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DEPARTMENT OF ENERGY AND MINES

MINERAL RESOURCES DIVISION

GEOLOGICAL REPORT

GR80-2

SAND AND GRAVEL RESOURCES AND QUATERNARY GEOLOGY OF THE PAS REGION

by

Vernon Singhroy and Richard Werstler

1980

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PREFACE

The report "Sand and Gravel Resources and Quaternary Geology of The Pas Region" was written jointly by Vernon Singhroy, who undertook the geological investigation and assessment of gravel reserves in the area, and Richard Werstler, who developed a methodology for determining aggregate demand information in Manitoba pertaining to small towns, particularly The Pas.

This study, the first of its kind to be published by the Mineral Resources Division, is aimed at providing detailed information on gravel deposits to the construction industry, basic data on gravel management to resource and land use planners, and scientific data on the Quaternary geology of the area. The results have already been used to formulate an aggregate resource management proposal for The Pas region.

Susan Ringrose,
Mineral Resources Division,
Winnipeg, January, 1980.

PART A

QUATERNARY GEOLOGY OF THE PAS REGION

by
V. Singhroy

INTRODUCTION

OBJECTIVES

The objectives of this study are to establish the Quaternary stratigraphy and to provide a surficial geology map of The Pas region and to provide a detailed base of sand and gravel resources information for use in aggregate resources and land use planning activities.

This report deals with the distribution, the properties and the relationships of surficial sediments in The Pas region. A description of the bedrock geology is followed by detailed analysis of the Quaternary geology. A reconstruction of the glacial history of the area is proposed and an evaluation undertaken of all surficial deposits with particular reference to sand and gravel resources.

LOCATION AND ACCESS

The Pas region, comprising 10,498 km^2 in northwestern Manitoba, lies between 50° 30′ and 54° 30′ north latitude and between 101° west longitude and the Saskatchewan-Manitoba boundary (Fig. 1). This region occupies about 50 Townships extending between Townships 50 and 63 and Ranges 24 to 29 West. Two map sheets comprise the study region: NW¼ 63F and SW¼ 63K. (These are presented at the 1:100 000 scale and are in the pocket of this report). The town of The Pas lies in the centre of the region.

Access throughout the region is by primary and secondary highways, and a number of forestry roads. Provincial Trunk Highway #10 divides the region into east and west sections. Three secondary highways radiate from the town of The Pas, providing access.

PHYSIOGRAPHY

The study region is divided into three physiographic subregions (Fig. 1): The Pas Moraine, the Saskatchewan River flood plain, and the hummocky ground moraine in the Cormorant-Rocky Lakes area.

The Pas Moraine is the highest topographic feature in the area, ranging from 272 to 330 m above sea level. The moraine, which is from 8 to 16 km wide, forms a convex escarpment facing south-west and rises between 25 and 33 m above the surrounding country. This feature extends from 15 km northeast of Wanless to Longpoint, on the west shore of Lake Winnipeg, over a total distance of 320 km. It is composed of poorly drained clayey till which forms a series of parallel northeast to southwest oriented flutings indicative of the direction of the last ice movement. A series of beach ridges have been created on the flanks of the moraine.

The alluvial flood plain of the Saskatchewan River is a flat, poorly drained area comprising the Pasquia basin, Rahls Island and the Saskatchewan River delta. The Pasquia basin is approximately 242 m above sea level, and is drained by the Saskatchewan, Pasquia and Carrot Rivers. Numerous meander scrolls (Plate 1A in Appendix A), abandoned channels and shallow lakes fringed by bogs occur within the Pasquia area. In the southwest nine drumlins, with general orientation of 339°, rise 4 to 15 m above the surrounding country. Rahls Island forms a partially drained agricultural belt east of The Pas, bounded by the Saskatchewan River on the northeast, Grace Lake on the west and Montreal Lake on the south. The Saskatchewan River delta, covering over 1500 km^2, extends from Kelsey Lake in the west to Moose Lake in the east and encompasses the northwestern portion of Cedar Lake. The delta is characterized by numerous distributaries and shallow muddy lakes.

PREVIOUS WORK

References have been made to The Pas moraine and its relationship to ice movements by Dowling (1900), McInnes (1913), and Antevs (1931). More recently, Craig (1965), Klassen (1965 and 1967), Elson (1967) and Tarnocai (1975) have provided additional information on the glacial history and surficial materials. Ritchie and Koivo (1975) have applied radiocarbon date analyses to sediments in the area. Aspects of the geohydrology have been studied by staff of the Prairie Farm Rehabilitation Administration since 1951 for reclamation projects in the Pasquia area. Pedersen (1973) has investigated the availability of groundwater. Baille (1951) and Davies et al. (1962) have described the Paleozoic bedrock. Ehrlich et al. (1960) have provided a detailed soil survey of the Pasquia map area and Tarnocai (1975) has published an interim soils report of the Cormorant Lake area.

MAPPING METHODS

Geological field investigations took place between May and September, 1976. Map units were determined in the field and delineated from panchromatic township photos at a scale of 1:31 680. Colour infra-red photographs at a scale of 1:125 000, flown in September 1976, were used in the delineation of geological contacts. Landsat enhancement techniques (Singhroy and Ringrose, 1976) and digital processing of Landsat data (Singhroy and Bruce, 1977) provided inventory information on sand and gravel pits, limestone quarries, regional Quaternary geology and aided in the identification of glacial, fluvial and organic deposits. Seismic refraction data were collected from 54 sites and electrical resistivity data from 112 sites. These were used to determine approximate thicknesses of sand, gravel and other surficial sediments (see Appendix E). An Atlas Copco Minute-man portable auger was used to obtain samples from 25 holes in the Pasquia basin and along The Pas Moraine. Thirty five test pits were dug with a backhoe to determine the approximate thickness of sand and gravel deposits. Additional field data were obtained through examination of road cuts, sand and gravel pits and natural exposures. A total of 355 sites were examined and sampled. Water well records, soils maps and foundation investigations were also used in this survey. Laboratory analyses of 135 samples consisted of pebble counts and particle size determination (sieving and pipette analysis).

A report of field activities (Singhroy, 1976) and a series of nine preliminary maps at a scale of 1:50 000 (Singhroy, 1977) were previously published.

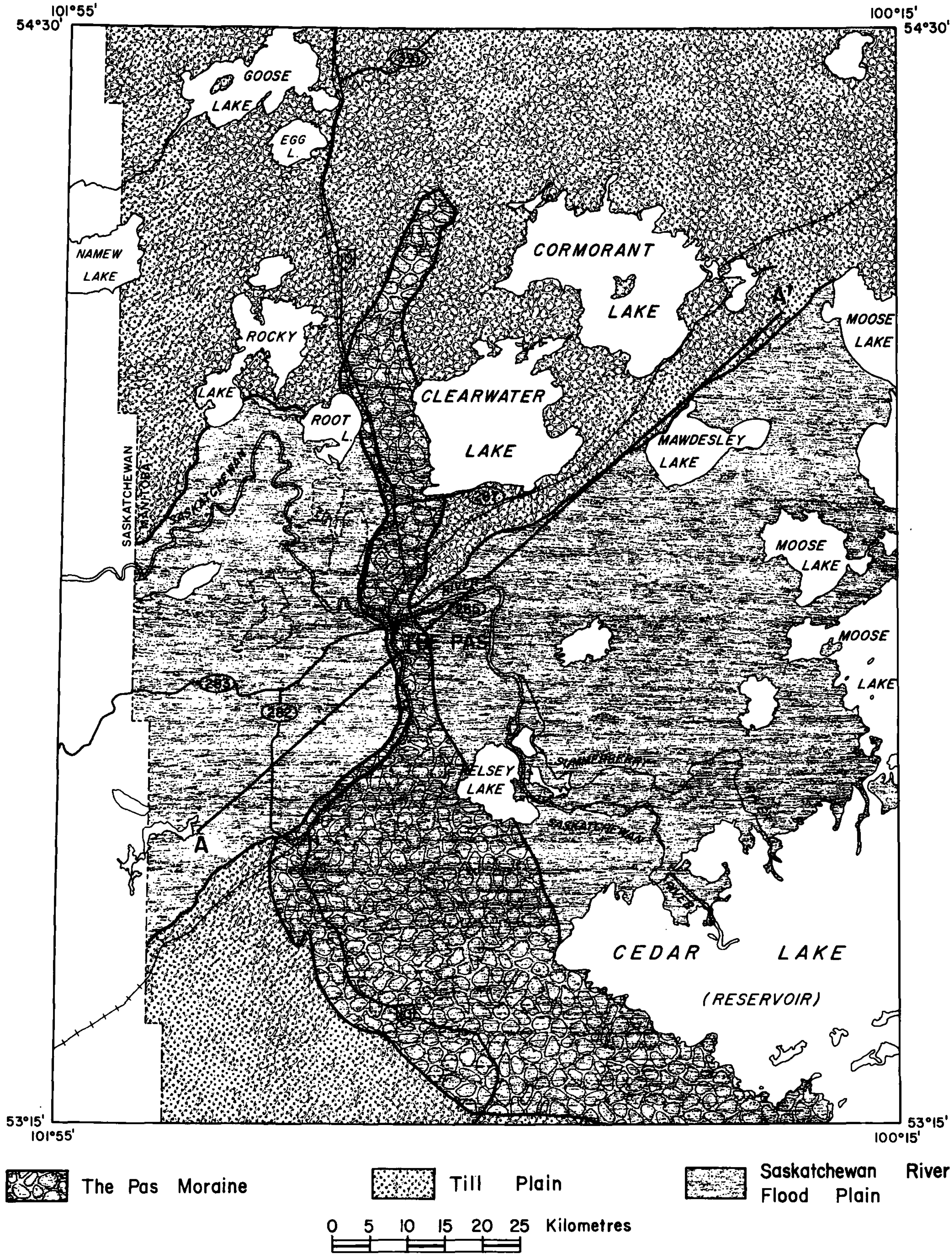

FIGURE 1. Physiographic sub-regions of The Pas Study Region (section AA' shown as Figure 5)

QUATERNARY GEOLOGY

A summary description of the Quaternary deposits found in The Pas region is presented as Table 1. A detailed account of observations made in pits, backhoe test holes and from drill logs is recorded as Appendix B. Appendix C presents tabulated sediment analyses and an illustration of textural characteristics of the sediments.

The following sections describe the sedimentary characteristics of each stratigraphic unit found in The Pas area, including a brief discussion of the bedrock geology.

BEDROCK GEOLOGY (Unit 1)

Ordovician and Silurian bedrock predominates within the map area. The bedrock surface is flat in the north half of the region (Plate 1B) and slopes south towards the Pasquia basin. Drill data around The Pas (Ehrlich et al, 1960 and Pedersen, 1973) show that The Pas Moraine is controlled by a bedrock ridge dipping eastwards towards Kelsey and Cedar Lakes. Outcrops are common above 272 m above sea level in the Cormorant-Clearwater-Yawningstone Lakes area, the Rocky-Atik Lakes area, and the area southwest of Bignell Lake.

In the Cormorant-Yawningstone Lakes area, outcrops of the Red River Formation are characteristically flat and smooth with a rectangular jointing pattern and numerous striae (averaging 038°; Plate 1B). Plate 2A illustrates the thinly bedded Red River Formation exposed in the Wanless Quarry, located in NE¼ 36-59-26W* (see Map 1, in pocket). In the Rocky-Atik Lakes area, mottled dolomite occurs along lake shorelines, and fossil-rich dolomite is exposed under thin glaciolacustrine deposits between Atik and Namew Lakes. In the area south of Bignell Lake, outcrops of the Stonewall Formation show evidence of karren development. Numerous solution holes, up to 6 cm long and 3 cm deep, form a complex group of micro-karst features on the yellowish-brown mottled surface of the dolomite outcrop.

GLACIAL DEPOSITS (Unit 2)

Three till units have been recognized in The Pas area. The upper and ablation tills were deposited during the latest ice advance from the northeast. The lower till is believed to have been deposited during an earlier ice advance from the northwest.

