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GEOLOGICAL AND NATURAL HISTORY SURVEY
3817 Mineral Point Road
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M.E. Ostrom, State Geologist and Director

THE GEOLOGICAL ENVIRONMENT OF THE SUPERIOR AREA, DOUGLAS COUNTY, WISCONSIN

by

J.T. Mengel

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1973

Bob De Groot

University of Wisconsin-Extension

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Prepared in cooperation with the

Department of Geology

University of Wisconsin-Superior

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Could this be titled Engineering Properties? or Physical Properties

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INTRODUCTION

(1.1) Purpose of Investigation

The City of Superior is the county seat of Douglas County, situated at the head of Lake Superior in northeastern Wisconsin. The city has a (1970) population of about 32,000 and serves as a regional center for several thousand more people in northwestern Wisconsin. Superior, together with its twin port of Duluth, Minnesota is the western terminus of the St. Lawrence Seaway and the fifth ranked port in the United States in tonnage of all types of cargo handled. Cargoes consist mainly of iron ores from the Mesabi Range and potash salts, petroleum and grain from the prairies, together with limestone and coal arriving from the lower Great Lakes.

Superiors' geologic setting gives it the finest harbor on the Great Lakes and makes it a natural connecting link between the mineral deposits of the southern Canadian Shield and the grain fields of the Dakotas and those other parts of the nation and the world which are accessible to deep water shipping. The geologic framework of the city determines port development, foundation conditions, water supply potential, land use, availability of construction materials, sites for waste disposal and influences many socio-economic and legal problems connected with development. This review of the geology of Superior is designed to provide knowledge of the physical framework of the city within which city and port planning, engineering design and environmental impact evaluations can be made more effectively.

(1.2) Location of Superior Area

The Superior area of this report is bounded by meridians 92° and 92° 15' west longitude and parallels 46° 37' 30" and 46° 47' 30" north latitude (Figure 1). The area of investigation includes portions of the following U. S. Geological Survey 7 1/2 minute topographic map quadrangles: Parkland, Superior, West Duluth, Duluth Heights, and Duluth, and by the Duluth-Superior Harbor and Vicinity quadrangle. The U. S. Army Corps of Engineers Meade-Harding Chart of 1861 and modern Lake Survey Chart 996 depict the harbor.

The city limits enclose a triangularly shaped area of about 44 square miles at the western end of the Lake Superior lowland (c.f. Martin, 1965, Chapter XVII), a red clay plain laid down under post-glacial lakes which filled this part of the Lake Superior basin 10,000 years ago. Superior is built on the smoothly undulating surface of the plain which slopes northward west? to a line of bluffs along the St. Louis River,* St. Louis Bay, Superior and Allouez Bays. ~~(Figure 1)~~

The harbor consists of an outer lagoon, Superior-Allouez Bays paralleling the shore of Lake Superior and an inner lagoon, St. Louis Bay, at right angles to the lake shore. Lake-head barrier spits, Minnesota Point and Wisconsin Point protect the outer lagoon from the lake, while an older set of barrier spits, Rices Point and Connors Point separates the two lagoons. Grassy Point, another barrier, separates St. Louis Bay from the estuary of the St. Louis River. ~~(Figure 1)~~

Lake Superior has a mean elevation of 602 feet above sea level, the

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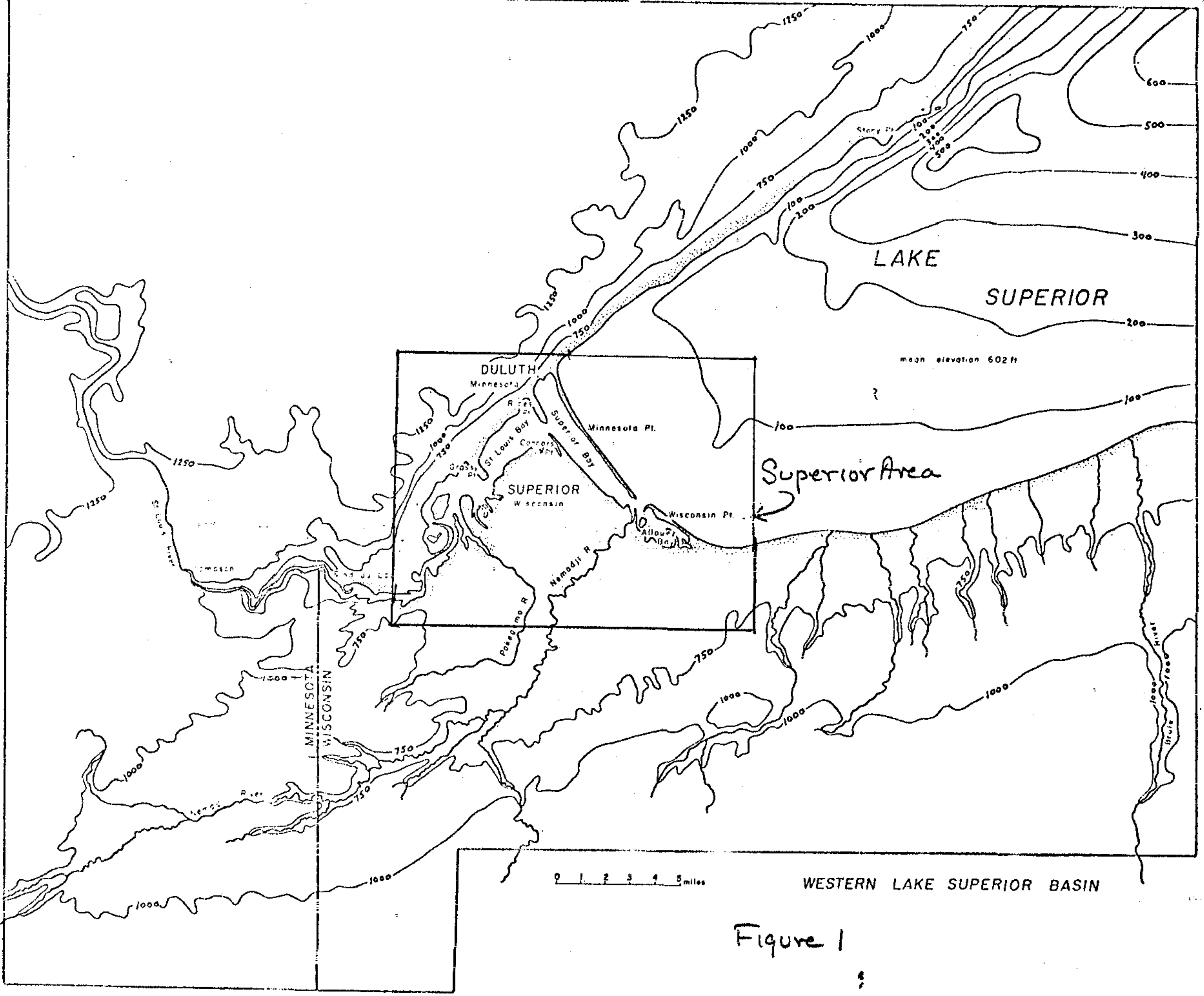
*Appendix A lists derivations of local place names.



Superior Area

Figure 1

plain under Superior is about 640 feet above sea level, and the Duluth escarpment rises to elevations of 1400 or 1500 feet, giving a relief of about 800 feet in the area. Dissection of the clay plain by the St. Louis and Nemadji River drainages produce a maximum of about 40 or 50 feet of relief within the city limits.

(1.3) Climate

Superior has a humid continental climate with long, cold winters during which extreme temperatures of -41°F have been recorded and warm summers in which temperatures to +106°F have been recorded. The mean growing season is 140 days and the mean annual precipitation is about 29 inches.

The first frost in autumn usually occurs in late September, with hard freezes in October or early November. The St. Louis and Nemadji Rivers and the Bays commonly remain open until mid November or early December. Lake Superior has not been known to develop complete ice cover in the past century and is usually navigated for about eight months, although consideration is now being given to the possibilities of year round operations.

An average of about 77 inches of snow falls annually, although in some years the total is considerably more or less than the long term average. The depth of seasonal freezing of the ground depends in large part on the depth of snow accumulation since the snow serves as an insulating cover. In poorly covered spots the frost may reach depths greater than 5 feet, although average depths are usually somewhat less than this.

(1.4) History of Development

Historical information on the City is contained in the works of Flower (1890), Shaw (undated), and Roberts (1969); harbor history is summarized in the work of Erickson (1940).

Superior is built on land that was in the possession of the Sioux Indians when missionaries and fur traders arrived to establish French sovereignty in the latter half of the seventeenth century. Among the early French adventurers was Jesuit Father Claude Allouez; who camped at the mouth of Bluff Creek in the summer of 1667 and Daniel Seiur du Luth who portaged Minnesota Point near the present ship canal on June 27, 1679 and in 1690 established a fur trading port on Connors Point.

Tradition has it that Chippewa (Ojibwa) Indians took possession after a battle fought on the site of the city in the mid eighteenth century. During the eighteenth century Indian settlements were located on the ends of Minnesota and Wisconsin Points, the base of Connors Point, along St. Louis Bay and the St. Louis River, on Pokegama Bay, and at the mouth of the Nemadji River. Small areas were cultivated on the flood plain of the Nemadji near its mouth, wild rice harvested from Allouez Bay and blueberries from the points, and fish taken on the various bays and in the lake near the Superior Entry.

The area passed from French to British sovereignty in 1763 and became American at the conclusion of the Revolutionary War in 1783. In 1793 Jean Baptiste Cadotte of the (British) Northwest Fur Company established a stockade and fur trading port, Fort St. Louis, at the base of Connors Point, perhaps displacing a Hudson's Bay Company post there. The base of the point was less marshy than the outer end and offered quiet anchorage for canoes on the Howards Bay side and convenient access to the main channel to the Lake on the Superior Bay side. Fur trading declined in importance during the early 19th century and by mid-century development of the site of the city of Superior depended on national economic developments and trends although it was still focused on the harbor.

In 1842 the Chippewa ceded rights to lands adjacent to Lake Superior in a treaty concluded at La Pointe, opening the region to permanent settlement. Wisconsin became a state* on May 29, 1848 and during the winter of 1853-54 the legislature created Douglas County, from a portion of La Pointe County, naming it for Senator Stephen A. Douglas of Illinois. Start of construction of the canal locks at Sault Ste. Marie in 1853 and belief that the then-proposed northern transcontinental railroad would have its eastern terminus at the head of Lake Superior led speculators to claim land on both sides of the Superior Entry and both sides of the mouth of the Nemadji River in 1853 and 1854. Shortly after this the Quebec pier was constructed on Superior Bay about a mile and a half west of the Nemadji, and a town site laid off on top of the clay bluffs south of the dock. A rival town, Superior City, was laid off to the west in what is now Central Park. The two settlements were merged in 1858 but the discordance in their street orientations can still be traced on city maps (c.f. any Plate)

After an initial boom the population of Superior declined to less than a thousand and remained low until the early 1880's. Fishing, timbering, and saw milling, the fueling of steamers and down lake shipment of fish, and lumber were the major occupations at this time. Logging took place along the Nemadji,

* Martin, 1965, pp. 481-487 reviews State boundaries and the history of their definition including boundary litigation with Minnesota over the boundary line from St Louis Bay to the falls of the St. Louis River above Fond du Lac, Minnesota.

Pokegama and St. Louis Rivers and on the sites of West and South Superior, wherever there were dense stands of White and Norway Pine, together with some fir or birch. The logs were rafted to the vicinity of Quebec Pier and to Howards Bay where they could be boomed in sheltered waters. Logging near the city declined in importance during the 1880's and sawmilling largely ceased during the first decade ~~after the start~~ of the twentieth century.

The railroad reached Superior in 1881 and the city evolved rapidly as the Land and River Improvement Company, under the leadership of General John Hammond, laid out West Superior, Billings Park and South Superior. Railroad oriented communities grew in Allouez and Itasca at this time and by 1887 these five separate communities were incorporated with East End and Central Park to become the City of Superior. The extensive elevator, coal dock, and ship yard system along St. Louis-Howards Bay and Connors Point was established between about 1885 and 1895 as were the ore docks and other port facilities in East End, Allouez and Itasca, so by the start of the present century the city had much of its present form and population size.

(1.5) Previous Investigations

No previous geologic report has been made on the city of Superior, although the general nature of the bedrock geology of northwestern Wisconsin was established nearly a century ago and described by Sweet (1880), Irving (1883), Grant (1901), Van Hise and Leith (1911) and Thwaites (1912). Reports by Lawson (1899), Schwartz (1949) and Taylor (1964a and 1964b) describe the bedrock geology of Duluth, and ones by Morey (1967) and Morey and Ojakangas (1970) describe other aspects of Minnesota bedrock geology in the vicinity.

Merrill (1936) and Loy (1963) have discussed evolution of the Points and Farrand (1969) has discussed the Quaternary history of Lake Superior. Winter (1971) discusses water quality and trophic condition of the Wisconsin Waters of Lake Superior, including parts of the harbor.

(1.6) Well and Locality Numbering System

Boreholes and wells used in this investigation are sequentially numbered from 1 to 211 starting with well 1 in the north central part of the map area (Plates 2-5) and increasing in number first southward and then in east-west traverses, ending with well 211 in the south western part of the map area. Wells penetrating rocks of Precambrian age are indicated with a larger circle, those which bottom in Quaternary rocks by a smaller circle.

Localities from which surface samples were taken are indicated by very small circles sequentially numbered from 1 to 71, starting in the north central part of the map area, with the numbers increasing in the same fashion as with those of the wells.

Localities which are notable from a geological and/or historical standpoint are indicated by double circles whose numbering system is similar to those of other localities and wells. Appendix B identifies the notable localities.

(1.7) Acknowledgements

This investigation could not have been conducted without the generous cooperation of many persons who, as representatives of governmental agencies and private companies, or as individuals, provided information and ideas and helped in other ways.

I am particularly indebted to Mr. Thomas Calabresa, Wisconsin Department of Natural Resources, Madison; Mr. Leo H. Ebert, Lakehead Testing Laboratory, Duluth; Mr. Emil Meitzner, Wisconsin Division of Highways, Superior; Mr. J. R. Allen, Minnesota Highway Department, Duluth; and Mr. Clarence Wang, U. S. Army Corps of Engineers, Lake Superior Area Office, Duluth.

Other important contributors included:

Burlington Northern, Incorporated

Chicago Bridge and Iron Company

City of Superior:

- Public Library
- Public Works Department
- Building Inspection Services

Douglas County Historical Museum

Duluth, Missabe and Iron Range Railway Company

Johnson and Larson, Engineers

Lakehead Pipeline Company

McLean Construction Company

Superior Water Light and Power Company

Zenith Dredge Company

The Administration, the Department of Geology, and students at the University of Wisconsin, Superior contributed many services.

I am particularly indebted to the following former students:

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Anthony Beauto

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Ronald Hendrickson

Rudolf Johnson

Charles Roberts

Andrew Van Alstine

Section 2
SUBSURFACE GEOLOGY

(2.1) General Stratigraphic Succession

Superior's central location with respect to the iron deposits of the Mesabi and Gogebic Iron Ranges, and proximity to the copper-nickel deposits of Minnesota and to the copper-bearing lavas of northern Wisconsin is evident on Figure 2 ~~Plate 1~~. These mineral deposits and the rocks which enclose them are Precambrian in age (Figure 3) and are part of the Canadian Shield. Rocks of Paleozoic and of Mesozoic age are not known near the city. ~~and~~ The youngest geologic events recorded are those of the Quaternary time period. Although the Quaternary time interval is only perhaps a million years long, the complex climatic changes that occurred ~~during it~~ determined the kind and rate of erosional and depositional processes active in the area and determined the immediate geologic setting of the city.

During the Pleistocene epoch of the Quaternary, continental glaciers developed four separate times, spreading outward from accumulation centers in the Hudson's Bay region to cover the Lake Superior region (c.f Bray, 1962, and Wright 1969). The latest of these ice advances, known as the Wisconsin Glacial Stage, is responsible for deposits of drift which lie deep beneath Superior. The Recent is the post-glacial time interval, beginning perhaps 10,000 or 11,000 years before ~~below~~ present (B.P.), during which lakes formed in the Lake Superior basin, and the majority of sedimentary deposits and landforms in the city of Superior were developed during the interval.

The geologic time scale and the general stratigraphic succession of the Superior area is shown in Figure 3 ~~2~~. Representative sequences of rocks as penetrated in bore holes in the area are shown in Figure 3.

Figure 2

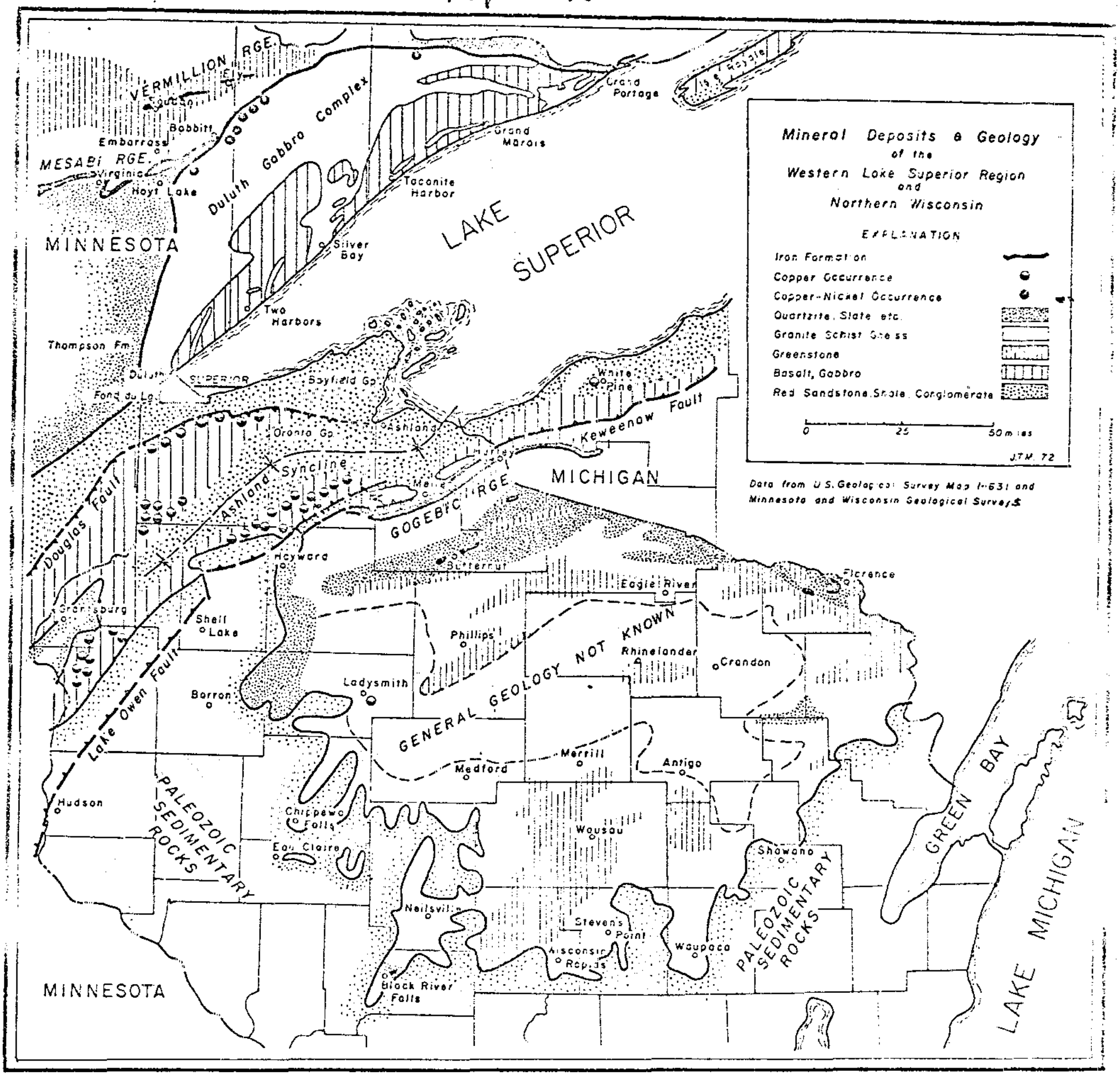
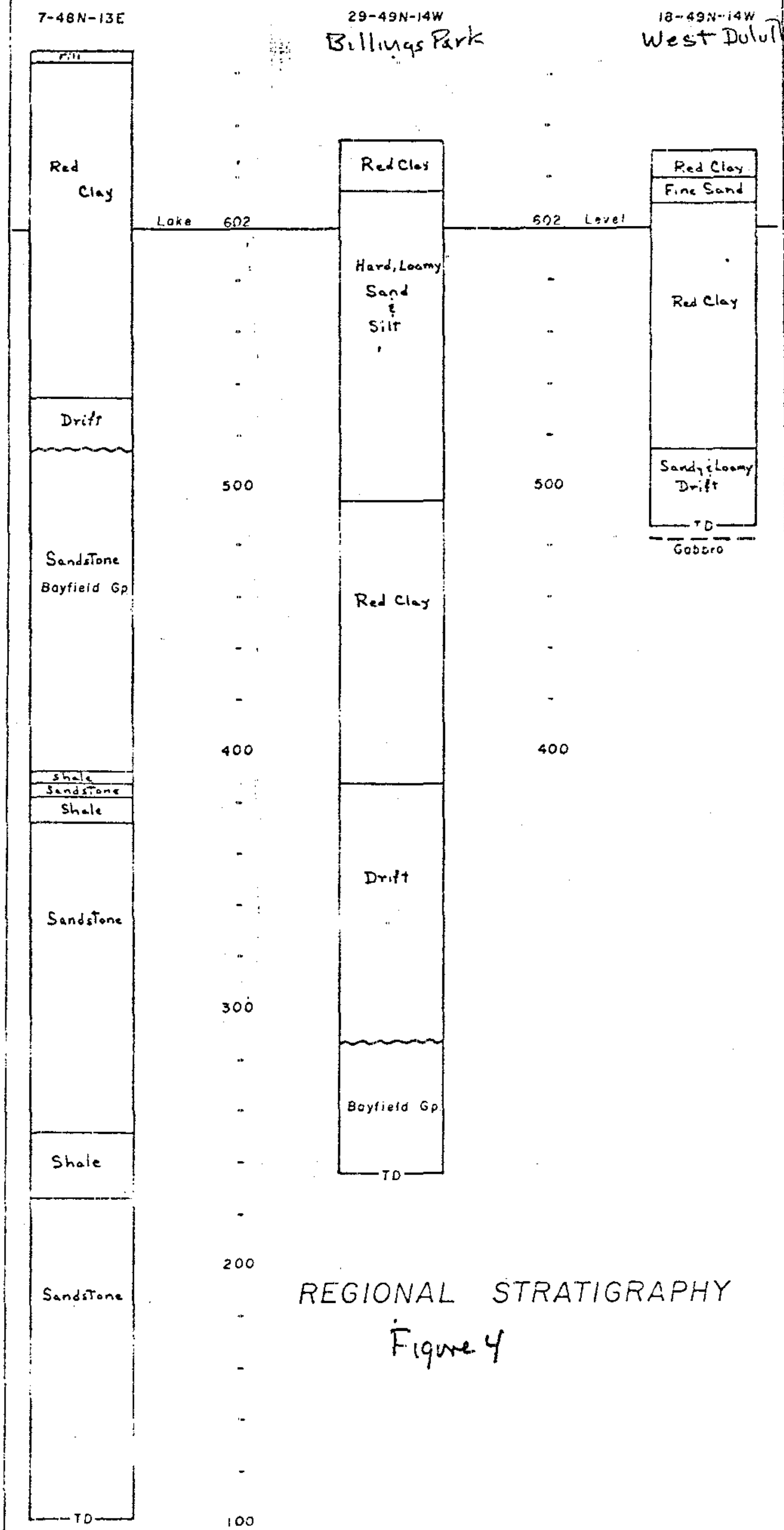

