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DEPARTMENT OF ENERGY AND MINES
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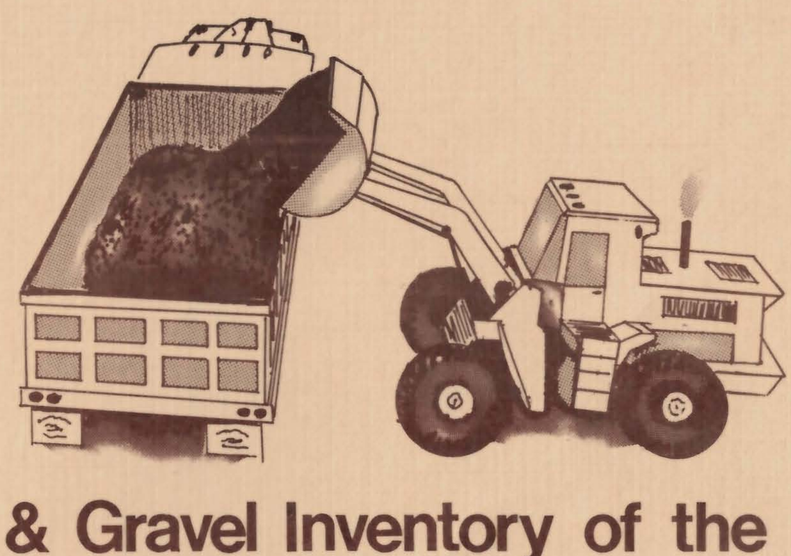
OF 81 - 2



Sand & Gravel Inventory of the Westlake Area

WGW western ground-water consultants

CONSULTING ENGINEERS AND GEOLOGISTS

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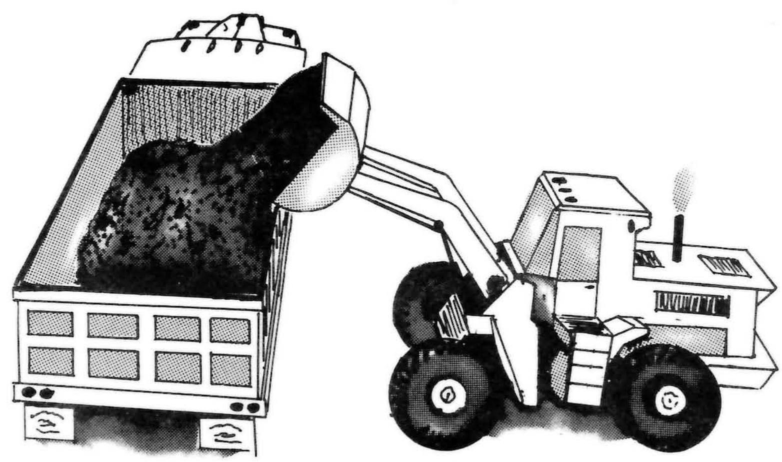

Sand & Gravel Inventory of the
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CONSULTING ENGINEERS AND GEOLOGISTS

October 21, 1981

Mr. W. A. Bardswich
Director, Mines Branch
Department of Energy and Mines
Mineral Resources Division
989 Century Street
Winnipeg, Manitoba
R3H 0W4

Dear Sir:

Re: Sand and Gravel Inventory of the Westlake Area

We are pleased to submit our report on the Sand and Gravel Inventory of the Westlake Area of Manitoba.

The submission consists of a written report complimented by seven detailed maps of the surficial geology and sand and gravel deposits of the area.

Also included is a folio of township air photo mosaics which delineate the individual sand and gravel deposits as well as bound copies of the field and laboratory inventory forms which present the quality and quantity data for each deposit.

We trust that this report will assist in the planning and management of these resources and that it will contribute to an understanding of both the local and regional Quaternary geology.

We would like to thank you for the opportunity to have worked on this project.

Respectfully submitted,

WESTERN GROUND-WATER CONSULTANTS LTD.

R. D. Sinclair, P. Eng.
Geological Engineer

J. P. Phimister, P. Eng.
Geologist

SUMMARY

An inventory of the sand and gravel resources of the Westlake Area of Manitoba has been carried out. The purpose of this study was to evaluate the quality and quantity of the granular resources in the region for both short and long-term resource planning. The major components of the inventory were the mapping of the Quaternary geology, the field sampling of granular deposits , the laboratory analysis of field samples for grain size distribution and the compilation of all other data and information.

The results of the study have been incorporated into a formal written report and a folio of maps for public distribution. Further back-up data supplied for the internal use of the Aggregate Resources Division include air photo mosaics which delineate the areal extent of the granular deposits, the field mapping data and the granular samples.

The sand and gravel resources are found in two main geologic formations, namely glaciolacustrine beach ridges and ice-contact deposits. The beach ridges are the most extensive of the deposits and contain 60% of the available sand and gravel reserves with the remainder associated with ice-contact deposits near Glenella and Tenby. The sand and gravel reserves for each municipality is presented in Table A.

The laboratory analyses demonstrated that the sand and gravel deposits were applicable to the lower grade requirements for Asphalt, Base Coarse, Traffic Gravel, Coarse Aggregate and Fine Concrete Aggregate. The stone content of the sand and gravel is predominently comprised of granitics and carbonates with very minor amounts of shale.

TABLE A

Sand and Gravel Reserves of the
Westlake Area, Manitoba

Municipality	Cubic Meters
North Norfolk	1,410,000
Lansdowne	35,419,000
Westbourne	1,409,000
Lakeview	4,267,000
Glenella	87,905,000
TOTAL	130,410,000

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SAND AND GRAVEL INVENTORY OF THE WESTLAKE AREA

1.0 INTRODUCTION

1.1 Objective

On August 19, 1980, Western Ground-Water Consultants Ltd. was contracted by the Mineral Resources Division of the Manitoba Department of Energy and Mines to conduct a sand and gravel inventory of the Westlake Area. The objective of this inventory was to determine the quantity, quality and areal distribution of the sand and gravel resources in the study area.

1.2 Scope

The scope of this study included two main components, firstly the quantitative and qualitative delineation of sand and gravel resources, and secondly; a Quaternary geological mapping program. The Quaternary mapping component complimented the major objective, the granular inventory, by providing a framework for evaluating the origin or genesis of the granular deposits.

The inventory and mapping components were divided into three distinct phases:

<u>Phase I</u> A compilation of all pertinent data and original aerial photograph interpretation

<u>Phase II</u> Geological field mapping, field sampling and laboratory analysis of granular deposits

Phase III Preparation of geological maps and report

The terms of reference for each of these phases are summarized below:

Phase I (a) the compilation of all pertinent geological information

(b) original aerial photograph interpretation at a scale of 1:50,000 or larger, in order to delineate all and gravel deposits, including both existing pit areas and previously unworked deposits as well as all other Quaternary geologic features

Phase II (a) field investigation to accurately delineate all sand and gravel deposits and Quaternary geology map units

(b) determination of granular deposit thicknesses by measurement of working pit faces by power auger boreholes, backhoe pits and by electrical resistivity profiles for estimated thicknesses greater than 5 m.

(c) the collection of a representative channel sample of each working pit face and backhoe pit. The completion of the appropriate Mineral Resources Division data forms for each deposit

(d) analysis of all sand and gravel samples using prescribed Mineral Resources Division forms for computer compilation of both the quantity and quality of each deposit

Phase III (a) the preparation of geological maps at a scale of 1:50,000 identifying all Quaternary deposits. Each granular deposit will be assigned a unique number and will clearly indicate the quality of each deposit, whether high, medium or low

(b) the final report will contain a brief discussion of the Quaternary history and stratigraphy, illustrated by the appropriate maps and cross-sections

(c) the text will summarize in tabular form, the quality, quantity and ownership of each sand and gravel deposit by municipality

(d) all samples, data forms and aerial photographs will be submitted to the Mineral Resources Division on completion of the study

(e) the submission to the Mineral Resources Division, of 100, appropriately bound reports complete with maps.

1.3 Location of Study Area

The Westlake Area, as shown in Figure 1, is located in south-central Manitoba, west of Lake Manitoba between longitudes $90^{o}30'$ and $99^{o}30'$ and latitudes $49^{o}50'$ and $50^{o}40'$. The study area encompasses a total area of 4200 km^2 (1600 mi^2) between Ranges 9 and 14 West and Townships 10 to 19. This area includes the municipalities of Glenella, Lakeview, Lansdowne, North Norfolk and Westbourne. The major towns include Gladstone, MacGregor, Austin and Plumas with populations ranging from approximately 1100 to 400 respectively. The main transportation routes through the area include the Trans-Canada Highway and Provincial Trunk Highways 4, 34 and 50.

Location Map

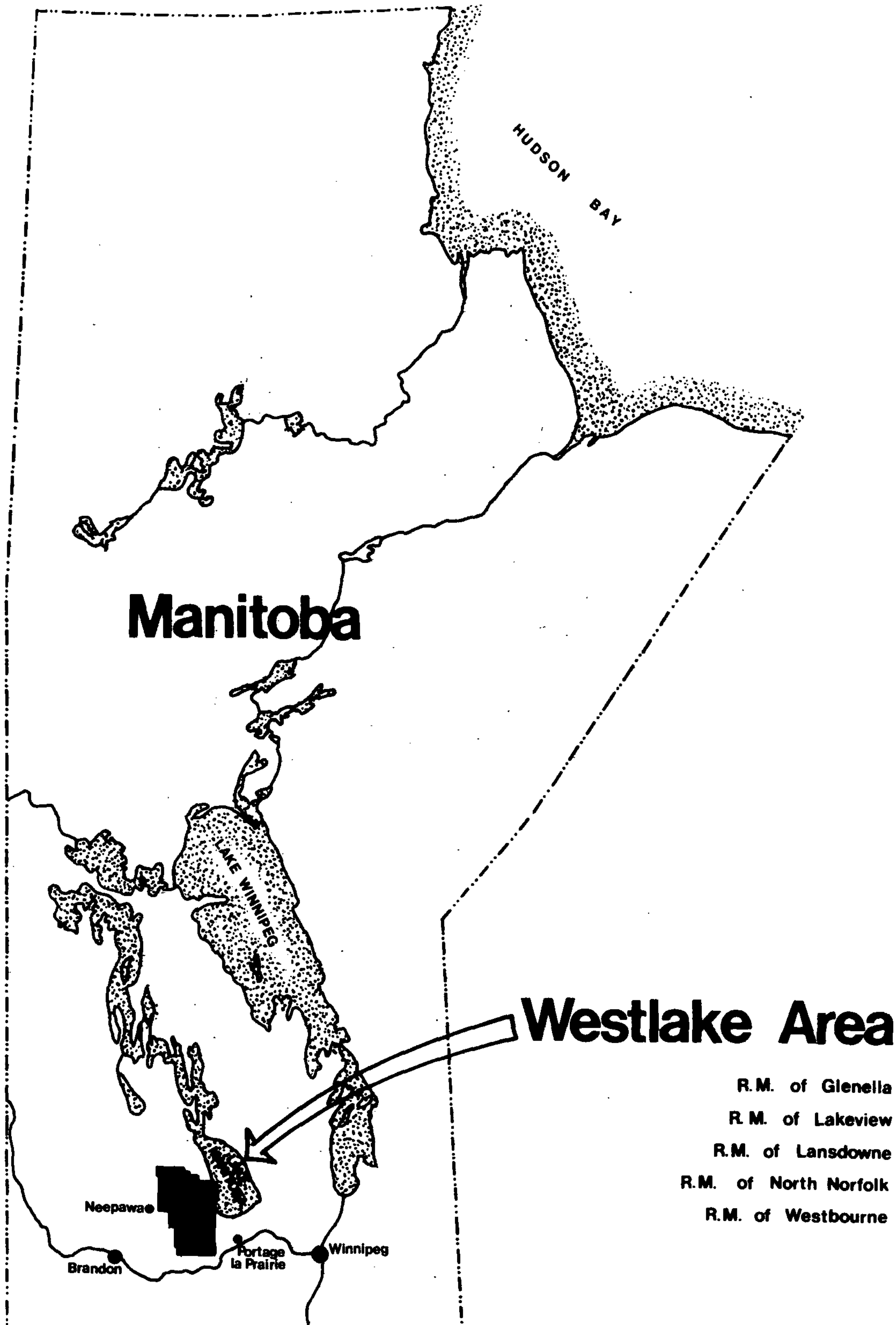


Figure 1: Location Map of the Westlake Area

1.4 Acknowledgements

The Western Ground-Water Consultants Ltd. Study Team consisted of:

R. D. Sinclair

P. E. Lohrenz

J. P. Phimister

Western Ground-Water Consultants Ltd. would like to thank Dr. Erik Nielsen and Mr. Robert Young of the Mineral Resources Division for their assistance during all phases of the study. Their helpfulness on field excursions and knowledge of the regional geology aided in the development of the local Quaternary geology. Thanks is also extended to Mr. Gaywood Matile, also of the Mineral Resources Division, for his aid in defining the field sampling and laboratory analytical techniques prescribed for this study.

The assistance of and information from local gravel pit operators, municipal and provincial roadway maintenance personnel, concrete contractors and well drillers was also greatly appreciated.

2.0 PHYSIOGRAPHY

The Westlake area, as shown in Figure 2, has been sub-divided into 4 main physiographic regions, namely the Lowlands, Sub-Escarpment, Escarpment and Uplands, (after Jenkins et al, 1974). Each of these physiographic regions has a number of unique physical characteristics, namely geology, geomorphology and topography, which, in conjunction with similar climatic conditions, has evolved similar soil types and drainage patterns. These factors are discussed for each of the 4 physiographic subdivisions.

