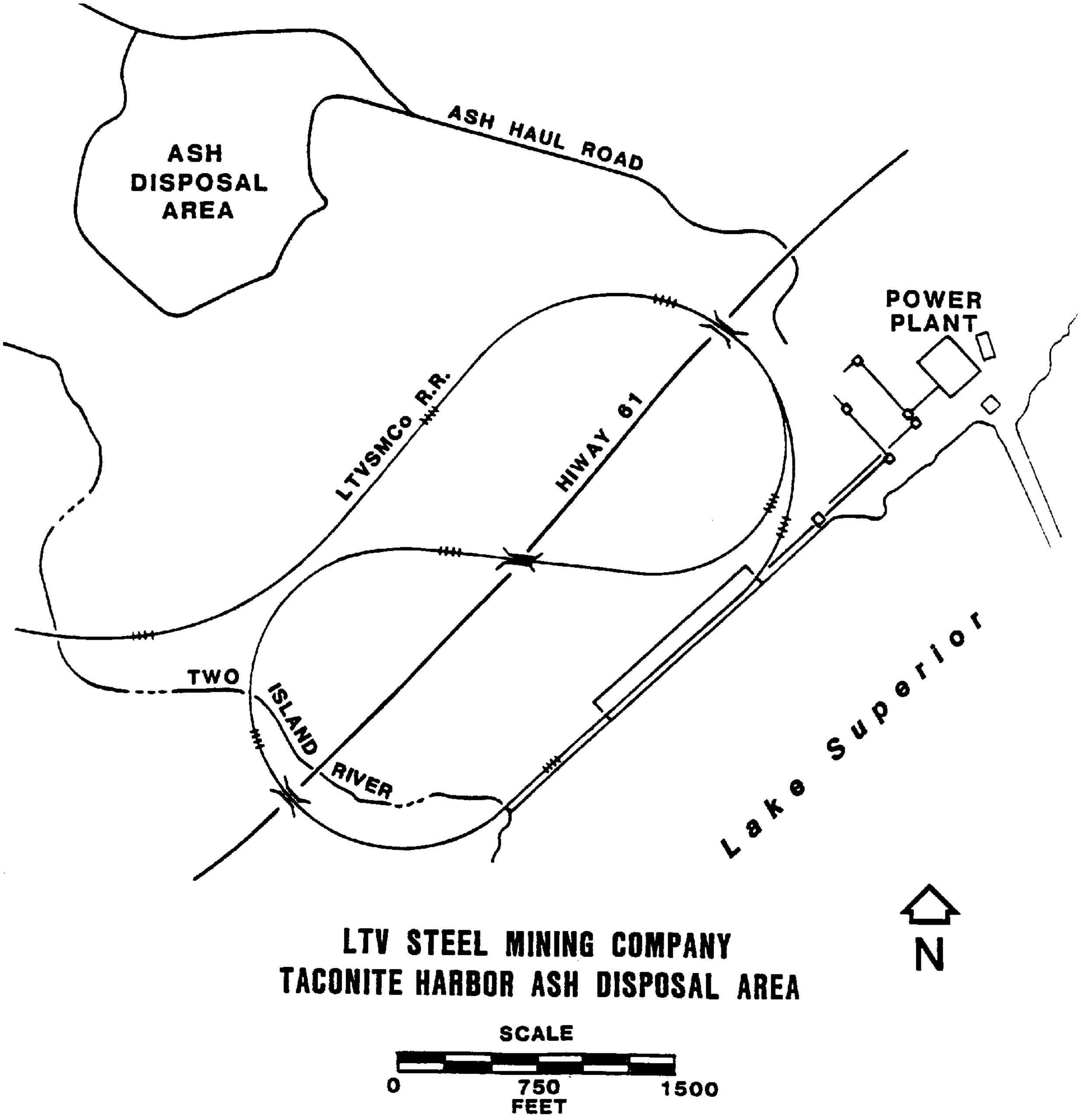


Figure 2-9. LTV Steel Mining Company Taconite Harbor Ash Disposal Site

(Source: Taconite Harbor NPDES Permit)

which is nominal 30-foot and is graded so that the raise is in 6 to 12-inch compacted increments. The area is designed to handle coal mill rejects and an ash/water mixture of either 101,700 tons per year of eastern coal ash or 153,000 tons per year of western coal ash. Completed lifts are covered with native soil material, fertilized, and stabilized with vegetation (mixed perennial grasses and legumes) (MPCA, 1991d). The Taconite Harbor facility was not visited by the EPA team.

The disposal site is located on the side of a hill with the top of the site near the crest. Due to the location of the site, run-on is limited to the minimal slope area between the crest of the hill and the top of the ash pile. Runoff from other adjacent areas is prevented from running onto the ash disposal area by a (clay-gravel) containment berm. The berm also serves as the operation/access road around the pile. Water drainage from the ash disposal site is collected by drop inlets and piped to a settling pond at the base of the pile. Discharge from the settling pond is pumped to the vegetated upper portion of the site for evapotranspiration.

In May 1991, Minnesota Pollution Control Agency (MPCA) personnel observed an intermittent discharge from the collection pond at the base of the ash pile. The discharge was presumed to be leachate and runoff from the pile. The discharge was not authorized under the facility's existing NPDES/SDS (State Disposal System) permit (MPCA, 1991). At the time that the discharge was observed, LTV SMCo. had applied for a solid waste permit for the construction and operation of the disposal site (application submitted on March 23, 1991). LTV SMCo. was preparing a response to MPCA questions related to the application. This response, which was submitted on September 1, 1991, was amended to include corrective actions for the discharge (LTV SMCo., 1990j).