LOWER TILL (Unit 2a)

The oldest glacial deposit observed in The Pas area is a very calcareous, pale to yellowish-brown (10YR 6/4)=, oxidized, stony till. It occurs below the clayey (2b) till of The Pas Moraine and is underlain by Paleozoic bedrock. Oxidized till was observed in a backhoe pit at NW¼28-59-26W, approximately 8 km southeast of Wanless, and at the surface and under gravel outwash in two drumlins in the Pasquia basin at 14-53-29W and 22-55-29W. This yellowish-brown till deposited in the drumlins of the Pasquia basin was recorded by Craig (1965). Similar oxidized till was logged by the

*Locations are given by quarter, section, township and range. All locations are west of the principal meridian.

=Munsell colour standards.

TABLE 1. SUMMARY OF QUATERNARY DEPOSITS IN THE PAS REGION

MAXIMUM THICKNESS	STRATIGRAPHIC UNIT	DEPOSITIONAL ENVIRONMENT	MATERIALS	MORPHOLOGIC EXPRESSION
5m	9	Organic deposits	Feather and sphagnum-mosses	Fens and bogs
15	8	Alluvial deposits	Sand, gravel, silt, clay	Flood plains, deltas and river terraces
5	7	Eolian deposits	Medium to fine sand	Dunes
10	6	Littoral deposits	Sand, gravel	Beach ridges
38	5	Lacustrine deposits	Silt, clay	Lake plain
		Glaciofluvial and Proglacial		
5	4	Glaciolacustrine deposits	Silt, clay, sand, gravel	Glaciolacustrine plain
5	3	Glaciofluvial deposits	Sand, gravel	Outwash plains, kames and eskers
		Glacial		
1	2c	Ablation till	Sand, gravel, boulders	Isolated pockets in till sheet
6	2b	Upper till	Sand, clay, silt, boulders	End and ground moraine
15	2a	Lower till	Oxidized sand, silt, boulders	Drumlins
	1	Paleozoic bedrock	Dolomite	Bedrock ridges and outcrops

Manitoba Water Resources Branch in 1973, occurring at depths between 8 and 64 m and overlain by lacustrine clay in the Pasquia basin, and by a clayey till on The Pas Moraine. Ripley, Klohn and Leonoff (1969) describe this till as "a clayey-silt binder, tan, very stiff to hard, containing boulders varying from 1.0 to 1.4 m in diameter, with moisture content* less than 10%, and unconfined compressive strength greater than 4½ tons per sq. ft.". Klassen (1965) recorded a similar, oxidized till, overlain by clayey till in the Grand Rapids area.

Textural analyses of six samples (Appendix C)! show a large size range. Gravel content (particles larger than 2mm) ranges between 26 and 74 percent, sand between 15 and 58 percent and silt and clay between 26 and 68 percent. Dolomite clasts from the underlying bedrock constitutes 85 to 90 percent of the gravel fraction of the till, and the remaining 10 to 15 percent comprises Shield-derived clasts. The sand fraction of the till generally shows a platykurtic, finely skewed distribution, is poorly sorted (with values ranging from 0.9 to 1.1), ranges in size from 1.3 to 1.9 phi, and is unimodal or bimodal. Figure 2 illustrates the distribution of the sand size fraction of all till samples.

UPPER TILL (Unit 2b)

The Pas Moraine and the surrounding (2a) till plain is covered by light grey (10 YR 7/2), calcareous, clayey till (Plate 2B). The till consists of 90 to 95 percent subrounded to angular Paleozoic clasts and 5 to 10 percent Precambrian material. The results of grain size analysis of 5 samples show a variability in texture. Particles larger than 2 mm vary from 14 to 39 percent, sand content from 11 to 55 percent and silt and clay content from 23 to 64 percent (Appendix C).

Analysis of the sand fraction shows poor sorting (with values ranging from 0.9 to 1.3), fine to coarse skewed distributions and a mean diameter ranging between 1.5 and 1.8 phi. Distributions shown on the histograms (Figure 2c) are all unimodal.

A sand thickness of 1 m above dolomite bedrock was recorded from a backhoe section south of Clearwater Lake at NW¼18-58-25W. Pedersen (1973) recorded 6 m of clayey till above the oxidized till at NE¼10-56-26W on the crest of The Pas Moraine. Ripley et al. (1969) recorded 2 m of highly plastic till over harder till at SE¼26-56-26W.

ABLATION TILL (Unit 2c)

Isolated pockets of (2c) ablation till are found associated with the clayey (2b) upper till. This calcareous, light yellowish-brown (10YR 6/4), stony, sandy till consists of large, rounded to angular, carbonate and Precambrian boulders (Plate 3A). Pebble counts show that carbonates vary from 70 to 90% and crystalline pebbles between 10 and 30%. Sand within the till is moderately to poorly sorted (Figure 2d), comprising between 50 to 56% of each sample. Gravel varies from 24 to 31 percent and silt and clay between 10 and 18 percent (Appendix C).

Ablation till is not extensive, occurring in shallow pockets on the sloping terrain and sometimes on the crest of flutings on The Pas Moraine. This till is not shown on the maps mainly because of its very local occurrence.

GLACIOFLUVIAL AND PROGLACIAL DEPOSITS (Unit 3)

Deposits of glaciofluvial origin in The Pas area consist of eskers, kames and outwash plains.

ESKERS

Ten minor eskers are found in the area. Eight eskers are situated on the eastern slope of The Pas Moraine, one is found to the northeast and the other to the southeast of Egg Lake. The eskers on The Pas Moraine are low, straight and discontinuous, often with bifurcating ridges which sometimes terminate as small deltas. The ridges are approximately 3 m in height and vary from 12 to 20 m in width. Textural analysis of the esker sediments shows the composition to be between 55 and 78 percent gravel, 19 to 40 percent sand and less than 3 percent silt and clay. The sand is very platykurtic, finely skewed, with poor sorting (1.1 — 1.3), a mean diameter ranging from 1.4 to 1.8 phi and no distinct mode (Figure 3). Pebbles are subangular to subrounded consisting of between 80 and 85 percent carbonates and between 15 and 20 percent Precambrian material (Appendix C).

The esker located northeast of Egg Lake (Deposit #31024 on Map 2, in pocket) forms a series of straight, elongated ridges varying from 2 to 4 m in height and 10 to 20 m in width. Textural analyses (Appendix C) show the composition to be 70 percent gravel and 30 percent sand. The sand fraction is very well sorted with a mean diameter of 1.2 phi. Pebbles are subangular to subrounded, consisting of 40 percent Precambrian material and 60 percent carbonates (Plate 3B). This relatively high percentage of Precambrian material in the esker sediments is due to its proximity to the Shield.

The esker to the southeast of Egg Lake (Deposit #31023) is more sinuous, low lying and sandy.

KAMES

Two small isolated kames, consisting of stratified sand and gravel, occur at SE¼12-61-27W and SE¼3-58-25W.

Sections observed in a gravel pit show that a southern kame (Deposit #31006 on Map 2) consists of an upper gravelly sand unit and a lower coarser gravel unit, underlain by a compact clayey till (Plate 4A). Gravel content ranges from 63 to 88 percent, sand from 20 to 50 percent and silt, less than 5 percent. Textural analyses show that the sand fraction is strongly finely skewed, moderately well sorted, with a mean diameter varying from 1 to 0.9 phi (Appendix C; Figure 3).

Pebble counts from the northern kame (Deposit #31022, Map 2) indicate that 45 percent of the clasts are granitic and 55 percent are carbonates, likely due to the short distance from the Shield. Grain size analyses of this feature indicate that the gravel content comprises 46 to 80 percent of the material, sand, 17 to 48 percent and silt, less than 4 percent.

OUTWASH

Glaciofluvial outwash deposits comprise a relatively small percentage of surficial material (within the map area). Three categories of deposit have been identified, based on sediment characteristics and size:

(i) A relatively large outwash plain occupies portions of sections 28, 29 and 33 of Townships 63, Range 25 West and continues as an apron along Highway 391, south of Simonhouse Lake. The sediment is predominantly coarse sand with minor gravel. The sand is moderately well sorted, finely skewed, with mean diameter of the particles varying between 0.9 and 1.7 phi (Figure 3c).

(ii) A smaller pebbly sand outwash plain, associated with meltwater channels, is found southwest of Athapapuskow Lake covering portions of sections 28, 29, 30 and 33 of 63-29 West. Gravel content of the sampled material is highly variable from 1 to 40 percent. Sand constitutes from 35 to 98 percent, and silt, less than 2 percent. The pebbles are subangular, indicating deposition near the ice front with very little subsequent reworking by meltwater. The sand is moderately sorted with mean size varying between 1.23 to 1.66 phi.

(iii) Small gravelly outwash deposits occur throughout the northern and eastern portions of the study region. The thickness of these sediments varies from 0.4 m (at the Melange deposit SW¼

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*Moisture content in percent dry weight.

!Textural terminology defined by Folk (1968).

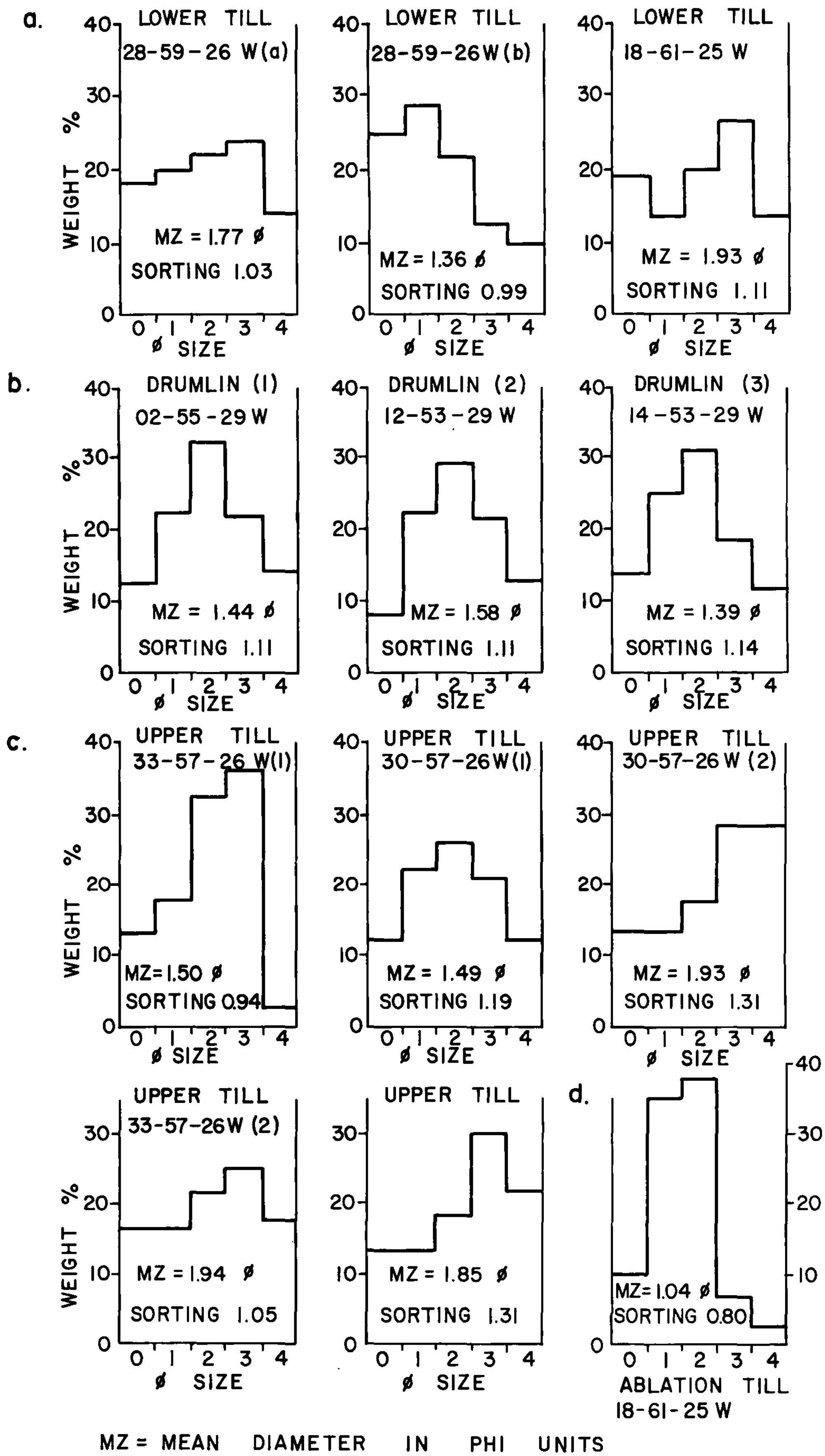


FIGURE 2. Distribution of Sand in Tills

33-57-24W; Plate 4B) to 4.0 m (SW¼10 and 11-58-24W). Sorting is highly variable, ranging from poorly sorted sand and gravel of the Melange deposit to moderately sorted stratified sand and gravel of the Finger deposit (SE¼13-58-24W). Sediment analysis shows that gravel constitutes from 60 to 70 percent, sand 23 to 31 percent, and silt and clay, 8 percent of the material (Appendix C). Pebble counts are high in dolomite (90 percent) and low in Precambrian material (10 percent).