2.1 Lowland Region

The Lowland Region, as shown on Figure 2, forms a continuous unit along the edge of Lake Manitoba. Along the east side of this unit, the surficial geology is predominantly clayey till while lacustrine clay predominates along the western edge. The clay was deposited on top of the till in a broad, north-south depression in the till surface. The topography of the Westlake area (Figure 3) shows this depression as a series of bogs and lakes that make up the Big Grass Marsh. Over most of this lowland area, the topography is relatively flat and the resulting drainage is poor. The till surface has especially poor drainage due to the numerous northwest trending ridges that block natural drainage and form extensive wet areas adjacent to the Big Grass Marsh.

The clay plain surface has somewhat better drainage as there are no natural blockages. However, the relatively low grade reduces peak river flow velocities with the result that the Whitemud River and its tributaries

Physiographic Regions

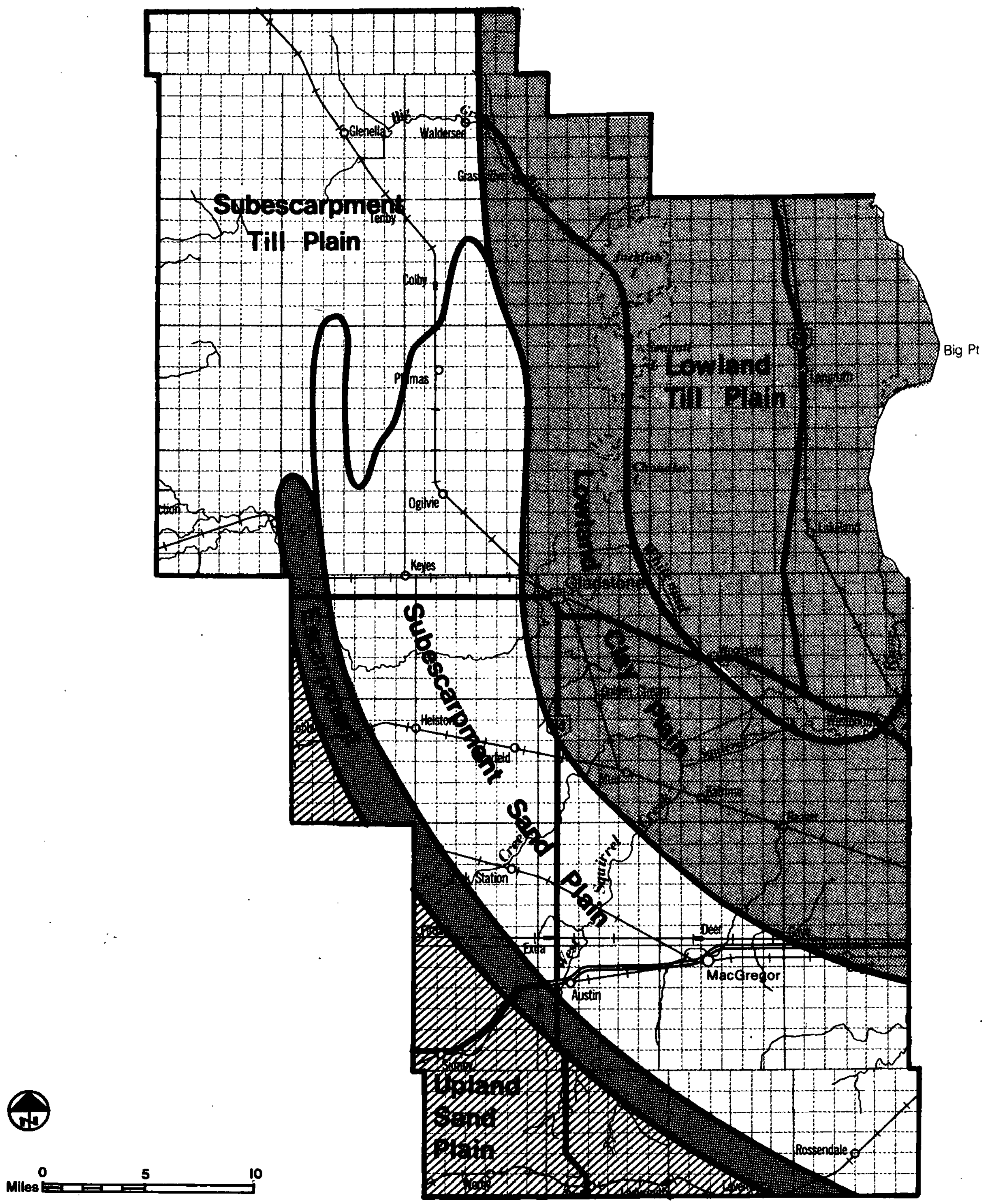


Figure 2: Physiographic Regions of the Westlake Area

(After Jenkins et al, 1974)

Elevations in Feet Above Sea Level

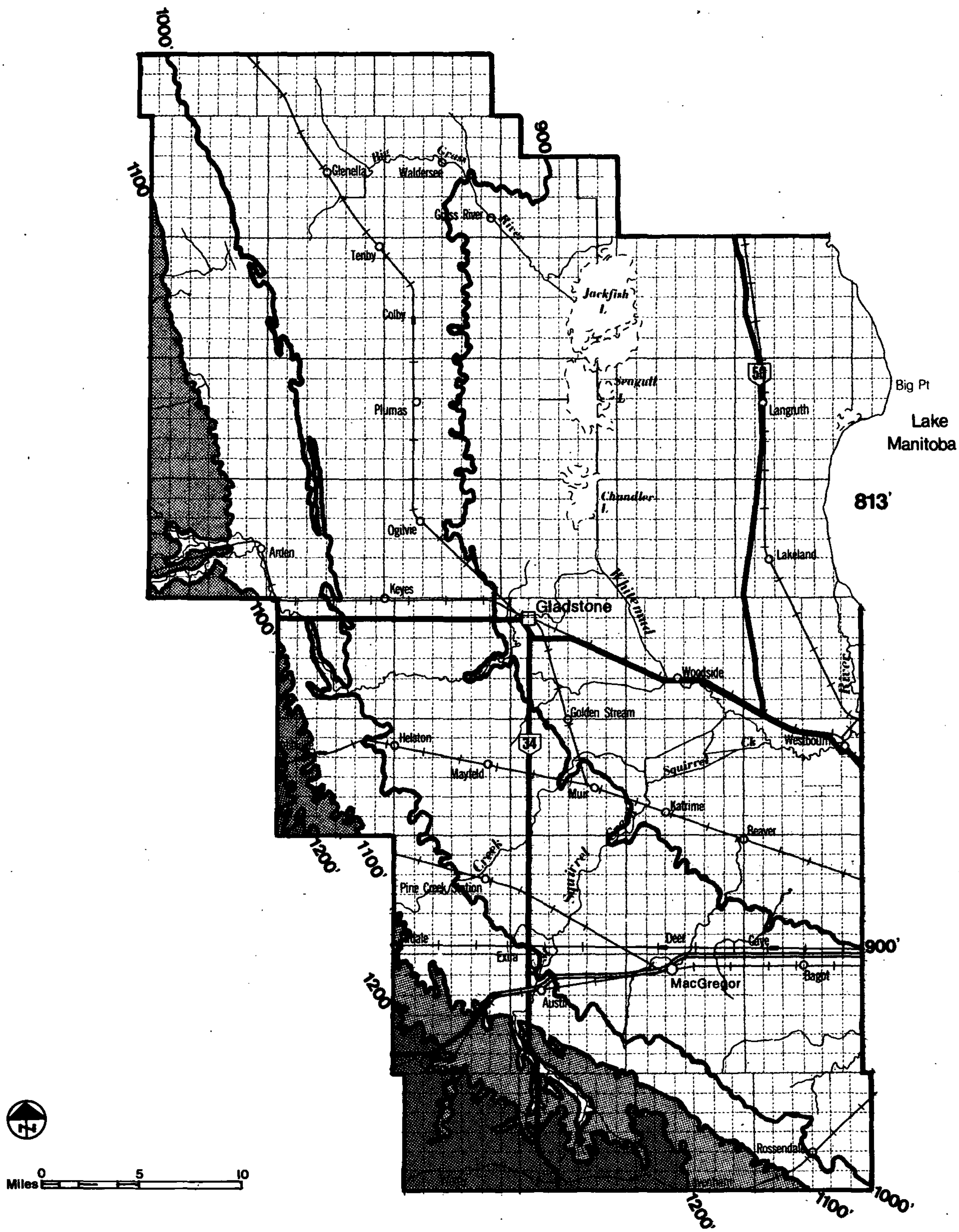


Figure 3: Topography of the Westlake Area

often cause severe flooding problems, especially between Gladstone and Westbourne. Even with extensive drainage upgrading, the low grade and regional convergence of water results in frequent and devastating flood conditions.

The soil conditions of the region closely reflect the parent geological materials and hydrologic conditions. The soils vary from clay loam to loamy sand and reflect the variability of the till. Stoniness is severe over much of the area, but especially on the higher ridges where water action has tended to wash out the finer material leaving a concentration of coarse stone. These soils have moderate to low natural fertility (Ehrlich et al, 1959, 1958).

Soils of the lake clay plain are described as clay loams of the Calcareous Meadow associates. These soils range from a moderate to a high natural fertility with high moisture retention capacity.

North and southeast of Gladstone, there is a third, less extensive soil group called the Gladstone association. This soil group has formed over a local alluvium that has been deposited during the numerous and extensive floods that have inundated the Gladstone to Westbourne area in the past. This soil group directly overlies the older, lacustrine deposit and forms a thin cover of predominantly, black silty sand. These alluvial soils are moderately fertile, especially in areas where the soil zone has had adequate time to develop.

2.2 Sub-Escarpment Region

The Sub-Escarpment Region, like the Lowland Region, is composed of both till and lake plain sediments. The till deposits are found in the northern part of the region between approximately 290 m (950 ft) and 335 m (1100 ft) A.S.L. while the silty sand deposits predominate in the south between 275 m (900 ft) and 320 m (1050 ft).

The till covered, northern, region, is characterized by an undulating series of northwest trending ridges that are in places capped by sand and gravel beach ridges. These granular deposits are most extensive at the upper elevations and significantly decrease in size to the east, toward the Lowland Region. Drainage is generally well defined along the western edge where steeper gradients have facilitated erosion through the till ridges. At lower elevations, drainage becomes progressively poorer until swamp and wetlands predominate and merge into the typical Lowland physiography. The soils of the area are typical for till and shoreline deposits, with the dominant soil associates being the Rendzina, Calcareous Meadow and the Imperfectly Drained Dark Grey Wooded (Ehrlich, 1958). These soils generally have a low fertility, especially along the beach shorelines where the moisture retention is poor. Stoniness hampers cultivation over much of the till covered region.

The sand covered, southern area, shown on Figure 2, blankets an extensive area between the Escarpment and Lowland Region. This area is characterized by a gently sloping sand plain which overlies and thins toward the Lowland deposits. Drainage is relatively well defined with the Whitemud River and Pine and Squirrel Creeks providing natural discharge routes. Flooding is a rare occurrence as the higher permeability of the sandy soil minimizes the potential for runoff.

Swamps increase in terms of both frequency and size to the north and east as the sands become thinner and the lower permeability of the underlying units causes the water table to rise into the sand. The soils of this area are predominantly of the Black Meadow association and have a moderate to high natural fertility (Ehrlich, et al, 1957, 1958).

2.3 Escarpment

The Escarpment Region is an areally small physiographic region in the Westlake area, and defines the shoreline of glacial Lake Agassiz. This region forms a thin elongated belt between the Sub-Escarpment and Upland Regions. The underlying geologic materials range from sand and gravel in the north where beach deposition occurred, to predominantly fine sand in the south where the basal deltaic deposits have been overlain by both advancing delta and dune sand.

The region is characterized by steep grades and by deeply eroded well defined, stream channels. Soils of this region are of the the Degrading Black association, typical of soils developed on parent materials ranging from sand to silty sand. Surface textures range from loamy fine sand to very fine sandy clay loam. These soils have a low natural fertility as good permeability and steep grades tend to minimize the moisture holding capacity (Ehrlich et al, 1957, 1958).

2.4 Uplands Region

In the Westlake Area, the Uplands Region is comprised almost entirely of dune sand and deltaic clay, silt and fine sand. Dune sand is the predominant surficial deposit in the southern part of the region. There, the underlying deltaic deposits are present at the base of depressions between dunes and at the base of river and stream channels. The deltaic deposits predominate at surface from south of Firdale to south of Arden.

The Upland Region is characterized by a gently undulating to rolling topography with deep cut, but widely spaced stream channels (Jenkins et al, 1974). Like the Sub-Escarpment Region, the sand surface of the Upland Region facilitates the downward percolation of precipitation and thereby reduces the volumes of runoff and the number of natural drainage channels.

Soils of the Upland Region are all of the Black association. They range from loams in the dune sand areas to silty and clayey loams in the areas underlain by deltaic deposits. This region has moderate soil fertility and good moisture holding capacity where the absence of wind blown sand has allowed an accumulation of organic matter.

3.0 BEDROCK GEOLOGY

3.1 General Geology

The bedrock geology of the study area (Figure 4), is composed of a number of Jurassic and Cretaceous formations. These formations make up part of a large sedimentary structure that includes the Williston Basin and the Elk Point Basin. These extensive sedimentary structures were formed through millions of years of geologic time by alternating periods of accumulation, subsidence, emergence and erosion. The centre of the thickest sedimentary sequence of the major structure, the Williston Basin, is located in western North Dakota (McCabe, 1966). Data, mainly from oil well logs, indicate that this basin in the Precambrian basement rocks is approximately 4000 metres (13,000 feet) deep in the centre. The dip of the Precambrian surface varies from approximately 3 metres/kilometre (17 feet/mile) at its outer edge in Manitoba to as much as 9 metres/ kilometre (50 feet/mile) towards the center of the basin.