2.3.2.5 Industrial Landfill

LTV SMCo. operates a St. Louis County-permitted industrial landfill at the Hoyt Lakes site to manage refuse generated at the Hoyt Lakes site. Furnace refractory bricks from the Hoyt Lakes agglomerator are also disposed of in this landfill.

2.3.2.6 Tire Storage Area

Tires are currently stored in a tire storage area at the Hoyt Lakes site (separated from the industrial landfill). The facility also contracts with outside companies who ship large tires offsite for use as cattle feeders and water tanks. Small tires sent offsite are used as feed for power plants at other facilities. The facility indicated that these beneficial reuses cost LTV SMCo. significantly less than past disposal fees.

The MPCA has enacted waste tire rules that require bonding as financial assurance. Bonding was originally waived for the LTV SMCo. facility under a temporary provisional permit. However, the State has included a bonding requirement in the permanent permit. At the time of the EPA site visit, LTV SMCo. was discussing this requirement with the State. Since that time, LTV SMCo. has gone forward with bonding as per the permit.

LTV SMCo.'s "Authorization to Operate A Waste Tire Storage Facility Under the Minnesota Pollution Control Agency Waste Tire Facility Permit Program" (MPCA WTSF 102) became effective on January 21, 1992 and is valid for a period a five years. The permit allows for the storage of only oversize waste tires generated by KTV SMCo. through its mining operations and sets upper limits on the volume of tires stored at the facility and the dimensions of the facility storage pile. "Oversize" waste tire refers to tires exceeding a 35-inch outside diameter or 14-inch width. The permit also required that LTV SMCo. establish a $22,800 bond within 30 days of the effective date of the permit (LTV SMCo., 1992b).

2.3.2.7 Sanitary Wastewater Treatment Plant

LTV SMCo. operates an onsite sewage treatment plant in accordance with SDS Permit No. MN C045756, to manage sewage and sanitary wastewater generated at the facility. The plant provides secondary biological treatment. Sewage from Mining Area No. 1 machine repair shops is routed to a septic tank-drainfield system, located to the south of the plant area. Sewage from the rest of the Hoyt Lakes facility is either contained in portable units and transported offsite for disposal, treated in site-specific septic tanks, or routed to the sewage treatment plant. Sewage sludge from the treatment plant is removed and disposed of at an offsite landfill by a licensed contractor (NPDES/SDS Permit No. MN 0042536). As noted previously, effluent from the wastewater treatment plant is discharged to the tailings emergency basin where it is recycled to the mill.

2.3.2.8 Other Wastes

LTV SMCo. currently contracts with outside firms to manage other wastes offsite as described below:

- Waste Oil - Oil Services, Inc., Eveleth, MN
- Spent Solvents - Safety Kleen Corp., Cloquet, MN
- PCBs - Dynex Environment, Inc., St. Paul, MN (PCBs used in transformers are exempted from Minnesota hazardous waste management requirements)
- Laboratory Wastes - Aptus Environmental Services, Lakeville, MN (Shipped under manifest, incinerated, and reported in hazardous waste management reports).

2.4 REGULATORY REQUIREMENTS AND COMPLIANCE

2.4.1 Permit to Mine

In 1969, the Minnesota Legislature passed a law requiring the development of a Mineland Reclamation Program. The law was subsequently amended in 1970 to require permitting of mines as well. Beginning in 1977 and continuing through 1979, the Minnesota Department of Natural Resources (MDNR) published draft rules that specifically addressed iron and taconite mines (because at the time these were the only metallic minerals mined in the State). Final rules were promulgated in 1980. The rules required mines to submit applications to the Office for a Permit to Mine. The rules required that the application describe their reclamation plans and also addressed issues such as siting criteria, water management, stockpiling, pit wall stability, and noise.

LTV SMCo. applied for a Permit to Mine in 1980; the permit was issued in 1989. According to the State, the delay in processing LTV SMCo.'s application was caused by the large volume of permits being processed by the MDNR at one time and issues related to the Dunka site. Specifically, the MDNR and LTV SMCo. agreed that standard reclamation procedures would not be appropriate for the Dunka site due to its atypical geology. Thus, the MDNR did not issue the permit until alternative reclamation technologies for Dunka were examined (see separate discussion of the Dunka site in Section 2.5).

LTV SMCo.'s Permit to Mine is updated annually and a Best Management Plan is approved annually by the State. Each year, the facility is required to submit an annual report and operating plan. The annual report summarizes mining activity by area, tailings basin operations, and reclamation activities that took place during the previous year. The operating plan also summarizes expected mining activities and statistics, tailings basin operations, and reclamation activities planned for the upcoming year.

The State has the authority to issue enforcement actions when permit conditions are violated. The State also conducts annual inspections and frequent informal visits during which inspectors make suggestions to facility personnel based on observations.

The MDNR has the authority to require closure/reclamation bonding, but had decided that this is unnecessary for the LTV SMCo. facility (except Dunka, as noted below).

2.4.2 NPDES/SDS Permits

The LTV SMCo. Hoyt Lakes facility maintains permits to discharge and to construct, install, and operate a wastewater disposal system for the Hoyt Lakes, Dunka, and Taconite Harbor sites under the National Pollutant Discharge Elimination System (NPDES) and the State Disposal System Permit program (SDS). The permits designate specific discharge outfalls for each of the facility's mining areas and other disturbed areas (i.e., mill and repair shops). Effluent limitations and monitoring and reporting requirements (frequency and type) are established for each outfall designated in the permits. The following NPDES/SDS permits are held by LTV SMCo.:

Table 2-1. NPDES Outfalls at LTV Steel Mining Company's Hoyt Lakes, Dunka, and Taconite Harbor Facilities