A small sand plain located in section 36-57-25W, has a sediment composition of 6 percent gravel, 92 percent sand, 1 percent silt and 1 percent clay.

GLACIOLACUSTRINE DEPOSITS (Unit 4)

Extensive areas of glaciolacustrine sediments are found in the Rocky-Atik Lakes and Wanless area (Plate 5A). The deposit comprises a light brownish grey (2.5YR 6/2), weakly calcareous clay that is very sticky when wet. Sediment analyses show that the silt and clay content varies from 75 to 80 percent, sand between 3 and 15 percent and fine gravel between 6 to 8 percent. The sand is poorly sorted with mean particle size ranging between 1.52 and 1.84 phi (Figure 3d). Analyses of soil profiles in the Rocky-Atik Lakes area (Tarnocai, 1975) show an increase in the clay content with depth varying from 36 to 84 percent and silt from 14 to 27 percent.

The thickness of glaciolacustrine sediment ranges from 60 cm to 80 cm, over dolomite bedrock west of Atik Lake. This shallow deposit is associated with carbonate boulders of varying sizes, and small pockets of outwash. Thicknesses of 1 to 3 m of glaciolacustrine clay were recorded southeast of Rocky Lake, where an absence of large boulders was noted.

LACUSTRINE DEPOSITS (Unit 5)

Lacustrine sediments are rarely found exposed on the surface in the Wanless area, and are overlain by alluvial sediment in the Pasquia and Cedar Lake areas. In the Wanless area, the sediment forms a blocky, stone free, pale brown (10YR 6/3), moderately calcareous clay. In the Pasquia basin, the sediment is 150 m thick, and can be subdivided into two units based on colour and composition. These are a grey silty clay and silt unit and a grey clay and silty clay unit (Pedersen, 1973). At SE¼ 21-56-25W, 30 m of lacustrine clay overlying till was intersected at a depth of 150 m (Pedersen, 1973).

LITTORAL DEPOSITS (Unit 6)

Continuous beach ridge deposition is found on the crest and west side of The Pas Moraine extending along the Easterville road and Highway 10 to north of Westray. Discontinuous beach ridges extend north of the junction of the Easterville road and Highway 10 to Freshford. North of The Pas, beach ridges extend from the Big Eddy Indian Reserve, along Highway 10 to Prospector. From Prospector, the feature extends along the Canadian National Railway to the northwest. Seven ridges have been identified 6 km north of The Pas. Heights of these ridges varies between 2 and 10 m, and width, between 6 and 20 m.

The beach ridges which comprise Lake Agassiz shorelines, provide the main source of sand and gravel to the area. The sediment composition is highly variable. Gravel constitutes the largest proportion, ranging from 35 to 95 percent; sand from 5 to 65 percent; and silt less than 5 percent (Appendix C). Mean particle size of beach sand samples varies from 0.02 to 1.86 phi (Figure 4). The sand fraction is very well to moderately sorted (with values ranging between 0.02 to 0.99). Pebble counts show high (80 percent) carbonate and low (20 percent) Precambrian content. Pebbles and cobbles are rounded to subrounded (Plate 5B).

Horizontal bedding is characteristic of Lake Agassiz beach ridges in the area (Plate 6A). Interbedded sand and gravel ranges in thickness from 10 cm to 1 m. Textural analysis and field observations show a fining upward sequence from gravel to sand. In the Root Lake ridges, 8 km east of Highway 10, well sorted sand beds, 3 m thick, were observed (Plate 6B). The horizontally bedded sand is differentiated by light and heavy minerals.

EOLIAN DEPOSITS (Unit 7)

The eolian sand is derived from beach sediments. Dunes occur in the Big Eddy Reserve at NE¼ 25-56-27W, and in the cemetery area, 0.9 km south of The Pas at NE¼ 27-55-26W. The sand is uniform, moderately sorted (0.52) with a mean size of 1.75 phi. Textural analysis of sand samples shows a composition of 72 percent medium sand, 24 percent fine sand, 1 percent very fine sand and 3 percent silt (Appendix C).

ALLUVIAL DEPOSITS (Unit 8)

Recent alluvial sediments are extensive in the map area. They occur throughout the Pasquia basin and the Cedar Lake basin.

According to drill data (Ehrlich et al, 1960), alluvial sediment reaches a thickness of 18 m in the Pasquia area. The sediment is light brownish grey (2.5YR 6/2), very calcareous, ranging from gravel and sand to clay. Sieve analyses show that sediment in the Cedar Lake area (30-59-26W) has a composition of 2 to 15 percent sand, 17 to 45 percent silt and 39 to 83 percent clay (Tarnocai 1975). Deposits on point bars, levees and meander scrolls are coarser with minor lag gravel associated with near-shore alluvial sand.

ORGANIC DEPOSITS (Unit 9)

Recent organic deposits consist of sphagnum and forest peat associated with black spruce bogs (Unit 9a), sphagnum and feather mosses occurring in fens (Unit 9b), and muck and shallow peat occurring in swamps (Unit 9c). These deposits exist in local depressions where a high water table is conducive to the growth of sphagnum and feather mosses.

Analysis of peat samples taken from different locations (Appendix D), shows that sphagnum varies from 1 to 79 percent, reed and sedge from 1 to 76 percent, and wood fragments from 1 to 30 percent. Humification is variable, ranging between 5 and 55 percent, resulting in the tan to dark brown colour of the peat. Thirteen of the 14 samples analysed are acidic. However, each sample exhibits a relatively high absorptive value when calculated on a dry basis and on a 25 percent moisture content (Appendix D).

ICE FLOW FEATURES

Glacial striae were recorded at several locations in the Rocky-Atik Lakes area. At NE¼ 28-60-28W (Plate 7A) three directions were noted. These indicate a movement from the east, with orientation of 290°, followed by a flow from the northwest (140°), and the latest advance from the northeast with an orientation of 222°. Crescentic gouges (Plate 7B), varying from 10 — 25 cm in length, indicate ice movement from the northeast. Asymmetrical grooves, 15 cm long, 2 cm wide and 1 cm deep, with an average orientation of 167°, provide evidence of ice movement from the northwest.

According to Boulton (1976, p. 309), flutings are "neither depositional nor erosional features, but result from post depositional deformation of existing materials". A series of parallel flutings, having northeast to southwest orientation, indicates the direction of ice movement (Plate 8A). These features are perpendicular to The Pas Moraine and dominate the low relief on the east side of the escarpment. They consist of clayey till with heights varying from 0.5 to 2 m, widths from 10 to 30 m, and lengths from 3 to 10 km.

Nine drumlins having a northwest to southeast orientation, averaging 159°, are found in the Pasquia basin. They rise 10 to 25 m above the surrounding alluvial plain and consist of a pale brown silty till with lag gravel deposits on their lee slopes.

GLACIAL HISTORY

Ice flow features indicate three intervals of glaciation. The only observed evidence of the oldest movement from the east was recorded from striae in the Rocky-Atik Lakes area. Klassen (1967)

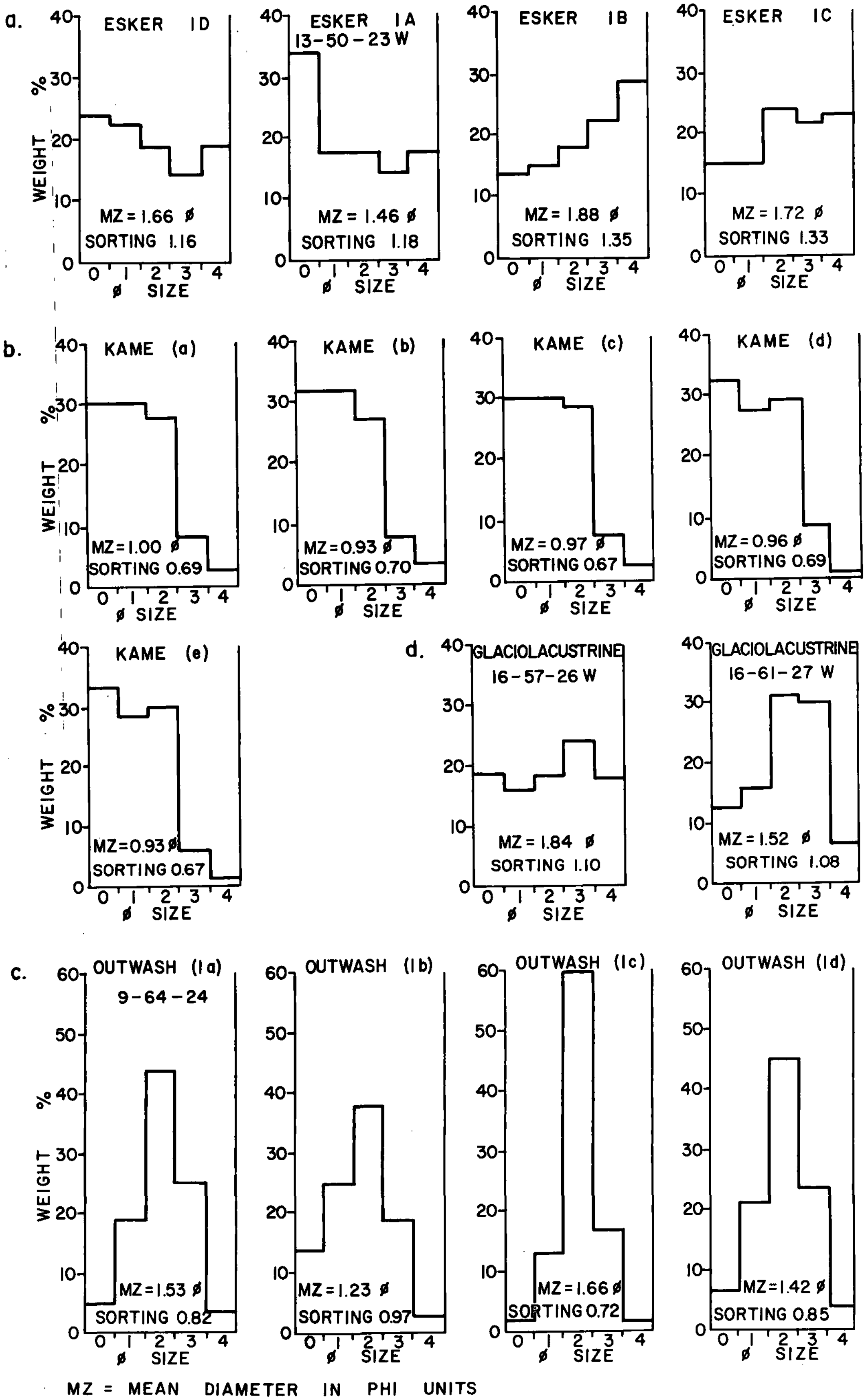
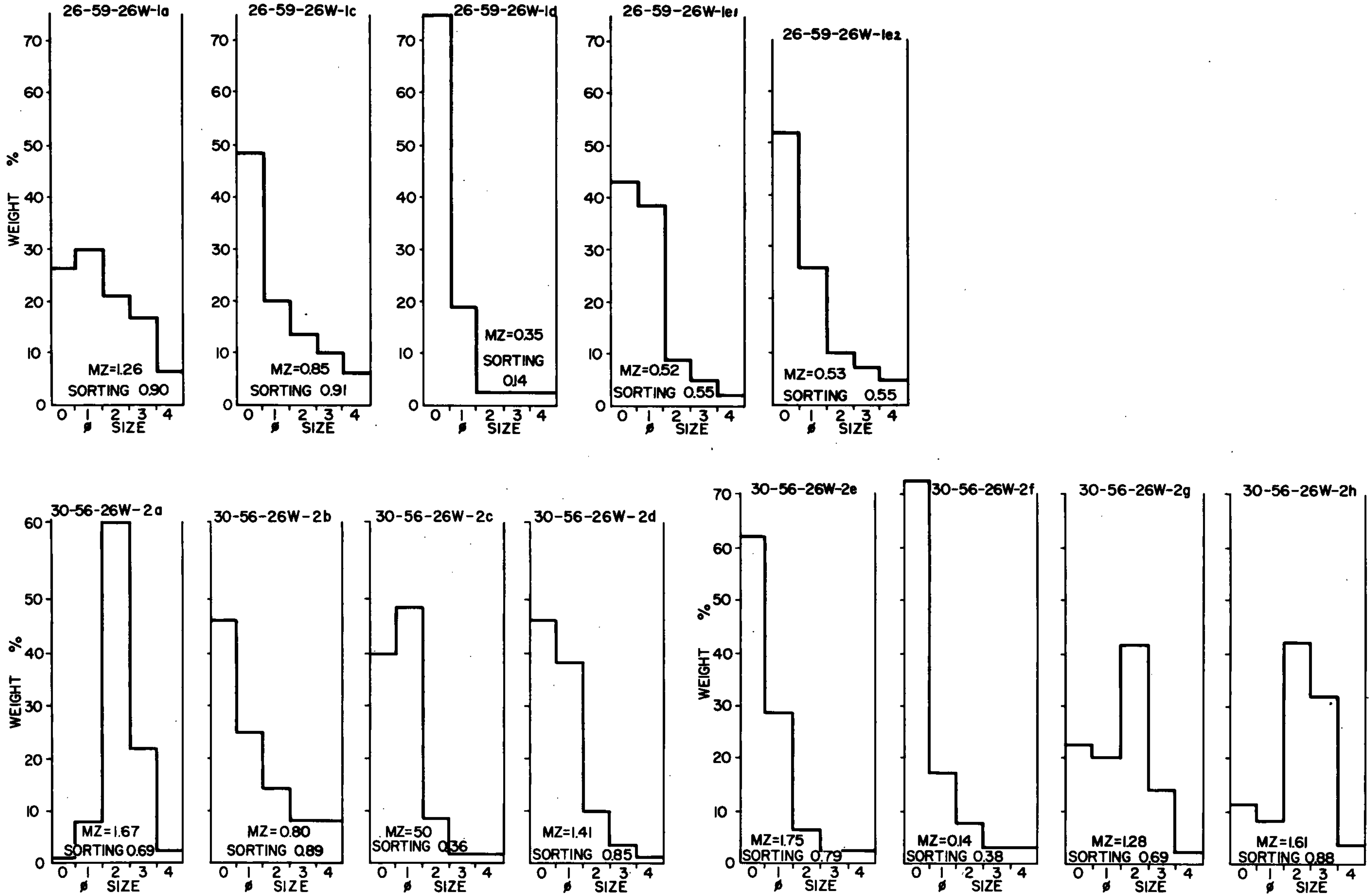


