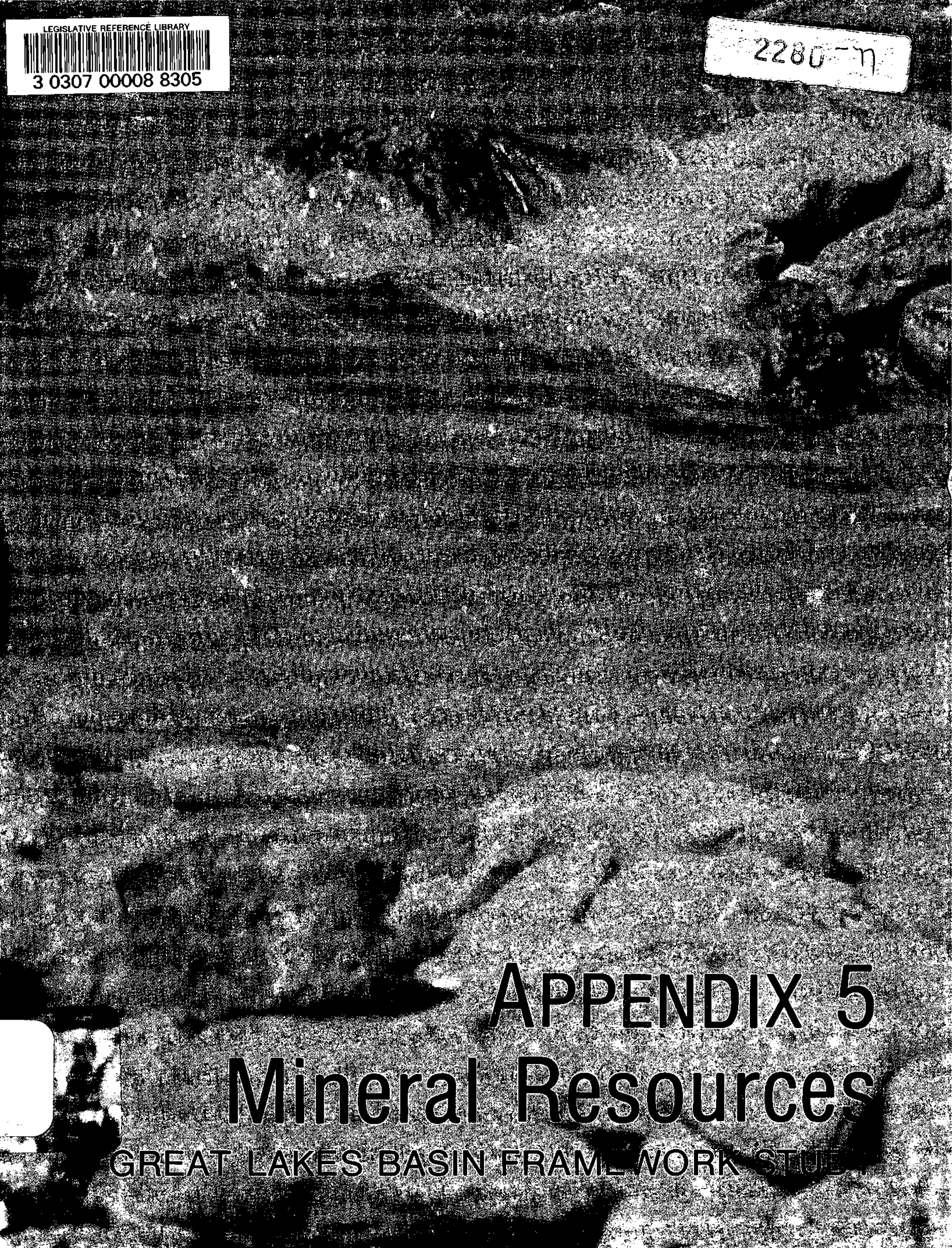

APPENDIX 5
Mineral Resources

GREAT LAKES BASIN FRAMEWORK STUDY

Great Lakes Basin Framework Study

APPENDIX 5

MINERAL RESOURCES

GREAT LAKES BASIN COMMISSION

Prepared by Mineral Resources Work Group

Sponsored by Bureau of Mines

U.S. Department of the Interior

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Cover photo by Kristine Moore Meves.

This appendix to the *Report* of the *Great Lakes Basin Framework Study* was prepared at field level under the auspices of the Great Lakes Basin Commission to provide data for use in the conduct of the Study and preparation of the *Report*. The conclusions and recommendations herein are those of the group preparing the appendix and not necessarily those of the Basin Commission. The recommendations of the Great Lakes Basin Commission are included in the *Report*.

OUTLINE

SYNOPSIS

The mineral industry of the Great Lakes Region is important to local and national economics. Total value of mineral production approached 1.5 billion dollars in 1968. The Region's mineral industry also plays a strategic role by supplying 100 percent of the iodine, 69 percent of the iron ore, 51 percent of the magnesium compounds, and 42 percent of the peat, lime, and bromine produced in the United States. Other mineral products are important in the more limited regional and local markets.

Future mineral production potential is good within the Region. The opening of new mines producing new mineral products can be anticipated because of technologic developments in mineral extraction and processing, although a timetable of such events cannot be made at present.

An adequate water supply is essential to the production of a number of mineral products. Consumptive water losses for mineral production are small and water withdrawals can be reduced through recirculation practices. Because recirculation is being used increasingly by the mineral industry, no serious water supply problems are anticipated. Pollution of surface and ground water is limited primarily to unrecorded oil, gas, and salt wells and test wells that were abandoned many years ago. There is no easy way to detect abandoned wells or tests, but legal provisions exist for their sealing when discovered. Pollution from other mineral producers is minor and technologies exist to eliminate such practices.

Land requirements of the mineral industry are the most critical single factor governing future mineral production. Only a small portion of land within the Great Lakes Region contains mineral material economically accessible to the mining industry. In many cases the location of mineral deposits is not known, preventing adequate planning for preservation of the resource inventory. Loss of mineral-bearing land is particularly critical around urban and suburban centers of the region where the sand, gravel, and stone resources are being rapidly depleted through restrictive zoning ordinances and construction activities overlying the deposits. Future supplies of low cost, high bulk aggregate minerals will have to be imported into several planning subareas in the near future, resulting in greatly increased costs due to transportation charges. Reclamation of mined lands is an integral part of most modern mining operations and must be considered in any land use planning efforts. Sequential use of reclaimed land varies considerably and is treated in only a very general manner.

FOREWORD

The original draft of Appendix 5, *Mineral Resources*, was written by William S. Miska, geologist, Bureau of Mines, Liaison Office, Indiana, and Thomas O. Friz, mining engineer, Division of Environment, Washington, D.C. The final draft was prepared under the direction of Donald F. Klyce, industry economist, Twin Cities Mineral Supply Field Office, Bureau of Mines, Minneapolis, Minnesota.

Congressional authority for the U.S. Bureau of Mines participation was expressed in Section 601 of the Economy Act of 1932, 47 Stat. 382, 417. The Twin Cities Mineral Supply Field Office, Bureau of Mines, Minneapolis, was appointed by the Great Lakes Basin Commission to chair the Mineral Resources Work Group, which was charged with the responsibility of preparing Appendix 5.

The Bureau authors of the appendix wish to express their appreciation to the Commission for its assistance in organizing the Mineral Resources Work Group with distinguished representatives from each of the eight States in the Basin. These people donated their time to the study, providing data input, technical advice, and critical reviews, all of which contributed immeasurably to the final product.

The authors wish to express their appreciation to members of the Mineral Resources Work Group including:

Harry J. Hardenberg, Deputy State Geologist, Michigan Geological Survey

Dr. Meredith E. Ostrom, Associate State Geologist, Wisconsin Geological Survey

Dr. Lawrence F. Rooney, former Head, Industrial Minerals Section, Indiana Geological Survey

Dr. Hubert E. Risser, Assistant Chief and Principal Mineral Economist, Illinois Geological Survey

Dr. Donald L. Norling, Deputy Director for Soils and Minerals, Ohio Department of Natural Resources

Dr. James F. Davis, State Geologist, New York Geological Survey

Dr. Arthur A. Socolow, Director, Pennsylvania Bureau of Topographic and Geologic Survey

Dr. Paul K. Sims, State Geologist, Minnesota Geological Survey

Dr. Carl I. Dutton, Geologist, U.S. Geological Survey, Madison, Wisconsin

Work group members provided the data given in the stratigraphic successions for each planning subarea, factors that permitted calculation of mineral-bearing land requirements, many references, technical advice on the nature of local land and water use practices, information on mineral problems, and critical reviews of the manuscript.

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INTRODUCTION

Purpose

The purpose of Appendix 5, *Mineral Resources*, is to provide basic data on the mineral industry and mineral resources. This information will aid in the formulation of a comprehensive plan for the optimal development and use of water and related land resources in the Great Lakes Basin.

Scope

This appendix deals principally with the 15 planning subareas that make up the five Great Lakes Region plan areas. Each planning subarea chapter includes current and projected mineral industry development, extent and availability of mineral resources, mineral industry land and water use problems, and recommendations for mineral development. All mineral commodities produced in the planning subareas are included in the report. Projections of production, land, and water are limited to those minerals that require significant land or water resources in their production. Future land and water use estimates reflect only the mining and quality improvement of mineral materials.

Summary production, water, and land use tables for the Great Lakes Region and the five plan areas are presented at the end of the report in the supplementary tables. This section also contains additional planning subarea tables on land disturbed by surface mining, water intake sources, and water discharge methods. Summary mineral production tables for selected commodities by planning subarea (PSA), plan area, and State are also included.

This report is based entirely upon information including published and unpublished State and Federal government reports and file data. Heavy reliance was placed on the judgment of professional personnel in industry, government, and education. No field examinations were undertaken to determine quantity or quality of mineral resources, the degree of mineral self-sufficiency, actual or alleged pollution by the mineral industry, extent or nature of specific reclamation programs and practices, the degree of adoption of technological innovations, or the extent of other mineral industry problems.

Geology and Distribution of Mineral Resources

The geologic history recorded in rocks and sediments of the Great Lakes Basin represents three geologic eras, the Precambrian, Paleozoic and Cenozoic. Rocks of the Precambrian era, oldest in the Basin, are mainly dense, hard igneous and metamorphic types such as granite, basalt, gneiss, marble, and schist. Although Precambrian rock forms the basement complex under the entire Basin area, it is exposed or lies near the surface only in the northwestern and extreme eastern parts of the Basin (Figure 5–1).

In the remainder of the Basin, Precambrian material is overlain by sedimentary rock that was deposited during the Paleozoic era. These consist mainly of horizontal to gently dipping beds of limestone, dolomite, shale, and sandstone that attain a maximum thickness of approximately 14,000 feet in the east-central part of Michigan's Lower Peninsula. Overlying both Precambrian and Paleozoic bedrock are unconsolidated sediments deposited during the Cenozoic era. These are of glacial and postglacial origin, forming a layer ranging from a few inches to several hundred feet in thickness.

Distribution of rocks and sediments from each of the three eras also defines the type and location of mineral resources and mineral production within the Basin. Virtually all the metal resources, including iron, zinc, lead, silver, and copper, occur in Precambrian rock. These resources are therefore produced in the northwestern and extreme eastern parts of the Basin. Paleozoic rock contains oil, gas, coal; nonmetallic minerals including limestone, dolomite, sandstone, shale, salt, and gypsum; and natural brines. The occurrence and production of these fuels and nonmetals depends on the geographic distribution and accessibility of certain formations. Nonmetal deposits of sand and gravel, clay, marl, and peat, found throughout the Basin, are contained in unconsolidated Cenozoic sediments.

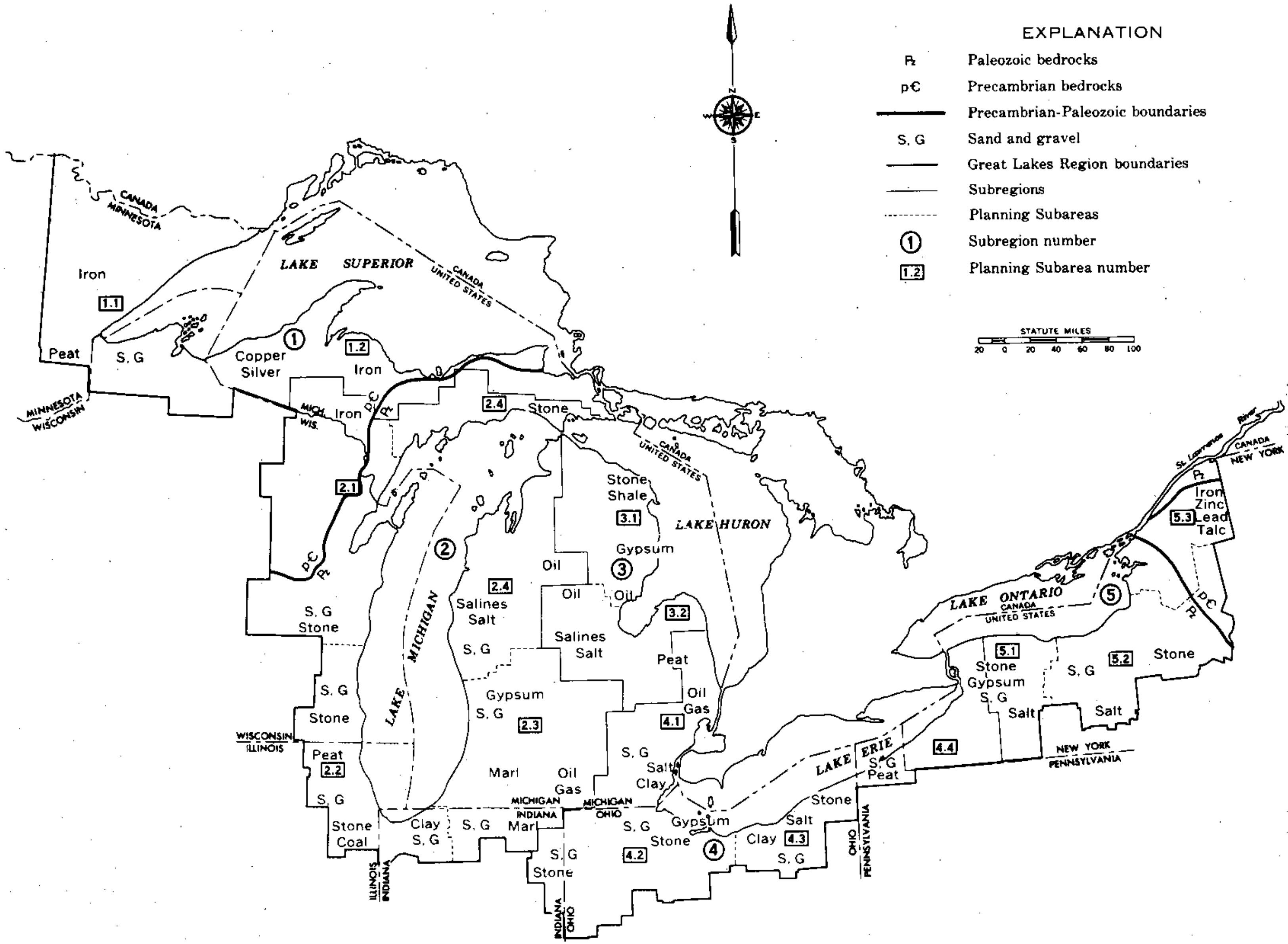

FIGURE 5–1 Great Lakes Region: Distribution of Bedrock Geology and Principal Mineral Production

TABLE 5–1 United States and Great Lakes Region Mineral Production—1968[1]

Commodity		National Quantity	Great Lakes Region Quantity	Percent of National
Cement:				
Portland	376-pound barrels	388,525,000	45,729,463	11.8
Masonry	280-pound barrels	23,167,000	2,483,654	10.7
Clays and shale	short tons	57,233,000	4,139,014	7.2
Coal, bituminous	short tons	545,245,000	593,543	0.1
Copper[2]	short tons	1,204,621	74,805	6.2
Iron ore (usable)	long tons, gross weight	81,934,000	56,635,595	69.1
Lead[2]	short tons	359,156	1,396	0.4
Lime	short tons	18,637,000	7,744,542	41.6
Magnesium compounds	short tons, MgO equivalent	525,210	266,406	50.7
Peat	short tons	619,161	260,509	42.1
Petroleum	42-gallon barrels	3,329,042,000	12,974,404	0.4
Sand and gravel	short tons	917,739,000	128,947,000	14.1
Silver[2]	troy ounces	32,729,000	500,428	1.5
Stone (crushed and broken)	short tons	815,946,000	110,557,798	13.5
Stone (dimension)	short tons	3,457,000	142,007	4.1
Zinc	short tons	529,446	66,194	12.5

[1]Excludes petroleum data for New York and Ohio, and natural gas and natural-gas liquids data, which are not available.
[2]Recoverable content of ores, etc.

Geographic distribution of principal mineral resources produced in each planning subarea of the Basin is shown in Figure 5–1. A generalized stratigraphic succession of major rock units by era, system, group, and formation designation is given in each planning subarea section along with formation thickness and mineral occurrences in that planning subarea.

Mineral Resources and Their Significance

Metals, nonmetals, and mineral fuels are produced in large quantities in the Great Lakes Region. Metal production in 1968 included copper, iron ore, lead, silver, and zinc. Iron ore, the principal metal ore produced in the Basin, totaled 57 million long tons valued at $597 million in 1968. This represents 69 percent of U.S. production of iron ore. Nonmetal production includes bromine, calcium compounds, clays and shale, grindstone, gypsum, iodine, potash, salt, sand and gravel, crushed and broken stone, dimension stone, and talc. The entire 1968 U.S. production of iodine came from the Great Lakes Region. Sand and gravel production in 1968 totaled 129 million tons valued at $124 million, 14 percent of the U.S. total, while crushed and broken stone production totaled 111 million tons valued at $154 million, also 14 percent of the U.S. total. Mineral fuels include bituminous coal, natural gas, peat, and petroleum. Although peat is considered a fuel substance, it is used primarily as a soil conditioner. In 1968, the Region's peat production totaled 619,161 tons valued at more than $7 million, representing 42 percent of U.S. production of this commodity. A comparison of the Great Lakes Region production and value of various minerals for 1968 is presented in Tables 5–1 and 5–2.

Portland and masonry cement, lime, and magnesium compounds are included in production tables for reference only. These commodities represent intermediate products produced by the stone and saline industries. Minerals used to manufacture the intermediates have a market value in the unprocessed state and are included in the production tables under the unprocessed commodity.

Mineral producers are the principal shippers of materials on the Great Lakes. The movement of coal, limestone, and iron ore, from all sources, accounts for 80 percent of the gross tonnage moved annually on the Lakes.

Methodology of Projections

General

The projections of mineral production, water use, and land use represent one of the

TABLE 5–2 United States and Great Lakes Region Mineral Production Value—1968[1] (thousands of dollars)

Commodity		National Value	Great Lakes Region Value	Percent of National
Cement:				
Portland	376-pound barrels	1,227,942	145,975	11.9
Masonry	280-pound barrels	66,259	6,986	10.5
Clays and shale	short tons	246,898	5,328	2.2
Copper[2]	short tons	1,008,195	62,607	6.2
Iron ore (usable)	long tons, gross weight	836,433	597,233	71.4
Lead[2]	short tons	94,903	369	0.4
Lime	short tons	249,639	98,553	39.5
Magnesium compounds	short tons, MgO equivalent	43,449	25,087	57.7
Peat	short tons	7,230	3,322	45.9
Petroleum	42-gallon barrels	9,794,826	38,287	0.4
Sand and gravel	short tons	1,020,336	124,311	12.2
Silver[2]	troy ounces	70,191	1,073	1.5
Stone (crushed and broken)	short tons	1,218,105	154,171	12.7
Stone (dimension)	short tons	99,648	4,323	4.3
Zinc[2]	short tons	142,950	17,872	12.5
Value of items that cannot be disclosed for the Great Lakes Region: Bituminous coal, bromine, calcium compounds, grindstones, gypsum, iodine, potash, salt and talc		3,038,604	193,876	6.4
Total		19,165,608	1,479,373	7.7

[1]Excludes petroleum data for New York and Ohio, and natural gas and natural-gas liquids data which are not available.
[2]Recoverable content of ores, etc.

major work efforts in the preparation of this appendix. Steps followed in developing these projections include:

(1) compilation and computerized analysis of thousands of mineral production records that served as the historical base upon which future mineral production was projected

(2) translation of the mineral production projections, by use of water ratios developed for each planning subarea commodity, into future water requirements

(3) translation of mineral production projections into future land requirements using per-acre mineral yield factors supplied by State work group members

To establish their validity, all projections were evaluated with respect to known geologic conditions, trends in mining and processing technology, planning subarea population and industrial growth, possibilities for product substitution, legal constraints, and specific problem situations. Many important problems became evident as a result of this analysis. They are included in the discussion of each planning subarea.

Production

Projections of mineral production for selected commodities in each planning subarea are based on the statistical analysis of previous local production data; U.S. Bureau of Mines national projections of primary mineral demand and production trends; various indices such as GNP (Gross National Product), Wholesale Price Index, and Building and Construction Cost Index that reflect broad national trends; various modifying parameters such as population growth patterns, per capita income, foreseeable technological changes, planned expansions or decreases in individual plant size and production capacity, and anticipated mineral resource depletion; and in some cases on economic and engineering judgment of local production changes.

Projections for petroleum and natural gas were not made beyond the present reserve limits of known fields because of the great uncertainty of future discoveries. Commodities such as iodine, bromine, talc, and grindstones are produced by only one or two companies and cannot be projected with any degree of accuracy or without disclosing confidential data. Various types of stone have been combined as either crushed and broken stone or dimension stone for projection purposes. Commodities such as magnesium compounds, potash, calcium compounds, portland cement, and masonry cement were not projected, as these are considered to be intermediate products.

The reader is referred to Appendix 19, *Economic and Demographic Studies*, for further details on projected production methodology and for mineral industry employment data. The U.S. Bureau of Mines worked in conjunction with the Economic and Demographic Studies Work Group on both production and employment projections. These, along with a detailed methodology, compose a separate section in that appendix. Appendix 19 also provides insight into the overall role of mineral production in the Basin's economy.

Water

Water use projections for each planning subarea are based on mineral-producer use patterns as determined by the 1962 U.S. Bureau of Mines Water Canvas of the Mineral Industry. The 1962 data were updated and modified to more accurately reflect conditions in 1968 and anticipated trends for the projection years. Water use is subdivided and defined as follows:

New Water Intake—water introduced from external sources for the first time.

Discharged Water—water (not recirculated or consumed) disposed to external sources.

Recirculated Water—water reused to conserve new water.

Consumed Water—water lost by evaporation as well as water lost in product.

Total Water—the quantity of water used to produce the finished product.

The mathematical relationships between the water use categories are as follows:

New Water Intake = Discharged Water + Consumed Water

Total Water = New Water Intake + Recirculated Water

Water use ratios for each of the above definitions were computed in gallons of water per ton of production for each commodity. This ratio times projected annual production yields the quantity of water required annually, expressed in millions of gallons. Depending upon the length of the production year, the number of production days was divided into the annual water requirement to provide daily water usage, expressed in millions of gallons per day (mgd), for each commodity. To avoid listing commodities with insignificant water usage, only the sum of the various water use categories is presented in the tables. Water-using commodities in each planning subarea are identified in the text in order of importance. Water use projections were not made for petroleum and natural gas although current water usage is described when known.

Land

Translation of production projections into annual land use requirements necessitated use of specific data on the occurrence of mineral deposits in each planning subarea. Data on the average mineable thickness for each type of deposit and average density of the mineral material were combined to give an estimated yield per acre of mineral-bearing land. State representatives to the Mineral Resources Work Group provided these factors for each commodity in their respective planning subareas because of their more intimate knowledge of local mineral occurrences. Each mineral-commodity projection was then divided by the appropriate estimated yield-per-acre factor to arrive at the total number of acres of mineral land required during the projection years. Estimated yields of mineral-bearing land by planning subarea and commodity are given in Table 5–3. The wide range in yields primarily reflects the difference in deposit thickness from one planning subarea to another. The weighted yield factors given for Planning Subareas 1.1, 2.1, 2.2, 2.3, and 4.2 result from differences in deposit thickness giving different yields from one State to another within the same planning subarea. The weighted factors are based on the share of total mineral output attributed to each State within each of these planning subareas. Specific figures used in calculating these weighted yields cannot be disclosed without indirectly providing access to certain confidential production data.

A slightly different methodology is required to arrive at the land use estimate for peat. All peat is assumed to be produced by the farming method, in which only the top few inches of a bog are removed each year. The cumulative projected production of peat was divided by the estimated yield as shown in Table 5–3 to

TABLE 5–3 Estimated Yields of Mineral-Bearing Land by Planning Subarea and Commodity (tons per acre)

Planning Subarea	Clay and shale	Coal	Gypsum	Peat	Sand and gravel	Stone, crushed	Stone, dimension
1.1	-------	-----	------	18,000	61,000[1]	325,000[1]	-------
1.2	-------	-----	------	------	54,000	223,000	-------
2.1	74,000	-----	------	------	60,200[1]	86,700[1]	21,000
2.2	75,000[1]	4,920	------	3,000[1]	84,000[1]	804,000[1]	21,000
2.3	88,000	-----	------	6,000	76,000	29,900[1]	11,000
2.4	88,000	-----	------	------	65,000	204,000	-------
3.1	141,000	-----	93,000	------	76,000	427,000	19,000
3.2	70,000	-----	------	8,000	33,000	56,000	11,000
4.1	70,000	-----	------	8,000	109,000	167,000	-------
4.2	17,500	-----	31,000	------	49,300[1]	352,000[1]	295,000
4.3	70,000	-----	------	------	43,600	295,000	147,000
4.4	70,000	-----	------	8,000	65,000	223,000	-------
5.1	-------	-----	------	------	54,000	204,000	-------
5.2	70,000	-----	------	8,000	33,000	186,000	-------
5.3	-------	-----	------	------	76,000	167,000	-------

[1]Weighted estimates based on mineral yield per acre and share of total production attributed to each State within the planning subarea.

determine the quantity of peat-bearing land that would be exhausted during the projection period. In addition, an average production rate of 134.4 tons of peat per acre per year was divided into the peat projection to determine the quantity of peat-bearing land necessary to sustain the projected annual production of peat. Total land required for peat production is therefore the sum of the exhausted land plus the acreage required for annual production.

In addition to the requirements for mineral-bearing lands, certain mineral producers have need of large acreages for process plant sites, ore storage areas, overburden and waste rock dumps, and tailings ponds. Within the Basin, this surface land use accounts for much of the land requirements projected for iron ore and all of the land projected for copper and zinc-lead. Use of non-mineral-bearing land ancillary to metal mining generally increases at irregular intervals as required rather than in annual increments. Land so employed is considered a relatively permanent addition to total acreage used, and is therefore constant for the projection period.

To determine the size and time of acreage increases for the various metal mining districts, heavy reliance was placed on engineering judgment, individual company expansion plans, and published long-range plans such as the Regional Development Plan for the Mesabi and Vermilion Ranges, Minnesota.[16]

For various technical reasons the Mineral Resources Work Group was concerned about the usefulness of land use projections. The principal concern is that the projections can be misleading or misinterpreted if the user of the data is unfamiliar with the nature of mineral resources and mineral industry activities. Three important relationships are discussed to help the reader better interpret the land use projections. These are the relationship between estimated yield-per-acre and occurrence of mineral deposits; the relationship between acreage estimates and availability of mineral-bearing lands; and the relationship between rate of mineral land usage and reclamation of mined lands.

The estimated yield-per-acre factor used in calculating the land use seems to imply that minerals occur in uniform deposits evenly distributed across a planning subarea. In fact, each mineral deposit is a unique occurrence, limited in size, shape, and quality and containing only a fixed quantity of usable material. Output from one deposit and the acreage supporting its production can differ considerably from that of another deposit, even when these deposits are in close proximity.

Acreage estimates calculated for each commodity may give the impression that all mineral-bearing lands have been located and will be available when needed. This is not the case. Mineral deposits are hidden beneath the surface of the earth and conclusions as to their occurrence and distribution must rely heavily upon incomplete field data and the extension of geological principles and theories. Land projections can only assume the existence of mineral-bearing land. The number of parcels and location of the acreage is not known. Once a deposit has been located and mapped, it may not be available for mineral extraction due to competing land uses or land use restrictions. If mineral production is to be sustained throughout the projection period, it becomes critical to locate mineral occurrences and to conserve the deposits for mineral extraction once they are found.

Although a vast quantity of mineral-bearing land is required to support projected mineral production, the assumption should not be made that this land will yield its mineral wealth and serve no useful purpose either before or after mineral extraction. Mineral land should be preserved for use, but prior to removal of the mineral material, many nondestructive land uses can occupy the land surface. The time required for actual mineral production is in most cases short, and once the mineral is removed the land can be subjected to modern reclamation practices. Specific practices and sequential land usage must be considered on an individual mine basis and therefore are beyond the scope of this report. However, recognition of such practices is necessary to understand overall land use patterns of the mineral industry.

Section 1

PLAN AREA 1.0

1.1 Planning Subarea 1.1, Lake Superior West

1.1.1 Status and Potential of the Mineral Industry

1.1.1.1 Resume

Mineral commodities produced in the four Minnesota and four Wisconsin counties that comprise Planning Subarea 1.1 include clay, iron ore, peat, sand and gravel, and stone (gabbro and basalt). Output and value of these products for 1960 and 1968 are summarized in Table 5–4. Cement and lime, manufactured at Duluth, Minnesota and Superior, Wisconsin from imported Michigan limestone and local blast furnace slag, are considered manufactured products and are included in the table for reference only. Because of the limited number of producers of cement, lime, peat, and stone, the quantities and values of these commodities must be withheld to avoid disclosing individual company confidential data. The value of iron ore is also withheld so that the total value of mineral products for Planning Subarea 1.1 and Plan Area 1.0 can be published. An estimated value of $424,000,000 for iron ore is obtained by using the 1968 average mine value for iron ore for the State of Minnesota,[4] $9.92 per long ton, times the tonnage produced in the planning subarea. Total value of mineral production in the planning subarea in 1968 was $442,447,329, with the estimated value for iron ore accounting for nearly 96 percent. From 1960 to 1968, all mineral commodities of Planning Subarea 1.1, with the exception of manufactured portland and masonry cements, increased in both output and value.

A total of 125 mineral operations were active in 1968. All counties had sand and gravel operations, two had production from peat bogs and stone quarries, and one county had a clay pit. All iron ore mines were in St. Louis County, Minnesota. Distribution of producing sites by State, county, and type of operation is pre-

TABLE 5–4 Planning Subarea 1.1: Mineral Production, 1960 and 1968

Commodity		1960		1968	
		Quantity	Dollar Value	Quantity	Dollar Value
Cement:					
Portland	376-pound barrels	W	W	W	W
Masonry	280-pound barrels	W	W	W	W
Clay	short tons	20	80	50	100
Iron ore (usable)	long tons, gross weight	42,239,727	369,530,900	42,749,198	W
Lime	short tons	W	W	W	W
Peat	short tons	W	W	W	W
Sand and gravel	short tons	3,271,472	2,159,172	5,754,000	3,687,000
Stone (crushed and broken)	short tons	W	W	55,000	W
Stone (dimension)	short tons	W	W	188	W
Value of items that cannot be disclosed		----------	7,928,503	----------	438,760,229
Total Planning Subarea 1.1		----------	379,618,655	----------	442,447,329

W Withheld to avoid disclosing individual company confidential data; included with "value of items that cannot be disclosed."

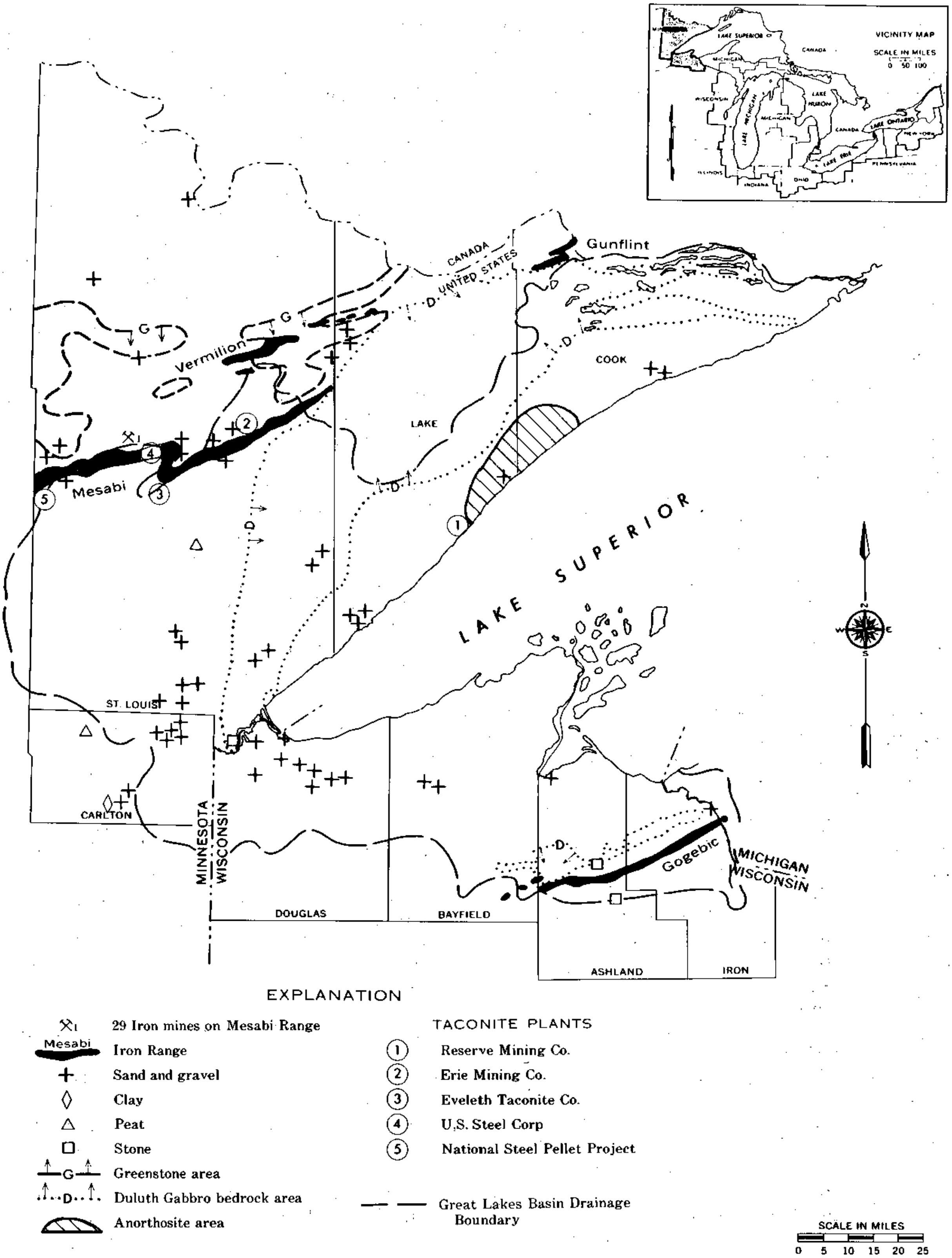

FIGURE 5–2 Planning Subarea 1.1: Distribution of Mineral Operations Active in 1968 and Major Mineral Resource Areas

TABLE 5–5 Planning Subarea 1.1: Active Mineral-Producing Sites by State, County, and Type of Operation, 1968

State County	Clay Pits	Iron Ore Mines	Peat Bogs	Sand and Gravel Pits	Stone Quarries Gabbro	Stone Quarries Basalt
Minnesota						
Carlton	1	—	1	13	-	-
Cook	-	—	-	2	-	-
Lake	-	—	-	8	-	-
St. Louis	-	38[1]	1	31	-	1
Subtotal	1	38	2	54	0	1
Wisconsin						
Ashland	-	—	-	2	2	-
Bayfield	-	—	-	4	-	-
Douglas	-	—	-	18	-	-
Iron	-	—	-	3	-	-
Subtotal	0	0	0	27	2	0
Total	1	38	2	81	2	1

[1]Includes 29 open-pit mines and 9 stockpile recovery operations.

sented in Table 5–5. Locations of selected operations are shown in Figure 5–2.

1.1.1.2 Resources and Reserves

The bedrock geology of Planning Subarea 1.1 is imperfectly known. Rocks of Precambrian age, including some of the oldest rocks in the United States, have been faulted, folded, metamorphosed, intruded, and eroded, and are now found under Cretaceous sediments and glacial debris. The complex relationship between various Precambrian formations is known only where the bedrock extrudes, where it has been exposed in surface and underground mines, or where it has been obtained as drill cores. The more significant formations, such as the Ely Greenstone, Duluth (gabbro) complex, and the several iron formations, have been broadly defined due to exploration interest. Much detailed work remains to be done before the geology is completely understood. This also applies to younger sedimentary formations, some of which have been classified as both Cambrian and late Precambrian in age. Bedrock of the planning subarea is iron formation in some locations and elsewhere provides a variety of stone suitable for quarrying. The bedrock also holds much potential for future mineral production. Overlying the bedrock are unconsolidated sediments of the Quaternary system that contain deposits of clay, peat, and sand and gravel. All the minerals currently produced in the planning subarea are extracted from pits and quarries, though underground iron mining did take place in the past. A generalized stratigraphic succession of Planning Subarea 1.1 is presented in Table 5–6 along with the formation thickness and mineral occurrences.

Portions of the Mesabi, Gogebic, and Gunflint iron ranges, as well as the entire Vermilion Range, are found within this area (Figure 5–2). At present, production is limited to the Mesabi Range where 29 mines and 9 stockpile recovery operations were active in 1968. Since mining first began on the Mesabi in 1892, shipments of hematite and magnetite ore from St. Louis County have totaled 2,130,000,000 gross tons. Current mining emphasis is on concentrates from magnetic taconites, with a subsequent reduction in natural or direct shipping-ore production. Five taconite plants were active in 1968 (Figure 5–2), with production from the National Steel Pellet Project split between St. Louis County and Itasca County, which lies outside the planning subarea. Production from these five pellet operations accounted for more than 63 percent of the iron ore produced in the area in 1968. Iron ore products are transported by rail to the ports of Taconite Harbor, Silver Bay, Two Harbors, Duluth, and Superior for transshipment by lake freighter to consuming districts in the lower Great Lakes Region. Reserves of Mesabi ore include 855 million gross tons of measured ore and 500 million gross tons of indicated-inferred ore, both averaging 50 percent Fe. Magnetic taconite reserves containing 200 percent Fe include approximately 6 billion gross tons of indicated-inferred ore and 15 billion gross tons of potential ore.[6] All iron mining activity within the planning subarea during the projection years is expected to be centered on the Mesabi Range, with taconite operations completely replacing natural ore production by 1980.

Mining first began on the Wisconsin portion of the Gogebic Range in 1885 and continued until the last mine closed in 1965. The bulk of the 70,696,000 gross tons of hematitic ore produced in Wisconsin during this time came from deep underground mines, some of which exceeded 3,500 feet in depth. Reserves of ore include 6,500,000 gross tons of measured ore, 30 million gross tons of indicated-inferred ore, both with a 52 percent Fe content, and 5 billion gross tons of potential ore with a 25 to 35 percent Fe content.[6] Although the reserves of iron ore on the Gogebic Range are extensive, most of the reserves are too deeply buried or are not readily amenable to benefication

TABLE 5–6 Planning Subarea 1.1: General Stratigraphic Succession and Mineral Resources

Era	System	Group	Formation	Thickness (feet)	Mineral Resources
Cenozoic	Quaternary			0–200	Clay, peat, sand, and gravel
Mesozoic[1]	Cretaceous[1]		Coleraine Sh.[1]	0–100	
Precambrian	Upper Precambrian[1]	Bayfield[2]	Chequamegon Ss.[2]	0–1,000	
		Upper Keweenawan[1]	Devils Island Ss.[2]	0–300	Silica sand(p)[2]
			Hinkley Ss.[1]	0–100	
			Orienta Ss.[2]	0–3,000	Stone(p)
			Fond du Lac Ss.[1]	0–2,000	
		Oronto[2]	Freda Ss.[2]	0–12,000	
			Nonesuch Sh.[2]	0–350	Copper(p)
			Outer Cong.[2]	0–1,200	Iron(p), stone(p)
		Middle Keweenawan[3]		0–21,000	Stone, titanium(p)[1] iron(p), copper(p) nickel(p); alum.(p)
		Lower Keweenawan	Puckwunge Fm.[1]	0–200	
	Middle Precambrian	Animikie[4]	Algoman Granite[1]		Iron, stone(p)
	Lower Precambrian	Knife Lake[1,5]	Ely Greenstone[1]	0–21,000	Iron(p)
		Keewatin[5]			Iron(p), base metals(p), stone

Source: Meredith E. Ostrom, Wisconsin Geological Survey and references 11, 12, 18.
Note: Indented names indicate approximate equivalents of those of another State listed above.
[1]In Minnesota
[2]In Wisconsin
[3]Formation includes Duluth, Gabbro, Logan intrusives, Beaver Bay Complex, Keweenaw Point Complex, North Shore Volcanics.
[4]Formation in Wisconsin Tyler Slate, Ironwood Iron Fm. Palms Qtzite., Bad River Dol., Sunday Qtzite. Formation in Minnesota Virginia Sl. (Rove Sl.), Biwabik Iron Fm. (Gunflint Iron Fm.), Pokegama Qtzite.
[5]Formation contains 18–20 members of slate, graywacke, iron formation, conglomerate, tuff, lava, and intrusives.
(p) Potential Resource

under current practices. Production is not anticipated during the projection period.

Exploratory work that has been carried out on the Gunflint Range resulted in numerous test pits and minor shipments of handsorted ore but no extensive mining operations. The iron formation is composed essentially of thin-bedded magnetic taconite. Average assays of the iron-bearing members range between 22 and 25 percent Fe. No estimate of reserves is available. Thinness, low grade, steep dip, and difficulty of beneficiation preclude the development of this range at least in the foreseeable future.

Iron ore was mined on the Vermilion Range exclusively by underground methods from 1884 until cessation of production in 1967. A total of 103,752,604 gross tons of ore was shipped during this interval. Considerable reserves of iron ore remain, composed primarily of hematite but with some magnetite, averaging 56 percent Fe. Included are 6 million gross tons of measured ore, 25 million gross tons of indicated-inferred ore, and 330 million gross tons of potential ore. A large tonnage of potential ore composed of jaspilite containing 35 percent Fe is also present, though no exact estimate is available.[6] Although large tonnages of reserve ore are available on the Vermilion Range, no production is anticipated during the projection period.

In addition to the iron ranges, reserves of titaniferous iron ore are contained in the Duluth gabbro. The bulk of these reserves are lean ore with an average assay of 25 percent Fe and 14 percent TiO_2. Reserve tonnage includes approximately 24,600,000 gross tons of measured ore, 60,500,000 gross tons of indicated ore, and 9,500,000 gross tons of inferred ore.[14] Fourteen deposits with reserves in excess of one million tons account for more than 86 percent of the total reserve tonnage. These deposits will remain as potential iron and titanium sources until technology or market demands makes their extraction and processing economically feasible.

Stone production in the area is currently limited to the quarrying of gabbro and basalt. Dimension gabbro is produced at two locations in Ashland County for use as architectural and monument stone. Annual production amounts to only a few hundred tons, and reserves are sufficiently large to support production for many years. Basalt is produced near Duluth in St. Louis County and crushed for local use as aggregate and roadstone. Reserves of this material are extremely large, and can support production throughout the projection period. Various types of rock including basalt, granite, marble, slate, anorthosite, and sandstone have been quarried at various locations in the past for use as dimension or crushed stone. Waste rock produced in conjunction with iron mining on the Vermilion, Mesabi, and Gogebic ranges has been used locally for railroad and highway construction and repair. The opening of new stone quarries depends primarily upon local demand for dimension and crushed stone products. To a lesser degree, the demand for dimension stone in larger population centers outside the planning subarea may stimulate production of specialty stones or silica sand in the future.

Clay production is limited to one site in Carlton County. The 50 tons of glacial lake clay produced at this pit in 1968 were used for tourist pottery and wall and floor tile. Glacial lake clay deposits exist at various locations within the planning subarea. The Coleraine shale in St. Louis County may have value as a clay material or for the manufacture of lightweight aggregate. Because these potential resources have not been thoroughly investigated, no reserve estimate for clay or shale is available. Future production of clay is primarily contingent upon local market demands, which may or may not develop during the projection period.