Outfall(s)	**Source of Discharge**	**Receiving Water Body**
Hoyt Lakes		
010, 050, 070, 080	Pumped dewatering discharge	Second Creek
020	Pumped dewatering discharge	Wynne Lake
030, 060	Pumped dewatering discharge	First Creek
090, 100	Pumped dewatering discharge	Wyman Creek
110	Gravity outflow from pit	Wyman Creek
sum-003	Composite of outfalls 090, 100, and 110	Wyman Creek
120	Pumped dewatering discharge	Colby Lake
130, 140, 150, 160	Pumped dewatering discharge	Second Creek
170, 180, 190, 200	Pumped dewatering discharge	Colby Lake
sum-002	Composite of outfalls 120, 170, 180, 190, and 200	Colby Lake
210	Pumped dewatering discharge	Wynne Lake
220	Pumped dewatering discharge	First Creek
250	Concentrator, agglomerator, and coal supply stockpile area runoff	Second Creek
251	Repair shops/tailings basin	Second Creek
Dunka Mining Area		
010	Dewatering basin overflow	Dunka River
020	Pumped dewatering discharge	Unnamed Creek
030	Pumped dewatering discharge	Billiken Creek
040	Treated Duluth Complex material stockpile seepage	Unnamed Creek
050	Treated Duluth Complex material stockpile seepage	Billiken Creek
060	Treated Duluth Complex material stockpile seepage	Flamingo Creek
Taconite Harbor		
010	Once-through non-contact condenser cooling water	Lake Superior
020, 030	Coal pile containment runoff	Lake Superior

- Hoyt Lakes - NPDES/SDS Permit No: MN 0042536 (Expires July 1996)
- Dunka Mining Area - NPDES/SDS Permit No: MN 0042579 (Expires April 1996)
- Taconite Harbor - NPDES/SDS Permit No: MN 0002208 (Expires March 1996)
- Plantside Sewage Plant - SDS Permit No: MNC 045756
- Taconite Harbor Village Sewage Plant - SDS Permit No: MNL 049549
- Tailing Basin Operating Permit - SDS Permit No: MNC 054089
- Taconite Harbor Dredging - SDS Permit No: MND 053180

Table 2-2. Parameters and Effluent Limits in NPDES/SDS Permits, LTV Steel Mining Company Facilities (continued)

Parameter	**Monitoring Frequency/Effluent Limits**
Dunka Mining Area Outfalls 040, 050, and 060	
Flow	Monitored daily
Total Suspended Solids	20 mg/l monthly average; 30 mg/l daily maximum
Dissolved Iron	1.0 mg/l monthly average; 2.0 mg/l daily maximum
Total Copper	23 µg/l monthly average; 65 µg/l daily maximum
Total Cobalt	50 µg/l monthly average; 50 µg/l daily maximum
Total Nickel	213 µg/l monthly average; 4582 µg/l daily maximum
Total Zinc	343 µg/l monthly average; 378 µg/l daily maximum
Sulfate	Monitored twice monthly
pH	6.5 - 8.5 s.u.
Floating solids, Visible foam, and Visible sheen	No discharge, other than trace amounts
Taconite Harbor Outfall 010	
Flow	Continuous measuring
Temperature	Continuous monitoring. Not increase the temperature of the receiving water above the natural temperature at the edge of the mixing zone (a radius of 1,000 feet from the point of discharge)
pH	6.0 - 9.0 s.u.
Floating solids, Visible foam, and Visible sheen	No discharge, other than trace amounts
Taconite Harbor Outfalls 020 and 030	
Flow	Monthly measurement
Total Suspended Solids	30 mg/l monthly average; 50 mg/l daily maximum
Oil and Grease	10 mg/l monthly average; 15 mg/l daily maximum
pH	6.0 - 9.0 s.u.
Floating solids, Visible foam, and Visible sheen	No discharge, other than trace amounts

NPDES-permitted outfall locations for Hoyt Lakes, Dunka, and Taconite Harbor, and monitoring requirements for each outfall are listed in Tables 2-1 and 2-2

Table 2-2. Parameters and Effluent Limits in NPDES/SDS Permits, LTV Steel Mining Company Facilities

Parameter	Monitoring Frequency/Effluent Limits
Hoyt Lakes Outfalls 010, 020, 030, 050, 060, 070, 080, 120, 130, 140, 150, 160, 170, 180, 190, 200, 210, and 220.	
Flow	Twice monthly
Turbidity	25 NTU
Total Suspended Solids	20 mg/l monthly average; 30 mg/l daily maximum
Dissolved Iron	1.0 mg/l monthly average; 2.0 mg/l daily maximum
pH	6.5 - 8.5 s.u.
Floating solids, Visible foam, and Visible sheen	No discharge, other than trace amounts
Hoyt Lakes Outfalls 090, 100, and 110	
Flow	Twice monthly
Turbidity	5 NTU
TSS	20 mg/l monthly average; 30 mg/l daily maximum
Asbestos	One million long fibers/liter three times annually
Dissolved Iron	1.0 mg/l monthly average; 2.0 mg/l daily maximum
Temperature	Not materially greater than the temperature recorded simultaneously at station 701
Un-ionized Ammonia (as nitrogen)	0.016 mg/l daily maximum
Color	15 Pt.-Co. units daily maximum
Chloride	50 mg/l daily maximum
Nitrate (as Nitrogen)	10 mg/l daily maximum
Nitrite (as nitrogen)	1 mg/l daily maximum
Oil	0.5 mg/l daily maximum
pH	6.5 - 8.5 s.u.
Floating solids, Visible foam, and Visible sheen	No discharge, other than trace amounts
Hoyt Lakes Outfalls 250 and 251	
Flow	Weekly
Total Hydrocarbons	10 mg/l monthly average; 15 mg/l daily maximum
Total Suspended Solids	30 mg/l monthly average; 60 mg/l daily maximum
Total Cadmium	67 µg/l daily maximum
Total Copper	35 µg/l daily maximum
Total Lead	164 µg/l daily maximum
Total Zinc	234 µg/l daily maximum
pH	6.0 - 9.0 s.u.
Floating solids, Visible foam, and Visible sheen	No discharge, other than trace amounts