FIGURE 3. Distribution of Sand in Glaciofluvial and Glaciolacustrine Sediments.



MZ= MEAN DIAMETER IN PHI UNITS

FIGURE 4. Distribution of Sand in Littoral Sediments

recorded similar evidence in the Grand Rapids area, to the east of the present study area.

A second advance from the northwest deposited a silty pale brown (lower) till found in drumlins in the Pasquia basin and below clayey till on The Pas Moraine. The northwest-southeast orientation of drumlins in the Pasquia, together with striae in the Rocky Lake area, support this proposed movement from the northwest. The highly oxidized nature of the lower till suggests that a relatively long interval elapsed between deposition of the two ice sheets. Klassen (1967) found evidence of a northwest flow followed by a northeast flow in the Grand Rapids area.

The last ice advance appears to have been from the northeast, indicated by the northeast-southwest series of parallel flutings east of The Pas Moraine (Plate 8A), and numerous northeast-southwest striae west of Rocky Lake. This last ice sheet produced The Pas Moraine around 10,800 years ago (Prest, 1969) and a clayey till sheet that covers the map area. Seismic refraction, electrical resistivity and water well data suggest that the moraine was formed by a build up of till in front of a bedrock escarpment (Figure 5). Klassen (1967) suggests that the clayey till is the result of a thin ice sheet from the northeast that advanced into and over previously deposited lacustrine sediments.

During the period of ice recession, glaciofluvial kames and eskers were deposited intermittently on the eastern side of The Pas moraine. Outwash deposits also accumulated, although the size of deposits suggests that related meltwater activity was minimal.

Evidence that the level of Lake Agassiz was rising during the period of proglacial discharge is represented by a thin layer of glaciolacustrine sediment associated with lacustrine clay in the Wanless-Namew Lake area.

Complete inundation by Lake Agassiz occurred at a later stage and occupied all the low-lying areas below 330 m. Lacustrine deposition appears to have been extensive in pre-existing troughs, as 30 m thicknesses are recorded above oxidized till in the Pasquia basin.

Beach ridges are common in the area. These occur at elevations between 270 m and 330 m, forming discontinuous ridges situated on the flanks of The Pas Moraine. These represent beach levels which span the Grand Rapids, Gimli, Lower Pas and The Pas levels suggested by Elson (1967). It may be inferred that Lake Agassiz drained the area after Grand Rapids time, about 8500 years before present.

The Saskatchewan River later flowed into the extended Cedar Lake, depositing up to 35 m of alluvium over lake clay in the Pasquia basin. This was followed by the development of peat deposits in local bogs and fens. Peat recovered from SW 28-54-27W by auger, below 5 m of alluvium, was dated at 3050 years B.P. (Klassen, 1965, GSC-476).

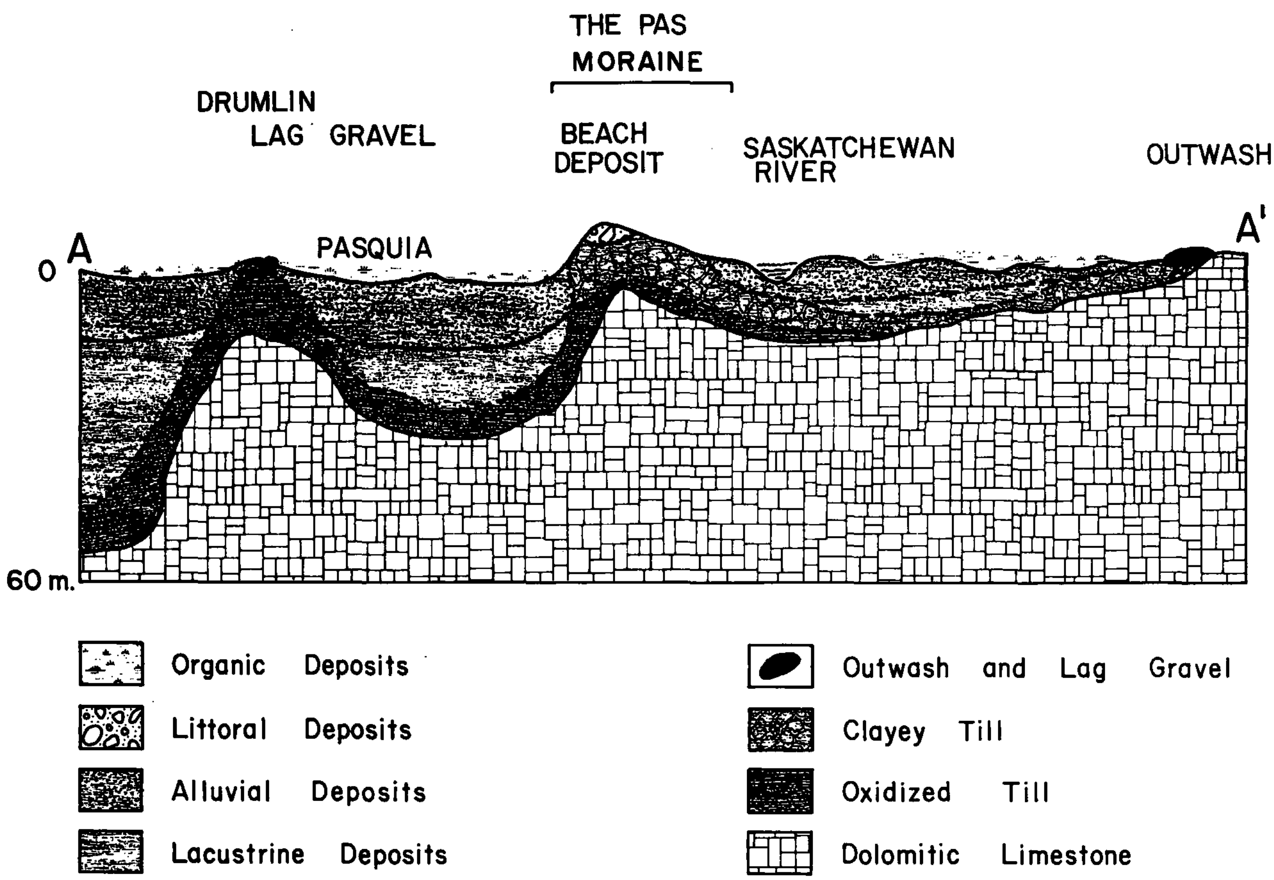


FIGURE 5. Generalized Stratigraphic Section through The Pas Region

EVALUATION OF SURFICIAL DEPOSITS

Surficial deposits of potential economic value in The Pas area include sand and gravel, till and peat. Sand and gravel deposits provide the main source of construction aggregate in the area.

SAND AND GRAVEL DEPOSITS

The principal sources of sand and gravel in The Pas area occur in Lake Agassiz beach ridges and lag beach deposits, outwash pockets, kames, minor eskers and lag gravel deposits associated with drumlins. Forty-four sand and gravel deposits have been identified and are shown on Map 2.

The evaluation of sand and gravel deposits is based on (1) quality, (2) quantity, (3) accessibility and (4) potential industrial use.

QUALITY

Assessment of quality is based on geological parameters. These include size of sediment, amount of deleterious substances within the sediment, degree of weathering and lithology of clasts. Quantification of these parameters is obtained from field observations and laboratory analyses.

Approximately 90 percent of all sand and gravel extracted from within The Pas region is from Lake Agassiz beach ridges. The gravel is characteristically rounded to subrounded, with carbonate clasts comprising from 80 to 95 percent and granitic clasts 5 to 20 percent. Organic material is minimal within the littoral sediments, occurring as very thin lenses within the granular beds, and generally not affecting the overall quality of the deposit.

A size-quality relationship (Figure 6) has been devised to evaluate the quality of a deposit based on the size distribution of sediments. This involves the plotting of the percent gravel, sand and mud on a ternary diagram, which is subdivided into four size categories. Sixty channel samples from 15 deposits were analysed and plotted on the size-quality diagram. Results show that 45 percent of the tested samples may be classified as high quality, 43 percent as medium-high quality and 12 percent as medium-low quality. It must be noted, however, that the distribution of sediments within one deposit may vary markedly. It is not realistic to generalise that each deposit belongs to a single category. This is exemplified by the Big Eddy and Root Lake deposits, samples from each showing a quality classification of high, medium-high and medium-low.

The size-quality relationship technique of evaluation indicates that 90 percent of all littoral sediment lies within high and medium-high categories. Kame and outwash sediments are characteristically in the medium-high range and eolian sand and till in the low category.

QUANTITY

Quantity is estimated from depth and areal extent of each deposit. Depth to water table is obtained from drill logs, excavations, pit faces and geophysical investigations. The area of the deposit is determined from field surveys and air photo interpretation. Table 2 lists a volume estimation for each deposit and Table 3 summarises total estimated reserves of sand and gravel in The Pas area based on quality. Reserve estimates are conservative and include only that portion of the deposit above the local water table. The forty-four deposits mapped total 215 million tonnes of granular material.