The Phanerozoic formations in Manitoba formed on the northeast flank of the Williston Basin and dip to the southwest, overlying the Precambrian basement rock. These Phanerozoic bedrock formations outcrop in a number of locations in southwest Manitoba; however, no bedrock exposures were observed in the Westlake area. There are bedrock outcroppings adjacent to the northwest corner of the study area but the gradual thickening of the till deposits toward the east covers all bedrock in the study area.

Bedrock Geology

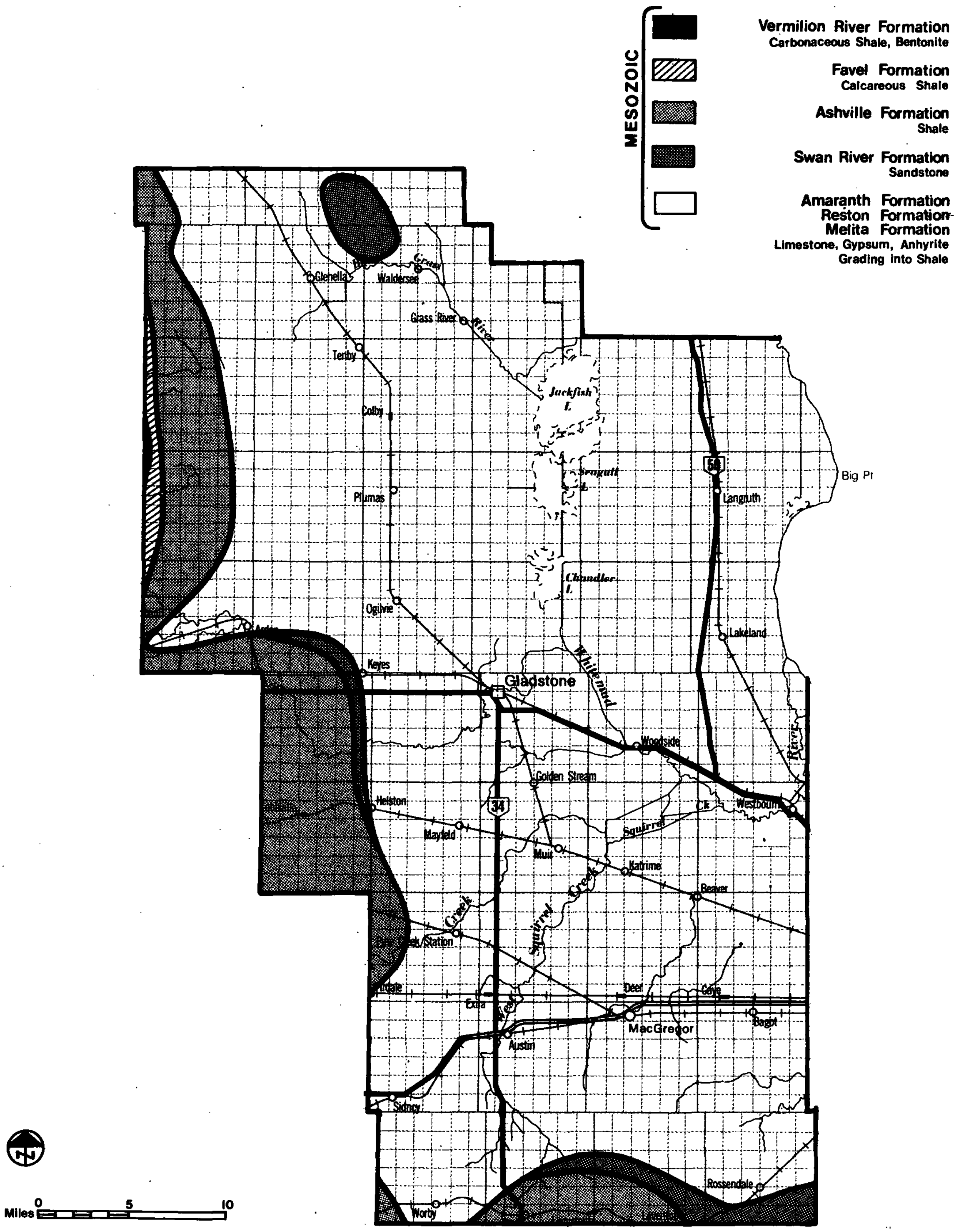


Figure 4: Bedrock Geology of the Westlake Area

(After Mineral Resources Division Map 79 - 2)

3.2 Jurassic Bedrock Formations

The Jurassic bedrock formations (Amaranth, Reston, and Melita formations) underly over 80 percent of the Westlake area. The Amaranth formation has been subdivided into a lower, reddish, dolomitic shale unit and an upper anhydrite and gypsum unit (Davies et al, 1962). Gypsum is presently being quarried near the town of Amaranth, which is located just north of the study area, adjacent to Lake Manitoba. The Reston and Melita formations grade from argillaceous limestones and shales to predominantly calcareous and vari-coloured shales.

The Waskada formation, located above the Melita formation in the southwest corner of the province, is not present in the Westlake area. This member was not deposited to the east or it was eroded during a period of pre-Cretaceous erosion (McCabe and Bannatyne, 1970).

3.3 Cretaceous Bedrock Formations

The Cretaceous period continued with the emergence that had started during late Jurassic time. The resultant period of erosion caused the formation of the Swan River Sandstone; however, by late Swan River time the period of emergence changed to a period of predominantly submergence. This submergent period extended through Cretaceous time and resulted in significant thicknesses of marine shale and glauconitic sandstone being deposited.

The Cretaceous bedrock has been subdivided into 4 major formations in the Westlake area, namely the Swan River, Ashville, Favel and Vermilion River formations. These formations subcrop along a narrow band along the south and west extremities of the area. The Swan River formation consists of grey kaolinitic shale overlain by pure quartz sand and glauconitic sand. The Ashville formation consists of a lower, dark grey, clayey shale and an upper, black, carbonaceous shale. The Favel formation is composed of grey shale with white, calcareous specks. The Vermilion River formation has been divided into 3 sub-units, namely the Morden, Boyne and Pembina members. All three units are composed predominantly of shale. The Morden member consists of dark grey, non-calcareous shale containing concretions of calcareous clay and iron pyrite. The Boyne member is a grey calcareous shale interlayed with thin beds of bentonite. The Pembina member is distinguished by alternating thin beds of carbonaceous shale and bentonite (Davies et al, 1962).

3.4 Bedrock Surface Topography

The bedrock surface topography of the Westlake area is shown in Figure 5. The bedrock surface rises from the east to the west and southwest with overall elevation differences of over 150 metres (500 feet). This pattern is similar to the surface topography and this indicates that the underlying bedrock has been a significant controlling factor in the development of the present topography.

Bedrock highs along the west side of the area correspond to topographic highs. Also, the bedrock contacts in the area are aligned with the bedrock topography and this implies some bedrock control in the development of the present bedrock surface. For example, bedrock valleys are prominent in the softer, Cretaceous shales while in the harder carbonates to the east, the pattern becomes gradually less discernible.

Bedrock Topography

Elevations in Feet Above Sea Level

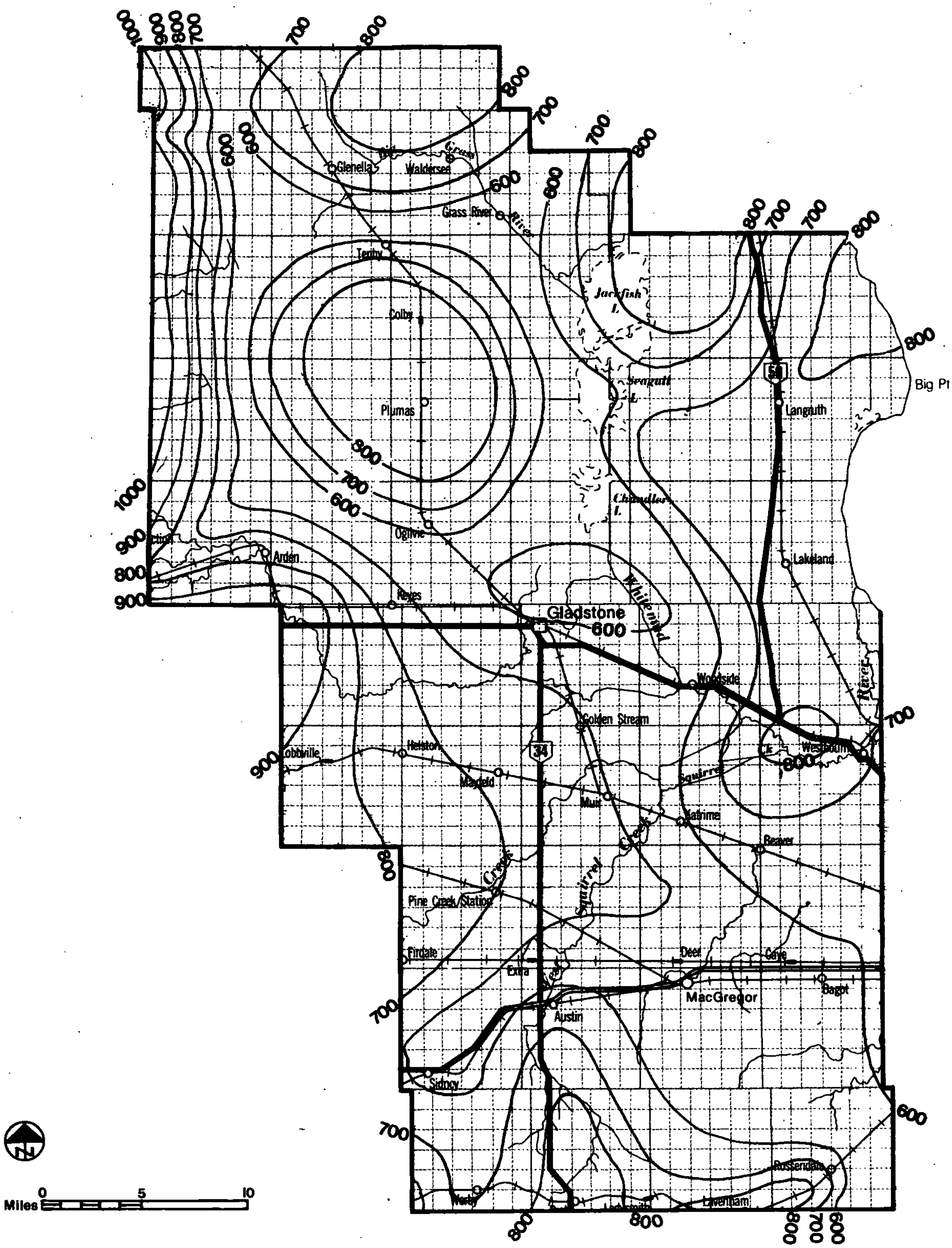


Figure 5: Bedrock Surface Topography of the Westlake Area
(After Teller & Bannatyne, 1976)

The major bedrock depression in the area is covered by a low, flood-prone area that extends northward from Gladstone and includes the Big Grass Marsh. To the southeast, the surface expression of this bedrock channel is less distinct due to a more complete infilling of the channel with glaciolacustrine sediments.

4.0 QUATERNARY GEOLOGICAL HISTORY

4.1 Introduction

The primary objective of this study was the evaluation of the quality and quantity of sand and gravel resources of the Westlake study area. The Quaternary geology was an integral part of this objective in that an understanding of the sequence and environment of sediment deposition provided a frame-work for interpreting the various modes of granular development.

In this study, the Quaternary geology has been subdivided into two main sections. The first section, which embodies section 4, includes a review of the historical Quaternary geology but with major emphasis directed to the inter-relationship between the more regional events and the genesis of the geological materials and structures observed in the study area. This involved a step-by-step interpretation of physical environments from which the present surficial geology evolved. The second section (section 5) discusses the lithology and geomorphology of the various geological units observed in the study area. Map sheets 1 to 7 present the surficial geology at a scale of 1:50,000 and these are located in the pocket at the back of this report.

4.2 Quaternary Geology

The basis for interpreting the Quaternary geology of the study area was a review of pertinent literature sources (see reference list), air photo interpretation (1:30,860, 1:80,000, Landsat 1:10,000,000) field mapping including reconnaissance backhoe pits and evaluation of numerous geological boreholes and water well logs. This information was used to interpret the local Quaternary history into a number of distinct events. These events or phases are outlined in the following sections. Geological maps, cross-sections and photographs have been included to clarify the interpreted sequence of historical events.

4.2.1 Glaciation

Studies of glacial geology in mid-continental North America demonstrate the existence of at least four major ice sheet advances as well as a number of interglacial stages (Flint, 1971). The major glacial stages included the Nebraskan, Kansan, Illinoian, and Wisconsin, in chronological order. In Manitoba, the surficial deposits are associated mainly with the Late Wisconsin Stage as the glacial deposits of the three earlier glacial periods were largely removed by the last ice advance (Davies et al, 1962). The Late Wisconsin Glacial Stage extended from approximately 25,000 B.P. (before present) to 10,000 B.P. (Flint, 1971).

The Late Wisconsin began with an ice advance from the north. Evidence from east of Lake Winnipeg indicates that there were two major ice advances during the Late Wisconsin; the first advance was from the northeast and the second from the northwest (McPherson et al, 1971).