Table 2-2. Parameters and Effluent Limits in NPDES/SDS Permits, LTV Steel Mining Company Facilities (continued)

Parameter	Monitoring Frequency/Effluent Limits
Dunka Mining Area Outfall 010	
Flow	Daily
Total Suspended Solids	20 mg/l monthly average; 30 mg/l daily maximum
Dissolved Iron	1.0 mg/l monthly average; 2.0 mg/l daily maximum
Total Copper	8.4 µg/l monthly average; 14 µg/l daily maximum
Total Cobalt	5 µg/l monthly average; 50 µg/l daily maximum
Total Nickel	126 µg/l monthly average; 1137 µg/l daily maximum
Total Zinc	85 µg/l monthly average; 94 µg/l daily maximum
Sulfate	Monitored twice monthly
pH	6.5 - 8.5 s.u.
Floating solids, Visible foam, and Visible sheen	No discharge, other than trace amounts
Dunka Mining Area Outfall 020	
Flow	Monitored daily
Total Suspended Solids	20 mg/l monthly average; 30 mg/l daily maximum
Turbidity	25 NTU daily maximum
Dissolved Iron	1.0 mg/l monthly average; 2.0 mg/l daily maximum
Total Copper	23 µg/l monthly average; 65 µg/l daily maximum
Total Cobalt	50 µg/l monthly average; 50 µg/l daily maximum
Total Nickel	213 µg/l monthly average; 4582 µg/l daily maximum
Total Zinc	343 µg/l monthly average; 378 µg/l daily maximum
Sulfate	Monitored twice monthly
pH	6.5 - 8.5 s.u.
Floating solids, Visible foam, and Visible sheen	No discharge, other than trace amounts

(MPCA, 1991a; MPCA, 1991b; 1991c; and MPCA, 1991d).

2.4.3 Air Permits

LTV SMCo. currently holds an air emissions permit for the Taconite Harbor power plant. Under a 1979 stipulation agreement with the State, a draft permit for the Hoyt Lakes facility will be completed by the MPCA (no time is specified).

LTV SMCo. currently submits biannual Air Pollutant Emissions Inventory Reports to the MPCA Air Quality Division. The reports summarize emissions at each facility emission point, the process(es) and equipment causing the emission, the process equipment working schedule, fuel type and consumption, capacity, and emission controls employed. The Taconite Harbor permit addresses monitoring of pollutants such as total particulates, lead, carbon monoxide, sulfur oxides, nitrogen oxides, volatile organic compounds, and particulates less than 10 microns. Table 2-3

Table 2-3. Major Sources of Air Emissions from LTV Steel Mining Company's Hoyt Lakes Facility

Emission Source
Boiler Stacks
Primary Crushing
Secondary Crushing
Pan Feeders
Drive Houses (Transfer Points)
Coarse Ore Storage
Vibrating Feeders and Conveyors
Fine Crushing
Transfer Point Belts
Fine Ore Storage
Fine Ore Feeders
Furnace Top Gas Stacks
Furnace Bottom Gas Stacks
Furnace Bentonite Additive Stacks
Bentonite Handling and Unloading
Bentonite Silo
Bentonite Conveyor
Bentonite Bin
Pellet Screening and Handling
Pellet Elevators
Chips Circuits
Recycle Pellet System
Chips Handling
Loading Pocket Bins and Chutes
Loading Pocket Pellet Load-Out
Transfer Conveyors
Stacker Conveyor
Coal Unloading and Conveying
Rail Coal Unloading
Coal Stockpile

summarizes the major point sources of air emissions from LTV SMCo.'s facility at Hoyt Lakes facility (there may be multiple units of each source listed on site).

2.4.4 State Water Permit

In 1950, LTV SMCo. was granted a permit from the MDNR (No. 49-135) to withdraw water from Colby Lake. As discussed previously in the Water Supply Section of this report, the provisions of this permit include the following:

- Whitewater Reservoir elevation must be maintained between 1,410 feet and 1,440 feet
- When Colby Lake drops below 1,439 feet, LTV SMCo. must pay back gallon for gallon all water that is pumped from Colby Lake to the plant
- Colby Lake pumping is limited to 15,000 gpm (the maximum pumping capacity of the three pumps is 13,300 gpm) (LTV SMCo., 1990a).

LTV SMCo. has also been issued several other MDNR Water Appropriation permits.

2.4.5 Corps of Engineers §404 Permit

In 1979, LTV SMCo. applied for a construction permit to install a 12 gauge multi-plate steel culvert and place approximately 2,313,000 cubic yards of fill material in the bed of Knox Creek (i.e., Second Creek) and in adjacent wetlands. This activity was required to provide passage for roadway and railroad traffic between the then proposed 2WX mining area and the ore processing plant. As part of the application procedure, an Environmental Impact Assessment was prepared and a finding of no significant impact was issued by the St. Paul District Corps of Engineers (St. Paul District Corps of Engineers, 1979). The finding was based on the limited area of disturbance and the measures proposed by the facility to minimize adverse impacts, primarily to local surface water quality (St. Paul District Corps of Engineers, 1979). The construction permit was issued in April, 1980 and expired at the end of December, 1983 (St. Paul District Corps of Engineers, 1980). Construction was completed prior to permit expiration. According to LTV SMCo., the Corps. of Engineers has also issued a permit for the maintenance dredging of Taconite Harbor.