ACCESSIBILITY

Accessibility includes locational factors such as proximity to major users and the transportation routes connecting the deposits to the users. Most of the sand and gravel deposits are accessible by roads, although not necessarily all weather roads. About 10 percent of the reserves in the study area lie within a 25 kilometre radius of the Town of The Pas. Accessibility is critical to the aggregate industry in the region, particularly because of the effect of haulage distance on the price of sand and gravel.

INDUSTRIAL USAGE ASSESSMENT

The type of industrial uses for which the sand and gravel is suited is related to the quality of the deposit. Because processing methods can modify sediment to fit a variety of uses, an objective classification is first based on the natural characteristics of the deposit. Specifications for 48 industrial uses are compared with textural parameters of sampled material and a rating index is determined for each deposit.

The industrial usage assessment is based on the number of industrial uses a particular deposit can accommodate. Sediment distribution is the only geological parameter taken into consideration. A computer program has been developed by the Aggregate Resources Section of the Mineral Resources Division which compares specification requirements of 48 different industrial uses with sieve analysis data derived from laboratory testing. The results include individual ratings (suitable, marginal or not suitable) for each use and a positive or negative indication of whether screening is required; whether it is necessary to remove silt and clay from the deposit; whether crushing is required; and whether it is necessary to add fines to meet the specifications for a particular use. Finally, an overall rating is given to the sample analysed, totalling the suitability of the sample for the 48 industrial uses. The ratings ranges from 1 to 9, 1 being the highest indicating material suitable for many uses and 9, the lowest. Table 4 shows a format of the output data included as an example of the Industrial Usage Assessment.

Table 5 summarises data compiled for the evaluation of sand and gravel deposits, and lists a high, medium or low potential for production for each deposit. This value for production is also illustrated on Map 2.

TILL DEPOSITS

Till is being used extensively as fill material by the municipality, local contractors and the Department of Highways. It is sometimes used as foundations for dry weather access roads by Manitoba Forestry Resources Ltd. The extensive use of till produces numerous water filled pits adjacent to roads. The Melange till pit at 33-58-24W, Rahls Island pit 19-56-25W and Rocky Lake pit 19-60-28W are presently being used.

PEAT DEPOSITS

Sphagnum peat occurs in most bogs and fens in The Pas area. No detailed sampling was carried out except in the Big Bog 80 kilometres south of The Pas along P.T.H. No. 10. Appendix D shows the results of peat analyses. Based on these results, only unhumified sphagnum moss at 28-50-25W and 30-50-26W appears to be of sufficient quality for economic extraction.

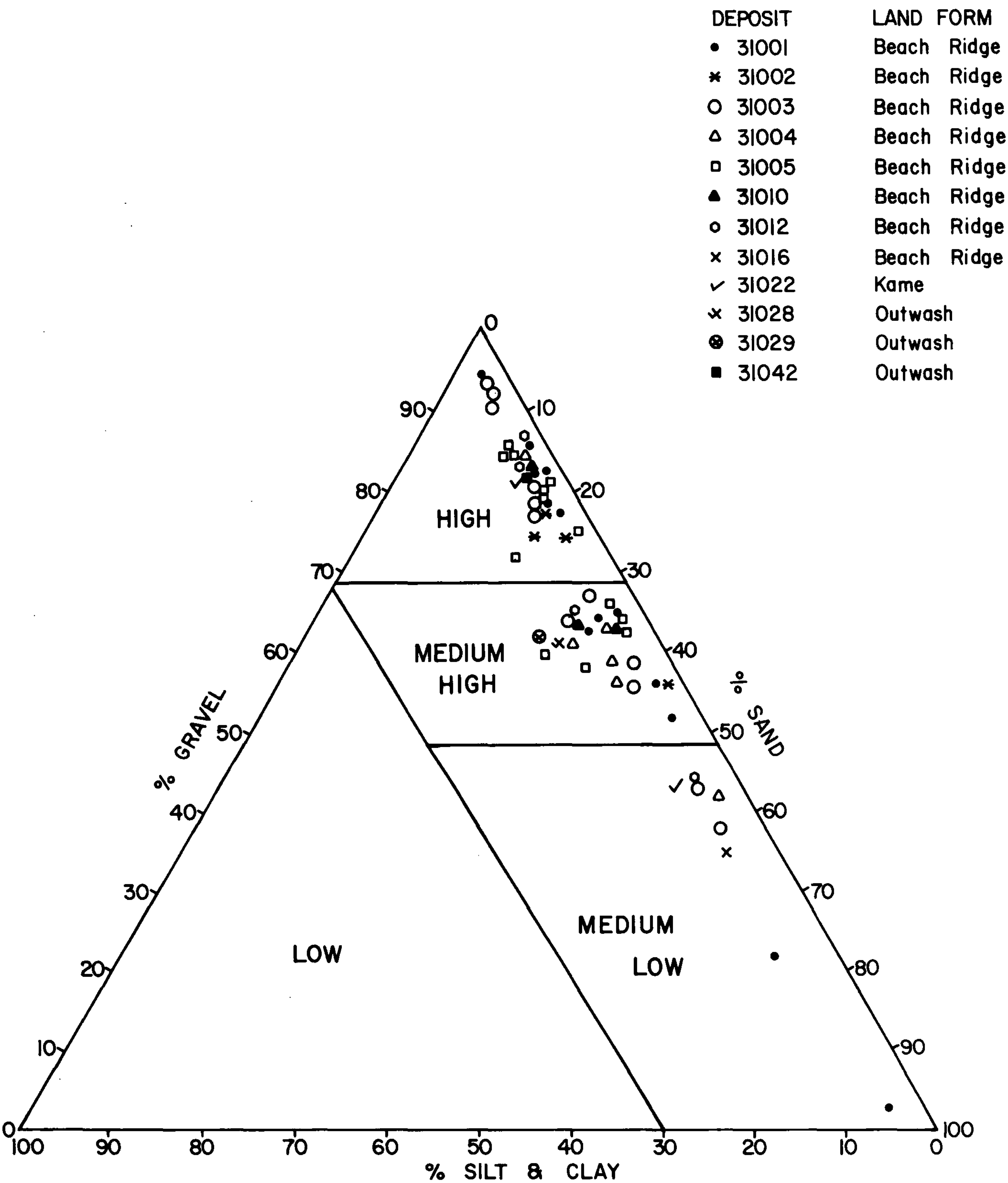


FIGURE 6. Size — Quality Relationships of The Pas Sand and Gravel Samples

TABLE 2. RESERVES OF SAND AND GRAVEL IN THE PAS REGION

DEPOSIT (see Map 2)	RESERVES ('000 tonnes)	PRODUCTION POTENTIAL	DEPOSIT	RESERVES ('000 tonnes)	PRODUCTION POTENTIAL
31001	8,826.1	High	31023	796.1	Low
31002	814.7	High	31024	2,581.7	Medium
31003	81,100.8	High	31025	130.1	Medium
31004	137.5	Medium	31026	302.7	Low
31005	13,616.8	High	31027	229.9	Low
31006	709.1	Low	31028	371.7	Low
31007	1,854.9	Medium	31029	54.7	Low
31008	738.1	Medium	31030	63.4	Medium
31009	552.3	Medium	31031	449.4	Low
31010	6,137.2	Medium	31032	72.9	Low
31011	780.0	Medium	31033	168.4	Low
31012	79,218.2	High	31034	302.0	Low
31013	625.2	Medium	31035	258.7	Low
31014	1,060.8	Medium	31036	1,117.6	Low
31015	2,813.7	Low	31037	1,409.6	Low
31016	247.1	Low	31038	130.4	Low
31017	303.9	Low	31039	3,042.1	Low
31018	237.2	Low	31040	46.0	Low
31019	605.9	Low	31041	523.7	Medium
31020	1,154.6	Low	31042	81.1	Low
31021	1,255.2	Low	31044	2.4	Low
31022	157.3	Medium			

TOTAL 215,081.2 thousand tonnes

TABLE 3. QUALITY OF SAND AND GRAVEL RESERVES IN THE PAS REGION

PRODUCTION POTENTIAL — QUALITY —	RESERVES ('000 tonnes)
High	183,576.6
Medium	15,342.2
Low	16,162.4
TOTAL	215,081.2

TABLE 4. SAMPLE OUTPUT FROM INDUSTRIAL USAGE ASSESSMENT

SAMPLE IDENTIFICATION 31012 05127W13SW CP2

AVAILABILITY OF CRUSHABLE MATERIAL ON SITE — NONE

WEIGHT OF SAND 17000.00 GMS. WASHED SAMPLE — WEIGHT BEFORE 1035.70 AFTER 1007.40 % LOSS 2.73

SIEVE SIZE	FINE FRACTION (GMS.)	SIEVE WEIGHTS (GMS.)	PERCENT	PERCENT PASSING	PERCENT RETAINED
4 IN		0.0	0.0	100.00	0.0
3 1/2 IN		0.0	0.0	100.00	0.0
3 IN		0.0	0.0	100.00	0.0
2 1/2 IN		0.0	0.0	100.00	0.0
2 IN		0.0	0.0	100.00	0.0
1 1/2 IN		0.0	0.0	100.00	0.0
1 IN		50.50	0.30	99.70	0.30
3/4 IN		67.00	0.39	99.31	0.69
5/8 IN	5.30	86.99	0.51	98.80	1.20
1/2 IN	3.90	64.01	0.37	98.43	1.57
3/8 IN	53.30	874.87	5.12	93.31	6.69
1/4 IN	164.90	2706.67	15.83	77.49	22.51
#4	190.50	3126.87	18.28	59.20	40.80
#8	368.40	6046.92	35.36	23.85	76.15
#10	36.70	602.39	3.52	20.33	79.67
#16	65.00	1066.91	6.24	14.09	85.91
#30	39.30	645.07	3.77	10.31	89.69
#40	11.60	190.40	1.11	9.20	90.80
#50	14.20	233.08	1.36	7.84	92.16
#80	36.40	597.47	3.49	4.35	95.65
#100	8.10	132.95	0.78	3.57	96.43
#200	7.10	116.54	0.68	2.89	97.11
<200 + W	30.07	493.65	2.89	0.0	100.00
TOTALS	1034.77	17102.29			

SPLITTING FACTOR 16.41

FINENESS MODULUS 4.89

% COBBLES 0.0 % PEBBLES 40.80 % GRANULES 38.88 % SAND 17.44 % SILT/CLAY 2.89

TABLE 4. SAMPLE OUTPUT FROM INDUSTRIAL USAGE ASSESSMENT (Cont'd)