Production of peat is limited to only two locations, not by a lack of quality deposits but by excessive distances to the major market areas. Most peat produced in Carlton County and reed-sedge peat produced in St. Louis County are used for horticultural purposes as a general soil conditioner. Local demand for this material is small. Producers in other areas of the country are closer to markets outside the area, and therefore maintain a competitive edge. Reserves of peat in Minnesota on an air-dried basis include more than 900 million tons in St. Louis County, 100 to 900 million tons in Lake County, 1 to 100 million tons in Carlton County, and less than one million tons in Cook County.[26] Workable peat beds also occur in the Wisconsin portion of the [illegible] but these are less common than the Minnesota deposits and no estimate of reserves is available. Reserves of peat in the planning subarea are sufficiently ample to support production well beyond the projection period.

Deposits of sand and gravel are found in the glacial and postglacial sediments that cover the entire area. Quality deposits are abundant and should be more than ample to meet local demand for many years. In those instances where glacial cover may be thin or lack sand and gravel deposits, bedrock can be quarried and crushed as a substitute material. No estimate of the quantity or quality of sand and gravel reserves is available.

In addition to the minerals currently produced, certain potential resources warrant consideration because of their prospects for future development.

A potential source of aluminum exists in the intrusive anorthosite bodies occurring along the shore of Lake Superior in Lake and Cook Counties (Figure 5–2). These anorthosite bodies contain between 29 and 32 percent Al_2O_3, no free silica, and only small amounts of extraneous mineral material. As such they have excellent potential as low grade aluminum sources. Potential reserves of anorthosite are estimated at 100 to 500 million tons. The proximity of these deposits to water transport routes adds to their desirability. Although it is not economically feasible to use these low grade deposits while 50 to 60 percent Al_2O_3 bauxite is available, use of such low grade deposits will probably be necessary within the next 10 to 20 years.[5]

The presence of copper and nickel sulfides in the Duluth gabbro of Minnesota and Wisconsin has been known since the late 1800s and has at various times stimulated exploration interest (Figure 5-2). The low grade of the deposits has prevented the mining of this material. Recent increases in metal prices, and constantly improving mining and metallurgical technology, have again stimulated interest in these sulfide deposits. The results of much of the exploration activity are not available but from the published information it appears that some marginal ore has been found. It is anticipated that some copper-nickel mining activity will begin within the projection period, but the location and site of such operations must at present remain open to speculation.

The Ely Greenstone belt, a portion of which lies within St. Louis and Lake Counties, may contain potential sulfide ore bodies (Figure 5-2). Considerable base metal mining activity has taken place on the Canadian extension of the formation. Indications of mineralization on the Minnesota portion are sufficient justification for detailed exploration of the greenstones. Creation of the Voyageurs National Park has complicated the exploration issue as portions of the greenstone belt have been considered for inclusion in the park. As a result, opposition to exploration has been generated by conservation groups. The outcome of this controversy and the location of workable deposits remains sufficiently in doubt to preclude any definite statement on the future potential of the greenstones.

Occurrences of kyanite, with associated garnet, are found in quantity in Iron County. These deposits may have commercial possibilities but lack of clear title to mineral rights has forestalled any detailed exploration.

1.1.2 Mineral Industry Projection

1.1.2.1 Production

Mineral Production for Planning Subarea 1.1 is summarized in Table 5-7 for 1968 and for projection years 1980, 2000, and 2020. All mineral production is expected to increase during this period. Cumulative production over the projection period is also included in the table, and provides an estimate of the vast quantities of mineral material that will be produced. There is the strong possibility that aluminum-bearing anorthosite, titaniferous iron ore, and copper-nickel sulfides will be mined in the area within the next 50 years. A more remote possibility exists that base metal sulfides and kyanite will be mined during this period.

TABLE 5-7 Planning Subarea 1.1: Projected Mineral Production by Selected Commodities (thousands of short tons unless otherwise noted)

Commodity	1968[1]	1980	2000	2020	1968 to 2020[2]
Iron ore[3]	42,749	49,600	68,100	93,600	3,337,600
Peat	W	12	15	20	752
Sand and gravel	5,754	6,720	11,020	18,060	538,520
Stone, crushed[4]	55	108	176	289	8,618

[1]Actual
[2]Cumulative
[3]Thousands of long tons
[4]Basalt
W Withheld to avoid disclosing individual company confidential data

1.1.2.2 Water

Water is used only in the production of iron ore and sand and gravel. Water use patterns for 1968 and for the projection years are presented in Table 5-8. Sand and gravel production is seasonal (from May through October). Water used by this industry is insignificant, less than one-fourth of one percent of the total, and is therefore included with the iron ore use on an annual basis. At the conference on The Matter of Pollution of the Interstate Waters of the Lake Superior Basin, Duluth, Minnesota, on May 13, 1968, Edward M. Furness, president of Reserve Mining Company, Silver Bay, Minnesota, gave the capacity of the Silver Bay Taconite Plant as approximately 10 million tons of iron ore pellets annually and water use at the plant as 350 thousand gallons per minute. This was translated into 504 million gallons per day (mgd). It was assumed that the plant would consume one percent, or 5 mgd, and discharge the remaining 499 mgd back into Lake Superior. Plant capacity and water use were held constant for the projection period. Upward trends in water use categories reflect the expected needs of iron ore proces-

TABLE 5-8 Planning Subarea 1.1: Projected Mineral Industry Water Use (millions of gallons per day)

	1968[1]	1980	2000	2020
New intake	542	572	604	649
Discharged	500	500	500	502
Recirculated	329	606	889	1,279
Consumed	42	72	104	147
Total water[2]	871	1,178	1,493	1,928

[1]Estimated
[2]Intake plus recirculated

sing plants in the immediate vicinity of the Mesabi Iron Range. Plants on the iron range recirculate all processing waters, and new intake only makes up for water consumed during processing. Discharge from mine unwatering, which is controlled and monitored by the Minnesota Conservation Department, was not included in Table 5-8, nor were any requirements included that may result from the mining of copper-nickel sulfide, titaniferous iron ore, or aluminum.

1.1.2.3 Land

As mineral substances are removed from the ground and the deposits are depleted, new mineral-bearing land must be brought into production. The land required to maintain projected mineral production is summarized in Table 5-9. The bulk of required land is centered around the Mesabi Iron Range. The Regional Development Plan for the Mesabi and Vermilion ranges has taken the requirements of the mineral industry into account in the land use plan.[16] Land use requirements for all mineral commodities should be planned on a long-range basis and other land users should be discouraged from preempting mineral-bearing lands until after the deposits have been mined.

1.1.3 Mineral Problems

The large size of the mineral industry and the intense degree of exploration within Planning Subarea 1.1 have contributed to a number of serious environmental and technical problems. The Regional Development Plan for the Mesabi and Vermilion Ranges is an attempt to plan orderly expansion of the iron industry, the local communities, and the growing tourist and recreation industries.[16] Land use patterns have been planned around the iron formation, the processing plants, and the tailings disposal area, providing for the orderly economic growth of the area while satisfying the needs of the local populace. The effects of dumping taconite mill tailings in Lake Superior at Silver Bay have been under study by the Reserve Mining Company, Environmental Protection Agency, U.S. Army Corps of Engineers, Bureau of Mines, U.S. Geological Survey, U.S. Fish and Wildlife Service, Bureau of Commercial Fisheries, various

TABLE 5-9 Planning Subarea 1.1: Projected Mineral-Bearing Land Requirements[1] (acres)

Commodity	1968[2]	1980	1968 to 1980[3]	2000	1968 to 2000[3]	2020	1968 to 2020[3]
Iron ore	50,000	75,000	75,000	150,000	150,000	250,000	250,000
Peat	600	600	600	650	650	700	700
Sand and gravel	94	110	1,153	181	4,061	296	8,828
Stone, crushed	------[4]	------[4]	3	-------[4]	11	1	27
Total	50,694	75,710	76,756	150,831	154,722	250,997	259,555

[1]Includes non-mineral-bearing surface lands required for iron ore production
[2]Estimated
[3]Cumulative
[4]Less than an acre

Minnesota, Wisconsin, and Michigan State agencies, and interested conservation groups. Although this situation has been the subject of considerable study and debate, the problem is still unresolved. For more details on the issues involved in the controversy, the reader is referred to Williams,[33] and the Federal Water Pollution Control Administration.[11]

The inclusion of potential mineral lands in the Voyageurs National Park has been the cause of concern and study by a number of groups. Proposed exploration activities in the Boundary Waters Canoe Area have recently come under fire by conservation groups who wish to preserve this wilderness area. Legal actions have been initiated to prevent exploration drilling on private lands and the entire matter remains controversial. The caved ground and abandoned mine shafts located along the Gogebic Range in Wisconsin are the subject of a current study by the Bureau of Mines. A safety hazard exists where stopes have caved to the surface and where abandoned shafts have not been capped or filled. Recommendations for remedial measures are expected to come from this study.

Technical problems include development of economical solutions to the environmental problems discussed above. Improvements are also being sought in exploration techniques for deeply buried ore bodies, development of economic beneficiation of low-grade hematites and metal sulfides, improvement of material handling techniques (particularly during the winter months) and improvement in the storage or disposal of lean ore, waste rock, stripped overburden, and tailings.

1.1.4 Summary and Conclusions, Including Alternatives

Reserves of all mineral commodities produced in the area exist in quantities large enough to support production activity for the next 50 years. Presence of mineral resources does not guarantee availability. It is recommended, therefore, that existing planning and study efforts incorporate additional programs to insure that valuable mineral resources are preserved and that planned development includes mineral extraction.

Periodic surveys of water use patterns of the mineral industry are recommended to keep abreast of intake and discharged water use changes.

1.2 Planning Subarea 1.2, Lake Superior East

1.2.1 Status and Potential of the Mineral Industry

1.2.1.1 Resume

Mineral commodities produced in the nine northern Michigan counties comprising Planning Subarea 1.2 include copper, iron ore, sand

TABLE 5-10 Planning Subarea 1.2: Mineral Production, 1960 and 1968

Commodity		1960 Quantity	1960 Dollar Value	1968 Quantity	1968 Dollar Value
Copper[1]	short tons	56,385	36,199,170	74,805	62,607,296
Iron ore (usable)	long tons, gross weight	6,773,116	62,223,817	9,250,340	W
Sand and gravel	short tons	2,018,574	1,567,466	1,965,000	1,418,000
Lime	short tons	W	W	---------	-----------
Silver[1]	troy ounces	---------	-----------	472,813	1,013,995
Stone (crushed and broken)	short tons	W	W	W	W
Stone (dimension)	short tons	145	3,050	---------	-----------
Value of items that cannot be disclosed		---------	4,126,192	---------	117,244,954
Total Planning Subarea 1.2		---------	104,119,695	---------	182,284,245

W Withheld to avoid disclosing individual company confidential data; included with "value of items that cannot be disclosed."

[1] Recoverable content of ores

TABLE 5–11 Planning Subarea 1.2: Active Mineral-Producing Sites by State, County, and Type of Operation, 1968

State County	Copper Mines	Iron Ore Mines	Sand and Gravel Pits	Stone Quarries: Basalt	Stone Quarries: Limestone and Dolomite
Michigan					
Alger	-	-	2	-	-
Baraga	-	-	1	-	-
Chippewa	-	-	4	-	1
Gogebic	-	-	9	-	-
Houghton	2[a]	-	3	2	1
Keweenaw	1[a]	-	1	-	-
Luce	-	-	2	-	-
Marquette	-	7[b]	10	-	-
Ontonagon	1[c]	-	3	-	-
Total	4	7	35	2	2

[a]These underground mines closed in 1969.
[b]Includes 5 open-pit and 2 underground mines.
[c]All of the planning subarea's silver output is a by-product of the copper produced at this underground mine.

and gravel, silver, and stone (limestone, dolomite, and basalt). Output and value of these products for 1960 and 1968 are summarized in Table 5–10. From 1960 to 1968, iron ore, copper, and crushed stone increased in output and value, sand and gravel decreased, and dimension stone and lime production ceased. The value of mineral products in 1968 was $182,284,245. Iron ore and copper production accounted for more than 95 percent of this value.

A total of 51 mineral operations were active in 1968. All counties had sand and gravel pits while three counties had copper mines, and two counties reported production from stone quarries. All iron ore mines were in Marquette County. Distribution of producing sites by State, county, and type of operation is presented in Table 5–11. Location of selected operations is shown in Figure 5–3.

TABLE 5–12 Planning Subarea 1.2: General Stratigraphic Succession and Mineral Resources

Era	System	Group	Formation	Thickness (feet)	Mineral Resources
Cenozoic	Quaternary				Sand and gravel
Paleozoic	Silurian		Engadine Dol.	0-500	Stone
		Manistique		0-500	Stone
		Burnt Bluff		0-500	Stone
		Cataract		100-110	
	Ordovician	Richmond		375-425	
		Trenton		150-250	Stone
		Black River			Stone
		Prairie du Chien		0-1,200	
	Cambrian		Trempealeau Fm.		
			Munising Fm.	0-1,200	
			Jacobsville Ss.		Stone
Precambrian	Upper Precambrian		Freda Ss.		
			Nonesuch Sh.		Copper, silver
			Copper Harbor Cong.		
		Portage Lake Lava Series			Copper
		South Range Series			Copper, stone
	Middle Precambrian	Paint River			
		Baraga			Iron
		Menominee			Iron
		Chocolay			Stone
	Lower Precambrian				Stone

Source: Harry J. Hardenberg, Michigan Geological Survey.

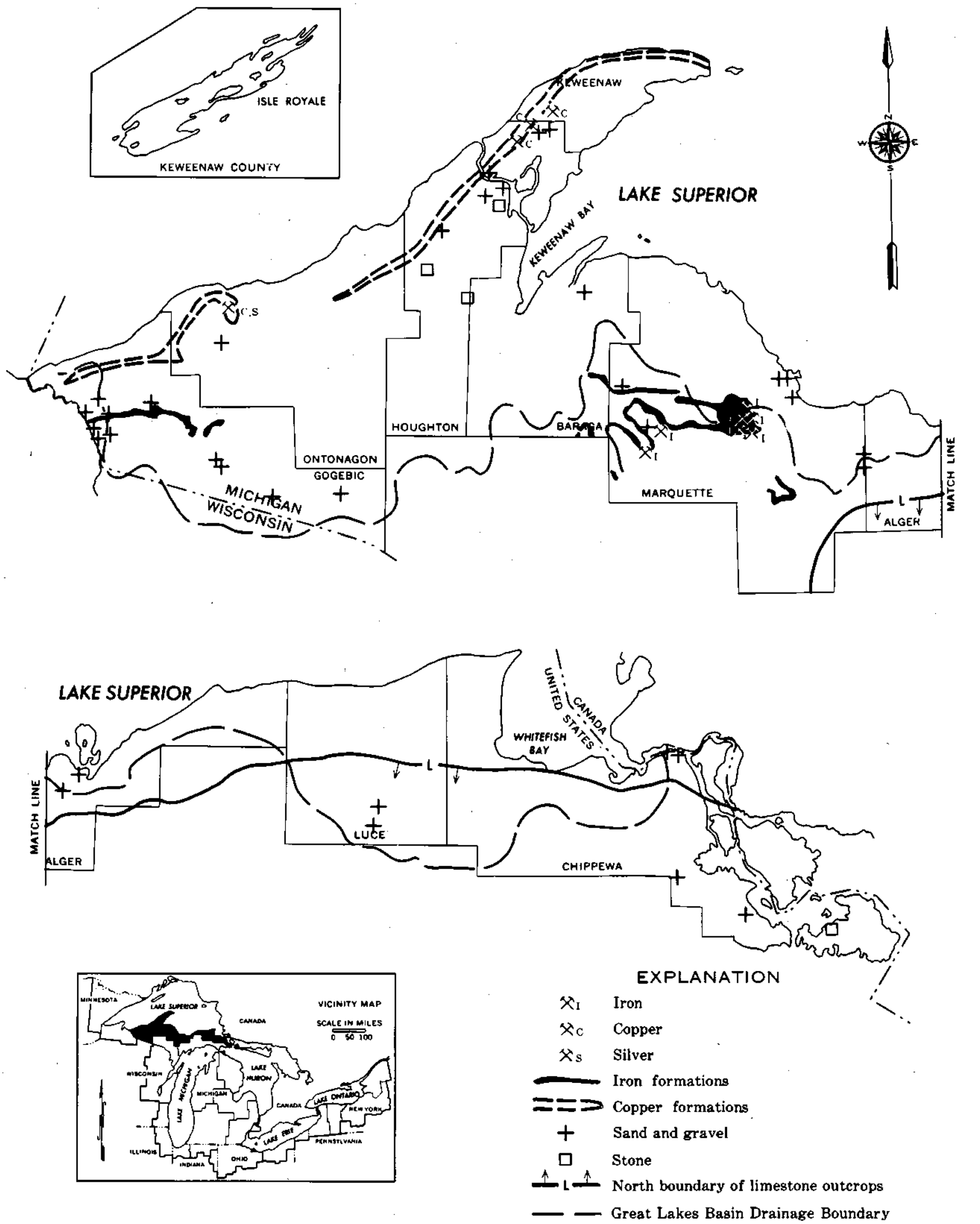

FIGURE 5-3 Planning Subarea 1.2: Distribution of Mineral Operations Active in 1968 and Major Mineral Resource Areas

1.2.1.2 Resources and Reserves

Bedrock in Planning Subarea 1.2 is composed of Precambrian, Cambrian, Ordovician, and Silurian formations, which yield iron ore, copper, silver, and stone. Overlying the bedrock are unconsolidated glacial and postglacial sediments of the Quaternary system that yield only sand and gravel. A generalized stratigraphic succession of the area is presented in Table 5–12, along with formation thickness and mineral occurrences. Copper, by-product silver, and minor amounts of iron ore are mined by underground methods; stone, sand and gravel, and most iron ore are mined by surface methods.

The Marquette Iron Range and a portion of the Gogebic Iron Range lie within Planning Subarea 1.2 (Figure 5–3). The Marquette Iron Range, in Marquette and Baraga Counties, produced the first ore in the Lake Superior region in 1845, and shipped the first ore via the Great Lakes in 1852. Cumulative production since this time has totaled 369,687,000 long tons. Production in 1968 came from two underground and four open-pit mines. In addition, an underground mine that had closed in 1967 shipped stockpiled ore. The bulk of the iron ore produced on the Marquette Range is concentrated, agglomerated, and pelletized before being shipped through the Port of Marquette to consuming districts in the lower Great Lakes Region. Reserves of hematite ore include 65 million long tons of measured and 185 million long tons of indicated-inferred ore averaging 51 percent Fe. Reserves of potential taconite ore averaging 25 to 45 percent Fe are estimated at 17½ billion long tons.[6] These reserves are sufficient to support production well beyond the projection period.

The Michigan portion of the Gogebic Range, located in Gogebic County, has recorded no production since the Peterson Mine closed in 1967. Since production first began at the Colby Mine in 1884, the Michigan portion of this range produced 249,626,000 long tons of iron ore. Reserves of hematite ore remaining include 31 million long tons of measured ore and 70 million long tons of indicated inferred ore averaging 52 percent Fe. Potential taconite ore containing 25 to 45 percent Fe is estimated at 2,750,000,000 long tons.[6] Most of the ore reserves on the Gogebic Range are deeply buried and are not easily concentrated under current technological practices. They are unlikely to be of economic importance during the projection period. New technological breakthroughs may result in a revival of mining activity at some future date.

The deposits of native copper in Keweenaw, Houghton, and Ontonagon Counties were first mined 3,500 to 4,000 years ago by prehistoric Indians who removed an estimated 250,000 to 500,000 tons of copper with fire, water, stone, and human effort.[8] This prehistoric mining activity had ceased many years before the first white explorers entered the area. These early explorers did note the presence of native copper and several early exploratory mining ventures were unsuccessfully attempted. Modern copper mining activity dates from 1844 with the opening of the Cliff Mine near Eagle River. Numerous mines have been active in the copper district over the years with production through 1968 totaling 5,866,388 tons of copper metal. Four underground mines were active in 1968. Since this time three of these have closed. The remaining mine, the White Pine Mine, produces copper from a sulfide ore deposit in sedimentary host rocks younger than the lavas of the native copper deposits. This mine also produces silver in conjunction with the copper. Reserves of both native and sulfide ore are estimated at 600 million tons of measured-indicated ore averaging 1.5 percent Cu, 3 billion tons of inferred ore averaging 1.0 percent Cu, and 10 billion tons of potential ore averaging 0.5 percent Cu. The above reserves also contain .10 to .25 ounces of silver per ton. Sufficient reserves of sulfide ore are present to support production well beyond the projection period. Although native copper constitutes the bulk of the reserves, future production from native metal deposits is contingent upon the resolution of numerous technical, economic, and labor problems. It is anticipated that these problems will be solved and that native copper mining will again take place in the area, although a timetable for this event would be speculative at present. The occurrence of copper sulfides in a quartzite-siltstone sequence in the Kona dolomite unit southwest of Marquette may be of future interest.

Although minor amounts of dimension stone were produced in the past, all current stone production is crushed for use as aggregate. Basalt is extracted in Houghton County from the old copper mine waste rock dumps, which are common in copper country. This rock is already broken as a result of the former copper mining activity, so that only crushing and screening operations are required to prepare it for use. Basalt reserves in these rock dumps should be ample for local use throughout the projection period. Ordovician limestone occurring as remnant hills is also quarried in Houghton County. Production for use as agricultural lime is small and reserves should be ample to supply this purpose for many years.

Silurian Niagara dolomite is quarried in Chippewa County for use as agricultural lime, concrete aggregate, flux stone, riprap, and sintered or dead-burned dolomite. Although the annual production at this location is large, the reserves of dolomite are more than ample to meet continued production needs.

Sand and gravel produced from Quaternary sediments in all counties of the PSA is devoted entirely to building, highway construction, paving, and fill. Reserves of sand and gravel have not been determined, though it is believed that sufficient material will be available throughout the projection period. In some cases, where sand and gravel is locally in short supply, crushed stone may be used as a substitute material.

Deposits of till and lake clay are found distributed throughout the area. Most of the clay deposits in till are small and of poor quality. The lake clay deposits, particularly those in eastern Chippewa County, are reported to be in excess of 300 feet thick and are suited for the manufacture of brick and tile.[2] The use of clay is dependent upon local demand for brick and tile, which is not presently sufficient to support a clay industry.

Extensive deposits of peat are found here, but lack of local demand and excessive distance from major market areas preclude profitable exploitation of this material at present.

Gold has been produced in Marquette County in the past, with production reported in excess of one-half million dollars. Subsequent exploration in the gold-producing area was not thought to be encouraging.

TABLE 5–13 Planning Subarea 1.2: Projected Mineral Production by Selected Commodities (thousands of short tons unless otherwise noted)

Commodity	1968[1]	1980	2000	2020	1968 to 2020[2]
Copper	75	100	180	330	8,920
Iron ore[3]	9,250	12,000	16,600	22,800	812,000
Sand and gravel	1,965	2,300	3,000	3,900	147,800
Silver[4]	473	640	1,160	2,090	57,040
Stone, crushed[5]	W	2,800	3,630	4,700	178,800

[1]Actual
[2]Cumulative
[3]Thousands of long tons
[4]Thousands of troy ounces
[5]Includes limestone and basalt
W Withheld to avoid disclosing individual company confidential data

1.2.2 Mineral Industry Projection

1.2.2.1 Production

Mineral production for PSA 1.2 is summarized in Table 5–13 for 1968 and the projection years 1980, 2000, and 2020. All mineral production is expected to increase during this period. Cumulative production over the projection period is also included in the table and provides an estimate of the large quantities of mineral substances necessary to meet the future demands.

1.2.2.2 Water

Water is used only in primary production of iron ore, copper, and crushed limestone. Stone is produced seasonally, generally from May through October, while iron and copper production are year-round functions. Water use patterns for 1968 and the projection years are presented in Table 5–14 at both the annual and seasonal rates. No serious water supply problems for mineral producers are foreseen during the next 50 years.

1.2.2.3 Land

The land requirements for mineral production in Planning Subarea 1.2 are summarized

TABLE 5–14 Planning Subarea 1.2: Projected Mineral Industry Water Use (millions of gallons per day)

	1968[1]	1980	2000	2020
New Intake				
May-October	34.5	43.4	69.8	117.2
Average for 365 days	30.2	38.9	64.9	112.1
Discharged				
May-October	22.2	27.2	42.4	70.2
Average for 365 days	18.0	22.8	37.7	65.3
Recirculated				
May-October	36.9	49.8	73.3	108.4
Average for 365 days	36.9	49.0	71.3	104.6
Consumed				
May-October	12.3	16.2	27.4	47.0
Average for 365 days	12.2	16.1	27.2	46.8
Total Water[2]				
May-October	71.4	93.2	143.1	225.6
Average for 365 days	67.1	87.9	136.2	216.7

[1]Estimated
[2]Intake plus recirculated

TABLE 5–15 Planning Subarea 1.2: Projected Mineral-Bearing Land Requirements[1] (acres)

Commodity	1968[2]	1980	1968 to 1980[3]	2000	1968 to 2000[3]	2020	1968 to 2020[3]
Copper	4,500	4,500	4,500	7,000	7,000	10,000	10,000
Iron ore	3,500	13,000	13,000	20,000	20,000	30,000	30,000
Sand and gravel	36	43	496	58	1,515	72	2,842
Stone, crushed	10	12	140	16	428	21	802
Total	8,046	17,555	18,136	27,074	28,943	40,093	43,644

[1]Includes non-mineral-bearing surface lands required for iron ore production
[2]Estimated
[3]Cumulative

by commodity in Table 5–15. Acreage requirements for copper and in part for iron ore production include non-mineral-bearing surface lands for plant sites and rock disposal areas. All other land must be mineral-bearing.

1.2.3 Mineral Problems

Surface and underground mining activity has caused various problems in the planning subarea. Land subsidence has been a problem on both the Gogebic and Marquette iron ranges, although ground movement has apparently stabilized on the Gogebic. Subsidence effects in the Ishpeming-Negaunee area have been resolved through purchase or movement of affected structures by the iron company. Seeding of old tailings ponds and contouring of waste dumps have been initiated by several mining companies with favorable results. Some abandoned mine shafts have been sealed and most have been fenced, although a continuing program of maintenance and surveillance may be required to maintain safety standards at these sites. In 1970, Michigan enacted a law that provides the State with powers governing surface metal mining activity, which will help alleviate some of these problems.

The severe winter weather has caused some production problems and has closed the Great Lakes to shipments of mineral materials during the winter months. Technical innovations have for the most part overcome this problem.

A land exchange between Cleveland-Cliffs Iron Company and the Michigan Department of Natural Resources benefited both parties. The State acquired prime recreational and conservation lands while the company received lands that permit consolidation of its low-grade iron mining operations. Mutual cooperation of this sort has resulted in furthering the goals of both conservation and industry.

1.2.4 Summary and Conclusions, Including Alternatives

Reserves of all mineral commodities produced within the area exist in quantities large enough to support production activity through the projection years. Since presence of mineral resources does not guarantee availability, it is recommended that planning efforts incorporate programs that permit exploration for mineral deposits, insure preservation of valuable mineral deposits, and develop plans that include mineral extraction.

Periodic surveys of water use patterns of the mineral industry are recommended to keep abreast of intake and discharged water use changes.

Section 2

PLAN AREA 2.0

2.1 Planning Subarea 2.1, Lake Michigan Northwest

2.1.1 Status and Potential of the Mineral Industry

2.1.1.1 Resume

Mineral commodities produced in the 20 Wisconsin and 3 Michigan counties that comprise Planning Subarea 2.1 include iron ore, sand and gravel, shale, and stone (limestone, dolomite, granite, and basalt). Output and value of these products for 1960 and 1968 are summarized in Table 5-16. Cement and lime, manufactured from both local and imported mineral materials, are included in the table for reference only. From 1960 to 1968, sand and gravel and stone production recorded moderate increases in both output and value while the remaining commodities declined in both areas. The total value of mineral products shown in Table 5-16 excludes cement and iron ore because the value of these mineral commodities cannot be disclosed without revealing individual company confidential data. However, an estimated value of iron ore can be obtained by multiplying the 1968 average mine value of iron ore for the State of Michigan,[4] $11.72 per long ton, times the tonnage produced. This brings the value of mineral products in 1968 to $55 million with iron ore making up approximately 70 percent of this amount.

A total of 155 mineral operations were active in 1968. Menominee County, Wisconsin, had no mineral operations while all remaining counties had sand and gravel pits. Fifteen counties had stone quarries, two counties had iron ore mines, and one county had a shale pit. Distribution of producing sites by State, county, and type of operation is presented in Table 5-17. Locations of selected operations are shown in Figure 5-4.

TABLE 5-16 Planning Subarea 2.1: Mineral Production, 1960 and 1968

Commodity		1960 Quantity	1960 Dollar Value	1968 Quantity	1968 Dollar Value
Cement:					
Portland	376-pound barrels	W	W	W	W
Shale	short tons	132,508	137,218	6,130	11,034
Iron ore (usable)	long tons, gross weight	4,034,824	W	3,448,688	W
Lime	short tons	100,573	1,524,998	94,186	1,478,459
Manganiferous ore (5-35 percent Mn)	short tons, gross wt.	180,460	W	---------	---------
Sand and gravel	short tons	7,320,368	5,455,467	8,423,000	6,210,000
Stone (crushed and broken)	short tons	2,249,925	3,706,502	3,388,900	6,343,193
Stone (dimension)	short tons	29,941	802,379	32,349	816,937
Total Planning Subarea 2.1		---------	11,626,564[a]	---------	14,859,623[a]

W Withheld to avoid disclosing individual company confidential data

[a]Incomplete total; excludes data for items indicated by symbol W, which must be withheld to avoid disclosing individual company confidential data.

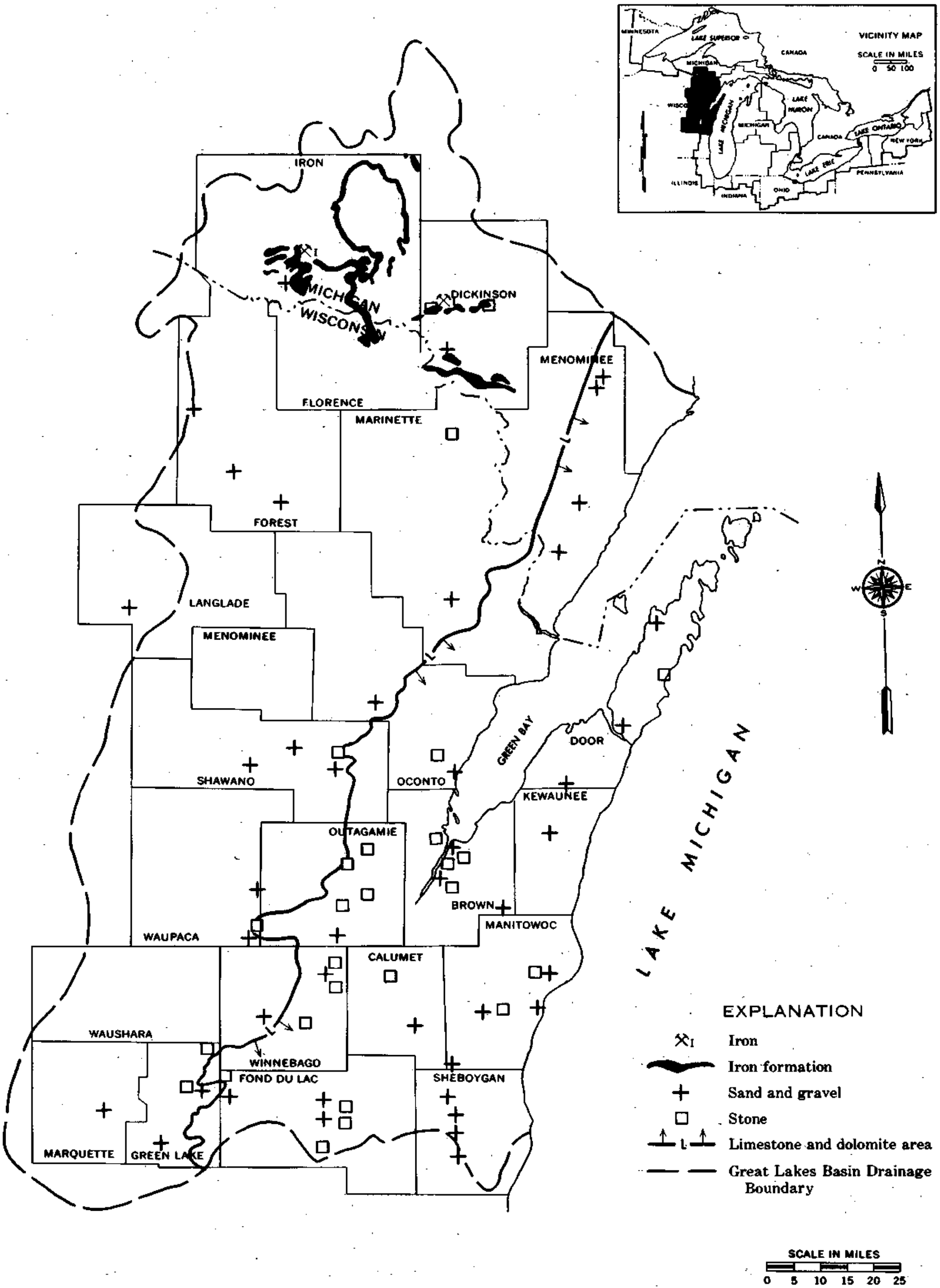

FIGURE 5-4 Planning Subarea 2.1: Distribution of Mineral Operations Active in 1968 and Major Mineral Resource Areas

TABLE 5–17 Planning Subarea 2.1: Active Mineral-Producing Sites by State, County, and Type of Operation, 1968

State County	Shale Pits	Iron Ore Mines	Sand and Gravel Pits	Stone Quarries: Limestone and Dolomite	Stone Quarries: Granite	Stone Quarries: Basalt
Michigan						
Dickinson	–	1[a]	5	1	1	–
Iron	–	4[b]	4	–	–	–
Menominee	–	–	3	–	–	–
Subtotal	0	5	12	1	1	0
Wisconsin						
Brown	–	–	10	8	–	–
Calumet	–	–	3	4	–	–
Door	–	–	5	3	–	–
Florence	–	–	1	––	–	–
Fond du Lac	1	–	6	11	–	–
Forest	–	–	4	––	–	–
Green Lake	–	–	7	1	–	–
Kewaunee	–	–	3	––	–	–
Langlade	–	–	2	––	–	–
Manitowoc	–	–	9	––	1	1
Marinette	–	–	2	1	1	–
Marquette	–	–	2	1	–	–
Menominee	–	–	––	––	–	–
Oconto	–	–	4	2	–	–
Outagamie	–	–	4	7	–	–
Shawano	–	–	6	2	–	–
Sheboygan	–	–	8	1	–	–
Waupaca	–	–	7	1	–	–
Waushara	–	–	1	––	–	–
Winnebago	–	–	3	3	–	–
Subtotal	1	0	87	45	2	1
Total	1	5	99	46	3	1

[a] Open-pit mine.
[b] Since 1968 three of these four underground mines have closed.

2.1.1.2 Resources and Reserves

Bedrock formations in Planning Subarea 2.1 range in age from igneous and metamorphic rock of the Precambrian system through the sediments of the Silurian system. The Precambrian rock yields iron ore, basalt, granite, and miscellaneous stone, while the younger sediments of the Ordovician and Silurian systems yield shale, limestone, and dolomite. Overlying the bedrock are unconsolidated sediments of the Quaternary system. These glacial sediments, which range up to 500 feet in thickness, contain sand and gravel, clay, and peat deposits. With the exception of one underground iron mine, all minerals are extracted from surface pits and quarries. A generalized stratigraphic succession of PSA 2.1 is presented in Table 5–18 along with formation thickness and mineral occurrences.

The Menominee iron mining district is the only area from which iron ore is produced. The iron formation is segmented across Michigan's Dickinson and Iron Counties with an extension into Florence County, Wisconsin (Figure 5–4). Individual deposits of direct shipping hematite and magnetite occur within the iron formation, along with large tonnages of lower-grade siliceous iron ores. Mining of the direct-shipping ore began in 1877 and reached its peak in the early 1900s. The number of active mines has declined from a high of 45 in

TABLE 5–18 Planning Subarea 2.1: General Stratigraphic Succession and Mineral Resources

Era	System	Group	Formation	Thickness (feet)	Mineral Resources
Cenozoic	Quaternary			0–500	Sand, gravel, clay, peat
Paleozoic	Silurian		Racine Dol.[1]		
			Manistique Fm.[1]		Dolomite
			Hendricks Dol.[1]	0–325	
			Byron Fm.[1]		
			Mayville Ls.[1]		
	Ordovician		Maquoketa Sh.[1]	0–400	Clay, expanded aggregate(p)
		Trenton[2]	Galena Dol.[1]		Dolomite,
		Black River[2]	Decorah Fm.[1]	180–270	limestone
			Platteville Dol.[1]		
			St. Peter Ss.	0–300	Silica sand[1]
		Prairie du Chien[2]	Oneota Dol.[1]		Dolomite[1]
	Cambrian	Trempealeau[1]	Jordan Ss.[1]		Silica sand(p)
			St. Lawrence Fm.[1]	0–600	Dolomite[1]
			Munising Fm.[2,3]		
			Lone Rock Fm.[1]	0–125	
			Wonewoc Fm.[1,3]	0–200	Silica sand(p)[1]
			Mt. Simon Fm.[1]	0–200	
Precambrian	Middle Precambrian	Paint River[2]			Iron ore
		Baraga[2]			
		Menominee[2]			Iron ore
		Chocolay[2]			
	Lower Precambrian	Dickinson[2]			Misc. stone

[1]In Wisconsin.
[2]In Michigan.
[3]Munising Formation in Michigan may be equivalent to Wonewoc Formation in Wisconsin.
(p) Potential Resource.
Source: Harry J. Hardenberg, Michigan Geological Survey and Meredith E. Ostrom, Wisconsin Geological Survey.

1913 to 5 in 1968. Since 1968, three of the four remaining underground mines have ceased production. Thus one underground mine is producing direct-shipping ore and one benefication plant is utilizing low-grade ore from an open-pit mine for the production of iron ore pellets. Ore is shipped from the range to the lower Great Lakes Region through the Port of Escanaba. Total reserves of iron ore include: 62,000,000 long tons of measured ore containing 50 percent Fe; 75,000,000 long tons of inferred ore containing 50 percent Fe; and 4,320,000,000 long tons of potential ore containing 25 to 45 percent Fe.[6] Future mining activity hinges principally on the development of adequate beneficiation techniques to treat the lower grade, nonmagnetic ores that remain.

Stone production includes the quarrying of basalt, granite, dolomite, pegmatite, and schist from Precambrian igneous rock and of shale, limestone, and dolomite from the younger sedimentary bedrock formations.

Basalt (andesite) is quarried, crushed, and sized for use as roofing granules in Marinette County. Reserves of andesite are sufficiently large to support production for many years.

Granite is quarried for use as monument stone in Marinette and Marquette Counties and dolomite (marble), pegmatite, and schist for use as ornamental exposed aggregate in Dickinson County. Production of these commodities is relatively minor. Sufficient reserves are available to maintain production rates for many years.

Maquoketa shale is quarried in Fond du Lac County for use in building bricks. In addition to being a clay substitute, the lower member of this shale formation constitutes a potential resource for the production of lightweight aggregate.[7] The Maquoketa shale extends in a narrow band from southern Door County through Fond du Lac County. It is included in the limestone and dolomite area shown on the map, Figure 5–4. Reserves of shale are very large, but overburden thickness and variability of composition within formations will dictate where production is economically feasible.

Limestone and dolomite, the most important stone quarried in the area, is produced principally from the Racine, Manistique, Hendricks, and Byron Formations of the Silurian system and the Galena, Decorah, Platteville, and Oneota Formations of the Ordovician system. Production of this stone is widespread in the southeastern half of the PSA, where bedrock sediments of this type predominate (Figure 5–4). Quarried stone is used in both rough and dressed states for dimension stone, in the crushed and broken state for aggregate, and in the pulverized state for agricultural purposes. Reserves of stone are not limited in quantity but are limited by economic constraints such as depth, quality of the strata, and availability of usable deposits. No shortages of limestone and dolomite are foreseen during the next 50 years.

Sandstone has, in the past, been quarried at various localities for use as dimension stone, and is currently taken from the St. Peter and Jordan sandstones in Green Lake County for use as molding sand. These sandstones also have potential as sources of glass sand. Distribution of the bedrock sandstone formations is shown in Figure 5–4. The St. Peter Sandstone Formation has been included in the limestone and dolomite area. No estimate of reserves of high-grade sandstone is available.

The glacial debris overlying the bedrock formations throughout the planning subarea contains deposits of clay, and sand gravel, and peat.

Clay, though presently not mined in the area, was important in the past as raw material for the manufacture of brick and heavy clay products. The bulk of this mined clay was of lacustrine origin and distributed over the southeastern half of the area. Reserves of clay remain, although the quality and extent of these deposits are not known. The high cost of labor and substitution of other construction materials for clay products contributed significantly to the decline of this industry. Increased prices for clay products and mechanization could bring about a revival of this industry in the future.

Sand and gravel deposits are found in unconsolidated glacial and postglacial sediments covering the entire PSA. Production was reported from all but Menominee County, Wisconsin in 1968. The bulk of the sand and gravel is used as aggregate in road construction, although several pits did produce molding and blast sand. Although sand and gravel reserves have not been determined, it is assumed that they are sufficient to meet the demands of the next 50 years.

Peat is not mined at present but does constitute a potential resource. The entire PSA falls within an area where workable peat beds are common. Much of the early exploratory work on peat deposits dealt with its fuel potential rather than its soil conditioning aspects. Future exploratory work may be necessary to delineate the various deposits of moss, reed-sedge, and humus peat. There is little doubt that commercial deposits of peat exist but exploitation is contingent upon the development of nearby markets. Estimates of peat reserves for the entire State of Wisconsin are 2½ billion net tons on approximately one million acres of peat land.[25] No separate estimates are available for the planning subarea.

Manganese nodules occur on the floor of Green Bay and in other parts of northern Lake Michigan, but these nodules do not constitute a mineral resource at present. Several other mineral occurrences have been reported within the area though none of these are currently being mined. Chrysotile asbestos and molybdenite are found in Marinette County. Epigenetic uranium is found in Dickinson and Iron Counties. Beryl is found in Dickinson and Shawano Counties. It is doubtful that production will come from any of these occurrences during the next 50 years.

2.1.2 Mineral Industry Projection

2.1.2.1 Production

Mineral production for Planning Subarea 2.1 is summarized in Table 5-19 for 1968 and the projection years 1980, 2000, and 2020. All mineral production is expected to increase during this period. Cumulative production over the projection period is also included in the table, and provides an estimate of the quantities of mineral substances necessary to meet future demands. There is a strong possibility that sandstone quarrying and peat mining may begin during the next 50 years.

TABLE 5-19 Planning Subarea 2.1: Projected Mineral Production by Selected Commodities (thousands of short tons unless otherwise noted)

Commodity	1968[1]	1980	2000	2020	1968 to 2020[2]
Shale	6	10	16	26	785
Iron ore[3]	3,449	2,500	3,800	5,600	184,000
Sand and gravel	8,423	12,700	22,000	38,300	1,080,800
Stone, crushed[4]	3,389	4,520	7,810	13,570	383,600
Stone, dimension[5]	32	50	85	140	4,122

[1] Actual
[2] Cumulative
[3] Thousands of long tons
[4] Includes limestone and basalt
[5] Includes limestone and granite

2.1.2.2 Water

Water is used in the primary production of all the mineral commodities except clay. Sand and gravel and stone are produced seasonally, generally from April through November, while iron ore production is a year-round function. Water use patterns in 1968 and for the projection years are presented in Table 5-20 at both the annual and seasonal rate. No serious problems of water supply to mineral producers is foreseen during the next 50 years.

2.1.2.3 Land

As mineral substances are removed from the ground and deposits depleted, new mineral-bearing land must be brought into production. Land required to maintain the projected production is summarized by commodity in Table 5-21. The acreage referred to in this table must be mineral-bearing. Each mineral deposit is unique, and other land users should be discouraged from preempting mining activities until after the deposit is mined.