2.5 THE DUNKA SITE

The Dunka site is located approximately 20 miles northeast of the main Hoyt Lakes facility. The site sits on private, State, Bureau of Land Management, and U.S. Forest Service lands; LTV SMCo. holds surface and mineral leases for the area. The Dunka pit is part of the easternmost extension of the Biwabik iron formation and is one of the smaller pits on the Mesabi Range at 3 miles in length. Ore from the Dunka site has traditionally been used as "sweetener" for ores from the main Hoyt Lakes pits. Although additional material may be removed from the pit for beneficiation, current plans call for no exploration activity at the site or enlargement of the pit.

2.5.1 Environmental Setting and Operations

The geology and environmental problems associated with the Dunka site are very unusual for the Iron Industry of the Mesabi Range or elsewhere. What makes the site unique is the presence of the sulfur-containing Duluth Complex and Virginia Formation hornfels material in this location.

The taconite ore at the Dunka site contacts Duluth Complex Material (DCM), a mafic intrusive rock unit, which contains zones of low grade copper-nickel sulfide mineralization and iron sulfide (mainly pyrrhotite). In fact, the Duluth Complex deposits are considered to be one of the largest known sources of copper and nickel resources (LTV SMCo., 1990g). Virginia Formation hornfels (up to 6 percent sulfur) are also present at the site.

Duluth Complex Material must be removed to reach portions of the taconite ore deposit. LTV SMCo. began removing this material from the pit and stockpiling it in the 1960s. LTV SMCo. has designated those Duluth Complex material stockpiles that contain an average of more than 0.2 mass percent copper oxides and/or 0.05 mass percent nickel oxides as gabbro stockpiles (designated as stockpiles 8012,

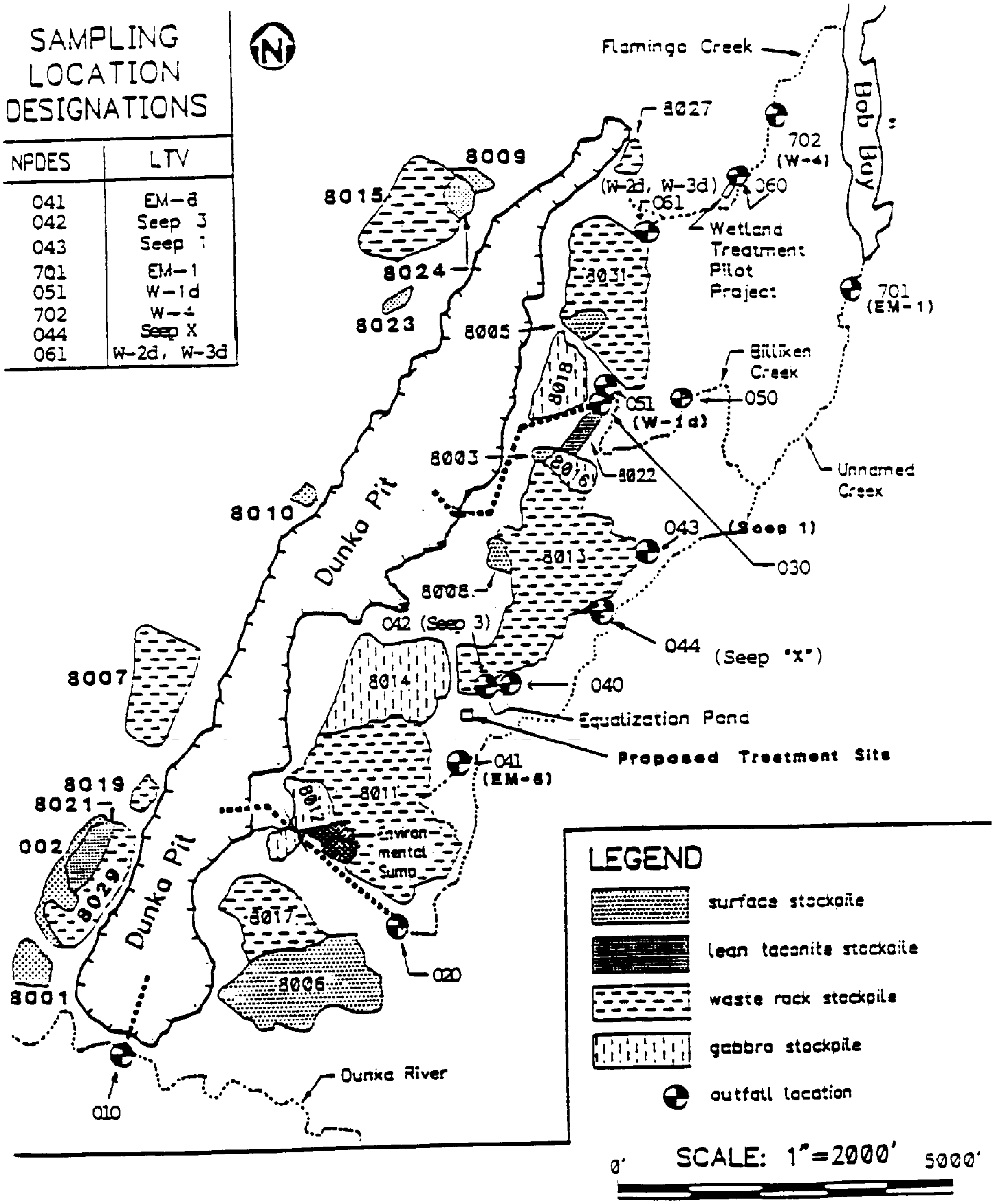


Figure 2-10. Dunka Site

(Source: Dunka NPDES Permit)

8014, 8016, and 8018) (see Figure 2-10). The remaining Duluth Complex material stockpiles are categorized as waste rock stockpiles and are made up of material containing less than 0.2 percent copper oxide and less than 0.05 percent nickel (designated as stockpiles 8007, 8011, 8013, 8015, 8017, 8019, 8027, 8029, and 8031) (LTV SMCo., 1990g). Also present at the site are lean taconite stockpiles (designated as stockpiles 8021, 8022, 8023, and 8024) and surface material stockpiles (designated as stockpiles 8001, 8002, 8003, 8005, 8006, 8008, 8009, and 8010) (MPCA, 1991a; and MPCA, 1991b).