NOTE — SUITABILITY OF SAMPLE IS BASED ONLY ON GRADING SPECIFICATIONS 31012 05127W13SW

INDUSTRIAL USE	TOTAL RESIDUAL	RATING	SCREENING REQUIRED	REMOVAL OF <#200 MATERIAL	CRUSHING REQUIRED: MATERIAL ON SITE	CRUSHING REQUIRED: MATERIAL NOT ON SITE	ADDITION OF FINES (MATERIAL < #4)
ASPHALT A (P. OF M.)	24.23	MARGINAL	YES		YES		
ASPHALT B (P. OF M.)	15.27	MARGINAL	YES				
ASPHALT C (P. OF M.)	58.45	NOT SUIT					
BASE COURSE A (P. OF M.)	15.36	MARGINAL	YES	YES			
BASE COURSE B (P. OF M.)	11.59	MARGINAL	YES	YES			
BASE COURSE C (P. OF M.)	1.11	MARGINAL		YES			
SUB-BASE/BASE COURSE A (ASTM D1241)	32.52	NOT SUIT					
SUB-BASE/BASE COURSE B (ASTM D1241)	30.93	NOT SUIT					
SUB-BASE/BASE/SURFACE COURSE C (ASTM D1241)	21.08	MARGINAL	YES	YES	YES		
SUB-BASE/BASE/SURFACE COURSE D (ASTM D1241)	40.49	NOT SUIT					
SUB-BASE/BASE/SURFACE COURSE E (ASTM D1241)	33.49	NOT SUIT					
SUB-BASE/BASE/SURFACE COURSE F (ASTM D1241)	71.11	NOT SUIT					
TRAFFIC GRAVEL A (P. OF M.)	19.47	MARGINAL	YES	YES	YES		
TRAFFIC GRAVEL B (P. OF M.)	19.47	MARGINAL	YES	YES	YES		
TRAFFIC GRAVEL C (P. OF M.)	9.49	MARGINAL	YES		YES		
TRAFFIC GRAVEL D (P. OF M.)	3.72	MARGINAL	YES		YES		
SEAL COAT A (P. OF M.)	25.32	MARGINAL	YES		YES		
SEAL COAT B (P. OF M.)	0.0	SUITABLE	YES				YES
SEAL COAT C (P. OF M.)	0.0	SUITABLE	YES				
COARSE AGGREGATE 1 (ASTM C33, D448)	221.20	NOT SUIT					
COARSE AGGREGATE 2 (ASTM C33, D448)	211.20	NOT SUIT					
COARSE AGGREGATE 24 (ASTM C33, D448)	224.63	NOT SUIT					
COARSE AGGREGATE 3 (ASTM C33, D448)	210.02	NOT SUIT					
COARSE AGGREGATE 357 (ASTM C33, D448)	154.23	NOT SUIT					
COARSE AGGREGATE 4 (ASTM C33, D448)	219.22	NOT SUIT					
COARSE AGGREGATE 467 (ASTM C33, D448)	148.72	NOT SUIT					
COARSE AGGREGATE 5 (ASTM C33, D448)	222.94	NOT SUIT					
COARSE AGGREGATE 56 (ASTM C33, D448)	222.15	NOT SUIT					
COARSE AGGREGATE 57 (ASTM C33, D448)	108.37	NOT SUIT					
COARSE AGGREGATE 6 (ASTM C33, D448)	178.59	NOT SUIT					
COARSE AGGREGATE 67 (ASTM C33, D448)	108.78	NOT SUIT					
COARSE AGGREGATE 68 (ASTM C33, D448)	87.91	NOT SUIT					
COARSE AGGREGATE 7 (ASTM C33, D448)	89.49	NOT SUIT					
COARSE AGGREGATE 78 (ASTM C33, D448)	78.68	NOT SUIT					
COARSE AGGREGATE 8 (ASTM C33, D448)	55.62	NOT SUIT					
COARSE AGGREGATE 89 (ASTM C33, D448)	14.36	MARGINAL	YES		YES		YES
COARSE AGGREGATE 9 (ASTM C33, D448)	32.14	NOT SUIT					
COARSE AGGREGATE 10 (ASTM C33, D448)	29.82	MARGINAL	YES				YES

TABLE 4. SAMPLE OUTPUT FROM INDUSTRIAL USAGE ASSESSMENT (Cont'd)

INDUSTRIAL USE	TOTAL RESIDUAL	RATING	SCREENING REQUIRED	REMOVAL OF <#200 MATERIAL	CRUSHING REQUIRED		ADDITION OF FINES (MATERIAL #4)
					MATERIAL ON SITE	MATERIAL NOT ON SITE	
FINE CONCRETE AGGREGATE (P. OF M.)	63.06	NOT SUIT					
FINE CONCRETE AGGREGATE I (ASTM C33, C404)	136.45	NOT SUIT					
FINE CONCRETE AGGREGATE II (ASTM C33, C404)	110.26	NOT SUIT					
MORTAR (ASTM C144)	54.72	NOT SUIT					
PORTLAND CEMENT (P.C.A.)	111.45	NOT SUIT					
BUILT-UP ROOFS (ASTM D1863)	89.99	NOT SUIT					
AIRFIELD RUNWAYS (P. OF M.)	10.93	MARGINAL	YES		YES		
PIT RUN (P. OF M.)	0.0	SUITABLE					
SEPTIC FIELDS (U.M.A.)	29.31	MARGINAL				YES	
SHOULDERS (P. OF M.)	0.0	SUITABLE					

OVERALL SAMPLE RATING (SCALE 1 — 9) IS 4

TABLE 5. EVALUATION OF SAND AND GRAVEL DEPOSITS IN THE PAS REGION

DEPOSIT NUMBER	DEPOSIT TYPE	QUALITY					QUANTITY	ACCESS	INDUSTRIAL USAGE ASSESSMENT	PRODUCTION POTENTIAL
		Average Size Distribution			Quality — Size Relationship	Lithology	Reserve Estimate ('000 tonnes)		Number of Samples ↘5/3 ← Rating	
		% Gravel	% Sand	% Mud		% carbonate: % granitic				
31001	Beach Ridge	63	34	3	Medium-high	80 : 20	8 826.1	P.T.H. 10	5/3, 4/4, 2/5, 1/7	High
31002	Beach Ridge	72	25	3	High	80 : 20	814.7	P.T.H. 10	1/3, 3/4	High
31003	Beach Ridge	71	26	3	High	90 : 10	81 100.8	P.T.H. 10	4/3, 8/4	High
31004	Beach Ridge	57	37	6	Medium-high	85 : 15	137.5	P.T.H. 10	2/3, 2/4, 1/5	Medium
31005	Beach Ridge	73	23	4	High	80 : 20	13 616.8	part P.T.H. 10 part no access	2/3, 9/4, 3/5	High
31006	Kame					90 : 10	709.1	no access		Low
31007	Meltwater Channel						1 854.9	no access		Medium
31008	Beach Ridge						738.1	no access		Medium
31009	Beach Ridge						552.3	no access		Medium
31010	Beach Ridge	74	24	2	High	80 : 20	6 137.2	part P.T.H. 10 part no access	2/4	Medium
31011	Beach Ridge						780.0	part P.T.H. 10 part no access		Medium
31012	Beach Ridge	77	20	3	High	90 : 10	79 218.2	P.T.H. 10	1/3, 3/4	High
31013	Beach Ridge						625.2	no access		Medium
31014	Meltwater Channel						1 060.8	no access		Medium
31015	Esker					90 : 10	2 813.7	no access		Low
31016	Beach Ridge	34	64	2	Medium-low	80 : 20	247.1	P.R. 282	1/5	Low
31017	Drumlin					95 : 5	303.9	gravel road		Low
31018	Drumlin					85 : 15	237.2	gravel road		Low
31019	Drumlin						605.9	gravel road		Low
31020	Drumlin						1 154.6	gravel road		Low
31021	Drumlin						1 255.2	P.R. 283		Low
31022	Kame	63	33	4	Medium-high	90 : 10	157.3	P.T.H. 10	1/3, 1/4	Medium
31023	Esker					40 : 60	796.1	P.T.H. 10		Low
31024	Esker					80 : 20	1 581.7	P.T.H. 10		Medium
31025	Kame	72	23	5	High	95 : 5	130.1	P.R. 287	1/4	Medium
31026	Outwash Plain					90 : 10	302.7	P.R. 287		Low
31027	Outwash Plain					95 : 5	229.9	P.R. 287		Low
31028	Outwash Plain	60	31	9	Medium-high	90 : 10	371.7	C.F.I. road	1/4	Low
31029	End Moraine	68	24	8	High	90 : 10	54.7	P.R. 287	1/3	Low

TABLE 5. EVALUATION OF SAND AND GRAVEL DEPOSITS IN THE PAS REGION (Cont'd)

DEPOSIT NUMBER	DEPOSIT TYPE	QUALITY					QUANTITY	ACCESS	INDUSTRIAL USAGE ASSESSMENT	PRODUCTION POTENTIAL
		Average Size Distribution			Quality — Size Relationship	Lithology	Reserve Estimate ('000 tonnes)		Number of Samples ↘ 5/3 ← Rating	
		% Gravel	% Sand	% Mud		% carbonate: % granitic				
31030	Outwash Plain					95 : 5	63.4	P.R. 287		Medium
31031	Drumlin						449.4	gravel road		Low
31032	Drumlin						72.9	trail		Low
31033	Drumlin						168.4	trail		Low
31034	Drumlin						302.0	gravel road		Low
31035	Drumlin						258.7	gravel road		Low
31036	Esker					80 : 20	1 117.6	C.F.I. road		Low
31037	Outwash Plain						1 409.6	P.R. 391		Low
31038	Beach Ridge						130.4	no access		Low
31039	Outwash Plain						3 042.1	C.F.I. road		Low
31040	Outwash Plain					90 : 10	46.0	C.F.I. road		Low
31041	Beach Ridge					80 : 20	523.7	C.F.I. road		Medium
31042	Outwash Plain					80 : 20	81.1	P.R. 287		Low
31044	Outwash Plain					90 : 10	2.4	P.R. 287		Low

PART B

SUPPLY AND DEMAND OF SAND AND GRAVEL RESOURCES IN THE PAS REGION — AN ECONOMIC ANALYSIS —

by
R. Werstler

INTRODUCTION

The following section of this report has been compiled to assist in future land use planning in The Pas area. By forecasting the future demands for sand and gravel until 2026 the life expectancy of available supplies has been determined.

Conclusions drawn from this economic study are relevant to land use planning activities. Although total reserves of sand and gravel in the region are adequate to meet future demands well beyond the next twenty-five years, shortages will occur in specific areas due to local distribution of the resource. A map (Figure 7) is presented which shows anticipated future flows of sand and gravel in the region, and gives information on the extent of requirements on specific pits and their uses according to different sectors of the construction industry.

For resource inventory purposes The Pas region has been defined as the area bounded by the Manitoba — Saskatchewan border on the west and Range 24W. on the east, and by Townships 50 and 63 inclusive on the north and south (Map 2). For the purposes of this economic study however, a twenty-five mile radius around The Pas was used as a limit because it is more appropriate for consideration of the economic aspects. The economic analysis is divided into a number of subsections dealing with the methodology, past trends in construction expenditures, aggregate usage co-efficients, the forecast of future demands and finally, a supply and demand analysis to determine the life of the reserves.