2.1.3 Mineral Problems

The problems associated with mineral production in Planning Subarea 2.1 are relatively

TABLE 5-20 Planning Subarea 2.1: Projected Mineral Industry Water Use (millions of gallons per day)

	1968[1]	1980	2000	2020
New Intake				
April-November	2.6	3.2	5.8	10.5
Average for 365 days	2.2	2.5	4.3	7.7
Discharged				
April-November	1.2	2.0	4.0	7.9
Average for 365 days	0.8	1.3	2.6	5.3
Recirculated				
April-November	13.9	11.9	19.9	33.2
Average for 365 days	13.3	10.8	17.7	28.6
Consumed				
April-November	1.4	1.2	1.8	2.6
Average for 365 days	1.4	1.2	1.7	2.4
Total Water[2]				
April-November	16.5	15.1	25.7	43.7
Average for 365 days	15.5	13.3	22.0	36.3

[1] Estimated
[2] Intake plus recirculated

TABLE 5–21 Planning Subarea 2.1: Projected Mineral-Bearing Land Requirements[1] (acres)

Commodity	1968[2]	1980	1968 to 1980[3]	2000	1968 to 2000[3]	2020	1968 to 2020[3]
Clays and shale	-----[4]	-----[4]	2	-----[4]	4	-----[4]	10
Iron ore	1,200	1,700	1,700	3,400	3,400	5,100	5,100
Sand and gravel	140	213	2,184	366	7,963	636	17,964
Stone, crushed	39	52	543	90	1,960	157	4,423
Stone, dimension	1	2	25	4	89	7	196
Total	1,380	1,967	4,454	3,860	13,416	5,900	27,693

[1]Includes non-mineral-bearing surface lands required for iron ore production
[2]Estimated
[3]Cumulative
[4]Less than an acre

limited at present. No large urban-suburban complexes exist, although the Fox River Valley from Green Bay to Lake Winnebago may develop along these lines in the future. Planning now for mineral extraction can eliminate many problems associated with production of aggregate materials in this potentially urban-suburban area.

Abandoned iron mines on the Menominee Range may be of concern in terms of unsealed mine openings and surface subsidence from the collapse of shallow underground workings. Most mining companies own the surface land above the underground workings to avoid liability from subsidence. Dangers do exist with subsiding ground and access to such unstable areas should be prevented.

2.1.4 Summary and Conclusions, Including Alternatives

Sufficient reserves of all mineral commodities produced within the planning subarea exist to support production activity for the next 50 years. Since presence of mineral resources does not guarantee availability, it is recommended that planning efforts within the planning subarea incorporate programs to insure that valuable mineral resources are preserved and that planned development include mineral extraction.

Periodic surveys of the water use patterns of the mineral industry are recommended to keep abreast of intake and discharged water use changes.

2.2 Planning Subarea 2.2, Lake Michigan Southwest

2.2.1 Status and Potential of the Mineral Industry

2.2.1.1 Resume

Mineral production in the seven Wisconsin, six Illinois, and four Indiana counties that comprise Planning Subarea 2.2 includes clay, bituminous coal, peat, sand and gravel, and stone (limestone and dolomite). Output and value of these products for 1960 and 1968 are presented in Table 5–22. Cement and lime, manufactured from both local and imported raw materials, are included in the table for reference only. From 1960 to 1968, output and value declines were recorded by clay and cement while coal, crushed stone, lime, and sand and gravel recorded increases. During this time, dimension stone and peat production declined but the value of both increased. Value of mineral production in the PSA was $110,036,114 in 1968, with crushed stone accounting for 34 percent and sand and gravel for 25 percent of this value.

TABLE 5–22 Planning Subarea 2.2: Mineral Production, 1960 and 1968

Commodity		1960 Quantity	1960 Dollar Value	1968 Quantity	1968 Dollar Value
Cement:					
Portland	376-pound barrels	W	W	W	W
Masonry	280-pound barrels	W	W	W	W
Clay	short tons	697,973	1,068,520	410,023	645,990
Coal, bituminous	short tons	368,573	W	593,543	W
Lime	short tons	W	W	1,257,703	17,537,270
Peat	short tons	14,679	168,795	8,664	193,860
Sand and gravel	short tons	23,654,007	19,519,664	30,683,000	27,206,000
Stone (crushed and broken)	short tons	20,389,480	27,506,830	26,766,352	37,525,732
Stone (dimension)	short tons	76,311	767,395	51,413	921,058
Value of items that cannot be disclosed		----------	42,986,813	----------	26,006,204
Total Planning Subarea 2.2		----------	92,018,017	----------	110,036,114

W Withheld to avoid disclosing individual company confidential data; included with "Value of items that cannot be disclosed."

A total of 219 nonmetallic mineral operations were active in the area during 1968. Waukesha County, Wisconsin, had the greatest number of operations, 58, as well as the most sand and gravel pits, 35, and most stone quarries, 22. Distribution of producing sites by State, county, and type of operation is presented in Table 5–23. Sand and gravel pits were producing in all 17 counties while stone quarries were producing in 8 counties, peat bogs in 5, and clay pits in 4. The only coal mine in the entire Great Lakes Region operated in Will County, Illinois. Locations of selected operations are shown in Figure 5–5.

2.2.1.2 Resources and Reserves

The bedrock geology in Planning Subarea 2.2 includes formations of Precambrian, Cambrian, Ordovician, Silurian, Devonian, Mississippian, and Pennsylvanian systems. Near-surface bedrock exposures contain minable deposits of coal and stone as well as other mineral material such as shale, which may be extracted in the future. The bedrock is largely covered by a mantle of unconsolidated sediments of the Quaternary system. These glacial and postglacial sediments contain deposits of clay, peat, and sand and gravel. The extraction of all mineral materials is by surface mining techniques. A generalized stratigraphic succession of PSA 2.2 is presented in Table 5–24 along with formation thickness and mineral occurrences.

TABLE 5–23 Planning Subarea 2.2: Active Mineral-Producing Sites by State, County, and Type of Operation, 1968

State County	Clay Pits	Strip Coal Mines	Peat Bogs	Sand and Gravel Pits	Limestone and Dolomite Quarries
Illinois					
Cook	3	-	1	5	8
DuPage	-	-	-	4	1
Kane	-	-	1	15	3
Lake	-	-	3	10	--
McHenry	-	-	-	17	1
Will	-	1	-	10	4
Subtotal	3	1	5	61	17
Indiana					
Lake	1	-	-	2	--
LaPorte	-	-	1	3	--
Porter	2	-	-	1	--
Starke	-	-	-	2	--
Subtotal	3	0	1	8	0
Wisconsin					
Kenosha	-	-	-	5	--
Milwaukee	-	-	-	3	2
Ozaukee	-	-	-	11	--
Racine	1	-	-	6	1
Walworth	-	-	-	20	--
Washington	-	-	-	13	--
Waukesha	-	-	1	35	22
Subtotal	1	0	1	93	25
Total	7	1	7	162	42

TABLE 5–24 Planning Subarea 2.2: General Stratigraphic Succession and Mineral Resources

Era	System	Group	Formation	Thickness (feet)	Mineral Resources
Cenozoic	Quaternary			0-450	Sand, gravel, clay, marl, peat
Paleozoic	Pennsylvanian	Kewanee[1]	Carbondale Fm.[1]	0-150	Clay, coal
			Spoon Fm.[1]		Clay
	Mississippian		Coldwater Sh.[2]		
			New Albany Sh.[2]	0-500	
			Sunbury Sh.[2]		
	Mississippian-Devonian	New Albany[1]	Ellsworth Sh.[2]	60-340	
	Devonian		Antrim Sh.[2]	60-200	Expanded aggregate(p)
			Traverse Fm.[2]	40-175	Limestone(p), dolomite(p)
			Detroit River Fm.[2]	40-175	Dolomite(p), limestone(p), gypsum (p), anhydrite(p)
	Silurian		Salina[2]	0-385	Dolomite, limestone
			Waubakee Dol.[3]	30	
			Racine Dol.[1,3]		Dolomite
			Wabash Fm.[2]	300-675	
			Louisville Ls.[2]		Dolomite, limestone
			Waldron Fm.[2]		
			Waukesha Dol.[1,3]		Dolomite
		Manistique[3]	Joliet Dol.[1]		Dolomite
			Salmonie Dol.[2]		Dolomite
			Kankakee Dol.[1]		Dolomite
			Brassfield Ls.[2]		Limestone
			Hendricks Dol.[3]	300-675	Dolomite
			Byron Dol.[3]		Dolomite
			Mayville Ls.[3]		Dolomite
			Edgewood Fm.[1]		Limestone
	Ordovician	Maquoketa[1]	Maquoketa Sh.[2,3]	100-225	Dolomite, limestone[1]; clay, expanded aggregate (p)[3]
		Galena[1]	Galena Dol.[3]		Dolomite(p)[1]; dolomite[3]
			Trenton Ls.[2]	200-330	
			Decorah Fm.[3]		Dolomite[3]
		Platteville[1]	Platteville Dol.[3]	200-330	Dolomite
			Black River Ls.[2]		
			St. Peter Ss.[1,3]	20-600	Silica sand(p)[1]
Cambrian		Prairie du Chien[1,3]	Knox Dol.[2]		
			Shakopee Dol.[1,3]		
			New Richmond Ss.[1]		
			Oneota Dol.[1,3]	0-250	Stone(p)[1]
			Gunter[1]		
	Cambrian	Trempealeau[3]	Eminence Dol.[1]	50-150	
			Jordan Ss.[3]		
			Potosi Dol.[1]	90-220	Stone(p)[1]
			St. Lawrence[3]		
			Franconia Fm.[1]	0-200	
			Lone Rock Fm.[3]		
			Wonewoc Fm.[3]		
			Ironton Ss.[1]		
			Galesville Ss.[1,2]	0-100	
			Eau Claire Fm.[1,2,3]	0-575	
			Mt. Simon Ss.[1,2,3]	0-2,800	
Precambrian					

[1]In Illinois.
[2]In Indiana.
[3]In Wisconsin.
(p) Potential Resource.
Source: Hubert E. Risser, Illinois Geological Survey; Lawrence F. Rooney, Indiana Geological Survey; and Meredith E. Ostrom, Wisconsin Geological Survey.

Bituminous coal is produced in southwestern Will County from the Colchester (No. 2) coal member, Carbondale Formation, Pennsylvanian system. Cumulative production of coal in this county from 1882 to 1968 totaled 41,800,00 tons. Strippable coal reserves in beds 18 inches or more in thickness total 21,600,000 tons and include 6,400,000 tons with 0 to 50 feet of overburden cover, 13,900,000 tons with 50 to 100 feet overburden cover, and 1,300,000 tons with 100 to 150 feet of overburden cover.[28] These reserves are not sufficient to support production through the projection period and coal mining will probably cease in the planning subarea before the year 2000.

Limestone and dolomite formations of the Silurian system are the principal source material for the planning subarea dimension and crushed stone industries. Dimension stone production is limited to Waukesha County, Wisconsin, and Kane and McHenry Counties in Illinois. The Lannon-Sussex area of Waukesha County accounts for more than 83 percent of production and more than 92 percent of the value. The bulk of dimension stone is used for architectural and construction purposes as rubble, house stone veneer, and flagging. Production of dimension stone in the planning subarea has been relatively constant for the past 20 years. This trend is expected to continue due to the high selling price, select market usage, and substitutability of other construction materials for dimension stone. Reserves of limestone and dolomite of suitable quality for dimension stone usage should be sufficient to support production through the projection period.

Crushed stone is currently produced in Milwaukee, Racine, and Waukesha Counties in Wisconsin, Cook, Du Page, Kane, McHenry, and Will Counties in Illinois, and in Lake County, Indiana. Near-surface exposures of high quality limestone and dolomite, favorable quarry locations near the major use areas, and the interchangeability of crushed stone for sand and gravel have given crushed stone a position of major importance in the aggregate market. Although reserves of limestone and dolomite are large, those locations where the bedrock is covered by relatively thin layers of overburden are becoming scarce. Preservation of the shallow bedrock occurrences for quarrying activity is necessary if this industry is to continue in close proximity to the market areas. It is assumed that quarry sites will be available and that production of crushed stone will continue at an increasing rate throughout the projection period. A potential source of limestone and dolomite is found in conjunction with gypsum and anhydrite deposits which occur beneath La Porte County, Indiana.[23] The potential underground mining of gypsum, anhydrite, and crushed stone is covered in detail in the Planning Subarea 2.3 report.

Although shale is not presently produced, potential shale resources suitable for the manufacture of lightweight aggregate have been defined. New Albany shale, which underlies the La Crosse area of La Porte County, Indiana, has reserves estimated at one billion tons of shale with less than 30 feet of overburden cover.[24] The Francis Creek shale found associated with the coal deposits in southwestern Will County, Illinois, is 40 to 60 feet thick and must be stripped prior to coal extraction. Usable shale reserves in this formation are large.[20] Limited testing of the Maquoketa shale in Wisconsin indicates potential for lightweight aggregate production but thick overburden in the planning subarea probably excludes its development.[7]

The clays found in Planning Subarea 2.2 are of glacial origin and occur as lake and alluvial sediments, till, or argillaceous loess. Lack of extensive clay deposits, continued depletion of existing deposits, and construction of expanding communities over potentially mineable deposits have contributed to the steady decline of the clay industry since its peak production years in the early 1900s. This decline is expected to continue, with cessation of clay production by the year 2000. Demand for clay products after this date will be met by clay producers in surrounding regions. At present, more than 97 percent of the clay is used for brick manufacturing, with the remaining clay used for foundry, stoneware, and heavy clay products.

Peat is produced at several locations within the PSA for use as a general soil conditioner. Available deposits of peat are for the most part small and can support current production rates for only a limited period of time. Much of the peat-bearing land has been lost to production as a result of surrounding land development or through inclusion of the land in State forests, various parks and recreation areas, and wildlife preserves. No estimate of peat reserves is available, but it is anticipated that peat production in the area will cease between 1980 and 2000.

The sand and gravel deposits found in Planning Subarea 2.2 were formed during and after the last glacial stage of the Quaternary

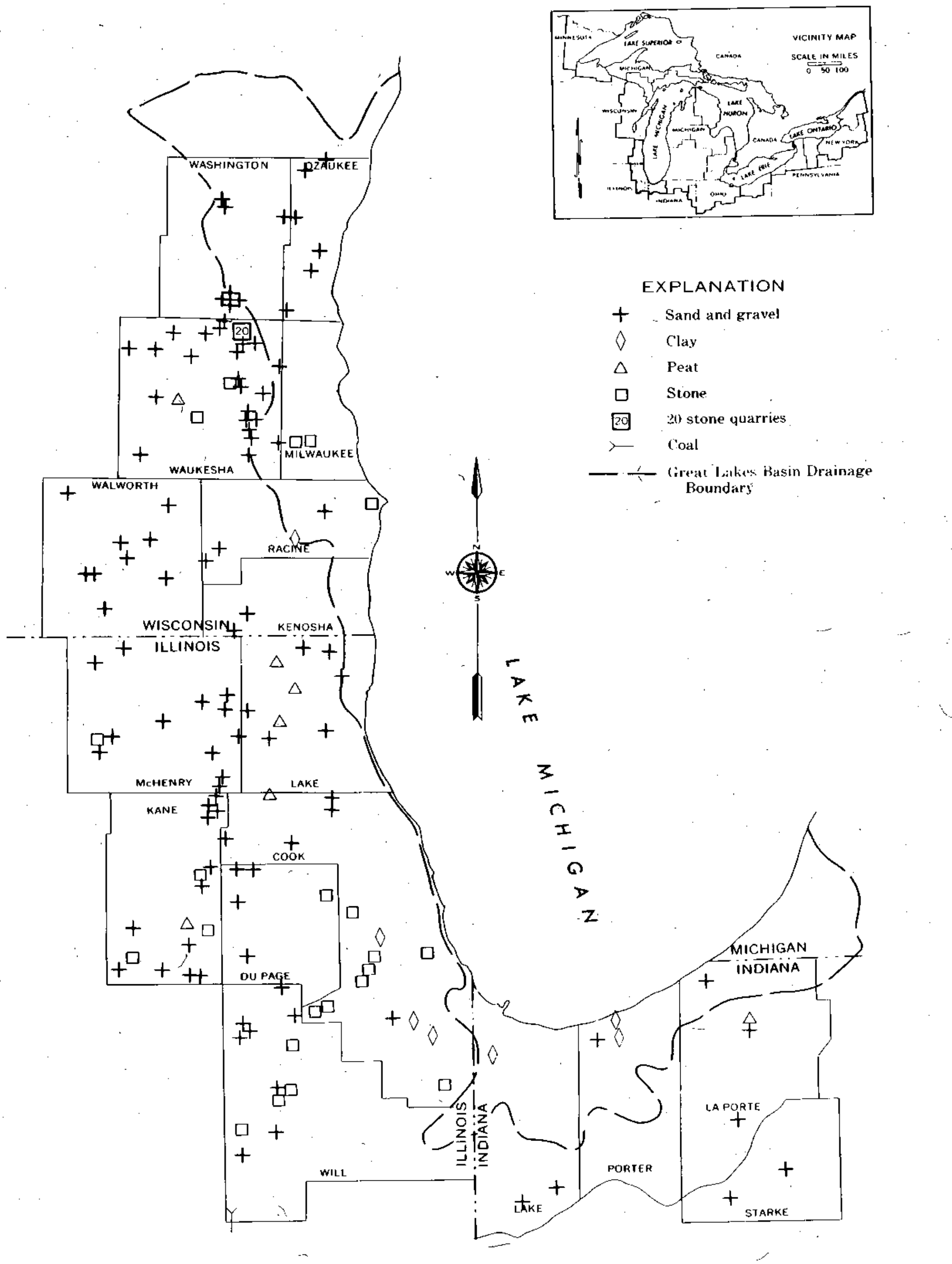

FIGURE 5–5 Planning Subarea 2.2: Distribution of Mineral Operations Active in 1968

system and occur in outwash plains, eskers, kames, stream terraces, and as dune sands. Large quantities of sand and gravel have been extracted from these deposits over the years to support construction and road building activities within the area. Current production is used primarily for paving, building, and fill, with minor production of specialty glass, molding, furnace, and engine sands. Local sand and gravel resources in those counties adjacent to Lake Michigan have been depleted through mineral extraction, erection of buildings on potential deposits, and placement of legal restrictions against mineral extraction. As a result, sand and gravel production has moved progressively outward from more densely populated centers. It is presently concentrated in the western portions of the area. Transportation distances from pit to major market areas are increasing, and the delivered price of such sand and gravel reflect these additional distances. Demand for sand and gravel is expected to increase to approximately five times the current level during the projection years. It is doubtful whether sufficient reserves are available within the PSA to support this production. However, no estimate of sand and gravel resources is available.

2.2.2 Mineral Industry Projection

2.2.2.1 Production

Mineral production for Planning Subarea 2.2 is summarized in Table 5–25 for 1968 and the projection years 1980, 2000, and 2020. Sand and gravel, crushed stone, and dimension stone production are expected to increase during this period while clay, coal, and peat production will cease before the year 2000. Sand and gravel production is projected to 2020 to indicate the quantity of this material required in the area, although it is doubtful that sufficient reserves are available to support this production.

2.2.2.2 Water

Water is used in the primary production of all mineral commodities except clay and peat. Sand and gravel production is seasonal, generally from April through November, while stone and coal are generally produced on a year-round basis. Water use patterns in 1968 and the projection years are presented in Table 5–26 at both the annual and seasonal rates. Sand and gravel production accounts for more than two-thirds of the water used in each category, with crushed stone and coal next in order of importance.

TABLE 5–25 Planning Subarea 2.2: Projected Mineral Production by Selected Commodities (thousands of short tons)

Commodity	1968[1]	1980	2000	2020	1968 to 2020[2]
Clay	410	250	0	0	6,400
Coal	594	260	0	0	6,400
Peat	9	3	0	0	78
Sand and gravel	30,683	43,300	79,700	146,700	3,933,800
Stone, crushed[3]	26,766	32,486	62,205	119,000	3,085,960
Stone, dimension[4]	51	53	56	59	2,864

[1]Actual
[2]Cumulative
[3]Includes limestone and marl
[4]Limestone

2.2.2.3 Land

Mineral-bearing lands under production are rapidly being depleted. To support projected mineral production, new mineral-bearing lands must be located and must be available for mineral extraction. Table 5–27 summarizes these mineral-bearing land requirements by commodity for the projection years and also includes cumulative land requirements for

TABLE 5–26 Planning Subarea 2.2: Projected Mineral Industry Water Use (millions of gallons per day)

	1968[1]	1980	2000	2020
New Intake				
April-November	21.9	48.5	88.6	161.9
Average for 365 days	16.0	34.0	61.9	112.6
Discharged				
April-November	21.1	47.3	85.9	158.2
Average for 365 days	15.4	33.1	59.9	109.9
Recirculated				
April-November	16.1	33.2	66.0	130.6
Average for 365 days	11.1	22.8	45.4	89.9
Consumed				
April-November	0.8	1.2	2.7	3.7
Average for 365 days	0.6	0.9	2.0	2.7
Total Water[2]				
April-November	38.0	81.7	154.6	292.5
Average for 365 days	27.1	56.8	107.3	202.5

[1]Estimated
[2]Intake plus recirculated

TABLE 5–27 Planning Subarea 2.2: Projected Mineral-Bearing Land Requirements (acres)

Commodity	1968[1]	1980	1968 to 1980[2]	2000	1968 to 2000[2]	2020	1968 to 2020[2]
Clays and shale	5	3	52	0	85	0	85
Coal	121	53	1,130	0	1,300	0	1,300
Peat	67	22	83	0	93	0	93
Sand and gravel	364	514	5,251	947	19,831	1,742	46,720
Stone, crushed	37	43	482	76	1,680	139	3,838
Stone, dimension	2	4	34	5	120	9	258
Total	596	639	7,032	1,028	23,109	1,890	52,294

[1]Estimated
[2]Cumulative

the plan periods. Serious problems are anticipated in finding sufficient mineral-bearing land to meet the requirements for minerals.

2.2.3 Mineral Problems

The major problem affecting the mineral industry in Planning Subarea 2.2 is that of mineral supply. Large reserves of minerals are present in the area, but these reserves are being lost at a rapid rate—not to production but to other land uses. Legal restrictions that locally prevent mineral extraction also effectively remove mineral deposits from available resource inventory. This is particularly serious in terms of sand and gravel and crushed stone production, because vast quantities of construction aggregate are required each year. The geologic distribution of formations favorable to the occurrence of sand and gravel has been mapped in the Illinois portion of the PSA but individual deposits have not been located or evaluated, and few attempts to preserve deposits for mineral extraction have been successful. A serious, concerted effort will be necessary on the part of geologists, engineers, planners, and mineral industry to prevent continued loss of mineral-bearing lands and to plan adequately for future mineral extraction. An alternative to the loss of mineral-bearing lands is importation of mineral materials from outside the PSA. Importation will mean increased delivered cost to cover transportation charges. The increase will be especially significant in those mineral commodities for which transportation makes up the major portion of delivered costs.

2.2.4 Summary and Conclusions, Including Alternatives

Clay, coal, and peat production are not expected to continue through the projection years. If no effort is made to preserve aggregate resources, sand and gravel and stone production will probably decline. Planning efforts should incorporate programs to insure that valuable mineral resources are preserved and that planned development includes mineral extraction.

Periodic surveys of water use patterns are recommended to keep abreast of intake and discharged water use changes.

2.3 Planning Subarea 2.3, Lake Michigan Southeast

2.3.1 Status and Potential of the Mineral Industry

2.3.1.1 Resume

The mineral industry in the 19 Michigan and 6 Indiana counties that make up Planning Subarea 2.3 produces clay and shale, gypsum, peat, petroleum and natural gas, sand and gravel, and stone (limestone, sandstone, and marl). Output and value of production for 1960 and 1968 are summarized in Table 5–28. Lime, a manufactured product, is included in the table for reference only. From 1960 to 1968, output and value of peat, sand and gravel, and gypsum increased while clay and shale, petroleum, and stone declined and lime production was discontinued. The value of mineral output in 1968 was $42,219,352, with petroleum accounting for 54 percent and sand and gravel 44 percent of this value.

A total of 309 nonmetallic mineral operations and 1,457 oil and gas wells were producing in 1968. All of the counties had sand and gravel operations. Oil and natural gas wells were active in 12 counties, marl pits in 17 counties, peat bogs in 8 counties, shale pits in 3 counties, limestone quarries in 2 counties, and gypsum mines and sandstone quarries in one county each. Distribution of producing sites by State, county, and type of operation is presented in Table 5–29. Locations of selected operations are shown in Figure 5–6.

2.3.1.2 Resources and Reserves

Sedimentary rocks in Planning Subarea 2.3 range upward from the Cambrian system of Paleozoic age to the Jurassic system of Mesozoic age. These rock formations yield oil and gas from deep wells, gypsum from underground mines, and limestone, sandstone, and shale from surface quarries and pits. Overlying these bedrock formations are unconsolidated sediments of the Quaternary system. These glacial sediments, which locally attain a thickness up to 500 feet, contain sand and gravel, peat, and marl deposits, which are dug or dredged by surface mining methods. A generalized stratigraphic succession of the area is presented in Table 5–30, with formation thickness and mineral occurrences.

More than 90 percent of the area's petroleum and natural gas production in 1968 came from the oil fields of the Albion-Pulaski-Scipio trend. These fields form a narrow band running northwest-southeast from the eastern part of Calhoun County, across the southwestern corner of Jackson County to the northern part of Hillsdale County (Figure 5–6). Since oil was discovered in 1957, this has been the most important petroleum-

TABLE 5–28 Planning Subarea 2.3: Mineral Production, 1960 and 1968[a]

Commodity		1960 Quantity	1960 Dollar Value	1968 Quantity	1968 Dollar Value
Clay and shale	short tons	111,806	167,709	95,020	142,530
Gypsum	short tons	W	W	W	W
Lime	short tons	6,017	79,287	----------	----------
Peat	short tons	8,404	68,703	26,304	226,173
Petroleum	42-gallon barrels	8,932,738	25,994,182	7,759,723	22,898,509
Sand and gravel	short tons	17,133,624	13,759,118	19,692,000	18,442,000
Stone (crushed and broken)	short tons	500,863	586,838	333,381	494,631
Stone (dimension)	short tons	12,670	95,545	2,009	15,509
Total Planning Subarea 2.3		----------	40,751,382[b]	----------	42,219,352[b]

W Withheld to avoid disclosing individual company confidential data

[a]Excludes data for natural gas and natural-gas liquids, which are not available

[b]Incomplete total. Excludes data for gypsum, which must be withheld to avoid disclosing individual company confidential data; and data for natural gas and natural-gas liquids, which are not available.

TABLE 5–29 Planning Subarea 2.3: Active Mineral-Producing Sites by State, County, and Type of Operation, 1968

State County	Clay and Shale Pits	Gypsum Mines	Peat Bogs	Sand and Gravel Pits	Stone Quarries and Pits: Limestone	Stone Quarries and Pits: Marl	Stone Quarries and Pits: Sandstone	Gas Wells	Oil Wells
Indiana									
Elkhart	–	–	–	17	–	3	–	–	–
Lagrange	–	–	–	9	–	3	–	–	–
Marshall	–	–	1	4	–	4	–	–	–
Noble	–	–	–	8	–	1	–	–	–
St. Joseph	–	–	–	8	–	1	–	–	–
Steuben	–	–	–	6	–	3	–	–	–
Subtotal	0	0	1	52	0	15	0	0	0
Michigan									
Allegan	–	–	1	12	–	2	–	14[a]	192[a]
Barry	–	–	–	14	–	2	–	—	39
Berrien	–	–	–	13	–	2	–	—	—
Branch	–	–	–	7	–	2	–	—	—
Calhoun	–	–	–	11	–	2	–	9	259[a]
Cass	–	–	–	8	–	4	–	—	7
Clinton	1	–	–	12	–	–	–	—	—
Eaton	1	–	1	10	1	–	–	—	—
Hillsdale	–	–	–	5	–	2	–	—	228
Ingham	–	–	1	17	–	–	–	—	—
Ionia	–	–	–	4	–	–	–	—	3[a]
Jackson	–	–	–	4	1	2	1	—	79[a]
Kalamazoo	–	–	1	9	–	3	–	—	—
Kent	–	2[b]	4	22	–	–	–	3[a]	216[a]
Montcalm	–	–	–	9	–	–	–	5	60[a]
Ottawa	–	–	–	13	–	2	–	9[a]	288[a]
St. Joseph	–	–	2	7	–	1	–	—	—
Shiawassee	1	–	2	12	–	–	–	—	6[a]
Van Buren	–	–	–	8	–	–	–	—	40
Subtotal	3	2	12	197	2	24	1	40[a]	1,417[a]
Total	3	2	13	249	2	39	1	40[a]	1,417[a]

[a]Estimated because oil and gas fields cross county boundaries
[b]Underground mines

TABLE 5–30 Planning Subarea 2.3: General Stratigraphic Succession and Mineral Resources

Era	System	Group	Formation	Thickness (feet)	Mineral Resources
Cenozoic	Quaternary			0–500	Sand, gravel, peat, marl, clay
Mesozoic	Jurassic[1]			0–150	
Paleozoic	Pennsylvanian		Grand River Fm.[1] Saginaw Fm.[1]	50–475	Sandstone Coal, shale, sandstone
	Mississippian	Grand Rapids[1]	Bayport Ls.[1]	40–125	Limestone
			Michigan Fm.[1]	50–400	Gypsum, gas
			Marshall Ss.[1]	50–300	Sandstone, brine
			Coldwater Sh. Sunbury Sh.	0–1100	Shale[1]
	Mississippian-Devonian		Ellsworth Sh.	0–625	
	Devonian		Antrim Sh.	60–600	
		Traverse[1]	Traverse Fm.[2]	40–525	Limestone(p), dolomite(p)[2]; gas, oil, brine[1]
			Rogers City Ls.[1] Dundee Ls.	0–300	Oil, gas, brine[1]
		Detroit River[1]	Detroit River Fm.[2]	0–1000	Oil, gas, brine[1]; dolomite(p), limestone(p), gypsum(p) anhydrite(p)[2]
			Bois Blanc Fm.[1]	0–200	
	Silurian	Bass Islands[1]		0–3100	
		Salina[1]	Salina Fm.[2]	0–3100	Oil, gas, potash (p), salt[1]
		Niagara[1]	Wabash Fm.[2] Louisville Ls.[2] Waldron Fm.[2] Salmonie Dol.[2]	300–675	Oil, gas[1]
		Cataract[1]		50–150	
	Ordovician	Richmond[1]		250–825	
		Trenton[1]		350–875	Oil, gas
		Black River[1]		350–875	Oil, gas
			St. Peter Ss.[1]	0–60	
		Prairie du Chien[1]		1500–3500	
	Cambrian		Trempealeau Fm.[1] Munising Fm.[1]	1500–3500	
Precambrian					

[1]In Michigan
[2]In Indiana
(p) Potential Resource
Source: Harry J. Hardenberg, Michigan Geological Survey and Lawrence F. Rooney, Indiana Geological Survey

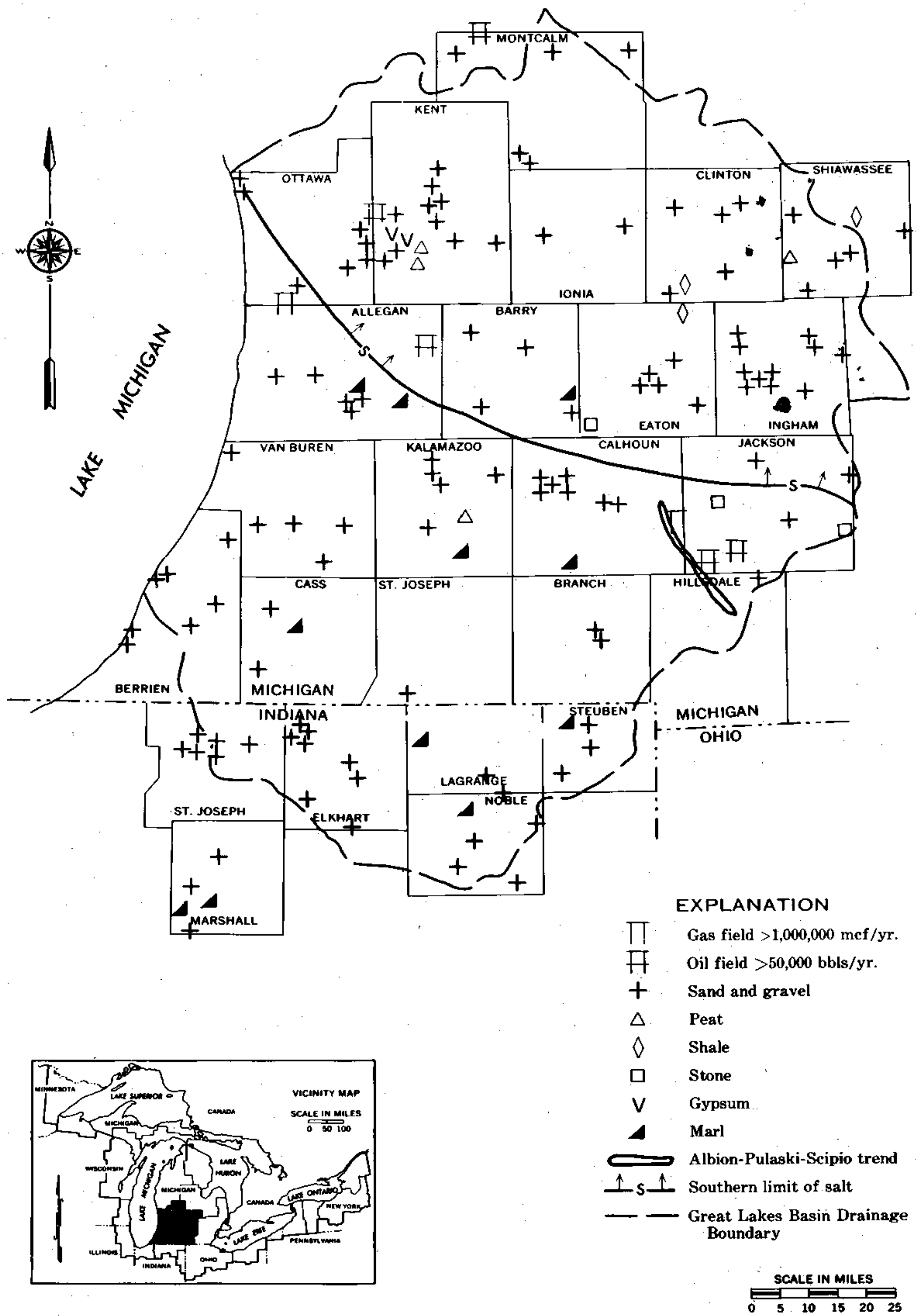

FIGURE 5–6 Planning Subarea 2.3: Distribution of Mineral Operations Active in 1968 and Major Mineral Resource Areas

producing area in the State of Michigan and in the Great Lakes Basin. Production comes from dolomites in the Trenton and Black River Groups of Ordovician age at depths ranging from 3,576 to 4,179 feet. Most of the gas is produced in association with oil. Oil and gas production in other parts of the area are mainly from Devonian and Mississippian rocks lying at shallower depths. At the current rate of decline in reserves, oil and gas production in Planning Subarea 2.3 will cease by 1985. However, improvements in exploration and production technology and new field discoveries could extend the production life of the area well beyond that date.

Gypsum occurs in the Michigan Formation of Mississippian age and in the Detroit River rocks of Devonian age. The Michigan Formation is mined in two underground operations in the Grand Rapids area in Kent County. This formation, near the surface in Kent County, underlies most of the northern and northeastern part of the area at depths to approximately 750 feet. Gypsum reserves in the Michigan Formation are believed to be large. The gypsum occurrence in the Detroit River rocks, recognized as a formation in Indiana but as a group in Michigan, is viewed as a potential resource in the Indiana part. The area of greatest potential includes parts of Marshall and St. Joseph Counties as well as adjoining La Porte County in Planning Subarea 2.2. Within these areas up to 30 feet of gypsum and anhydrite lie within 330 to 500 feet of the surface.[25] Anhydrite is a potential source of sulphur but with current technology it is not competitive with other sources of sulphur.

Buried limestone and dolomite formations of the Devonian system are considered a potential resource in northern Indiana, where there is high local demand for stone and a lack of surface quarries. This stone, which would be suited for construction, metallurgical, and agricultural purposes, overlies the gypsum and anhydrite bed discussed above. According to the Indiana Geological Survey, the stone could be produced separately at depths as shallow as 300 feet or produced jointly with gypsum or anhydrite.[23] An underground mining complex of either type would require only minor land and water resources and should have no objectionable effect on the local rural environment.

Stone quarrying currently is confined to limestone and sandstone formations in Eaton and Jackson Counties, Michigan. The limestone is quarried from the Bayport limestone of Mississippian age for use as crushed stone, agricultural limestone and dimension stone (rubble). Sandstone is produced from the Marshall sandstone, also of Mississippian age, for dimension stone use. These formations extrude at various locations in the northern part of the area. For the uses mentioned, the reserves of both types of stone are large, although the suitability of the limestone for agricultural purposes varies with the locality.

The Michigan Coal Basin underlies most of the northeastern part as far south as the central part of Jackson County and as far west as Kent County. The coal occurs as thin discontinuous beds in the Saginaw Formation of Pennsylvanian age. It is of poor quality and considered uneconomic to mine.

Clay and shale resources are abundant, widely distributed, and readily accessible. Most of the clay is of glacial origin while the shales are mainly in strata of the Mississippian and Pennsylvanian systems of Paleozoic age. In the early part of the century numerous local firms utilized these resources extensively to produce brick, tile, and pottery.[24] Only three sites were producing clay and shale for the manufacture of clay products in 1968 (Table 5–29). Since then a new operation in Ottawa County has begun to produce clay for the manufacture of lightweight aggregate.

Marl, a mixture of clay and calcium carbonate found in lakes of glacial origin, is widely distributed throughout the area. Deposits range in area from a fraction of an acre to a hundred acres or more and in thickness to a maximum of approximately 15 feet. In the absence of suitable limestone resources for agricultural use, marl serves as a satisfactory substitute for treating soils deficient in lime. The lack of limestone quarries and the ease with which marl can be dug or dredged and prepared for use accounts for the large number of small marl producers within the planning subarea.

A variety of sand- and gravel-bearing features are found in unconsolidated glacial and postglacial sediments covering the entire area. The most striking are long narrow ridges called eskers and the sand dunes along Lake Michigan. Although sand and gravel reserves are thought to be very large, deposits are being exhausted or lost to other land users, particularly near urban centers where the demand for aggregate and competition for land are greatest. In the case of the sand dune area, reserves of industrial sand are sufficient to support many years of production without encroaching on areas being set aside for parks and other shore developments.

The size of the peat resource is not known. Although deposits are small in comparison to those in the northern part of Michigan, they are believed to be many times larger than projected demand to the year 2020.

Other resources having considerable economic potential include natural brine and salt. Natural brine, the source of saline production in Planning Subareas 2.4 and 3.2, occurs in various Palezoic formations that underlie nearly the entire area. Brine, produced along with oil in Planning Subarea 2.3, amounted to more than 28,000 barrels per day in 1968. Although some oil field brine is used by local highway departments for dust abatement and ice control, most of it is returned to subsurface formations. Thick salt beds within the Salina Group of the Silurian system underlie the northern part of the area (Figure 5–6). In addition to salt, occurrences of potash have also been noted in the Salina strata. Potash occurrences may represent a potential resource but considerable exploration work will be required to determine their economic significance.

2.3.2 Mineral Industry Projection

2.3.2.1 Production

Projected mineral production for Planning Subarea 2.3 is summarized in Table 5–31. With the exception of petroleum, natural gas, and dimension stone, all mineral production is expected to increase during the projection period. In the case of crushed stone, it would be necessary to revise the projection upward significantly if an underground limestone mine is opened in northern Indiana.

2.3.2.2 Water

Sand and gravel production accounts for nearly all of the fresh water used by the mineral industries in Planning Subarea 2.3. Sand and gravel are produced seasonally, generally from April through November. Water use patterns in 1968 and for the projected years are presented in Table 5–32 at both the seasonal and average annual rate.

TABLE 5–31 Planning Subarea 2.3: Projected Mineral Production by Selected Commodities (thousands of short tons)

Commodity	1968[1]	1980	2000	2020	1968 to 2020[2]
Clay and shale	95	180	310	550	15,222
Peat	26	16	21	27	1,030
Sand and gravel	19,692	26,000	44,000	73,000	2,141,800
Stone, crushed[3]	333	400	580	920	29,210
Stone, dimension[4]	2	2	2	2	104

[1]Actual
[2]Cumulative
[3]Includes limestone and marl
[4]Includes limestone and sandstone

2.3.2.3 Land

Land required to maintain the projected mineral production is summarized by commodity in Table 5–33. The acreage referred to in this table must be mineral-bearing. Each mineral deposit is unique, exhaustible, and nonrenewable. Where competing land uses jeopardize production from mineral-bearing land, planners should consider the benefits of sequential land use and permit mining activities to deplete the mineral deposit before the initiation of other land use projects.

2.3.3 Mineral Problems

Although competing land uses have removed large acreages of sand- and gravel-bearing land from the resource inventory, this has not yet seriously jeopardized future supply of these resources within the PSA. However, without proper mineral conservation measures the situation would become critical by the end of this century. Several cities,

TABLE 5–32 Planning Subarea 2.3: Projected Mineral Industry Water Use (millions of gallons per day)

	1968[1]	1980	2000	2020
New Intake				
April-November	16.3	26.9	55.2	107.7
Average for 365 days	10.9	18.0	36.9	72.0
Discharged				
April-November	15.9	26.2	53.4	104.4
Average for 365 days	10.6	17.5	35.7	69.8
Recirculated				
April-November	12.4	21.1	44.6	89.8
Average for 365 days	8.3	14.1	29.8	60.0
Consumed				
April-November	0.4	0.7	1.8	3.3
Average for 365 days	0.3	0.5	1.2	2.2
Total Water[2]				
April-November	28.7	48.0	99.8	197.5
Average for 365 days	19.2	32.1	66.7	132.0

[1]Estimated
[2]Intake plus recirculated

TABLE 5–33 Planning Subarea 2.3: Projected Mineral-Bearing Land Requirements (acres)

Commodity	1968[1]	1980	1968 to 1980[2]	2000	1968 to 2000[2]	2020	1968 to 2020[2]
Clays and shale	1	2	20	4	75	6	173
Peat	194	119	224	157	249	201	373
Sand and gravel	259	342	3,576	579	12,788	961	28,180
Stone, crushed	12	14	166	19	496	28	978
Stone, dimension	---[3]	---[3]	1	---[3]	3	-----[3]	8
Total	466	477	3,987	759	13,611	1,196	29,712

[1]Estimated
[2]Cumulative
[3]Less than an acre

Lansing in particular, are already beginning to experience higher costs for aggregate trucked over ever-increasing distances because nearby deposits have been exhausted or lost to urban expansion. Competing land uses have not seriously affected production of dune sand but a long-standing conflict exists between industrial use of dune sand, conservation of the dunes, and urban expansion along the Lake Michigan shoreline.

2.3.4 Summary and Conclusions, Including Alternatives

With the exception of petroleum and natural gas, reserves of all mineral commodities exist in quantities large enough to support mineral activity many times in excess of that projected to 2020. However, aggregate mineral supply problems can be expected in and around many expanding urban centers. To offset the diseconomies incurred by the public when local resources are lost to other land uses, it is recommended that planning measures be incorporated to locate and protect valuable potential mineral resources in and around large communities in the area. Periodic surveys of the water use patterns of the sand and gravel industry are also recommended to keep abreast of intake and discharged water use changes.

2.4 Planning Subarea 2.4, Lake Michigan Northeast

2.4.1 Status and Potential of the Mineral Industry

2.4.1.1 Resume

Peat, petroleum and natural gas, salt, sand and gravel, shale, and stone (dolomite and limestone) are produced in the 21 Michigan counties that comprise Planning Subarea 2.4. In addition, lime and cement are manufactured from local shale and limestone, while bromine, calcium compounds, and magnesium compounds (salines) are extracted or manufactured from natural brines. Output and value of mineral products for 1960 and 1968 are summarized in Table 5–34. From 1960 to 1968, all mineral commodities except bromine and petroleum increased in both output and value. Dimension stone production was discontinued in 1962, while peat production commenced in 1964. The value of mineral production in 1968 was $83,280,530. Of this value, magnesium compounds accounted for 24 percent; crushed stone, 15 percent; petroleum, 7 percent; sand and gravel, 6 percent; and bromine, 3 percent.