In the Westlake area, glacial till deposits demonstrate strong fluting or scour grooves that correspond with a glacial advance from the northwest, as shown on surficial geology maps 1 and 4. These northwest trending

Quaternary Geology

RECENT

9 SWAMP DEPOSITS

8 ALLUVIUM DEPOSITS

7 LACUSTRINE DEPOSITS

6 SHORELINE DEPOSITS

LATE GLACIAL

5 EOLIAN DEPOSITS

4 SHORELINE DEPOSITS
- 4A Beach Ridge
- 4B Fore Shore

3 GLACIOLACUSTRINE DEPOSITS
- 3A Lake Plain - Clay
- 3B Lake Plain - Sand
- 3C Deltaic - Clay, Silt and Sand

GLACIAL

2 ICE CONTACT DEPOSITS

1 TILL DEPOSITS

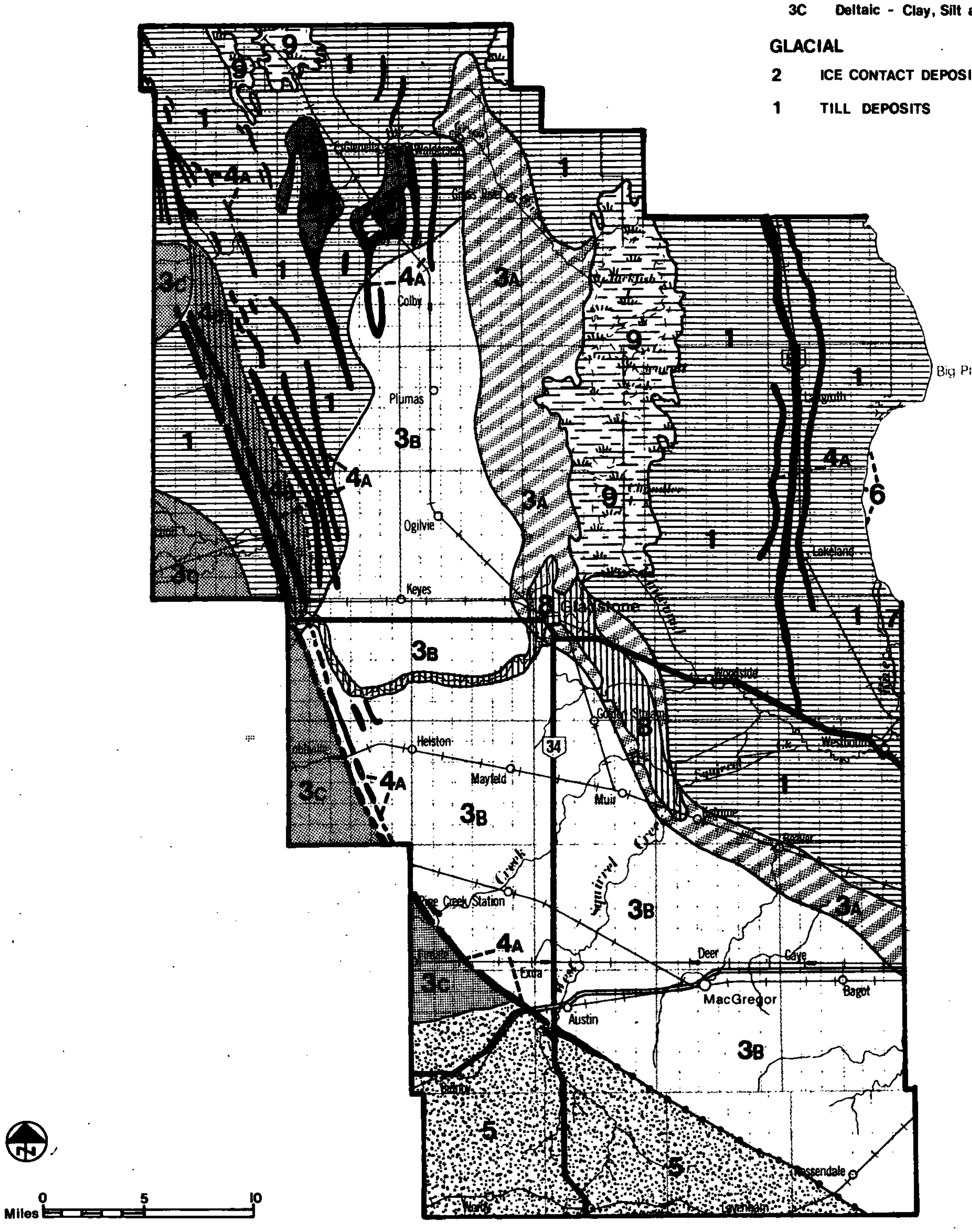


Figure 6: Quaternary Geology of the Westlake Area

(For more detail, see Maps 1-7 in back pocket of this report)

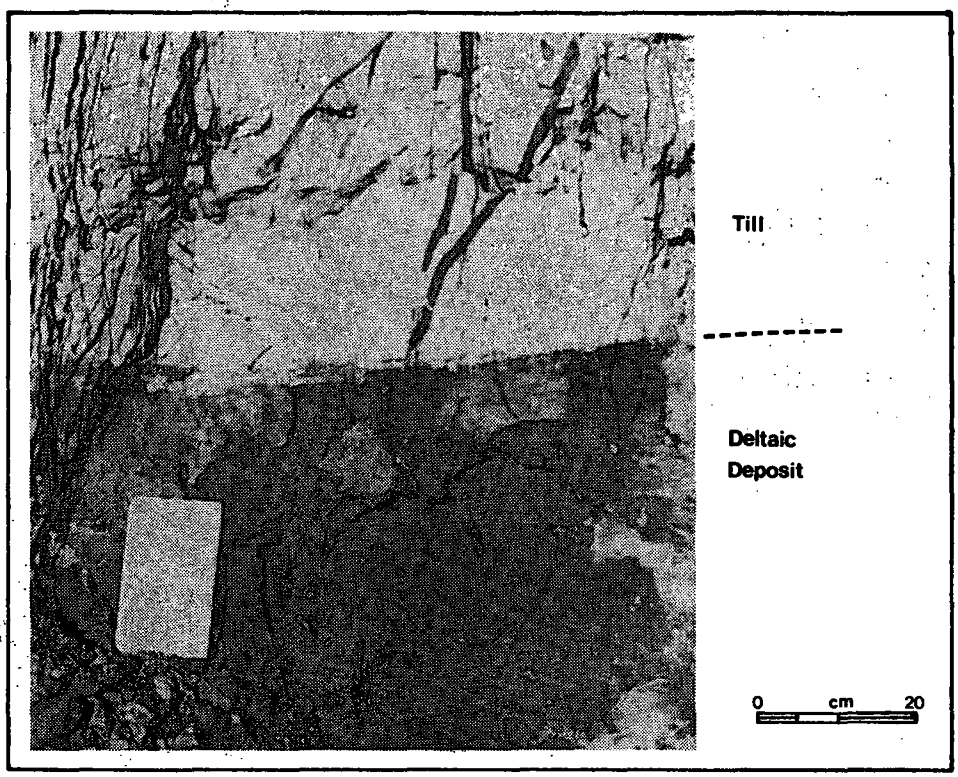
lineations are observed over most of the till covered areas but are most pronounced in the lowland till deposits adjacent to the Big Grass Marsh. It appears that the surface expression of the earlier glacial advance has been obliterated by the last advance. Subsurface geological information obtained from the borehole logs of test drilling programs within and adjacent to the Westlake area do, however, demonstrate the existence of a number of glacial advances (Fenton and Anderson, 1971).

The test drilling and field mapping program conducted by Fenton and Anderson (1971) in the Lake Manitoba delta region, just east of the Westlake area demonstrated the presence of 3 till units interlayed with stratified glaciofluvial deposits. The borehole data within the Westlake area also indicates a number of glacial advances and retreats.

The relationship of this interlayed till to the regional stratigraphy is presented in Figure 7, an orthographic representation of the regional surficial and bedrock geology. The field mapping and geologic borehole data indicates that the till forms a continuous unit that caps the bedrock throughout the study area. Fenton and Anderson (1971) have interpreted this till to be of Wisconsin age as no evidence of significant weathering in any of the layers could be found.

The borehole information of Fenton and Anderson (1971) also indicates the presence of a discontinuous clay layer, approximately 1 metre (3.3 feet) thick, below the upper till and above what they have designated as a middle till. A similar sequence was also observed in the

Westlake area near Arden, in a section along the Whitemud River. There, approximately 20 metres (66 feet) of yellow-brown silty clay till overlies at least 2 metres (6.6 feet) of interlayed clay and silt. (See Photograph 1).



Photograph 1: Contact of till overlying deltaic deposits near Arden, Manitoba Geological Mapping Site 77.

The fine grained sequence of clay and silt is very similar in both structure and texture to the deltaic deposits observed further to the south. It would appear that the lacustrine deposit below the till is a remnant of an earlier phase of the Assiniboine delta complex. Fenton and Anderson (1971) have suggested, a minor re-advance of Lake Agassiz.

Orthographic Projection

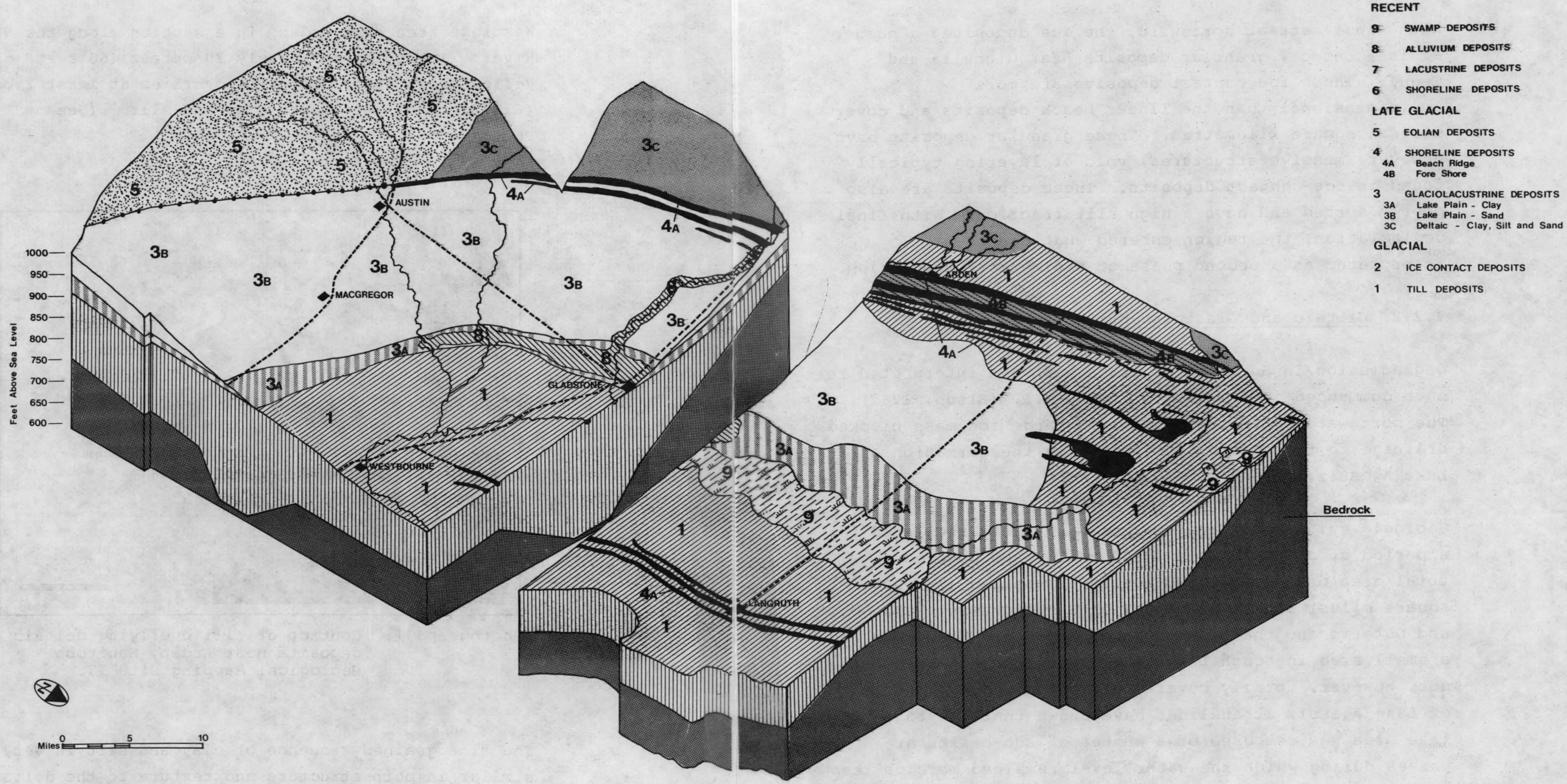


Figure 7: Quaternary Geology & Stratigraphy of the Westlake Area

With final retreat northward, the ice deposited a number of ice-contact, granular deposits near Glenella and Tenby. These ice contact deposits are more equidimensional than the linear beach deposits and cover several square kilometres. These granular deposits have, however, massive structures, void of layering typically found in ice-contact deposits. These deposits are also poorly sorted and have a high silt fraction. With final deglaciation, the region entered what has been interpreted as a second phase of sedimentary deposition.

4.2.2 Deltaic and Glaciolacustrine Deposition

Deglaciation in Southern Manitoba has been interpreted to have commenced just prior to 12,500 B.P. (Elson, 1967). The northward retreat of this last large ice mass blocked drainage to the north and resulted in the formation of Lake Agassiz.