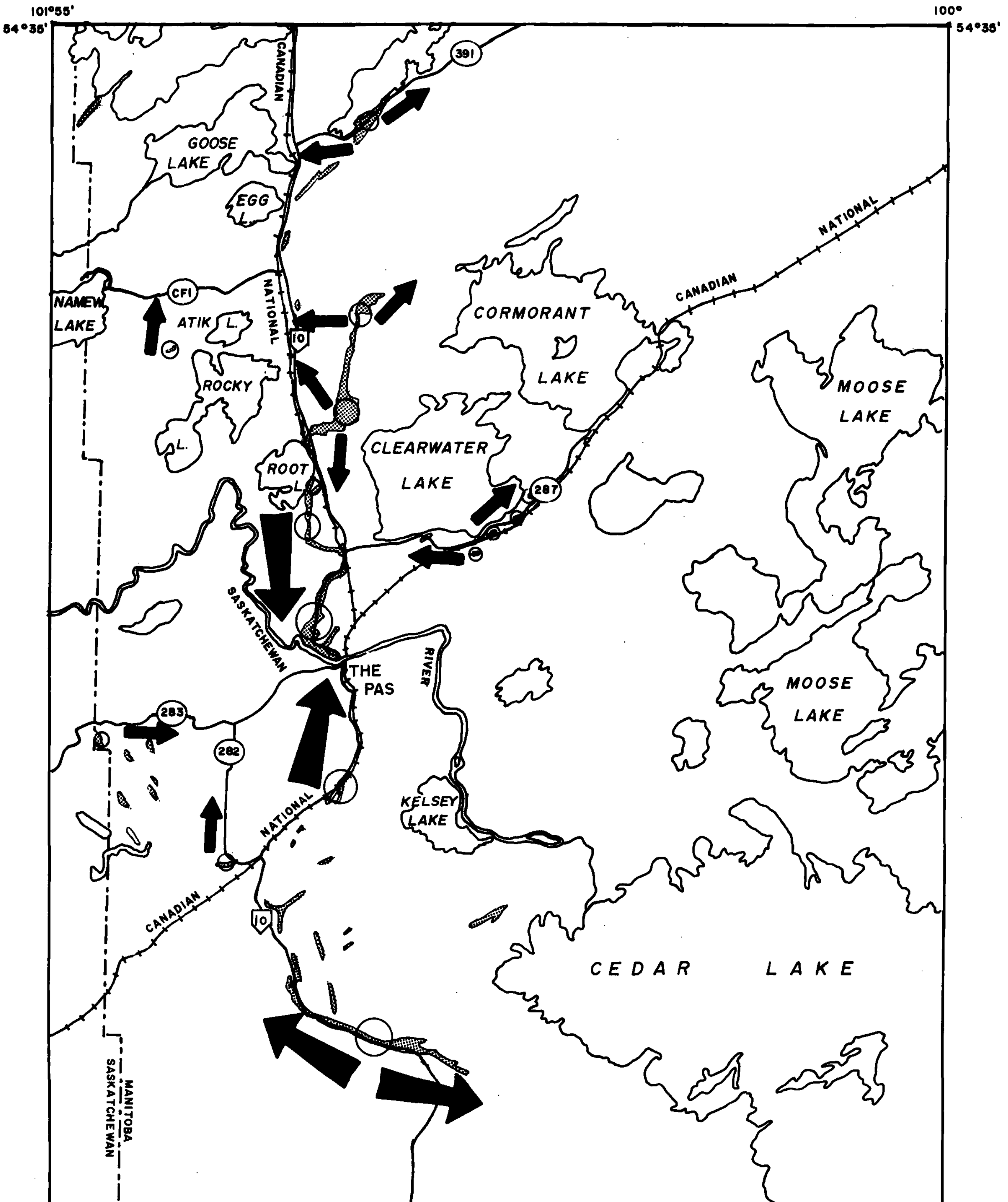


FIGURE 7. Future Flows of Sand and Gravel in The Pas Region

ANALYSIS

FORECAST OF FUTURE DEMANDS

METHODOLOGY

An estimation of future demands for a commodity such as sand and gravel presents a difficult problem due to the data requirements involved. The available statistics give estimates of annual production of construction aggregates for the Province of Manitoba. There are no published statistics estimating annual requirements for individual communities. The most practical method of solving this problem of information deficiency is to survey major contractors who operate in the study area. For a community such as The Pas, this was not a large problem. Some time was spent in The Pas and in Winnipeg interviewing contractors and intermediate users of sand and gravel in order to get an accurate estimate of annual requirements for sectors of construction activity such as residential, non-residential, road construction and engineering construction. Published statistics are available for values of annual expenditures in each of these sectors of construction activity. A number of sources were consulted to get these values, including Statistics Canada publications, the Manitoba Department of Highways annual reports, and the financial accounts of municipalities in the Province of Manitoba.

The methodology for this study was developed after a thorough examination of a similar project in the Winnipeg region which was done by Underwood, McLellan & Associates (1975). The UMA Group forecasted aggregate demands in the Winnipeg region based on estimates of future construction expenditures for Manitoba. Construction activity in the Winnipeg region was assumed to remain at a constant proportion of total Manitoba construction expenditures for the forecasted years. After estimating expenditures in the Winnipeg region for a base year (1973), the percentage for each sector of construction activity in the region relative to the total provincial expenditures was calculated and applied to the forecast of Manitoba construction. Estimates of the annual requirements for the base year were made and aggregate usage co-efficients were calculated to determine the quantity of aggregate material required per dollar of construction expenditure in each sector. These co-efficients were then applied to the forecasted construction expenditures for Winnipeg to arrive at a forecast of future demands for aggregates in the region.

The methodology which is applied to The Pas study is similar, but revisions have been made to fit the special circumstances related to a smaller scale of analysis. For the Winnipeg region, construction expenditures were determined according to the forecasted expenditures for the Province. This was justified on the grounds that construction activity in Winnipeg accounts for a large proportion of total provincial construction and that errors in estimation would tend to cancel out due to the large numbers involved. This approach is not applicable to The Pas area because of its small size and because trends in Manitoba construction activity do not necessarily reflect trends in The Pas. To deal with this situation, primary data were acquired for The Pas region for as many years as possible, and a forecast of future construction expenditures made on the basis of these data using regression analysis and past trends. The regression model used for the Winnipeg study forecasted future construction expenditures by using number of households as the independent variable. This method was not followed for The Pas study because population or number of households gives a very poor fit to the regression equation and the assumption that the level of activity in each sector is a constant proportion of total construction expenditures is too restrictive. For The Pas study, a system of regression equations was developed to forecast construction expenditures for each sector independently.

Due to the wide variety of grades available, sand and gravel used for construction purposes is mainly pit run material which requires no processing. In an area such as The Pas, standards are more relaxed in order to minimize the amount of crushing and screening required. Materials are differentiated into a few discernable categories such as sand, fine gravel and coarse gravel. Because of this, demand was not differentiated according to any categories based on an assessment of quality.

The methodology for the study is outlined according to the following procedure:

1. Determine annual estimates of construction expenditures for each sector of construction in The Pas region. There are five sectors of construction: residential, non-residential, provincial road, municipal road and other engineering construction.
2. Develop regression equations to forecast future construction expenditures for each sector of activity and derive the forecast.
3. Determine estimates of demands for sand and gravel for each sector of activity for base year 1974 by surveying suppliers, major end users and intermediate users.
4. Derive the aggregate usage co-efficients using annual requirements for 1974 relative to construction expenditures in that year for each sector of construction activity.
5. Apply aggregate usage co-efficients to the forecasted construction expenditures to determine future demands for sand and gravel in The Pas region to the year 2001.
6. Project estimates of future demands to the year 2026 on the basis of extrapolated trends.
7. Derive an alternative forecast on the basis of alternative assumptions about future construction expenditures.

CONSTRUCTION EXPENDITURES

Construction expenditures in The Pas area have exhibited cyclical trends over the past decade. This has been the result of the small size of the community, as well as the involvement of government in institutional construction and economic development programs. The Pas area has a population of approximately 10,000 people encompassing the Town, the Carrot Valley Settlement and The Big Eddy Reserve. In a community of this size, any significant construction project in one year will produce a large increase in construction expenditures followed by a decrease in activity until another major projects begins. Recent major projects in The Pas include the development of Churchill Forest Industries (now Manitoba Forest Products) and the Otineka Mall. Institutional construction, for the provision of services such as schools, hospitals, government offices and recreational facilities, has increased significantly; but this has occurred only randomly over the years according to when the facilities were required and as funds became available.

The Churchill Forest Industries project, although a contributor to the fluctuations in construction expenditures, has created large distortions due to its overwhelming size in relation to the community. This project has brought an influx of people into The Pas area and with the increase in population came an increase in residential construction to provide necessary housing. Institutional construction also rose significantly, as demands for social services increased. In recent years, the Town of The Pas has added facilities such as schools, a sports complex, and new municipal offices. There are some projects envisaged for the near future such as a new school board office and sports facilities for the Reserve, however in time the thrust in this type of building will likely subside. Another major area of activity has been in the Carrot River Valley where the Manitoba Department of Agriculture has been involved in an extension program to promote farming. An extensive system of roads has been built in this region to provide access. These farms are now beginning to operate on a lucrative basis and people are building new homes and expanding their operations thereby increasing construction in this area.

Construction expenditures, for the purposes of analysis, have been delineated into five major sectors. These are: residential and non-residential construction, provincial road and municipal road construction and engineering construction. Residential construction expenditures encompass all activity related to the development of new single dwelling units, multiple dwellings and mobile home parks, as well as construction for repair and maintenance of existing homes. Non-residential construction takes into account all institutional, industrial and commercial building. Road construction has been divided into two sectors which separate roadbuilding carried out by the Provincial Government from roadbuilding in the Town of The Pas which is done by the Municipality. These sectors have been kept separate because there are some differences between types of roads constructed and between trends in expenditures. Finally, the engineering construction sector includes sewer and water projects, railroad buildings, dams and mine shafts. The data available for these construction sectors give a complete series of estimates as far back as 1966. Other information such as municipal revenue, provincial revenue, total income for the census division, corporate profits and population were compiled for the 1966-74 period.

Estimates of residential and non-residential construction expenditures were obtained from Statistics Canada publication 64-001: Building Permits in Canada. This source however, may not give an accurate reflection of the true value of construction, because building permits give only the estimated value before a project is started rather than the actual cost incurred. Estimates for provincial government road construction were obtained from the Department of Highways annual reports by totalling expenditures for construction and maintenance of roads in The Pas area. Municipal road construction expenditures were estimated by using the values for capital expenditures on transportation from the financial accounts for the Municipality. This source was also used to estimate engineering construction. The financial accounts give the capital expenditures on sewer and water projects which is the major component of construction in this fifth sector. Other components of total engineering construction are of negligible importance for The Pas area so they are ignored.

This information is given in current dollar terms, ignoring the effect of inflation, and if used in this form would result in an inaccurate forecast of future demands. In order to compensate for this, the inflationary component must be netted out by adjusting the data into constant dollar terms.

The appropriate implicit price deflators for each sector of construction were used to adjust the data to constant 1971 dollar terms. Table 6 is a compilation of construction expenditures for each sector from 1966 to 1974.

REGRESSION EQUATIONS AND FUTURE CONSTRUCTION EXPENDITURES

Regression equations used to derive the forecast of future construction expenditures were developed independently for each sector of construction. The model itself however, consists of five equations, some of which are interdependently determined. The logic behind this systematic approach is that the level of construction activity in one sector depends upon the level of activity in another. For example, engineering construction which mainly consists of sewer and water projects is determined by the level of residential construction. Other sectors, such as roadbuilding, were autonomously explained by government revenues at the provincial or municipal levels. Once the five equations were derived, there still remained the task of projecting the autonomous variables in order to calculate annual estimates of future construction expenditures in each sector. The autonomous variables which include provincial and municipal revenues as well as income and corporate profits were projected by regressing observed values against time. An assumption behind this method is that past trends will continue into the future. Projected values were adjusted downward because future income is not expected to grow at the same rate as in the past.

The first equation in the system is for engineering construction expenditures. A regression was run using residential construction expenditures as the independent variable for the reasons stated above. This was not sufficiently explanatory however, and a second regression was attempted using residential construction expenditures in period T + 1 as the independent variable. This yielded better results which may be due to the fact that the sewer and water facilities are installed before the dwellings are built. Also, the values for engineering construction are actual expenditures while those for residential construction are only estimated values which may be another reason for the difference in the time element. The regression equation for the engineering construction sector is:

$$\text{CENGIN} = 7.25088 + 0.02345\ \text{CRES}\ (T + 1) \qquad (1)$$

The second equation explains residential construction expenditures. A number of variables were considered such as population and income, however their explanatory power was insufficient. The major determining the factor in explaining residential construction was the level of non-residential construction in the area. The logic for this relationship rests on the fact that non-residential construction whether industrial, commercial or institutional creates new employment which attracts families into the area requiring an expansion in the existing housing stock. The equation for this sector is:

$$\text{CRES} = 480.715 + 0.20386\ \text{CNONRES} \qquad (2)$$

Equation three determines non-residential construction expenditures. The explanatory variables for this sector are autonomous to the model. These are total income for the census division and corporate profits. In order to increase the explanatory power of this equation, a dummy variable was introduced to account for the distortion in construction expenditures due to the C.F.I. project. The dummy variable takes the value zero for each year except 1970 where it is given a value of one. The purpose of this is to regress non-residential expenditures against the two independent variables for each year except the C.F.I. year where the dummy enters as a third variable to account for the increase in expenditures resulting from the project. The regression equation for non-residential construction expenditures is:

$$\text{CNONRES} = -3432.034 + 0.08190\ \text{INCOME} - 0.00196\ \text{CORPROFS} + 8203.068\ \text{Di} \qquad (3)$$

The final two equations are for roadbuilding construction expenditures at the provincial and municipal levels. Government revenues at the respective levels give the best predictive results for these sectors. Tax revenues not only reflect the ability to finance road construction projects, but also can be taken as an indicator of the level of economic activity, residential and industrial development, all of which explain the level of roadbuidling which can be expected to occur. The equations for provincial government road construction and municipal road construction are:

$$\text{CROADPR} = 127.932 + 0.00136\ \text{PROVREV} \qquad (4)$$

$$\text{CROADMUN} = 31.800 + 0.17591\ \text{MUNREV} \qquad (5)$$

The equations all yielded significant explanatory power with R^2 co-efficients ranging from .70 to .98. The R^2 co-efficient of determination is an estimate of percentage of variation in the dependent variable explained by variation in the independent variables. Values for the autonomous variables over the 1966 to 1974 period are given in Table 7. Again these have been adjusted into constant dollar terms using the appropriate price indeces.