TABLE 5–34 Planning Subarea 2.4: Mineral Production, 1960 and 1968[a]

Commodity		1960 Quantity	1960 Dollar Value	1968 Quantity	1968 Dollar Value
Bromine	pounds	9,758,184	2,531,737	9,146,530	2,145,885
Calcium compounds	short tons	W	W	W	W
Cement:					
Portland	376-pound barrels	W	W	W	W
Masonry	280-pound barrels	W	W	W	W
Shale	short tons	W	W	W	W
Lime	short tons	W	W	W	W
Magnesium compounds (MgO equivalent)	short tons	64,808	6,464,113	219,455	19,975,716
Peat	short tons	---------	----------	W	W
Petroleum	42-gallon barrels	2,234,375	6,502,011	1,876,012	5,536,007
Salt	short tons	W	W	W	W
Sand and gravel	short tons	5,002,377	4,252,751	5,442,000	4,956,000
Stone (crushed and broken)	short tons	7,704,981	9,609,823	9,322,173	12,158,268
Stone (dimension)	short tons	50	75	---------	----------
Value of items that cannot be disclosed		---------	22,196,093	---------	38,508,654
Total Planning Subarea 2.4		---------	51,556,603	---------	83,280,530

W Withheld to avoid disclosing individual company confidential data; included with "Value of items that cannot be disclosed."

[a]Excludes data for natural gas and natural-gas liquids, which are not available

A total of 126 nonmetallic mineral operations and 690 oil and gas wells were producing in 1968. All counties had sand and gravel operations. In three counties sand and gravel was the only mineral commodity mined. Oil and natural gas wells were active in 12 counties; limestone and dolomite quarries in 5; saline operations, salt mines, and shale pits in 2 counties each; and a peat bog in one county. A breakdown of producing sites by State, county, and type of operation is presented in Table 5–35. Selected operations are shown in Figure 5–7.

2.4.1.2 Resources and Reserves

Except for a relatively thin and discontinuous layer of Mesozoic rock, all the sedimentary formations in Planning Subarea 2.4 are of Paleozoic age. The formations range upward from Munising Formation of the Cambrian system to the Grand River Formation of the Pennsylvanian system. Oil, gas, salt, and brine are extracted from the formations through wells. Surface quarries and pits yield limestone, dolomite, and shale. Overlying the bedrock formations are varying thicknesses of unconsolidated Quaternary sediments of glacial origin. These sediments contain sand and gravel and peat deposits that are mined in surface pits. A generalized stratigraphic succession of Planning Subarea 2.4 is presented in Table 5–36 along with formation thickness and mineral occurrences.

Salt is produced from artificial brines obtained from solid rock-salt layers in the Detroit River Group of the Devonian system and the Salina Group of the Silurian system. The salines are derived from natural brine, which is produced from porous rocks in the Detroit River Group. The thick sequence of rocks containing the salt beds and the various brine-producing formations underlie all of the planning subarea south of Emmet County (Figure 5–7). Reserves of both are enormous in terms of tonnage, but the concentration of valuable salines in the brine varies with the formation.

Petroleum and natural gas are produced from rocks of the Mississippian, Devonian, and Silurian systems. The sequence of Devonian rocks from the top of the Traverse Group to the bottom of the Detroit River Group has accounted for more than 99 percent of cumula-

TABLE 5-35 Planning Subarea 2.4: Active Mineral-Producing Sites by State, County, and Type of Operation, 1968

State County	Shale Pits	Salines[a]	Salt Mines	Sand and Gravel Pits	Limestone and Dolomite Quarries	Gas Wells	Oil Wells
Michigan							
Antrim	1	-	-	4	-	-	---
Benzie	-	-	-	1	-	-	---
Charlevoix	-	-	-	5	1	-	---
Delta	-	-	-	8	1	-	---
Emmet	1	-	-	10	1	-	---
Grand Traverse	-	-	-	2	-	3	---
Kalkaska	-	-	-	3	-	-	1
Lake	-	-	-	6	-	-	92[b]
Leelanau	-	-	-	6	-	-	---
Mackinac	-	-	-	6	4	-	---
Manistee	-	3[c]	2[c]	5	-	1	---
Mason	-	2[c]	-	6	-	3	85[b]
Mecosta[d]	-	-	-	7	-	18	36
Missaukee	-	-	-	1	-	11	50[b]
Muskegon	-	-	1[c]	6	-	10	33
Newaygo	-	-	-	10	-	8	24
Oceana	-	-	-	5	-	1	68
Osceola	-	-	-	3	-	11	113[b]
Roscommon	-	-	-	9	-	2	120[b]
Schoolcraft	-	-	-	2	1	-	---
Wexford	-	-	-	2	-	-	---
Total	2	5	3	107	8	68	622[b]

[a]Includes bromine, calcium compounds, and magnesium compounds.
[b]Estimated as oil fields cross county boundaries.
[c]Brine well operations.
[d]Mecosta County had the only peat operation in Planning Subarea 2.4 during 1968.

TABLE 5–36 Planning Subarea 2.4: General Stratigraphic Succession and Mineral Resources

Era	System	Group	Formation	Thickness (feet)	Mineral Resources
Cenozoic	Quaternary				Sand, gravel, peat, marl
Mesozoic	Jurassic			0– 200	
Paleozoic	Pennsylvanian		Grand River Fm. Saginaw Fm.	110– 550	
	Mississippian	Grand Rapids	Bayport Ls.	40– 125	
			Michigan Fm.	50– 500	Gas
			Marshall Ss.	50– 300	Brine
			Coldwater Sh.	500–1,050	
	Mississippian-Devonian		Ellsworth Sh.	0– 625	Shale
	Devonian		Antrim Sh.	125– 650	Shale
		Traverse		340– 800	Limestone, shale, oil, gas, brine
			Rogers City Ls. Dundee Ls.	35– 315	Oil, gas, brine Oil, gas, brine
		Detroit River		350–1,600	Oil, gas, brine, salt, gypsum (p)
			Bois Blanc Fm.	0– 950	
	Silurian	Bass Islands		0–4,400	
		Salina		0–4,400	Oil, gas, salt, potash (p)
			Engadine Dol.	125– 800+	Oil, gas, dolomite
		Manistique		125– 800+	Dolomite, limestone
		Burnt Bluff		125– 800+	Limestone, dolomite
		Cataract		50– 160	
	Ordovician	Richmond		350– 740	
		Trenton		300– 775	Limestone
		Black River		300– 775	Limestone
			St. Peter Ss.	0– 60	
		Prairie du Chien		300–2,600	
	Cambrian		Trempealeau Fm. Munising Fm.	300–2,600	
Pre-cambrian					

(p) Potential Resource
Source: Harry J. Hardenberg, Michigan Geological Survey.

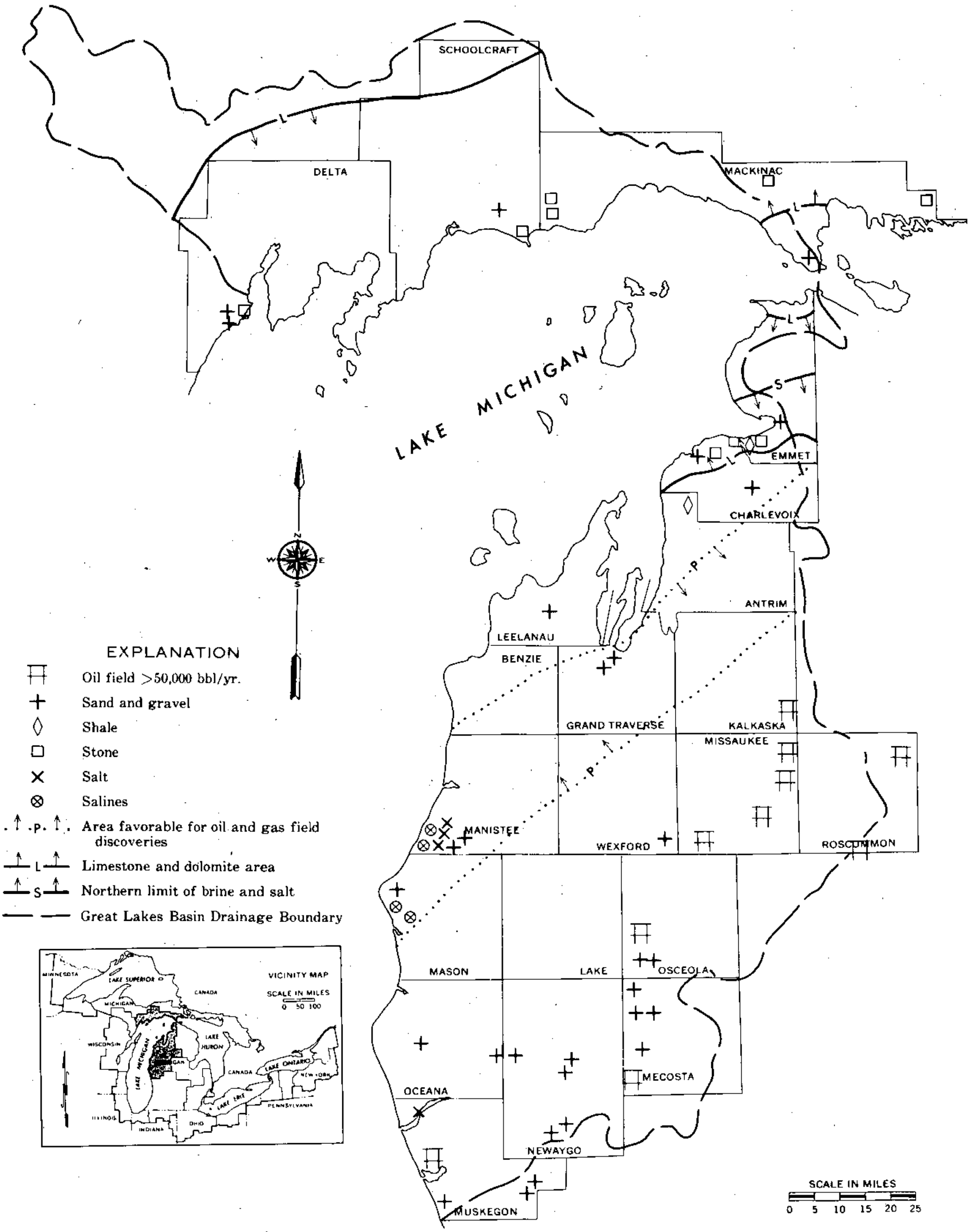

FIGURE 5-7 Planning Subarea 2.4: Distribution of Mineral Operations Active in 1968 and Major Mineral Resource Areas

tive oil production, of which approximately 35 percent came from the Dundee limestone. The same sequence of rocks also accounted for 22 percent of cumulative gas production while 73 percent came from the Michigan Formation of Mississippian age. Proven reserves of oil and gas at the end of 1968 were sufficient to support current production rates for approximately four or five years. Since this time new oil and gas discoveries in the lower Silurian formations have stimulated exploration and drilling activities in parts of Grand Traverse, Kalkaska, and Antrim Counties as well as in adjoining counties in Planning Subarea 3.1. The area considered favorable for future Silurian oil and gas discoveries is shown in Figure 5–7. New field discoveries will undoubtedly lead to an increase in oil and gas production and extend the production life of the area well into the future.

Limestone and dolomite formations of the Devonian, Silurian, and Ordovician systems underlie most of the area north of Charlevoix County (Figure 5–7). Surface or near-surface exposures of limestone and dolomite are found only at scattered locations, generally close to Lake Michigan. The bulk of the crushed limestone and dolomite comes from Silurian sediments that form a band 5 to 20 miles wide from Seul Choix Point in Schoolcraft County to the easternmost point of Drummond Island in Chippewa County. Much of this stone is shipped to lake ports in the lower Great Lakes Region where it is used as flux in iron and steelmaking plants or for the manufacture of cement and lime. Reserves of usable stone are very large. A number of deposits are each known to have reserves of ten to several hundred million tons.[30]

The southern peninsula portion of the planning subarea is richly endowed with sand- and gravel-bearing glacial and postglacial features. The northern counties have large areas of exposed bedrock, but even these are believed to have sufficient reserves to meet the sand and gravel demands of the next 50 years.

The Ellsworth shale of Mississippian-Devonian age in Antrim County and shale of the Devonian Traverse Group in Emmet County are mined for use in the manufacture of cement. Numerous exposures of Ellsworth shale are found in the bluffs and hills near the village of Ellsworth. The best exposures of Traverse Group shales are limited to the mining sites in Emmet County. No estimate of reserves of usable shale is available at this time.

Gypsum and potash occurrences may represent potential resources within the planning subarea. The gypsum occurs in strata of the Detroit River Group of the Devonian system, while potash occurs in the Salina Group of the Silurian system. Few data are available on these occurrences. Considerable exploration work will be required to determine their economic significance.

TABLE 5–37 Planning Subarea 2.4: Projected Mineral Production by Selected Commodities (thousands of short tons)

Commodity	1968[1]	1980	2000	2020	1968 to 2020[2]
Clays and shale	323	400	640	1,030	31,300
Salt	W	900	2,000	4,000	98,000
Sand and gravel	5,442	7,600	12,000	20,100	594,400
Stone, crushed[3]	9,322	12,400	21,100	36,000	1,034,400

[1] Actual
[2] Cumulative
[3] Limestone and dolomite
W Withheld to avoid disclosing individual company confidential data

2.4.2 Mineral Industry Projection

2.4.2.1 Production

Projected mineral production for Planning Subarea 2.4 is summarized in Table 5–37. With the exception of petroleum and natural gas, all mineral production is expected to increase during the projection period. Saline production, which requires only negligible amounts of land and fresh water, was not projected.

2.4.2.2 Water

Water is used in primary production of salt, sand and gravel, and crushed stone. Currently, salt producers, who operate throughout the year, account for the bulk of new intake water and water discharged. However, sand and gravel and crushed stone producers, who operate seasonally, are expected to be the principal water users before the year 2000. Water use patterns in 1968 and for the projected years are presented in Table 5–38 at both the annual and seasonal rate.

Water is also injected into oil-producing formations by the petroleum industry to increase the recovery of oil. Brine, which is produced in conjunction with the oil and fresh water from surface sources, is also used in

TABLE 5–38 Planning Subarea 2.4: Projected Mineral Industry Water Use (millions of gallons per day)

	1968[1]	1980	2000	2020
New Intake				
April-November	5.1	6.7	7.4	12.2
Average for 365 days	4.4	5.7	5.8	9.6
Discharged				
April-November	5.0	6.6	7.1	11.8
Average for 365 days	4.3	5.6	5.6	9.3
Recirculated				
April-November	1.5	2.5	4.2	8.1
Average for 365 days	1.0	1.8	3.0	6.0
Consumed				
April-November	0.1	0.1	0.3	0.4
Average for 365 days	0.1	0.1	0.2	0.3
Total Water[2]				
April-November	6.6	9.2	11.6	20.3
Average for 365 days	5.4	7.5	8.8	15.6

[1]Estimated
[2]Intake plus recirculated

these secondary recovery techniques. Fresh water injection during 1968 averaged approximately 0.3 million gallons per day. The uncertainties of future oil production in the area preclude a water use projection for the petroleum industry.

2.4.2.3 Land

The land required to maintain projected mineral production is summarized by commodity in Table 5–39. The acreage referred to in this table must be mineral-bearing. Because each mineral deposit is unique, other land uses should be discouraged from preempting mining activities until after the deposit is mined.

2.4.3 Mineral Problems

No serious long-range water or land problems are foreseen for mineral producers in Planning Subarea 2.4. The mineral problems associated with large expanding urban centers are absent in this area. Mineral supply problems may develop in or near some of the small communities, but these are likely to be local in effect and continue only until other nearby sources of supply can be established.

The petroleum industry faces a new problem in obtaining oil exploration rights. In March 1970 a sale of 79,152 acres of oil and gas leases in northern Michigan was blocked by the Michigan legislature. This unprecedented action was sparked by a recreational group in Emmet County who contended that there are no assurances that oil development could be carried on without endangering rivers and lakes.

2.4.4 Summary and Conclusions, Including Alternatives

With the possible exception of petroleum and natural gas, reserves of all mineral commodities produced within the area exist in quantities large enough to support production

TABLE 5–39 Planning Subarea 2.4: Projected Mineral-Bearing Land Requirements (acres)

Commodity	1968[1]	1980	1968 to 1980[2]	2000	1968 to 2000[2]	2020	1968 to 2020[2]
Clays and shale	4	5	48	8	132	12	356
Sand and gravel	84	117	1,191	185	3,165	309	9,145
Stone, crushed	46	61	629	103	2,272	176	5,071
Total	134	183	1,868	296	5,569	497	14,572

[1]Estimated
[2]Cumulative

activity in excess of that projected for the next 50 years. Because presence of mineral resources does not guarantee availability, it is recommended that planning efforts incorporate programs to insure that valuable mineral resources are preserved and that planned development includes mineral extraction.

Periodic surveys of water use patterns of the mineral industry are recommended to keep abreast of intake and discharged water use changes.

Section 3

PLAN AREA 3.0

3.1 Planning Subarea 3.1, Lake Huron North

3.1.1 Status and Potential of the Mineral Industry

3.1.1.1 Resume

Mineral production in the 11 Michigan counties that make up Planning Subarea 3.1 includes gypsum, petroleum and natural gas, sand and gravel, shale, and limestone. Output and value of mineral products for 1960 and 1968 are summarized in Table 5–40. Cement, manufactured from local limestone and shale, is included in the table for reference only. From 1960 to 1968, gypsum output remained constant while shale, sand and gravel, and crushed and broken stone increased in both output and value. Petroleum and dimension stone decreased in both areas during this time. The value of mineral production in the PSA was $72,796,834 in 1968, with crushed and broken limestone accounting for 28 percent; petroleum, approximately 4 percent; and sand and gravel, 3 percent of this value.

A total of 51 nonmetallic mineral operations and 518 oil and gas wells were producing in 1968. All the counties had sand and gravel operations. Oil and natural gas wells were active in six counties, limestone quarries in four, and shale and gypsum operations in one county each. A breakdown of producing sites by county and type of operation is presented in Table 5–41. Selected operations are shown in Figure 5–8.

3.1.1.2 Resources and Reserves

Except for minor isolated occurrences of Mesozoic rocks, all the sedimentary formations in Planning Subarea 3.1 are of Paleozoic age. The formations range upward from the Munising Formation of the Cambrian system to the Saginaw Formation of the Pennsylvanian system. Oil and gas are extracted from

TABLE 5–40 Planning Subarea 3.1: Mineral Production, 1960 and 1968[a]

Commodity		1960 Quantity	1960 Dollar Value	1968 Quantity	1968 Dollar Value
Cement:					
Portland	376-pound barrels	W	W	W	W
Masonry	280-pound barrels	W	W	W	W
Shale	short tons	W	W	W	W
Gypsum	short tons	W	W	W	W
Petroleum	42-gallon barrels	1,112,129	3,236,285	880,994	2,599,764
Sand and gravel	short tons	2,443,467	1,650,384	3,049,000	2,326,000
Stone (crushed and broken)	short tons	19,090,014	16,445,472	21,566,352	20,219,460
Stone (dimension)	short tons	W	W	W	W
Value of items that cannot be disclosed		----------	38,599,954	----------	47,651,610
Total Planning Subarea 3.1		----------	59,932,095[b]	----------	72,796,834[b]

W Withheld to avoid disclosing individual company confidential data; included with "Value of items that cannot be disclosed."

[a]Excludes data for natural gas and natural-gas liquids, which are not available

[b]Incomplete total. Excludes data for natural gas and natural-gas liquids, which are not available.

TABLE 5–41 Planning Subarea 3.1: Active Mineral-Producing Sites by State, County, and Type of Operation, 1968

State County	Shale Pits	Gypsum Quarries	Sand and Gravel Pits	Limestone Quarries	Gas Wells	Oil Wells
Michigan						
Alcona	-	-	4	-	--	---
Alpena	1	-	6	1	--	---
Arenac	-	-	2	3	20	143[a]
Cheboygan	-	-	1	2	--	---
Crawford	-	-	6	-	14	51
Iosco	-	3	2	-	--	---
Montmorency	-	-	1	-	--	1
Ogemaw	-	-	9	-	--	272[a]
Oscoda	-	-	1	-	--	1[a]
Otsego	-	-	2	-	16	---
Presque Isle	-	-	4	3	--	---
Total	1	3	38	9	50	468[a]

[a]Estimated, as oil fields cross county boundaries

the formations through wells; surface quarries and pits yield shale, limestone, and gypsum. Overlying the sedimentary rocks are varying thicknesses of unconsolidated Quaternary sediments of glacial origin that contain deposits of sand and gravel, marl, and peat. Currently only sand and gravel, excavated by surface methods, is taken from the glacial sediments. A generalized stratigraphic succession of Planning Subarea 3.1 is presented in Table 5–42 along with the formation thickness and mineral occurrences.

Petroleum and natural gas are produced from limestone and sandstone formations in the Mississippian, Devonian, and Silurian systems. Devonian limestone formations have accounted for more than 99 percent of the cumulative oil production of which approximately 67 percent came from the Dundee limestone. Most of the remaining oil production has come from limestones in the Detroit River Group, which also accounted for approximately 71 percent of the cumulative gas production. Another gas-producing formation is the Berea Sandstone Formation of the Mississippian system, which has produced 27 percent of the area's cumulative gas production. Proven reserves of oil and gas at the end of 1968 were sufficient to support current production rates for four or five years. Since 1968, new oil and gas discoveries in the deeper-lying Silurian formations have stimulated exploration and drilling activities in Presque Isle, Cheboygan, and Otsego Counties as well as in the adjoining counties of Planning Subarea 2.4. The area considered favorable for future Silurian oil and gas discoveries is shown in Figure 5–8. New field discoveries will undoubtedly lead to an increase in oil and gas production and extend the production life of the area well into the future.

Limestone is quarried from Devonian formations in Alpena, Presque Isle, and Cheboygan Counties and from Mississippian formations in Arenac County (Figure 5–8). Surface or near-surface exposures of Devonian formations include a narrow belt across the central part of Cheboygan County and the east-central part of Presque Isle County, and numerous large connected areas along the Lake Huron shoreline in Presque Isle and Alpena Counties. The two near-shore quarries in Presque Isle County account for the bulk of crushed limestone output, most of which is shipped via lake freighter to cement, lime, chemical, iron and steelmaking plants at ports in the lower Great Lakes Region. Crushed limestone produced in Alpena County is used in the manufacture of cement at the world's largest cement plant, located near the quarry

TABLE 5-42 Planning Subarea Planning Subarea 3.1: General Stratigraphic Succession and Mineral Resources

Era	System	Group	Formation	Thickness (feet)	Mineral Resources
Cenozoic	Quaternary				Sand, gravel, marl, peat
Mesozoic	Jurassic			0- 25	
Paleozoic	Pennsylvanian		Saginaw Fm.	50- 400	
	Mississippian	Grand Rapids	Bayport Ls.	0- 25	Limestone
			Michigan Fm.	50- 250	Gypsum
			Marshall Ss.	50- 300	
			Coldwater Sh.	925-1,150	
			Sunbury Sh. / Berea Ss. / Bedford Sh.	10- 250	Gas
	Devonian		Antrim Sh.	150- 650	Shale, gas
		Traverse		650- 850	Limestone, oil, gas, brine, shale
			Rogers City Ls.	80- 460	Limestone, oil, gas, brine
			Dundee Ls.		Limestone, oil, gas, brine
		Detroit River		350-1,400	Oil, gas, brine, salt
			Bois Blanc Fm.	250-1,000	
	Silurian	Bass Islands / Salina		600-4,200	Oil, gas, salt
		Niagara		250- 750	Oil, gas
		Cataract		100- 160	
	Ordovician	Richmond		450- 775	
		Trenton / Black River		300- 900	
		Prairie du Chien		700-2,000	
	Cambrian		Trempealeau Fm. / Munising Fm.	700-2,000	
Precambrian					

Source: Harry J. Hardenberg, Michigan Geological Survey

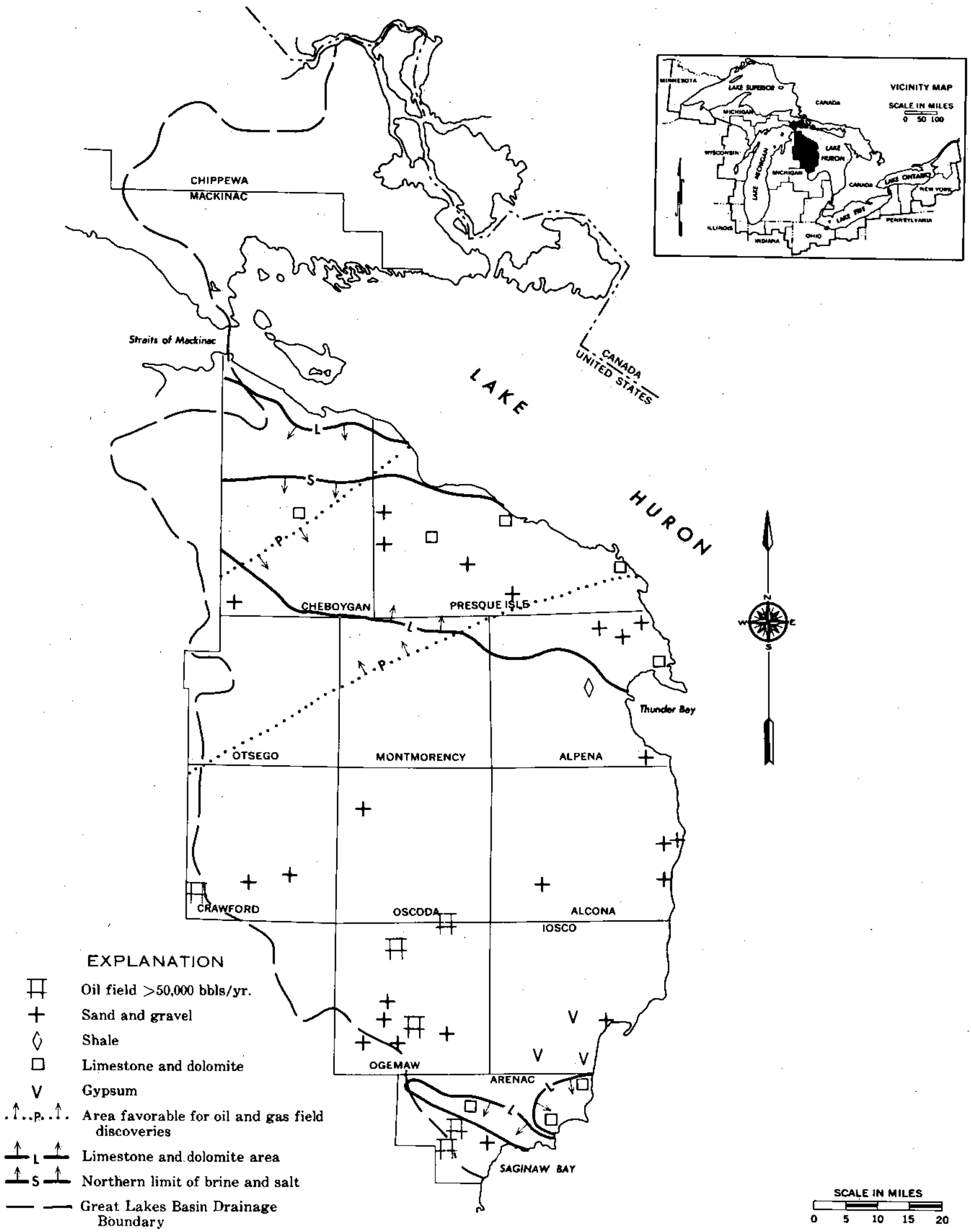

FIGURE 5–8 Planning Subarea 3.1: Distribution of Mineral Operations Active in 1968 and Major Mineral Resource Areas

site. Except for minor quantities of dimension limestone produced in the western part of Presque Isle County, limestone produced in the area is crushed, primarily for local use in road construction and maintenance. Reserves of usable stone in both the Devonian and the Mississippian limestone formations are very large.

The source of shale for cement manufacture in Alpena County is the Antrim shale of the Devonian system. This ranges from 150 to 650 feet in thickness and forms the bedrock surface under most of the southern part of Alpena County and the northern part of Montmorency County. Although exposures are limited, usable reserves of accessible shale are believed to be large.

A bed of shale occurring in the Traverse Group of the Devonian system in Presque Isle County has been found suitable for the manufacture of lightweight aggregate.[1] The shale, known as the Bell shale, is approximately 60 to 70 feet thick where exposed near Lake Huron.

Gypsum has been quarried by surface methods in Iosco County since the middle 1870s. Much of the early production was sold as soil conditioner. Current output is used in the manufacture of gypsum building materials and in cement to slow its setting. The gypsum occurs in three horizontal layers in the Michigan Formation of Mississippian age. The layers are separated by 5-foot-thick layers of shale and are overlain by glacial sediments ranging up to 75 feet in thickness. The uppermost gypsum layer averages approximately 16 feet in thickness and is 93 percent gypsum. The middle layer is 5 feet in thickness and 86 percent gypsum, and the lower layer 7 feet in thickness and 94 percent gypsum. Gypsum reserves within Iosco County are believed to be large enough to support increasing production through the projection period.

Sand and gravel deposits are widely scattered within the Quaternary glacial and post glacial sediments that blanket nearly the entire area. Their principal use is in local building and highway construction projects. Although the full extent of the sand and gravel is not known, reserves are believed to be many times in excess of that needed to support projected production.

Unused resources of considerable magnitude exist within the area, but large-scale development of these resources during the projection period is considered unlikely. Included in this category are salt, brine, marl, and peat. Salt- and brine-bearing formations underlie the entire area except the northern parts of Cheboygan and Presque Isle Counties (Figure 5–8). Marl and peat deposits occur in the glacial sediments and range in size from a fraction of an acre to a hundred acres or more.

TABLE 5–43 Planning Subarea 3.1: Projected Mineral Production by Selected Commodities (thousands of short tons)

Commodity	1968[1]	1980	2000	2020	1968 to 2020[2]
Gypsum	W	1,400	1,900	2,600	93,600
Sand and gravel	3,049	4,100	6,800	11,400	333,600
Stone, crushed[3]	21,566	28,600	47,700	80,000	2,337,600

[1]Actual
[2]Cumulative
[3]Limestone
W Withheld to avoid disclosing individual company confidential data

3.1.2 Mineral Industry Projection

3.1.2.1 Production

Projected mineral production for Planning Subarea 3.1 is summarized in Table 5–43. With the possible exception of petroleum, natural gas, and dimension limestone, all mineral production is expected to increase during the projection period.

3.1.2.2 Water

Crushed stone production accounts for most of the fresh water used by the mineral industries in Planning Subarea 3.1. Sand and gravel producers account for the remainder. Both are produced on a seasonal basis, generally from April through November. Water use patterns in 1968 and for the projected years are presented in Table 5–44 at both the seasonal and average annual rate.

Water is also injected into oil-producing formations by the petroleum industry to increase recovery of oil. Both fresh water from ground-water sources and brine produced in conjunction with oil are used in these secondary recovery techniques. During 1968 fresh water injection averaged nearly 0.6 million gallons per day. The uncertainties of future oil production preclude a water use projection for the petroleum industry.

TABLE 5–44 Planning Subarea 3.1: Projected Mineral Industry Water Use (millions of gallons per day)

	1968[1]	1980	2000	2020
New Intake				
April-November	20.9	27.9	40.3	61.3
Average for 365 days	14.0	18.7	27.0	41.0
Discharged				
April-November	18.4	24.4	34.8	51.3
Average for 365 days	12.3	16.3	23.3	34.3
Recirculated				
April-November	1.2	1.5	8.3	20.7
Average for 365 days	0.8	1.0	5.6	13.8
Consumed				
April-November	2.5	3.5	5.5	10.0
Average for 365 days	1.7	2.4	3.7	6.7
Total Water[2]				
April-November	22.1	29.4	48.6	82.0
Average for 365 days	14.8	19.7	32.6	54.8

[1]Estimated
[2]Intake plus recirculated

3.1.2.3 Land

Land required to maintain projected mineral production is summarized by commodity in Table 5–45. The acreage referred to in this table must be mineral-bearing.

3.1.3 Mineral Problems

The combination of low population and bountiful mineral resources in Planning Subarea 3.1 could be expected to allow for orderly growth of the mineral industries within a high-quality environment. No serious long-range water or land problems are foreseen for the mineral producers here.

The problem concerning oil exploration activities, which was introduced in the preceding chapter on Planning Subarea 2.4, applies to Planning Subarea 3.1 as well. The reader is referred to earlier discussion of this problem.

3.1.4 Summary and Conclusions, Including Alternatives

Sufficient reserves of gypsum, sand and gravel, shale and limestone exist in the area to support production activity during the projection period.

Periodic surveys of the water use patterns of the mineral industry are recommended to keep abreast of intake and discharged water use changes.

3.2 Planning Subarea 3.2, Lake Huron Central

3.2.1 Status and Potential of the Mineral Industry

3.2.1.1 Resume

Mineral production in the 11 Michigan counties which make up Planning Subarea 3.2 includes clay, peat, petroleum and natural gas,

TABLE 5–45 Planning Subarea 3.1: Projected Mineral-Bearing Land Requirements (acres)

Commodity	1968[1]	1980	1968 to 1980[2]	2000	1968 to 2000[2]	2020	1968 to 2020[2]
Clays and shale	6	7	81	13	292	22	652
Gypsum	13	15	168	20	523	28	1,006
Sand and gravel	40	54	561	89	1,995	150	4,389
Stone, crushed	51	67	697	112	2,460	187	5,474
Total	110	143	1,507	234	5,270	387	11,521

[1]Estimated
[2]Cumulative

salt, sand and gravel, and limestone. Cement and lime are manufactured from both local and imported raw materials. Bromine, calcium compounds, iodine, magnesium compounds, and potash (salines) are extracted or manufactured from natural brines. Output and value of mineral products for 1960 and 1968 are presented in Table 5–46. From 1960 to 1968, bromine, iodine, lime, cement, calcium compounds, peat, and salt increased in output and value while crushed and broken stone, clay, and petroleum decreased in both. Sand and gravel, dimension stone, and magnesium compounds declined in output but increased in value during this time while potash increased in output and declined in value. The value of mineral products was $81,853,664 in 1968, with bromine accounting for more than 50 percent of this total and magnesium compounds, petroleum, and sand and gravel for more than 6 percent each.

A total of 76 nonmetallic mineral operations and 1,298 oil and gas wells were active for the planning subarea in 1968. All counties had sand and gravel pits and oil wells, while natural gas wells were productive in five counties, saline operations in three, salt mines and peat bogs in two, and clay and stone operations in one county each. Distribution of producing sites by State, county, and type of operation is presented in Table 5–47. Locations of selected mineral operations are shown in Figure 5–9.

3.2.1.2 Resources and Reserves

The sedimentary rocks underlying Planning Subarea 3.2 range from the deeply buried formations of the Cambrian system through the near-surface exposures of the Mississippian and Pennsylvanian systems. The formations contain oil, natural gas, brine, salt, stone, and coal deposits. Unconsolidated glacial and postglacial sediments of the Quaternary system that overlie the bedrock surface contain deposits of clay, sand and gravel, peat, and marl. Mineral materials are extracted by surface excavation and wells. A generalized stratigraphic succession is presented in Table

TABLE 5–46 Planning Subarea 3.2: Mineral Production, 1960 and 1968[a]

Commodity		1960 Quantity	1960 Dollar Value	1968 Quantity	1968 Dollar Value
Bromine	pounds	W	W	W	W
Calcium compounds	short tons	W	W	W	W
Cement:					
Portland	376-pound barrels	W	W	W	W
Masonry	280-pound barrels	W	W	W	W
Clay	short tons	W	W	W	W
Iodine	pounds	---------	----------	W	W
Lime	short tons	W	W	W	W
Magnesium compounds (MgO equivalent)	short tons	W	W	46,951	5,111,420
Peat	short tons	W	W	W	W
Petroleum	42-gallon barrels	2,903,258	8,448,452	1,832,034	5,406,231
Potash	short tons	W	W	W	W
Salt	short tons	W	W	W	W
Sand and gravel	short tons	5,770,723	4,267,149	5,564,000	5,243,000
Stone (crushed and broken)	short tons	W	W	436,845	633,227
Stone (dimension)	short tons	W	W	1,371	18,512
Value of items that cannot be disclosed		---------	45,403,432	---------	65,441,274
Total Planning Subarea 3.2		---------	58,119,033	---------	81,853,664

W Withheld to avoid disclosing individual company confidential data; included with "Value of items that cannot be disclosed."

[a]Excludes data for natural gas and natural-gas liquids, which are not available

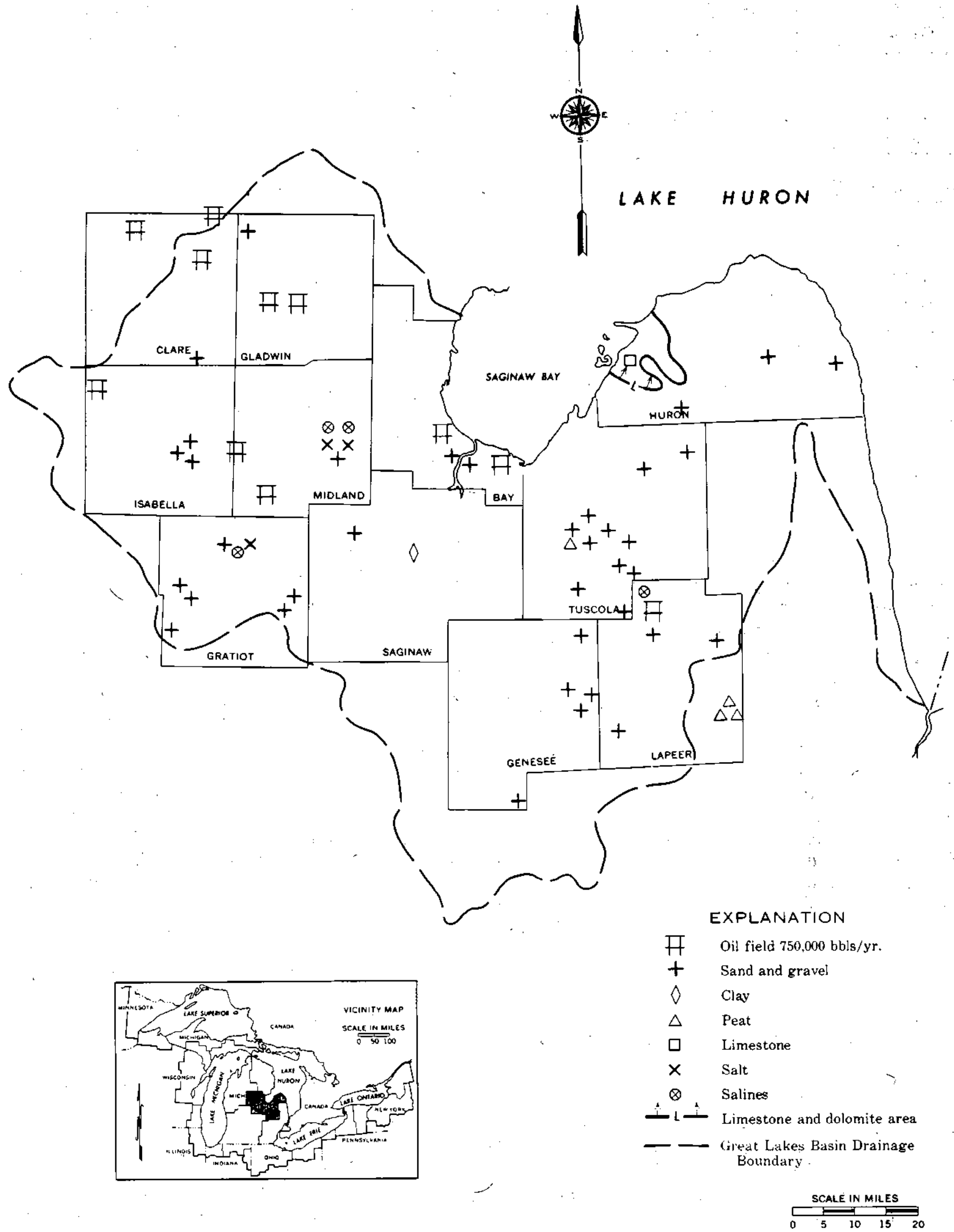

FIGURE 5–9 Planning Subarea 3.2: Distribution of Mineral Operations Active in 1968

TABLE 5–47 Planning Subarea 3.2: Active Mineral-Producing Sites by State, County, and Type of Operation, 1968

State County	Clay Pits	Peat Bogs	Salines[a]	Salt Mines	Sand and Gravel Pits	Lime-stone Quarries	Gas Wells	Oil Wells
Michigan								
Bay	-	-	-	-	2	-	-	369
Clare	-	-	-	-	2	-	9	89[b]
Genesee	-	-	-	-	11	-	-	14[b]
Gladwin	-	-	-	-	2	-	-	224[b]
Gratiot	-	-	1[c]	1[c]	11	-	1	20
Huron	-	-	-	-	5	1	-	4
Isabella	-	-	-	-	4	-	9	204[b]
Lapeer	-	4	1[c]	-	3	-	-	19
Midland	-	-	2[c]	2[c]	2	-	2	213[b]
Saginaw	1	-	-	-	2	-	1	60[b]
Tuscola	-	1	-	-	18	-	-	60[b]
Total	1	5	4	3	62	1	22	1,276[b]

[a]Includes bromine, calcium compounds, iodine, magnesium compounds, and potash.
[b]Estimated, as oil fields cross county boundaries.
[c]Brine well operations.

5–48 along with formation thicknesses and mineral occurrences.

Petroleum and natural gas are produced from the Devonian and Mississippian formations that underlie the entire area at varying depths. Dundee limestone of the Devonian system yielded 82 percent of cumulative oil production and the Michigan Formation, of the Mississippian system, 76 percent of the cumulative natural gas production. Most remaining oil production and all of the remaining gas production has come from other formations in the Devonian system. Proven reserves of petroleum and natural gas are sufficient to support current production rates for approximately four years. The possible discovery of new fields, particularly in Silurian strata, could extend production life. Uncertainty about exploratory petroleum and natural gas drilling makes it difficult to estimate the future potential of this industry.

Natural brines are found in Mississippian and Devonian formations. Salt beds are found in Devonian and Silurian formations. Salt and brines are both produced from the various formations through wells. In addition to salt, brines are the source of bromine, iodine, calcium compounds, magnesium compounds, and potash. The entire United States production of iodine is recovered by the Dow Chemical Company from brines produced in Midland County.[3] All of the salt and most of the brine carrying formations underlie the entire planning subarea. Reserves of salt and brine are undetermined.

Both crushed and dimension limestone are taken from Bayport limestone at a quarry in Huron County. The bulk of quarry production is crushed for use as aggregate material. Dimension stone is marketed in both rough and cut form. Reserves of limestone are sufficient to support production throughout the projection period.

Marshall sandstone, underlying the northern portion of Huron County, was at one time quarried for use as grindstones. The quarries in this area have been abandoned since 1929, although some intermittent, short-lived production has taken place since this date. Although reserves of material suitable for

TABLE 5-48 Planning Subarea 3.2: General Stratigraphic Succession and Mineral Resources

Era	System	Group	Formation	Thickness (feet)	Mineral Resources
Cenozoic	Quaternary				Sand, gravel, clay, peat, marl
Mesozoic	Jurassic			0- 150	
Paleozoic	Pennsylvanian		Grand River Fm. Saginaw Fm.	75- 750	Coal, brine
	Mississippian		Bayport Ls.	15- 125	Limestone
			Michigan Fm.	50- 500	Gas
			Marshall Ss.	50- 350	Sandstone, brine
			Coldwater Sh.	800-1,150	
			Sunbury Sh. Berea Ss. Bedford Sh.	10- 460	Oil, brine
	Devonian		Antrim Sh.	150- 650	
		Traverse		370- 820	Oil, gas
			Rogers City Ls. Dundee Ls.	50- 475	Oil, gas, brine Oil, gas, brine
		Detroit River		500-1,600	Oil, gas, brine, salt
			Bois Blanc Fm.	50- 850	
	Silurian	Bass Islands Salina		2,200-5,000	Oil, gas, salt
		Niagara		100- 300	Oil, gas
		Cataract		150- 160	
	Ordovician	Richmond		600- 850	
		Trenton Black River		625- 850	
		Prairie du Chien		600-2,600	
	Cambrian		Trempealeau Fm. Munising Fm.	600-2,600	
Precambrian					

Source: Harry J. Hardenberg, Michigan Geological Survey

grindstones remain, it is unlikely that production of sandstone for this use will occur during the projection period.

Coal was mined at one time by underground methods in Bay, Genesee, Huron, Midland, Saginaw, and Tuscola Counties from the Saginaw Formation of the Pennsylvanian system. Coal production ceased due to the thinness of the coal beds, the low grade and high sulphur content of the coal, and the high cost of underground mining. No future coal production is anticipated here.