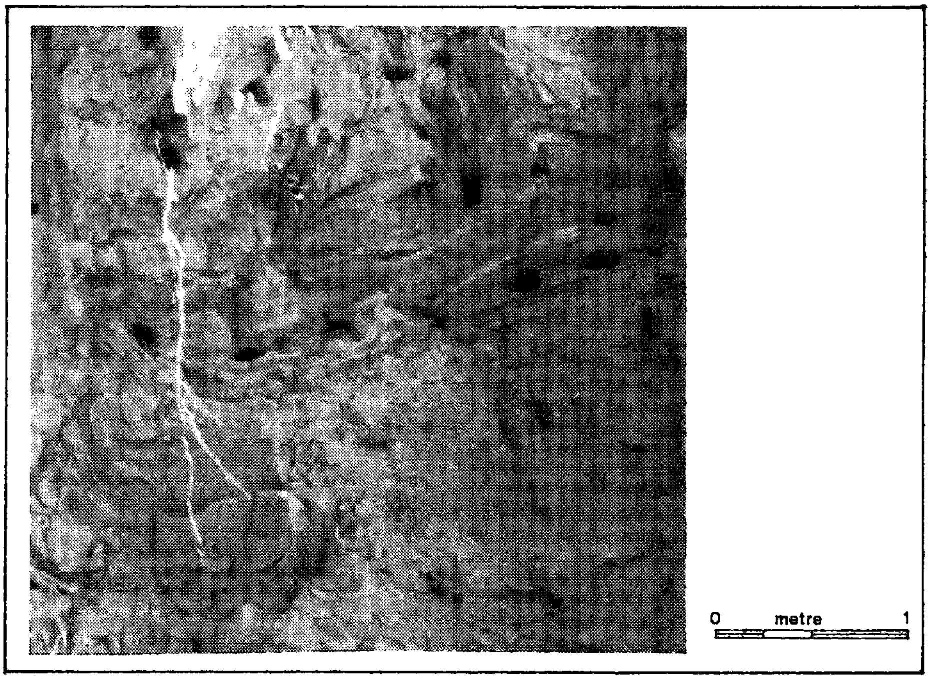
Geologic evidence indicates that Lake Agassiz existed for a period of approximately 4,300 years, and covered a total area of some 500,000 square kilometres (200,000 square miles) in the provinces of Saskatchewan, Manitoba and Ontario and the states of North Dakota, Minnesota and a small area in South Dakota. This extensive area was not, however, totally covered at any one time. Studies of Lake Agassiz strandlines have shown that the total lake area was composed of a number of sub-basins or phases during which the water level remained more or less constant. The transition from one phase to another was related to both the retreat of the ice margin and the deepening of drainage outlets by erosion (Elson 1967).

The earliest extent of Lake Agassiz, the Herman phase, has been estimated to have commenced approximately 12,500 years B.P. During this phase the Assiniboine delta formed at the western extent of Lake Agassiz from sediment eroded from the Assiniboine and Qu'Appelle glacial spillway systems. It was during the Herman phase that the major proportion of the Assiniboine delta sediments were deposited (Elson, 1967).

The Westlake area is at the distal edge of the Assiniboine delta complex and, as a consequence, was subjected to deposition of more fine grained sedimentary materials. As shown in Figure 6, the interlayed clays, silts and very fine sands of the delta complex extend to the western and southern edge of study area. Photograph 2 at geological mapping site 20, just south of Austin on P.T.H. 34 typifies the crossbedding and load structures observed in the deltaic deposits.

Below the deltaic deposits, there is a sequence of, deep water, lake plain clays that were progressively covered as the delta spread to the east. These clay deposits outcrop beyond the eastern extent of the delta where they overlie basal till deposits.

Prior to the start of sedimentation from the Assiniboine delta, the upper till surface topography in the Westlake area was a somewhat subdued version of the bedrock surface topography (Figure 5). With the influx of deltaic sediments from the west, deep depressions in the south of the area began to infill with sediment. Borehole data indicate thicknesses of deltaic sediments ranging from 75 to more than 100 metres (256-328 feet). The total overburden thickness, in the deepest of these depressions, is approximately 200 metres (650 feet) as shown on Figure 8. To the northwest, the pronounced rise



Photograph 2: Structural features in deltaic deposits, near Austin, Manitoba. Geological Mapping Site 23

in elevation of the till surface above 350 metres (1150 feet) A.S.L., was sufficient to restrict the depositional environment to but a few depressional areas. To the east, the reason for limited deposition of the lake plain deposits on the till surface is less clear.

To the east, the till plain is as much as 200 metres (388 feet) lower in elevation than to the west, yet not even a thin veneer of glaciolacustrine deposition was observed. It is possible that any lake plain deposits that did mantle the till were washed off during subsequent water

Overburden Thickness

Contour Interval - 100 feet

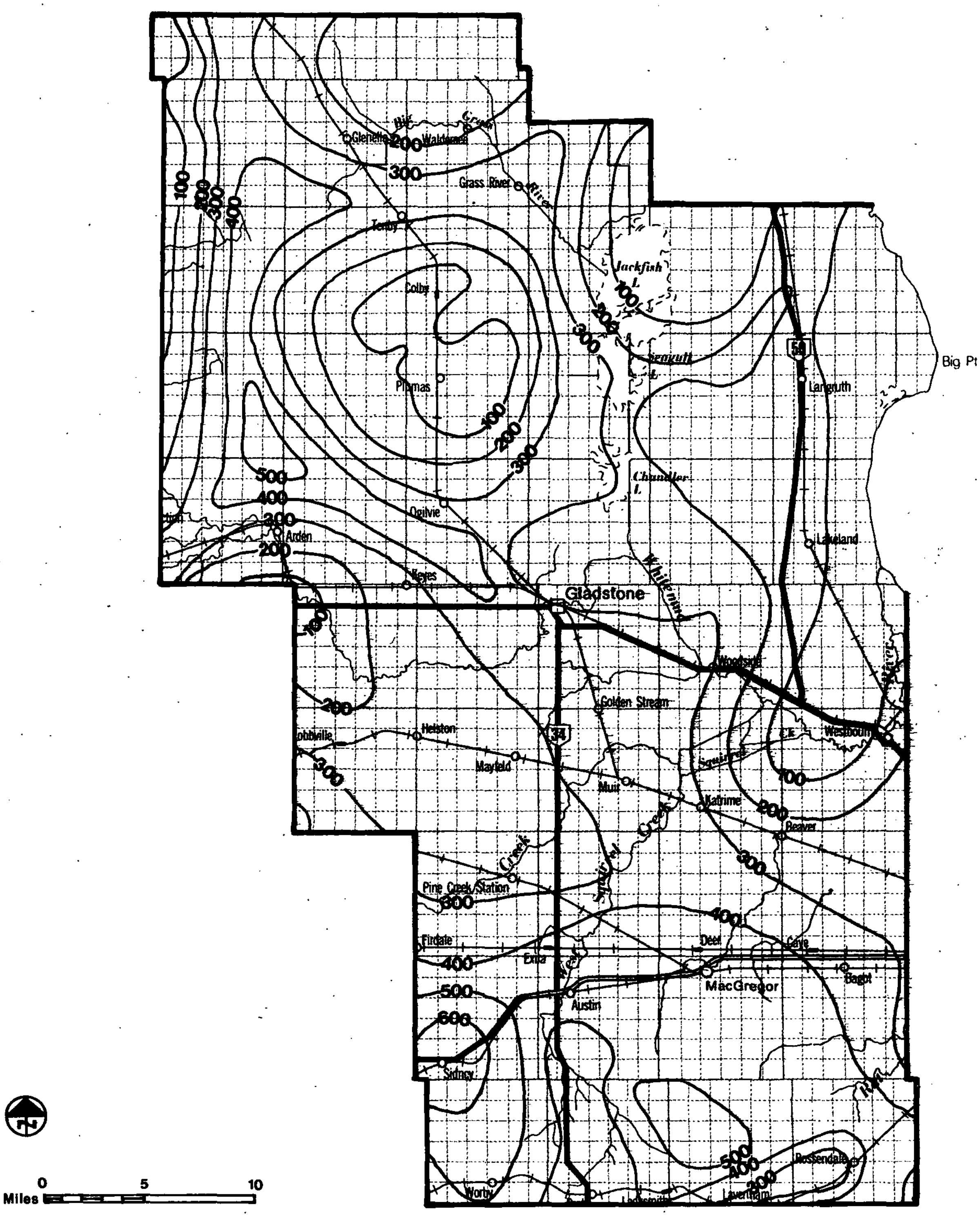


Figure 8 : Overburden Thickness of the Westlake Area

(After Teller, 1976)

level declines. Also, the Riding Mountain Escarpment may have presented a barrier to deposition on its east flank and coupled with drainage to the south, may have further restricted sedimentation from the west, into the northern basin of Lake Agassiz.

4.2.3 Lake Level Decline

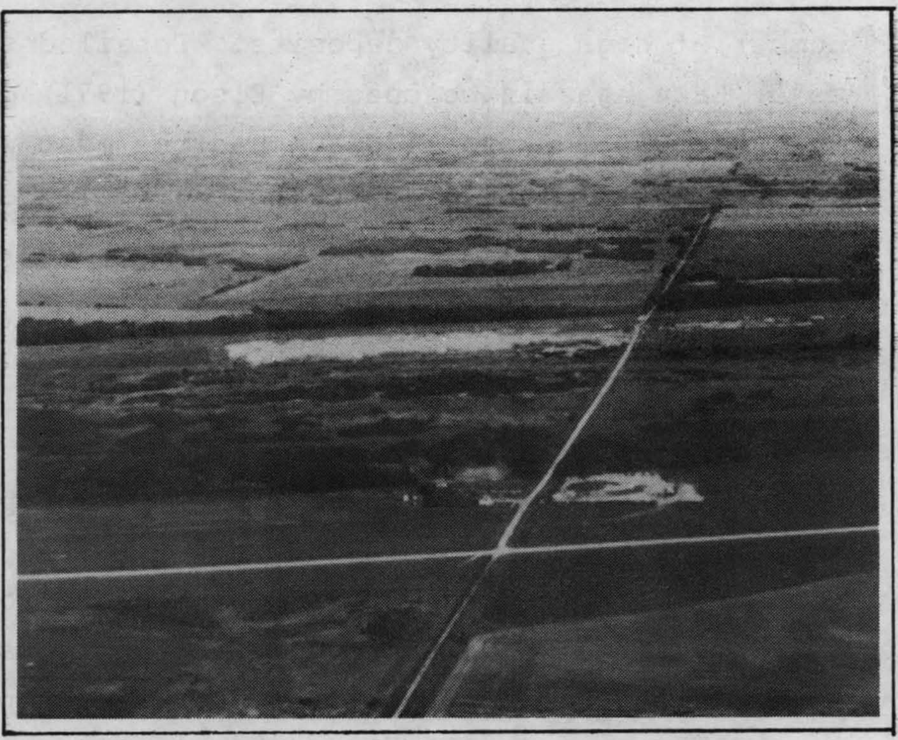
During the Herman phase, Lake Agassiz was at its maximum elevation and all drainage was to the south through Lake Traverse (Elson, 1967). Erosion at this outlet, coupled with a period of accelerated ice retreat, resulted in a significant water level decline. This decline modified the sedimentation pattern in the Assiniboine delta and resulted in an influx of fine sand into the study area. This sand formed a blanket over most of the deltaic and lake plain deposits and to a more limited degree, over the till. This period of lake level decline continued with only a few pauses until the waterplane intersected the western and southern edges of the study area. There, the water level remained stable for a period of several hundred years (Elson, 1967).

The major consequence of this period of water level stability within the study area was the formation of an extensive beach deposit, known as the Upper Campbell Beach. The Upper Campbell Beach is the most prominent geological feature in the study area, forming a continuous ridge along the west and south boundaries of the area for a distance of approximately 100 kilometres (62 miles) (see Figure 6). This beach ridge is an important source of sand and gravel, especially near the town of Arden. There, the beach is underlain by till and the reworking and washing by wave action produced a number of high quality deposits. Detailed studies of all major Lake Agassiz beaches by Elson (1971) demonstrated that the Upper Campbell Beach had the most well-rounded pebbles of all Lake Agassiz beach deposits and he attributed this to the longest period of water level stability during Lake Agassiz history.

The development of the Upper Campbell Beach was followed by a period during which ice retreat opened outlets on the east side of Lake Agassiz, near Lake Nipigon (Elson, 1967). The opening of the outlets resulted in a significant and rapid water level decline to a waterplane just above that of the present Lake Manitoba. This low phase, the Burnside phase of Lake Agassiz spanned a period of approximately 10,000 to 11,000 B.P.

A subsequent re-advance of the ice sheet in the east, resulted in the closing of the outlets, through Lake Nipigon. Lake Agassiz II was formed and water levels rose until drainage was again to the south. During this period, the Lower Campbell Beach was formed. Isostatic rebound had uplifted the Upper Cambell Beach above the water level and resulted in a new, relatively unworked till surface being at the waterplane surface. Ensuing wave action built the Lower Campbell Beach into a source of sand and gravel, comparable to the Upper Campbell Beach. Photograph 3 shows an aerial view of the Upper and Lower Campbell Beaches near the town of Arden.

During the last period of deglaciation, the eastern outlets of Lake Agassiz II were again re-opened at Lake Nipigon. This initiated a second period of lake level decline, which formed a number of smaller, sub-parallel and semi-continuous beach ridges below the Campbell

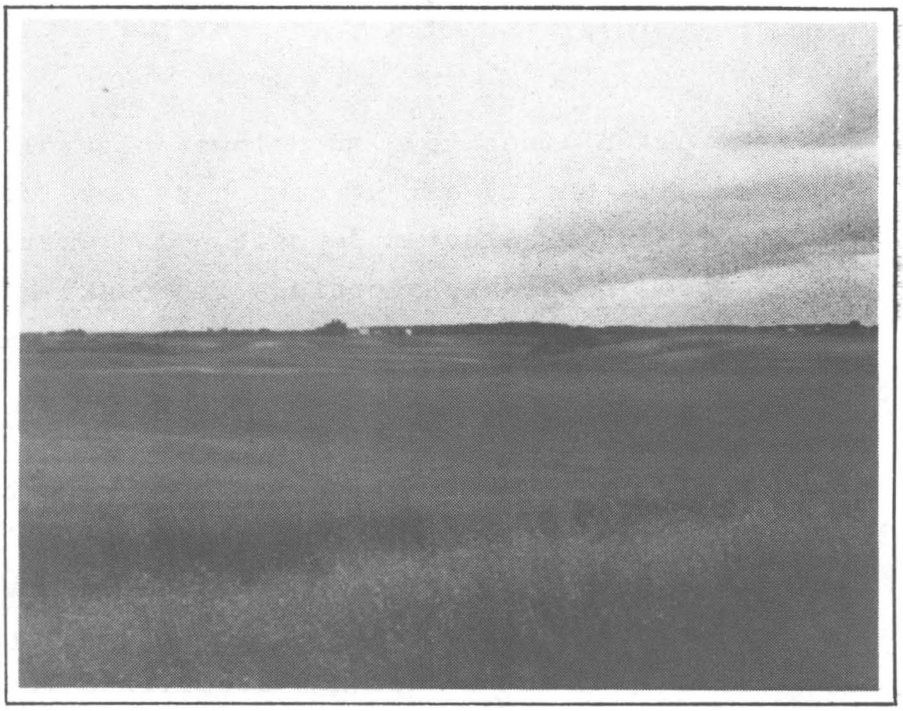


Photograph 3: Aerial view of pit operations on Upper and Lower Campbell Beaches near Arden, Manitoba.