Mineral Deposits & Geology of the Western Lake Superior Region and Northern Wisconsin
EXPLANATION
Iron Formation
Copper Occurrence
Copper-Nickel Occurrence
Quartzite, Slate etc.
Granite Schist Gneiss
Greenstone
Basalt, Gabbro
Red Sandstone, Shale, Conglomerate
0
25
50 miles
J.T.M. 72
Data from U.S. Geological Survey Map I-631 and Minnesota and Wisconsin Geological Surveys
VERMILLION RGE.
MESABI RGE.
Duluth Gabbro Complex
Bobbitt
Embarrass
Virginia
Hoyt Lake
Grand Portage
Grand Marais
Taconite Harbor
Silver Bay
Two Harbors
LAKE SUPERIOR
MINNESOTA
Thompson Fm.
Duluth
SUPERIOR
Fond du Lac
Bayfield Gp.
Ashland
Oronto Gp.
White Pine
Keweenaw Fault
Douglas Fault
Ashland Syncline
GOGEBIC RGE.
MICHIGAN
Hayward
Butternut
Eagle River
Florence
Grantsburg
Shell Lake
Lake Owen Fault
Phillips
Rhinelander
Crandon
GENERAL GEOLOGY NOT KNOWN
Ladysmith
Barron
Merrill
Medford
Antigo
Hudson
PALEOZOIC SEDIMENTARY ROCKS
Chippewa Falls
Eau Claire
Wausau
Shawano
GREEN BAY
LAKE MICHIGAN
Neillsville
Stevens Point
Wisconsin Rapids
Waupaca
Black River Falls
MINNESOTA

Figure ~~2~~ 3

Geologic Time Scale and Stratigraphic Succession

Age of Rocks	Rock Units		
	Superior and Vicinity		Western Upper Michigan and Bayfield Peninsula
Late Cenozoic 25,000 (?) years	Post Glacial Lake and Stream Deposits (Recent) Glacial and Meltwater Deposits (Pleistocene)		
Mesozoic	Missing due to non-deposition or erosion		
Paleozoic	Missing due to erosion		
Late Precambrian 1.1 billion years	Fond du Lac Formation (sandstone and shale)	Bayfield Group	Chequamegon Sandstone Devils Island Sandstone Orienta Sandstone
	Missing (?)	Oronto Group	Freda Sandstone Nonesuch Shale (copper-bearing) Copper Harbor Conglomerate
	Duluth Complex (Gabbro and related intrusive rocks) North Shore Lava Group (Basaltic fissure flows)		Mellen Gabbro Body (Gabbro and related intrusive rocks) Portage Lake Lava Group and un-named lava group of northern Wisconsin (copper-bearing basaltic fissure flows)
Middle Precambrian 1.7 billion years	Thompson Formation (slate and graywacke)		Granitic intrusive rocks of the Penokean Orogeny and older metaigneous and metasedimentary rocks including Ironwood Iron Formation

Sources: Goldich and others (1961), Hamblin (1961), Morey (1967), Thwaites (1912), Tyler and others (1940), Wright (1969).



REGIONAL STRATIGRAPHY

Figure 4

(2.2) Consolidated Rocks of Precambrian Age

Interpretation of subsurface geology in the Superior area is based on water well driller's logs, The logs of core holes drilled for various engineering purposes, and extrapolated outcrop information. Slates and graywacke sandstones of the Middle Precambrian Thompson formation are the oldest rocks exposed at the head of Lake Superior. Above the Thompson formation is a thick sequence of basaltic lavas which have been intruded by the Duluth Complex of gabbros and related rocks. The youngest bedrocks are the gently tilted reddish sandstones of the Bayfield Group of Late Precambrian age which underlie the city of Superior beneath a cover of about 600 feet of Quaternary deposits.

(2.2.1) Thompson Formation (Middle Precambrian)

In the type area near Fond du Lac (Cloquet 7 1/2 minute Quadrangle) the Thompson formation is a sequence of dark colored slates, siltstones and graywackes (Schwartz, 1949; Morey and Ojakangas, 1970) which were folded and metamorphosed during the Penokean orogeny 1700 million years ago. Intrusion of the vast thickness of the Duluth Complex may well have eliminated the Thompson formation from beneath Superior.

(2.2.2) North Shore Volcanic Group (Late Precambrian)

The North Shore Lava Group is unconformable with the underlying Thompson formation as can be seen along the center line of sections 17 and 20, T49N, R15W in the Esko 7 1/2 minute quadrangle in Duluth. The Group consists of mildly deformed basaltic fissure flows accompanied by andesitic and felsitic material, together with some interflow sandstones and conglomerates (cf. Schwartz, 1949;

and Green, 1971). Basalts are encountered in boreholes 1, 2, 4, and 5 along the northerly base of Minnesota Point and eastward to Erickson Park where they are well exposed along the lake shore. It is probable that deep drilling on Wisconsin Point would also penetrate the Lava Group within perhaps one thousand to two thousand feet of the surface after penetrating the red sandstones of the Bayfield Group. No holes have encountered the Group beneath Superior to date.

(2.2.3) Duluth Complex (Late Precambrian)

The Duluth Complex of gabbros and related anorthosites (plagioclase feldspar-rich gabbros), troctolites (olivene-rich gabbros) and felsites is a sheet-like body several miles thick intruded into the base of the North Shore Lava Group. Layered olivene-rich gabbros crop out in the West Duluth 7 1/2 minute quadrangle and are encountered by bore holes 8*, 17, 20, 21, 22, 23, 26, 27, 28, 29, 33. Plagioclase feldspar-rich gabbros crop out in the Duluth 7 1/2 minute quadrangle and are encountered by boreholes 65, 66, and 211 along the northerly side of Superior Bay.

Work by Taylor (1964a, 1964b) has determined the distribution and nature of this important rock unit in Duluth. It is thought that the Complex represents multiple magma sources derived from the Earth's mantle during the Late Precambrian episode of rift development which is now marked by the Mid Continent Gravity High (Mooney, and Others, 1970 and Davidson, 1971). Gravity studies suggest that the Complex probably extends southward far enough to be present under Superior although it has not been penetrated by drilling.

---

*Logs of these and other wells used in this report are listed in Appendix C.

(2.2.4) Bayfield Group (Late Precambrian)

In the basin underlying Lake Superior is a late Precambrian age sequence of reddish sandy sediments which is divided into an older Oronto Group of arkosic (feldspar-rich) sandstones and a younger, more quartzone sequence, The Bayfield Group. Recent study by Meyers (1971) indicates that the Bayfield Group sandstones were derived from older sediments and deposited on an alluvial plain by low gradient, meandering streams.

The best available subsurface description of the Bayfield Group rocks in the Superior area is from NW1/4NW1/4 sec. 7-49N-13E where a 575 foot deep well was drilled into them in 1937. The log of this well (number 180, Appendix C) is shown in Figure ~~3~~ 4. To the southwest of Superior, in the vicinity of Fond du Lac, Minnesota are exposures of several hundred feet of Bayfield Group conglomerates, sandstones, and shales which have been described, measures and mapped by Thwaites (1912) and Morey (1967). Morey has proposed to name these rocks the Fond du Lac formation. The thinner-bedded more shaley upper part of this sequence, Thwaites' "Amnicon Formation," may underlie Superior where older reports (Thwaites, 1912; and Weidman and Schultz, 1915) refer to the presence of considerable shale beneath the city. No well has entirely penetrated the blanket of Bayfield Group sedimentary rocks beneath Superior and it is probable that, at the least, upward of a thousand feet of the Group is present.

During the nineteenth century, sandstones of the Bayfield Group were quarried at two principal sites near Superior. The Duluth Brownstone Company operated a quarry in lots 1 and 2 6-48N-15W along the St. Louis River near Fond du Lac. This quarry was originally opened in 1869. Stone from it was loaded on scows and towed to Duluth or Superior for processing. Buckley (1898, Chapter VIII) lists the following test results for stone from this quarry:

?, is this correct

Dry weight: 146 16/ft^3 (2 samples)

Specific gravity: 2.62; 2.65 (2 samples)

Porosity: 10.4; 11.5% (2 samples)

Ultimate strength in unconfined compression:

- bed - 4668; 5931 psi (2 samples)
- edge - 6052 psi (1 sample)

Modulus of elasticity:

- bed - 80,600 psi (1 sample)
- edge - 90,900 psi (1 sample)

He also notes (p. 365) that the average of twenty tests of Lake Superior brownstone, half of which were made on edge and the other half on bed was 4816 psi, ultimate strength in unconfined compression. (South Range 7 1/2 min. Quadrangle, Center 29-48N-12W)

The Acadian Brownstone Quarry at Amnicon Falls, supplied over a million cubic feet of stone between about 1886 and 1897, including that used for the foundation of the Old Main Building, University of Wisconsin-Superior and a number of other public buildings and churches in Superior. As far as is known, neither of these two quarries or others near Superior were in operation on a large scale during the twentieth century.

(2.3) Bedrock Surface Topography ?

Lake Superior occupies a depression, up to 900 feet deep, carved out of the Bayfield and Oronto Group sedimentary rocks by stream and ice erosion during Cenozoic time. In

Superior area, at the

the western end of the lake, a major depression parallels the northerly shore (cf. Figure 1, and Farrand, 1969). This north shore depression which stands out clearly on the bedrock surface topography map of the Superior area (Plate 2 1) as a north-easterly trending low area about a mile wide which reaches depths greater than 600 feet below present Lake level. A tributary depression beneath the valley of the Pokegama River is also evident. Twenty five to fifty feet of relief is present locally on the bedrock surface and can be demonstrated wherever well control density is sufficient. A larger high area brings gabbro to the surface at the foot of 27th Street West in Duluth, where it is clearly visible from Interstate Highway 35 near the 27th Street West exit.

Gabbro bedrock forms the northerly limb of the north shore depression in Duluth except in the vicinity of the base of Minnesota Point where the North Shore Lava Group is present. The Fond du Lac sandstone subcrops beneath the entire city of Superior, forming the southerly limb of the depression. The sandstone is unconformable on top of the gabbro but the inferred contact shown in Plate 2 1 may be fault-controlled, at least in part. Many early reports on the western Lake Superior region have visualized the existence of a steeply dipping fault controlling the Duluth escarpment (cf. for examples), Merrill (1936), and Martin (1965).

No a Gravity study by Thiel (1956) and by the Geology Department of the University of Wisconsin-Superior have not been able to confirm the existence of major faulting in the Superior area so the inferred contact shown in Plate 2 1 is visualized as sedimentary in nature.

(2.4) Overburden Thickness

About 600 feet of Quaternary age sedimentary deposits are present along the axis of the north shore depression between Superior and Duluth (Plate ~~3~~ 4). Elsewhere under Superior 200 or 300 feet of overburden is present. A belt of thicker sedimentary cover follows the valley of the Pokegama River and is present along an axis marked by Dutchman's Creek. It is highly improbable that bedrock will be encountered by an engineering operation within 150 feet of the surface in the Wisconsin portion of the Superior Area although the presence of boulders in the lower part of the stratigraphic sequence may ~~suggest~~ simulate such an encounter at a depths of — to — feet.

(2.5) Unconsolidated Rocks of Quaternary Age

Quaternary stratigraphic relationships are shown schematically in Figure ~~4~~ 5, which illustrates ten of the most common stratigraphic sequences encountered in bore holes in Superior and vicinity. ~~[illegible]~~

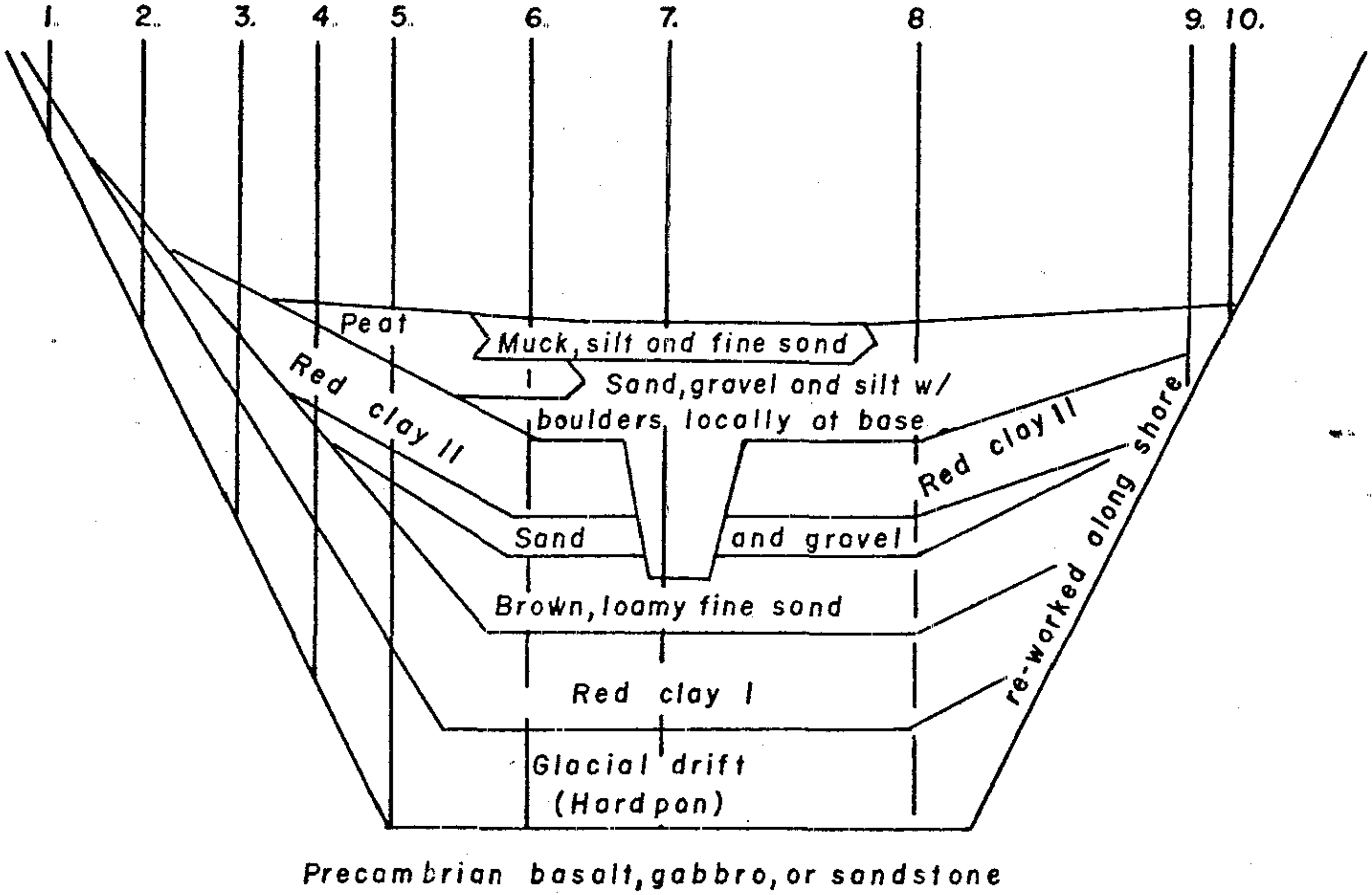
Figures ~~3~~ 4 and ~~4~~ 5 show that in the Superior area glacial drift is overlain by red clay followed by sands and gravels and a younger red clay on which the city is built. Dissection by the St. Louis and Nemadji drainage exposes the sandy deposits providing a source for much of the sand in the harbor. Modern peat and muck overlie the harbor sands in places while in others sand or silt deposition continued today.

(2.5.1) Glacial Drift

A blanket of glacial drift, probably of latest Wisconsin age, everywhere overlies the Bayfield Group bedrock of the Superior area. Drift thickness is a function of elevation as can be seen in Figure ~~7~~ 6. This Figure also

Figure 5

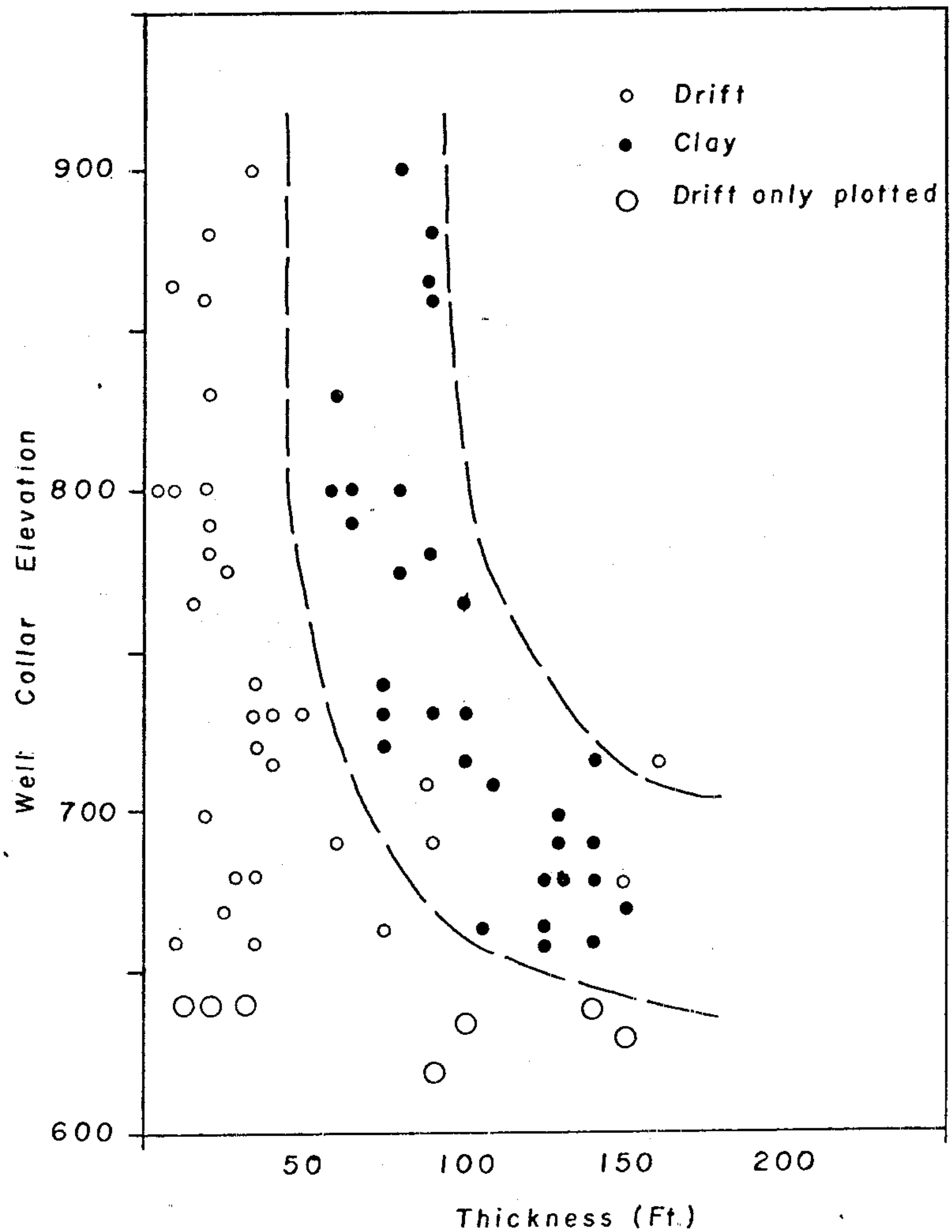
Quaternary Stratigraphic Relationships



1. Glacial drift on Precambrian gabbro, basalt, or sandstone
2. Lake deposited red clay on drift
3. Early and late red clay deposits on drift
4. Peat above red clay deposits and thin sand or gravel on drift
5. Peat above red clay resting on brown loamy sand below which is an older red clay and drift
6. Muck on peat and post-glacial sands which lie on red clay below which is loamy sand, and older red clay and drift
7. Muck and silt or fine sand, on post glacial sands which rest w/ erosional contact on brown loamy sands, red clay, and drift
8. Modern sands resting on post glacial sands which lie on red clay brown loamy sand, red clay and drift
9. Modern sands and gravels on red clay resting on Precambrian bedrock

Figure 6

Thickness-Elevation Relationships
Quaternary Deposits



demonstrates that 25 to 50 feet of drift is present except toward the bottom of the north shore depression between Superior and Duluth where upward of 200 feet is known; plate 2. Limited deep well control suggests that thicker accumulations of drift form northwesterly trending belts more than 100 feet thick under West Superior and the Pokegama River Valley. (Plate 2) These thicker drift accumulations are ~~[illegible]~~ gravelly and contain boulders. They probably represent pauses in the deterioration of the last tongue of ice which filled the Superior basin. These coarse grained drifts are sometimes an important source of groundwater (Section 7). Eastward beyond the inferred limit of the bouldery/gravelly deposits the drift ranges from silty or sandy clay to an argillaceous sand containing a little gravel and few boulders and is probably relatively less often an aquifer.

(2.5.2) Red Clay I

Stiff, lake-deposited ~~brick~~ brownish-red or gray~~ish~~ clay overlies the drift and is more or less gradational with it. Along the foot of the Duluth escarpment and beneath Superior south of a line between Oliver and Itasca (Plate 3) almost the entire succession above the drift is clay containing scattered pebbles and cobbles and small quantities of silt or fine sand. Both illite and montmorillonite have been identified* in the clays and considerable calcareous and other rock-flour is also present - the ground up debris of all the rock types disturbed during glacial times. South of Superior clays are well developed to elevations of at least 900 feet (Figure ~~7~~ 6) but very little clay is found above an elevation of 700 feet along the Duluth escarpment. As shown in Figure ~~4~~ 5 both a lower red clay (I) and an upper

(* X-ray analysis of 14 samples from the area is presently being completed by Mr. Frantz Meyer of the U.W.-S. Physics Department) red clay (II) unit are present. In the present state of knowledge there is no certainty as to which layer extends to higher elevations, especially to the south of Superior where the clays are thickest.

(2.5.3) Loamy Brown Sand and Gravel

Along the St. Louis River and under Superior north of an inferred limit line between Oliver and Itasca (Plate 3) the lower red clay (I) is overlain by brown, poorly permeable dense loamy to sandy deposits (Figure 5). The lower part of this sequence is silty and generally finer in grain size (Localities 41, 49, 55) than the upper part, which in many exposures contains coarse sand and/or gravel (Localities 50, 51, 56, 57). Cross bedding is common on a variety of scales with the lamination inclined toward the north shore depression or the Lake. Considerable interlayering of coarser and finer material takes place at the very top of the unit* and a silty layer separates its top from the overlying red clay in Localities 56, 57 . Grain size determinations for sands from This unit are given in Appendix E .