Glacial lake clay is the prime clay source in the area. Although the lake clays are found in most area counties, production is presently confined to Saginaw County where clay is used in the manufacture of cement. No estimates of glacial lake clay reserves are available. Because only one clay producer is actively mining the substance, clay projections cannot be made without disclosing the production plans of this company. Clay production is, however, expected to continue throughout the projection period. Reserves should be sufficient to support this production.

The bulk of the peat produced is reed-sedge peat produced at four sites in Lapeer County. A minor amount of moss peat is also produced from a single bog in Tuscola County. Both types of peat are used as general soil conditioners. Because some of the larger peat bogs will be depleted during the next 20 to 25 years, smaller bogs are expected to be brought into production to maintain output during the remainder of the projection period. Peat deposits can support production well beyond the projection period.

Sand and gravel is produced in all area

counties, for use primarily as aggregate in paving and building construction, or as fill. Molding sand is also produced in Tuscola, Saginaw, and Bay Counties. High-quality deposits of sand and gravel are found in those glacial sediments deposited by moving water. Sand deposits are also found in former glacial-lake beds. Reserves of sand and gravel are not known, but are assumed to be sufficient to support production during the projection period.

Marl was produced for approximately 30 years in Saginaw County and used in the manufacture of cement. High grade marl deposits in this area were exhausted in the 1930s and production ceased. Although other marl deposits are available, renewed production of marl is not expected during the projection period.

3.2.2 Mineral Industry Projection

3.2.2.1 Production

Projected mineral production is summarized in Table 5–49. With the exception of petroleum and natural gas, all mineral production is expected to increase during the projection period. Clay production, not included in the table, will probably maintain a constant level during this time period.

3.2.2.2 Water

Sand and gravel and salt production account for most fresh water used by the mineral industry in Planning Subarea 3.2. Sand and gravel production is seasonal from April to November. Brine production is a year-round function. Water use patterns in 1968 and for the projection years are presented in Table 5–50 at both the seasonal and average annual rate.

The petroleum industry uses minor amounts of fresh water and brine for the secondary recovery of oil. Fresh water was injected into producing formations at a rate of 0.2 million gallons per day in 1968. Uncertainties of future oil production by secondary recovery techniques precludes a water use projection for this activity.

TABLE 5–49 Planning Subarea 3.2: Projected Mineral Production by Selected Commodities (thousands of short tons)

Commodity	1968[1]	1980	2000	2020	1968 to 2020[2]
Peat	W	120	150	200	7,520
Salt	W	1,250	2,640	5,560	133,200
Sand and gravel	5,564	7,210	12,050	20,130	589,460
Stone, crushed[3]	437	610	1,020	1,710	48,960

[1]Actual
[2]Cumulative
[3]Limestone
W Withheld to avoid disclosing individual company confidential data

3.2.2.3 Land

Land required to maintain the projected mineral production is summarized by commodity in Table 5–51. The acreage referred to in this table must be mineral-bearing.

3.2.3 Mineral Problems

Land-use conflicts involving mineral producers may arise in the vicinity of Flint, Saginaw, Bay City, and Midland as these population centers expand. Proper land use planning that takes into account the mineral needs and supplies of an area can forestall or eliminate conflicts between mineral producers and other land users.

The large number of abandoned, unplugged

TABLE 5–50 Planning Subarea 3.2: Projected Mineral Industry Water Use (millions of gallons per day)

	1968[1]	1980	2000	2020
New Intake				
April–November	3.9	5.5	10.1	19.0
Average for 365 days	2.6	3.7	6.8	12.7
Discharged				
April–November	3.9	5.3	9.8	18.6
Average for 365 days	2.6	3.6	6.6	12.4
Recirculated				
April–November	6.9	14.1	24.2	48.5
Average for 365 days	4.6	7.6	16.2	32.4
Consumed				
April–November	0.0	0.2	0.3	0.4
Average for 365 days	0.0	0.1	0.2	0.3
Total Water[2]				
April–November	10.8	19.6	34.3	67.5
Average for 365 days	7.2	11.3	23.0	45.1

[1]Estimated
[2]Intake plus recirculated

TABLE 5–51 Planning Subarea 3.2: Projected Mineral-Bearing Land Requirements (acres)

Commodity	1968[1]	1980	1968 to 1980[2]	2000	1968 to 2000[2]	2020	1968 to 2020[2]
Clays and shale	3	4	45	7	156	11	335
Peat	843	896	1,071	1,119	1,631	1,493	2,433
Sand and gravel	169	218	2,275	365	8,111	610	17,862
Stone, crushed	8	11	114	18	405	31	892
Stone, dimension	-----[3]	-----[3]	1	-----[3]	4	-----[3]	7
Total	1,023	1,129	3,506	1,509	10,307	2,145	21,529

[1]Estimated
[2]Cumulative
[3]Less than an acre

coal and brine test holes have contributed to the pollution of ground water supplies.

3.2.4 Summary and Conclusions, Including Alternatives

All mineral commodities produced within the planning subarea, with the exception of petroleum and natural gas, exist in quantities large enough to support production activity during the projection period.

Periodic surveys of the water use patterns of the mineral industry are recommended to keep abreast of intake and discharged water use changes.

Section 4

PLAN AREA 4.0

4.1 Planning Subarea 4.1, Lake Erie Northwest

4.1.1 Status and Potential of the Mineral Industry

4.1.1.1 Resume

The mineral commodities produced in the Michigan counties that make up Planning Subarea 4.1 include clay, peat, petroleum and natural gas, salt, sand and gravel, limestone, and dolomite. Output and value of production for 1960 and 1968 are summarized in Table 5-52. Calcium compounds, cement, and lime, included in Table 5-52 for reference only, are manufactured from imported and local mineral materials. From 1960 to 1968, all mineral commodities except peat increased in output and value. The value of mineral products in 1968 was $113,761,834 with salt and sand and gravel each accounting for approximately 22 percent and lime for approximately 14 percent of this value.

A total of 117 nonmetallic mineral operations and 460 oil and gas wells were producing in 1968. All counties except Monroe had producing sand and gravel operations and all counties except Sanilac had producing oil and gas wells. Four counties each had production from clay pits and peat bogs. Salt mines and stone quarries operated in two counties each. Distribution of producing sites by county and type of operation is presented in Table 5-53. Locations of selected operations are shown in Figure 5-10.

4.1.1.2 Resources and Reserves

The sedimentary bedrock formations under Planning Subarea 4.1 are of Paleozoic age. The formations range upward from the Munising Formation of the Cambrian system to the Saginaw Group of the Pennsylvanian system. Bedrock formations yield oil, gas, and salt

TABLE 5-52 Planning Subarea 4.2: Mineral Production, 1960 and 1968[a]

Commodity		1960 Quantity	1960 Dollar Value	1968 Quantity	1968 Dollar Value
Calcium compounds	short tons	----------	----------	W	W
Cement:					
Portland	376-pound barrels	6,730,657	23,394,636	W	W
Masonry	280-pound barrels	W	W	W	W
Clay	short tons	644,306	707,806	1,144,639	1,272,077
Lime	short tons	W	W	1,317,116	15,615,188
Peat	short tons	140,510	2,052,592	W	W
Petroleum	42-gallon barrels	482,500	1,404,070	625,641	1,846,231
Salt	short tons	3,102,514	25,150,398	3,367,324	25,349,600
Sand and gravel	short tons	14,635,686	14,269,175	23,029,000	24,626,000
Stone (crushed and broken)	short tons	1,387,830	1,728,491	W	W
Value of items that cannot be disclosed		----------	12,736,353	----------	45,052,738
Total Planning Subarea 4.1		----------	81,443,521	----------	113,761,834

W Withheld to avoid disclosing individual company confidential data; included with "Value of items that cannot be disclosed."

[a]Excludes data for natural gas and natural-gas liquids, which are not available

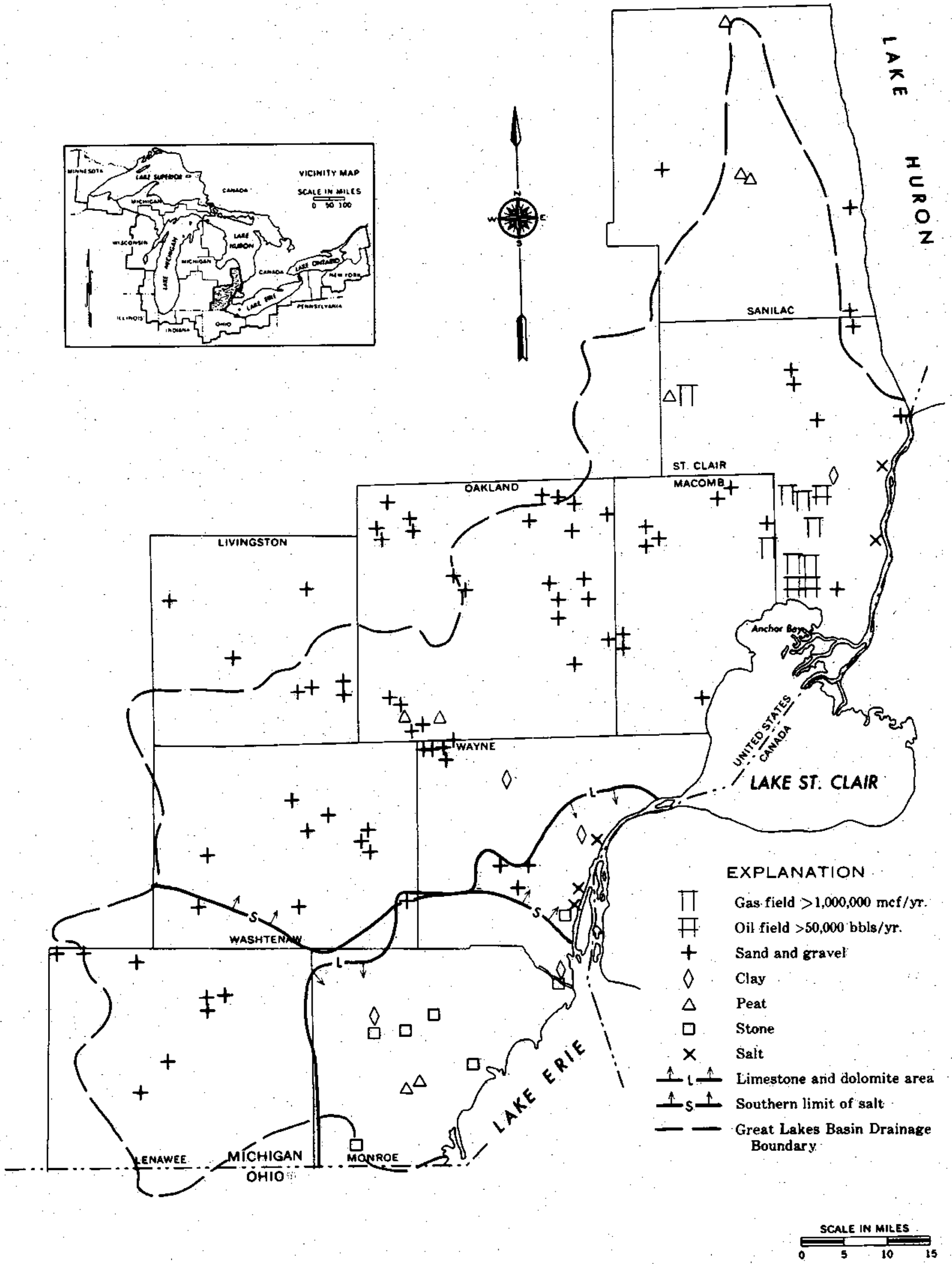

FIGURE 5-10 Planning Subarea 4.1: Distribution of Mineral Operations Active in 1968 and Major Mineral Resource Areas

TABLE 5–53 Planning Subarea 4.1: Active Mineral-Producing Sites by State, County, and Type of Operation, 1968

State County	Clay Pits	Peat Bogs	Salt Mines	Sand and Gravel Pits	Limestone and Dolomite Quarries	Gas Wells	Oil Wells
Michigan							
Lenawee	1	–	–	9	–	70	2
Livingston	–	–	–	8	–	5[a]	1
Macomb	–	–	–	15	–	10	3
Monroe	2	2	–	—	5	---	20
Oakland	–	2	–	24	–	4[a]	4[a]
St. Clair	1	1	2[b]	7	–	80	245
Sanilac	–	3	–	6	–	---	---
Washtenaw	–	–	–	11	–	5[a]	4[a]
Wayne	3	–	3[c]	10	2	3	4
Total	7	8	5	90	7	177[a]	283[a]

[a]Estimated, as oil and gas fields cross county boundaries
[b]Brine well operations
[c]Includes one underground mine, and two brine well operations

from deep wells and stone from surface quarries. Salt is also mined by underground methods in the Detroit area. Overlying the bedrock formations are unconsolidated Quaternary sediments of glacial origin. These sediments, locally attaining a thickness of several hundred feet, contain clay, peat, and sand and gravel deposits mined by surface methods. A generalized stratigraphic succession of Planning Subarea 4.1 is presented in Table 5–54 along with the formation thickness and mineral occurrences.

Petroleum and natural gas are produced principally from the Salina and Niagara Groups of the Silurian system. These strata account for 81 percent of the cumulative oil production and 83 percent of the cumulative gas production.[18] The bulk of remaining production is derived from the Trenton and Black River Groups of the Ordovician system. Proven reserves of oil and gas are sufficient to support current production rates for four or five years. New discoveries, improvements in exploration technology, and the development of workable secondary recovery techniques would increase the reserves. The uncertainty that surrounds discovery of new producing fields makes estimates of this area's petroleum and natural gas industry potentials impossible to determine.

Salt and artificial brines are produced from the rocks of the Salina Group of the Silurian system, which underlie this area at depths between 1,000 and 3,000 feet (Figure 5–10). Accumulations of salt often total as much as 500 feet in this group and provide salt reserves that are enormous in terms of in-place tonnage. Barring unfavorable influences, these reserves are sufficient to support production for many thousands of years.

Crushed stone production is limited to the Dundee limestone and the Detroit River Group of the Devonian system and the Bass Island Group of the Silurian system, which extrude beneath parts of Wayne and Monroe Counties (Figure 5–10). Dundee limestone is of sufficient purity to be used in the manufacture of cement. Less pure limestones and dolomites of the Detroit River and Bass Island Groups are crushed for use as aggregate, ballast, and agricultural lime. The quarrying of stone can take place only where overlying glacial materials are thin enough to permit economical stripping and exposure of the rock. Such occurrences are not numerous and should be preserved for quarrying activity.

TABLE 5-54 Planning Subarea 4.1: General Stratigraphic Succession and Mineral Resources

Era	System	Group	Formation	Thickness, (feet)	Mineral Resources
Cenozoic	Quaternary				Sand, gravel, clay, peat
Paleozoic	Pennsylvanian	Saginaw		0- 50	
	Mississippian		Michigan Fm.	50- 75	
			Marshall Ss.	50- 150	
			Coldwater Sh.	1,000-1,150	Shale
			Sunbury Sh.	50- 400	
			Berea Ss.		
			Bedford Sh.		
	Devonian		Antrim Sh.	100- 250	
		Traverse		90- 690	Oil
			Rogers City Ls.	35- 360	Oil, limestone
			Dundee Ls.		
		Detroit River		200- 900	Gas, limestone, sandstone
			Bois Blanc Fm.	0-6,000	
	Silurian	Bass Islands		400-3,000	Dolomite
		Salina			Salt, oil, gas
		Niagara		100- 475	Oil, gas
		Cataract		100- 160	
	Ordovician	Richmond		575- 825	
		Trenton		650- 900	Oil, gas
		Black River			Oil, gas
			St. Peter Ss.	0- 40	
		Prairie du Chien		200-1,800	
	Cambrian		Trempealeau Fm.	200-1,800	
			Munising Fm.		
Precambrian					

Source: Harry J. Hardenberg, Michigan Geological Survey

Loss of production sites can result in the eventual decline of stone production, even though large tonnages of stone remain in place.

Glacial lake clays, which constitute the area's principal source of clay, are largely confined to the eastern half of the area. No estimate of clay reserves is available. If the known deposits can be mined, sufficient reserves are available to meet demands for the next 50 years. Shale, from bedrock formations in the western two-thirds and northern one-half of the area, may possibly be used as a clay substitute or for lightweight aggregates if the reserves of glacial lake clays should be exhausted. However, except along Lake Huron in the northern part of the planning subarea, the shale is likely to be under too great a drift cover to be worked by surface mining methods. No estimate of reserves of usable shale is available at this time.

The bulk of moss, reed-sedge, and humus peat deposits are found in the northern and western portions of the PSA. Reserves are sufficient to meet the demands of the next 50 years. Accumulations of peat range in depth from a few inches to more than 20 feet. The lateral extent of most deposits is limited. A few large peat bogs currently are being mined in St. Clair and Sanilac Counties. Although these deposits can sustain production for some time, reserves are limited. A decline in production from these deposits can be expected in the future.

Glacial and postglacial features that have potential for sand and gravel deposits predominate in the western half of the area. Sand and gravel may constitute only a small proportion of such features, and the deposits differ considerably in terms of quality. Reserves of sand and gravel are not known, but it is

TABLE 5-55 Planning Subarea 4.1: Projected Mineral Production by Selected Commodities (thousands of short tons)

Commodity	1968[1]	1980	2000	2020	1968 to 2020[2]
Clays and shale	1,145	1,330	2,140	3,430	104,380
Peat	W	130	170	210	8,240
Salt	3,367	4,800	10,200	21,600	515,400
Sand and gravel	23,029	28,580	47,750	79,780	2,336,080
Stone, crushed[3]	W	4,250	6,840	10,980	333,800

[1]Actual
[2]Cumulative
[3]Limestone
W Withheld to avoid disclosing individual company confidential data

reasonable to assume that sufficient material exists to meet the demands during the projection period.

4.1.2 Mineral Industry Projection

4.1.2.1 Production

Mineral production for Planning Subarea 4.1 is summarized for 1968 and projection years 1980, 2000, and 2020 in Table 5-55. With the exception of petroleum and natural gas, all mineral production is expected to increase during this period. Cumulative production over the projection period is also included in the table and provides an estimate of the vast quantities of mineral substances necessary to meet future demands.

TABLE 5-56 Planning Subarea 4.1: Projected Mineral Industry Water Use (millions of gallons per day)

	1968[1]	1980	2000	2020
New Intake				
April-November	59.6	81.2	143.0	239.7
Average for 365 days	41.5	56.6	100.8	171.2
Discharged				
April-November	58.1	79.1	139.3	233.5
Average for 365 days	40.5	55.2	98.3	167.1
Recirculated				
April-November	44.5	64.3	117.5	203.8
Average for 365 days	29.8	43.0	78.7	136.8
Consumed				
April-November	1.5	2.1	3.7	6.2
Average for 365 days	1.0	1.4	2.5	4.1
Total Water[2]				
April-November	104.1	145.5	260.5	443.5
Average for 365 days	71.3	99.6	179.5	308.0

[1]Estimated
[2]Intake plus recirculated

4.1.2.2 Water

Water is used in the primary production of only three mineral commodities here: sand and gravel, salt, and crushed stone. Sand and gravel, generally produced seasonally from April through November, accounts for the bulk of water usage by the mineral industry. Water use patterns in 1968 and for the projection years are presented in Table 5-56 at both the annual and seasonal rate.

4.1.2.3 Land

As mineral substances are removed from the ground and deposits are depleted, new mineral land must be brought into production. Land required to maintain the projected production is summarized by commodity in Table 5-57. The acreage referred to in this table must be mineral-bearing. Because each mineral deposit is unique, other land users should be discouraged from preempting mining activities until after the deposit is mined.

4.1.3 Mineral Problems

Competing land uses have removed large acreages of mineral-bearing land from the resource inventory. One such conflict arises from the growth of major cities such as Detroit, Ann Arbor, and Pontiac, and their suburbs. Land is subdivided and buildings erected with little concern for underlying minerals. A second conflict exists between surface property owners and the underground salt mine and salt-brine well producers in St. Clair and Wayne Counties. Economic exploitation of underground deposits requires that the producer obtain mineral rights, through purchase or lease, to that portion of the bed underlying the surface property. Where the land has been subdivided into small parcels, new mineral rights acquisition must be negotiated with each individual property owner; a time-consuming and often unsuccessful activity.

No serious problem of water supply is foreseen for mineral producers in this planning subarea. Discharge and recirculation practices of the sand and gravel producers can be

TABLE 5–57 Planning Subarea 4.1: Projected Mineral-Bearing Land Requirements (acres)

Commodity	1968[1]	1980	1968 to 1980[2]	2000	1968 to 2000[2]	2020	1968 to 2020[2]
Clays and shale	16	19	210	31	695	49	1,510
Peat	700	950	1,130	1,200	1,755	1,600	2,600
Sand and gravel	211	262	2,838	438	9,732	732	21,538
Stone, crushed	20	25	270	41	932	66	2,000
Total	947	1,256	4,448	1,710	13,114	2,447	27,648

[1]Estimated
[2]Cumulative

expected to change in an effort to eliminate possible pollution or siltation of local water-courses. Abandoned oil and gas wells and salt tests are an ever-present source of pollution. The locations of many early test wells were not recorded, and the wells were not sealed when abandoned. St. Clair County probably contains the largest percentage of unrecorded oil wells. These wells are potential ground-water polluters with oil, gas, or brine fluid seepages. State laws provide for the sealing of modern wells and any abandoned wells that are located. No quick methods for locating abandoned wells have been devised, so no easy solution exists. Sealing of wells can be costly.

4.1.4 Summary and Conclusions, Including Alternatives

All mineral commodities produced within the PSA, with the exception of petroleum and natural gas, exist in quantities large enough to support production activity during the projection period, provided proper measures are taken to locate and protect mineral resources. It is recommended that the location, extent, and evaluation of potential mineral deposits be determined in order that planned development can incorporate mineral extraction. Top priority should be given to Wayne, Oakland, and Macomb Counties, where the bulk of the rapid growth is taking place, and loss of mineral resources is most critical.

Periodic surveys of the water use patterns of the mineral industry are recommended to keep abreast of intake and discharged water use changes. Sand and gravel production is the major water user, and representative surveys of this industry may provide sufficient information that an entire minerals industry survey will not be necessary.

4.2 Planning Subarea 4.2, Lake Erie Southwest

4.2.1 Status and Potential of the Mineral Industry

4.2.1.1 Resume

Mineral commodities produced in Planning Subarea 4.2, composed of 3 counties in Indiana and 20 counties in Ohio, include clay, gypsum, peat, petroleum and natural gas, sand and gravel, and stone (limestone, dolomite, and sandstone). Output and value of production for 1960 and 1968 are summarized in Table 5–58. Cement and lime, manufactured from local stone and clay, are included in the table for reference only. From 1960 to 1968, crushed and broken stone, lime, portlant cement, gypsum, and sand and gravel increased in both output and value. Clay and masonry cement decreased in both areas during this time, while dimension stone and peat increased in value but decreased in output. Mineral pro-

TABLE 5–58 Planning Subarea 4.2: Mineral Production, 1960 and 1968[a]

Commodity		1960 Quantity	1960 Dollar Value	1968 Quantity	1968 Dollar Value
Cement:					
Portland	376-pound barrels	2,882,400	9,840,838	W	W
Masonry	280-pound barrels	W	W	W	W
Clay	short tons	383,470	495,555	356,155	433,117
Gypsum	short tons	W	W	W	W
Lime	short tons	1,794,098	29,118,374	2,072,291	31,193,313
Peat	short tons	1,176	W	574	38,030
Sand and gravel	short tons	2,539,845	2,396,960	3,838,000	4,074,000
Stone (crushed and broken)	short tons	19,911,337	26,752,975	27,511,165	39,988,156
Stone (dimension)	short tons	9,891	23,631	7,657	93,040
Value of items that cannot be disclosed		----------	2,123,615	----------	14,125,953
Total Planning Subarea 4.2		----------	70,751,948	----------	89,945,609

W Withheld to avoid disclosing individual company confidential data; included with "Value of items that cannot be disclosed."

[a]Excludes data for petroleum, natural gas, and natural-gas liquids, which are not available

duction in 1968 was valued at $89,945,609, with crushed and broken stone accounting for 44 percent; lime, 35 percent; and sand and gravel, 5 percent.

A total of 144 mineral operations were active in 1968. All counties, except Fulton County, Ohio, reported nonmetallic production. Limestone and dolomite quarries were active in 17 counties, sand and gravel pits in 16, clay pits in 10, sandstone quarries and peat bogs each in 2 counties, and gypsum mines in one. Although the number and output of oil and natural gas wells are not known, counties that may have had producing wells during 1968 are indicated in Table 5–59, along with a distribution of nonmetallic mining sites by State, county, and type of operation. Locations of selected operations are shown in Figure 5–11.

4.2.1.2 Resources and Reserves

Planning Subarea 4.2 is underlain by sedimentary formations of Paleozoic age. The formations yield oil and gas from wells. An underground mine yields gypsum, and surface quarries yield limestone, dolomite, sandstone, and gypsum. Overlying the Paleozoic formations are unconsolidated glacial sediments of the Quaternary system. These materials, as thick as 400 feet, contain sand and gravel, peat, and clay deposits that are mined by surface methods. A generalized straitigraphic succession of Planning Subarea 4.2 with formation thickness and mineral occurrences is presented in Table 5–60.

Petroleum and natural gas are produced primarily from strata in the Cambrian and Ordovician systems. Large oil-bearing zones within Ordovician strata extend across the area in a general northeast-southwest direction, from Lucas and Ottawa Counties along Lake Erie to Mercer and Auglaize Counties near the Ohio-Indiana border. During the late 1800s, this area had hundreds of producing oil and gas wells, most of which have since been abandoned. Oil and gas production from Cambrian strata has been confined mainly to small areas in Erie and Huron Counties in the eastern part of the PSA. Although oil- and gas-bearing zones are fairly extensive, reserves in the Cambrian and Ordovician systems are believed to be small and the chance of finding large new fields in these strata is believed to be slight.

Gypsum is produced by both underground and surface mining methods near the shore of Sandusky Bay in Ottawa County. It occurs in shallow-lying beds in the Salina Group of the Silurian system. Two beds averaging ap-

TABLE 5–59 Planning Subarea 4.2: Active Mineral-Producing Sites by State, County, and Type of Operation, 1968

State County	Clay and Shale Pits	Gypsum Mines	Peat Bogs	Sand and Gravel Pits	Stone Quarries: Limestone and Dolomite	Stone Quarries: Sand-stone	Gas Wells	Oil Wells
Indiana								
Adams	1	-	-	2	3	-	----	N.A.
Allen	-	-	-	5	4	-	----	----
DeKalb	-	-	-	7	-	-	N.A.	----
Subtotal	1	0	0	14	7	0	N.A.	N.A.
Ohio								
Allen	--	-	-	1	5	-	----	N.A.
Auglaize	1	-	-	8	1	-	N.A.	N.A.
Crawford	--	-	-	1	1	-	----	N.A.
Defiance	--	-	-	1	--	-	----	N.A.
Erie	--	-	-	6	4	2	----	N.A.
Fulton	--	-	-	--	--	-	N.A.	----
Hancock	1	-	-	--	3	-	N.A.	N.A.
Henry	2	-	-	2	--	-	N.A.	----
Huron	--	-	1	5	--	2	N.A.	N.A.
Lucas	1	-	-	4	5	-	----	N.A.
Mercer	--	-	-	--	2	-	N.A.	N.A.
Ottawa	--	2[a]	-	1	4	-	N.A.	N.A.
Paulding	3	-	-	--	3	-	----	N.A.
Putnam	3	-	-	1	3	-	N.A.	N.A.
Sandusky	--	-	-	1	8	-	----	N.A.
Seneca	2	-	-	--	4	-	N.A.	N.A.
Van Wert	1	-	-	--	3	-	N.A.	N.A.
Williams	--	-	-	7	--	-	N.A.	N.A.
Wood	--	-	-	--	6	-	N.A.	N.A.
Wyandot	1	-	1	5	4	-	N.A.	N.A.
Subtotal	15	2	2	43	56	4	N.A.	N.A.
Total	16	2	2	57	63	4	N.A.	N.A.

[a]Includes one quarry and one underground mine
N.A. Not Available

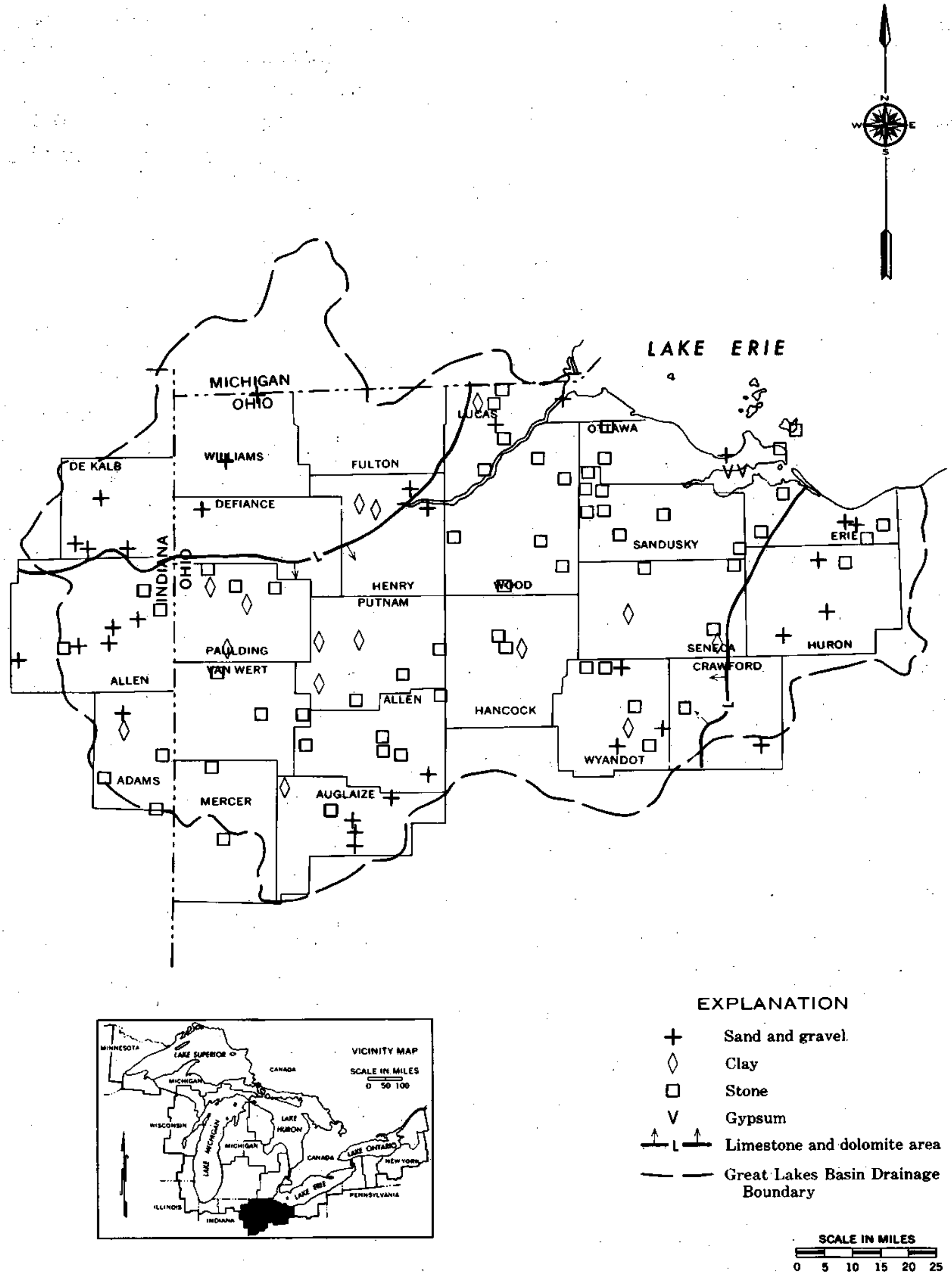

FIGURE 5-11 Planning Subarea 4.2: Distribution of Mineral Operations Active in 1968 and Major Mineral Resource Areas

TABLE 5-60 Planning Subarea 4.2: General Stratigraphic Succession and Mineral Resources

Era	System	Group	Formation	Thickness (feet)	Mineral Resources
Cenozoic	Quaternary			0-400	Sand, gravel, peat, marl, clay
Paleozoic	Mississippian		Berea Ss.[1]	0-40	Sandstone
			Bedford Sh.[1]	0-100	
	Mississippian-Devonian[2]		Ellsworth Sh.	0-340	
	Devonian		Antrim Sh.	0-200	
			Tenmile Creek Dol.[1]	0-50	Dolomite
			Silica Fm.[1]	0-50	Limestone
			Dundee Ls.[1]	0-100	Limestone, dolomite
			Traverse Fm.[2]	0-175	Limestone(p), dolomite(p)
		Detroit River[1]	Detroit River Fm.[2]	0-175	Dolomite(p), limestone(p), gypsum(p)
	Silurian	Bass Islands	Raisin River Dol.[1]	0-500	
		Salina[1]	Salina Fm.[2]		Gypsum[1], dolomite, limestone[2]
		Lockport[1]		200	Dolomite
			Wabash Fm.[2]	0-200	Dolomite
			Louisville Ls.[2]	0-150	Dolomite, limestone
			Waldron Fm.[2]	0-40	Dolomite
			Salamonie Dol.[2]	0-330	Dolomite
	Ordovician				Oil, gas
	Cambrian				Oil[1], gas[1]

[1]In Ohio
[2]In Indiana
(p) Potential Resource
Source: Horace R. Collins, Ohio Division of Geological Survey and Lawrence F. Rooney, Indiana Geological Survey

proximately 10 feet in thickness are being mined. Both are situated above the surface water level of Lake Erie. Although the size of gypsum resources is not known, it is believed that reserves are sufficient to support gypsum production for many years.

An occurrence of evaporite beds, which may contain gypsum, is viewed as a potential gypsum resource in De Kalb County, Indiana. The evaporites occur in the Detroit River rocks, approximately 500 to 600 feet below the surface.[25] These rocks are recognized as a formation in Indiana but as a group in Ohio.

Limestone and dolomite formations of the Silurian and Devonian systems comprise the largest bedrock surface in the planning subarea (Figure 5-11). Production in Indiana is from Silurian strata. The Devonian formations are considered potential sources of both limestone and dolomite. Quarries in the Ohio part of the area produce from both Devonian and Silurian formations. The bulk of the output from this PSA is crushed and broken limestone and dolomite for use as construction aggregate, metallurgical flux, and in the manufacture of lime and cement. Small quantities of dimension limestone are also produced. Reserves of stone are enormous in terms of in-place tonnage. However, much of it is covered by various thicknesses of glacial drift that hamper location of new quarry sites. Overburden thickness and the increasing demands of other land users are expected to result in a trend toward deeper quarries during the projection period.

Minor quantities of sandstone are quarried from the Berea sandstone of the Mississippian system in the eastern part of Erie and Huron Counties. The bulk of the sandstone output is sold as crushed and broken stone, though small quantities of dimension standstone are also produced. Reserves of usable sandstone within the Berea Formation are large.

Sand and gravel deposits are found in glacial and postglacial sediments, which cover the entire PSA including the bed of Lake Erie. Production methods include dredging of submerged deposits, as in the Maumee Estuary, which constitutes an important source of sand and gravel in this part of Ohio. Output is used mainly in building and road construction. Although the full extent of the sand and gravel resource of Planning Subarea 4.2 is not known, reserves are believed to be many times in excess of that needed to support production through the projection period.

Clay and peat deposits are also found in the blanket of glacial sediments covering the PSA. The clay is used in the manufacture of cement and common clay products. Peat is used primarily for soil improvement. Clay and peat production is relatively insignificant compared to the size of these resources within the planning subarea.

4.2.2 Mineral Industry Projection

4.2.2.1 Production

Mineral production for Planning Subarea 4.2 is summarized for 1968 and the projection years 1980, 2000, and 2020 in Table 5–61. Sand and gravel, clay, and crushed stone production is expected to increase during this period, but petroleum and natural gas production will probably cease.

4.2.2.2 Water

Water is used in primary production of crushed stone, sand and gravel, and gypsum. Stone and sand and gravel producers, who operate on a seasonal basis, account for most of the water usage. Water use patterns for 1968 and the projection years are presented in Table 5–62 at both annual and seasonal rates.

TABLE 5–61 Planning Subarea 4.2: Projected Mineral Production by Selected Commodities (thousands of short tons)

Commodity	1968[1]	1980	2000	2020	1968 to 2020[2]
Clay	356	470	750	1,200	36,620
Sand and gravel	3,838	4,760	7,960	13,300	389,360
Stone, crushed[3]	27,511	36,740	61,390	102,600	2,997,640

[1] Actual
[2] Cumulative
[3] Includes limestone and sandstone

4.2.2.3 Land

Mineral-bearing land required to maintain projected mineral production is summarized in Table 5–63. In the case of crushed stone, acreage estimates reflect the anticipated trend toward deeper quarries during the projection period. An average quarry depth of 50 feet was used to calculate the acreage requirement for the 1968 to 1980 period, 100 feet for the 1980 to 2000 period, and 150 feet for the 2000 to 2020 period. This accounts for the decline in annual acreage requirements from 221 in 1980 to 185 in 2000, while annual production is projected to increase from 36,740,000 tons to 61,390,000 tons during the same period. Should the trend toward deeper quarries fail to materialize and the current average quarry depth of approximately 50 feet be maintained through the entire projection period, an additional 10,000 acres of quarry land will be required to sustain stone production through the year 2020.

In addition to land areas, the projected sand and gravel acreage estimates include water areas mined by dredging. Although no estimate of the acreage conducive to dredging is available, it is likely that principal dredging

TABLE 5–62 Planning Subarea 4.2: Projected Mineral Industry Water Use (millions of gallons per day)

	1968[1]	1980	2000	2020
New Intake				
April–November	22.1	30.8	51.7	81.6
Average for 365 days	20.3	27.9	45.9	70.3
Discharged				
April–November	21.2	29.5	49.3	75.5
Average for 365 days	19.4	26.7	43.7	66.5
Recirculated				
April–November	7.3	9.9	20.1	39.8
Average for 365 days	6.1	8.2	16.7	33.6
Consumed				
April–November	0.9	1.3	2.4	6.1
Average for 365 days	0.9	1.2	2.2	3.8
Total Water[2]				
April–November	29.4	40.7	71.8	121.4
Average for 365 days	26.4	36.1	62.6	103.9

[1] Estimated
[2] Intake plus recirculated

TABLE 5–63 Planning Subarea 4.2: Projected Mineral-Bearing Land Requirements (acres)

Commodity	1968[1]	1980	1968 to 1980[2]	2000	1968 to 2000[2]	2020	1968 to 2020[2]
Clays and shale	18	27	281	43	978	69	2,093
Gypsum	11	15	161	20	503	26	964
Sand and gravel	78	97	1,005	161	4,026	270	7,898
Stone, crushed	168	221	2,268	185	5,226	206	8,516
Stone, dimension	---[3]	---[3]	-----[3]	---[3]	1	---[3]	2
Total	275	360	3,715	409	10,734	571	19,473

[1]Estimated
[2]Cumulative
[3]Less than an acre

operations will take place in the Maumee Estuary and offshore in Lake Erie.

4.2.3 Mineral Problems

Oil and gas seepage from unplugged abandoned wells into surface and ground water supplies has long been a pollution problem, particularly in the Ohio part of the area. Records of these old wells are practically nonexistent. No easy methods for locating abondoned wells have been devised, so no quick solution to the problem exists.

Although competing land uses have removed large acreages of mineral-bearing land from the resource inventory, the problem has not yet seriously jeopardized future supply of minerals within the PSA. Unless proper mineral conservation measures are adopted, population growth and increasing land use demands can be expected to affect the planning subarea's mineral production potential by the end of the projection period.

4.2.4 Summary and Conclusions, Including Alternatives

Sufficient reserves of clay, stone, and sand and gravel exist in the area to support mineral activity many times in excess of that projected to 2020. The extent of the gypsum resource is not known, by gypsum production is expected to continue for many years. Petroleum and natural gas production should cease well before the year 2000.

Planning measures to locate valuable mineral-bearing lands and preserve them from other land uses are recommended particularly in those areas that will be affected by urban expansion. The Fort Wayne and Toledo areas should be given first priority in mineral resource planning. Resource planning for the Maumee Estuary and resource areas in and near Lake Erie should also receive early consideration.

Periodic surveys of water use patterns of the mineral industry are also recommended to keep abreast of intake and discharged water use changes.

4.3 Planning Subarea 4.3 Lake Erie Central

4.3.1 Status and Potential of the Mineral Industry

4.3.1.1 Resume

Clay and shale, peat, petroleum and natural gas, salt, sand and gravel, and stone (limestone and sandstone) are produced in the

TABLE 5–64 Planning Subarea 4.3: Mineral Production, 1960 and 1968[a]

Commodity		1960 Quantity	1960 Dollar Value	1968 Quantity	1968 Dollar Value
Cement:					
Portland	376-pound barrels	W	W	W	W
Masonry	280-pound barrels	W	W	W	W
Clay and shale	short tons	684,933	826,932	485,519	1,063,004
Coal, bituminous	short tons	84,331	318,328	---------	----------
Grindstones	short tons	W	W	W	W
Lime	short tons	1,137,231	12,965,088	1,454,330	15,962,522
Peat	short tons	W	W	W	W
Salt	short tons	W	W	W	W
Sand and gravel	short tons	6,554,658	8,197,001	W	W
Stone (crushed and broken)	short tons	1,707,816	5,753,430	1,682,084	5,098,660
Stone (dimension)	short tons	W	W	W	W
Value of items that cannot be disclosed		---------	28,800,503	---------	48,136,448
Total Planning Subarea 4.3		---------	56,861,282	---------	70,260,634

W Withheld to avoid disclosing individual company confidential data; included with "Value of items that cannot be disclosed."

[a]Excludes data for petroleum, natural gas, and natural-gas liquids, which are not available

eight Ohio counties that make up Planning Subarea 4.3. Output and value of mineral products for 1960 and 1968 are summarized in Table 5–64. Lime, cement, and grindstones, included in Table 5–64 for reference only, are manufactured from both local and imported mineral materials. From 1960 to 1968, the output and value of sand and gravel, salt, and lime increased while stone, peat, and cement decreased in both areas and coal production was discontinued. Grindstones, clay, and shale decreased in output and increased in value during this time. The value of mineral products in 1968 was $70,260,634. Of this value, lime accounted for 23 percent; crushed and broken stone, 7 percent; and clay and shale, 2 percent.

A total of 103 nonmetallic mineral operations were active in 1968. The number of producing oil and gas wells in the area is not known. All counties had production from sand and gravel pits and gas wells. Sandstone quarries were active in five counties, salt mines, shale pits, and oil wells in three each, peat bogs in two, and a limestone quarry and a clay pit in one county each. A breakdown of producing sites by county and type of operation is presented in Table 5–65. Selected operations are shown in Figure 5–12.

4.3.1.2 Resources and Reserves

Planning Subarea 4.3 is underlain by Paleozoic sedimentary formations which yield oil, gas, and salt from deep wells, salt and limestone from underground mines, and sandstone, shale, and clay from surface quarries and pits. Overlying the bedrock formations are unconsolidated glacial sediments of the Quaternary system. These sediments locally are as thick as 300 feet and contain sand, gravel, peat, and clay deposits that are mined by surface methods. The generalized stratigraphic succession of Planning Subarea 4.3 is presented in Table 5–66 along with formation thickness and mineral occurrences.

Salt is produced from rocks of the Salina Group of the Silurian system. Except for the western half of Lorain County, the area is underlain by one or more beds of Salina salt. Depth to these salt beds increases from approximately 1,300 feet in Lorain County to a maximum of approximately 2,750 feet in the southern part of Summit County.[21]

The combined thickness of these beds exceeds 300 feet in parts of Summit and Portage Counties. In terms of in-place tonnage, reserves of salt measure in the hundreds of billions of tons. In addition, salt can be extracted

TABLE 5-65 Planning Subarea 4.3: Active Mineral-Producing Sites by State, County, and Type of Operation, 1968

State County	Shale Pits	Peat Bogs	Salt Mines	Sand and Gravel Pits	Stone Quarries Lime-stone	Stone Quarries Sand-stone	Gas Wells	Oil Wells
Ohio								
Ashtabula	-	-	-	6	-	--	N.A.	----
Cuyahoga	5	1	1[a]	7	-	--	N.A.	----
Geauga	-	-	-	9	-	2	N.A.	----
Lake	-	-	2[b]	5	-	1	N.A.	----
Lorain	-	-	-	3	-	2	N.A.	N.A.
Medina	1[c]	-	-	7	-	--	N.A.	N.A.
Portage	-	1	-	24	-	2	N.A.	N.A.
Summit	1	-	2[d]	16	1[e]	3	N.A.	----
Total	7	2	5	77	1	10	N.A.	N.A.