Beaches (Elson, 1967). In some cases these beach ridges contain gravel deposits suitable for local needs. In general, however, these deposits are poor and decrease in quality both eastward and southward. To the east, the beach ridges are smaller and finer as a consequence of shorter periods of lake level stability.

To the south, the decrease in granular content is directly related to the thicker glaciolacustrine and deltaic deposition over the till. The sediment cover on the till eliminated the local source of granular material and limited the development of granular deposits to those associated with near-shore currents. There was certainly some migration of sand and gravel as a result of these currents, but, there was apparently insufficient time to move large volumes of granular material southward. South of Austin, the higher quality sand and gravel in the Upper Campbell Beach is only 1 metre (3.3 feet) thick and only a few kilometres to the southwest, this granular material disappears completely.

Concurrent with the formation of numerous beach deposits, lake level decline exposed expanses of sand in the Assiniboine delta complex to the west of the study area. This exposed sand, coupled with the prevailing westerly winds, precipitated the eastward migration of significant eolian deposits. The extensive area of sand dune deposits behind the Campbell Beach and overlying the more fine-grained deltaic deposits as shown on Figure 6, is indicative of the large sand volumes that were displaced eastward. Photograph 4, taken south of Austin typifies this undulating dune topography.



Photograph 4: Undulating sand dune topography near Austin, Manitoba

Continuing ice retreat caused a gradual lowering of the Lake Agassiz water level and by about 7300 years B.P., disintegration of the ice sheet lying across the Nelson River valley, caused Lake Agassiz to drain into Hudson Bay (Elson, 1967).

4.2.4 Recent

Since the end of glaciation, there has been only limited changes in the geological materials and landscape. River erosion, the formation of alluvium deposits, the migration of sand dunes, and the formation of peat bogs and soil cover were the major modifications.

The upland areas, west of the Campbell beaches have been the main areas of erosion. Here, the steeper grade of the land has produced relatively fast moving streams that have eroded deep, steep-walled valleys in the till and deltaic deposits.

The lake plain areas have much lower natural grades and consequently, nearly all streams have developed some form of floodplain or alluvium deposit. The Whitemud River, for example, regularly overflows its banks between Gladstone and Westbourne and has formed an extensive alluvium deposit around Gladstone.

Sand migration by wind action has been reported to be as much as 3 metres (10 feet) in depth at some locations south of Austin where the local residents have indicated that a number of fence lines are buried. Improved cultivation practices have now stabilized most of the dune areas in the region.

In the Westlake area, the beach deposits along Lake Manitoba have been developed since Lake Agassiz drained into Hudson Bay, a period of approximately 7,500 years. This time frame is much longer than any phase of Lake Agassiz, yet the beach deposits are less extensive than even the small Agassiz beach deposits observed only a few kilometres inland. The formation of beaches over this extended time period is apparently offset by the more favourable conditions for beach development that were present during Lake Agassiz time.

Peat and muck deposits are most extensive in the north end of the study area, mainly in depressions on the till surface. The most significant deposit occurs north of Gladstone in the large lowland area called Big Grass Marsh.

5.0 GEOLOGY

In this section, the lithology and geomorphology of the various surficial deposits observed in the Westlake area are discussed. The location and extent of these deposits are shown in the map of Quaternary Geology (Figure 6) and the stratigraphic and relative thicknesses are presented on the orthographic projection of the Westlake area (Figure 7).

5.1 Glacial

5.1.1 Till Deposits

The till deposits in the study area vary from a massive, grey-brown clay till in the eastern area near Lake Manitoba to a stratified, yellow-brown silt till in the western area, in the vicinity of the Campbell Beaches. The grey-brown clay till demonstrates a well developed northwest lineation pattern on the air photos. These lineations are grooves or flutings in the till surface and have an amplitude of between 1 and 3 metres (3-10 feet). The petrographic composition of pebbles in this till are of granitic and carbonate origin and the proportion of each type is approximately equal. Also, as the stone size increases, there is a noticeable increase in the granitic fraction. The till thickness varies between 30 and 50 metres (100 and 200 feet) near Lake Manitoba.

The yellow-brown silt till also exhibits a northwest lineation pattern, however, it is less well defined and the ridges are more widely spaced than the till to the east. This silt till also demonstrates some stratification. The contact between more massive till zones for example, often exhibits discontinuous layering with compositions ranging from sand to white marl. The petrographic composition of the pebbles from the till is again, almost evenly proportional between granitic and carbonates. The thicknesses of the till deposits in the northwest part of the area ranges from less than 30 metres (100 feet) to over 125 metres (400 feet).

5.1.2 Ice Contact Deposits

A number of ice contact deposits were delineated in the north part of the study area near the communities of Glenella and Tenby (Figures 6 and 7). These deposits cover several square kilometres and are much more equidimensional than the more lenticular, beach deposits. These deposits have been delineated using numerous well logs and a number of backhoe pits dug during this study and a previous evaluation by the Manitoba Department of Highways.

These deposits were indistinct on the air photographs and demonstrated no discernible surface relief with the exception of the beach ridges that intersect these deposits. Geophysical profiling was conducted over the deposit in an effort to more accurately delineate their extent. This information is presented in section 6.

The structure and lithology of these ice contact deposits is that of massive, silty sand and gravel. There is no visible layering or lamination that would indicate deposition as a series of sequential events, typical of outwash deposits. The silt content is also noticeably higher than in any of the beach deposits and the angular nature of the stone fraction indicates deposition in water with poor washing and sorting capability.

The overall quality of these deposits is low as they contain a high silt content that would require washing for all uses except possibly road construction. Also, the water table is high and is generally within 2 metres (6.6 feet) of the surface.

5.2 Late Glacial

5.2.1 Glaciolacustrine Beach Deposits

The glaciolacustrine beach deposits are the most striking geomorphological features in the study area (Figure 6) The Upper Campbell Beach, the largest of these deposits, forms a long, narrow, almost continuous ridge that closely follows the topographic contours for a distance of approximately 100 kilometres (62 miles) along the west and south edges of the Westlake area. In the north end of the study area, this large beach structure has formed along the northwest trending till ridges that predominate in the region. The reworking of this till base has formed a number of extensive, high quality sand and gravel deposits that vary from a few metres to over 5 metres (16 feet) in thickness and up to a 100 metres (330 feet) in width. To the south, the till deposits have been overlain by a thick sequence of fine-grained deltaic deposits and as a consequence, the Upper Cambell Beach is an erosional, wave cut terrace feature, void of any granular content.

The Lower Campbell Beach is very similar to the Upper Campbell Beach in terms of beach development in the northern part of the study area. In the south, the Lower Campbell Beach merges with the Upper Campbell Beach. The merging of these beaches in the south was caused by the low grade at the base of the wave cut terrace and the absence of till as a source for beach development.

Below the Campbell Beaches, to the east, there is another sequence of small, semi-continuous, northwest trending beach ridges. It would appear that in many situations, these small beach deposits were formed along the margin of the many grooved or fluted structures that are visible on the till surface. The relief facilitated beach development at a single location as vertical water changes resulted in only slight horizontal movement of the waterplane.

The quality of these small deposits is generally much lower than that of the Campbell Beach. Shallower water and shorter periods of waterplane stability restricted both the quantity and quality of these deposits. The widths and depths of these ridges vary from approximately 10 to 20 metres (33 to 66 feet) and 1 to 3 metres (3 to 10 feet) respectively.

The lithology of the pebble fraction in the beach deposits was generally equally divided between granitics and carbonates. Also, there was no shale fraction evident in the beach deposits. This was in spite of the fact that shale bedrock underlies most of the major beach area. It would appear that the till cap over the shale bedrock minimized the potential of the subsequent shale erosion and incorporation of shale into the upper till. To the west and south of the Westlake area, the shale content in the tills is significant and this deleterious material has been incorporated into the sands and gravel deposits of these regions (Elson, 1955; Klassen, 1971).

5.2.2 Glaciolacustrine Delta and Lake Plain Deposits

The deltaic deposits are located along the western and southern extremities of the Westlake area (Figure 6 and 7). These deposits are typified by interlayed clay, silt and very fine sand that grade upward into more silty fine sands. The clay and silt layering are often highly contorted from slumping and show ball-and-pillow deformation structures.

The upper, more sandy deltaic deposits resulted from the eastern migration of the Assiniboine delta associated with dropping water levels in Lake Agassiz. These sands show fine laminations with well developed cross-bedding structures. The slope of these beds is towards the northeast. The relief of the deltaic deposits varies from approximately 2 to 5 metres (6.6 to 16.5 feet) in the more northerly exposures where dune development is limited to approximately 5 to 10 metres (16.5 to 33 feet) in the south where wind action has caused significant erosion of the sandy deltaic deposits.

The lake plain deposits are composed of an upper silty fine sand unit and a lower clay unit as with the deltaic deposits, the fine sand unit results from the eastern migration of the Assiniboine delta. The lake plain deposits are somewhat finer grained than the deltaic deposits and structurally are quite massive and demonstrate no visible laminations. Also, the backhoe test pits in the lower clay unit demonstrated a significant stone content. These stones are predominantly carbonate clasts and in most cases, these rocks have been leached to form a soft white, powdery mass at the outer edge. Fenton and Anderson (1971) also noted the presence of stones within the lake plain clay deposits and attributed their presence to the dropping of debris from ice floating in Lake Agassiz. The relief on the lake plain deposits is low and generally less than 1 to 2 metres (3.3 to 6.6 feet).

5.2.3 Eolian Deposits

The eolian deposits have formed behind the Upper Campbell Beach from the wind erosion of the sandy, upper deltaic deposits. The major structures are crescentic or longitudinal dunes and these often demonstrate highly interlayed structures with large cross-bedding features. The sand is generally well sorted, fine to medium in size, with little or no stone or other deleterious material.

The dune structures have a relief that varies from approximately 3 metres (10 feet) to as much as 20 metres (66 feet).

5.3 Recent

5.3.1 Alluvium

Alluvium or flood plain deposits are associated with almost every river and stream in the study area. The major alluvium deposit, located in the vicinity of Gladstone is composed of black silty sand, often with mollusk fragments. Meander channels through this deposit are faint and near the edges, cultivation has all but masked the boundaries. Relief is low and varies between approximately 1 to 2 metres (3.3 to 6.6 feet).

5.3.2 Lacustrine Deposits

There is only a small, localized lacustrine deposit along the east edge of the Westlake area, adjacent to the Lake Manitoba delta. This deposit is associated with an earlier phase of Lake Manitoba when the water level was somewhat higher and the delta was further to the south. The deposit is composed of clay and silt with relief less than 1 metre (3.3 feet).

5.3.3 Shoreline Deposits

The recent shoreline deposits along Lake Manitoba are in their early stages of development. Beach deposits are thin and narrow and over extensive areas have insufficient relief to prevent inland swamps from merging directly into the lake. Beach deposits, where they are present are very coarse and cobbly with little or no sand fraction. The foreshore deposits are boulder lag deposits that have resulted from washing of the surface till deposit.

5.3.4 Peat and Muck Deposits

Peat and muck deposits are located mainly in the low depressions between the northwest trending ridges of the till plain (Figures 6 and 7). These deposits form by the bioaccumulation of carbon. Many swamp and bog plant forms are capable of concentrating carbon dioxide from the atmosphere directly into cell carbon. This carbon accumulates with each yearly cycle and can result in significant and valuable peat deposits.

6.0 SAND AND GRAVEL RESOURCES: QUALITY AND QUANTITY ASSESSMENT

6.1 Introduction

The major objective of this study was the evaluation of the quality and quantity of the sand and gravel resources of the Westlake Area. This evaluation was initiated by a Quaternary geology mapping program in which the granular resources were delineated and categorized by mode of origin. These aspects of the study have been discussed in the previous sections and have been incorporated into the maps in the back pocket of the report. This section discusses the methodology utilized for the quantitative and qualitative evaluation of the granular resources in the Westlake Area.

6.2 Methodolgy

The initial phase of the granular inventory of the Westlake Area entailed the collection and examination of existing data, reports and maps. Included in this phase were the examination of air photographs, Department of Highways block files, well logs and the many geological studies outlined in the references. Additional local information was gathered from discussions with gravel pit operators and well drillers from the area. Also, a preliminary airplane flight was made over the area in order to get a good general overview of the geology and the locations of the major sand and gravel operations. From this information, preliminary delineations of the surficial geology and the granular deposits were made.

On completion of this initial phase, an intensive field program was carried out to verify the preliminary geology and evaluate the quality and quantity of the sand and gravel resources. The field mapping of the geology necessitated that many of the surficial deposits be delineated by the characteristics of the surface materials observed on open fields, in shallow ditch-cut sections and in shallow hand-augered boreholes. This was necessary because there were few geologic sections that presented well defined stratigraphic sequences. The best stratigraphic sections were observed along the escarpment of the Campbell Beaches, where the higher land grades provided a more continuous erosional environment. Below the escarpment area, most of the river cuts are in floodplain areas, where alluvium has blanketed the area. Backhoe pits were required on part of these lowland areas to interpolate geologic boundaries.