Deep bore control is not adequate to define the lateral relationships of this sandy unit with the red clay sequence but there is little evidence of interbedding of the two rock types. The upper surface of the deposit exhibits considerable (20 feet) relief in the north end of West Superior (Holes 103, 107,). The top of the unit occurs at lower elevations under the easterly part of its extent than along the St. Louis River near Oliver or Billings Park. A maximum total thickness of about 200 feet for the entire sequence is present along the axis of the north shore depression. The gravelly material near Oliver is apparently about 10-15 feet thick, but has not been drilled sufficiently to establish its true thickness range or extent. Other sand and gravel resources are discussed in Appendix F.

*A calcified but not badly worn radius bone of a deer was recovered from the upper part of this unit just south of Sample Locality 43 during well digging operations. The bone is presently in the Geology Department collection University of Wisconsin - Superior and was identified by Dr. Paul Lukens of the Biology Dept.

(2.5.4) Red Clay II

The plain on which Superior is built is underlain by a 15 to 50 foot thick red clay layer. This clay is typically brick red or red brown in color but becomes gray when organic matter is present and is a lighter shade of color when dry. The clay is mixed with several percent of silt, fine to medium sand, and enough finely ground limestone and/or dolomite to form concretions toward its upper surface. Thin sandy accumulations and scattered pebbles, cobbles and even boulders are found on top of the clay plain - and rarely within the clay unit itself. The surficial materials are more common along the eastern, southern and southwestern margins of the Superior area. They represent coarser materials winnowed from the clay during the fall in lake level to its lowest stages and also ice rafting of particles during times when the plain was fully inundated. The source of the clay unit itself was the Late Precambrian sand-shale sequence (Bayfield and Oronto Group sediments) of the Superior basin and rock flour resulting from abrasion of particles during ice transport. Prominent development of clays to an elevation of about 700 feet on the Duluth escarpment may indicate flooding of the plain to at least this level at the time the clay accumulated offshore in a post-glacial lake.

[illegible]

[illegible]

~~Contours on the clay surface based on extrapolation of the elevations of the layer in areas not strongly affected by stream dissection depict the~~

(2.6) Lake Levels

Although much remains to be learned about the history of Lake Superior it is possible to recognize various early stages in its development through a study of high level beach deposits and shore line features. The beach of Glacial Lake Duluth at an elevation of about 1070-1080 (Localities 1,2,3) marks the most persistent water level recorded in the western end of the Lake Superior basin, although higher levels, especially one at 1110-20 are known. The 1070-1080 beach is strongly developed in Wisconsin in Douglas County from about 48N-10W to 47N-15W. Prominent deposits of sand and gravel occur at many places along this contour interval. This beach is particularly well developed between the villages of Maple and Poplar (Poplar NW 7 1/2 minute Quadrangle).

In eastern Douglas County the Brule river valley was a 2-3 mile wide strait in 48 and 47N-10W and drainage from the lake flowed south into the Mississippi system through the St. Croix river. In the earliest stages of its development drainage from the Lake probably also passed to the Mississippi via the Moose River in Minnesota (Bray, 1962; Wright, 1969). As ice retreat permitted drainage through lower elevation outlets farther east, the Brule river became separated from the St. Croix by a divide at an elevation of about 1022 feet in the vicinity of Solon Springs in Douglas County. When this happened the direction of flow of the Brule reversed and it is now a tributary of Lake Superior. Development of the St. Louis and Nemadji drainages across the former lake floor also took place at this time perhaps 9500 B.P.

Lower beach lines have also been reported on the Superior lowland plain in Douglas County. A. W. Farrand (1969) notes one at about 1010 and Wisconsin Geological Survey unpublished reports emphasize one at about 980 on which the village of Poplar is built. From general considerations in the Lake Superior basin Farrand believes there to be subsequent beach developments at about 860, 710, 650, 450 (Lake Minong, the first full lake in the Superior basin 9200 B.P.), 375 (Lake Houghton, the lowest lake stage 8500 B.P.), 610 (Lake Nippissing, 4000 B.P.), 595 (Lake Algoma, 3200 B.P.). None of these lower stages are nearly as well developed in Douglas County or the Superior area as the one of Glacial Lake Duluth although they may be discernable. It seems probable on the basis of the stratigraphy of the Quaternary sediments in the Superior area that prior to the Minong and Houghton low water stages there was a final period of high water which was responsible for red clay II, the surface clay of the Superior area. Since red clays are very well developed to an elevation of about 700 feet and the surface of the clay plain in the Superior area is at least 650 it would seem probable that such a postulated late deep water phase stood at high elevations. This late high phase was preceded by a set of conditions which permitted the development of high energy sediments - very coarse gravel and pebbly sand deposits - from Oliver eastward to the harbor and southward under the city of Superior. Thus the evolution of the lake may be more complex than is inferred from beach line evidence alone.

Since 1922 the level of the Lake has been regulated by control works in the St. Mary's River at Sault Ste. Marie, Michigan. These works are directed by the International Lake Superior Board of Control, consisting of representatives from the U. S. Army Corps of Engineers and officials of the Canadian government. The function of the Board is to determine the amount of water available for power generation at the Soo and to maintain the level of Lake Superior at an elevation of 600 feet. Since 1957 the level of the lake has varied only about a foot from this direction. Water levels are lowest in March or April and

level

highest in August. Winds blowing consistently from a single direction for several days produce greater apparent changes in water level, although these last for only short periods and may be entirely reversed within a period of a week. Changes in atmospheric pressure accompanying the passage of weather fronts over the Lake sometimes generate sieches, which are rapid, general rises in lake level.

NEAR-SURFACE GEOLOGY

(3.1) Red Clay Surface Contours

Contours on the red clay II surface, based on extrapolation of the elevations of the layer in areas not strongly affected by stream dissection depict the original configuration of the lake floor (Plate ~~4~~ 3). It is evident that the surface expression of the north shore depression controlled the location of the St. Louis River and that another, less prominent depression to the east influenced the location of the Nemadji River. The divide between the two drainages is a structurally high area, and other lesser highs and lows can be identified on Plate ~~4~~ 3.

Low water lake stages following clay deposition allowed deep incision of the major drainages into the red clay II surface and the development of an asymmetrically dendritic tributary drainage pattern. Many partially drained depressions remain to be fully integrated into the through going drainage system. These depressions help to regulate the rapid run off from the impervious clay surface. Incision of some of the larger drainages into the underlying sandy unit also helps regulate run off and provides year-round flow in some drainages. Incision has carried the St. Louis drainage deep enough to expose the underlying sands and gravels from Howards Bay to Oliver. Elimination of the upper red clay (II) along the landward half of Rices Point suggests that the bottom of the St. Louis Valley may be as much as a hundred feet below modern lake level in this vicinity. Evidence from Holes 148, 149, 150, 151, 152, 153, 155 shows that the Nemadji did not become as deeply incised - perhaps not substantially below its modern depth during spring floods.

A general rise in lake level toward a maximum of about 610 feet during the Nippissing Stage 5000-4000 years ago (Loy, 1963; Farrand, 1969) caused the deeper parts of the St. Louis valley to become aggraded with sandy materials and subjected the upper red clay layer to strong wave attack, creating bluffs along St. Louis Bay and Allouez Bay. The wave eroded shore platform cut in red clay II forms the floor for the harbor sands of the Wisconsin portion of Superior Bay and is the substratum on which the outer half of Minnesota Point and all of Wisconsin Point rests. Contours on this erosion surface (Plate 3) indicate the approximate depth to red clay below mean water level anywhere in the Wisconsin portion of Superior-Allouez Bay. Post-Nippissing erosion changes the orientation of the bluff-line eastward from Sample Locality 26. The change in orientation is a measure of the dynamic nature of the environment the Points exist in, and a warning that changes are constantly taking place.

A large number of crystalline rock boulders (erratics) occur at or near the base of the harbor sands under Superior Bay, especially (but not exclusively) in the area designated on Plate 3. Maximum boulder size recorded to date is 5 x 6 x 7 feet. Appendix D lists measurements of others recovered in 1968. Boulders recovered during dredging operations in the Superior Front Channel are disposed of in the 21st Street Slip along the west side of Rices Point.

The lithology, size, and number of these boulders indicate that ice transport is a part of their depositional history. Concentration of the boulders along the less-steep easterly side of the divide between the Nemadji and St. Louis drainages may indicate release from stranded ice floes just as happens along the easterly two thirds of the Minnesota-Wisconsin Point barrier system today. Older ice rafted boulders derived from erosion of the clay plain surface also contributed to the buildup of the cobble-boulder pavement which is present.

~~[illegible]~~

(3.2) Harbor Stratigraphy

Stratigraphic sequences in Superior Bay and barrier spit stratigraphy is shown (respectively) in Figures 8 and 9. Examination of these sequences in conjunction with Plate 3 and Figure 5 will give an understanding of the subsurface geology of the harbor area. From Plate 3 it can be seen that the uppermost red clay (II) dips smoothly below water level in the vicinity of Howards Bay and is found beneath harbor sands on Connors Point and the outer end of Rices Point (Figure 9). Red Clay II is eroded, under Superior Bay forming ~~[illegible]~~ The shore platform beneath the harbor, and Minnesota and Wisconsin Points, from opposite the Gate eastward ~~[illegible]~~ beyond Allouez Bay. From Plate 3 it is evident that the brown loamy to gravelly sands beneath red clay II do not extend east of the Nemadji river and that to the east the entire stratigraphic succession is composed of red clay down to the glacial drift next above bedrock (Holes) as in Sequence 3, Figure 5. The top of the loamy to gravelly sands occurs at a lower stratigraphic position in East End (Hole 142) than in West Superior (Holes 87, 88, 89, 90) and the shore platform does not intersect these beds under Superior Bay. To the west red clay II is thin (10-20 feet), but is relatively steeply inclined into the north shore depression, hence is preserved under Connors and Rices Points.

Incision of the St. Louis River drainage at the time of low lake stages (Farrand's, (1969), Houghton Stage, elevation 375 feet, 8500 B.P.) carried the channel of the river beneath red clay II and eliminated it from beneath St. Louis Bay (where it occurs on the crest of the bluffs, Figures 4 and 5 and Sequence 7, Figure 5) and from the northerly

Figure 7

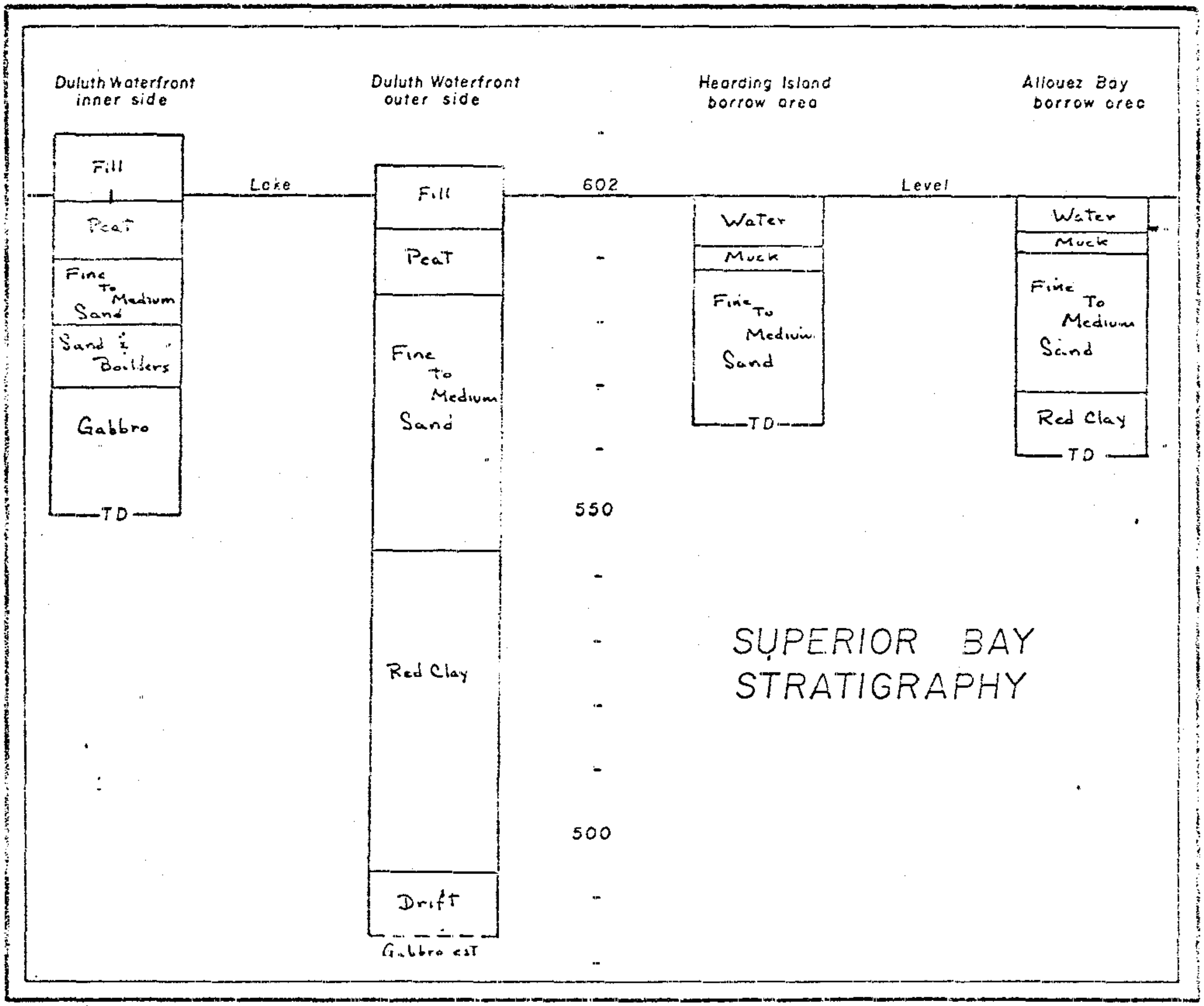
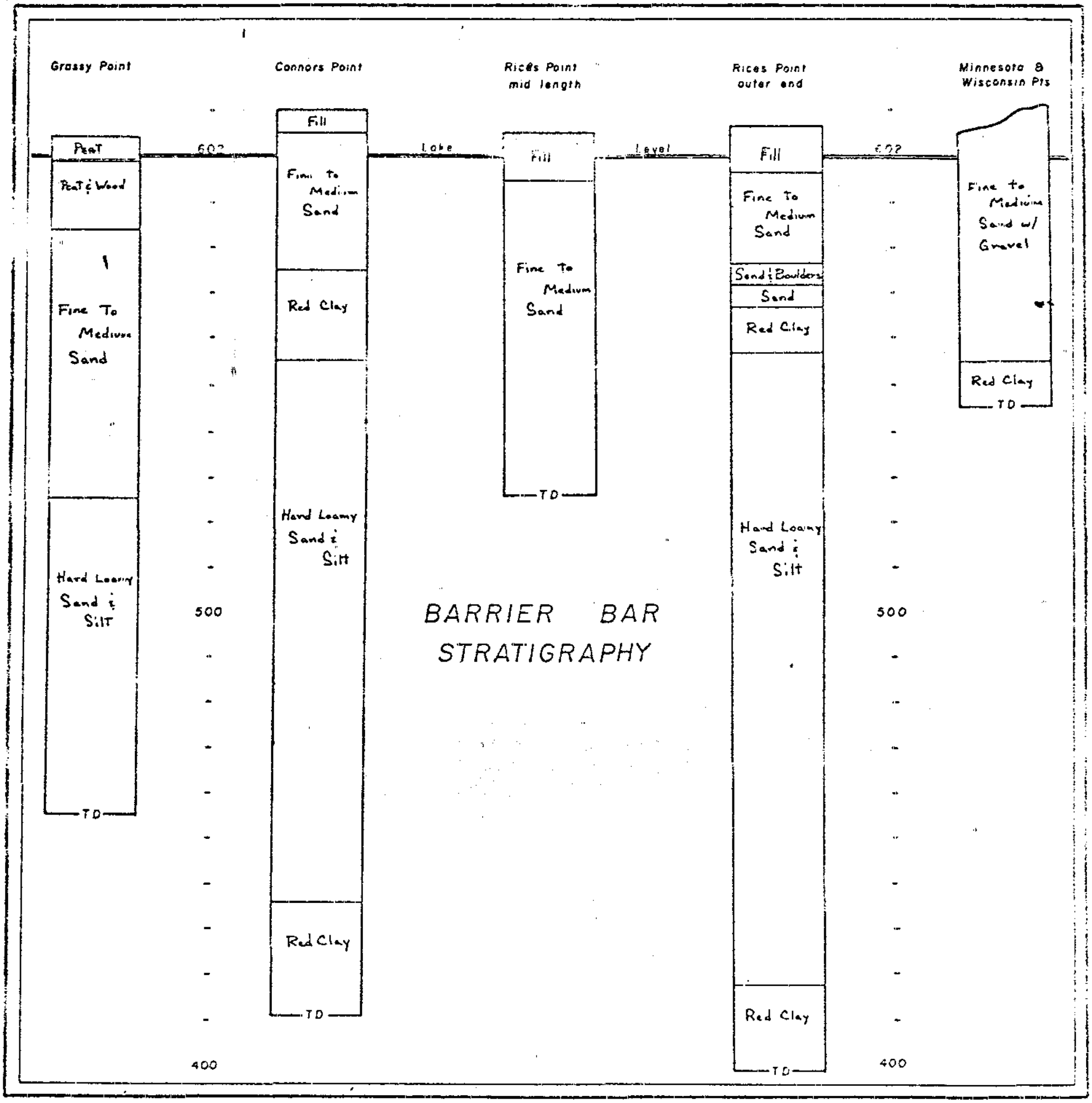

Duluth Waterfront inner side
Duluth Waterfront outer side
Hearding Island borrow area
Allouez Bay borrow area
Fill
Peat
Fine To Medium Sand
Sand & Boulders
Gabbro
TD
Lake
602
Level
Fill
Peat
Fine to Medium Sand
Red Clay
Drift
Gabbro est
Water
Muck
Fine To Medium Sand
TD
Water
Muck
Fine To Medium Sand
Red Clay
TD
550
500
SUPERIOR BAY
STRATIGRAPHY

Figure 8

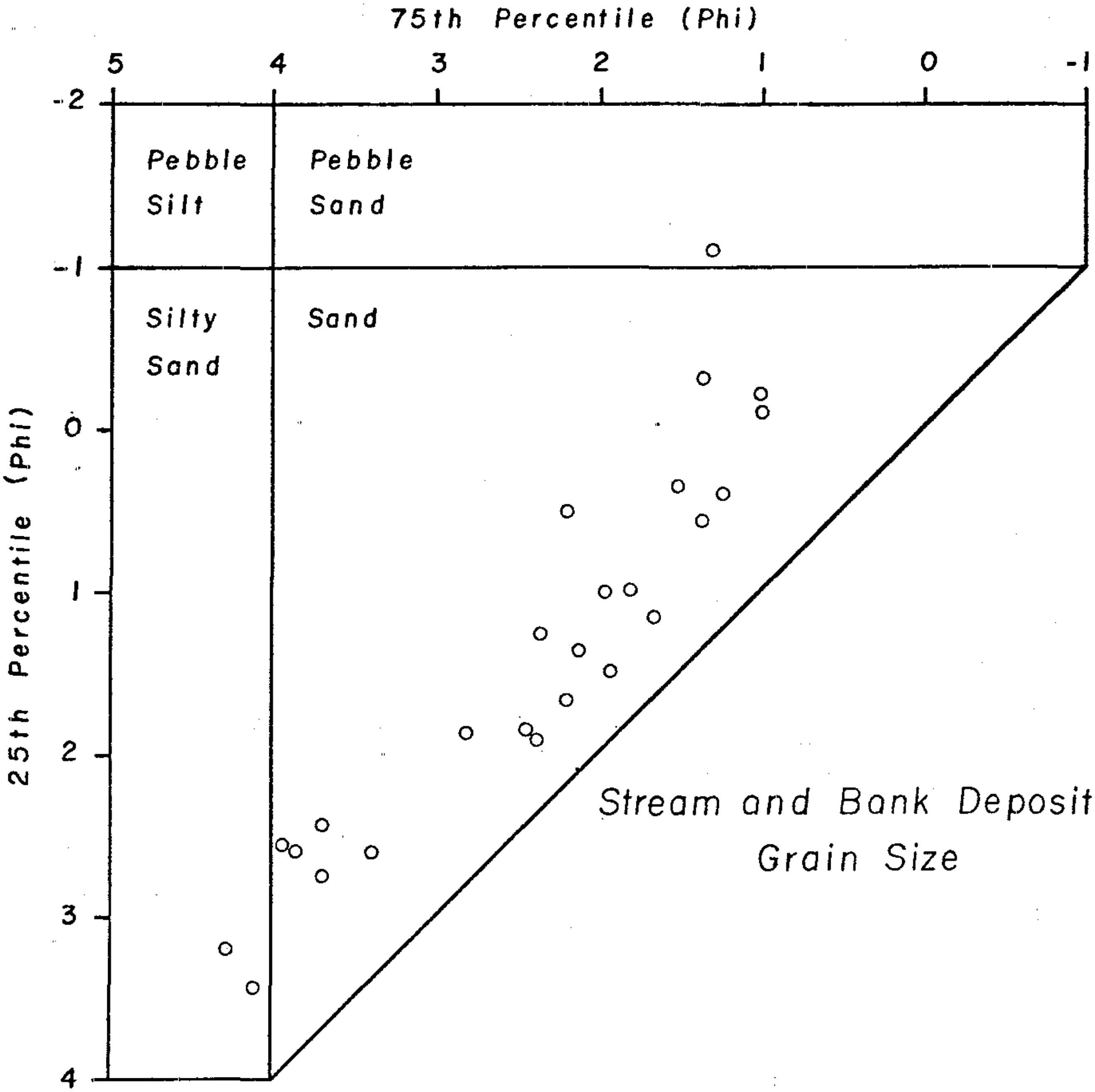

Grassy Point
Connors Point
Rices Point mid length
Rices Point outer end
Minnesota & Wisconsin Pts
Lake Level
602
500
400
Peat
Peat & Wood
Fine To Medium Sand
Hard Loamy Sand & Silt
TD
Fill
Fine to Medium Sand
Red Clay
Hard Loamy Sand & Silt
Red Clay
TD
Fill
Fine To Medium Sand
TD
Fill
Fine To Medium Sand
Sand & Boulders
Sand
Red Clay
Hard Loamy Sand & Silt
Red Clay
TD
Fine to Medium Sand w/ Gravel
Red Clay
TD
BARRIER BAR STRATIGRAPHY

end of Superior Bay where it is missing from the westerly base of Rices Point eastward to the lake shore beyond the base of Minnesota Point. Red clay I occurs at depth beneath St. Louis Bay under both Connors and Rices Points (as in Sequence 7, Figure and westward where Holes 87, 88, 89 encounter it at a depth of perhaps 150 feet along the eastern margin of the North Shore Depression. This lower red clay (I) subcrops irregularly along the northerly shore of the depression from West Duluth eastward to the outer side of the Duluth waterfront in the vicinity of the Duluth Arena Auditorium (Holes 9, 15). Along the Duluth waterfront from Rices Point to Minnesota Point ~~the upper surface of~~ red clay I has been eroded and ~~and the clay~~ is overlapped by several tens of feet of harbor sands which also extend farther shoreward along the inner side of the Duluth waterfront (Figure 8 and Sequence 7, Figure 5). In West Duluth, as under Billings Park in Superior, the surface of the clay plain is red clay II, which is underlain by the brown loamy to gravelly sandy unit as in Sequences 5 and 6, Figure 5. This unit is poorly developed along the northerly side of the Bay although it can be identified as a layer of several feet of sandy to gravelly material beneath ~~10 to 20~~ 10 to 15 feet of red clay (Holes 58, 59, 61, 62, 63, 64). Along the southerly side of the Bay this unit forms the lower two thirds of the banks, extending 15 to 20 feet above modern water level. Erosion of this unit (as in Sequence 7, Figure 5) during incision of the St. Louis drainage and subsequently, as a result of wave action during smoothing of the Bay shores in Nippissing high water time (Elevation 610, 4000 B.P., Farrand, 1969) has been the principal source of the harbor sands which now lie unconformably above it in the north shore depression. With presently available well control there is no way to identify this erosional contact although such identification is theoretically possible due to the greater resistance to penetration of the older brown silty to gravelly sands. Gravel has been and is being introduced into the north shore depression by streams flowing down the Duluth escarpment (Figure 7), by erosion of the gravelly deposits of the sandy unit in the vicinity of Oliver, and by ice rafting and, in the case of the Points, by along shore drift, mainly from the north shore. The Highland moraine (Leverett, 1929 and Wright, 1969) and related deposits along the crest of the Duluth escarpment and the blanket of drift on the face of the escarpment itself make the northerly side of the Lake the principal gravel source. To the southwest of Superior the surface of the clay plain has considerable gravel in it and on it, apparently as a very thin layer at the surface. Material from this thin layer and derived from Bayfield Group sedimentary bedrocks to the southwest presently forms bars in the Nemadji river within the map area, and is being introduced to the eastern end of Superior Bay at the mouth of the river. Figure 10 and 11 compare stream and bank deposit grain size with that of the dredge spoil banks which sample material from the harbor floor. Grain size distribution ~~parameters~~ data for these samples are given in Tables and . Modern harbor sedimentation involves offshore downslope movement of typically fine to medium grained sands eroded from the banks and river transport of silt and fine sand, together with clay which is introduced mainly by runoff over red clay II. Wind transport of silt and sand from exposed banks during winter storms and subseqent ice rafting contributes to sedimentation throughout the harbor. Black sand build ups along the Superior Bay shore of Wisconsin Point are probably mainly of this origin - being derived from the adjacent ore docks. However, it should be noted that small concentrations of "iron-rich" black sands" occur everywhere.