LTV SMCo. has removed and stockpiled approximately 50 million tons of Duluth Complex material which cover 320 acres. In addition, during stripping operations at the Dunka site, approximately 295,000 tons of Virginia Formation hornfels were blasted. This broken hornfels were left in the mine pit. Plans to remove and stockpile this material were being reviewed with the MPCA (MPCA, 1991a; and MPCA, 1991b).

The pit is divided into two sections (north and south). Mine water from the north section of the pit is currently pumped into the southern section where it is discharged, after settling, (untreated) to the Dunka river. The discharge is addressed by LTV SMCo.'s NPDES permit.

Copper and nickel concentrations as high as 1.7 and 40 mg/L, respectively, have been observed in seepage/runoff from Duluth Complex waste rock stockpiles at the site. Toxicity testing of the leachate showed that copper and nickel concentrations exceeded the 48-hour lethal concentration (LC50) for Daphnia pulicaria; nickel concentrations also exceeded the 96-hour LC50 for fathead minnow. Concentrations of calcium, magnesium, and sulfate in the stockpile drainage were also elevated (MDNR, 1990). According to LTV SMCo., there is some question whether the metals were the toxic agent.

Table 2-9. Average Parameter Concentrations at W-4* Sampling Site, 1975 - 1990

Year	Average Parameter Concentrations				
	Flow (cfs)	pH (s.u.)	Copper (total)	Nickel (total)	Iron (filt)
1980	0.172	7.3	0.016	0.038	0.3
1981	0.336	7.0	0.013	0.059	0.6
1982	0.548	6.9	0.009	0.045	N/A
1983	0.375	6.6	0.008	0.016	0.5
1984	0.461	7.1	0.008	0.042	0.6
1985	0.547	6.9	0.010	0.062	0.4
1986	0.499	6.8	0.012	0.059	0.9
1987	0.078	6.9	0.012	0.124	1.9
1988	0.216	7.1	0.011	0.163	0.3
1989	0.297	7.0	0.013	0.178	0.3
1990	0.232	7.0	0.030	0.128	0.4

*This monitoring station is on Flamingo Creek, downstream of the Wetlands Treatment site, and receives effluent from waste rock stockpiles 8031 and 8027.

Surface water monitoring data collected at the Dunka site (monitoring stations EM-1, EM-8, Seep X, Seep 3, Seep 1, W-4, and W1-D) between 1975 and 1990 are presented in Tables 2-4 through 2-10

Table 2-5. Average Parameter Concentrations at EM-1* Sampling Site, 1975 - 1990

Year	Average Parameter Concentrations				
	Flow (cfs)	**pH (s.u.)**	**Copper (total)**	**Nickel (total)**	**Iron (filt)**
1975	N/A	7.6	0.008	0.33	N/A
1976	N/A	7.6	0.009	0.08	N/A
1977	4.83	7.2	0.010	0.20	N/A
1978	9.35	7.3	0.007	0.20	N/A
1979	7.71	7.2	0.006	0.24	N/A
1980	6.42	7.3	0.007	0.24	0.3
1981	7.95	7.6	0.005	0.16	0.2
1982	6.93	7.2	0.005	0.29	N/A
1983	4.85	6.8	0.007	0.44	0.3
1984	4.92	7.4	0.006	0.39	0.2
1985	7.35	7.2	0.009	0.39	0.4
1986	6.22	7.2	0.008	0.33	0.4
1987	4.63	7.4	0.008	0.39	N/A
1988	9.27	7.2	0.008	0.38	N/A
1989	7.23	7.2	0.007	0.49	N/A
1990	7.06	7.3	0.014	0.75	0.3

*This monitoring station is located on Unnamed Creek, downstream of discharges from several stockpiles, at the mouth of Bob Bay.

Table 2-5. Average Parameter Concentrations at EM-8* Sampling Site, 1975 - 1990

Year	Average Parameter Concentrations				
	Flow (cfs)	**pH (s.u.)**	**Copper (total)**	**Nickel (total)**	**Iron (filt)**
1975	N/A	7.3	0.041	2.40	N/A
1976	N/A	7.4	0.017	2.10	N/A
1977	N/A	7.3	0.033	1.32	N/A
1978	N/A	8.3	0.050	2.05	N/A
1979	0.320	6.9	0.098	4.21	0.10
1980	0.438	7.1	0.115	5.06	0.10
1981	0.269	7.0	0.019	1.79	0.04
1982	0.403	6.9	0.010	1.67	N/A
1983	0.289	6.7	0.010	1.55	0.1
1984	0.196	7.3	0.013	1.88	0.1
1985	0.158	7.0	0.015	1.71	0.3
1986	0.191	7.0	0.015	1.58	0.2
1987	0.099	7.2	0.013	2.36	0.2
1988	0.477	7.0	0.037	2.59	0.3
1989	0.824	7.0	0.068	3.10	0.1
1990	0.402	7.2	0.070	3.37	0.2

*This monitoring station is on Unnamed Creek and receives effluent from waste rock stockpile 8011.