Concurrent with the geological field mapping, backhoe test pits were dug and a sampling program of the granular deposits in the area was carried out.

In total, eight weeks of backhoe work was carried out in the Westlake area. Approximately seven weeks of this time was utilized to delineate the sand and gravel resources of the area and the remaining week for geologic mapping purposes. Information gathered from this work was recorded on forms supplied by the Mineral Resources Division. A sample of these forms is included in Appendix A and the data is summarized in Tables 1 to 5.

Channel samples were taken for the majority of the backhoe pit sections in the sand and gravel deposits. These samples were taken from the full height of the sand and gravel layers, as shown in Figure 9. They did not include topsoil or the layers of fine sand at the surface or till, clay or fine sand at the base of the section.

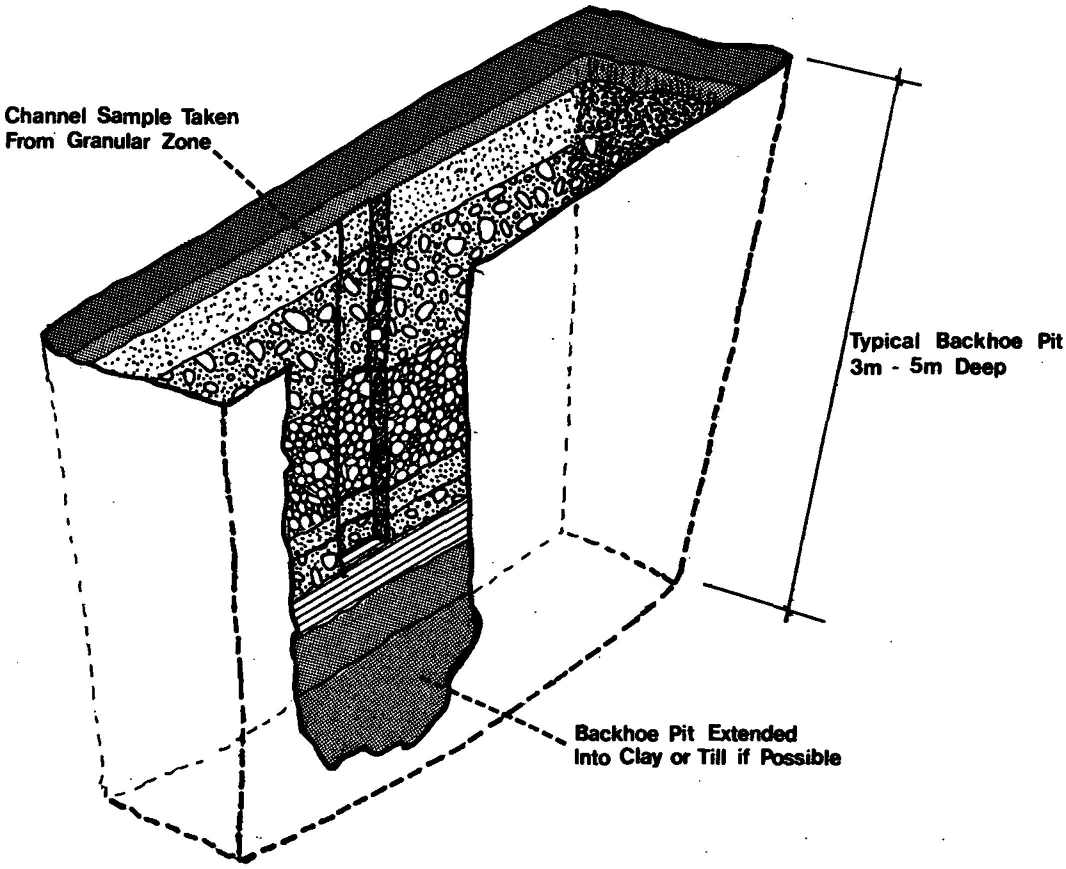


Figure 9 : Diagramatic Representation of Channel Sample Taken from Typical Backhoe Pit.

In other words, only the economic layers of sand and gravel were sampled. In most instances, fine surface sand was pushed aside by pit operation to gain access to the better quality granular material. The average thickness of the economic material was estimated from the length of the channel sample.

A visual assessment of the deposit was made in the field. On completion of the sieve analysis a high, medium, or low quality was assigned to the gravel deposit using the following criteria. This information is presented on the maps in the back of this report.

High - 50% of sample greater than #4 sieve with crushable material.

Medium - 50% of sample greater than #4 sieve with no crushable material.

Low - 50% of sample less than #4 sieve.

It should be noted that the above criteria have been based on the range of sand and gravel quality observed in the Westlake Area and may, therefore, differ from the province-wide classification used by the Aggregate Resources Division.

The areal extent of each deposit was estimated by planimetry over each quarter section. This data, in conjunction with the average thickness of the deposit provided estimates of the volume of sand and gravel available in each quarter section. A summary of this information is presented in Tables 1-5.

On completion of the channel sampling program, individual samples were sieved for an exact analysis of the size range of the granular material. The samples ranged in size from 1.5 to 2.5 kilograms. The complete sample was divided into coarse and fine fractions, the coarse ranging from 3/4 inch to 4 inch and the fine fraction from 5/8 inch to less than the 200 screen size. The fine fraction was then physically split, using a splitter box into a 100 gm to 200 gm portion. The split portion of the fine fraction was weighed and then washed on the #200 sieve by running clean water over it. This sample was redried, reweighed and vibrated through the 5/8 inch to number 200 screens. The weight retained on each screen was weighed and the weight recorded on form 4 (Appendix A).

Electrical resistivity surveys were carried out over two large ice contact granular deposits near Glenella and Tenby (Map 1). A Geonics Model EM31 resistivity meter was used. This meter facilitated a continuous determination of the geophysical signature along a survey line over the deposit. The effective penetration depth of this instrument is approximately 20 feet. This instrument induces an electro-magnetic field in the ground through a transmitter. This magnetic field is synthesized by the instrument to produce a direct earth conductivity measurement in mmhos/metre. This instrument indicated that the conductivity of the surficial deposits varied from approximately zero mhos over sand and gravel to over 20 mhos over till. The pattern or signature was, however, irregular with a number of anomalous readings, possibly related to the variable fine fraction observed within gravel and backhoe pits.

6.3 Estimated Quality and Quantity:

The results of the sand and gravel inventory for the Westlake Area are presented in tabular form below. The granular resources have been tabled by municipality in order to conform with the many regional planning studies that are ongoing across the province. Each deposit has been given a unique number for identification purposes and the location of each deposit has been identified on the maps in the back pocket. The quantity and quality for each of these deposits has been clearly presented in the tables. It should be noted that more detailed information on each deposit has been stored on computer files and is available from the Mineral Resources Division of the Department of Energy, Mines and Resources, Province of Manitoba. Computer printouts are available on each deposit outlining the grain size distribution of each deposit as determined by sieve analysis as well as the potential uses of the deposit. Also, the reserves for each deposit are available for each section and quarter section.

TABLE 1 - QUALITY AND QUANTITY OF SAND & GRAVEL DEPOSITS OF THE RURAL MUNICIPALITY OF NORTH NORFOLK

DEPOSIT NUMBER	EXPOSURE NUMBER	TOWNSHIP	RANGE	SECTION	PERCENT PEBBLES	PERCENT GRANULES	PERCENT SAND	PERCENT SILT/CLAY	TOTAL DEPOSIT RESERVES (Cu. m.)
008000A	069	12	12W	4NW	24.27	18.95	54.73	2.05	
	072	12	12W	17SW	19.73	14.70	61.55	4.02	237,600
008000B	057	11	12W	33NE	58.27	17.97	21.90	1.86	
	064				40.53	23.41	31.09	4.97	181,400
008000C	062	11	12W	27NE	45.51	9.75	41.91	2.83	143,000
008000D		11	12W						190,000
008000E	058	11	12W	24NW	33.74	13.80	51.22	1.24	57,800
008000F	005	11	11W	19SW	57.16	15.14	23.68	4.03	108,400
008000G	016	11	11W	16SW	12.46	11.56	71.66	4.33	
	023				37.12	8.89	50.37	3.63	
	015	11	11W	17SE	6.05	6.35	77.84	9.76	
	014	11	11W	17SW	47.97	15.21	33.05	3.77	
	011	11	11W	18NE	55.49	9.60	33.23	1.68	
	013				0.0	3.51	90.77	5.72	217,000
008000H	007	11	11W						900
008001	073	12	12W	17SW	13.14	19.18	63.32	4.36	
	075	12	12W	18NE	10.22	5.99	73.43	10.37	108,000
009001	076	12	12W	19SW	23.91	14.72	58.50	2.87	112,750
009003		12	12W						53,000
Total Sand & Gravel Reserves - R.M. of North Norfolk									1,409,850

Pebbles - >#8 Canadian Standard Sieve Series
Granules - #10 - #8 Canadian Standard Sieve Series
Sand - #200 - #16 Canadian Standard Sieve Series
Silt/Clay - <#200 Canadian Standard Sieve Series

TABLE 2 - QUALITY AND QUANTITY OF SAND & GRAVEL DEPOSITS OF THE RURAL MUNICIPALITY OF LANSDOWNE

DEPOSIT NUMBER	EXPOSURE NUMBER	TOWNSHIP	RANGE	SECTION	PERCENT PEBBLES	PERCENT GRANULES	PERCENT SAND	PERCENT SILT/CLAY	TOTAL DEPOSIT RESERVES (Cu. m.)
010005		013	13W						12,000
010008A		013	31W						91,000
010008B		013	13W						12,000
010010		013	31W						7,200
010011	079	013	13W	16NE	26.80	7.56	61.54	4.10	20,000
010012		013	13W						205,000
010013		013	13W						15,000
010014		013	13W						39,000
010015	081	013	13W	32NE	20.48	16.81	60.53	2.18	578,500
010016		013	13W						3,300
010017		013	13W						113,000
010018		013	13W						89,500
010019		013	13W						43,200
010020		014	13W						11,400
010021		014	13W						28,800
010023		014	13W						33,600
010025		014	13W						77,000
010026		014	13W						82,000
010027	083	014	13W	19NW	15.27	17.49	65.60	1.64	
	086	014	13W	30NW	46.35	19.51	30.67	3.46	110,500
010028		014	13W						9,000
010029		014	13W						20,000
010030		014	13W						16,000
010031		014	13W						36,000
010032		014	13W						18,500
010033		014	13W						69,000
010034	087	014	13W	31NW	47.45	4.33	45.70	2.51	
	088				26.75	18.61	51.13	3.51	10,000
011020K		013	13W						29,550

TABLE 2 - QUALITY AND QUANTITY OF SAND & GRAVEL DEPOSITS OF THE RURAL MUNICIPALITY OF LANSDOWNE (Cont'd)

DEPOSIT NUMBER	EXPOSURE NUMBER	TOWNSHIP	RANGE	SECTION	PERCENT PEBBLES	PERCENT GRANULES	PERCENT SAND	PERCENT SILT/CLAY	TOTAL DEPOSIT RESERVES (Cu. m.)
011020L	078	013	13W	02NW	45.21	14.83	37.84	2.13	30,000
011022A		014	13W						31,000
011022B		014	13W						15,000
011025		013	13W						12,000
012000	084	014	13W	20SW	36.07	14.54	45.37	4.02	53,000
021050E	090	015	13W	07SW	51.58	14.67	32.06	1.69	
	091				34.09	12.93	50.13	2.84	277,650
021051B	089	015	13W	07SE	36.37	13.04	48.42	2.16	
	093	015	13W	18SW	21.68	5.62	68.99	3.71	2,999,000
021055		017	13W						306,000
021056	092	015	13W	17SE	53.17	21.61	24.09	1.12	723,000
021057		015	13W						1,305,500
021058		016	13W						60,000
021059A		016	13W						481,500
021059B		015	13W						273,500
021098		016	13W						1,497,000
022001A	121	017	13W	16SE	27.28	10.06	58.66	4.00	4,287,000
022001B		017	13W						3,430,500
022002		017	13W						4,972,500
022003A		017	13W						793,000
022003B	113	017	13W	35SE	42.83	16.07	34.12	6.99	
	112	017	13W	36NE	51.39	12.10	32.10	4.41	4,837,100
021029D		017	14W						280,500
021036B		017	14W						468,500
021037		017	14W						147,000
021045A		017	14W						26,000
021045B		017	14W						20,000
021045C		017	14W						56,000
021046A		017	14W						90,000
021046B		017	14W						198,000
021046C		016	14W						175,000
021048		017	14W						150,000

TABLE 2 - QUALITY AND QUANTITY OF SAND & GRAVEL DEPOSITS OF THE RURAL MUNICIPALITY OF LANSDOWNE (Cont'd)

DEPOSIT NUMBER	EXPOSURE NUMBER	TOWNSHIP	RANGE	SECTION	PERCENT PEBBLES	PERCENT GRANULES	PERCENT SAND	PERCENT SILT/CLAY	TOTAL DEPOSIT RESERVES
021050A		017	14W						24,500
021050B		017	14W						22,500
021050C	107	016	14W	33SW	12.86	10.12	72.88	4.14	
	108	017	14W	08SW					199,350
021050D		016	14W						681,900
021050E	101	015	14W	35NE	38.89	13.30	41.83	5.98	
	102				46.97	13.33	36.48	3.22	
	105	016	14W	15SW					1,788,700
021051A	104	016	14W	11NW					
	106	016	14W	22SE	38.00	8.00	48.08	5.92	1,012,000
021051B	095	015	14W	24SE	27.06	9.80	59.40	3.74	
	097	015	14W	35NE	26.53	8.33	59.28	5.86	
	098				24.03	10.85	62.74	2.39	
	099				24.44	5.73	66.46	3.38	
	100				40.44	8.74	46.27	4.55	
	096	015	14W	36SW	60.88	10.38	25.20	3.54	
	103	016	14W	11SW	33.95	12.01	52.67	1.37	1,131,400
021053		017	14W						132,000
021054		017	14W						100,000
021055		017	14W						49,000
021056		016	14W						368,000
021057		016	14W						70,000
021084		017	14W						65,000
Total Sand & Gravel Reserves - R.M. of Landsdowne									35,419,650