(3.3) Barrier Spit Origin and Stratigraphy

Barrier spits are a product of storm wave action which disturbs sandy bottom sediments, creating low, more or less submerged bars paralleling the shore line (c.f. Loy, 1963). Once seasonal and longer term variations in wave intensity and water level permit buildup of the bar above mean water level a dune develops behind the beach. Waves approaching the beach from an angle rush

Figure 9


75th Percentile (Phi)
5
4
3
2
1
0
-1
-2
-1
0
1
2
3
4
25th Percentile (Phi)
Pebble Silt
Pebble Sand
Silty Sand
Sand
Stream and Bank Deposit Grain Size

up the sand in the direction of approach and Their water recedes at right angles to the shore - resulting in movement of sand down drift. The spit constantly changes in response to wind, wave, and current activity and its stability is very dependent on vegetation which establishes itself on the dune ridge, anchoring sand in place, and in the continuity of sand supply along the beach zone. Building of barriers which interrupt drift or cause loss of sand to deep water beyond normal seasonal wave depth, or otherwise deny sand to the dunes threatens the stability of the entire barrier. Quarrying of sand for construction purposes or well drawdown of the water table under the vegetation also threaten barrier stability. Even under natural conditions the barrier is a fragile structure subject to periodic disruption through blow-outs and wash-overs during unusually severe climatic conditions and by long term changes in water level and shifts in the sand supply - wave and current energy equilibrium.

The sandy substratum beneath the barrier spits of the Superior area (c.f. Figure 9) began its development during the rise in Lake level between the time of the lowest lake stages (Farrand's Houghton Stage; 8500 B.P.) and the time of the Nippissing high water stage about 4000 years ago (Farrand, 1969). The rising waters developed a transgressive blanket of sands which aggraded the St. Louis and other drainages and covered the uppermost red clay (II). Additional sandy material was added to the blanket during smoothing of the shores of St. Louis Bay and development of the bluffs and shore platform between Central Park and Dutchmans Creek during the Nippissing high water stage and by river and stream runoff. (c.f. Martin, 1965; Merrill, 1936; and especially Loy, 1963 for other views)

Grassy Point, the innermost of the barrier spits, developed during Nippissing time at the inner limit of strong wave action in St. Louis Bay (c.f. Loy, 1963). Rices and Connors Points are perhaps partially contemporaneous in their development although mainly a product of a declining water level during the Algoma retreat 3200 years ago (Farrand, 1969). Rices Point grew outward on the westerly side of the gabbro projection known as the Point of Rocks on the Duluth shore and Connors Point from the Superior shore where the dip of the stiff red clay II takes it below water level into the north shore depression in West Superior. Howards Bay was probably kept open originally through stream drainage and was later deepened by stream erosion during the Algoma retreat.

Minnesota and Wisconsin Points are developed toward the outer margin of thick sand accumulation during the Algoma retreat. In their present state the Points opposite Superior represent 50-75 foot thick accumulations of sand containing a few percent gravel (c.f. Figure 9 and Table). Continuing rise of lake level with regional subsidence (Moore, 1948) may be expected to tend toward the eventual elimination of the Points and a renewal of wave attack on the bluffs below the City. Although this circumstance may never come to pass there is no doubt that every effort to promote barrier stability must be made and no human disruption can be permitted without full study of the probable consequences.

Section 4

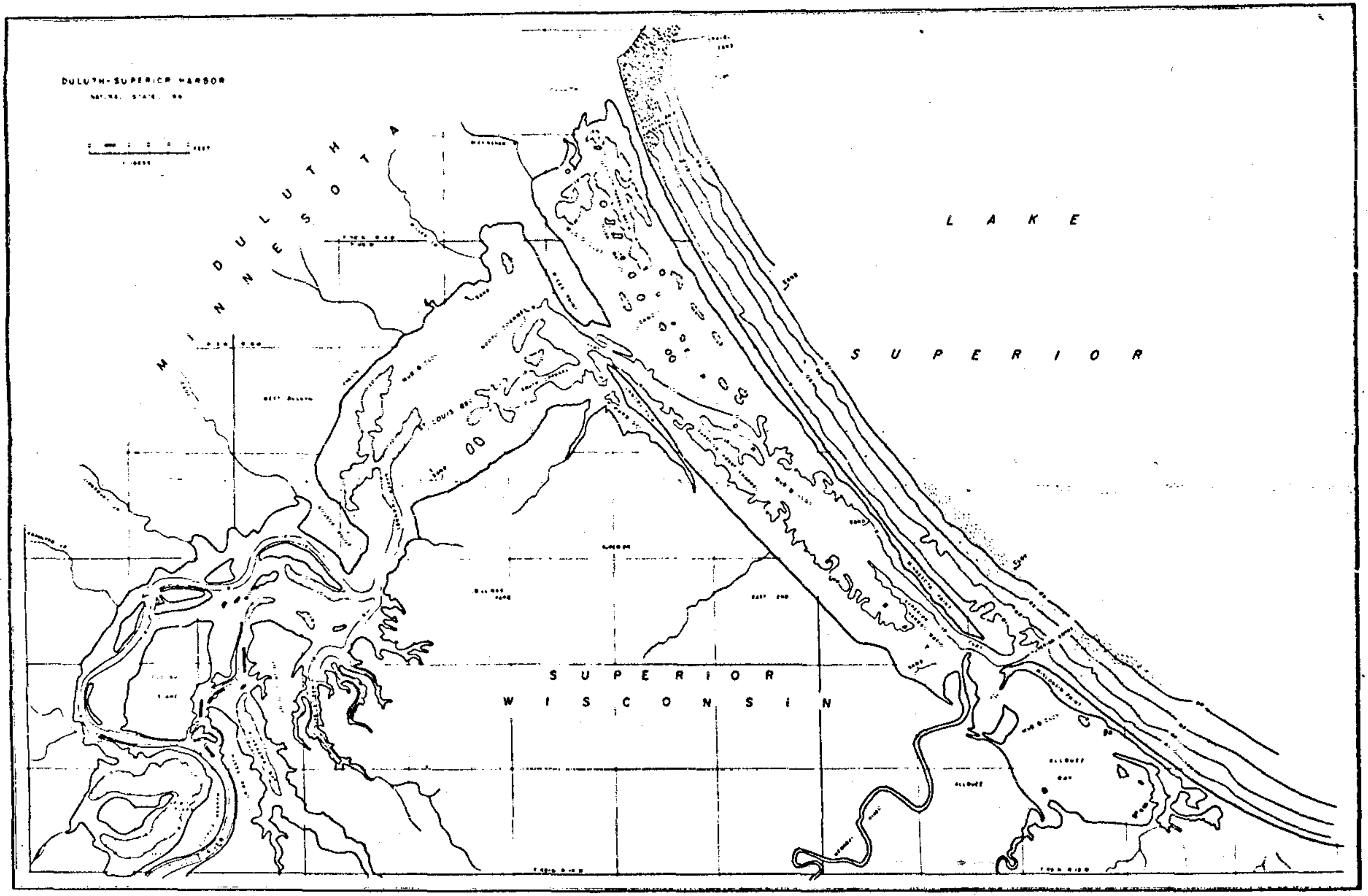
THE HARBOR

(4.1) The Harbor in its Natural State, 1861

As noted previously, The harbor consists of an outer lagoon, Superior-Allouez Bay, paralleling the shore of Lake Superior and an inner estuarine lagoon, St. Louis Bay at right angles to the lake shore. Lake head barrier spits, Minnesota Point and Wisconsin Point protect the outer lagoon from the lake, while an earlier set of barrier spits, Rices Point and Connors Point separate the two lagoons (c.f. Figure 1).

In historic time a single inlet from Lake Superior to Superior Bay allowed discharge from the St. Louis and Nemadji Rivers into the lake. The natural inlet, the Superior Entry, was about 2000 feet wide with an irregular deep channel less than 500 feet wide (Plate Figure 7 from U.S. Army Corps of Engineers Meade-Hearding Chart of 1861). Average shoal depth in the channel was about 8 or 9 feet except during Spring high water when it reached a maximum of about 14 or 15 feet and during north east storms when it decreased to perhaps 3 or 4 feet (Ensign, 1898). The drowned channel of the St. Louis River across Superior Bay extended in nearly a straight line from the inlet to the Gate, the inlet between Rices and Connors Points. A shoal divided the channel to the east of Connors Point, creating a navigation hazard. Outside the channel, which in places was over 20 feet deep, Superior Bay averaged less than 10 feet deep and had local shallows and gentle depressions paralleling the lake shore.

Similarly, St. Louis Bay, upstream from the Gate average less than 10 feet deep especially towards its center where the meandering course of the upper St. Louis River was smoothed by sediment deposition. The natural shore line of the Bay was regular except for Howards Bay along the westerly side of Connors Point and a broad indentation on the westerly side of Rices Point which was later


DULUTH-SUPERIOR HARBOR
LAKE SUPERIOR
DULUTH
MINNESOTA
SUPERIOR
WISCONSIN

Figwell

developed into the 21st AVenue West Slip. Grassy Point bounds the westerly end of St. Louis Bay and above the inlet between the Point and the Wisconsin shore, the St. Louis estuary widens again and is interrupted by islands and drowned natural levees (Kilchlis Meadow, for example).

The south shore of this part of the estuary is deeply dissected by steep sided drowned youthful drainages tributary to the River. Natural historic water depths in these youthful tributaries ranged from a maximum of 15 to 20 feet to a minimum of less than 10 feet toward their mouths. A natural channel about 10 to 15 feet deep departs from the main channel of the St. Louis and passes along the easterly side of Clough Island to about a mile and a half west of Grassy Point (Plate Figure 7). Development of this channel probably took place during the Algoma low water stage 3200 years B.P. (Farrand, 1969), preceded estuary development, and represents a shortening of the course of the St. Louis through breaching of a meander loop by piping - removal of unconsolidated materials by subsurface water flow - taking place in the sandy deposits beneath the uppermost red clay (II).

The surface of Clough Island and of Spirit Island are isolated remnants of this uppermost red clay blanket of the Superior Plain. The original meandering channel of the St. Louis extends from Clough Island for about 9 miles farther upstream to the rapids at the Duluth escarpment above Fond du Lac and was marked by drowned natural levees, marshy shoal islands and submerged shoals.

The upper part of the river channel from Fond du Lac to Grassy Point was and is floored by sand containing small amounts of gravel. In water less than 10 feet deep sand was the natural surficial bottom material along the margins of St. Louis Bay (Plate Figure 7) and in Superior Bay along the easterly side of Connors Point and the Superior waterfront and along the westerly side of Minnesota Point from opposite the Gate to the Superior Entry. Scattered areas of sand also occurred in local shallow spots, while in areas where water was more than 10 feet deep, muds (silt and clay) accumulated on the bottom surface as they did in the protected waters of Allouez Bay, Spirit Lake, and the various tributary bays. Close to shore the muds give way to organic rich sediments.

A number of islands consisting of a "boggy formation" supporting a growth of bushes and small trees (cf. Stewart-Taylor, n.d.) were found in the northerly portion of Superior Bay (Figure 7), following the development of the Duluth Ship Canal in 1870. These were gradually detached from their substratum by current action and ice drift. The last floated out into the Lake in 1885 (Darling, 1898). Similar islands and a marshy peninsula in Allouez Bay are presently being gradually destroyed by the slowly rising lake waters (Moore, 1948) and increased wave and current activity following the removal of the recurved end of Wisconsin Point and development of the Allouez Bay channel in 1892-96 and modern development work and recreational activities. Stumps in the floor of the Bay and in Spirit Lake farther up river, are remnants of the extensive forest which covered the sandy sediments of the Bay floors during the Algoma low water stage. The mature pine forests on the ends of Minnesota and Wisconsin Points contain trees up to about 200 years old (Davidson and Bernard, 1969), the last reasonably undisturbed remnants of the original vegetation of the area. Pine forests were previously present also on Connors Point and to a lesser degree on Rices Point at the time of the early settlement of the city of Superior.

The northerly end of Superior bay was bordered by lake-level marshes extending a considerable distance outward from shore (Stewart-Taylor, n.d.). A narrow band of open water extended shoreward opposite about First Avenue West and open water continued toward the base of Minnesota Point where "in some years there was an opening large enough to admit canoes and row boats, but sometimes the storms would close this opening with gravel. This was known as The Little Portage." Wieland (1936); And was probably approximately the place where Sieur Du Lhut portaged the Point when he entered the harbor on June 27, 1679.

~~HISTORY OF PORT DEVELOPMENT~~ (4.2) History of Port Development

During 1823-25 Lake Superior and the Twin Ports harbor were charted by Lieutenant (Later Admiral) Henry Wolsey Bayfield of the Royal Navy in connection with a boundary dispute with Great Britain later settled by the Webster-Ashburton Treaty of 1842. Bayfield established a zero bearing monument on the former end of Minnesota Point near the Superior Entry. A lighthouse (Locality 4), built of red brick imported from Cleveland, Ohio, was erected above this monument in 1855-58 and continued in use until 1878 (Aguar, 1971). The remains of the tower are still visible today rising above the pine forest north of the Entry. At the time the tower was originally constructed it stood close to the waters of the Entry and during high water it was possible to row almost to the base of the tower (Bardon, n.d.). When the first piers were built to confine the deepest channel in the Entry, following the Federal River and Harbor Act of March 2, 1867 (Corps of Engineers, 1932), stone mounds were put in the shallows from the lighthouse to the piers, causing sand and driftwood to accumulate and extending Minnesota Point about a quarter of a mile southward. Sand and stone filled crib piers were used to create a 350 foot wide channel in the Entry to increase water depth by making use of the scouring action of the current setting in and out of the Entry. Access to the Quebec dock was improved by removal of the shoal along the natural channel of the St. Louis River between the dock and the Entry, although the channel of the river remained too narrow (Plate) for easy navigation to and beyond Connors Point and the use of tugs was required, especially by sailing vessels.

Construction of the Lake Superior and Mississippi River Railroad (now part of the Burlington Northern) was initiated in 1868 from Duluth. Rails and equipment were unloaded at the DaCosta dock on the natural channel on the west end of Rices Point after being worked through the Superior Entry and up the channel across Superior Bay (Aguar, 1971, p. 8). Regular train service with the Twin Cities was established on August 1, 1870, adding to the need for better harbor facilities in the northerly end of Superior Bay. Work was commenced on the Duluth Ship Canal in the Fall of 1870 and completed on April 29, 1871 (Aguar, 1971, p. 9). Erection of wood crib piers and other improvements were completed shortly thereafter under the auspices of the Northern Pacific Railroad and under federal control following implementation of the River and Harbor Act of March 3, 1871. A sheet pile dike was erected from (former) Spruce Street on Rices Point to about 20th Avenue on Minnesota Point (See any Plate) to prevent loss of the scouring action of water flow in the Superior Entry. By June of 1872 the dike had been improved into a 250 foot wide structure 4490 feet long built of timber cribs filled with gabbro from the Point of Rocks and sand from Minnesota Point (Bardon, n.d.). The dike was built during controversy (c.f. Ensign, 1898) between interests in Duluth and Minnesota and others in Superior and Wisconsin over harbor development and was never economically popular after it was built. Water pressures generated by fluctuating differences in the harbor and the lake water levels caused engineering failure of the dike within a year after construction and helped demonstrate that it had little bearing on current strength and scour in the Superior Entry. The dike was breached in 1873 and later removed by the Corps of Engineers to improve harbor navigation.

Federal funds for development of both harbor entrances and for channels in the harbor became available in 1873. Dredging of a harbor basin in the northerly end of Superior bay, development of a channel along the northerly end of Minnesota Point to serve saw mill docks there (c.f. Aguar, 1971, p. 8-9), and another channel along the easterly side of Rices Point to join with the natural deep water channel at the Gate took place during the following years. Channels along the Wisconsin and Minnesota dock lines in St. Louis Bay were dredged in the last 1880's and early 1890's, connecting the natural deep water channel at the Gate with that in the inlet between Grassy Point and the Wisconsin shore.

Development of the brownstone quarries near Fond du Lac led to removal of shoals from the upper St. Louis River in the late 1880's and to alteration of some of the meanders and marshy islands between Rices Point and Spirt Lake. Such alterations have continued to be made from time to time down to the present. Dredge spoil from some of these operations has been used to extend the end of Dwights Point, forming several acres of new land from former lake-level marshes. Spoil from channel and basin development near the Gate was deposited as an island to help prevent ice drainage to the long timber trestle built by the Northern Pacific in 1885, connecting West Superior with Rices Point. Portions of this sand deposit have been borrowed for highway construction purposes in recent years. The St. Paul and Duluth Railroad (now part of the Soo Line) built the Grassy Point railroad bridge in 1887 and in 1895 the Great Northern built the former Interstate Bridge across the Gate. The embankment on Connors Point leading to this bridge was originally a timber trestle which was filled in as it deteriorated. The embankment is now a potential source of sand for construction purposes.

The present dock and harbor lines in Superior were established in 1882, concurrently with the development of West Superior. Tower, Bay and Hughitt Avenue slips were dredged to 1st Avenue and the space between and behind was unfilled with sand to create docks and eliminate marshy ground. The extensive elevator, coal dock, and ship yard system along St. Louis Bay - Howards Bay and Connors Point was originally established between about 1885 and 1895 as were the ore docks, elevators and other port facilities in East End, Allouez and Itasca. The Northern Pacific (Burlington Northern) ore docks in Allouez were constructed to ship ore from the Mesabi Range and the first ore shipment of 4500 tons took place in 1893 from Dock Number 1. Initial ore dock development took place progressively over the years 1892-1911, causing elimination of a marshy, sandy island to the east of the mouth of the Nemadji (c.f. Plate Figure 7). Material from this dredging was used to widen the ends of Wisconsin and Minnesota Points. Improvements and modifications of the original structures has taken place continually down to the present. Taconite loading facilities were added most recently (1966-67). Comparable modifications of the elevator systems have also taken place. Changing patterns of iron ore production, increasing automation, reduced usage of coal, and decline in the use of lake vessels for package freight shipments have caused abandonment or near abandonment of some port facilities. A project (of the 'teens and '20's) to develop full scale port facilities on Wisconsin Point, serviced by a belt line railroad to connect with a similar railroad in Minnesota, never came into being although the rail grade was established in Superior (c.f. any Plate).

During 1891 sand control fences were erected on the outer end of Minnesota Point near the old lighthouse to prevent sand being blown into the Superior Entry. Wind erosion caused destruction of an Indian cemetary west of the lighthouse during 1876 (Bardon, n.d.) and remains a problem today. Any activities which threaten vegetation on the Points tend to create serious problems which require expensive remedial measures to correct. A "double post and board fence of a total length of 1216 feet filled in with brush and stone to catch the sand" was built across a low, narrow part of Minnesota Point known as "The Opening" (illustrated in Merrill, 1935) about a mile and a half to two miles north of the Entry, to prevent the lake from cutting through into the bay during storms (Corps of Engineers, 1892, pp. 299, and 2137). As early as August 31, 1867 prior to dredging the Duluth Ship Canal it was proposed to cut through the Point in this vicinity to form a second entry to Superior Bay. The width of the Point was stated to be only about 200 feet from Lake shore to bay shore here (Ensign,1898).

The recurved natural end of Wisconsin Point (c.f. Figure 7 Plate) was partially removed in 1892-1896 to open up the Allouez Bay Channel. Spoil from this dredging was deposited on the western side of the Nemadji River extending as far as present Hog Island. Spoil was also deposited on the shoreward side of the Northern Pacific Railroad trestle which had been built in 1881 a few hundred feet offshore of the clay bluffs below East End, extending eastward to Itasca and westward to Connors Point. Hog Island is a product of relocation of sandy spoil at the time the (now abandoned) Great Northern ore dock was built to handle manganiferous iron ore from the Cuyuna Range during the First World War. Barkers Island and additions to the fill behind the railroad trestly are the product of the development and improvement of the Superior Front Channel, which replaced the natural channel across Superior Bay at the turn of the century. The natural channel has been gradually in filled, although it is still discernable on the harbor chart (Chart 966-Duluth Superior Harbor, Minn. and Wis.). Improvements in the Superior and the Duluth portions of the harbor were consolidated by the river and harbor act of June 3, 1896 (Corps of Engineers, 1832, pp. 13-14).

New piers of concrete on stone filled cribs founded on piles were completed in the Duluth Ship Canal in 1901 and the Superior Entry was widened to 500 feet and all-concrete piers completed in 1909. The Duluth Harbor Basin was originally completed in 1915 and the Superior Harbor Basin in 1919-20. Dredgings from the

Superior Harbor Basin have been added to the ends of both Minnesota and Wisconsin Points. Hearding Island, Oatka Beach* and other additions to the northerly end of Minnesota Point reflect improvements of the Duluth Harbor Basin and other elements of the dredged basin system in northerly Superior Bay from the early 1930's onward. Dredge spoil has been important in widening and otherwise developing Rices Point, most recently for the route of Interstate Highway 35 and for the Clure Marine Terminal. Much spoil was used as fill during port development and excess sandy material was disposed of in Lake Superior off the Superior Entry and elsewhere.