[a]Underground mine
[b]Includes one underground mine and one brine well operation
[c]Clay and shale
[d]Brine well operations
[e]Underground quarry
N.A. Not Available

TABLE 5-66 Planning Subarea 4.3: General Stratigraphic Succession and Mineral Resources

Era	System	Group	Formation	Thickness (feet)	Mineral Resources
Cenozoic	Quaternary			0-300	Sand, gravel, peat, clay
Paleozoic	Pennsylvanian	Pottsville		0-150	Coal, clay, shale, conglomerate
	Mississippian		Cuyahoga Fm.	0-425	
			Berea Ss.	0-150	Oil, gas, sandstone, brine
			Bedford Sh.	0-100	Shale
	Devonian		Ohio Sh.	350-1500	Shale, gas
			Delaware Ls.	0-50	Brine
			Columbus Ls.	175	Limestone, brine
			Oriskany Ss.	0-70	Oil, gas, brine
	Silurian	Bass Islands	Raisin River Fm.	0-250	
		Salina		0-1250	Salt
		Lockport		475	
			Clinton Fm.	250	Gas
		Albion	Medina Ss.	250	Oil, gas
	Ordovician				
	Cambrian				Oil, gas (p)
Precambrian					

(p) Potential Resource
Source: Horace R. Collins, Ohio Division of Geological Survey

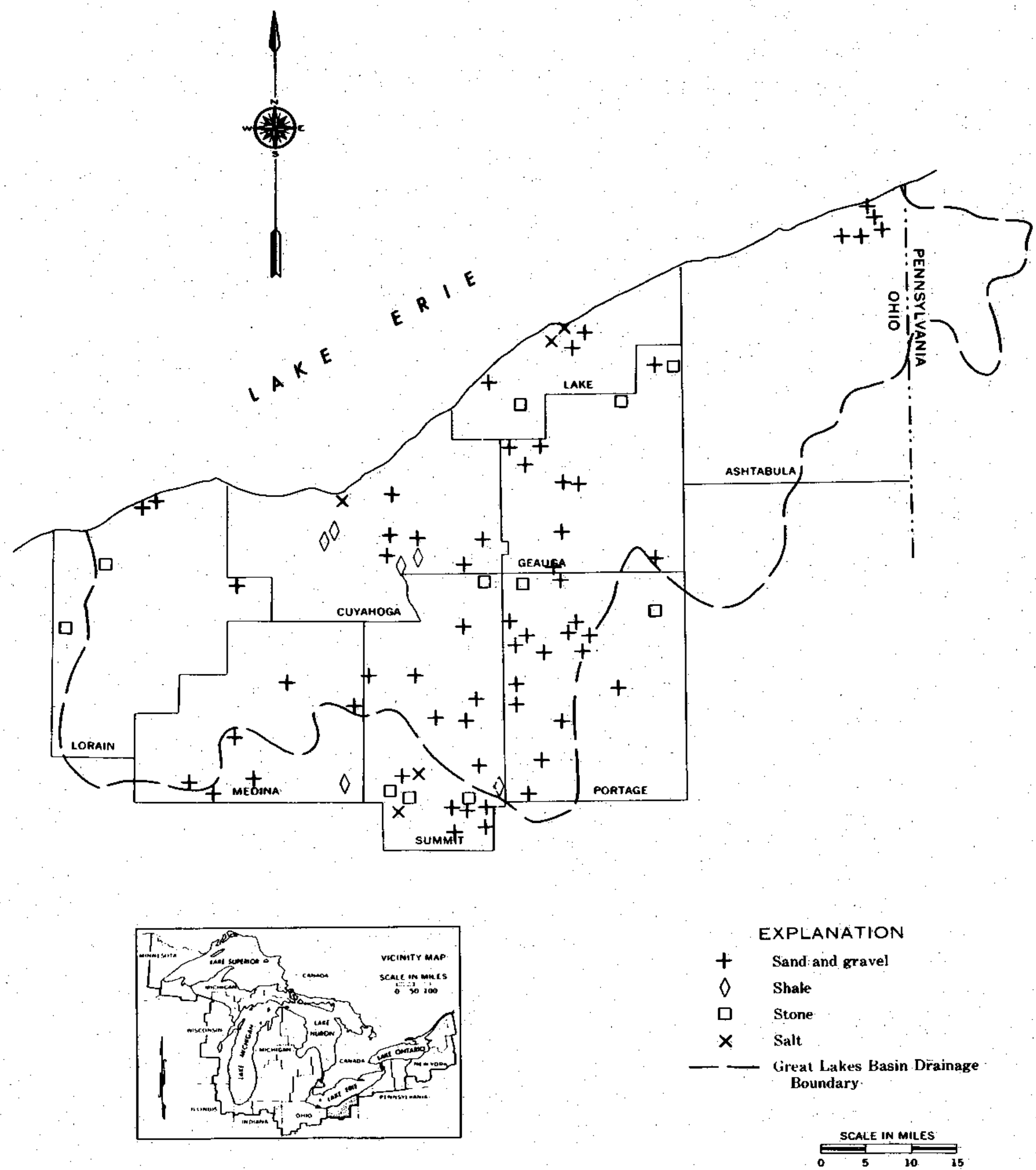

FIGURE 5–12 Planning Subarea 4.3: Distribution of Mineral Operations Active in 1968

from the natural brines that occur in a number of formations overlying the salt beds. Reserves of salt and brine are sufficient to support salt production in the PSA for many thousands of years.

Petroleum and natural gas are produced from the Berea and Oriskany sandstones of the Devonian system and the Clinton Formation of the Silurian system. Gas-bearing zones within these formations underlie large parts of the area. The bulk of land underlain by oil-bearing zones is found in Medina County. Reserves in the Silurian and Devonian systems are believed to be small. Chances of finding extensive new fields are believed to be slight, but the search for new reserves in these strata has expanded to include areas offshore in Lake Erie. The deeper Cambrian strata, which yield oil and gas to the south of the planning subarea, remain to be fully tested in this part of Ohio.

Limestone is quarried by underground methods from the Columbus limestone of the Devonian system. The formation is part of a thick sequence of limestone and dolomite strata called "Big Lime," which lies more than 200 feet below the surface and extends under the entire PSA. Most of the quarried stone is used in the manufacture of cement near the quarry site. Some of the stone is also marketed as aggregate and dimension stone. Reserves of usable limestone are believed to be very large.

Planning Subarea 4.3 accounts for an appreciable share of Ohio's sandstone production. Lorain County leads the State in dimension sandstone output and Geauga County leads in production of crushed sandstone. The source of the dimension stone is the Berea sandstone of Mississippian age, which is exposed at scattered locations in the western part of the area. Stone from this formation is also used in the manufacture of grindstones and in crushed form as aggregate. Most of the sandstone production in the southern and eastern parts of the planning subarea is from a conglomerate formation in the Pennsylvanian system. The formation, which extrudes extensively in Geauga, Portage, Summit, and Medina Counties, is exceptionally pure, with a silicon dioxide content of more than 96 percent.[12] Because of its purity, the stone is quarried for many uses besides that of aggregate including refractory quartzite, foundry sand, fire and furnace sand, metallurgical pebble, engine sand, blast sand, filler, and glass sand. Reserves of sandstone in both the Berea and the conglomerate formation are sufficient to support production many times in excess of that projected for the next 50 years.

The most accessible and abundant resources in Planning Subarea 4.3 are shale and clay. Shale formations of the Devonian, Mississippian, and Pennsylvanian systems make up the major rock outcrops, for example in the cliffs along Lake Erie. Principal production is from the Ohio and Bedford shales of the Devonian and Mississippian systems respectively. In addition to clay products, the Bedford shale is also used in the manufacture of lightweight aggregate. Clay, found in the Pennsylvanian coal formation, forms the bulk of the material in the glacial drift. Only the Pennsylvanian formation clays are used to manufacture common clay products. The products made from the glacial clays are generally of low quality. Reserves of shale and clay for production of common clay products are inexhaustible.

Coal-bearing rocks of the Pennsylvanian system underlie nearly all of Portage County and parts of Geauga, Lake, Cuyahoga, Summit, and Medina Counties. Only the southern half of Portage County and the southeastern part of Summit County are underlain by coal seams of any appreciable thickness. Previous coal mining within the area was confined to stripping operations in a small part of southern Portage County. Two seams were mined, averaging approximately 24 and 18 inches in thickness. Although a significant tonnage of coal remains, it is doubtful that mining will be resumed because the beds are thin.

Sand and gravel deposits are widely scattered within the area including the bed of Lake Erie. The full extent of the occurrence of these deposits and their size and quality are not well known. Since land-based sand and gravel operations generally require considerable surface area, there can be no doubt that widespread urban development in this part of Ohio is threatening availability of the greater part of the sand and gravel resources.

Workable peat deposits are largely confined to Medina, Summit, Portage, Geauga, and Ashtabula Counties. Some of the deposits cover several hundred acres, with thicknesses varying to approximately 15 feet. The larger bogs with the best quality peat are found in Portage and Summit Counties. Peat reserves are sufficient for the needs of the planning subarea during the projection period.

TABLE 5–67 Planning Subarea 4.3: Projected Mineral Production by Selected Commodities (thousands of short tons)

Commodity	1968[1]	1980	2000	2020	1968 to 2020[2]
Clays and shale	486	660	1,070	1,700	51,960
Salt	W	7,900	17,000	36,600	862,400
Sand and gravel	W	9,400	17,300	31,800	853,400
Stone, crushed[3]	1,682	2,180	3,600	6,100	177,480

[1]Actual
[2]Cumulative
[3]Includes limestone and sandstone
W Withheld to avoid disclosing individual company confidential data

4.3.2 Mineral Industry Projection

4.3.2.1 Production

Projected mineral production for Planning Subarea 4.3 is summarized in Table 5–67. With the exception of petroleum, natural gas, and dimension stone, all mineral production is expected to increase significantly during the next 50 years.

4.3.2.2 Water

Water is used in the primary production of salt and sand and gravel. Salt producers who operate throughout the year account for the bulk of new water intake and consumed water. Sand and gravel producers operate seasonally, and account for most of the water that is discharged and recirculated. Water use patterns in 1968 and for the projected years are presented in Table 5–68 at both annual and seasonal rates.

The petroleum industry uses water to increase the recovery of petroleum in the Berea sandstone in Medina County. Brackish water from a shallow formation is pumped to the surface and then repumped into the oil-producing zones. The amount of water used and the quantities that may be required for future secondary recovery projects in the area are not known.

4.3.2.3 Land

The mineral-bearing land required to maintain projected mineral production is summarized in Table 5–69. Since output from such land can vary over wide limits, depending on the quality of the deposits, planners should consider the benefits of sequential land use and permit mining interests to excavate high quality mineral deposits before other land use projects are initiated. This is particularly important for sand and gravel resources in the area.

4.3.3 Mineral Problems

The loss of sand and gravel resources to urban expansion in and around the sprawling Cleveland metropolitan area has been recognized as a major problem for a number of years.

Another problem in the Cleveland area is the locations of oil and gas wells abandoned years ago before plugging operations were required. Over the years seeping gas from unplugged wells has contaminated surface water supplies and caused explosions and fires in a number of dwellings and buildings in the area. No easy methods for locating abandoned wells have been devised, and thus there is no quick solution to the problem.

Local problems have resulted from careless practices in the exploring, drilling, and operation of oil, gas, and brine wells. Improper drilling procedures have on occasion resulted in surface pollution from salt water spills. Un-

TABLE 5–68 Planning Subarea 4.3: Projected Mineral Industry Water Use (millions of gallons per day)

	1968[1]	1980	2000	2020
New Intake				
April–November	24.3	38.7	77.4	152.4
Average for 365 days	20.7	31.8	64.7	129.6
Discharged				
April–November	14.4	23.6	45.4	83.4
Average for 365 days	11.0	17.0	33.0	61.4
Recirculated				
April–November	8.0	13.6	27.4	55.6
Average for 365 days	5.8	10.4	21.2	43.3
Consumed				
April–November	9.9	15.1	32.0	69.0
Average for 365 days	9.7	14.8	31.7	68.2
Total Water[2]				
April–November	32.3	52.3	104.8	208.0
Average for 365 days	26.5	42.2	85.9	172.9

[1]Estimated
[2]Intake plus recirculated

TABLE 5–69 Planning Subarea 4.3: Projected Mineral-Bearing Land Requirements (acres)

Commodity	1968[1]	1980	1968 to 1980[2]	2000	1968 to 2000[2]	2020	1968 to 2020[2]
Clays and shale	7	9	99	15	347	24	742
Sand and gravel	167	216	2,188	397	8,312	729	19,573
Stone, crushed	11	15	154	24	546	41	1,203
Stone, dimension	---[3]	---[3]	3	---[3]	8	1	16
Total	185	240	2,444	436	9,213	795	21,534

[1]Estimated
[2]Cumulative
[3]Less than an acre

plugged seismic shot holes are believed to have allowed salt water to contaminate ground water. Such incidents have caused public concern over the more recent offshore drilling activities in Lake Erie. The matter remains a subject of considerable controversy in Pennsylvania, New York, and Ontario, Canada, as well as in Ohio. Although contamination problems are not insurmountable, public concern over the matter should be recognized.

Appendix F20, *Federal Laws, Policies, and Institutional Arrangements*, and Appendix S20, *State Laws, Policies, and Institutional Arrangements*, provide information on the degree of public control over the problems mentioned above.

4.3.4 Summary and Conclusions, Including Alternatives

Reserves of all mineral commodities produced within the area, with the possible exception of petroleum and natural gas, exist in large enough quantities to support production activity in excess of that projected to 2020. However, sand and gravel supply problems will become serious if proper conservation measures are not undertaken within the near future. It is recommended that planning measures be devised to locate and protect high quality sand and gravel deposits, particularly in and around the Cleveland metropolitan area.

Periodic surveys of the water use patterns of the salt and sand and gravel industries are also recommended to keep abreast of intake and discharged water use changes.

4.4 Planning Subarea 4.4, Lake Erie East

4.4.1 Status and Potential of the Mineral Industry

4.4.1.1 Resume

The one Pennsylvania and four New York counties that form Planning Subarea 4.4 produce clay, shale, gypsum, peat, petroleum and natural gas, sand and gravel, and stone (limestone and dolomite). Output and value of these products for 1960 and 1968 are summarized in Table 5–70. Cement and lime, which are manufactured from imported limestone, are included in the table for reference only. From 1960 to 1968, the output and value of sand and gravel, peat, and lime increased while that for clay and shale, gypsum, cement, and crushed and broken stone decreased. Dimension limestone production, which began in 1967, was relatively insignificant. The value of mineral products in 1968 was $23,634,384. Of

TABLE 5–70 Planning Subarea 4.4: Mineral Production, 1960 and 1968[a]

Commodity		1960 Quantity	1960 Dollar Value	1968 Quantity	1968 Dollar Value
Cement:					
Portland	376-pound barrels	W	W	W	W
Masonry	280-pound barrels	W	W	---------	---------
Clay and shale	short tons	344,332	351,482	198,813	191,165
Gypsum	short tons	W	W	W	W
Lime	short tons	W	W	W	W
Peat	short tons	W	W	W	W
Sand and gravel	short tons	2,616,095	3,570,343	5,791,000	7,611,000
Stone (crushed and broken)	short tons	8,469,219	11,620,608	3,396,687	6,076,760
Stone (dimension)	short tons	---------	---------	W	W
Value of items that cannot be disclosed		---------	18,280,559	---------	9,755,423
Total Planning Subarea 4.4		---------	33,822,992	---------	23,634,348

W Withheld to avoid disclosing individual company confidential data; included with "Value of items that cannot be disclosed."

[a]Excludes data for petroleum, natural gas, and natural-gas liquids, which are not available

this amount, sand and gravel accounted for 32 percent; crushed and broken stone, 26 percent; and clay and shale, approximately one percent.

A total of 48 nonmetallic mineral operations and an estimated 2,930 oil and gas wells were producing in 1968. All of the counties had sand and gravel pits, while three counties had gas wells, two each had stone quarries and peat bogs, and one county had producing oil wells. Erie County, New York, the only county with shale and gypsum operations, led in the number of nonmetallic mineral operations. A breakdown of producing sites by county and type of operation is presented in Table 5–71. Selected operations are shown in Figure 5–13.

4.4.1.2 Resources and Reserves

Sedimentary formations in Planning Subarea 4.4 range upward from the Cambrian to the Devonian systems of Paleozoic age. Structurally, the beds dip and thicken across the area from north to south. Oil and gas are pumped from both shallow and deep-lying formations. Gypsum is mined in shallow underground workings, while limestone and shale are extracted from surface quarries and pits. Overlying most of the bedrock formations are unconsolidated Quaternary sediments of glacial origin. These contain sand and gravel, clay, and peat deposits that are mined by surface methods. A generalized stratigraphic succession of Planning Subarea 4.4 is presented in Table 5–72, along with formation thickness and mineral occurrences.

Natural gas is produced principally from sandstone formations in the Medina Group of the Silurian system. Some gas is also produced for domestic use from shallow shale formations in the Devonian system. Numerous gas-bearing zones or fields have been found but a large number have been abandoned or converted to storage reservoirs for imported gas. Gas reserves are small and considered relatively insignificant compared to the demand for gas. Currently, the search for new reserves in the Lake Erie basin has been expanded to include areas offshore in Lake Erie.

Petroleum is produced in the southern part of Cattaraugus County. Production is from several sand lenses in upper Devonian strata with the Bradford and Chipmunk sands being the main producers. These sands are believed to be nearly exhausted after many years of declining output. The chances for new petroleum field discoveries in the planning subarea are considered small.

Gypsum is mined underground from the

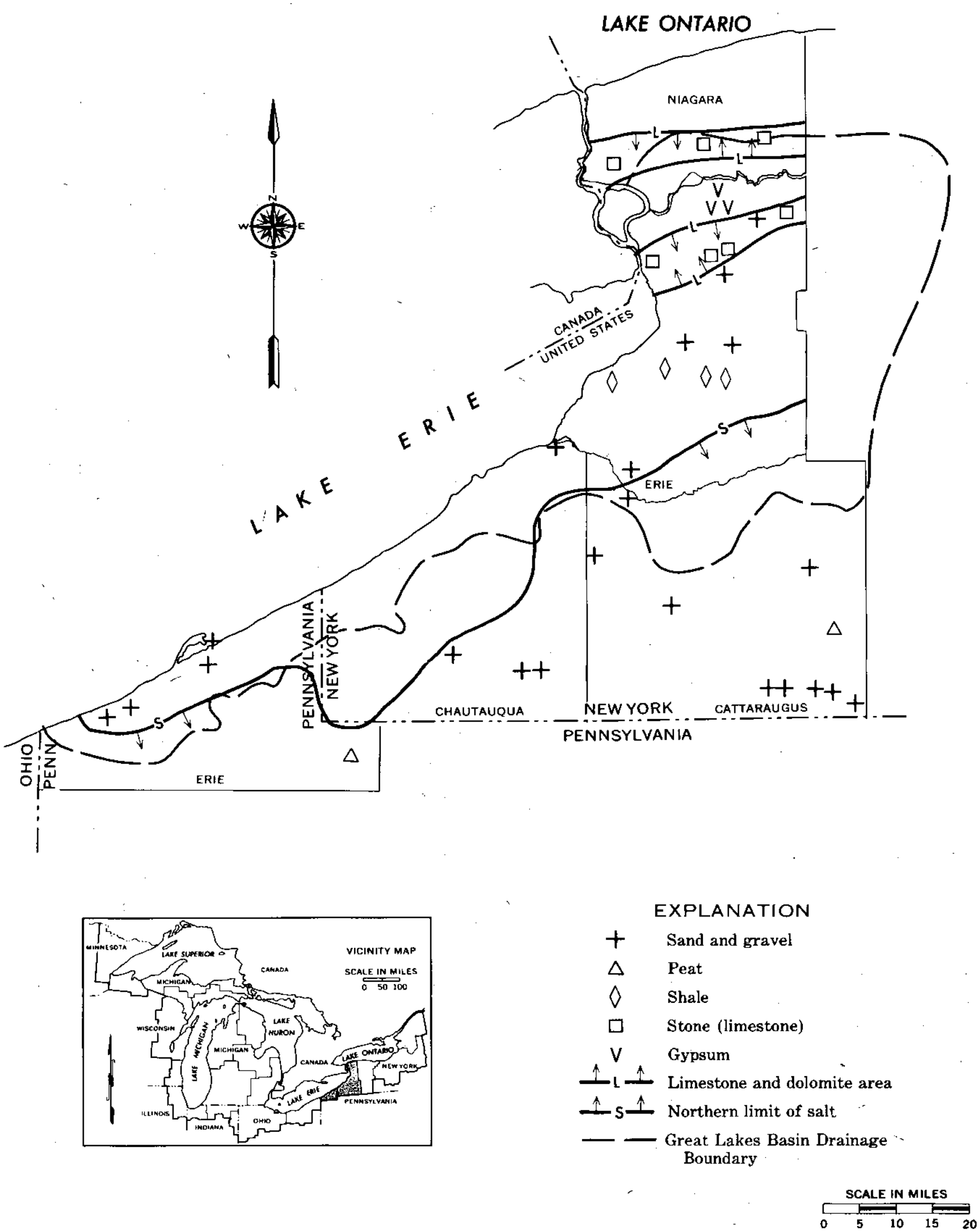

FIGURE 5–13 Planning Subarea 4.4: Distribution of Mineral Operations Active in 1968 and Major Mineral Resource Areas

TABLE 5–71 Planning Subarea 4.4: Active Mineral-Producing Sites by State, County, and Type of Operation, 1968

State County	Clay and Shale Pits	Gypsum Mines	Peat Bogs	Sand and Gravel Pits	Limestone and Dolomite Quarries	Gas Wells[a]	Oil Wells[a]
Pennsylvania							
Erie	-	-	1	6	-	300	-----
New York							
Cattaraugus	-	-	1	12	-	30	2,000
Chautauqua	-	-	-	5	-	---	-----
Erie	5	3[b]	-	7	4	600	-----
Niagara	-	-	-	1	3	---	-----
Subtotal	5	3	1	25	7	630	2,000
Total	5	3	2	31	7	930	2,000

[a]Estimated
[b]Underground mines

Salina Group of the Silurian system. The gypsum-bearing strata form a belt extending across the northern part of Erie County, New York. This belt ranges in width from a few hundred to several thousand feet, and is largely covered by glacial drift. Gypsum deposits within the belt average 4 to 6 feet in thickness and are limited in depth to approximately 250 feet. Below that depth the gypsum grades into anhydrite, which is of no commercial value at present. Although the size of the gypsum resource is not known, it is believed that reserves are sufficient to support increasing gypsum production during the projection period.

Salt, which also occurs in strata of the Salina Group, underlies the southern part of the area (Figure 5–13). Depth to the salt beds ranges from approximately 800 to 2,500 feet below sea level. The maximum thickness of salt beds, approximately 300 feet, occurs in the southern part of Cattaraugus County, where they are also found at the greatest depth. Reserves of salt are sufficient to support large-scale mining. The outlook for initiating salt mining in the area is uncertain, however, because of the availability of salt from other nearby areas.

Two parallel limestone and dolomite belts cross the northern part of the PSA (Figure 5–13). The northernmost belt, located in Niagara County, consists of strata of the Clinton and Guelph-Lockport Groups of the Silurian system. The belt in Erie County to the south contains the Onondaga Formation of the Devonian system. Stone quarried from both belts is used primarily for aggregate. Smaller quantities are used for railroad ballast, agricultural stone, metallurgical flux, and other purposes. Usable stone reserves in both belts are believed to be very large.

Clay and shale are mined in Erie County, New York, for use in the manufacture of cement, lightweight aggregate, building brick, flowerpots, and other common clay products. The clay occurs in the glacial sediments of the Quaternary system, and is found throughout the area in deposits ranging from less than one foot to more than 60 feet thick. Shale constitutes much of the bedrock underlying the glacial drift. The most important shale mined for clay product manufacture has been the Hamilton Group of the Devonian system, which forms an east-west trending belt across the central part of Erie County. Clay and shale reserves are extremely large. Their utility for the manufacture of various clay products is a matter for local investigation and testing.

Sand and gravel deposits are found in the glacial and postglacial sediments that cover the entire PSA. Good-quality deposits are fairly well distributed on land and offshore in

TABLE 5–72 Planning Subarea 4.4: General Stratigraphic Succession and Mineral Resources

Era	System	Group	Formation	Thickness (feet)	Mineral Resources
Cenozoic	Quaternary			0- 100+	Sand, gravel, peat, marl, clay
Paleozoic	Devonian	Conewango[1]		500- 600	
		Conneaut[1]	Chadakoin Fm.	350- 400	Oil
		Canadaway		1,000-1,200	Sandstone
		Java		100- 120	
		West Falls		415- 475	Gas
		Sonyea		45- 100	Gas
		Genesee		10- 50	
			Tully Ls.	(0- 30)	Gas (in subsurface)
		Hamilton*		120- 300	Gas, shale
			Onondaga Ls.[1]	150	Limestone, oil
			Springvale Ss.[1]	0- 10	
			Oriskany Fm.[1,2]	0- 20	Oil (in subsurface)
		Helderberg[1]		(0- 50)	Limestone (in subsurface)
	Silurian	Bass Islands[2]		74	Oil
		Bertie[1]	Akron Dol.[1]	(0- 45)	
		Salina	Camillus Sh.		Gypsum (subsurface)
			Syracuse Fm.	700- 800	Salt
			Vernon Sh.		
		Guelph-Lockport[2]	Lockport Dol.[1,2]	250	Dolomite
		Clinton*		110	Gas
	Ordovician	Medina*		150	Gas
			Queenston Sh.	1,000	
			Oswego Ss.[1]	(70- 100)	
			Reedsville Sh.[2]	565	
			Lorraine Sh.[1]	850	
		Trenton shale	Utica Sh.[1,2]		
		Trenton Limestone*		(300- 600)	
		Black River[1]		(200- 300)	(subsurface)
	Cambrian		Little Falls Dol.	(0- 100)	(subsurface)
			Theresa Dol.	(0- 700)	
			Potsdam Ss.	(0- 180)	(subsurface)
Precambrian					(subsurface)

[1]In New York
[2]In Pennsylvania

*Subdivisions not included in this report
()Thickness for unit which is not exposed at surface

Source: James F. Davis, New York State Geological Survey and reference 29

Lake Erie. Although the full extent of the resource is not known, there appears to be no shortage of sand and gravel reserves. Supply problems may develop in the vicinity of expanding communities because sand and gravel-bearing lands are usually areas of good drainage, which are zoned for building construction and other uses excluding mining.

Peat deposits are widespread throughout the area. It has been stated that it would be difficult to find a spot in the entire State of New York that is more than 10 miles from a peat swamp.[15] Though the size of the peat resource in the New York portion of the Planning Subarea is quite large, it has not been measured. Reserves in Erie County, Pennsylvania, are more than 3 million cubic yards at deposits currently being mined. Reserves at other bogs in the county probably total more.[31] At the current rate of production, the reserves in Erie County alone could supply all the area's demand for peat for hundreds of years.

Other resources that were used extensively in the past include sandstone and marl. A considerable tonnage of sandstone from Devonian formations was quarried for building stone in Erie County, Pennsylvania, where more than 40 quarries were active at the turn of the century.[31] Marl, which occurs in the glacial sediments, was used extensively for the manufacture of cement in New York. Although both resources are plentiful, neither is expected to be mined during the projection period because of the availability of substitute materials at lower cost.

4.4.2 Mineral Industry Projection

4.4.2.1 Production

Projected mineral production for Planning Subarea 4.4 is summarized in Table 5–73. With the exception of petroleum, all mineral production is expected to increase during the projection period.

TABLE 5–73 Planning Subarea 4.4: Projected Mineral Production by Selected Commodities (thousands of short tons)

Commodity	1968[1]	1980	2000	2020	1968 to 2020[2]
Clays and shale	199	270	430	690	21,020
Sand and gravel	5,791	7,200	13,280	24,460	655,400
Stone, crushed[3]	3,397	4,420	7,390	12,350	361,520

[1]Actual
[2]Cumulative
[3]Limestone

TABLE 5–74 Planning Subarea 4.4: Projected Mineral Industry Water Use (millions of gallons per day)

	1968[1]	1980	2000	2020
New Intake				
April-November	9.1	12.7	22.9	39.6
Average for 365 days	6.1	8.5	15.3	26.5
Discharged				
April-November	8.8	12.1	21.9	38.0
Average for 365 days	5.9	8.1	14.7	25.4
Recirculated				
April-November	1.9	3.1	7.0	15.2
Average for 365 days	1.3	2.1	4.7	10.2
Consumed				
April-November	0.3	0.6	1.0	1.6
Average for 365 days	0.2	0.4	0.6	1.1
Total Water[2]				
April-November	11.0	15.8	29.9	54.8
Average for 365 days	7.4	10.6	20.0	36.7

[1]Estimated
[2]Intake plus recirculated

4.4.2.2 Water

Sand and gravel production accounts for most of the fresh water use by the nonmetallic mineral industries in Planning Subarea 4.4. Production is seasonal, generally from April through November. Water use patterns in 1968 and for the projected years are presented in Table 5–74 at both the seasonal and average annual rate.

Water use by the petroleum industry in recovery of oil dates back to the early 1900s. Water injected into oil-producing zones is believed to have come from surface and ground water supplies. Data on the current rate of water injection are not available.

4.4.2.3 Land

Land required to maintain the projected mineral production is estimated by commodity in Table 5–75. The acreage referred to in this table must be mineral-bearing. Since each mineral deposit is unique, exhaustible, and nonrenewable, planners should permit mineral producers to deplete deposits or to locate

TABLE 5–75 Planning Subarea 4.4: Projected Mineral-Bearing Land Requirements (acres)

Commodity	1968[1]	1980	1968 to 1980[2]	2000	1968 to 2000[2]	2020	1968 to 2020[2]
Clays and shale	3	4	40	6	140	10	300
Peat	65	65	76	82	117	104	170
Sand and gravel	89	111	1,126	204	4,277	376	10,083
Stone, crushed	15	20	206	33	736	55	1,620
Total	172	200	1,448	325	5,270	545	12,173

[1]Estimated
[2]Cumulative

other suitable deposits before preempting mining activities. Sequential land use, in which mining is permitted to precede other land use projects, can prevent loss of minerals and insure their production at reasonable costs.

4.4.3 Mineral Problems

Seepage from abandoned petroleum and natural gas wells and the concern over offshore drilling in Lake Erie, which were introduced in Planning Subarea 4.3, apply to PSA 4.4 as well. The reader is referred to earlier discussion of these problems.

4.4.4 Summary and Conclusions, Including Alternatives

Gypsum, limestone, dolomite, shale, and sand and gravel exist in the area in quantities large enough to support the increasing production activity projected to 2020. Though loss of mineral resources to urban expansion is not a serious problem at this time, it is recommended that proper conservation measures be considered to avoid possible supply problems in the vicinity of the larger urban centers. Periodic surveys of the water use patterns of the sand and gravel industry are also recommended to keep abreast of intake and discharged water use changes.

Section 5

PLAN AREA 5.0

5.1 Planning Subarea 5.1, Lake Ontario West

5.1.1 Status and Potential of the Mineral Industry

5.1.1.1 Resume

The six New York counties forming Planning Subarea 5.1 produce gypsum, salt, sand and gravel, petroleum and natural gas, and stone (limestone, dolomite, and sandstone). Output and value of mineral products for 1960 and 1968 are summarized in Table 5–76. From 1960 to 1968, sand and gravel, salt, and crushed and broken stone increased in both output and value while gypsum declined. Dimension stone increased in value but decreased in output during this time period. Value of mineral production in 1968 was $33,903,048, with crushed and broken stone accounting for approximately 16 percent, and sand and gravel for 11 percent of this value.

A total of 41 nonmetallic mineral operations and an estimated 3,535 oil and gas wells were producing in 1968. All counties except Wyoming had sand and gravel operations, and all counties except Orleans had producing natural gas wells. Limestone quarries were active in three counties, gypsum and salt mines in two counties, and oil wells and a sandstone quarry in one county each. A breakdown of producing sites by State, county, and type of operation is presented in Table 5–77. Selected operations are shown in Figure 5–14.

5.1.1.2 Resources and Reserves

Sedimentary formations in Planning Subarea 5.1 dip and thicken in a southerly direction across the region. The oldest and most deeply buried is the Potsdam sandstone of the Cambrian system. The most recent strata belong to the Conewango Group of the Devonian system. Petroleum, natural gas, and salt are extracted from various formations through wells. Salt is also mined by underground methods. Limestone, dolomite, and sandstone are quarried at the surface. Overlying the bedrock formations are unconsolidated glacial sediments of the Quaternary system containing deposits of sand and gravel, peat, marl, and clay. All of these minerals can be exca-

TABLE 5–76 Planning Subarea 5.1: Mineral Production, 1960 and 1968[a]

Commodity		1960 Quantity	1960 Dollar Value	1968 Quantity	1968 Dollar Value
Gypsum	short tons	W	W	W	W
Salt	short tons	W	W	W	W
Sand and gravel	short tons	2,419,258	2,492,280	3,053,000	3,770,000
Stone (crushed and broken)	short tons	1,913,739	3,200,491	2,769,945	5,288,922
Stone (dimension)	short tons	W	W	W	W
Value of items that cannot be disclosed		---------	17,012,189	---------	24,844,126
Total Planning Subarea 5.1		---------	22,704,960	---------	33,903,048

W Withheld to avoid disclosing individual company confidential data; included with "Value of items that cannot be disclosed."

[a]Excludes data for petroleum, natural gas, and natural-gas liquids, which are not available

TABLE 5–77 Planning Subarea 5.1: Active Mineral-Producing Sites by State, County, and Type of Operation, 1968

State County	Gypsum Mines	Salt Mines	Sand and Gravel Pits	Stone Quarries: Limestone and Dolomite	Stone Quarries: Sandstone	Gas Wells[a]	Oil Wells[a]
New York							
Allegany	–	–	4	–	–	3,400	15
Genesee	1[b]	–	5	4	–	70	--
Livingston	–	1[b]	5	1	–	20	--
Monroe	1[b]	–	8	3	–	5	--
Orleans	–	–	6	–	–	-----	--
Wyoming	–	1[c]	--	–	1	25	--
Total	2	2	28	8	1	3,520	15

[a]Estimated
[b]Underground mine
[c]Brine well operation

vated from surface pits, but only sand and gravel are currently produced from the glacial sediments. A general stratigraphic succession of Planning Subarea 5.1 is presented in Table 5–78 along with the formation thickness and mineral occurrences.

Natural gas and petroleum occur in several bedrock formations. The principal gas producers are sandstones in the Medina Group of the Silurian system and the Oriskany sandstone of the Devonian system. Many of the wells in Allegany County produce minor quantities of gas for domestic use from shallow Devonian formations. Petroleum production, which is confined to Allegany County, is from a number of sands in the Canadaway Group of the Devonian system. The main producer is the Richburg sand which lies approximately 1,100 feet below the surface. Petroleum and natural gas reserves in the area are small, and the chances of discovering large new reserves are considered slight.

Salt, which occurs in the Salina Group of the Silurian system, is the principal mineral produced in the area. The bulk of the salt comes from an underground operation in Livingston County, which is believed to be the largest rock salt mine in the world (Figure 5–14). Salt has been mined from an area of more than 2,000 acres since production began in the 1880s.[20] Most of the workings are nearly 1,300 feet below the surface. The maximum depth to salt in the planning subarea is approximately 3,000 feet below sea level datum in the southern part of Allegany County where the salt reaches a maximum thickness of approximately 600 feet.[17] Salt reserves within the area are enormous in terms of in-place tonnage.

Gypsum mined by underground methods in Planning Subarea 5.1 is derived from the same formation that is mined for gypsum in Planning Subarea 4.4 to the west. Since the general characteristics of the gypsum belt are the same in both areas, the reader is referred to Subsection 4.4, Planning Subarea 4.4, for the description of the occurrence of this resource. Within PSA 5.1 the belt of gypsum-bearing strata extends across Genesee and Monroe Counties and passes into Ontario County in Planning Subarea 5.2 to the east. Total gypsum reserves in PSA 5.1 are not known, but it is believed that in-place tonnage is sufficiently large to support increasing gypsum production during the projection period.

The parallel limestone and dolomite belts cross the northern part of the area and extend into adjoining PSAs to the east and west (Figure 5–14). Principal geologic formations include the Onondaga limestone and the Helderberg Group of the Devonian system in the southernmost belt and the Lockport dolomite and Clinton Group of the Silurian system in the northernmost belt. The formations are

TABLE 5–78 Planning Subarea 5.1: General Stratigraphic Sucession and Mineral Resources

Era	System	Group	Formation	Thickness (feet)	Mineral Resources
Cenozoic	Quaternary			0-100	Sand, gravel, peat marl, clay
Paleozoic	Devonian	Conewango*		0-600	
		Conneaut*		0-600	
		Canadaway*		1200	Oil
		Java*		100-700	Sandstone
		West Falls*		415-1200	Gas, sandstone
		Sonyea*		50-300	Gas
		Genesee*		10-300	
			Tully Ls.	0-15	Gas
		Hamilton*		315-700	Gas
			Onondaga Ls.	150	Gas, limestone
			Springvale Ss.	0-10	Gas
			Oriskany Fm.	0-70	Gas, sandstone, brine
		Helderberg*		(0-50)	Limestone (in sub-surface)
	Silurian	Bertie*		0-45	
		Salina	Camillus Sh.		Gypsum
			Syracuse Fm.	400-500	Salt
			Vernon Sh.		Salt
			Lockport Dol.	150-200	Gas, dolomite
		Clinton*		150	
		Medina	Grimsby Ss.	75-170	Gas, sandstone
			Whirlpool Ss.	0-125	Gas, sandstone
	Ordovician		Queenston Sh.	1000	Gas, sandstone
			Oswego Ss.	(100)	
		Lorraine	Lorraine Sh.	(500-700)	
		Trenton shales	Utica Shale	(200-450)	
		Trenton limestones*		(600-700)	Gas
		Black River*		(200-450)	
		Beekmantown*	Tribes Hill Ls.	(0-50)	
	Cambrian		Little Falls Dol.	(0-100)	
			Theresa Dol.	(0-700)	Gas
			Potsdam Ss.	(0-150)	Gas, oil
Precambrian					

*Subdivisions not included in this report.
( ) Thickness in subsurface for unit not exposed in planning subarea.
Source: James F. Davis, New York State Geological Survey.

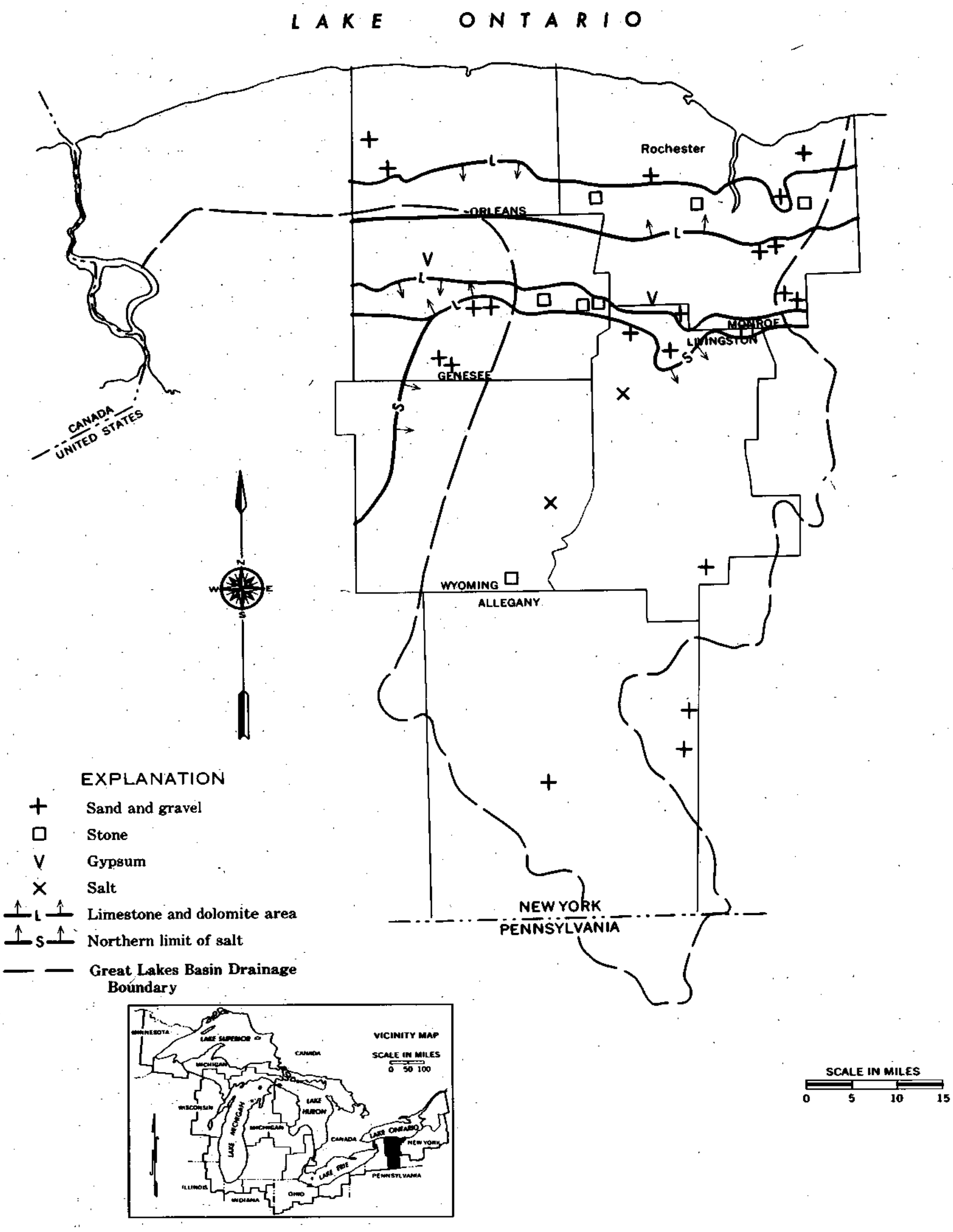

FIGURE 5–14 Planning Subarea 5.1: Distribution of Mineral Operations Active in 1968 and Major Mineral Resource Areas

TABLE 5-79 Planning Subarea 5.1: Projected Mineral Production by Selected Commodities (thousands of short tons)

Commodity	1968[1]	1980	2000	2020	1968 to 2020[2]
Sand and gravel	3,053	4,080	6,820	11,400	333,680
Stone, crushed[3]	2,770	3,610	6,030	10,100	295,260

[1]Actual
[2]Cumulative
[3]Limestone and dolomite

quarried in Genesee and Monroe Counties. Most of the stone is crushed for use as aggregate. Reserves of usable stone in both belts are believed to be very large.

Dimension sandstone is quarried in Wyoming County from the Java and West Falls Groups of the Devonian system. This quarry produces rough dimension stone for use as rubble and irregular-shaped facing stone as well as sawed and cut dimension stone for architectural work. The fine-grained, blue-gray products are commonly referred to as "bluestone." Reserves of usable stone are very large.

The area is covered by glacial and postglacial deposits of the type mined for sand and gravel. Although the full extent of the resource is not known, sand and gravel reserves are believed to be sufficient to meet the needs of the PSA indefinitely. However, since urban expansion tends to preempt mining activities both legally and by building on deposits, local sand and gravel supply problems can be expected in the vicinity of the expanding communities.

5.1.2 Mineral Industry Projection

5.1.2.1 Production

Projected mineral production for Planning Subarea 5.1 is summarized in Table 5-79. With the exception of petroleum and natural gas, all mineral production within the planning subarea is expected to increase during the projection period.

5.1.2.2 Water

Water is used in the primary production of salt, crushed and broken stone, and sand and gravel. Sand and gravel production is seasonal, generally from April through November. Water use patterns in 1968 and for the projected years are presented in Table 5-80 at both the seasonal and average annual rates. Discharge resulting from unwatering of gypsum mines was not included in Table 5-80.

The petroleum industry injects water into oil-bearing sands to increase the flow of oil into producing wells. Data on the quantities of water used for this purpose are not available.

5.1.2.3 Land

In this planning subarea, as in all others, many acres of mineral-bearing land will be required to maintain the projected mineral production. An estimate of the surface land which will be used to support future stone and sand and gravel production is given in Table 5-81. No land use estimates are given for gypsum and salt, which are mined by underground methods, because the use of small tracts of land for surface facilities can be expected to remain fixed for extended periods of time.