Pebbles - >#8 Canadian Standard Sieve Series
Granules - #10 - #8 Canadian Standard Sieve Series
Sand - #200 - #16 Canadian Standard Sieve Series
Silt/Clay - <#200 Canadian Standard Sieve Series

TABLE 3 - QUALITY AND QUANTITY OF SAND & GRAVEL DEPOSITS OF THE RURAL MUNICIPALITY OF WESTBOURNE

DEPOSIT NUMBER	EXPOSURE NUMBER	TOWNSHIP	RANGE	SECTION	PERCENT PEBBLES	PERCENT GRANULES	PERCENT SAND	PERCENT SILT/CLAY	TOTAL DEPOSIT RESERVES (Cu. m.)
022011		014	09W						9,000
022003C	116	017	12W	31NE	23.83	21.89	49.99	4.29	
	115	017	12W	31SE	12.49	5.98	77.10	4.42	1,390,000
022006		017	12W						10,000
Total Sand & Gravel Reserves - R.M. of Westbourne									1,409,000

TABLE 4 - QUALITY AND QUANTITY OF SAND & GRAVEL DEPOSITS OF THE RURAL MUNICIPALITY OF LAKEVIEW

DEPOSIT NUMBER	EXPOSURE NUMBER	TOWNSHIP	RANGE	SECTION	PERCENT PEBBLES	PERCENT GRANULES	PERCENT SAND	PERCENT SILT/CLAY	TOTAL DEPOSIT RESERVES (Cu. m.)
022009	128	015	09W	30SW	20.50	14.04	63.19	2.26	
	130	015	10W	13SE	30.40	14.04	53.53	2.03	
	125	016	09W	07SW	28.17	11.70	56.72	3.41	2,788,000
022010	127	015	09W	19NE	25.95	11.97	58.31	3.77	
	123	017	09W	07NE	11.66	11.86	73.02	3.46	
	122	017	09W	30SW	12.95	21.52	62.48	3.05	385,650
022011	129	015	09W	20SW	11.65	11.84	73.06	3.45	1,093,600
Total Sand & Gravel Reserves - R.M. of Lakeview									4,267,250

Pebbles - $>$#8 Canadian Standard Sieve Series
Granules - #10 - #8 Canadian Standard Sieve Series
Sand - #200 - #16 Canadian Standard Sieve Series
Silt/Clay - $<$#200 Canadian Standard Sieve Series

TABLE 5 - QUALITY AND QUANTITY OF SAND & GRAVEL DEPOSITS OF THE RURAL MUNICIPALITY OF GLENELLA

DEPOSIT NUMBER	EXPOSURE NUMBER	TOWNSHIP	RANGE	SECTION	PERCENT PEBBLES	PERCENT GRANULES	PERCENT SAND	PERCENT SILT/CLAY	TOTAL DEPOSIT RESERVES (Cu. m.)
021023E		018	14W						948,000
021023F		018	14W						30,000
021023G		018	14W						23,400
021029A		018	14W						239,000
021029B		018	14W						64,000
021029C		018	14W						48,000
021029D		018	14W						5,612,250
021030		018	14W						27,800
021031		018	14W						77,000
021035		018	14W						128,000
021036A	110	018	14W	03NE	6.38	2.21	88.98	2.43	123,200
021039		018	14W						195,000
021042A		018	14W						62,500
021042B		018	14W						8,400
021100		018	14W						270,000
021101		018	14W						480,000
021201		018	14W						170,000
021202		018	14W						85,000
022001B	120	018	13W	08SW	19.12	18.68	57.20	4.99	
	119	018	13W	20NW	47.26	10.81	39.43	2.50	52,566,000
022003B	117	018	13W	12NE	35.10	8.49	53.38	3.04	16,920,500
022003C		018	12W						6,765,000
022005	118	018	13W	25NE	25.48	7.56	64.99	1.96	564,000
022006		018	12W						1,580,000
021015A		019	14W						45,000
021015B		019	14W						20,000
021021A		019	14W						77,000
021022		019	14W						92,000
022005		019	13W						684,500
Total Sand & Gravel Reserves - R.M. of Glenella									87,905,550

Pebbles - >#8 Canadian Standard Sieve Series
Granules - #10 - #8 Canadian Standard Sieve Series
Sand - #200 - #16 Canadian Standard Sieve Series
Silt/Clay - <#200 Canadian Standard Sieve Series

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Appendix A

FORM 1

SAND & GRAVEL INVENTORY

DEPOSIT STATUS

DEPOSIT NO: ______ __ SUB

LANDFORM __ (if Z specify ______________________)

COMPLETELY DEFINED __ (Y, N)

OWNERSHIP & RESERVES

LOCATION							OWNERSHIP				
TWP	RNG	SCT	¼ SCT	APPROXIMATE AREA (HA.)	AVERAGE DEPTH (m.)	% DEPLETED NOT AVAILABLE					

FORM 2

SAND AND GRAVEL INVENTORY

EXPOSURE–STRATIGRAPHIC SECTION DATA

DEPOSIT NO. SUB

TOWNSHIP RANGE SECTION 1/4 SECTION

EXPOSURE NO.

EXPOSURE TYPE | MATERIAL USE | LAND USE | THICKNESS OF ECONOMIC UNIT (m.) | VISUAL QUALITY | Y M D DATE EXAMINED

MATERIAL DESCRIPTION

COMMENTS

STRATIGRAPHIC SECTION

GEOLOGIST | HEIGHT OF SECTION | HEIGHT EXAMINED (m.) | DEPTH TO WATER TABLE (m.)

MATERIAL AT BASE OF SECTION

% LITHOLOGY % LITHOLOGY

PRIMARY SECONDARY

GROSS LITHOLOGY

PRIMARY SECONDARY

DELETERIOUS SUBSTANCES

CHANNEL SAMPLE (Y,N)

CHECK

MATERIAL LARGER THAN 15CM AVAILABLE BUT NOT SAMPLED

STRATIGRAPHIC SECTION

GEOLOGIST | HEIGHT OF SECTION | HEIGHT EXAMINED (m.) | DEPTH TO WATER TABLE (m.)

MATERIAL AT BASE OF SECTION

% LITHOLOGY % LITHOLOGY

PRIMARY SECONDARY

GROSS LITHOLOGY

PRIMARY SECONDARY

DELETERIOUS SUBSTANCES

CHANNEL SAMPLE (Y,N)

CHECK

MATERIAL LARGER THAN 15CM AVAILABLE BUT NOT SAMPLED

SAND AND GRAVEL INVENTORY **FORM 3**

QUATERNARY GEOLOGY (SUB-UNIT DATA)

DEPOSIT	SUB

TOWNSHIP	RANGE	SECTION	1/4 SECTION

EXPOSURE

STRAT. SECTION

	TOP (m.)	BOTTOM (m.)	DELETERIOUS SUBSTANCES	LITHO-MORPHOLOGY				COHESION	ACID REACTION (N,W,S)	SEDIMENT TYPE	SEDIMENTARY STRUCTURE	NATURE OF DEPOSITIONAL INTERFACE	POST-DEPOSITIONAL STRUCTURE/WEATHERING	PALEOFLOW DIRECTION	DIP		NO. OF STRAT. SAMPLES
				%	LITHOLOGY	ROUNDNESS	CLAST SHAPE								DEGREES	DIRECTION	
1.																	
2.																	
3.																	
4.																	
5.																	
6.																	
7.																	
8.																	
9.																	
10.																	

SAND AND GRAVEL INVENTORY

QUATERNARY GEOLOGY (SUB-UNIT DATA)

FORM 3

DEPOSIT	SUB

TOWNSHIP	RANGE	SECTION	1/4 SECTION

EXPOSURE

STRAT. SECTION

	TOP (m.)	BOTTOM (m.)	DELETERIOUS SUBSTANCES	LITHO-MORPHOLOGY				COHESION	ACID REACTION (N,W,S)	SEDIMENT TYPE	SEDIMENTARY STRUCTURE	NATURE OF DEPOSITIONAL INTERFACE	POST-DEPOSITIONAL STRUCTURE/WEATHERING	PALEOFLOW DIRECTION	DIP		NO. OF STRAT. SAMPLES
				%	LITHOLOGY	ROUNDNESS	CLAST SHAPE								DEGREES	DIRECTION	
1.																	
2.																	
3.																	
4.																	
5.																	
6.																	
7.																	
8.																	
9.																	
10.																	

SIEVE ANALYSIS

	DEPOSIT NO.	SUB	TWP.	RNG.	SCT.	¼ SCT.	EXPOSURE	STRAT. SCT.
SAMPLE NO.								

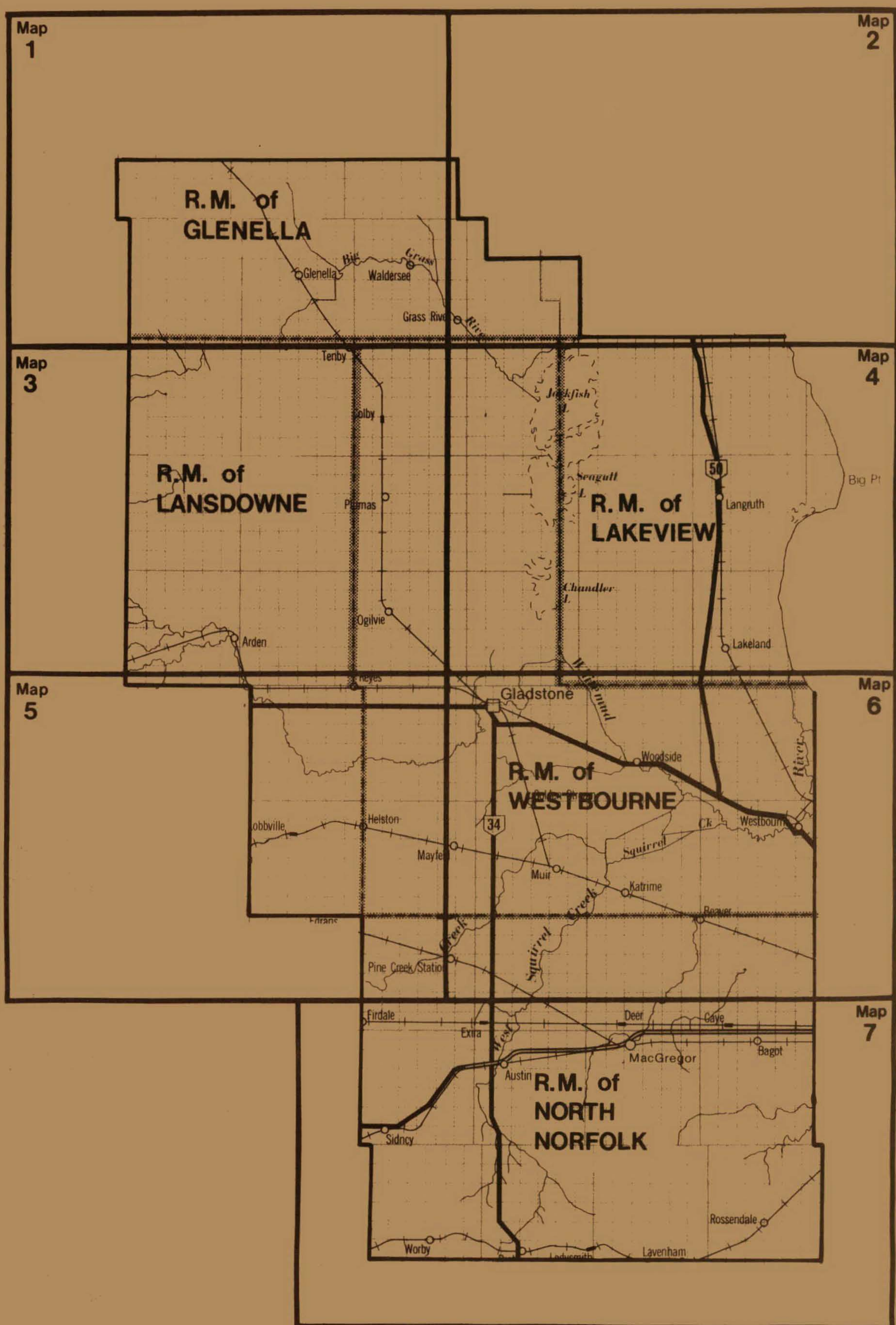
NAME ____________________

CRUSHABLE MATERIAL ☐ (Y,N) (1,0)

WEIGHT OF FINE FRACTION __________ GMS.

WEIGHT BEFORE WASHING __________ GMS. WEIGHT AFTER WASHING __________ GMS.

Screen	mm	phi units	Weight on Sieve (Gms.)	
4"	101.6	-6.65		COARSE FRACTION
3½"	88.9	-6.47		
3"	76.2	-6.25		
2½"	63.5	-6.00		
2"	50.8	-5.67		
1½"	38.1	-5.25		
1"	25.4	-4.67		
3/4"	19.1	-4.25		
5/8"	15.9	-4.00		FINE FRACTION
1/2"	12.7	-3.67		
3/8"	9.5	-3.25		
1/4"	6.35	-2.67		
#4	4.76	-2.25		
#8	2.38	-1.25		
#10	2.00	-1.00		
#16	1.19	-0.25		
#30	0.59	+0.75		
#40	0.42	+1.25		
#50	0.30	+1.75		
#80	0.177	+2.50		
#100	0.149	+2.75		
#200	0.074	+3.75		
<200				



SURFICIAL GEOLOGY INDEX MAP