In recent years the harbor sands have been exploited for construction materials (Borrow areas indicated on all Plates). As can be judged from Plate 3 only a limited amount of sand is available from beneath the Wisconsin portion of Superior-Allouez Bay. Aggradation of the deeply incised St. Louis drainage makes more sand available in the Minnesota portion of the Bay and throughout St. Louis Bay. However, indiscriminant borrowing of sand from the Bay bottoms may affect bank stability through increased wave attach due to deeper water and through loss of lateral support. Existing problems from wave activity in the Bays are indicated by the need for rip rap along most of the Superior Bay shore, the Wisconsin Point side of Allouez Bay, and local areas of private or commercial rip rap in St. Louis Bay. If power boating increases in the harbor and St. Louis River, even more extensive protective measures will be required in future years, especially along the St. Louis River and Bay shores in Wisconsin where the easily eroded sands beneath Red Clay II are exposed to constant wave attack.

Raising lake level to help alleviate flooding on the lower Great Lakes will also have serious effects both in the St. Louis estuary and along the exposed clay banks east of Wisconsin Point along Lake Superior if it is continued for long periods.

* c.f. Bernard and Davidson, 1969, who review plant succession on dredge spoil here.

Larson (1949) has reviewed the history of the timber industry in the Duluth District, which embraced Superior and Douglas County, Wisconsin as well as communities such as Cloquet along the St. Louis River west of Duluth in Minnesota. As early as 1855 there were small sawmills in the vicinity of Oneota and in East End, but it was not until the 1880's that the industry began to be fully developed. According to Larson (pp. 247-264) lumbermen cut 33 million feet of wood in Duluth in 1881, by 1894 the cut had risen to 343 million feet and in 1902, the peak year 443 million feet were cut. In 1902 the Duluth District cut reached a record total of 1,031,775,000 feet. However within a decade the industry passed out of existence as the supply of logs became exhausted. While it lasted, the lumber industry was focused on the harbor especially along the St. Louis drainage, and to a lesser extent the northerly half of Superior Bay.

Five to 15 feet or more of sawdust and lumber mill wastes have accumulated along Superior Bay in the city of Superior, especially in the vicinity of Quebec Pier and adjacent to Connors Point (Hole 125). Similar conditions exist along the northerly margin of the bay and along the base of Minnesota Point. Along the northerly shore of St. Louis Bay between Grassy Point and Oneota (Holes 68, 70, 73, 74, 75, 76) several feet to several yards of sawdust and slashings accumulated close to the former shore line both above and below water level and in places the terrain is still spoken of as "organic" half a century after the end of production. Mill wastes are often underlain and/or overlain by peaty deposits and in other places are covered with fill. Dredging and spoil disposal have redistributed or buried mill wastes, especially along the route of Interstate Highway 35 in the vicinity of the 21st Avenue West Slip. Sawdust and chips from the mills became widely distributed by the winds, in some instances being carried upstream in the St. Louis estuary by the prevailing northeasterly winds, to become an important constituent of organic accumulations in the bays along the southerly shore of the estuary and may be found almost everywhere.

Perfectly preserved horse manure is found in areas where livery stables were maintained, as, for example, in the vicinity of the Clure Marine terminal on the eastern end of Rices Point. Small to considerable quantities of ores, limestone, coal, slag, cinders, fly ash, and other man-related inorganic and organic materials are widely distributed on the harbor floor and along the principal channels especially in the vicinity of the various source docks and industries. Holes 71 and 81 report (respectively) fly ash and general lumber and steel mill wastes. Slag was dumped in Spirit Lake at a time when it could not be utilized for cement manufacture and construction fill, as it was more recently. Winter (1971) has reviewed water quality and trophic conditions of Lake Superior (Wisconsin Waters) including portions of the harbor. Current information on the chemistry of bottom sediments should be sought from the Corps of Engineers Duluth office and various other public sources.

Section 5
SURFICIAL AND FOUNDATION GEOLOGY

(5.1) General Conditions

The surficial geology of the Superior area is outlined on Plate 4 which illustrates the widespread distribution of wetlands on the low relief clay upland surface. The marshes along the Bay shores and major drainages, and the areas of steep slope adjacent to the major drainages where land slips pose a problem to be overcome in the maintenance of engineering works. The areas mostly unsuitable for engineering development have been stippled for easy reference.

A zone of rapid shoreline erosion eastward from sample localities 26 and 27 (35 and 36-49N-13W) should also be noted. In this area the upland is a gently undulating clay surface with sparse to dense cover which includes (hazel, aspen, birch, dogwood, willow, currant, spruce, pine, white cedar and locally maple.) The clay bluff averages perhaps 40 feet in height above a narrow (0-25 foot) sandy to locally bouldery beach which slopes gently toward offshore shallows. ~~covered with~~ Turbid water resulting from beach erosion ~~which, at a minimum,~~ during calm periods, extends several hundred feet offshore, and during and after prolonged periods of severe weather may extend thousands of yards offshore. The high mobility of the clays when wet and the existence of several sets of high angle joints contribute to the rapid collapse of the banks as they are attacked by waves which under ~~more~~ wave attack, often overrid~~ing~~e the sandy beach completely. Careful planning should precede any proposed development of this area if grief is to be minimized.

Why not give this in a footnote – it is not really important to discuss

(5.2) Wetlands

Wetlands occur most extensively on the non urbanized portions of the red clay upland surface. Three wetlands occupy shallow basins that contain partially decayed vegetable matter preserved under conditions created by poor drainage. Complete decay of the plant materials is retarded by the development of toxins which destroy the microorganisms necessary for decomposition. A general review of the characteristics of Wisconsin wetland soils is given by Phillips (1970). Q? The maximum depth of organic deposits [on the plain] in wetland in Superior is in the order of 5 to 10 feet, and hole 130 is the only bore encountering more than a foot or two of such accumulations. These wetlands pose no special construction problems although improvement of drainage may be necessary. Wetland areas are usually covered with a second growth woods of poplar and a dense undergrowth of willows, alders and dogwood. Pines replace the poplars in dryer areas and white birches develop on some of the organic terrain especially toward the margins of the through-going drainage systems which are beginning to establish themselves on the clay surface.

The site of West Superior between Howards Bay and 28th Street was cleared by burning the original very dense forest cover of pines, birches, and spruce. Many of the remaining logs were used to fill wetlands or low areas, especially in the vicinity of Tower and Oakes Avenues between Winter and Eleventh Streets in the vicinity of the Union Depot and a number of localities south of Howards Bay. Another wet section between Water and Second Streets,* bounded by Hughitt and Baxter Avenues was ~~later~~ used as a land fill site, and an area north of First Street and east of Cumming Avenue was filled and improved with Bay sands. Borings for approaches to the High (Blatnik) Bridge showed 3-4 feet of gray to black silty clay fill over natural stiff red clay along Hammond Avenue between 3rd and 4th Streets. Borings along 4th Street between Grand and Weeks Avenues showed 5-7 feet of clay and cinder fill and east of Weeks Avenue about 3 feet of clean lake sand fill overlies about 3 feet of mucky red to black clay which

* Areas of fill are indicated by light stipple pattern (Plate 4)

was the native surface material. Immunerable other areas such as portions of the University of Wisconsin-Superior campus along the former line of Grand Avenue have been filled, leveled and natural waters diverted into drains or ditches.

(5.3) Lake Marshes

Marshy areas at Lake level are developed locally throughout the Superior region especially along the southern and eastern margins of Allouez Bay. These areas support a growth of sedges, cattails and reeds while wild rice grows in the shallows farther offshore. Marshes are extensively developed along the lower course of the Nemadji River below County Highway C where the river meanders over a half mile wide flood plain bordered by 20 to 40 foot high clay bluffs. Oxbow lakes are common and drowned meander bend lowlands are developed within the natural levee system especially near the mouth. Regional subsidence documented for the last century (Moore, 1948) is flooding sites close to the original settlements in the East End where the loamy soils of the natural levees and sands of the point bars were formed by early residents. A majority of the flood plain below County Highway C has been designated a flood prone area by the U. S. Army Corps of Engineers (c.f. Plate 4). Flooding is frequent during the Spring breakup when extensive ice jams develop after severe winters.

(5.4) Slope Stability

A heavy dashed line and heavy dot stipple pattern outlines areas subject to slope stability problems (Plate 4). As a rule slips are most frequent on steep slopes adjacent to the through-going drainages at elevations below the 650 foot contour line. Slip takes place by the plastic flow of clays, by slippage along pre-existing high angle joints, and by development of rotational shear surfaces as the bank becomes oversteepened or overloaded. Failure along preexisting joints is most common in areas of active erosion of the toe of the slope, such ~~as~~ conditions exists along the St. Louis Bay and River shores where the Nemadji meanders against the valley walls of its flood plain, and along Lake Superior. ~~but cannot be disregarded~~ ~~even~~ slope instability may also be a problem on level areas such as the Burlington Northern taconite storage facility (Hole 16) where joint and rotational slip failure occurred under excessive surface loading.

Several prominent slip areas are identified on the Plates as special localities 11, 13, 14, 15, 16. The most severe problems are presently being encountered to the east of Wisconsin Point where the wastage of the clay banks exceeds several feet per year over most of the south shore of Lake Superior between the Point and the village of Port Wing. Because of the regional subsidence at a rate of about 1 foot/century (Moore, 1948) which tilts the lake against this shore, no ultimate solution to this problem is possible. ~~although~~ However, interim measures such as groins may give a measure of relief and structures in the vicinity of stream mouths are in some measure protected by natural sand beaches below the bluffs. Fill provides such protection along the southerly shore of Superior Bay in the East End and Central Park.

(5.5) Foundation Conditions

The long term stability of the grain elevators at the base of Connors Point and the ore docks in Allouez testify to the suitability of the Quaternary sediments as foundations for major engineering structures. Foundations in both areas usually rest on piles and are concrete slabs in the case of the elevators and isolated concrete floatings in the case of the ore docks and the High (Blatnik) Bridge. Portions of the structures rest on several feet to about 20 or 30 feet of harbor sands, which in turn overlie native red clay. Depth to clay can readily be estimated from data on Plate 3. In the Connors Point vicinity longer piles are bottomed in the hard brown sandy beds beneath the red clay (Sequences 5, 6, or 8, Figure 5). These sands are missing from the stratigraphic sequence beneath the waterfront to the east of the Nemadji River (as in Sequence 3, Figure 5) and are also missing south of the "inferred limit" line shown on Plate 3. No important thickness of sands have been encountered beneath the surficial clay of the plain in West Duluth although up to about 20 feet of sand beneath perhaps 10-15 feet of clay is present in some wells (58, 59, 61, 62, 63, 64), the remainder of the section being clay lying above glacial drift (as in Sequence 4, Figure 5). Two horizons of drift separated by clay are reported in Well 59, with the highest horizon about 10 feet thick, lying at a depth of 32 feet. It is probable that this is part of the loamy sand-gravel layer beneath the upper red clay (II) and not actually a drift horizon.

I or II?

This discussion departs from foundation conditions.

Structures along the northerly shore of St. Louis and Superior Bays are founded on harbor sands which generally overlie red clay at depths up to several tens of feet (as in Sequence 7, Figure 5). It seems probable that the red clay present here is red clay I - as is inferred from the dashed contour on Plate 3. The engineering properties of this clay are similar to those of red clay II. Stratigraphic relationships from the base of Rices Point eastward to the base of Minnesota Point are summarized in Figure 8 and Sequences 9 and 10, Figure 5. In this area the youngest red clay has been removed and complex interrelationships exist between clay, sand, gravel, and gabbro bedrock.

departs from discussion

Foundations along the Duluth escarpment above an elevation of about 675-700 feet encounter a short stratigraphic section consisting mainly of argillaceous sands and gravels and sometimes boulders, lying directly on gabbro bedrock in West Duluth or on basalts from the base of Minnesota Point eastward. Wells 65, 66, and 211 are representative, although a greater thickness of sand and gravel may be encountered locally (Sequence 1, Figure 5). Because of the high fine material content these sand-gravel accumulations do not normally conduct troublesome amounts of water. Little if any water that would cause foundation problems is transmitted by red clay II or red clay I and no true water table exists in areas underlain entirely by red clay and drift. Small amounts of water may be encountered in the loamy sand-gravel unit beneath red clay II, although this layer is sufficiently impermeable not to transmit high volumes of water and would not be expected to pose a construction problem. However, this sandy interval is frequently classified as being "quick sand" and should be entered cautiously.

(5.6) Engineering Properties of Clays I and II

Engineering data on the properties of the clays of the Superior area have been obtained from construction work in the vicinity of the University of Wisconsin-Superior, the Burlington Northern Taconite Storage Facility in Allouez, the Murphy Oil Company refinery and the vicinity of Howards Bay. Because of the visual similarity of the clays throughout the area and their common origin it is probable that the range of properties (1) shown in Table 1 and the representative values (2) of these properties are of the correct order of magnitude. However, even within short distances, the stiffness of the clays may vary considerably within this range and specific tests are required for particular engineering purposes. don't understand

(5.7) Clay Products

The major source of brick and tile clay products during the development of modern Superior was the Nemadji Brick and Tile Company opened in 1882 at the foot of 13th Street ~~and~~ adjacent to the Nemadji River and later moved to the foot of 17th Street and the River (Localities 17 and 18). A small brickyard was operated along Tower Bay Slip early in the history of West Superior. The West Superior

TABLE 1

Engineering Properties of Clays I and II

	Dry Density (lbs./ft.^{3}	Wet Density lbs./ft.^{3}	Average Water Content (%)	Liquid Limit (%)	Plasticity Index (%)	Internal Friction Angle (°)	Cohesion (lbs./ft.^{2})	Unconfined Compression Strength (lbs./in.^{2})
(1)	53-101	113-125	24-77	51-85	27-39	10-20	250	500-6500
(2)	75	120	40	65	35	15	250	2750

reference 2

Brick Company (Locality 9) operated in the vicinity of the West Superior Iron and Steel Company plant (Locality 10) starting about 1888 and the Seager and Guinniss Brick Company (Locality 12) used ~~operated on~~ native clays in South Superior during the same era. None of these operations survived into the present century and no published technical data is available on the character of the bricks.

A clay sample "from the City of Superior" was tested by Ries (1906, p. 167-168) who notes the sample showed a tendency to crack badly in air drying, and that the presence of many scattered lime "pebbles" militate against production of a good quality of bricks. Additional testing of clay is necessary to confirm or deny the brick-making potential of the clays.

Bloating is a property of certain clays to expand at high temperature forming a particle which can be used together with slag, cinders, or scoria to form light-weight concrete aggregate. Bloating tests on clays similar to those in the Superior area have been conducted by the Minnesota Geological Survey (Prokopovich and Schwartz, 1957) on samples from Carlton County, indicating a suitability for this purpose. Similar tests should be conducted in the Superior area.

The U. S. Bureau of Mines has tested various northern Michigan and Wisconsin glacial lake clays for suitability as iron ore pellet binders in taconite processing (Miska, 1969). Results were negative on the samples taken but a previous study (R.I. 7206) indicated satisfactory results from some Minnesota clays, indicating the desirability for additional examination of Wisconsin clays.

Section 6
WASTE DISPOSAL ~~SITES~~ POTENTIAL

(6.1) Solid Waste Disposal

Solid waste disposal sites in Superior used during the last half century are shown on Plate 4 . The geology of sites 2-7 is nearly identical - a native red clay substratum overlain by a foot or two of peaty materials. The thickness of the clay substratum is at least 20 feet in the northerly sites and probably exceeds 50 feet in the southerly sites, the poor permeability of the clay tends to prevent downward passage of lechates and favors entrance to surface runoff waters. ← statement on merits of site

The sanitary land fill on the base of Wisconsin Point is on a sand substratum which is gradually being flooded by the previously noted (Moore, 1948) downwarping of the region. Wastes are covered by successive blankets of red clay imported to the site from nearby red clay bluffs (sample locality 28), creating an artificial mound which is scheduled to become a recreational site in the future. The continued regional subsidence is gradually altering land-water relationships on the Point, probably necessitating protective structures to prevent wave erosion of the land fill within a few years unless present trends are reversed. Artificial deepening of Lake Superior will also accelerate erosion, shortening the time interval before protective structures are required to prevent wave redistribution of solid wastes. Careful study to determine the native, and rate of changes ~~in the~~ geometry of the Point - South Shore clay bank system is needed at once. ? does this need support

Possible alternative waste disposal sites in the area all have geologic settings similar to those which have already been utilized. A geologically possible approach to new disposal sites, in conjunction with extraction of sand and gravel* would be to first mine the 10-15 foot thick gravelly beds beneath 5 to 15 feet of surficial red clays in the shaded area (Plate 4) north of Oliver, then use the excavation for disposal, covering the wastes with the already mined clay. The low permeability of the deeper loamy sands and silts

* Little sand and/or gravel is currently produced in the Wisconsin portion of the Superior area but is imported from central Douglas County or from the crest of the Duluth escarpment in Minnesota. Appendix F reviews the nature and availability of sand and gravel deposits

here would minimize spreading of the lechates although permitting downward flow, favoring the breakdown of the wastes. Water tables information is lacking in this area although the zone of permanent water saturation is probably well below postulated disposal depths owing to the clay blanket over the surface in most of the area and the 30-40 foot relief above the St. Louis River of the present surface.

Study by auger holes would be required to establish the water table configuration, to evaluate the sand-gravel potential and the character, porosity, permeability and other properties of the sediments below the sand/gravel layer. Wisconsin Division of Highways test results on sandy material taken from a pit in SESE 1-48N-15W indicated its usefulness for highway sub base and gave grade sizes as indicated below in Table 2.

TABLE 2.

Sieve No.	Percent Passing
4	100
10	83
40	40
60	21
100	10
200	4

Sandy layers intercolated with gravel layers sampled in localities 56 and 57 have been noted in ~~Table~~ Appendix E, but the gravel content has not been evaluated owing to the very limited exposures presently available.

Proper restoration practices would be required to insure return to the area to later use as a very attractive residential, recreational, or commercial location.

(6.2) Liquid Waste Disposal

During the past quarter of a century the practice of injecting liquid industrial wastes into subsurface reservoir rocks has been employed in some parts of the United States. No such wells have been operated in Superior and it is unlikely that the geological framework provides suitable sites for such disposal. The thickness of the Bayfield Group bedrock beneath Superior is unknown but is probably not great and is known to contain a number of shaly units and enough clay to reduce its capacity to receive and transmit fluids. The uppermost portion of these rocks is locally an aquifer in conjunction with the overlying glacial drift. Contamination of this aquifer by vertical movement of fluids along high angle fractures such as those mapped in the Fond du Lac, Minn. area by Thwaites (1912) would be a threat to the water supply of many outlying businesses and households.

Loamy sands and gravelly materials beneath the uppermost red clay inside of the "inferred limit" line of Plate 3 have sufficient permeability to receive septic tank effluents. A depth of 10 to 20 feet is indicated to reach the top of these beds along the St Louis River in the western margin of the city. Inquiry as to more specific conditions can be made of the Wisconsin Geological & Natural History Survey representative at the University of Wisconsin-Superior. For any septic effluent disposal system to be satisfactory dry wells must penetrate the sandy beds because the clay above will accept very little water no matter how large a drain field is installed in it. It is possible that limited disposal of other degradable wastes in this rock unit would be feasible since it is of limited use as an aquifer. However seepage from this unit contributes to the flow of both the Nemadji and St. Louis Rivers, as well as providing household water locally along the St. Louis and any program of waste injection would require careful study before implementation.

Septic systems should not be used for disposal of high volumes of wastes on either Minnesota or Wisconsin Point since the sands here are readily permeable and in full connection with the waters of both the lake and the bays to the west of them.

Section 7
WATER SUPPLY

(7.1) Surface Water

Early residents of East End, Central Park and Connors Point first obtained water directly from Superior Bay ~~and~~ but later obtained it from wells drilled for the purpose by the town. The present surface water supply system evolved with the growth of West Superior and the other new communities within the city in the late years of the 19th Century. In 1886 the Superior Water Works Company built the first water plant at the foot of Tower Avenue, drawing water from Tower Bay Slip, and in 1886 a new pump station was constructed at the foot of Winter Street and Hill Avenue to draw water from Superior Bay (Anon., n.d.; Show, n.d.). This water proved to be discolored and odorous. In 1889 the Superior Water Light and Power Company was formed from the previous operations of the Superior Water Works Company, the Superior Light and Fuel Company, and the Superior Arc Light and Power Company, receiving the grant of the right to install water, gas, and electric properties in the city from the Land and River Improvement Company.

The pumping station was moved to its present site at 18th Avenue and East First Street in 1891 and water was pumped from Lake Superior 2000 feet off Minnesota Point. Cloudy water from this source caused development of a well field in an area about 1500 x 200 feet ~~sequence~~ square on Minnesota Point across from the pumping station starting in 1897. Water drawn from fifty foot deep wells in the sands of the Point contains enough iron derived from the black sands present to cause discoloration and slime deposits and ~~must~~ had to be filtered and aerated to remove this nuisance.

Construction of the Cloquet Water Line intake in Lake Superior 10,400 feet offshore from the well field (cf. any Plate) has provided an alternate water supply source - but one which is also troubled by cloudy water following northeast storms. At present (1973) both sources are used about equally, depending on weather conditions. The total capacity of the system is about 18.5 million gallons per day (24 hours) and normal usage is about 4.5 million gallons per day. Chemical analyses of the water are given in Table which is taken from data in Anon. (1970).

It is doubtful whether any location for a water intake can be chosen on the lake bottom off of the Twin Ports which will not suffer periodic influxes of cloudy water owing to the large scale introduction of suspended clays into the lake from erosion of the South Shore, the introduction of suspended clay and silt by the Nemadji River, and the introduction of natural organic - rich waters containing sundry man-related wastes from both the Duluth Ship Canal and the Superior Entry. The suspended materials form a turbid cloud in the water which after severe weather conditions may be visible at the surface and at other times settles gradually toward the bottom, but which is seldom completely absent owing to current circulation and density flow down slope from the lakehead. Raising the intake as high above lake bottom as is consistent with avoidance of interference from shipping should minimize times of cloudy water intake.