5.1.3 Mineral Problems

No serious long-range water or land problems are foreseen for mineral producers in Planning Subarea 5.1. Urban expansion may

TABLE 5-80 Planning Subarea 5.1: Projected Mineral Industry Water Use (millions of gallons per day)

	1968[1]	1980	2000	2020
New Intake				
April-November	2.7	9.4	16.2	28.2
Average for 365 days	1.9	6.4	11.0	19.2
Discharged				
April-November	2.2	8.9	15.2	24.7
Average for 365 days	1.5	6.0	10.2	16.6
Recirculated				
April-November	1.8	5.1	9.3	17.4
Average for 365 days	1.4	3.7	6.8	12.8
Consumed				
April-November	0.5	0.5	1.0	3.5
Average for 365 days	0.4	0.4	0.8	2.6
Total Water[2]				
April-November	4.5	14.5	25.5	45.6
Average for 365 days	3.3	10.1	17.8	32.0

[1]Estimated
[2]Intake plus recirculated

TABLE 5–81 Planning Subarea 5.1: Projected Mineral-Bearing Land Requirements (acres)

Commodity	1968[1]	1980	1968 to 1980[2]	2000	1968 to 2000[2]	2020	1968 to 2020[2]
Sand and gravel	57	76	787	126	2,805	211	6,179
Stone, crushed	14	18	184	30	657	50	1,447
Total	71	94	971	156	3,462	261	7,626

[1]Estimated
[2]Cumulative

create sand and gravel supply problems in or near some communities, but these are expected to be local in effect. The nature of the underground openings in the salt beds are such that the occurrence of a rapid or pronounced subsidence of land at the surface is considered remote. Subsidence may be a possibility over near-surface gypsum seams that have been mined, although no subsidence is known to have taken place to date.

5.1.4 Summary and Conclusions, Including Alternatives

Gypsum, salt, sand and gravel, and stone exist in the area in quantities many times in excess of that needed to support production activity to the year 2020. Since presence of mineral resources does not guarantee availability, it is recommended that planning efforts within the planning subarea incorporate pro-

TABLE 5–82 Planning Subarea 5.2: Mineral Production, 1960 and 1968[a]

Commodity		1960 Quantity	1960 Dollar Value	1968 Quantity	1968 Dollar Value
Cement:					
Portland	376-pound barrels	W	W	W	W
Masonry	280-pound barrels	W	W	W	W
Clay and shale	short tons	W	W	W	W
Iron oxide pigments	short tons	W	W	---------	----------
Lime	short tons	W	W	W	W
Peat	short tons	W	W	W	W
Salt	short tons	W	W	W	W
Sand and gravel	short tons	3,079,510	3,352,208	4,333,000	4,490,000
Stone (crushed and broken)	short tons	5,165,853	7,386,840	6,914,382	10,968,092
Stone (dimension)	short tons	W	W	W	W
Value of items that cannot be disclosed		---------	24,439,408	---------	27,218,527
Total Planning Subarea 5.2		---------	35,178,456	---------	42,676,619

W Withheld to avoid disclosing individual company confidential data; included with "Value of items that cannot be disclosed."

[a]Excludes data for petroleum, natural gas, and natural-gas liquids, which are not available

grams to insure that valuable mineral resources, particularly sand and gravel and stone, are preserved and that planned development includes mineral extraction.

Periodic surveys of the water use patterns of the mineral industry are recommended to keep abreast of intake and discharged water use changes.

5.2 Planning Subarea 5.2, Lake Ontario Central

5.2.1 Status and Potential of the Mineral Industry

5.2.1.1 Resume

Clay and shale, natural gas, peat, salt, sand and gravel, and stone (limestone, dolomite, and sandstone) are produced in the 12 New York counties that form Planning Subarea 5.2. Output and value of mineral products for 1960 and 1968 are summarized in Table 5–82. Cement, lime, and iron oxide pigments, which are manufactured from local mineral materials, are included in the table for reference only. From 1960 to 1968, sand and gravel, salt, and crushed and broken stone increased in both output and value. Cement, lime, peat, and dimension stone decreased in both areas during this time while clay and shale increased in value but decreased in output. The production of iron oxide pigments was discontinued in 1960. The value of mineral production in 1968 was $42,676,619, with crushed and broken stone accounting for 26 percent and sand and gravel 11 percent of this value.

A total of 89 nonmetallic mineral operations and an estimated 103 natural gas wells were producing in 1968. All counties except Seneca County had sand and gravel operations. Stone quarries were active in nine counties, natural gas wells in six, salt mines in three, peat bogs in two, and clay and shale pits in one county. A breakdown of producing sites by State, coun-

TABLE 5–83 Planning Subarea 5.2: Active Mineral-Producing Sites by State, County, and Type of Operation, 1968

State County	Clay and Shale Pits	Peat Bogs	Salt Mines	Sand and Gravel Pits	Stone Quarries: Limestone and Dolomite	Stone Quarries: Sandstone	Gas Wells[a]
New York							
Cayuga	–	–	–	4	1	–	20
Herkimer	–	–	–	3	3	–	---
Madison	–	–	–	1	3	–	---
Oneida	–	–	–	11	1	–	5
Onondaga	3	–	1[b]	8	4	–	---
Ontario	–	1	–	14	1	–	65
Oswego	–	–	–	7	--	–	5
Schuyler	–	–	2[b]	3	--	–	---
Seneca	–	1	–	--	1	–	5
Tompkins	–	–	1[c]	2	1	1	---
Wayne	–	–	–	8	2	–	---
Yates	–	–	–	1	--	–	3
Total	3	2	4	62	17	1	103

[a]Estimated
[b]Brine well operations
[c]Underground mine

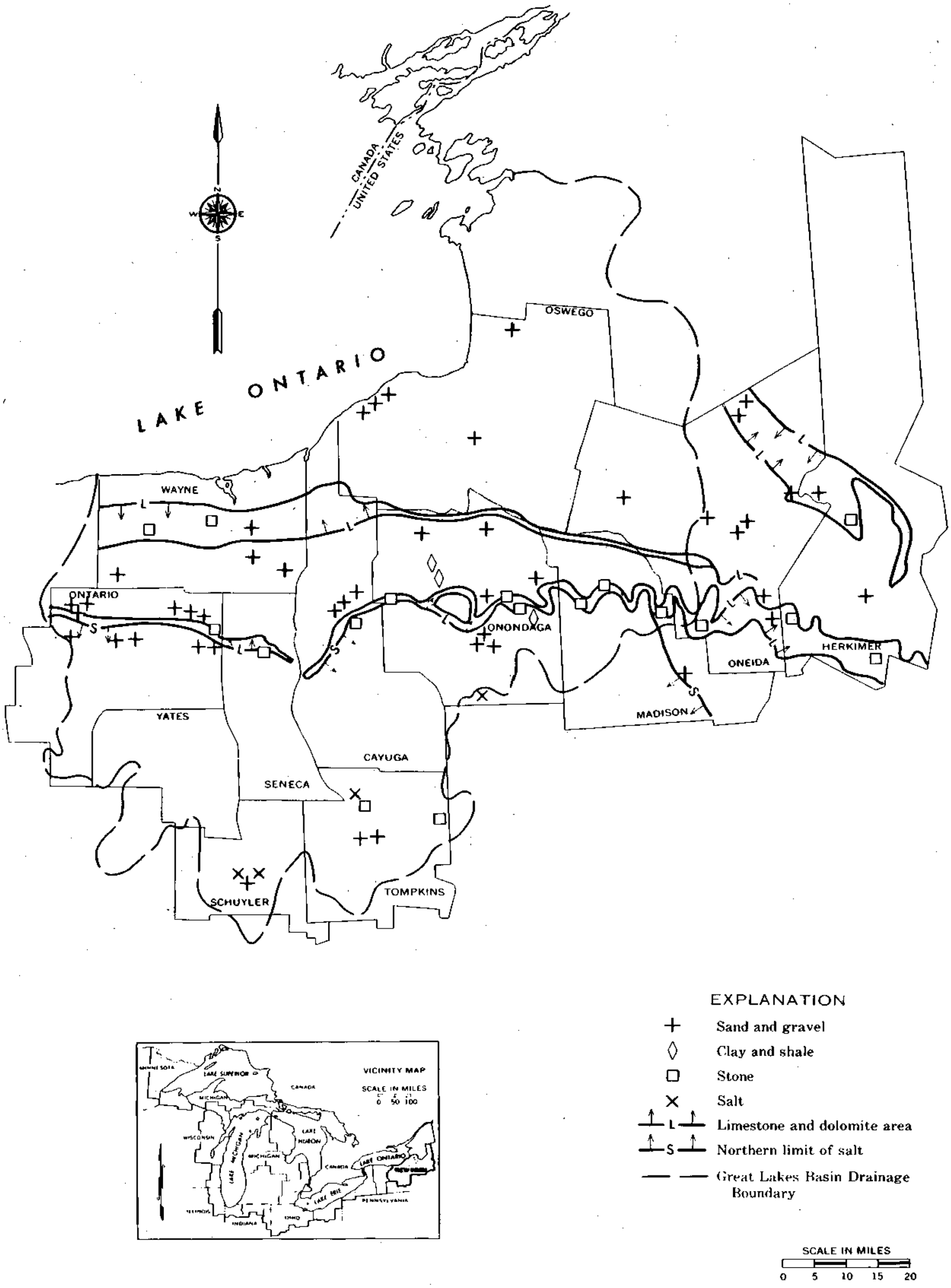

FIGURE 5–15 Planning Subarea 5.2: Distribution of Mineral Operations Active in 1968 and Major Mineral Resource Areas

ty, and type of operation is presented in Table 5–83. Selected operations are shown in Figure 5–15.

5.2.1.2 Resources and Reserves

Bedrock in Planning Subarea 5.2 includes Precambrian rocks and Paleozoic sedimentary formations. The Precambrian rocks form the bedrock in most of Herkimer County and the northeastern tip of Oneida County. Sedimentary formations, which range upward from the Potsdam Sandstone Formation of the Cambrian system to the Sonyea Group of the Devonian system, dip and thicken across the area in a southerly direction, with the older formations forming the bedrock in the northern part and the younger formations in the southern part. Various formations yield natural gas and salt to wells. Salt is also mined underground. Limestone, dolomite, and sandstone are quarried from surface formations. Overlying much of the bedrock are unconsolidated glacial sediments of the Quaternary system that contain deposits of sand and gravel, peat, marl, clay, and diatomite. All of these materials can be extracted from surface pits. Production is currently limited to sand and gravel, peat, and clay. A generalized stratigraphic succession of Planning Subarea 5.2 is presented in Table 5–84 along with formation thickness and mineral occurrences.

Although some wells yield natural gas from shallow Devonian formations, the principal gas producer is the Medina Group of the Silurian system. Gas occurs in those sandstone strata within the Medina that are sufficiently porous to serve as reservoirs. It is absent in impermeable zones. Porous sandstone areas are characteristically erratic in occurrence and irregularly distributed within the area. Reserves of natural gas are small and the chance of major new discoveries within the Medina Group or any other strata within the area is considered slight.

Salt is mined from the Salina Group of the Silurian system, which underlies the southern half of the area (Figure 5-15). Depth to the salt ranges from approximately 200 feet above sea level along the northern edge of the salt occurrence in Ontario County to more than 1,500 feet below sea level in the southern part of Schuyler County.[17] The zone containing salt beds reaches a maximum thickness of 1,300 feet in Schuyler county. Individual salt beds within the zone range from 15 inches to 548 feet in thickness. Although contaminants render many salt beds uneconomic to mine and process, salt reserves within the area are considered inexhaustible.

Gypsum also occurs in the strata of the Salina Group of the Silurian system. During the last century numerous outcrops were quarried to produce gypsum for agricultural uses and as a cement additive to slow hardening. In addition to gypsum, many of the old quarries also produced impure limestone from upper Silurian formations for the manufacture of natural cement. Ranging up to 60 feet in thickness, the gypsum beds of Planning Subarea 5.2 are thicker than in any other part of the Salina gypsum belt, which extends across New York from Erie County in Planning Subarea 4.4 to Herkimer County in the eastern part of Planning Subarea 5.2.

The area is richly endowed with limestones and dolomites. Current production is used for agricultural stone, aggregate, railroad ballast, roadstone, dimension stone, and raw material for the manufacture of cement and quicklime. The principal limestone and dolomite outcrops form three long narrow belts (Figure 5–15). The belt extending across Wayne County to the south central part of Oneida County is made up of formations assigned to the Lockport and Clinton Groups of the Silurian system. The southermost belt, which crosses the width of the area from eastern Ontario County to western Herkimer County, consists of strata of the Onondaga limestone and the Helderberg Group of the Devonian system. The Helderberg Group strata are the source of dimension stone production in Onondaga County. The belt that cuts across Herkimer and Oneida Counties and passes into Planning Subarea 5.3 to the north is formed by the limestone strata of the Trenton Group of the Ordovician system. Usable stone reserves in each of the three belts are very large.

Minor quantities of sandstone are quarried as dimension stone at a single site in the western part of Tompkins County. The source of sandstone is the Sonyea Group of the Devonian system. Reserves of usable stone in the Sonyea Group are believed to be more than sufficient for the needs of the area during the projection period.

Prior to 1965, iron oxide pigments for use in paints were produced from iron ore, which occurs as "fossil" and "oolitic" hematite interbedded with limestone and shales in the Clinton Group of the Silurian system. During the last century, this ore was also mined for foundry use. The iron ore beds extrude across the

TABLE 5–84 Planning Subarea 5.2: General Stratigraphic Succession and Mineral Resources

Era	System	Group	Formation	Thickness, (feet)	Mineral Resources
Cenozoic	Quaternary			0– 100	Sand, gravel, peat, marl, clay, diatomite
		Java		0– 700	
Paleozoic	Devonian	Sonyea*		300-1,000	Gas, (subsurface) sandstone
		Genesee*		300-1,000	
			Tully Ls.	0– 30	Gas, (subsurface) limestone
		Hamilton*		225-2,000	Gas, shale
			Onondaga Ls.	70– 100	Gas, limestone
		Ulster*		0– 100	
		Helderberg*		0– 250	Limestone
	Silurian	Bertie*		0– 90	
		Salina	Camillus Sh.	75	Gypsum
			Syracuse Fm.	150 (200-2,000)	Salt
			Vernon Sh.	200	Shale
			Lockport Dol.	75– 150	Gas, dolomite
		Clinton*		0– 380	Iron ore
		Medina	Grimsby Ss.	0– 100	Gas, sandstone
			Whirlpool Ss.	0– 25	Gas, sandstone
	Ordovician		Queenston Sh.	0– 620	Gas, sandstone
			Oswego Ss.	0– 160	
			Lorraine Sh.	0– 800	
		Trenton shales	Utica Sh.	100-1,500	
		Trenton limestones		50– 600	Gas, limestone
		Black River*		25– 250	
			Tribes Hill	0– 50	
	Cambrian		Little Falls Dol.	0– 200	
			Theresa Dol.	(0– 800)	
			Potsdam Ss.	(0– 75)	
Pre-cambrian					Granite

* Subdivisions not included in this report.
( ) Thickness in subsurface of unit not outcropping in planning subarea

Source: James F. Davis, New York State Geological Survey area from Herkimer County to Monroe County in Planning Subarea 5.1 to the west. These beds range from thin partings to more than 6 feet in thickness and have an iron content averaging between 20 and 45 percent. Although the beds contain hundreds of millions of tons of hematite in place, this resource is not economical to mine because of thick overburden cover, thinness of the ore beds, and the low grade of the ore.

Current production of both clay and shale is limited to Onondaga County. Shale excavated from the Hamilton Group of the Devonian system is used in the manufacture of cement, while Vernon shale of the Silurian system is used to produce lightweight aggregate. Clay, which occurs abundantly in the glacial sediments of the Quaternary system, is used for making art pottery and flowerpots. Shale and clay reserves within the area are very large, although their utility for various clay products manufacture is a matter for local investigation and testing.

The principal source of aggregate is sand and gravel occurring in the unconsolidated Quaternary sediments. The full extent of the resource is not known. Quality sand and gravel deposits appear to be fairly abundant and should be more then ample to meet local demand for many years.

Peat swamps are widespread throughout the area and range up to several thousand acres in size. If compared to the extent and availability of the resource, current and projected production is relatively insignificant. Although the size of the peat resource is large, it has not been measured.

Other mineral materials that were produced in the past include marl and diatomite or diatomaceous earth. Both are found in lakes of glacial origin. The marl, used in the manufacture of cement, occurs extensively through the central part of the PSA in deposits ranging up to 30 feet in thickness and covering several thousand acres. Principal diatomite deposits are confined to lakes in the Adirondack region in northern Herkimer County. Single deposits have been estimated to contain from 100,000 to more than 1,000,000 cubic yards of usable material.[15] Previously, production was used entirely in the manufacture of silver polish. Production of either marl or diatomite during the the projection period is considered unlikely.

TABLE 5–85 Planning Subarea 5.2: Projected Mineral Production by Selected Commodities (thousands of short tons)

Commodity	1968[1]	1980	2000	2020	1968 to 2020[2]
Clays and shale	W	100	160	260	7,850
Sand and gravel	4,333	5,850	9,780	16,300	478,000
Stone, crushed[3]	6,914	9,390	15,690	26,200	767,440

[1]Actual
[2]Cumulative
[3]Limestone
W Withheld to avoid disclosing individual company confidential data

5.2.2 Mineral Industry Projection

5.2.2.1 Production

Projected mineral production for Planning Subarea 5.2 is summarized in Table 5-85. With the exception of natural gas, all mineral production is expected to increase during the projection period.

5.2.2.2 Water

Water is used in the primary production of salt, crushed stone, and sand and gravel. Salt producers who operate throughout the year account for the bulk of the water usage. Crushed stone and sand and gravel producers operate seasonally. Water use patterns in 1968 and for the projection years are presented in Table 5–86 at both the annual and season rates.

5.2.2.3 Land

As mineral substances are removed from the ground and deposits are depleted, new mineral-bearing land must be brought into production. Land required to maintain the projected production is summarized by commodity in Table 5-87.

5.2.3 Mineral Problems

Although aggregate resources are plentiful in the area, local sand and gravel supply problems are anticipated in the vicinity of expanding communities. For example, within the Syracuse area in Onondaga County, sand and gravel deposits are expected to be depleted by 1990.[8]

TABLE 5–86 Planning Subarea 5.2: Projected Mineral Industry Water Use (millions of gallons per day)

	1968[1]	1980	2000	2020
New Intake				
April-November	12.8	18.4	33.4	58.7
Average for 365 days	12.2	17.5	31.7	55.6
Discharged				
April-November	9.1	13.2	22.6	36.6
Average for 365 days	8.5	12.4	21.1	33.8
Recirculated				
April-November	1.5	3.6	10.2	27.4
Average for 365 days	1.1	2.9	8.8	24.8
Consumed				
April-November	3.7	5.2	10.8	22.1
Average for 365 days	3.7	5.1	10.6	21.8
Total Water[2]				
April-November	14.3	22.0	43.6	86.1
Average for 365 days	13.3	20.4	40.5	80.4

[1]Estimated
[2]Intake plus recirculated

5.2.4 Summary and Conclusions, Including Alternatives

Vast reserves of salt, stone, clay, shale, and peat can support the planning subarea needs for many years beyond the projection period. The same is probably true of sand and gravel, although the sizeable acreage required for projected and sand and gravel production may not always be available at reasonable cost, particularly in and around urban centers. It is recommended that land use planning efforts include measures to insure the preservation and availability of quality sand and gravel deposits for future mining. Periodic surveys of water use patterns of the mineral industry are also recommended to keep abreast of intake and discharged water use changes.

5.3 Planning Subarea 5.3, Lake Ontario East

5.3.1 Status and Potential of the Mineral Industry

5.3.1.1 Resume

Mineral industries in the three New York counties that make up Planning Subarea 5.3 produce iron ore, lead, sand and gravel, silver, stone (marble, limestone, and dolomite), talc, and zinc. Output and value of mineral products for 1960 and 1968 are summarized in Table 5–88. From 1960 to 1968, dimension stone production ceased. Only talc and lead increased in output, while value gains were reported for talc, lead, silver, and zinc. The value of mineral products in 1968 was $39,818,149, with zinc accounting for 45 percent, and crushed and broken stone, 5 percent.

A total of 37 mineral operations were active in 1968. All of the counties had stone quarries and sand and gravel operations. All of the iron ore, zinc, lead, silver, and talc mines were cen-

TABLE 5–87 Planning Subarea 5.2: Projected Mineral-Bearing Land Requirements (acres)

Commodity	1968[1]	1980	1968 to 1980[2]	2000	1968 to 2000[2]	2020	1968 to 2020[2]
Clays and shale	1	1	15	2	52	4	112
Peat	8	8	10	8	12	8	19
Sand and gravel	131	177	1,845	296	6,582	494	14,485
Stone, crushed	37	50	525	84	1,874	141	4,126
Total	177	236	2,395	390	8,520	647	18,742

[1]Estimated
[2]Cumulative

TABLE 5–88 Planning Subarea 5.3: Mineral Production, 1960 and 1968[a]

Commodity		1960 Quantity	1960 Dollar Value	1968 Quantity	1968 Dollar Value
Iron ore (usable)	long tons, gross weight	1,536,506	W	1,187,369	W
Lead[b]	short tons	775	181,350	1,396	368,879
Sand and gravel	short tons	1,483,018	1,618,008	W	W
Silver[b]	troy ounces	49,324	44,641	27,615	59,223
Stone (crushed and broken)	short tons	782,143	1,909,133	768,008	1,836,071
Stone (dimension)	short tons	W	W	---------	---------
Talc	short tons	W	W	W	W
Zinc[b]	short tons	66,364	17,121,912	66,194	17,872,380
Value of items that cannot be disclosed		---------	22,784,362	---------	19,681,596
Total Planning Subarea 5.3		---------	43,659,406[c]	---------	39,818,149[c]

W Withheld to avoid disclosing individual company confidential data; included with "Value of items that cannot be disclosed."

[a]Excludes data for petroleum, natural gas, and natural-gas liquids, which are not available.
[b]Recoverable content of ores, etc.
[c]Incomplete total. Excludes data for petroleum, natural gas, and natural-gas liquids, which are not available.

tered in the southern part of St. Lawrence County. Distribution of producing sites by State, county, and commodity is presented in Table 5–89. Locations of the sites are shown in Figure 5–16.

5.3.1.2 Resources and Reserves

The bedrock in Planning Subarea 5.3 includes Precambrian, Cambrian, and Ordovician formations. Talc, marble, and all of the

TABLE 5–89 Planning Subarea 5.3: Active Mineral-Producing Sites by State, County, and Type of Operation, 1968

State County	Iron Ore Mines	Zinc, Lead and Silver Mines	Talc Mines	Sand and Gravel Pits	Stone Quarries: Limestone and Dolomite	Stone Quarries: Marble
New York						
Jefferson	-	-	-	10	1	-
Lewis	-	-	-	3	3[a]	-
St. Lawrence	1[b]	2[c]	3[d]	11	2	1
Total	1	2	3	24	6	1

[a]Includes one underground quarry
[b]Open-pit mine
[c]Includes one underground zinc mine and one underground zinc-lead-silver mine
[d]Includes two underground mines and one open-pit mine

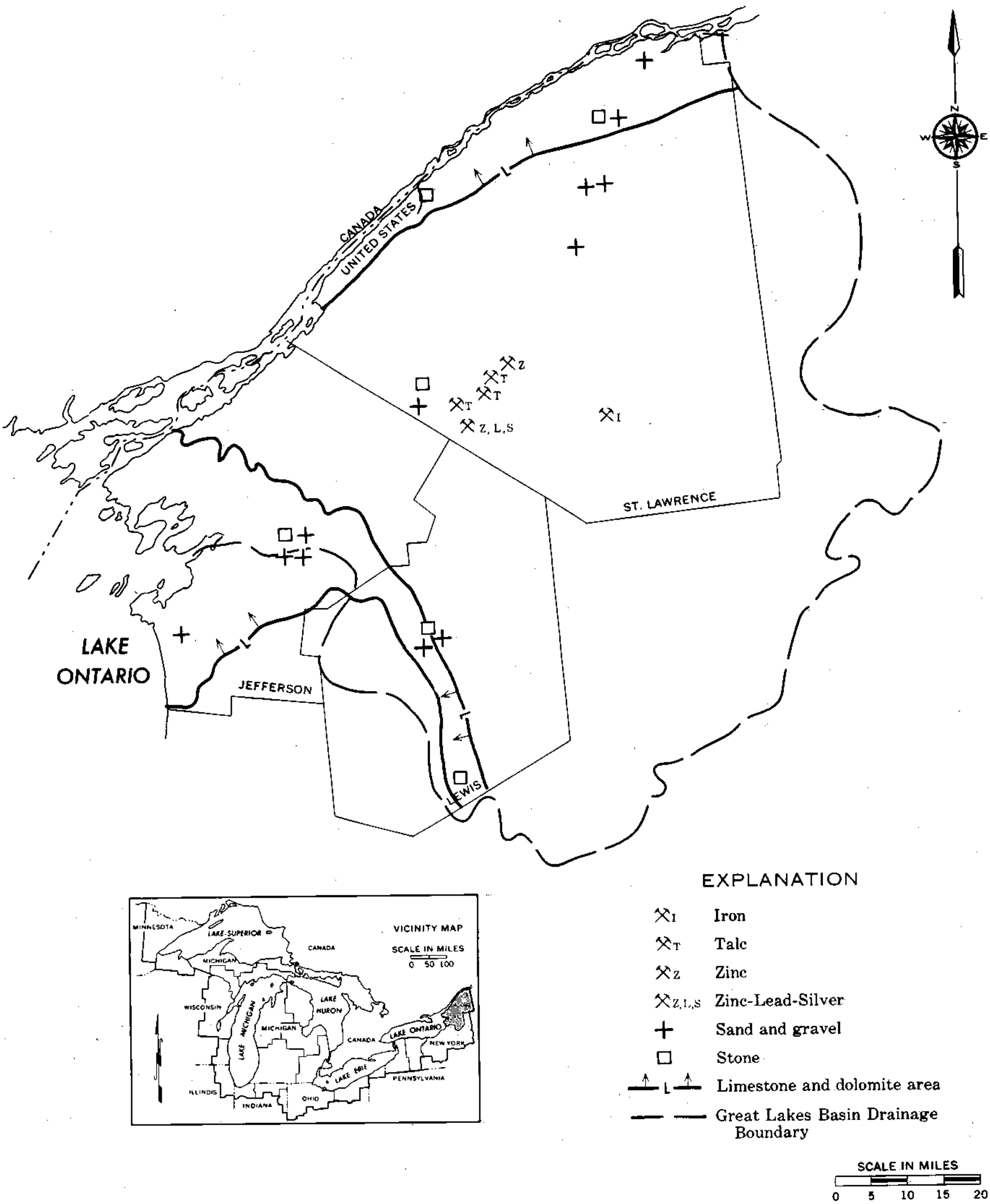

FIGURE 5–16 Planning Subarea 5.3: Distribution of Mineral Operations Active in 1968 and Major Mineral Resource Areas

TABLE 5-90 Planning Subarea 5.3: General Stratigraphic Succession and Mineral Resources

Era	System	Group	Formation	Thickness (feet) At Surface	Mineral Resources
Cenozoic	Quaternary			0-150	Sand, gravel, peat, and diatomite
Paleozoic	Silurian	Medina	Grimsby Ss.	20	
	Ordovician		Queenston Sh.	40	
			Oswego Ss.	150	Sandstone
		Lorraine	Pulaski Fm.	200	
			Whetstone Gulf Fm.	400-600	Sandstone, shale
		Trenton shales	Utica Sh.	40-250	Shale
		Trenton limestones*		450-500	Limestone
		Black River*		50-240	
	Cambrian		Ogdensburg Dol.	0-150	Dolomite
			Theresa Dol.	50-150	Dolomite
			Potsdam Ss.	0-150	Sandstone
Precambrian					Iron ore, lead, zinc, silver, feldspar, talc, marble, granite Potential mineral resources: beryllium, graphite, fluorspar, garnet, pyrite, titanium, uranium, and vanadium.

* Subdivisions not included in this report

Source: James F. Davis, New York State Geological Survey

metallic ores are taken from Precambrian rocks. The Ordovician and Cambrian sedimentary strata yield limestone and dolomite. Overlying the bedrock are unconsolidated glacial and postglacial sediments of the Quaternary system, which currently yield only sand and gravel. Zinc, lead, silver, some stone, and much of the talc are mined underground. Stone and talc are also mined by surface methods, as are iron ore and sand and gravel. A generalized stratigraphic succession of Planning Subarea 5.3 is presented in Table 5-90, along with formation thickness and mineral occurrences.

Sphalerite and galena are the sulfide minerals mined for zinc and lead respectively. Sphalerite occurs separately and also in combination with galena and pyrite (iron sulfide) as replacement bodies or veins. These pinch and swell in the recrystallized and highly altered Grenville marble of Precambrian age. Silver, associated with galena, is recovered as a byproduct during the lead smelting process. As evidenced by the large output of zinc, sphalerite occurs more abundantly than the lead mineral galena. This discouraged mining in the area in the last century, because there was little use for zinc at that time and the mixture of galena, sphalerite, and pyrite represented an uneconomical separation process for lead production. Although lead was sporadically produced from small galena deposits during the 1800s, known sphalerite deposits remained virtually untouched for 80 years until the first zinc mine opened in 1915. This operation, the Edward mine, is still producing. The Balmat mine, currently producing all of the area's lead and silver in addition to zinc, began operation in 1928.[15] At both mines, ore veins of consistent grade are believed to extend to depths well below current mining levels. Therefore, reserves are believed to be sufficient to support an increase in zinc, lead, and silver production during the projection period.

Talc occurs in the Grenville marble in close proximity to the zinc-lead sulfide deposits and has been mined in St. Lawrence County without interruption since 1880. The talc-bearing beds range up to 400 feet in thickness and their dip extends down more than 2,000 feet. Generally, the grade of ore is less than 25 percent talc. Principal uses of this soft, grit-free commodity are in the manufacture of ceramics, paint, rubber, and covering materials for floors and walls. Reserves of talc within the area are sufficiently large to maintain the current rate of talc production well beyond the projection period.

Iron ore production is centered in the magnetite district of south-central St. Lawrence County. Deposits occur as replacement bodies in narrow belts of metamorphosed Precambrian sedimentary rocks enclosed by granite and granite gneiss. The discovery of magnetite ore in the area dates from at least 1813 and various mining interests operated in the area between 1830 and 1919. The Benson mines deposits, the principal ore bodies in the district, were reopened in 1943 and continue to produce ore. The main ore body is approximately 2 miles long, one mile wide, and 200 feet thick, with an iron content of approximately 25 percent. Measured ore reserves at the Benson mines deposits, which include some hematite in addition to magnetite, totaled 103 million long tons in 1955 plus inferred and potential ore, each estimated at more than 10 million long tons. Ore reserves at more than 40 other known deposits in the district include less than 10 million long tons of measured ore; 15 million long tons of indicated ore; 50 million long tons of inferred ore; and 80 million long tons of potential ore.[6]

Although minor quantities of dimension stone were produced in the past, all current stone production is classified as crushed and broken. In Lewis and Jefferson Counties, production from the Trenton Group limestones of the Ordovician system is used as concrete aggregate, roadstone, and as filler in paint, rubber, calcimine, putty, paper, and pottery. In the northern part of St. Lawrence County, limestone and dolomite quarried from formations of the Cambrian and Ordovician systems are used as concrete aggregate, roadstone, agricultural stone, and in cement manufacture. A quarry in the southern part of St. Lawrence County produces crushed marble from Precambrian rocks for use as roadstone and agricultural stone (Figure 5–16). Usable stone reserves, which also include sandstone, granite, and other types of igneous and metamorphic rocks, are extensive.

Sand and gravel, produced from Quaternary sediments which range up to 150 feet in thickness, is used in building and highway construction, paving, and fill. Reserves of sand and gravel have not been determined, though it is believed that sufficient material will be available to support production during the projection period. Where sand and gravel are locally in short supply, crushed stone can probably be obtained as a substitute material.

In addition to current production in the area, certain other mineral resources warrant consideration because of their former importance and their future development prospects.

Graphite, a soft black mineral composed of carbon, was mined in the eastern part of St. Lawrence County from 1937 to 1942. Source of this material was a graphite schist occurrence in the Grenville marble of Precambrian age. Output, which averaged approximately 65 tons per day in 1940 and 1941, ceased when high-grade 20 to 25 percent graphite ore became low-grade hard ore at depth.[15] Subsequent exploration has failed to locate other commercial graphite deposits. The outlook for future graphite mining in the planning subarea does not appear promising at this time.

A belt of hematite iron ore is located in the Jefferson, Lewis, and St. Lawrence tri-county area. The hematite occurs as seams in the Grenville marble and was mined by a number of small producers from 1825 to 1910. Total output of hematite ore from the belt was approximately 2,500,000 tons.[19] Remaining reserves, estimated at less than 2,000,000 long tons,[6] are considered relatively insignificant.

Closely associated with the hematite seams, and occurring in the same geologic formation, are pyrite (iron sulfide) deposits. Bands of pyrite-bearing rocks range from a few feet to more than 50 feet in width and generally are from 5 to 10 percent pyrite by volume. More than 600,000 long tons of pyrite concentrates, averaging approximately 40 percent elemental sulfur, were produced between 1883 and 1921.[22] The concentrates were shipped to roasting plants for extraction of elemental sulfur used to manufacture sulfuric acid. Although pyrite reserves have not been determined, mining of pyrite during the projection period is unlikely due to the availability of sulfur from other sources.

Feldspar crystals ranging from a few inches up to several feet in length have been found at

TABLE 5–91 Planning Subarea 5.3: Projected Mineral Production by Selected Commodities (thousands of short tons unless otherwise noted)

Commodity	1968[1]	1980	2000	2020	1968 to 2020[2]
Iron ore[3]	1,187	1,450	1,990	2,740	97,600
Lead	1	2	2	2	101
Sand and gravel	W	1,360	2,270	3,800	111,160
Silver[4]	28	42	42	42	2,100
Stone, crushed[5]	768	950	1,590	2,660	77,800
Zinc	66	95	95	95	4,766

[1]Actual
[2]Cumulative
[3]Thousands of long tons
[4]Thousands of troy ounces
[5]Includes limestone and marble
W Withheld to avoid disclosing individual company confidential data

various localities in the Precambrian rocks of St. Lawrence County. Large crystals such as these occur in pegmatites, which are coarsely textured modifications of granite. Feldspar is used extensively as a raw material in the glass and ceramic manufacturing industries. Although some feldspar has been mined from pegmatites in St. Lawrence County, there has been no interest in these deposits for many years because of the availability of quality feldspar deposits closer to consuming areas in other parts of the nation.

Many other mineral resources are found in the Precambrian rocks of St. Lawrence County. Those which may have future development prospects include beryllium, fluorspar, garnet, titanium, uranium, and vanadium. Although the minerals have not been found in sufficient concentration to warrant mining, their occurrence and distribution suggests that potentially commercial deposits may be present.

5.3.2 Mineral Industry Projection

5.3.2.1 Production

Although the planning subarea has a variety of future mineral production prospects, only minerals in current production were projected. The projections are summarized in Table 5–91. Zinc, silver, and lead production are expected to increase during the 1970s and remain constant after 1980. Iron ore, sand and gravel, and stone production are expected to increase during the entire projection period.

TABLE 5–92 Planning Subarea 5.3: Projected Mineral Industry Water Use (millions of gallons per day)

	1968[1]	1980	2000	2020
New Intake				
May-October	2.2	3.1	4.1	6.2
Average for 365 days	2.0	2.6	3.4	5.0
Discharged				
May-October	0.9	1.3	1.7	2.9
Average for 365 days	0.7	0.9	1.1	1.8
Recirculated				
May-October	10.7	13.2	17.9	24.8
Average for 365 days	10.6	13.0	17.7	24.4
Consumed				
May-October	1.3	1.8	2.4	3.3
Average for 365 days	1.3	1.7	2.3	3.2
Total Water[2]				
May-October	12.9	16.3	22.0	31.0
Average for 365 days	12.6	15.6	21.1	29.4

[1]Estimated
[2]Intake plus recirculated

5.3.2.2 Water

Water is used in the primary production of iron ore, sand and gravel, crushed stone, and zinc-lead. Sand and gravel and crushed stone are produced seasonally, while iron ore and zinc-lead mining is a year-round activity. Water use patterns in 1968 and for the projected years are presented in Table 5–92 at both the seasonal and average annual rate.

5.3.2.3 Land

Land requirements for mineral production in Planning Subarea 5.3 are summarized by commodity in Table 5–93. Acreage requirements for zinc-lead and, in part, for iron ore production include non-mineral-bearing surface lands for plant sites and rock and tailings disposal areas. All other land must be mineral-bearing.

5.3.3 Mineral Problems

No serious water or land problems have been reported and none are foreseen for mineral producers in Planning Subarea 5.3.

TABLE 5-93 Planning Subarea 5.3: Projected Mineral-Bearing Land Requirements[1] (acres)

Commodity	1968[2]	1980	1968 to 1980[3]	2000	1968 to 2000[3]	2020	1968 to 2020[3]
Iron ore	900	1,000	1,000	1,200	1,200	1,500	1,500
Sand and gravel	10	18	186	30	664	50	1,462
Stone, crushed	5	6	59	10	211	16	466
Zinc-lead	250	500	500	500	500	700	700
Total	1,165	1,524	1,745	1,740	2,575	2,266	4,128

[1] Includes non-mineral-bearing surface lands required for iron ore and zinc-lead production
[2] Estimated
[3] Cumulative

5.3.4 Summary and Conclusions, Including Alternatives

Sufficient reserves of iron ore, sand and gravel, stone, talc, lead, and zinc exist in the area to support production activity during the projection period.

Although water usage is relatively small, it is essential for mineral production. To insure that planning provides for adequate supplies, periodic surveys of the water use patterns of the mineral industry are recommended to keep abreast of the intake and discharged water use changes.

SUMMARY

Metals, nonmetals, and mineral fuels produced by the Great Lakes Region mineral industry were valued at $1,496,257,854 in 1968. Current metal production includes copper, iron ore, lead, silver, and zinc. During the 52-year projection period, copper and silver production will quadruple while iron ore, lead, and zinc production will double. Continued exploration and advances in mining technology will undoubtedly result in the opening of additional metal mines during the projection period. Nonmetallic minerals for which projections were made include clays, shale, gypsum, salt, sand and gravel, crushed stone, and dimension stone. During the projection period, salt production will increase to approximately seven times the present level, sand and gravel, crushed stone, and dimension stone production will quadruple, clay and shale production will triple, and gypsum production will double. All other nonmetallic minerals are expected to maintain or increase their present production rates. Mineral fuel production includes coal, natural gas, peat, and petroleum. Peat production used for nonfuel purposes will double during the projection period, while coal production will cease by the year 2000. Petroleum and natural gas production will probably decline during the projection period unless additional discoveries are made.

Water use patterns of the mineral industry reflect both the increase in material being processed and the projected increases in mineral production. Average annual new water intake will increase to 1,494 mgd in 2020 from the present rate of 727 mgd. Discharged water will increase from the 1968 rate of 652 mgd to 1,181 mgd in the year 2020. Recirculated water use will reflect the progressive use of closed water systems, increasing from the present level of 461 mgd to 1,900 mgd in 2020. Water consumption is expected to increase to 313 mgd from the present rate of 75 mgd. Total water use (intake plus recirculated) by the mineral industry is projected at 3,394 mgd in 2020 as compared to 1,188 mgd at present. Although increased water requirements are projected, there appear to be no serious water supply problems facing the mineral industry. However, the quality of water discharged by the mineral industry may require upgrading to meet future standards. Pollution of ground and surface waters from abandoned wells, tests, and mines will decrease during the projection period as sources of pollution are located and corrected.

The land requirements of the Great Lakes Region mineral industry are expected to increase from 65,441 acres in 1968 to 310,637 acres in 2020. Total cumulative acreage required for the 52-year period is 571,844 acres. Although acreage requirements of the mineral industry are relatively small, they are unique in that the land must contain mineral materials that can be extracted economically. As only a small amount of land in the Region contains mineral materials and an even smaller portion of this acreage contains workable deposits, the problem of discovery and land acquisition takes on critical proportions. At present, restrictive zoning ordinances that prohibit or severely restrict mineral extraction and the construction of roads and structures on mineral-bearing land remove valuable mineral deposits from the resource inventory. Land use planning is thus vitally important to future mineral production as well as planned reclamation and sequential land use.

GLOSSARY

consumed water—water lost by evaporation, as well as that lost in the product.

discharged water—water (not recirculated or consumed) disposed to external sources.

new water intake—water introduced from external sources for the first time.

recirculated water—water used to conserve new water.

total water—quantity of water used to produce finished product.

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SUPPLEMENTARY TABLES

TABLE 5–94 Great Lakes Region: Mineral Production, 1960 and 1968[1]

Commodity	1960		1968	
	Quantity	Value	Quantity	Value
Cement:				
Portland....376-pound barrels..	43,720,899	$150,215,455	45,729,463	$145,974,738
Masonry....280-pound barrels..	2,386,589	7,033,929	2,483,654	6,985,513
Clay and shale....short tons..	4,073,668	4,859,638	4,139,014	5,327,612
Coal, bituminous....do....	452,904	W	593,543	W
Copper (recoverable content of ores, etc.)....do....	56,385	36,199,170	74,805	62,607,296
Iron ore (usable)....long tons, gross weight..	54,584,173	486,480,576	56,635,595	597,232,792
Lead (recoverable content of ores, etc.)....short tons..	775	181,350	1,396	368,879
Lime....do....	5,752,584	78,750,017	7,744,542	98,553,213
Magnesium compounds....short tons, MgO equivalent..	W	W	266,406	25,087,136
Manganiferous ore (5 to 35 percent Mn)....short tons, gross weight..	180,460	W	-----	-----
Natural gas....million cubic feet..	20,790	4,449,000	40,480	10,160,000
Natural-gas liquids:				
Natural gasoline....thousand 42-gallon barrels..	W	W	1,066	3,177,000
LP gases....do....	W	W	1,384	3,432,000
Peat....short tons..	238,038	3,093,356	260,509	3,322,260
Petroleum....42-gallon barrels..	2/ 15,899,000	2/ 46,266,000	12,974,404	38,286,742
Sand and gravel 2/....short tons..	101,060,482	89,494,826	129,121,000	124,424,000
Silver (recoverable content of ores, etc.)....troy ounces..	49,324	44,641	500,428	1,073,218
Stone (crushed and broken)....short tons..	91,859,610	119,884,341	110,557,798	154,170,674
Stone (dimension)....do....	193,742	4,283,746	142,007	4,323,495
Zinc (recoverable content of ores, etc.)....do....	66,364	17,121,912	66,194	17,872,380
Value of items that cannot be disclosed: bromine, calcium compounds, gem stones, grindstones, gypsum, iodine (1968), iron oxide pigments (1960), potash, salt, talc, and items indicated by symbol W....	XXXXX	141,923,440	XXXXX	193,878,906
Total Great Lakes Region....	XXXXX	$1,190,281,397	XXXXX	$1,496,257,854

W Withheld to avoid disclosing individual company confidential data; included with "Value of items that cannot be disclosed."
1/ Excludes petroleum, natural gas, and natural-gas liquids data for New York and Ohio, which are not available.
2/ Includes some data which could not be assigned to specific Plan Area.

TABLE 5-95 Plan Area 1.0: Mineral Production, 1960 and 1968

Commodity	1960		1968	
	Quantity	Value	Quantity	Value
Cement:				
Portland....................376-pound barrels..	W	W	W	W
Masonry....................280-pound barrels..	W	W	W	W
Clay.............................short tons..	20	$80	50	$100
Copper (recoverable content of ores, etc.)..do....	56,385	36,199,170	74,805	62,607,296
Iron ore (usable).......long tons, gross weight..	49,012,843	431,754,717	51,999,538	545,432,335
Lime.............................short tons..	W	W	W	W
Peat....................................do....	W	W	W	W
Sand and gravel.........................do....	5,290,046	3,726,638	7,719,000	5,105,000
Silver (recoverable content of ores, etc.) troy ounces..	-----	-----	472,813	1,013,995
Stone (crushed and broken)............short tons..	W	W	W	W
Stone (dimension).......................do....	W	W	188	W
Value of items that cannot be disclosed..........	XXXXX	12,057,745	XXXXX	10,572,848
Total Plan Area 1.0.........................	XXXXX	$483,738,350	XXXXX	$624,731,574

W Withheld to avoid disclosing individual company confidential data; included with "Value of items that cannot be disclosed."