Table 2-7. Average Parameter Concentrations at Seep-3* Sampling Site, 1975 - 1990

	Average Parameter Concentrations				
Year	Flow (cfs)	pH (s.u.)	Copper (total)	Nickel (total)	Iron (filt)
1975	N/A	7.1	0.116	13.94	N/A
1976	N/A	7.1	0.417	27.20	N/A
1977	N/A	7.3	0.530	16.90	N/A
1978	N/A	7.8	0.807	11.39	N/A
1979	0.013	7.1	0.088	4.78	0.6
1980	0.016	6.9	0.186	4.70	0.9
1981	0.015	7.3	0.135	6.93	1.0
1982	0.020	7.0	0.067	3.64	N/A
1983	0.037	6.7	0.088	3.02	0.2
1984	0.010	7.6	0.052	2.49	0.2
1985	0.018	7.4	0.057	2.52	0.2
1986	0.017	7.4	0.070	2.91	0.1
1987	0.010	7.7	0.210	11.99	0.1
1988	0.016	7.1	0.526	39.79	0.1
1989	0.016	6.3	1.122	37.31	1.3
1990	0.009	7.1	0.141	17.55	4.3

*This monitoring station receives effluent from waste rock stockpile 8031.

Table 2-6. Average Parameter Concentrations at Seep-X* Sampling Site, 1975 - 1990

	Average Parameter Concentrations				
Year	Flow (cfs)	pH (s.u.)	Copper (total)	Nickel (total)	Iron (filt)
1990	0.1433	6.5	0.75	2.44	0.1

*This monitoring station receives effluent from waste rock stockpile 8031.

(LTV SMCo., Undated d). W-4 is a sampling point that contains the combined flow from W-2D and W-3D. The locations of these monitoring stations are shown in Figure 2-10.

As shown in Figure 2-10, most of the seepage from waste rock piles at the Dunka site has historically been discharged to Unnamed Creek. Unnamed Creek flows into Bob Bay, a part of Birch Lake. In a 1976-1977 study of trace metals in Bob Bay, it was found that concentrations of copper, nickel, cobalt, and zinc in the waters of the Bay were higher than the regional average concentrations and decreased with distance from the mouth of Unnamed Creek. Elevated metal concentrations were also observed in the sediments, as well as in aquatic plant and clam tissue. In the study, it was estimated that the total discharge from the Dunka watershed into Bob Bay through Unnamed Creek was 500 million gallons per year. Unnamed Creek contributes more than 90 percent of the trace metals load to Bob's Bay. Annual loading is over one ton of nickel. Less than 40 percent of this nickel load was found to be removed from the system through natural lake processes (MDNR, 1984). According to LTV SMCo., carbon dating of sediment samples from Bob Bay indicates significant metal concentrations which predate mining.

While the MDNR has conducted sampling at the site and has found that more than 95 percent of all leachate samples taken from the site between 1976 and 1980 had pH values between 6.0 and 8.5; values as low as 5.0 at Seep 1 were also reported (see Table 2-8) (MDNR, 1991).

2.5.2 Mitigation

The State and LTV SMCo. are currently working to develop technologies to mitigate leachate generation and release of trace metals associated with stockpile drainage. The technologies currently being tested and employed include pile capping/channeling to limit infiltration, active treatment utilizing wetland treatment to remove metals, and neutralization of runoff to increase pH and removal of metals. The ultimate goal is a passive treatment system that will require little or no maintenance. Specific mitigation measures are further described below.

2.5.2.1 Capping/Channeling

Table 2-8. Average Parameter Concentrations at Seep-1* Sampling Site, 1975 - 1990

	Average Parameter Concentrations				
Year	**Flow (cfs)**	**pH (s.u.)**	**Copper (total)**	**Nickel (total)**	**Iron (filt)**
1986	0.014	5.4	0.529	14.49	0.4
1987	0.008	5.5	0.449	14.83	0.6
1988	0.010	6.1	0.691	14.88	0.3
1989	0.043	5.2	0.922	14.97	0.1
1990	0.012	5.0	1.177	15.39	0.2

*This monitoring station receives effluent from waste rock stockpile 8013.

The facility is currently testing methods to "cap" the gabbro stockpiles to reduce infiltration. As part of this effort, LTV SMCo. is screening surface materials/glacial till to two sizes (minus 3 inch and -1/2 inch). The reject oversize material is used to cover the sideslopes of the gabbro stockpiles; the minus 3 inch material is used as a buffer layer immediately on top of the rock and as topsoil cover. The -1/2 inch material is used as the barrier layer (18" in depth) as a cap on the gabbro stockpiles. In addition, LTV SMCo. places one foot of topsoil over the -1/2 inch material and seeds the tops of these piles.

In August 1990, LTV SMCo. applied for Army Corps of Engineers approval to do channeling work in Unnamed Creek as part of its mitigation plan. Originally, the headwaters of Unnamed Creek flowed directly under one of the stockpiles at the Dunka site and into the pit. According to the plan, Unnamed Creek upstream of the site stockpiles was diverted to the pit. Additional ditching to lower water levels and enhance drainage from the toe of the other stockpiles was also part of this plan. In addition, LTV SMCo. began contouring the stockpile to promote controlled runoff from the piles and reduce the amount of precipitation available to infiltrate the gabbro material. The runoff is channeled to Unnamed Creek. LTV SMCo. personnel have indicated that the total cost of rechanneling activities at the Dunka site has been approximately $600,000 (LTV SMCo., 1990e; LTV SMCo., 1990f; Department of the Army, 1990a; Department of the Army, 1990b).

2.5.2.2 Wetlands Treatment

Previous studies of waste rock stockpile seepage/runoff flows entering a white cedar swamp (wetland) prior to flowing toward Unnamed Creek between July 1976 and August 1977 demonstrated that wetlands treatment could remove metals. Average input copper and nickel concentrations in solution in the drainage to the wetland were 0.62 and 17.9 mg/L, respectively. Analysis of water quality and peat samples indicated that at least 30 percent of the nickel and essentially 100 percent of the copper was being removed from the drainage by peat sequestration (MDNR, 1984). Analysis of overall mass removal indicated that over 80 percent of the nickel and copper entering the wetlands were retained.