TABLE

Chemical Analyses of Superior Public Water Supply

	Well Field	Lake (Cloquet Pipeline)
Alkalinity		
Total ($CaCO_3$)	50	40
Calcium (Ca)	17	13
Chlorides (Cl)	4	1
Fluorides (F)	0.1	0.05
Hardness (Total)	54	44
Iron (Fe)	0.89	0.16
Magnesium (Mg)	2	3
Manganese (Mn)	0.06	0.04
Nitrites (N)	<0.003	0.021
Nitrates (N)	<0.5	0.24
Sodium (Na)	2	1
Sulfates (SO_4)	3	4
Total Solids	60	62
pH (Su) Lab	7.5	7.3
pH (Su) Field	7.0	7.3
H_2S	-	-

(7.2) Ground Water

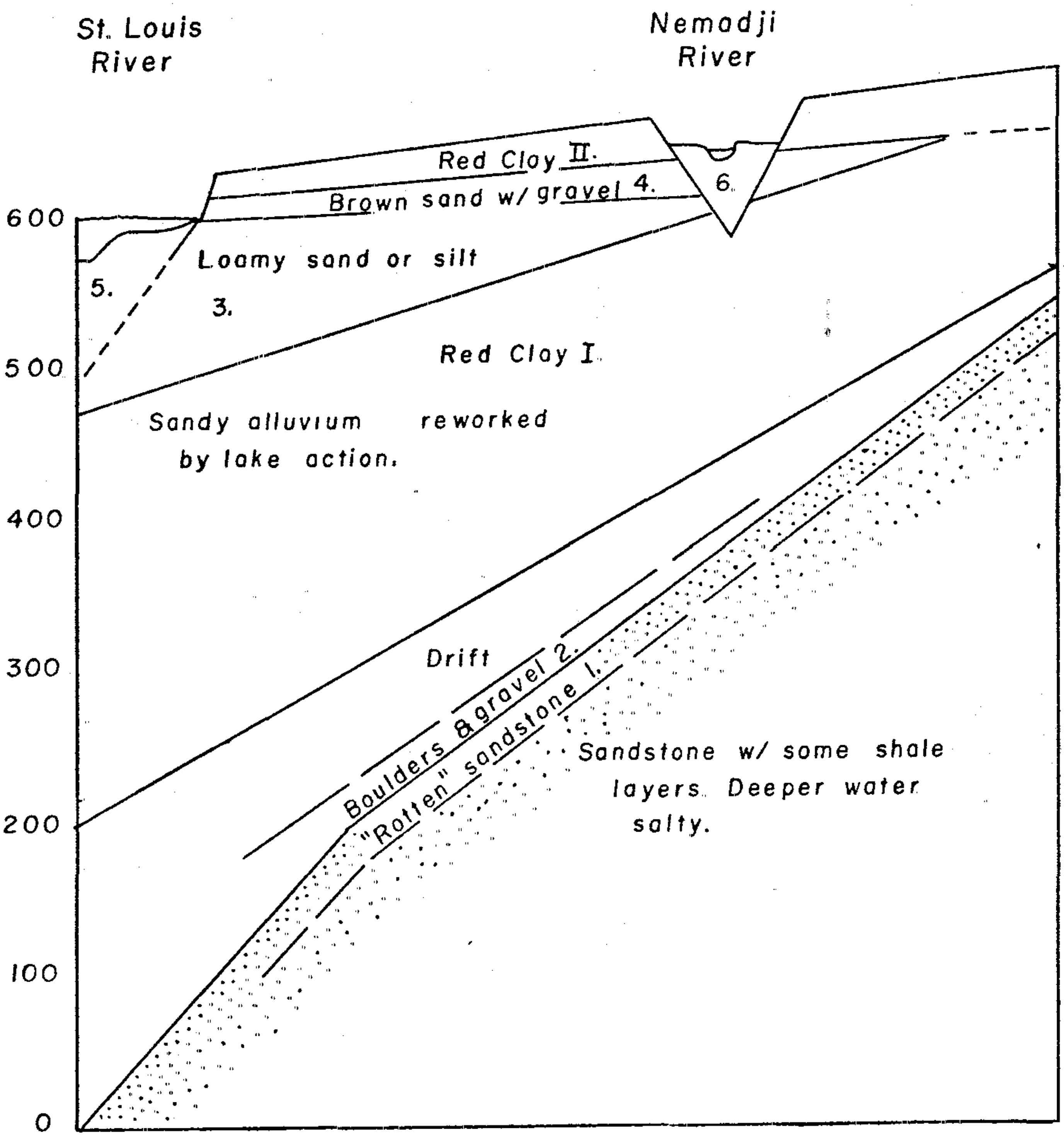
Six ground water aquifers, exclusive of the Minnesota-Wisconsin Point sands are illustrated on Figure 12 which is a schematic cross section of the Wisconsin portion of the Superior area.

Domestic, agricultural and industrial consumers who do not require sustained high capacity yields can obtain adequate high quality, moderately hard, water from the Bayfield Group red sandstones throughout the Wisconsin portion of the Superior area. Depths from the surface to the top of the sandstone can be estimated from the overburden thickness map (Plate 2), and range from 500-600 feet along the St. Louis River to 150-200 feet along the southeast side of the area. A weathered or disturbed "rotten" sandstone zone is encountered at the surface of the Bayfield Group in places where the bedrock has been directly affected by ice and/or melt water. Experience throughout the Superior area confirms the presence of salty water at depths of more than about 100 feet below the contact between the bedrock surface and the overlying Quaternary age sediments. Deep drilling for potable water in the sandstones is therefore unlikely to be successful.

Glacial drift overlies bedrock throughout the Superior area. The lower portions of the drift generally contain sand/gravel deposits within the "inferred limit" line of Plate 3 . These deposits are excellent sources of ground water when encountered. This aquifer is closely associated with that in the upper part of the Bayfield Group bedrock and is the best potential aquifer in the area. Presently this aquifer supplies water to home owners within the city limits in 29-49N-14W and adjacent areas (Wells 87, 88, 89 and vicinity), in South Superior (Well 165) and to most other home owners, farms, and businesses

Figure 12

Schematic Representative Geologic Cross Section Superior, Wisconsin, Identifying Six Aquifer Types



1" = 100' vertical scale
No horizontal scale

outside of the city limits. Owing to the rise of the bedrock and drift to higher elevations south of Superior this aquifer system is artesian in character (c.f. descriptions in Weidman and Schultz, 1915, pp. 316-317.), although today few if any wells flow at the surface, as was common in the 19th Century. Production data is not available from which to make a reliable evaluation of what quantities of water are available from the artesian aquifer system but perhaps 1000 gallons per minute may be generally obtainable and higher rates of production might be anticipated in wells encountering thick sand/gravel deposits in the glacial drift unit.

The loamy brown sands and gravels beneath red clay II are present at shallow depth northward of the "inferred limit" line on Plate 3. In general these beds are too poorly permeable and too protected from recharge by the overlying clay to be a source of water even for domestic wells. Locally, as in the vicinity of wells 89 and 181, limited production has been obtained from this source, and it is probable that such production might be realized north of the "inferred limit" line (Plate 3) in the vicinity of the St. Louis River and the various bays along its southerly shore where seasonal springs caused by interception of downward moving water by thin clay horizons are known in a few localities. There is good potential for dug wells in this area and one such well presently (1973) supplies domestic water in the vicinity of well 87. Provision should be made for adequate storage capacity to handle anticipated needs for sustained high volume use because experience in the vicinity of well 87 indicates that recharge from other parts of the aquifer and ~~the~~ infiltration from the river is slow.

The silts, sands and gravels of the St. Louis River and Nemadji River valleys are potential aquifers for some industrial users although the presence of organic matter in them may reduce water quality. Water produced from alluvium is apt to be of generally higher quality than that produced directly from rivers owing to the natural filtering action of the alluvium and receipt of infiltration from higher parts of the underlying sand-gravel aquifer in this case. The warmer temperature of such shallow ? alluvial aquifers makes this water preferred to that from the deep artesian ? aquifer for agricultural uses. No production from the shallow aquifers is presently known, probably because of the steepness of river banks and lack of flood plain in the St. Louis estuary and the problems of flooding, coupled with high, unstable banks along the Nemadji.

Is this based on data? I suspect just the reverse to be true, i.e., the shallower waters will be colder and the deep aquifers warmer - also, there is probably not that much differential to make it a factor in Ag use

REFERENCES

Aguar, C.E., 1971. Exploring St. Louis County Historical Sites: St. Louis Co. Hist. Soc., 2228 E. Superior St., Duluth, Minn.

Anonymous, History of Superior's electric, gas and water supply and Superior Water, Light and Power Company. Printed for private circulation by Superior Water, Light and Power Company, Superior, Wisconsin. (in J. D. Hill Library, Univ. of Wis.-Superior.)

Anonymous, 1970. State of Wisconsin public water supply data; Wis. Dept. Nat. Resources Div. Environmental Protection, Madison, Wisconsin.

Bardon, J.A. Recollections of early days in Superior; Indexed and organized by W.P.A. Project 7916, Douglas Co. Hist. Museum, Superior, Wisconsin.

Bernard, J.M. and D.W. Davidson, 1969, A floristic resurvey of a land fill area 32 years after deposition, the Oatka beach addition, Minnesota Point, Minnesota: Amer. Midland Nat., 82, No. 2, pp. 559-563.

Buckley, E.R., 1898. Building and ornamental stones of Wisconsin; Wisc. Geol. Nat. Hist. Surv. Bull. 4.

Darling, Captain, 1904. Government engineer lectures on History of Superior harbor at Carniege Library, Superior; Vault typescript, Superior Public Library (LS627En7s).

Davidson, D.W., and J. M. Bernard, 1969. Mature pine forests in Duluth Harbor area; Jour. Minn. Acad. SCi. 35, No. 2 and 3, p. 118-121.

Ensign, J.D., History of Duluth harbor; Indexed and organized by W.P.A. Project 3264, Superior Public Library, Superior, Wis.

Erickson, V.G., 1940 (editor). History of Duluth-Superior harbor; U. S. Corps of Engineers Office, Duluth, Minn.

Farrand, W.R., 1969. The Quaternary history of Lake Superior; Proc. 12th Ann. Conf. Great Lakes Res., Internat. Assoc. Great Lakes Res., p. 181-197.

Flower, F.A., 1890, The eye of the northwest, first annual report of the statistician of Superior, Wisconsin: Superior, Wisconsin (in Superior Public Library).

Grant, U.S., 1900. Preliminary report on the copper-bearing rocks of Douglas County, Wisconsin; Wisc. Geol. Nat. Hist. Surv., Bull. 6.

Irving, R.D. 1883. The copper-bearing rocks of Lake Superior; U. S. Geol. Surv. Mon. 5.

Lawson, A. C. 1899. Observations on lake levels at Duluth: in Geology of Minnesota, N.H. Winchell, vol. 4, pp. 219-221.

Leverett, Frank, 1929. Moraines and shore lines of the Lake Superior Region: U. S. Geol. Surv. Prof. Paper 154-A.

Loy, W.G., 1963. The evolution of bay-head bars in western Lake Superior: Pub. No. 10, Great Lakes Res. Div., Univ. Mich., Ann Arbor.

Martin, Lawrence, 1965. The physical geography of Wisconsin: Univ. Wis. Press, Madison. (originally -1932- Wis. Geol. Nat. Hist. Surv. Bull. 36). 1916 version revised.

Merrill, J.A., 1936. The wonderland of Lake Superior: Burgess Pub. Co., Minneapolis (in J.D. Hill Library, Univ. Wis.-Superior.)

Meyers, W.D., 1971. The sedimentology and tectonic significance of the Bayfield Group, Wisconsin and Minnesota: Proc. 17th Ann. Inst. Lk. Sup. Geol., p. 54-55.

Miska, W.S., 1969. Testing of northern Michigan and Wisconsin glacial lake clays for utilization as iron ore pellet binder; U. S. Bur. Mines open file report, Minneapolis, Minn.

Mooney, H.M., P. R. Farnham, S.H. Johnson, Gary Volz, Campbell Craddock, 1970. Seismic studies over the midcontinent gravity high in Minnesota and northwestern Wisconsin: Minn. Geol. Surv. Rept. Inv. 11.

Moore, Sherman, 1948. Crustal movements in the Great Lakes area: Bull. Geol. Soc. Amer., 59, pp. 697-710.

Morey, G.B., 1967. Stratigraphy and petrology of the type Fond du Lac Formation, Duluth, Minnesota: Minn. Geol. Surv., Rep. of Inv. 7.

Morey, G.B., and R. W. Ojakangas, 1970. Sedimentology of the Middle Precambrian Thompson Formation, East Central Minnesota: Minn. Geol. Surv. Rept. Inv. 13.

Phillips, John, 1970. Wisconsin's wetland soils: Wis. Dept. Nat. Res. Research Rpt. 57, Madison, Wisconsin.

Prokopovich, Nikola, and G.M. Schwartz, 1957. Preliminary survey of bloating clays and shales in Minnesota: Minn. Geol. Surv. Summ. Rept. No. 10.

Ries, Heinrich, 1906. The clays of Wisconsin: Wis. Geol. Nat. Hist. Surv. Bull. 15.

Ries, Heinrich, and F. L. Gallup, 1906. Report on the moulding sands of Wisconsin in Clays of Wisconsin: Wis. Geol. Nat. Hist. Surv., Bull. 15.

Roberts, Arthur, 1969. Land speculation in Superior, Talk to Douglas Co. Mus. Ann. Meeting. (reprinted Douglas Co. Hist. Mus, Superior, Wis. (in J.D. Hill Library, Univ. of Wis.-Superior.)

Schwartz, G.M., 1949. Geology of the Duluth metropolitan area: Minn. Geol. Surv. Bull. 37.

Shaw, Reginald. No Date. The study of Superior, Wisconsin: Univ. of Wis.-Madison Doctoral Thesis reproduced for use in ninth grade social studies, Superior Public Schools, 1949. (in J.D. Hill Library, Univ. of Wis.-Superior and Superior Public Library.)

Sweet, E.T., 1880. Geology of the western Lake Superior District, Geology of Wisconsin, vol. 3, pp. 303-362.

Taylor, 1964a. Geology of the Duluth gabbro complex: Minn. Geol. Surv. Bull. 44.

_______ 1964b. Bedrock geology of Duluth and vicinity, St. Louis County, Minnesota; Minn. Geol. Surv. Geol. Map. Ser. GM-1.

Thiel, E.C., 1956. Correlation of gravity anomalies with Keweenawan geology of Wisconsin and Minnesota: Bull. Geol. Soc. Amer., 67, pp. 1079-1100.

Thwaites, F.T., 1912. Sandstones of the Wisconsin coast of Lake Superior: Wis. Geol. Nat. Hist. Surv., Bull. 25.

Van Hise, C.R. and C. K. Leith, 1911. The geology of the Lake Superior region: U. S. Geol. Surv. Mon. 52.

Weidman, Samuel, and A. R. Schultz, 1915. The underground and surface water supplies of Wisconsin: Wis. Geol. Nat. Hist. Surv. Bull. 35.

Winter, D.R. 1971. Water quality and trophic condition of Lake Superior (Wisconsin waters): Wis. Dept. Nat. Res. Research Rpt. 68, Madison, Wisconsin.

Annual Report of Chief of Engineers, U.S. Army, to the Secretary of War for year 1892. 4 parts. Washington, Govt. Printing Office 1892. (in J.D. Hill Library, Univ. of Wis.-Superior.)

APPENDIX ~~B~~ A

~~[illegible]~~ Derivation of Local Place Names

Geographic names are derived from Chippewa words, or commemorate historic figures great and small. Nemadji-Chippewa, meaning left hand; Pokegama-Chippewa-meaning bay or lake at one side of a river; St. Louis-French for Louis XIV; Allouez-French Jesuit Father Claude Allouez 1666 visitor to the area; (Clough (Island)-Judge Solon H. Clough an early settler; Connors Point-B.H. Connor, early homesteader on the peninsula; Howards Bay-J.D. Howard, early mill owner on Connors Point; Rices Point-Orin Rice, owner of a log house on the point in 1855. These and many other local names are identified by Flower (1890, p. 192-196).

The name Itasca was coined in 1832 by W. T. Boutwell and H. R. Schoolcraft who believed Itasca Lake, Minnesota to be the true source of the Mississippi River. Boutwell cited this in Latin as veritas caput and Schoolcraft joined the tail of the first with the head of the second to form the word Itasca (Stewart, 1970, p. 224).

The name "Dutchman's Creek" comes from the Dutch Vorbeck brothers who fished and farmed there in the late 19th Century (Bardon, n.d.).

The name Superior (Lac Superieur) was given to the Lake by the French in the 17th Century and meant "upper lake" as compared with Lakes Huron and Michigan. According to Stewart, 1970, p.466) "It assumed the English form after the ending of the French domination, and to some extent necessarily assumed something of the English connotation, viz. 'better'." The city takes the name of the lake.

APPENDIX B

Notable Localities

Locality	Description
1.	Lake Duluth sea cliff, head of 9th Ave. West, Lawson (1899, p. 219).
2.	Lake Duluth beach, between 6 and 8th Ave. West at elevation 1077, Lawson (1899, p. 219). Localities 1, 2, 3, are classic localities on which much evidence for high level lake stages rests. Described in some detail before their disturbance by more recent construction.
3.	Lake Duluth beaches at 1137, 1112 and 1072 ft. elevations, Lawson (1899, p. 220).
4.	First lighthouse (1858-1878), brick tower still standing above Bayfield zero bearing monument.
5.	Stockade historical marker site. Fort built to protect Superior residents from possible Indian violence during Civil War-never used in anger and subsequently destroyed for fire wood.
6.	Upper Town Dock (19th Century).
7.	Conan's Dock (19th and early 20th Century).
8.	Approximate site of Fort St. Louis stockade and for trading post - late 18th Century.
9.	West Superior Brick Company brickyard site (1888). Bricks used for adjacent steel plant buildings. Flower (1890, p. 169) mentions moulding sands from this vicinity - possibly from sands beneath red clay II, present at shallow depth line.
10.	West Superior Iron and Steel Company founded 1888 and continued in intermittent operation into early 20th Century (1916). Produced cast iron pipes and plates for whaleback lake steamers built in Superior in this era. Coking ovens to supply the steel company and for shipment to Montana for use in copper smelting were established (1888) at the western end of dock facilities north of this locality.

Locality	Description
11.	Clay slide area, State Highway 105 periodically offset by sliding towards Pokegama River valley.
12.	Seager and Guinniss Brick yard, late 19th Century.
13.	Clay slide area. Burlington Northern trestle offset by slides.
14.	Clay slide area, County Highway A destroyed and rerouted east of Nemadji valley wall.
15.	Clay slide area, local damage.
16.	Clay slide area, local damage.
17.	Nemadji Brick and Tile Company kilns and brickyard (1885), foot of 17th Street. Shipment down Nemadji River by boat for use in West Superior, etc.
18.	Nemadji Brick and Tile Company original site (1882), foot of 13th Street.

APPENDIX C
Well Records

Wells indicated as "Test hole" were drilled to obtain specific information about the stratigraphy and engineering properties of the rocks penetrated; wells indicated as "Water well" were drilled to obtain water and logged by the driller for that purpose.

		Thickness (Feet)	Depth (Feet)
1:	Test hole		
	Gravel, loamy and clay	5	0
	Clay	17	5
	Basement (basalt)	-	22
2:	Test hole		
	Water	20	0
	Sand, fine	12	20
	Basalt	12	32
3:	Test hole		
	Water	22	0
	Sand, fine	40	22
4:	Test hole		
	Gravel	5	0
	Sand and gravel	16	5
	Sand, fine	33	21
	Sand and gravel	5	54
	Basalt	9	59
5:	Test hole		
	Sand, fine	16	0
	Sand and gravel	10	16
	Sand, fine	34	26
	Clay	4	60
	Loam, sandy	7	64
	Basalt	7	71

		Thickness (Feet)	Depth (Feet)
6:	Test hole		
	Water	15	0
	Sand, fine, with peat	10	15
	Sand, fine	26	25
7:	Test hole		
	Sand and gravel, loamy with wood	10	0
	Loam, silty, clayey	5	10
	Clay, loamy	5	15
	Bed rock	-	15
8:	Test hole		
	Sand, fine	4	0
	Loam, sandy clay	2	4
	Sand with cinders	6	6
	Wood chips	3	12
	Sand with cinders	6	15
	Sand, fine	33	21
	Gravel	3	54
	Clay	28	57
	Gabbro	10	85
9:	Test hole		
	Fill: clay, brick, cinders	7	0
	Fill: coal and wood	4	7
	Wood	2	11
	Peat and muck	6	13
	Sand, brown, coarse, with gravel and few wood chips	12	19
	Sand, brown, fine with lenses of heavy sand and traces of wood below 55 ft.	31	31
	Sand, brown, very fine loamy with small amount of o.m.	6	62
	Clay, brown rather stiff to medium	8	68
10:	Test hole		
	Water	25	0
	Mud and sand	7	25
	Sand, coarse, and gravel	8	32
11:	Test hole		
	Water	14	0
	Sand and mud	4	14
	Sand and gravel with small boulders below 40 ft.	34	18

		Thickness (Feet)	Depth (Feet)
12:	Test hole		
	Water	22	0
	Sand and gravel	31	22
13:	Test hole		
	Water	26	0
	Silt, with wood fragments	2	26
	Sand, well sorted	2	28
14:	Test hole		
	Water	26	0
	Sand, well sorted	3	26
15:	Test hole		
	Fill: Silty sand, cinders, a little gravel wood, brick	12	0
	Peat, a little wood, black	8	12
	Sand, brown, fine, medium to very dense with few lenses of silty sand, and peat	40	20
	Clay, red brown, medium to soft	13	60
	Silt, gray brown, medium dense	3	73
	Clay, red brown, soft	9	76
	Clay, gray brown, with a little gravel	14	85
	Clay, red brown, with a few sand lenses, soft	10	99
	Clay, red brown, soft	10	109
	Sand, brown, silty, with a little gravel and a few boulders, very dense		
	Silt, brown, very dense	3	119
	Sand, gray brown, clayey with some gravel and boulders, very stiff	3	121
16:	Test hole		
	Fill: loamy sand and gravel, cinders, wood	13	0
	Peat	3	13
	Sand and gravel with sandy loam	9	16
	Sand, fine	20	25
	Sand, loamy	10	45
	Clay, soft	15	55
17:	Test hole		
	Loam, sandy and gravel	5	0
	Sand and gravel	23	5
	Sand, fine	19	28
	Clay, soft	32	47
	Gabbro	16	79

		Thickness (Feet)	Depth (Feet)
18:	Test hole		
	Fill	5	0
	Sand, loamy, peaty, soft	9	5
	Sand, with o.m., soft	5	14
	Sand	19	19
		27	38
19:	Test hole		
	Sand, black, loamy, soft	9	0
	Clay, very soft	5	9
	Sand, loamy	1	14
	Clay	9	15
	Sand, fine	13	25
	Clay	23	38
	Clay, silty	14	61
	Sand, fine with some gravel, hard	36	75
20:	Test hole		
	Fill	10	0
	Sand and gravel (stream) with some o.m.	15	10
	Clay, red, stiff - to surface in some bores	5	25
	Sand, silty	50	30
	Gabbro	-	80
21:	Test hole		
	Peat, sand, and gravel	2	0
	Clay, soft	18	2
	Clay	12	20
	Sand, fine, loamy, hard	9	32
	Sand, loamy, hard	10	41
	Gabbro	10	51
22:	Test hole		
	Fill	2	0
	Silt, loamy	16	2
	Loam, silty, very soft	22	18
	Clay	2	40
	Silt, loamy	2	42
	Clay, soft	38	44
	Clay, silty	4	82
	Till, loamy, hard	5	86
	Sand and gravel, loamy	19	91
	Gabbro	4	110