TABLE 5-96 Plan Area 2.0: Mineral Production, 1960 and 1968[1]

Commodity	1960		1968	
	Quantity	Value	Quantity	Value
Bromine.................................pounds..	9,758,184	$2,531,737	9,146,530	$2,145,885
Calcium compounds.....................short tons..	W	W	W	W
Cement:				
Portland....................376-pound barrels..	13,501,865	46,432,561	11,510,238	37,645,031
Masonry....................280-pound barrels..	W	W	299,157	864,272
Clay and shale.......................short tons..	W	W	833,957	1,175,873
Gypsum..................................do....	W	W	W	W
Coal, bituminous........................do....	368,573	W	593,543	W
Iron ore (usable).........long tons, gross weight..	4,034,824	W	3,448,688	W
Lime.................................short tons..	916,464	14,228,604	W	W
Magnesium compounds....short tons, MgO equivalent..	64,808	6,464,113	219,455	19,975,716
Manganiferous ore (5 to 35 percent Mn) short tons, gross weight..	180,460	W	-----	-----
Peat.................................short tons..	23,083	237,498	W	W
Petroleum.......................42-gallon barrels..	11,167,113	32,496,193	9,635,735	28,434,516
Salt.................................short tons..	W	W	W	W
Sand and gravel.........................do....	53,110,376	42,987,000	64,240,000	56,814,000
Stone (crushed and broken)..................do....	30,845,249	41,409,993	39,810,806	56,521,824
Stone (dimension).......................do....	118,972	1,665,394	85,771	1,753,504
Value of items that cannot be disclosed...........	XXXXX	48,966,331	XXXXX	80,659,920
Total Plan Area 2.0.........................	XXXXX	$237,419,424	XXXXX	$285,990,541

W Withheld to avoid disclosing individual company confidential data; included with "Value of items that cannot be disclosed."

1/ Excludes data for natural gas and natural-gas liquids, which are not available.

TABLE 5–97 Plan Area 3.0: Mineral Production, 1960 and 1968[1]

Commodity	1960		1968	
	Quantity	Value	Quantity	Value
Bromine....................pounds..	W	W	W	W
Calcium compounds..........short tons..	W	W	W	W
Cement:				
Portland..........376-pound barrels..	W	W	W	W
Masonry...........280-pound barrels..	W	W	W	W
Clay and shale.............short tons..	W	W	W	W
Gypsum.....................do....	W	W	W	W
Iodine.....................pounds..	-----	-----	W	W
Lime.......................short tons..	W	W	W	W
Magnesium compounds...short tons, MgO equivalent..	W	W	46,951	$5,111,420
Peat.......................short tons..	W	W	W	W
Petroleum..........42-gallon barrels..	4,015,387	$11,684,737	2,713,028	8,005,995
Potash.....................short tons..	W	W	W	W
Salt.......................do....	W	W	W	W
Sand and gravel............do....	8,214,190	5,917,533	8,613,000	7,569,000
Stone (crushed and broken).......do....	W	W	22,003,197	20,852,687
Stone (dimension)..........do....	W	W	W	W
Value of items that cannot be disclosed..........	XXXXX	100,448,858	XXXXX	113,111,396
Total Plan Area 3.0....................	XXXXX	$118,051,128	XXXXX	$154,650,498

W Withheld to avoid disclosing individual company confidential data; included with "Value of items that cannot be disclosed."

1/ Excludes data for natural gas and natural-gas liquids, which are not available.

TABLE 5–98 Plan Area 4.0: Mineral Production, 1960 and 1968[1]

Commodity	1960		1968	
	Quantity	Value	Quantity	Value
Calcium compounds..........short tons..	-----	-----	W	W
Cement:				
Portland..........376-pound barrels..	16,456,800	$56,550,363	17,567,820	$55,227,575
Masonry...........280-pound barrels..	882,387	2,541,640	W	W
Clay and shale.............short tons..	2,057,041	2,381,775	2,185,126	2,959,363
Coal, bituminous...........do....	84,331	318,328	-----	-----
Grindstones................do....	W	W	W	W
Gypsum.....................do....	758,381	3,858,144	666,561	3,215,345
Lime.......................do....	3,935,249	55,842,885	W	W
Peat.......................do....	147,027	2,147,965	108,598	1,205,575
Petroleum..........42-gallon barrels..	2/482,500	2/1,404,070	2/625,641	2/1,846,231
Salt.......................short tons..	W	W	W	W
Sand and gravel............do....	26,346,284	28,433,479	W	W
Stone (crushed and broken).......do....	31,476,202	45,855,504	W	W
Stone (dimension)..........do....	W	W	W	W
Value of items that cannot be disclosed..........	XXXXX	43,545,590	XXXXX	233,148,336
Total Plan Area 4.0....................	XXXXX	$242,879,743	XXXXX	$297,602,425

W Withheld to avoid disclosing individual company confidential data; included with "Value of items that cannot be disclosed."

1/ Excludes petroleum data for New York and Ohio, and natural gas and natural-gas liquids data, which are not available.

2/ Excludes petroleum data for New York and Ohio, which are not available.

TABLE 5–99 Plan Area 5.0: Mineral Production, 1960 and 1968[1]

Commodity	1960		1968	
	Quantity	Value	Quantity	Value
Cement:				
Portland....................376-pound barrels..	W	W	W	W
Masonry.....................280-pound barrels..	W	W	W	W
Clay and shale.......................short tons..	W	W	W	W
Gypsum....................................do....	W	W	W	W
Iron ore (usable)........long tons, gross weight..	1,536,506	W	1,187,369	W
Iron oxide pigments..................short tons..	W	W	-----	-----
Lead (recoverable content of ores, etc.)....do....	775	$181,350	1,396	$368,879
Lime......................................do....	W	W	W	W
Peat......................................do....	W	W	W	W
Salt......................................do....	4,007,960	30,763,284	5,217,566	42,487,852
Sand and gravel...........................do....	6,981,786	7,462,496	W	W
Silver (recoverable content of ores, etc.) troy ounces..	49,324	44,641	27,615	59,223
Stone (crushed and broken)...........short tons..	7,861,735	12,496,464	10,452,335	18,093,085
Stone (dimension).........................do....	W	W	W	W
Talc......................................do....	W	W	W	W
Zinc (recoverable content of ores, etc.)....do....	66,364	17,121,912	66,194	17,872,380
Value of items that cannot be disclosed...........	XXXXX	33,472,675	XXXXX	37,516,397
Total Plan Area 5.0...........................	XXXXX	$101,542,822	XXXXX	$116,397,816

W Withheld to avoid disclosing individual company confidential data; included with "Value of items that cannot be disclosed."

1/ Excludes data for petroleum, natural gas, and natural-gas liquids, which are not available.

TABLE 5-100 Crushed Stone Production in the Great Lakes Region in 1960 and 1968 by Planning Subarea, Plan Area, and State (in short tons)

	1960		1968	
	Quantity	Value	Quantity	Value
Subarea:				
Subarea 1.1.........	W	W	55,000	W
Subarea 1.2.........	W	W	W	W
Subarea 2.1.........	2,249,925	$3,706,502	3,388,900	$6,343,193
Subarea 2.2.........	20,389,480	27,506,830	26,766,352	37,525,732
Subarea 2.3.........	500,863	586,838	333,381	494,631
Subarea 2.4.........	7,704,981	9,609,823	9,322,173	12,158,268
Subarea 3.1.........	19,090,014	16,445,472	21,566,352	20,219,460
Subarea 3.2.........	W	W	436,845	633,227
Subarea 4.1.........	1,387,830	1,728,491	W	W
Subarea 4.2.........	19,911,337	26,752,975	27,511,165	39,988,156
Subarea 4.3.........	1,707,816	5,753,430	1,682,084	5,098,660
Subarea 4.4.........	8,469,219	11,620,608	3,396,687	6,076,760
Subarea 5.1.........	1,913,739	3,200,491	2,769,945	5,288,922
Subarea 5.2.........	5,165,853	7,386,840	6,914,382	10,968,092
Subarea 5.3.........	782,143	1,909,133	768,008	1,836,071
Plan Area:				
Plan Area 1.0.......	W	W	W	W
Plan Area 2.0.......	30,845,249	41,409,993	39,810,806	56,521,824
Plan Area 3.0.......	W	W	22,003,197	20,852,687
Plan Area 4.0.......	31,476,202	45,855,504	W	W
Plan Area 5.0.......	7,861,735	12,496,464	10,452,335	18,093,085
State:				
Illinois............	17,397,410	23,911,040	23,899,368	33,492,582
Indiana.............	1,094,168	1,625,631	1,838,856	W
Michigan............	31,237,769	32,117,581	37,274,803	41,026,207
Minnesota...........	10,009	12,652	55,000	W
New York............	16,330,954	24,117,072	13,849,022	24,169,845
Ohio................	20,556,370	30,902,368	27,389,321	42,391,702
Pennsylvania........	-----	-----	-----	-----
Wisconsin...........	5,232,930	7,197,997	6,251,428	10,257,663
Total Great Lakes	91,859,610	$119,884,341	110,557,798	$154,170,674

W Withheld to avoid disclosing individual company confidential data; included with "Value of items that cannot be disclosed."

TABLE 5-101 Sand and Gravel Production in the Great Lakes Region in 1960 and 1968 by Planning Subarea, Plan Area, and State (in short tons)

	1960		1968	
	Quantity	Value	Quantity	Value
Subarea:				
Subarea 1.1.........	3,271,472	$2,159,172	5,754,000	$3,687,000
Subarea 1.2.........	2,018,574	1,567,466	1,965,000	1,418,000
Subarea 2.1.........	7,320,368	5,455,467	8,423,000	6,210,000
Subarea 2.2.........	23,654,007	19,519,664	30,683,000	27,206,000
Subarea 2.3.........	17,133,624	13,759,118	19,692,000	18,442,000
Subarea 2.4.........	5,002,377	4,252,751	5,442,000	4,956,000
Subarea 3.1.........	2,443,467	1,650,384	3,049,000	2,326,000
Subarea 3.2.........	5,770,723	4,267,149	5,564,000	5,243,000
Subarea 4.1.........	14,635,686	14,269,175	23,029,000	24,626,000
Subarea 4.2.........	2,539,845	2,396,960	3,838,000	4,074,000
Subarea 4.3.........	6,554,658	8,197,001	W	W
Subarea 4.4.........	2,616,095	3,570,343	5,791,000	7,611,000
Subarea 5.1.........	2,419,258	2,492,280	3,053,000	3,770,000
Subarea 5.2.........	3,079,510	3,352,208	4,333,000	4,490,000
Subarea 5.3.........	1,483,018	1,618,008	W	W
Plan Area:				
Plan Area 1.0.......	5,290,046	3,726,638	7,719,000	5,105,000
Plan Area 2.0.......	53,110,376	42,987,000	64,240,000	56,814,000
Plan Area 3.0.......	8,214,190	5,917,533	8,613,000	7,569,000
Plan Area 4.0.......	26,346,284	28,433,479	W	W
Plan Area 5.0.......	6,981,786	7,462,496	W	W
State:				
Illinois............	13,373,358	11,638,357	18,073,000	17,040,000
Indiana.............	4,395,195	3,929,053	6,143,000	6,125,000
Michigan 1/.........	46,910,195	39,304,400	56,663,000	54,979,000
Minnesota...........	3,006,398	1,997,829	3,422,000	2,381,000
New York............	W	W	W	W
Ohio................	7,821,730	9,638,495	W	W
Pennsylvania........	W	W	W	W
Wisconsin...........	15,955,725	11,953,853	21,045,000	15,145,000
Total Great Lakes 1/	101,060,482	$89,494,826	129,121,000	$124,424,000

W Withheld to avoid disclosing individual company confidential data; included with "Value of items that cannot be disclosed."

1/ Includes some data which could not be assigned to specific Plan Areas.

TABLE 5–102 Clay Production in the Great Lakes Region in 1960 and 1968 by Planning Subarea, Plan Area, and State (in short tons)

	1960		1968	
	Quantity	Value	Quantity	Value
Subarea:				
Subarea 1.1..........	20	$80	50	$100
Subarea 1.2..........	-----	-----	-----	-----
Subarea 2.1..........	132,508	137,218	6,130	11,034
Subarea 2.2..........	697,973	1,068,520	410,023	645,990
Subarea 2.3..........	111,806	167,709	95,020	142,530
Subarea 2.4..........	W	W	322,784	376,319
Subarea 3.1..........	W	W	W	W
Subarea 3.2..........	W	W	W	W
Subarea 4.1..........	644,306	707,806	1,144,639	1,272,077
Subarea 4.2..........	383,470	495,555	356,155	433,117
Subarea 4.3..........	684,933	826,932	485,519	1,063,004
Subarea 4.4..........	344,332	351,482	198,813	191,165
Subarea 5.1..........	-----	-----	-----	-----
Subarea 5.2..........	W	W	W	W
Subarea 5.3..........	-----	-----	-----	-----
Plan Area:				
Plan Area 1.0.......	20	80	50	100
Plan Area 2.0.......	W	W	833,957	1,175,873
Plan Area 3.0.......	W	W	W	W
Plan Area 4.0.......	2,057,041	2,381,775	2,185,126	2,959,363
Plan Area 5.0.......	W	W	W	W
State:				
Illinois............	607,203	886,130	287,979	401,902
Indiana.............	W	W	W	W
Michigan............	1,737,588	1,904,389	2,599,351	2,905,880
Minnesota...........	20	80	50	100
New York............	W	W	W	W
Ohio................	1,024,616	1,234,913	802,527	1,417,827
Pennsylvania........	-----	-----	-----	-----
Wisconsin...........	133,358	139,768	8,930	16,634
Total Great Lakes	4,073,668	$4,859,638	4,139,014	$5,327,612

W Withheld to avoid disclosing individual company confidential data; included with "Value of items that cannot be disclosed."

TABLE 5-103 Great Lakes Region: Projected Mineral Production by Selected Commodities (thousands of short tons, unless otherwise noted)

Commodity	1968 1/	1980	2000	2020	1968 to 2020 2/
Clays and shale	4,139	5,070	7,876	12,856	390,987
Coal	594	260	0	0	6,400
Copper	75	100	180	330	8,920
Gypsum	W	2,210	2,990	4,070	147,140
Iron ore 3/	56,636	65,550	90,490	124,740	4,431,200
Lead	1	2	2	2	101
Peat	261	289	367	471	18,150
Salt	W	23,140	49,330	104,620	2,491,840
Sand and gravel	128,947	171,160	295,730	512,430	14,517,260
Silver 4/	500	682	1,202	2,132	59,140
Stone, crushed 5/	110,558	143,464	247,951	427,179	12,119,088
Stone, dimension 6/	142	195	310	595	15,126
Zinc	66	95	95	95	4,766

1/ Actual.
2/ Cumulative.
3/ Thousands of long tons.
4/ Thousands of troy ounces.
5/ Includes limestone, basalt, marl, sandstone, and marble.
6/ Includes limestone, sandstone, and granite.
W Withheld to avoid disclosing individual company confidential data.

TABLE 5-104 Plan Area 1.0: Projected Mineral Production by Selected Commodities (thousands of short tons, unless otherwise noted)

Commodity	1968 1/	1980	2000	2020	1968 to 2020 2/
Copper	75	100	180	330	8,920
Iron ore 3/	52,000	61,600	84,700	116,400	4,149,600
Peat	W	12	15	20	752
Sand and gravel	7,719	9,020	14,020	21,960	686,320
Silver 4/	473	640	1,160	2,090	57,040
Stone, crushed 5/	W	2,908	5,006	4,989	187,418

1/ Actual.
2/ Cumulative.
3/ Thousands of long tons.
4/ Thousands of troy ounces.
5/ Includes limestone and basalt.
W Withheld to avoid disclosing individual company confidential data.

TABLE 5–105 Plan Area 2.0: Projected Mineral Production by Selected Commodities (thousands of short tons, unless otherwise noted)

Commodity	1968[1/]	1980	2000	2020	1968 to 2020[2/]
Clay and shale.....	834	840	966	1,606	53,707
Coal...............	594	260	0	0	6,400
Iron ore[3/].........	3,449	2,500	3,800	5,600	184,000
Peat...............	W	19	21	27	1,108
Salt...............	W	900	2,000	4,000	98,000
Sand and gravel....	64,240	89,600	157,700	278,100	7,750,800
Stone, crushed[4/]...	39,811	49,806	91,695	169,490	4,533,170
Stone, dimension[5/].	86	122	197	422	9,646

1/ Actual.
2/ Cumulative.
3/ Thousands of long tons.
4/ Includes limestone, basalt, and marl.
5/ Includes limestone, sandstone, and granite.
W Withheld to avoid disclosing individual company confidential data.

TABLE 5–106 Plan Area 3.0: Projected Mineral Production by Selected Commodities (thousands of short tons)

Commodity	1968[1/]	1980	2000	2020	1968 to 2020[2/]
Gypsum.............	W	1,400	1,900	2,600	93,600
Peat...............	W	120	150	200	7,520
Salt...............	W	1,250	2,640	5,560	133,200
Sand and gravel.....	8,613	11,310	18,850	31,530	923,060
Stone, crushed[3/]....	22,003	29,210	48,720	81,710	2,387,560
Stone, dimension[3/]..	W	2	2	2	78

1/ Actual.
2/ Cumulative.
3/ Limestone.
W Withheld to avoid disclosing individual company confidential data.

TABLE 5–107 Plan Area 4.0: Projected Mineral Production by Selected Commodities (thousands of short tons)

Commodity	1968 1/	1980	2000	2020	1968 to 2020 2/
Clays and shale.....	2,185	2,730	4,390	7,020	213,980
Gypsum.............	667	810	1,090	1,470	53,540
Peat...............	109	138	181	224	8,770
Salt...............	W	12,700	27,200	58,200	1,357,800
Sand and gravel.....	W	49,940	86,290	149,340	4,234,240
Stone, crushed 3/....	W	47,590	79,220	132,030	3,870,440
Stone, dimension 3/..	W	68	108	168	5,246

1/ Actual.
2/ Cumulative.
3/ Includes limestone and sandstone.
W Withheld to avoid disclosing individual company confidential data.

TABLE 5–108 Plan Area 5.0: Projected Mineral Production by Selected Commodities (thousands of short tons, unless otherwise noted)

Commodity	1968 1/	1980	2000	2020	1968 to 2020 2/
Clays and shale.....	W	100	160	260	7,850
Iron ore 3/.........	1,187	1,450	1,990	2,740	97,600
Lead...............	1	2	2	2	101
Salt...............	5,218	8,290	17,490	36,860	882,840
Sand and gravel.....	W	11,290	18,870	31,500	922,840
Silver 4/...........	28	42	42	42	2,100
Stone, crushed 5/....	10,452	13,950	23,310	38,960	1,140,500
Stone, dimension 6/..	W	3	3	3	156
Zinc...............	66	95	95	95	4,766

1/ Actual.
2/ Cumulative.
3/ Thousands of long tons.
4/ Thousands of troy ounces.
5/ Includes limestone and marl.
6/ Includes limestone and sandstone.
W Withheld to avoid disclosing individual company confidential data.

TABLE 5-109 Great Lakes Region: Source of New Water Used and Water Discharged by the Mineral Industries in 1968, Estimated (millions of gallons per day)

	Seasonal Peak[1/]	Average for 365 days
New Intake		
Streams	42	33
Lakes[2/]	652	623
Ground water	55	45
Mines	28	24
Other	3	2
Total	780	727
Discharged		
Surface[2/]	664	623
Underground	38	29
Total	702	652

1/ Peak usage, owing to seasonal mineral producers who operate only during the warmer months of the year, varies by subarea from April 1 to November 31 or May 1 to October 31. Whereas the greatest water usage is in Subarea 1.1, the northern most subarea, the seasonal variation is due primarily to water usage in subareas located in the southern part of the basin.

2/ Includes Lake Superior, see tables in Plan Area 1.0, Subarea 1.1, and Subarea 1.2.

TABLE 5-110 Plan Area 1.0: Source of New Water Used and Water Discharged by the Mineral Industries in 1968, Estimated (millions of gallons per day)

	May-October	Average for 365 days
New Intake		
Streams................	5.4	5.4
Lake Superior..........	534.3	530.0
Other lakes............	26.7	26.7
Ground water...........	1.0	1.0
Mines..................	9.1	9.1
Total.............	576.5	572.2
Discharged		
Lake Superior..........	507.5	503.3
Surface................	14.7	14.7
Total.............	522.2	518.0

TABLE 5-111 Planning Subarea 1.1: Source of New Water Used and Water Discharged by the Mineral Industries in 1968, Estimated (millions of gallons per day)

	Average for 365 days
New Intake	
Lake Superior............................	504
Other lakes..............................	25
Streams..................................	3
Ground water.............................	1
Mines....................................	9
Total............................	542
Discharged	
Lake Superior............................	499
Surface..................................	1
Total............................	500

TABLE 5–112 Planning Subarea 1.2: Source of New Water Used and Water Discharged by the Mineral Industries in 1968, Estimated (millions of gallons per day)

	May-October	Average for 365 days
New Intake		
Lake Superior..........	30.3	26.0
Streams................	2.4	2.4
Other lakes............	1.7	1.7
Mines..................	0.1	0.1
Total.............	34.5	30.2
Discharged		
Lake Superior..........	8.5	4.3
Surface................	13.7	13.7
Total.............	22.2	18.0

TABLE 5–113 Plan Area 2.0: Source of New Water Used and Water Discharged by the Mineral Industries in 1968, Estimated (millions of gallons per day)

	April-November	Average for 365 days
New Intake		
Streams.................	16.0	11.7
Lakes...................	9.6	7.4
Ground water............	15.9	10.7
Mines...................	4.0	3.3
Purchased...............	0.3	0.3
Other...................	0.1	0.1
Total.............	45.9	33.5
Discharged		
Surface.................	40.2	28.6
Underground.............	2.8	2.4
Sewer...................	0.2	0.1
Total.............	43.2	31.1

TABLE 5–114 Planning Subarea 2.1: Source of New Water Used and Water Discharged by the Mineral Industries in 1968, Estimated (millions of gallons per day)

	April-November	Average for 365 days
New Intake		
Streams..................	1.4	1.2
Lakes....................	0.2	0.1
Ground water.............	0.7	0.6
Purchased................	0.3	0.3
Total..............	2.6	2.2
Discharged		
Surface..................	1.1	0.7
Underground..............	0.1	0.1
Total..............	1.2	0.8

TABLE 5–115 Planning Subarea 2.2: Source of New Water Used and Water Discharged by the Mineral Industries in 1968, Estimated (millions of gallons per day)

	April-November	Average for 365 days
New Intake		
Streams..................	11.7	8.5
Lakes....................	2.0	1.4
Ground water.............	6.0	4.0
Mines....................	2.2	2.1
Total..............	21.9	16.0
Discharged		
Surface..................	20.9	15.3
Sewer....................	0.2	0.1
Total..............	21.1	15.4

TABLE 5–116 Planning Subarea 2.3: Source of New Water Used and Water Discharged by the Mineral Industries in 1968, Estimated (millions of gallons per day)

	April-November	Average for 365 days
New Intake		
Streams	2.9	2.0
Lakes	2.4	1.6
Ground water	9.2	6.1
Mines	1.8	1.2
Total	16.3	10.9
Discharged		
Surface	15.9	10.6
Underground	insig.	insig.
Total	15.9	10.6

TABLE 5–117 Planning Subarea 2.4: Source of New Water Used and Water Discharged by the Mineral Industries in 1968, Estimated (millions of gallons per day)

	April-November	Average for 365 days
New Intake		
Lakes	5.0	4.3
Other	0.1	0.1
Total	5.1	4.4
Discharged		
Surface	2.3	2.0
Underground	2.7	2.3
Total	5.0	4.3

TABLE 5–118 Plan Area 3.0: Source of New Water Used and Water Discharged by the Mineral Industries in 1968, Estimated (millions of gallons per day)

	April-November	Average for 365 days
New Intake		
Streams..................	0.3	0.2
Lakes....................	22.7	15.2
Ground water............	1.8	1.2
Total.............	24.8	16.6
Discharged		
Surface..................	2.4	1.6
Underground.............	19.9	13.3
Total.............	22.3	14.9

TABLE 5–119 Planning Subarea 3.1: Source of New Water Used and Water Discharged by the Mineral Industries in 1968, Estimated (millions of gallons per day)

	April-November	Average for 365 days
New Intake		
Lakes....................	20.9	14.0
Ground water............	insig.	insig.
Total.............	20.9	14.0
Discharged		
Surface..................	0.4	0.2
Underground.............	18.0	12.1
Total.............	18.4	12.3

TABLE 5–120 Planning Subarea 3.2: Source of New Water Used and Water Discharged by the Mineral Industries in 1968, Estimated (millions of gallons per day)

	April-November	Average for 365 days
New Intake		
Streams	0.3	0.2
Lakes	1.8	1.2
Ground water	1.8	1.2
Total	3.9	2.6
Discharged		
Surface	2.0	1.4
Underground	1.9	1.2
Total	3.9	2.6

TABLE 5–121 Plan Area 4.0: Source of New Water Used and Water Discharged by the Mineral Industries in 1968, Estimated (millions of gallons per day)

	April-November	Average for 365 days
New Intake		
Streams	16.3	12.5
Lakes	49.2	34.2
Ground water	34.1	30.2
Mines	13.4	9.8
Other	2.1	1.9
Total	115.1	88.6
Discharged		
Surface	87.9	64.3
Underground	14.3	12.2
Sewer	0.3	0.3
Total	102.5	76.8

TABLE 5–122 Planning Subarea 4.1: Source of New Water Used and Water Discharged by the Mineral Industries in 1968, Estimated (millions of gallons per day)

	April-November	Average for 365 days
New Intake		
Streams.................	10.1	8.0
Lakes...................	31.6	20.8
Ground water............	6.0	3.9
Mines...................	11.9	8.8
Total.............	59.6	41.5
Discharged		
Surface.................	48.2	31.8
Underground.............	9.9	8.7
Total.............	58.1	40.5

TABLE 5–123 Planning Subarea 4.2: Source of New Water Used and Water Discharged by the Mineral Industries in 1968, Estimated (millions of gallons per day)

	April-November	Average for 365 days
New Intake		
Streams.................	4.2	2.8
Lakes...................	2.7	1.8
Ground water............	13.7	14.7
Mines...................	1.5	1.0
Total.............	22.1	20.3
Discharged		
Surface.................	19.7	18.0
Underground.............	1.5	1.4
Total.............	21.2	19.4

TABLE 5–124 Planning Subarea 4.3: Source of New Water Used and Water Discharged by the Mineral Industries in 1968, Estimated (millions of gallons per day)

	April-November	Average for 365 days
New Intake		
Streams	1.9	1.6
Lakes	9.2	7.8
Ground water	11.2	9.5
Other	2.0	1.8
Total	24.3	20.7
Discharged		
Surface	12.3	9.3
Underground	1.8	1.4
Sewer	0.3	0.3
Total	14.4	11.0

TABLE 5–125 Planning Subarea 4.4: Source of New Water Used and Water Discharged by the Mineral Industries in 1968, Estimated (millions of gallons per day)

	April-November	Average for 365 days
New Intake		
Streams	0.1	0.1
Lakes	5.7	3.8
Ground water	3.2	2.1
Other	0.1	0.1
Total	9.1	6.1
Discharged		
Surface	7.7	5.2
Underground	1.1	0.7
Total	8.8	5.9

TABLE 5–126 Plan Area 5.0: Source of New Water Used and Water Discharged by the Mineral Industries in 1968, Estimated (millions of gallons per day)

	April-November	Average for 365 days
New Intake		
Streams..................	4.2	3.5
Lakes....................	9.6	9.6
Ground water............	2.4	1.6
Mines....................	1.3	1.3
Other....................	0.2	0.1
Total.............	17.7	16.1
Discharged		
Surface..................	10.8	9.9
Underground.............	1.4	0.8
Total.............	12.2	10.7

TABLE 5–127 Planning Subarea 5.1: Source of New Water Used and Water Discharged by the Mineral Industries in 1968, Estimated (millions of gallons per day)

	April-November	Average for 365 days
New Intake		
Streams..................	1.1	0.8
Lakes....................	0.1	0.1
Ground water............	1.3	0.9
Other....................	0.2	0.1
Total.............	2.7	1.9
Discharged		
Surface..................	1.6	1.2
Underground.............	0.6	0.3
Total.............	2.2	1.5

TABLE 5–128 Planning Subarea 5.2: Source of New Water Used and Water Discharged by the Mineral Industries in 1968, Estimated (millions of gallons per day)

	April-November	Average for 365 days
New Intake		
Streams.................	2.9	2.6
Lakes...................	7.8	7.8
Ground water............	0.9	0.6
Mines...................	1.2	1.2
Total.............	12.8	12.2
Discharged		
Surface.................	8.5	8.1
Underground.............	0.6	0.4
Total.............	9.1	8.5

TABLE 5–129 Planning Subarea 5.3: Source of New Water Used and Water Discharged by the Mineral Industries in 1968, Estimated (millions of gallons per day)

	May-October	Average for 365 days
New Intake		
Streams.................	0.2	0.1
Lakes...................	1.7	1.7
Ground water............	0.2	0.1
Mines...................	0.1	0.1
Total.............	2.2	2.0
Discharged		
Surface.................	0.7	0.6
Underground.............	0.2	0.1
Total.............	0.9	0.7

TABLE 5-130 Great Lakes Region: Projected Mineral Industry Water Use (millions of gallons per day)

	1968 1/	1980	2000	2020
New Intake				
Seasonal peak 2/.........	780	928	1,230	1,745
Average for 365 days....	727	845	1,084	1,494
Discharged				
Seasonal peak 2/.........	702	807	1,894	1,419
Average for 365 days....	652	727	894	1,181
Recirculated				
Seasonal peak 2/.........	494	853	1,339	2,102
Average for 365 days....	461	796	1,233	1,900
Consumed				
Seasonal peak 2/.........	78	121	197	326
Average for 365 days....	75	118	190	313
Total Water 3/				
Seasonal peak 2/.........	1,274	1,781	2,569	3,847
Average for 365 days....	1,188	1,641	2,317	3,394

1/ Estimated.
2/ Peak usage, owing to seasonal mineral producers who operate only during the warmer months of the year, varies by subarea from April 1 to November 30 or May 1 to October 31. Whereas the greatest water usage is in Subarea 1.1, the northern most subarea, the seasonal variation is due primarily to water usage in subareas located in the southern part of the basin.
3/ Intake plus recirculated.

TABLE 5-131 Plan Area 1.0: Projected Mineral Industry Water Use (millions of gallons per day)

	1968 1/	1980	2000	2020
New Intake				
May-October.............	576.5	615.4	673.8	766.2
Average for 365 days....	572.2	610.9	668.9	761.1
Discharged				
May-October.............	522.2	527.2	542.4	572.2
Average for 365 days....	518.0	522.8	537.7	567.3
Recirculated				
May-October.............	365.9	655.8	962.3	1,387.4
Average for 365 days....	365.9	655.0	960.3	1,383.6
Consumed				
May-October.............	54.3	88.2	131.4	194.0
Average for 365 days....	54.2	88.1	131.2	193.8
Total Water 2/				
May-October.............	942.4	1,271.2	1,636.1	2,153.6
Average for 365 days....	938.1	1,265.9	1,629.2	2,144.7

1/ Estimated.
2/ Intake plus recirculated.

TABLE 5–132 Plan Area 2.0: Projected Mineral Industry Water Use (millions of gallons per day)

	1968 1/	1980	2000	2020
New Intake				
April-November..........	45.9	85.3	157.0	292.3
Average for 365 days....	33.5	60.2	108.9	201.9
Discharged				
April-November..........	43.2	82.1	150.4	282.3
Average for 365 days....	31.1	57.5	103.8	194.3
Recirculated				
April-November..........	43.9	68.7	134.7	261.7
Average for 365 days....	33.7	49.5	95.9	184.5
Consumed				
April-November..........	2.7	3.2	6.6	10.0
Average for 365 days....	2.4	2.7	5.1	7.6
Total Water 2/				
April-November..........	89.8	154.0	291.7	554.0
Average for 365 days....	67.2	109.7	204.8	386.4

1/ Estimated.
2/ Intake plus recirculated.

TABLE 5–133 Plan Area 3.0: Projected Mineral Industry Water Use (millions of gallons per day)

	1968 1/	1980	2000	2020
New Intake				
April-November..........	24.8	33.4	50.4	80.3
Average for 365 days....	16.6	22.4	33.8	53.7
Discharged				
April-November..........	22.3	29.7	44.6	69.9
Average for 365 days....	14.9	19.9	29.9	46.7
Recirculated				
April-November..........	8.1	15.6	32.5	69.2
Average for 365 days....	5.4	8.6	21.8	46.2
Consumed				
April-November..........	2.5	3.7	5.8	10.4
Average for 365 days....	1.7	2.5	3.9	7.0
Total Water 2/				
April-November..........	32.9	49.0	82.9	149.5
Average for 365 days....	22.0	31.0	55.6	99.9

1/ Estimated.
2/ Intake plus recirculated.

TABLE 5–134 Plan Area 4.0: Projected Mineral Industry Water Use (millions of gallons per day)

	1968 1/	1980	2000	2020
New Intake				
April-November..........	115.1	163.4	295.0	513.3
Average for 365 days....	88.6	124.8	226.7	397.6
Discharged				
April-November..........	102.5	144.3	255.9	430.4
Average for 365 days....	76.8	107.0	189.7	320.4
Recirculated				
April-November..........	61.7	90.9	172.0	314.4
Average for 365 days....	43.0	63.7	121.3	223.9
Consumed				
April-November..........	12.6	19.1	39.1	82.9
Average for 365 days....	11.8	17.8	37.0	77.2
Total Water 2/				
April-November..........	176.8	254.3	467.0	827.7
Average for 365 days....	131.6	188.5	348.0	621.5

1/ Estimated.
2/ Intake plus recirculated.

TABLE 5–135 Plan Area 5.0: Projected Mineral Industry Water Use (millions of gallons per day)

	1968 1/	1980	2000	2020
New Intake				
April-November..........	17.7	30.9	53.7	93.1
Average for 365 days....	16.1	26.5	46.1	79.8
Discharged				
April-November..........	12.2	23.4	39.5	64.2
Average for 365 days....	10.7	19.3	32.4	52.2
Recirculated				
April-November..........	14.0	21.9	37.4	69.6
Average for 365 days....	13.1	19.6	33.3	62.0
Consumed				
April-November..........	5.5	7.5	14.2	28.9
Average for 365 days....	5.4	7.2	13.7	27.6
Total Water 2/				
April-November..........	31.7	52.8	91.1	162.7
Average for 365 days....	29.2	46.1	79.4	141.8

1/ Estimated.
2/ Intake plus recirculated.

TABLE 5–136 Great Lakes Region: Total Land Disturbed by Mining Activities as of January 1, 1965, by Commodity and Plan Area (acres)

Commodity	Plan Area					Great Lakes Region Total
	1.0	2.0	3.0	4.0	5.0	
Copper............	2,000					2,000
Clay and shale....	80	506	260	2,433	570	3,849
Coal..............		5,488		728		6,216
Gypsum............			1,105	377	40	1,522
Iron ore..........	47,615	449			630	48,694
Peat..............	620	200	675	418	32	1,945
Sand and gravel....	7,949	37,655	14,005	19,214	11,977	90,800
Stone.............	1,614	7,364	3,876	9,291	3,875	26,020
Other.............	40	15		1,487	180	1,722
Total........	59,918	51,677	19,921	33,948	17,304	182,768

TABLE 5–137 Plan Area 1.0: Total Land Disturbed by Mining Activities as of January 1, 1965, by Commodity and Planning Subarea (acres)

Commodity	Subarea		Plan Area Total
	1.1	1.2	
Copper...................		2,000	2,000
Clay and shale...........	80		80
Iron ore.................	45,800	1,815	47,615
Peat.....................	620		620
Sand and gravel..........	5,420	2,529	7,949
Stone....................	200	1,414	1,614
Other....................	25	15	40
Total...............	52,145	7,773	59,918

TABLE 5–138 Plan Area 2.0: Total Land Disturbed by Mining Activities as of January 1, 1965, by Commodity and Planning Subarea (acres)

Commodity	Subarea				Plan Area Total
	2.1	2.2	2.3	2.4	
Clay and shale.....		318	128	60	506
Coal...............		5,400	88		5,488
Iron ore...........	449				449
Peat...............			200		200
Sand and gravel....	10,610	11,499	10,399	5,147	37,655
Stone..............	3,167	2,247	350	1,600	7,364
Other..............	10	5			15
Total.........	14,236	19,469	11,165	6,807	51,677

TABLE 5–139 Plan Area 3.0: Total Land Disturbed by Mining Activities as of January 1, 1965, by Commodity and Planning Subarea (acres)

Commodity	Subarea		Plan Area Total
	3.1	3.2	
Clay and shale.........	210	50	260
Gypsum.................	1,105		1,105
Peat...................		675	675
Sand and gravel........	2,400	11,605	14,005
Stone..................	3,391	485	3,876
Total.............	7,106	12,815	19,921

TABLE 5–140 Plan Area 4.0: Total Land Disturbed by Mining Activities as of January 1, 1965, by Commodity and Planning Subarea (acres)

Commodity	Subarea				Plan Area Total
	4.1	4.2	4.3	4.4	
Clay and shale.....	155	1,642	511	125	2,433
Coal...............			728		728
Gypsum.............		377			377
Peat...............	345		48	25	418
Sand and gravel....	4,972	7,001	3,481	3,760	19,214
Stone..............	727	6,318	1,146	1,100	9,291
Other..............		25	1,462		1,487
Total.........	6,199	15,363	7,376	5,010	33,948

TABLE 5–141 Plan Area 5.0: Total Land Disturbed by Mining Activities as of January 1, 1965, by Commodity and Planning Subarea (acres)

Commodity	Subarea			Plan Area Total
	5.1	5.2	5.3	
Clay and shale.......		495	75	570
Gypsum...............	30	10		40
Iron ore.............		130	500	630
Peat.................	11	21		32
Sand and gravel......	2,856	8,688	433	11,977
Stone................	525	3,303	47	3,875
Other................		77	103	180
Total...........	3,422	12,724	1,158	17,304

TABLE 5-142 Great Lakes Region: Projected Mineral-Bearing Land Requirements[1] (acres)

By Commodity

Commodity	1968 2/	1980	1968 to 1980 3/	2000	1968 to 2000 3/	2020	1968 to 2020 3/
Clays and shale......	64	81	893	129	2,956	207	6,368
Coal.........	121	53	1,130	0	1,300	0	1,300
Copper.......	4,500	4,500	4,500	7,000	7,000	10,000	10,000
Iron ore.....	55,600	90,700	90,700	174,600	174,600	286,600	286,600
Peat.........	2,477	2,660	3,194	3,216	4,507	4,106	6,388
Gypsum.......	24	30	329	40	1,026	54	1,970
Sand and gravel.....	1,929	2,568	26,662	4,422	95,827	7,638	217,148
Stone, crushed....	473	615	6,440	841	19,894	1,315	40,883
Stone, dimension..	3	6	64	9	225	17	487
Zinc-lead....	250	500	500	500	500	700	700
Total.....	65,441	101,713	134,412	190,757	307,835	310,637	571,844

By Plan Area

Plan Area	1968 2/	1980	1968 to 1980 3/	2000	1968 to 2000 3/	2020	1968 to 2020 3/
1.0..........	58,740	93,265	94,892	177,905	183,665	291,090	303,199
2.0..........	2,576	3,266	17,341	5,943	55,705	9,483	124,271
3.0..........	1,133	1,272	5,013	1,743	15,577	2,532	33,050
4.0..........	1,579	2,056	12,055	2,880	38,331	4,358	80,828
5.0..........	1,413	1,854	5,111	2,286	14,557	3,174	30,496
Total.....	65,441	101,713	134,412	190,757	307,835	310,637	571,844

1/ Includes nonmineral-bearing surface lands required for copper, iron ore and zinc-lead production.

2/ Estimated.

3/ Cumulative.

TABLE 5–143 Plan Area 1.0: Projected Mineral-Bearing Land Requirements[1] (acres)

Commodity	1968 2/	1980	1968 to 1980 3/	2000	1968 to 2000 3/	2020	1968 to 2020 3/
Copper.......	4,500	4,500	4,500	7,000	7,000	10,000	10,000
Iron ore.....	53,500	88,000	88,000	170,000	170,000	280,000	280,000
Peat.........	600	600	600	650	650	700	700
Sand and gravel.....	130	153	1,649	239	5,576	368	11,670
Stone, crushed....	10	12	143	16	439	22	829
Total....	58,740	93,265	94,892	177,905	183,665	291,090	303,199

1/ Includes nonmineral-bearing surface lands required for copper and iron ore production.
2/ Estimated.
3/ Cumulative.

TABLE 5–144 Plan Area 2.0: Projected Mineral-Bearing Land Requirements[1] (acres)

Commodity	1968 2/	1980	1968 to 1980 3/	2000	1968 to 2000 3/	2020	1968 to 2020 3/
Clays and shale.......	10	10	122	12	296	18	624
Coal..........	121	53	1,130	0	1,300	0	1,300
Iron ore......	1,200	1,700	1,700	3,400	3,400	5,100	5,100
Peat..........	261	141	307	157	342	201	466
Sand and gravel......	847	1,186	12,202	2,077	43,747	3,648	102,009
Stone, crushed.....	134	170	1,820	288	6,408	500	14,310
Stone, dimension...	3	6	60	9	212	16	462
Total.....	2,576	3,266	17,341	5,943	55,705	9,483	124,271

1/ Includes nonmineral-bearing surface lands required for iron ore production.
2/ Estimated.
3/ Cumulative.

TABLE 5–145 Plan Area 3.0: Projected Mineral-Bearing Land Requirements[1] (acres)

Commodity	1968 1/	1980	1968 to 1980 2/	2000	1968 to 2000 2/	2020	1968 to 2020 2/
Clays and shale......	9	11	126	20	448	33	987
Peat.........	843	896	1,071	1,119	1,631	1,493	2,433
Gypsum.......	13	15	168	20	523	28	1,006
Sand and gravel......	209	272	2,836	454	10,106	760	22,251
Stone, crushed....	59	78	811	130	2,865	218	6,366
Stone, dimension..	3/	3/	1	3/	4	3/	7
Total...	1,133	1,272	5,013	1,743	15,577	2,532	33,050

1/ Estimated.
2/ Cumulative.
3/ Less than an acre.

TABLE 5–146 Plan Area 4.0: Projected Mineral-Bearing Land Requirements[1] (acres)

Commodity	1968	1980	1968 to 1980 2/	2000	1968 to 2000 2/	2020	1968 to 2020 2/
Clays and shale......	44	59	630	95	2,160	152	4,645
Gypsum.......	11	15	161	20	503	26	964
Peat.........	765	1,015	1,206	1,282	1,872	1,704	2,770
Sand and gravel.....	545	686	7,157	1,200	26,347	2,107	59,092
Stone, crushed....	214	281	2,898	283	7,440	368	13,339
Stone, dimension..	3/	3/	3	3/	9	1	18
Total...	1,579	2,056	12,055	2,880	38,331	4,358	80,828

1/ Estimated.
2/ Cumulative.
3/ Less than an acre.

TABLE 5–147 Plan Area 5.0: Projected Mineral-Bearing Land Requirements[1] (acres)

Commodity	1968 2/	1980	1968 to 1980 3/	2000	1968 to 2000 3/	2020	1968 to 2020 3/
Clays and shale......	1	1	15	2	52	4	112
Iron ore.....	900	1,000	1,000	1,200	1,200	1,500	1,500
Peat.........	8	8	10	8	12	8	19
Sand and gravel.....	198	271	2,818	452	10,051	755	22,126
Stone, crushed....	56	74	768	124	2,742	207	6,039
Zinc-lead....	250	500	500	500	500	700	700
Total....	1,413	1,854	5,111	2,286	14,557	3,174	30,496

1/ Includes nonmineral-bearing surface lands required for iron ore and zinc-lead production.
2/ Estimated.
3/ Cumulative.

GREAT LAKES BASIN FRAME-
WORK STUDY - APPENDIX 5

AUTHOR

TITLE GREAT LAKES BASIN FRAMEWORK STUDY - APPENDIX 5

DATE DUE	BORROWER'S NAME
FEB 15 1980	DAVIDSON 296-0656

GREAT LAKES BASIN COMMISSION
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State of Illinois
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State of Michigan
State of Minnesota
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Department of Housing & Urban Development
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Department of Transportation
Environmental Protection Agency
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Great Lakes Commission