Subsequently, a pilot-scale wetland treatment project was initiated in cooperation with MDNR and MPCA to determine the capability of an enhanced or modified wetland to remove heavy metals from mine stockpile seepage (Department of the Army, 1990b). The system consisted of four wetlands test cells constructed of peat from the surrounding area. Each cell measured approximately 20 feet by 100 feet. Different water levels, contact times, vegetation, and flow distribution methods were examined.

According to LTV SMCo., this project has proven effective and has been expanded to treat all runoff from Seeps W-2d and W-3d. An additional system has been constructed to treat runoff from Seep W-1d.

2.5.2.3 Neutralization/Metals Removal

LTV SMCo. has installed a system that neutralizes and removes metals from limited flows of seepage (10 gpm) from Seeps 1 and 3. The full-scale system, when implemented, will treat all seepage from

Seeps 1, 3, X, and EM-8 (total flow approximately 350 gpm) in a 1.5 acre (2.5 million gallon) equalization basin lined with a flexible membrane liner (FML). The equalization basin acts as a buffer between the seeps, which are pumped directly into the basin, and the plant itself. In the treatment plant, lime is added at a rate of 2.5 pounds per 1,000 gallons of liquid. Cationic and anionic flocculating agents are added, the sludge thickened in a plate thickener, and the overflow from the thickener is passed through a sand filter. The thickened sludge is passed through a filter press.

Results from the pilot-scale system have shown that this process provides a greater than 90 percent reduction in nickel levels. While the filter sludge has elevated levels of nickel, TCLP data prepared for LTV SMCo. by an independent laboratory indicates that the sludge is not a hazardous waste. At the time of site visit, LTV SMCo. was examining potential markets to sell the material and received permission from the MPCA to store the sludge in a defined area of the tailings basin at Hoyt Lakes.

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APPENDIX 2-A

ADDITIONAL INFORMATION PROVIDED BY LTV SMCo.

After the site visit, EPA requested additional information from LTV SMCo. regarding the following topics:

- Wetlands data and Area 2WX construction permit
- The number of lean taconite ore piles and the total quantity of material stored
- The ultimate fate of solids which settle in the emergency basin
- The parameters monitored in the tailings impoundment
- The location of the industrial landfill and the tire storage area
- The type of treatment used at the sanitary wastewater plant.

LTV SMCo. responded to several of these information requests verbally during a January 1992 telephone conversation. Specifically, LTV SMCo. provided information concerning the ultimate fate of solids which settle in the basin (dredged by a contractor and recycled to the mill), the locations of the industrial landfill and the tire storage area (both at the Hoyt Lakes site), and the type of treatment used at LTV SMCo.'s sanitary wastewater plant (secondary biological treatment).

In addition, LTV SMCo. submitted several documents to EPA concerning a construction project in a local wetland area. These documents are listed below:

- Application for a Department of the Army Permit
- Notice of Application for Permit
- Final Environmental Impact Assessment
- Department of the Army Permit.

As part of an subsequent request by EPA, LTV SMCo. later provided lean taconite ore stockpile data and a copy of MPCA Waste Tire Permit No. WTSF-102.

APPENDIX 2-B

MAJOR COMMENTS PROVIDED BY LTV SMCO., THE MINNESOTA POLLUTION CONTROL AGENCY (MPCA), AND THE MINNESOTA DEPARTMENT OF NATURAL RESOURCES (MDNR) AND EPA'S RESPONSE TO COMMENTS

LTV SMCo., the Minnesota Pollution Control Agency, and the Minnesota Department of Natural Resources all submitted comments in the form of mark-ups of the draft text. The major comments and EPA's responses are presented below. In general, all editorial and technical comments were accepted.

Comment: LTV Steel Mining Company requested that it be referred to as LTV SMCo., rather than as LTV.

Response: The document has been revised to include this change.

Comment: LTV SMCo. clarified and updated the discussion of area surface water.

Response: The document has been revised to include this change.

Comment: LTV SMCo. requested clarification of the specific location that the EPA site visit team observed algal growth in the tailings impoundment.

Response: EPA deleted the reference to observed algal growth.

Comment: LTV SMCo. notified EPA that it has gone forward with bonding for the Tire Storage Area and forwarded a copy of the permit to EPA.

Response: The document has been revised to include these changes.

Comment: LTV SMCo. notified EPA that the Minnesota State legislature did not pass a more restrictive financial assurance bill for mine closure/reclamation as anticipated.

Response: The document has been revised to include these changes.

Comment: LTV SMCo. notified EPA of several additional permits held by the facilities.

Response: The document has been revised to include descriptions of the additional permits.

Comments: LTV SMCo. amended the discussion of the Dunka mine site to note that there are still questions remaining as to the cause of increased metals concentrations in Bob Bay.

Response: The document has been revised to include these changes.

Comment: LTV SMCo. noted that the facility is working with the MPCA and the MDNR to define a remediation strategy for the Dunka site.

Response: The document has been revised to include this change.

Comment: The MPCA clarified and updated the discussion of area use of mine water as sources of drinking water.

Response: The document has been revised to include this change.

Comment: The MDNR clarified and updated the discussion of area hydrogeology.

Response: The document has been revised to include this change.

Comment: The MDNR clarified and updated the discussion of area wetlands.

Response: The document has been revised to include these changes.

Comment: The MDNR clarified and updated the discussion of State reclamation requirements for glacial till, waste rock, and lean ore stockpiles.

Response: The document has been revised to include these changes.

Comment: LTV SMCo. and the MDNR clarified and updated the discussion of broken hornfels at the Dunka mine site.

Response: The document has been revised to include these changes.

Comment: LTV SMCo. and the NDNR clarified and updated the discussion of mitigation at the Funka site, including channeling, capping, and wetlands treatment.

Response: The document has been revised to include these changes.