		Thickness (Feet)	Depth (Feet)
23:	Test hole		
	Sand, loamy, gravel, and boulders	15	0
	Peat	5	15
	Clay loam, silty, and fine sand, soft	30	20
	Loam, sand	2	50
	Clay	11	52
	Sand and gravel, loamy, hard	8	63
	Gabbro	8	71
24:	Test hole		
	Sand and gravel	6	0
	Loam, silty, organic	4	6
	Clay loam, silty, peaty	4	10
	Peat	4	14
	Clay	34	18
	Sand, loamy, very fine, hard	27	52
	Loam, silty, very firm	3	79
	Clay	28	82
	Clay loam, silty, firm	12	110
	Loamy sand with boulders, hard	16	122
25:	Test hole		
	Water	5	0
	Muck	5	5
	Sand, fine with seams of peat and clay very soft	8	10
	Sand, fine, hard	17	18
	Muck	5	35
	Sand, fine, very firm	12	40
	Sand, very fine, hard	34	52
	Clay, firm	16	102
26:	Test hole		
	Peat	14	0
	Muck	6	14
	Sand, loamy, very soft	4	20
	Clay, silty, very soft	16	24
	Clay	46	40
	Loam, silty, very firm	29	86
	Sand and gravel, hard	46	115
	Gabbro	11	161
27:	Test hole		
	Sand, gravel, and wood	7	0
	Gabbro	24	7

		Thickness (Feet)	Depth (Feet)
28:	Test hole		
	Sand, clay, and gravel	7	0
	Peat and loam	8	7
	Sand and gravel	2	15
	Loam, silty, very firm, hard	13	17
	Sand, fine, loamy, hard	5	30
	Till, fine sandy, loamy, hard	16	35
	Boulders	6	51
	Sand and gravel	4	57
	Gabbro	13	61
29:	Test hole		
	Sand	3	0
	Sand, fine, loamy, hard	22	3
	Loam, silty, firm to very firm	8	25
	Clay and boulders	7	33
	Sand, gravel and boulders	12	40
	Sand, fine	6	52
	Gabbro	5	58
30:	Test hole		
	Peat	15	0
	Clay, very soft, organic	29	15
	Loam, silty, fine sand, very soft	15	44
	Clay, organic, very soft	15	59
	Sand, loamy, soft	6	74
	Clay	48	80
	Clay, hard	6	128
31:	Test hole		
	Peat, muck, wood	15	0
	Sand, fine, soft	3	15
	Clay, soft	20	18
	Sand, fine, very firm to hard	29	38
32:	Test hole		
	Clay, loam	4	0
	Clay, silty	6	4
	Sand, very fine to silty loam	21	10
	Boulders and clay	3	31
	Gabbro	10	34

	Thickness (Feet)	Depth (Feet)
33: Test hole		
Clay, with silt	10	0
Clay	12	10
Sand, fine, very firm	8	22
Loam, silty, very firm	12	30
Clay	23	42
Clay, silty	20	65
Loam, silty, firm	30	85
Sand, fine, loamy, hard	8	105
Gabbro	6	113
34: Test hole		
Water	10	0
Muck	3	10
Loam	2	13
Sand	34	15
35: Test hole		
Water	21	0
Muck	2	21
Sand, fine, loamy	2	23
Sand, fine	2	25
Sand, with some gravel	2	27
Sand, fine	6	29
36: Test hole		
Fill: silty sand and sand	6	0
Sand, brown, fine to medium, dense to very dense, with varying gravel	37	6
Sand, brown, fine, with a little gravel, very dense	33	43
37: Test hole		
Sand, brown, medium, loamy	75	0
38: Test hole		
Sand, brown, with 20% o.m. and silt	8	0
Peat and muck	3	8
Sand, brown, medium, dense with trace of gravel	10	11
39: Test hole		
Water	27	0
Silt	1	27
Sand, well sorted	1	28

		Thickness (Feet)	Depth (Feet)
40:	Test hole		
	Water	7	0
	Silt and muck	4	7
	Sand, brown, fine	24	11
41:	Test hole		
	Water	26	0
	Silt, inorganic	2	26
	Sand, silty	1	28
42:	Test hole		
	Water	26	0
	Silt, sandy	2	26
	Sand, silty	1	28
43:	Test hole		
	Fill, cinders and wood	3	0
	Sand, fine to medium	12	3
	Sand, fine to coarse and fine to medium gravel	35	15
	Clay, brown, soft	17	50
	Sand, brown, very fine, dense	19	67
	Clay, brown, silty, soft	16	86
	Silt, brown, clayey, dense	32	102
	Clay, brown, very silty	25	134
	Sand, brown, very fine, dense	12	159
44:	Test hole		
	Fill: cinders, wood and trash	6	0
	Sand, fine to medium	13	6
	Sand, fine to coarse and fine to medium gravel	30	19
	Clay, red, soft to firm	47	49
	Sand, brown, very fine, dense	25	96
	Silt, brown, clayey, very dense	49	121
45:	Test hole		
	Fill: sand, cinders, and partially decayed wood	12	0
	Sand, fine to coarse	8	12
	Sand, fine to coarse and fine to medium gravel	33	20
	Clay, red, firm	24	53
	Sand, brown, very fine, dense	42	77
	Silt, brown, dense	52	119

		Thickness (Feet)	Depth (Feet)
46:	Test hole		
	Muck, wood, and sand	20	0
	Sand, fine to coarse, and fine to medium gravel	6	20
	Sand, fine to coarse	11	26
	Sand, fine to coarse and fine to coarse gravel	11	37
	Clay, red, soft	41	48
	Sand, brown, very fine, dense	42	89
	Silt, brown, very dense	61	131
	Clay, red, stiff	8	192
47:	Test hole		
	Water	14	0
	Silt, peaty	8	14
	Silt	7	22
48:	Test hole		
	Water	12	0
	Silt, peaty	5	12
	Peat	3	17
	Sand, silty	9	20
49:	Test hole		
	Water	14	0
	Muck	5	14
	Clay and silty loam, brown	6	19
	Sand, brown, medium with lenses of sandy loam and coarse sand and medium gravel at 30 ft. and 50 ft.	49	25
	Loam, brown fine sandy	2	74
50:	Test hole		
	Water	7	0
	Muck	9	7
	Loam, brown sandy, fine with sand lenses	3	16
	Loam, gray brown, silty, clayey	4	19
	Clay, brown, very soft	17	23
	Sand, brown, medium	13	40
	Sand, brown, fine	5	53
	Loam, brown, silty, with lenses of fine sand	5	58
	Sand, brown, fine	3	63

		Thickness (Feet)	Depth (Feet)
51:	Test hole		
	Water	8	0
	Muck	11	8
	Sand, brown, medium	5	19
	Clay, brown, soft	14	24
	Sand, brown, medium, with a little fine gravel	9	38
	Sandy loam, brown, very fine	4	47
52:	Test hole		
	Fill and muck	4	0
	Sand, brown, fine	5	4
	Muck, brown, silty	3	9
	Sand, brown, fine with wood at 15 ft.	7	12
	Silt, brown and silty clay with some wood	14	19
	Sand, brown, very fine	11	33
	Clay, red brown, rather soft	17	44
53:	Test hole		
	Clay, soft	14	0
	Sand, loamy, very fine	4	14
	Sand, fine, firm	6	18
	Sand, very fine, loamy, hard	49	24
	Clay, firm	29	73
	Loam, silty clayey	5	102
	Loam, fine sand, very fine sand, hard	56	107
	Sand, loamy, fine	27	163
54:	Test hole		
	Clay, soft	28	0
	Clay	7	28
	Sand, loamy, very fine, hard	10	35
	Clay	73	45
	Loam, silty clay, firm	4	118
	Loam, silty, hard	68	122
55:	Test hole		
	Water	28	0
	Clay, gray brown, with trace of o.m.	4	28
	Clay, brown, very soft	16	32
	Sand, brown, medium, with a little gravel and o.m.	9	48
	Clay, brown, with trace of o.m.	12	57
	Loam, brown, silty	2	69
	Sand, brown, fine, with lenses of silty loam and trace of decayed wood	5	71
	Loam, brown, fine sandy with trace of o.m.	10	76

		Thickness (Feet)	Depth (Feet)
56:	Test hole		
	Water	19	0
	Loam, dark brown, organic, very soft	20	19
	Clay, brown, very soft	10	39
	Loam, brown, sandy, coarse with some fine gravel	9	49
	Sand, brown, medium	15	58
	Loam, brown, silty	13	73
57:	Test hole		
	Water	6	0
	Mud and sand	7	6
	Sand and mud	22	13
58:	Test hole		
	Clay, soft	12	0
	Sand, fine	10	12
	Loam, silty	10	22
	Clay to silty clay	71	32
	Sand to fine sand	27	103
59:	Test hole		
	Sand and gravel	2	0
	Clay	10	2
	Sand, fine, firm	20	12
	Till, silty loam, soft	10	32
	Clay, soft	32	42
	Clay	25	74
	Loam, silty, clay	16	99
	Loam, silty, clayey, firm to hard	45	115
60:	Test hole		
	Fill	2	0
	Clay	5	2
	Clay, firm	8	7
	Loam, silty	14	15
	Clay, soft	33	29
	Clay	30	62
	Clay, firm	15	92
	Clay, silty, firm	18	107
	Loam, silty, clayey, hard	14	125
	Till, silty, loamy	6	139
61:	Test hole		
	Clay, red brown, rather stiff	6	0
	Sand, brown, fine grained	11	6
	Silt, brown, with layers of clay and sand	6	17
	Clay, red brown, very soft	31	23
	Clay, brown, with layers of gray clay, medium to rather stiff	20	54
	Clay, brown, with layers of silt, stiff	27	74

		Thickness (Feet)	Depth (Feet)
62:	Test hole		
	Fill	2	0
	Clay, red brown, rather stiff	8	12
	Sand, fine grain, with a little gravel dense	14	10
	Clay, red brown, stiff	4	24
	Clay, red brown, soft to medium and gray brown medium to rather stiff below 45 ft.	49	28
	Clay, brown, with silt lenses, rather stiff	26	77
63:	Test hole		
	Clay	12	0
	Sand, fine, firm	5	12
	Clay, very soft	21	17
	Clay, soft	17	38
	Clay	31	55
	Clay, firm	26	86
	Till, silty, loamy, very firm, hard	33	112
64:	Test hole		
	Clay	2	0
	Loam, sandy	3	2
	Sand and gravel, loamy	3	5
	Clay, soft	52	8
	Clay	20	60
	Clay, silty	17	80
	Till, very fine silty loamy, hard	37	97
65:	Test hole		
	Clay	39	0
	Clay, silty	11	39
	Till, fine sandy loamy, hard	5	50
	Sand, loamy, fine, hard	8	55
	Gabbro	12	63
66:	Test hole		
	Clay, sandy	4	0
	Loam, very finely sandy, firm	4	4
	Sand and gravel	4	8
	Gabbro	7	12

		Thickness (Feet)	Depth (Feet)
67:	Test hole		
	Fill	8	0
	Ash	4	8
	Clay, loam, red brown, with a little sand and gravel	4	12
	Sand, brown, silty with traces of decayed wood	11	16
	Loam, brown, silty	13	27
	Sand, brown, silty, very fine	7	40
	Clay, red brown, medium stiff	44	47
68:	Test hole		
	Fill: brown sand and gravel	3	0
	Loam, brown with loamy sand lenses and trace of wood	9	3
	Sand, brown, fine, with layers of silty loam	12	12
	Clay, red brown, soft	7	24
69:	Test hole		
	Wood	6	0
	Peat	3	6
	Sand, brown, medium, loamy	8	9
	Sand, brown, medium	10	17
	Loam, brown, silty	4	27
70:	Test hole		
	Peat, with some wood below water level	14	0
	Sand, brown, loamy, with wood chips	3	14
	Loam, brown, silty with some o.m. below 27'	14	17
71:	Test hole		
	Fill	3	0
	Sand, brown, loose	6	3
	Sand, gray, loose, with o.m.	8	9
	Sand, brown, fine, loose	8	17
	Sand, brown, fine, silty, loose	2	25
	Silt, gray, with trace of sand, loose	26	27
	Silt, gray, with trace of clay	10	53
	Clay, brown, silty, soft	39	63
	Sand, brown, with trace of silt	11	102
	Silt and sand layers alternating, brown, firm	2	113

		Thickness (Feet)	Depth (Feet)
72:	Test hole		
	Water	9	0
	Silt, inorganic	15	9
	Sand, silty	3	24
73:	Test hole		
	Wood	13	0
	Sand, brown, medium with a few lenses of loamy sand	18	13
74:	Test hole		
	Peat above 5 ft. and wood below	14	0
	Sand, brown, medium with trace of o.m.	13	14
	Loam, brown, silty	4	27
75:	Test hole		
	Water	4	0
	Peat, brown, fibrous, very soft	9	4
	Silt, gray, sandy, very loose	5	13
	Sand, gray, with trace of silt	9	18
	Sand, gray, alternating layers with silty, fine sand	5	27
	Silt, gray, with some fine sand seams	38	32
	Clay, brown, very soft	27	70
	Silt, gray, firm, with fine sandy layers	16	97
	Clay, brown, silty, stiff	6	113
	Silt, brown, firm, with alternating layers of silty fine sand	9	119
	Sand, brown, with trace of silt, firm	3	128
76:	Test hole		
	Water	14	0
	Muck, dark brown with peat and wood	6	14
	Muck, brown, silty with wood	13	20
	Sand, brown, medium	6	33
	Loam, brown, silty with trace of o.m.	9	39
	Sand, brown, well graded	9	48
	Loam, brown, silty with layers of silty clay and wood	13	57
	Sand, brown, fine loamy, with layers of sand and trace of wood	23	70
	Loam, brown, silty with lenses of fine sandy loam	13	93

		Thickness (Feet)	Depth (Feet)
77:	Test hole		
	Water	4	0
	Sand, silty	8	4
	Silt, inorganic	14	12
78:	Test hole		
	Water	4	0
	Silt, peaty	15	4
	Peat, silty	3	19
	Clay	1	22
	Silt	1	23
	Sand, well sorted	4	24
79:	Test hole		
	Water	15	0
	Sand and mud	20	15
80:	Test hole		
	Water	3	0
	Sand and mud	28	3
81:	Test hole		
	Slag	4	0
	Sand, brown, medium w/coal dust	6	4
	Peat and decayed wood	6	10
82:	Test hole		
	Water	3	0
	Sand	2	3
	Sand and mud	30	5
83:	Test hole		
	Water	6	0
	Silt, sandy to peaty	16	6
	Sand, well graded to silty	5	22
84:	Test hole		
	Water	5	0
	Peat	3	5
	Sand, well sorted to silty	18	8
85:	Water well		
	Sand	10	0
	Sand, dirty	26	10
	Silt	84	36
	Clay, red	65	120
	Hard pan	23	185
	Clay	12	208
	Hard pan	95	220
	Sand, muddy	15	315
	Sand	8	330

		Thickness (Feet)	Depth (Feet)
86:	Water well		
	Clay, red	160	0
	Clay, blue	140	160
	Hard pan red	105	300
	Sandstone, soft	5	405
	Sandstone, fine	375	410
87:	Water well		
	Clay	12	0
	Sand, dirty	18	12
	Silt or quicksand	128	30
	Clay, red	42	158
	Clay, blue	60	200
	Clay, red	50	260
	Hard pan	20	310
	Sand, muddy	14	330
	Sandstone	36	344
88:	Water well		
	Clay, red	17	0
	Sand, dry	15	17
	Silt	84	32
	Clay, red	179	116
	Hard pan	19	295
	Sandstone	20	314
89:	Water well		
	Clay, red	18	0
	Sand, dry	17	18
	Sand, quick	90	35
	Clay, red	129	125
	Hard pan	16	254
	Sandstone, soft	10	270
	Sandstone	38	280
90:	Test hole		
	Clay, red brown with thin inclusions of o.m. at 9 ft., rather stiff to stiff	23	0
	Clay, brown, silty, stiff	6	23
	Sand, brown, fine grained, very dense	4	29
	Silt, light brown, with lenses of sand, very dense	8	33

	Thickness (Feet)	Depth (Feet)
91: Test hole		
Sand, brown, fine, silty, firm	7	0
Sand, brown, fine, firm	7	7
Sand, brown, silty, firm, with clay seams	10	14
Silt and clay, firm	4	24
Sand, brown, fine, silty, dense	14	28
Silt, brown, with trace fine sand, firm	4	42
Silt, brown, fine sandy, dense	17	46
Silt, brown, firm, with trace fine sand	4	63
Silt, brown, sandy, dense	6	67
Sand, brown, fine, very dense	17	73
92: Test hole		
Water	4	0
Muck, brown with a little peat	8	9
Clay, brown, silty, soft	2	12
Sand, brown, medium	9	14
Loam, brown, silty with layers of fine sandy loam	53	23
93: Test hole		
Overburden	627	0
Sandstone	150	627
94: Test hole		
Clay, red brown, stiff	6	0
Sand, light brown, fine, loamy	5	6
Sand, light brown, fine	7	11
Clay loam, red brown, silty with lenses of silty sand	4	18
Sand, light brown, fine, loamy	6	22
Sand, light brown, fine loamy with lenses of silty and sandy loam	23	28
95: Test hole		
Clay, red, stiff	11	0
Sand, brown, fine, firm	3	11
Sand, brown, very fine with trace of silt, firm	20	14
Sand, gray, silty, with thin seams of red clay	2	34
Sand, brown, fine, with some silt	8	36
Silt, brown, with trace of sand, firm	8	44
Sand, brown, fine, silty, firm	4	52
Sand, brown, fine, silty, dense	4	56
Sand, gray, fine, silty, dense	6	4

		Thickness (Feet)	Depth (Feet)
96:	Test hole		
	Water	7	0
	Peat	2	7
	Sand, silty	15	9
	Silt, inorganic	2	24
97:	Test hole		
	Water	10	0
	Silt, inorganic	7	10
	Sand, silty	5	17
	Sand, well sorted	4	22
98:	Test hole		
	Water	5	0
	Silt, inorganic	8	5
	Sand, silty	14	13
99:	Test hole		
	Water	13	0
	Silt, organic	3	13
	Silt, inorganic, with cinders	2	16
	Clay	4	18
	Sand, silty	7	22
100:	Test hole		
	Fill: loam, brown with wood	5	0
	Loam, silty, brown with wood and sand lenses	19	5
	Sand, brown, fine	14	24
	Loam, brown, with fine sand and lenses of silty loam	33	38
101:	Test hole		
	Water	5	0
	Loam, brown, silty with peat at 15-20	25	5
	Sand, brown, medium to coarse with some gravel and wood	20	30
102:	Test hole		
	Muck, wood, and sand	3	0
	Sand, fine to coarse, with gravel	17	3
	Clay, red, soft	36	20
	Sand, brown, very fine, dense	26	56
	Silt, brown, clayey, dense	90	82

		Thickness (Feet)	Depth (Feet)
103:	Test hole		
	Muck, wood, sand	9	0
	Sand, fine to coarse with fine to coarse gravel	30	9
	Clay, red, firm	12	39
	Silt, brown, dense	129	51
	Clay, red, stiff	20	180
104:	Test hole		
	Water	21	0
	Silt, sandy	1	21
	Sand, silty	5	22
105:	Test hole		
	Water	26	0
	Sand, silty	3	26
106:	Test hole		
	Water	26	0
	Silt, inorganic	3	26
107:	Test hole		
	Fill: fine to coarse sand	10	0
	Muck, sand, decayed wood	13	10
	Sand, fine to coarse, with fine gravel	30	23
	Clay, red, soft	14	53
	Silt, brown, dense	53	67
108:	Test hole		
	Water	13	0
	Silt, peaty	3	13
	Silt, with cinders	2	16
	Clay, red, sandy	5	18
	Sand, silty	6	23
109:	Water well		
	Fill: cinders	3	0
	Gravel, sandy	4	3
	Clay, red, soft	40	7
	Clay, red, with a trace of gravel	53	47
	Clay, red, with fine sand with boulders at 135	35	100
	Clay, red, with occasional boulders	135	135
	Clay, red, with fine sand	15	270
	Clay, red	61	285
	Clay, red with fine sand	149	346
	Clay, red, with find sand, hard	32	495
	Gravel, very coarse, with small boulders	16	527
	Clay, red	7	543
	Rock	-	550

		Thickness (Feet)	Depth (Feet)
110:	Test hole		
	Clay, red brown	10	0
	Loam, with very fine sand	3	10
	Clay, red brown, medium	3	13
	Loam, brown, with very fine sand	45	16
111:	Test hole		
	Fill: sand, soft clay over peat	10	0
	Clay, brown, silty	22	10
	Clay, red brown, rather stiff	9	32
112:	Test hole		
	Slabs	6	0
	Clay, red, soft, with sand and layers of o.m. between 6 and 9 ft.	13	6
	Clay, red brown, with some wood and a layer of black clay at 20 ft.	9	19
	Clay, red brown, medium	4	28
	Loam, brown, silty, very dense	10	32
	Sand, brown, medium, loamy, very dense	6	42
	Loam, brown, silty, with lenses and layers of fine sandy loam and loamy sand	42	48
113:	Test hole		
	Clay, sand, and muck	21	0
	Clay, red, stiff	21	21
	Sand, brown, very fine, dense	42	42
	Silt, brown, sandy, very dense	15	84
114:	Test hole		
	Fill: broken concrete, cinders	4	0
	Fill: brown fine sand	4	4
	Clay, red, firm	29	8
	Sand, brown, very fine, dense	61	37
	Silt, brown, sandy, dense	53	98
115:	Test hole		
	Water	15	0
	Clay, red	11	15
	Sand, well sorted	4	26
116:	Test hole		
	Water	25	0
	Sand, clayey	3	25

		Thickness (Feet)	Depth (Feet)
117:	Test hole		
	Water	7	0
	Sand and mud	12	7
	Sand	17	19
	Sand and gravel	2	36
	Clay	2	38
118:	Test hole		
	Water	19	0
	Clay, red	10	19
119:	Test hole		
	Water	18	0
	Silt, sandy	2	18
	Clay, red	9	22
120:	Test hole		
	Fill: trash dump	9	0
	Clay, red, stiff	19	9
	Sand, brown, very fine, dense	62	28
	Silt, brown, sandy, dense	61	90
121:	Test hole		
	Fill: cinders, clay, broken concrete	4	0
	Clay, red, stiff	6	4
	Sand, brown, very fine, dense	25	10
	Silt, brown, clayey, dense	13	35
	Sand, brown, very fine, silty, dense	37	48
	Silt, brown, dense	25	85
122:	Water well		
	Clay, red and hard pan	75	0
	Hard pan, sandy	75	75
	Hard pan	50	150
	Hard pan with large boulders	150	200
	Brownstone	261	350
123:	Water well		
	Clay, red	25	0
	Silt, sandy	43	27
	Clay, red	35	70
	Silt	25	105
	Clay, red	25	130
	Silt, dirty, sandy	32	155
	Hard pan and small rocks	82	187
	Sandstone	331	269

		Thickness (Feet)	Depth (Feet)
124:	Test hole		
	Sand, red, fine to medium, very wore	4	0
	Clay, red, stiff	26	4
125:	Test hole		
	Fill: lower 3 ft. wood	10	0
	Sand, brown, fine	25	10
	Clay, red	15	35
	Loam, brown, silty, with lenses of sandy loam	30	50
126:	Test hole		
	Water	8	0
	Sand and mud	11	8
	Sand	13	19
	Sand and gravel	1	32
	Clay	7	33
127:	Test hole		
	Water	9	0
	Sand and mud	22	9
	Sand, gravel, and small boulders	3	31
	Clay	6	34
128:	Test hole		
	Clay, red, with trace of fine gravel	46	0
	Silt, brown, with some fine sand	5	46
129:	Test hole		
	Fill: black silty sand and clay	4	0
	Clay, red brown, with few laminations of brown silt	16	4
	Silt, brown, with sand lenses, very dense	4	20
	Sand, brown, silty, very dense	4	24
	Sand, brown, very fine	5	28
	Sand, brown, very fine, very dense	28	33
130:	Test hole		
	Cinders and clay	3	0
	Peat	6	3
	Clay, red, water soaked	12	9

		Thickness (Feet)	Depth (Feet)
131:	Test hole		
	Topsoil: lean clay with black and dark brown color	2	0
	Clay, red brown, stiff	37	2
	Sand, brown, silty, very dense	5	39
	Silt, tan and light brown, with lenses of clay, very dense	7	44
132:	Test hole		
	Water	16	0
	Sand and mud	14	16
	Gravel and boulders packed solid	0	30
133:	Test hole		
	Water	22	0
	Sand and gravel with one 12" and one 2' x 18" x 3" boulder	5	27
134:	Test hole		
	Water	22	0
	Mud and fine sand	6	22
	Gravel, fine	2	28
	Gravel, coarse and small boulders	5	30
	Sand	5	35
135:	Test hole		
	Water	8	0
	Sand and mud	21	8
	Sand and gravel	2	29
	Gravel, coarse	2	31
	Gravel	7	33
136:	Test hole		
	Water	9	0
	Sand and mud	21	9
	Sand and gravel	3	30
	Gravel, coarse	3	33
137:	Water well		
	Sand, coarse with a little fine gravel	30	0
	Sand, medium with a little fine gravel	5	30
	Sand, coarse, with a little fine gravel	5	35
	Gravel, very fine and medium sand	10	40
	Clay, red	-	50
138:	Test hole		
	Water	21	0
	Silt, inorganic	9	21

		Thickness (Feet)	Depth (Feet)
139:	Test hole		
	Water	7	0
	Sand and mud	29	7
	Sand and gravel	3	36
	Clay	0	36
140:	Test hole		
	Water	26	0
	Silt, sandy	3	26
141:	Water well		
	Fill	10	0
	Sand, dirty	17	10
	Clay, red	21	27
	Sand, dirty	15	48
	Sand, clean, fine	11	63
	Sand, clean	4	74
	Sand, clean, coarse	8	70
142:	Test hole		
	Sand and gravel, loose	3	0
	Clay, red, soft	3	3
	Clay, red,stiff	5	6
	Clay, red, medium	31	11
	Clay, red, stiff, with trace of gravel	25	42
	Clay, red, stiff with silt seams	2	67
	Sand, brown, fine, dense	11	69
143:	Test hole		
	Topsoil	1	0
	Clay, red, stiff	7	1
	Clay, red, medium	32	8
	Silt, dense, brown	4	40
	Sand, silt, clay, gravel mix, brown very dense	20	44
144:	Test hole		
	Topsoil, black	1	0
	Clay, red, medium	2	1
	Clay, red, stiff	20	3
	Clay, red, medium	17	23
145:	Water well		
	Clay, red	150	0
	Hard pan and boulders	110	150
	Sandstone	15	260

		Thickness (Feet)	Depth (Feet)
146:	Test hole		
	Clay, red brown, medium to stiff	50	0
	Clay, red, with silt lenses, sand layer 53-54, rather stiff clay	65	50
	Sand, red brown, silty with a little gravel	10	115
147:	Water well		
	Clay, red	85	0
	Sand, dirty	17	85
	Gravel	6	102
148:	Test hole		
	Peat	2	0
	Clay, red brown, soft to medium	38	2
	Clay, red brown, stiff	8	40
	Clay, brown and gray, soft	17	48
	Clay, brown and gray, stiff	10	65
	Clay, brown, with some gravel	16	75
149:	Test hole		
	Water	25	0
	Sand and mud	15	25
150:	Test hole		
	Water	25	0
	Silt, inorganic	3	25
	Sand, silty	2	28
151:	Test hole		
	Water	20	0
	Silt, inorganic	3	20
	Peat, sandy	5	23
	Sand	12	28
	Sand, gravelly	3	40
	Sand, w/wood fragments	10	43
	Clay	4	53
152:	Test hole		
	Water	22	0
	Sand	12	22
	Sand and gravel	14	34
	Gravel, coarse	3	48
	Clay	10	51

		Thickness (Feet)	Depth (Feet)
153:	Test hole		
	Water	25	0
	Sand	22	25
	Sand and gravel	6	47
	Clay	9	53
154:	Test hole		
	Water	26	0
	Clay, sandy toward bottom	4	26
155:	Test hole		
	Fill	6	0
	Clay, brown, organic, with wood	10	6
	Sand, brown, fine	24	16
	Clay, dark gray, rather stiff	3	40
	Clay, red brown, medium	14	43
	Loam, brown, clayey, with lenses of sandy loam, very stiff	10	57
	Clay, red brown and gray, rather stiff	33	67
156:	Test hole		
	Clay, red brown	53	0
	Loam, brown with lenses of silty loam and sand	18	53
157:	Test hole		
	Water	20	0
	Silt, inorganic	7	20
	Sand, silty	2	27
158:	Water well		
	Overburden	125	0
	Sandstone	175	125
159:	Test hole		
	Clay, red brown w/inclusions of gray clay below 42 feet	90	0
160:	Test hole		
	Water	5	0
	Silt, dark	3	5
	Sand	20	8
	Clay, red	5	28
161:	Test hole		
	Clay, red brown	45	0

		Thickness (Feet)	Depth (Feet)
162:	Water well		
	Old well	140	0
	Hard pan	32	140
	Sandstone	6	172
163:	Water well		
	Clay, red	135	0
	Hard pan	40	135
	Gravel	4	175
164:	Water well		
	Clay, red	20	0
	Sand and gravel	20	20
	Clay and silt	110	40
	Clay, red	140	150
	Hard pan	10	290
	Gravel	5	300
165:	Water well		
	Clay, red	130	0
	Hard pan	46	130
	Sand, muddy	9	176
	Hard pan	91	185
	Sandstone	34	276
166:	Water well		
	Clay	100	0
	Hard pan	20	100
	Sand	3	120
167:	Water well		
	Clay, red	40	0
	Clay, blue	20	40
	Clay, red	40	60
	Hard pan and boulders	67	100
	Sandstone	49	167
168:	Water well		
	Clay, red	120	0
	Hard pan	100	120
	Sandstone	20	220
169:	Water well		
	Clay, red	140	0
	Hard pan	24	140
	Sandstone	71	164

		Thickness (Feet)	Depth (Feet)
170:	Water well		
	Soil	3	0
	Clay	152	3
	Clay and rotten sandstone	21	155
	Sandstone	174	176
171:	Water well		
	Clay, red	95	0
	Clay, blue	15	95
	Clay, red	65	110
	Sandstone, loose	8	175
	Sandstone	37	183
172:	Test hole		
	Sand, red, silty, loose	6	0
	Clay, red, soft	16	6
	Clay, red and gray, with trace of silt	6	22
173:	Water well		
	Clay	165	0
	Hard pan	20	165
	Sandstone	15	185
174:	Water well		
	Clay	80	0
	Clay, blue	15	80
	Clay, red	60	95
	Hard pan and loose sandstone	15	155
	Sandstone	65	170
175:	Water well		
	Clay, red	135	0
	Hard pan	65	135
	Sandstone	31	200
176:	Water well		
	Clay, red	120	0
	Hard pan	18	120
	Sandstone	5	138
177:	Water well		
	Clay, red	120	0
	Hard pan, sandy	28	120
	Sandstone, soft	34	148
	Sandstone, red	43	182

		Thickness (Feet)	Depth (Feet)
178:	Water well		
	Clay	135	0
	Hard pan	20	135
	Sandstone	-	155
179:	Water well		
	Clay, red	80	0
	Hard pan and boulders	55	80
	Water gravel	4	135
180:	Water well		
	Fill	4	0
	Clay, red	50	4
	Sand, red, quick	11	54
	Clay, red	70	65
	Clay, red and stones	20	135
	Sand rock	125	155
	Shale, sandy	5	280
	Sand rock	10	285
	Shale	10	295
	Sand rock	120	305
	Shale, red sandy	25	425
	Sand rock	45	450
	Sand rock, hard	80	495
181:	Water well		
	Clay, red	97	0
	Clay, blue	23	97
	Clay, red	27	120
	Hard pan	23	147
	Sandstone, soft	8	170
	Sandstone	322	178
182:	Water well		
	Clay, red	167	0
	Hard pan	15	167
	Sandstone, soft	5	182
	Sandstone, firm	15	187
183:	Water well		
	Clay, red	80	0
	Clay, blue	8	80
	Clay, red	17	88
	Hard pan	43	105
	Sand, dirty	21	148
	Sand, clean	4	169
	Gravel	2	173

		Thickness (Feet)	Depth (Feet)
184:	Water well		
	Clay, red	232	0
	Hard pan	47	232
	Sandstone	51	279
185:	Water well		
	Clay, red	140	0
	Hard pan, red	105	140
	Sandstone	20	245
186:	Water well		
	Clay, red	80	0
	Clay, blue	25	80
	Clay, red	30	105
	Hard pan	17	135
	Gravel	2	152
187:	Water well		
	Clay, red	19	0
	Sand and gravel	18	19
	Clay, blue	15	38
	Clay, red	37	53
	Clay, blue	22	90
	Clay, red	106	112
	Clay, green, gummy	17	218
	Hard pan	18	235
	Gravel, clean	8	253
	Sand, clean	13	258
188:	Water well		
	Clay	180	0
	Hard pan	85	180
	Sandstone	5	265
189:	Water well		
	Clay	125	0
	Hard pan	20	125
	Sand	3	145
190:	Water well		
	Clay, red	118	0
	Hard pan, red	57	118
	Sandstone	16	175

		Thickness (Feet)	Depth (Feet)
191:	Test hole		
	Fill	7	0
	Sand, medium to coarse with trace of gravel	5	7
	Silt, red, sandy, loose	10	12
	Sand, firm brown	5	22
	Clay, brown, silty, with some wood	40	27
	Sand, brown, silty, with gravel, firm	5	67
	Clay, brown, soft	5	77
192:	Water well		
	Clay, red	65	0
	Clay, blue	20	65
	Clay, red	20	85
	Hard pan	25	105
	Gravel, dirty	4	130
	Sandstone, loose	3	134
	Sandstone	7	137
193:	Water well		
	Clay, red	150	0
	Hard pan and rotten sandstone	25	150
	Sandstone	30	175
194:	Water well		
	Clay, red	115	0
	Hard pan, red	8	115
	Sandstone, soft	7	123
	Sandstone, fine	50	130
195:	Water well		
	Clay, red	60	0
	Clay, blue	30	60
	Clay, red	15	90
	Hard pan	52	105
	Sandstone	43	157
196:	Water well		
	Clay, red	80	0
	Hard pan, red	36	80
	Sandstone	55	116
197:	Water well		
	Clay, red	150	0
	Sand, muddy	29	150
	Clay	71	179
	Hard pan	43	250
	Sandstone	27	293

		Thickness (Feet)	Depth (Feet)
198:	Water well		
	Clay	84	0
	Hard pan	67	84
	Sandstone	45	151
199:	Water well		
	Clay, red	130	0
	Hard pan	11	130
	Sandstone	20	141
200:	Test hole		
	Clay, red, stiff w/trace of gravel	10	0
	Clay, red, medium	4	10
	Clay, red and gray, stiff	8	14
	Clay, red and gray, with silt seams	6	22
201:	Water well		
	Clay, red	50	0
	Clay, blue	10	50
	Clay, red	15	60
	Hard pan	53	85
	Sandstone	62	138
202:	Water well		
	Clay	84	0
	Hard pan	55	84
	Sandstone	-	139
203:	Water well		
	Clay, red	123	0
	Sandstone	57	123
204:	Water well		
	Clay, red	96	0
	Hard pan red	20	96
	Sandstone	42	116
205:	Water well		
	Clay, red	85	0
	Clay, blue	15	85
	Clay, red	35	100
	Hard pan	18	135
	Sandstone, rotten	10	153
	Sandstone	37	163

		Thickness (Feet)	Depth (Feet)
206:	Water well		
	Clay, red	81	0
	Clay, blue	7	81
	Clay, red	14	88
	Hard pan	30	102
	Sandstone, rotten	6	132
	Sandstone	9	138
207:	Water well		
	Clay, red	105	0
	Clay, blue	10	105
	Clay, red	30	115
	Hard pan	65	145
	Clay, sandy	22	210
	Sandstone, rotten	26	232
	Sandstone, clean, hard	18	258
208:	Water well		
	Clay	90	0
	Hard pan	40	90
	Sandstone	-	130
209:	Water well		
	Clay	105	0
	Hard pan	49	105
	Sandstone	47	154
210:	Test hole		
	Clay, red, very stiff	9	0
	Clay, red and gray, stiff	19	9
	Silt, clayey, very stiff	7	28
	Clay, red and gray, stiff	8	35
	Silt, gray, firm	10	43
	Clay, red and gray, stiff	10	53
	Silt, gray, firm	9	63
211:	Test hole		
	Clay loam and sandy loam with some gravel and lenses of water-bearing sand directly over bedrock (gabbro)	9	0

APPENDIX D

Boulders Recovered From Cloquet Water Line Trench
Superior Bay, 1968

Zenith Dredge Company

Coordinates	Measured Rocks (ft.)		
27 + 25 to 27 + 50	3 x 3 x 3 3 x 3 x 2.5 2.5 x 3 x 2.5 3.5 x 2.5 x 2	4.5 x 2.5 x 3 5 x 2.5 x 2 1 x 3.5 x 3 3 x 3 x 2	2.5 x 2 x 3 4.5 x 2 x 3
25 + 75 to 26 + 00	3.5 x 2 x 2 5 x 3.5 x 3	4 x 3 x 2 3 x 2 x 2	
23 + 50 to 23 + 75	5.5 x 4 x 3 4.5 x 3 x 2	4 x 3.5 x 3.5 3 x 3.5 x 2	3 x 3 x 1.5
18 + 00 to 17 + 41	3.5 x 2 x 2 4 x 3 x 2 3.5 x 2 x 2.5 2.5 x 2.5 x 2 3 x 3 x 1.5	6 x 5 x 7 4 x 3.5 x 2 3 x 3.5 x 2.5 3 x 3 x 4	4 x 3 x 2 2.5 x 2.5 x 1 2.5 x 2.5 x 1 3 x 3 x 2

Data from Job 6802, work sheets from derrick boat "Adele" courtesy of Mr. Keith Yetter, Zenith Dredge Company. Disposal in 21st Avenue West Slip, Duluth. No lithologic identification beyond "crystalline;" probably mainly diabasic and gabbroic material from North Shore together with granitic and gneissic rocks from more northerly parts of Canadian Shield.

APPENDIX E.

Sandy Sediment Grain Size Parameters

All data reported are for samples collected for the Superior Area study and analyzed in the Geology Department of the University of Wisconsin-Superior. Weight percentages of gravel, coarse sand, medium sand, fine sand and very fine sand and mud for each sample are reported. The following conventions were used:

Gravel - Gv - material retained on # 10 sieve
Coarse Sand - CS - material retained on # 35 sieve
Medium Sand - MS - material retained on # 60 sieve
Fine Sand - FS - Material retained on # 120 sieve
Very Fine Sand and Mud - VFS and Mud - material passing # 120 sieve and retained in the pan.

Bank Sands Below Red Clay II

Sample Locality	Gv % (WT.)	CS %	MS %	FS %	VFS Mud %
38	0.12	1.95	35.34	56.09	43.91
41	0.22	2.82	8.72	21.27	66.93
42a	0.0	2.09	7.67	39.75	50.52
42b	5.40	31.80	29.31	29.62	3.91
45	0.0	0.0	1.14	58.04	40.83
46a	0.0	0.09	2.36	44.40	53.15
47a	0.0	1.02	2.15	15.02	81.80
47b	0.0	0.71	31.59	63.98	3.72
48	0.06	22.91	62.90	11.81	2.32
50a	0.0	0.02	0.23	6.08	93.70
51a	0.0	0.59	3.19	35.80	60.41
51b	26.38	39.06	27.13	6.86	0.55
54	2.42	15.21	39.11	36.59	6.66
55	—	—	—	—	100.00
56					
57					
69	0.89	3.43	28.13	49.39	18.16

Dredge Spoil Banks

Sample Locality	Gv % (WT.)	CS %	MS %	FS %	VFS Mud %
18	7.64	31.40	36.28	22.59	2.09
29 a.	0.27	16.63	62.41	20.23	0.45
29 b.	0.00	4.70	61.96	32.48	0.86
32	6.74	34.92	42.67	14.75	0.92
33 a	3.99	22.06	33.71	37.79	2.46
33 b	10.98	19.96	26.66	38.94	3.46
36	0.19	3.19	33.43	60.55	2.62
37	0.36	5.18	37.71	53.31	3.40
Clure a	0.00	0.55	25.57	65.08	8.80
clure b	0.06	0.12	4.13	55.62	40.08
clure c	0.00	0.14	0.20	21.27	78.39
46 a	0.00	3.09	49.00	45.13	2.77
46 b	0.85	18.85	41.27	22.90	16.14
46 c	1.36	29.55	38.98	19.67	10.43

Minnesota Point

Sample Locality	Gv % (wt.)	CS %	MS %	FS %	VFS Mud %
Lake Beach					
1	0.19	39.77	37.10	22.81	0.11
2	1.37	30.18	57.13	11.27	0.03
5	1.90	10.37	49.44	38.16	0.12
6	0.00	9.37	75.99	14.60	0.03
10	0.96	84.61	14.25	0.09	0.09
11	0.00	17.46	74.81	7.34	0.38
12	0.00	21.21	66.48	12.27	0.03
15	0.00	30.94	68.09	0.83	0.16
Dune					
1	0.00	0.04	12.21	83.68	4.07
2	0.00	1.48	32.26	64.81	0.44
Bay Beach					
3	0.00	0.48	6.88	92.11	0.53
7	0.29	10.06	77.09	12.12	0.43
9	0.00	52.29	46.37	0.80	0.52
12	0.31	47.14	52.33	0.14	0.80
13	1.14	20.77	67.34	10.54	0.19
14	0.47	15.10	60.75	22.94	0.74

Wisconsin Point

Sample Locality	Gv % (wt.)	CS %	MS %	FS %	VFS Mud %
		Lake Beach			
16	0.00	0.27	91.51	8.16	0.04
17	2.96	24.07	44.34	28.33	0.30
19	0.00	31.24	60.15	8.47	0.12
21	0.09	8.21	76.60	14.93	0.18
23	0.25	16.29	82.03	1.38	0.05
25	0.00	59.19	34.83	4.78	0.20
26	0.52	15.34	81.08	2.87	0.18
27	3.51	13.94	75.41	7.07	0.06
		Dune			
21	0.0	7.56	75.05	16.71	0.67
23	0.0	19.69	74.67	5.57	0.07
25	0.0	0.15	59.63	39.90	0.30
		Bay Beach			
18	0.05	0.59	68.49	30.65	0.22
20	0.00	9.14	84.52	6.25	0.08
22	0.00	4.37	93.70	1.80	0.13
25	0.00	25.69	72.11	2.20	0.03
		Bay Beach Black Sand			
18	0.00	0.45	4.64	73.76	21.15
20	0.00	1.02	14.01	84.84	0.13
22	0.00	0.05	37.72	62.71	0.02
24	0.00	0.05	3.14	92.54	0.27

Sample Locality	GV % (wt)	CS %	MS %	FS %	VFS Mud %
Westerly Superior Bay Beaches					
31	0.00	0.00	10.77	87.84	1.39
32	10.33	41.46	44.83	3.29	0.09
34	0.00	24.10	70.77	4.99	0.15
35	0.00	0.30	21.39	77.01	1.30
37	3.74	66.66	23.48	5.99	0.13
St. Louis Bay, North Shore					
Near Well 30	2.50	13.36	49.65	33.83	0.66
St. Louis River Beaches					
43	0.00	0.59	45.25	50.34	3.83
45	0.00	6.52	46.62	44.82	2.04
48	0.03	21.27	50.07	20.76	6.87
49	0.00	0.58	52.24	43.86	3.22
51	0.01	12.76	58.94	24.51	3.78
River and Creek Sands					
63	5.21	20.08	53.02	20.49	1.18
65a	0.00	15.68	78.68	5.33	0.34
65b.	0.00	1.14	81.85	16.14	0.95
66a.	0.00	0.76	58.62	39.63	0.99
66b.	2.67	72.94	22.33	1.45	0.61
70	0.31	61.72	35.15	2.56	0.45

of sand and gravel particles will weaken concrete and therefore sand and gravel produced for aggregate are usually washed before use. The sands of the Bay bottoms, the St Louis River and the valley of the Nemadji contain little undeserable rock or mineral matter and are of suitable quality for high grade uses, however exploitation of these resources on a large scale tends to alter the dynamic equilibrium of the environment from which they come and may cause other costs. At present most of the aggregate used in the Superior area comes from the crest of the Duluth escarpment both in that city and in the communities to the west. Gravel pits currently (1973) in use by the Wisconsin Highway Department are located to the south of Superior above the 900 or 1000 foot elevation above the clay plain surface where glacial drift or outwash deposits are present over much of Douglas County. Pits currently being used or available for use are as follows:

R12W

NE SE 32-49N-12W	Base course aggregate
NE NE 13-48N-12W	Subbase aggregate
NW SW 20-48N-12W	Gravel aggregate
SW SE 24-48N-12W	Base course aggregate
NW NW 25-48N-12W	Base course gravel
NW NE 32-48N-12W	Base course aggregate
NW SE 6-47N-12W	Gravel aggregate

R13W

SE NW 33-49N-13W	Subbase select borrow (Sample locality 29)
SW SE 34-48N-13W	Base course gravel
NE NE 1-47N-13W	Crushed gabbro aggregate
W 1/2 9-47N-13W	Gravel aggregate

R14W

NW NW 9-47N-14W	Gravel aggregate
NW NW 13-47N-14W	Base course aggregate
SW SW 7-46N-14W	Gravel aggregate
NE NW 28-47N-14W	Subbase aggregate

R15W

SESE 1-48N-15W	Subbase aggregate
7-8-48N-15W	Gravel
SE-9-48N-15W	Bituminous gravel
NE NE 29-47N-15W	Subbase aggregate

Supplied courtesy of The Wisconsin Highway Department, Superior.

Sand and Gravel

Sand and gravel are used primarily in construction as a fill material and as aggregate for mixture with portland cement to produce concrete, or with asphalt to produce bituminous paving. Specifications for fill are the least stringent and generally sand and gravel are of acceptable quality for fill as they are mined. However, fill with stones larger than three inches in diameter is unacceptable for some uses such as for highway construction and oversized material must be crushed before it is acceptable. In the Superior area there is no gravel which is coarse enough to require crushing except on the Minnesota side of the St Louis River and along the crest of the Duluth escarpment where glacial drift and outwash frequently contains very coarse particles.

Sand and gravel used as aggregate in bituminous paving or in portland cement is usually sorted according to size at or near the excavation site. Material greater than a quarter of an inch in diameter is classed as gravel and that less than a quarter inch but greater than .0006 inch is sand. Clay and silt adhering to the surfaces