A forecast to the year 2001 was developed for this data by using regression equations where time was taken as the explanatory variable. The equations give the average trend rate of growth for each variable based upon past observed values. Values observed over the

TABLE 6. CONSTRUCTION EXPENDITURES IN THE PAS AREA — 1966-1974
(constant 1971 Dollars, $000's)

YEAR	RESIDENTIAL	NON-RESIDENTIAL	PROVINCIAL ROAD	MUNICIPAL ROAD	OTHER ENGINEERING	TOTAL
1966	362.7	678.3	478.8	64.3	35.6	1,619.7
1967	304.2	127.0	339.2	52.7	26.4	849.5
1968	584.9	175.3	1,275.9	62.0	10.6	2,108.7
1969	1,471.4	647.3	1,001.5	91.3	20.5	3,232.0
1970	3,094.4	11,622.4	754.2	166.3	21.4	15,658.7
1971	1,142.0	3,796.0	904.5	174.9	81.2	6,098.6
1972	419.1	3,583.4	1,176.4	260.8	61.2	5,500.9
1973	697.3	264.0	751.3	350.7	8.5	2,071.8
1974	610.2	492.6	2,621.4	451.1	17.6	4,192.9

TABLE 7. REGRESSION DATA
(constant 1971 Dollars, $000's)

Year	Municipal Revenue	Provincial Revenue	Income by Census Division	Corporate Profits
1966	484.8	258,900	63,357	959,415
1967	519.3	332,202	85,443	890,950
1968	627.3	338,655	101,332	2,408,400
1969	734.1	510,565	127,363	2,647,033
1970	1,015.4	648,117	146,037	2,602,044
1971	1,215.4	709,508	156,931	3,461,000
1972	1,741.2	878,042	184,296	4,923,504
1973	1,972.1	1,047,199	227,811	7,634,298
1974	2,834.2	1,208,289	313,396	10,673,750

TABLE 8. FORECASTED MUNICIPAL REVENUES
(constant 1971 Dollars, $000's)

1975	3,010.269	1988	5,307.619
1976	3,284.681	1989	5,342.031
1977	3,309.092	1990	5,396.443
1978	3,363.503	1991	5,450.856
1979	3,407.915	1992	5,595.266
1980	3,582.327	1993	5,849.677
1981	3,656.739	1994	6,424.089
1982	3,831.150	1995	7,098.501
1983	4,005.561	1996	7,272.910
1984	4,479.973	1997	7,317.324
1985	4,754.385	1998	7,391.735
1986	5,028.798	1999	7,456.147
1987	5,103.208	2000	7,660.559
		2001	8,044.973

1966 to 1974 period were graphed along with predicted values for future years. The forecasted values were then adjusted according to assumptions regarding changes in future developments which would be expected to occur along with adjustments to project the cyclical trends which have been observed in the past. Forecasted values for the autonomous variables are listed in Tables 8, 9, 10 and 11.

Using the forecasted data and the regression equations, estimates of future construction expenditures can be derived for each sector. The forecasted values of construction expenditures are given in Table 12.

PRESENT DEMANDS AND AGGREGATE USAGE CO-EFFICIENTS

Demand for sand and gravel in The Pas area was estimated by using information provided by all primary and intermediate users. The major users in the area include the Department of Highways, Norcana Concrete, Borger Industries, Mulder Brothers, Manitoba Forest Products and the Town of The Pas. Survey questionnaires were sent to various government departments, road contractors and residentail builders to determine the extent of their requirements for the base year 1974. Information from the Mining Recorders Office and The Pas Band was also used to fill in gaps. From the data collected, requirements for sand and gravel were allocated to the appropriate sectors of construction and aggregated to determine the extent of demands for each sector.

Using the demands for each sector of construction and corresponding expenditures for the base year 1974, the aggregate usage co-efficients were calculated. These co-efficients indicate the number of tonnes of sand and gravel required per dollar of construction expenditures for each of the various sectors. This information is provided in Table 13.

The calculated co-efficients were compared with similar estimates derived for other studies of this kind. The estimates for The Pas area were well in line although they tended to be a little higher than other co-efficients.

FORECAST OF FUTURE DEMANDS

By applying the aggregate usage co-efficients to forecasted construction expenditures in each sector, a forecast of the demands for sand and gravel is obtained. The future requirements projected for The Pas area according to this method are listed in Table 14.

Future demands for sand and gravel in The Pas area have been forecasted on the basis of estimated demands within a twenty-five mile radius of the Town. This provides an accurate reflection of the total demands for the area due to the sparse population and limited construction activity beyond this boundary. Consideration of aggregate demand from the study region as defined in Part A of this report might increase the forecast by 10 to 12 percent incorporating gravel requirements from Cranberry Portage (a community with population of 800) and from road works on the southern extension of P.T.H. 10, the Easterville Road, and P.T.H. 391. The remaining analysis, therefore, includes the demand component for the region (Map 2) as well as the area (25 miles radius around The Pas).

THE LIFE EXPECTANCY OF EXISTING RESERVES

Aggregate requirements for The Pas area are forecasted to reach 0.9 million tonnes per annum by the year 2001 and 1.4 million tonnes by the year 2026. In the total region, demands will reach one million tonnes by the year 2001 and 1.6 million tonnes by 2026. Cumulative requirements to the year 2026, according to this forecast, will be 43.8 million tonnes within the 25 mile radius and 48.7 million tonnes for the region. The assumption behind this forecast is that The Pas will maintain relatively strong rates of growth in comparison with the rest of Manitoba. Under these circumstances the rising levels of construction activity would place heavy demands on existing deposits in the immediate vicinity of The Pas. There is an abundance of sand and gravel in The Pas area however, and supplies should last beyond the year 2001.

Two forecasts have been developed on the basis of different assumptions concerning the growth in construction activity. The figures given above reflect the demands which are predicted to occur under the base forecast using the regression equations to arrive at future construction expenditures and a forecast of future requirements. An alternate forecast has been developed incorporating conditions of lower growth for The Pas area. Cumulative aggregate requirements which can be expected to occur under these circumstances will be 35.5 million tonnes for The Pas area and 39.5 million tonnes for the region by the year 2026. The annual requirements under the base forecast and the alternate forecast are listed in Tables 15 and 16.

It has been estimated that there are approximately 215 million tonnes of sand and gravel available in The Pas region (Tables 2 and 3). The available quantities have been determined as part of the mapping project for the region (Part A of this report). These are conservative estimates giving only the amount of material found above water table. Quarrying below the water table does not seem to be a likely alternative for The Pas region for some time to come.

From the estimates of available reserves and the forecasted demands, the rate of depletion and the life expectancy of the deposits in The Pas region can be determined. This is illustrated by Figures 8 and 9 for the base forecast and the alternate forecast respectively. These show cumulative gravel consumption which is expected to occur within the 25 mile radius and for the total region. Depletion of available resources will occur in the years where supply meets cumulative demand.

According to predicted demands under the base forecast, the gravel reserves within the 25 mile radius will last until about the year 2044, while under the alternate forecast supply will meet demand until beyond the year 2050. A large portion of the demand for gravel is concentrated on the Big Eddy Reserve which supplies approximately 60 to 70 percent of the region's annual requirements. There are approximately 8 million tonnes here which can be expected to last until the year 1992 according to projections under the base forecast. For the total region there are adequate supplies available to meet future demands well beyond the next fifty years. Although the total aggregate resource base for The Pas region can last for some time yet, depletion of individual pits can cause problems by dislocating demands and increasing hauling distances. The anticipated future flows of sand and gravel and their uses for particular construction sectors are indicated in Figure 7.

TABLE 9. FORECASTED PROVINCIAL REVENUES (constant 1971 Dollars, $000's)

1975	1,257,952.6	1988	2,800,632.7
1976	1,376,620.4	1989	2,919,300.4
1977	1,495,288.0	1990	3,037,968.1
1978	1,613,955.7	1991	3,156,635.8
1979	1,732,623.4	1992	3,275,303.5
1980	1,851,291.1	1993	3,393,971.2
1981	1,969,958.8	1994	3,512,638.9
1982	2,088,626.5	1995	3,631,306.6
1983	2,207,294.2	1996	3;749,974.3
1984	2,325,961.9	1997	3,868,642.0
1985	2,444,629.6	1998	3,987,309.7
1986	2,563,297.3	1999	4,105,977.4
1987	2,681,965.0	2000	4,224,645.1
		2001	4,343,312.8

TABLE 10. FORECASTED INCOME FOR THE CENSUS DIVISION (constant 1971 Dollars, $000's)

1975	343,447	1988	643,044
1976	360,493	1989	650,090
1977	375,539	1990	697,136
1978	386,585	1991	723,182
1979	396,631	1992	756,228
1980	409,677	1993	778,273
1981	421,723	1994	784,319
1982	437,769	1995	790,365
1983	456,814	1996	797,411
1984	498,860	1997	819,457
1985	549,906	1998	834,503
1986	613,952	1999	856,549
1987	636,988	2000	881,595
		2001	914,611

TABLE 11. FORECASTED CORPORATE PROFITS (constant 1971 Dollars, $000's)

1975	11,333,223	1988	23,501,719
1976	11,815,415	1989	24,583,911
1977	11,597,607	1990	25,666,103
1978	12,379,799	1991	25,948,295
1979	13,261,991	1992	26,630,487
1980	14,144,183	1993	26,912,679
1981	15,326,375	1994	27,894,871
1982	16,308,567	1995	28,577,063
1983	16,990,759	1996	29,877,063
1984	18,572,951	1997	29,941,447
1985	19,655,143	1998	30,323,639
1986	20,037,335	1999	30,805,831
1987	21,519,527	2000	31,105,022
		2001	31,570,215

TABLE 12. FORECAST OF FUTURE CONSTRUCTION EXPENDITURES (constant 1971 Dollars, $000's)

Year	Residential Construction	Non-Residential Construction	Provincial Road Construction	Municipal Road Construction	Engineering Construction	Total Construction
1966	362.7	678.3	478.8	64.3	35.6	1,619.7
1967	304.2	127.0	339.2	52.7	26.4	849.5
1968	584.9	175.3	1,275.9	62.0	10.6	2,108.7
1969	1,471.4	647.3	1,001.5	91.3	20.5	3,232.0
1970	3,094.4	11,622.4	754.2	166.3	21.4	15,658.7
1971	1,142.0	3,796.0	904.5	174.9	81.2	6,098.6
1972	419.1	3,583.4	1,176.4	260.8	61.2	5,500.9
1973	697.3	264.0	751.3	350.7	8.5	2,071.8
1974	610.2	492.6	2,621.4	451.1	17.6	4,192.9
1975	986.9	2,483.2	1,838.75	497.74	32.55	5,839.1
1976	1,078.9	2,934.1	2,000.14	546.01	40.48	6,599.6
1977	1,417.1	4,593.3	2,161.52	550.30	37.48	8,759.7
1978	1,289.0	3,964.8	2,322.91	559.87	33.14	8,169.7
1979	1,104.2	3,058.5	2,484.30	567.68	29.99	7,244.7
1980	969.5	2,397.9	2,645.69	598.36	29.68	6,635.1
1981	698.3	1,067.4	2,807.08	611.46	20.71	5,204.9
1982	573.8	456.5	2,968.46	642.13	21.77	4,662.6
1983	619.2	679.1	3,129.85	672.82	23.41	5,124.4
1984	688.9	1,021.6	3,291.24	756.27	33.25	5,791.3
1985	1,108.8	3,081.2	3,452.63	804.54	54.75	8,501.9
1986	2,025.5	7,577.5	3,614.02	852.82	49.88	14,119.7
1987	1,817.8	6,559.0	3,775.40	865.91	33.68	13,051.8
1988	1,126.9	3,169.9	3,936.79	901.86	26.30	9,161.8
1989	812.2	1,625.8	4,098.18	907.92	34.57	7,478.7
1990	1,165.2	3,357.8	4,259.57	917.49	42.13	9,742.2
1991	1,478.4	4,937.9	4,420.96	927.06	48.68	11,822.0
1992	1,766.5	6,307.3	4,582.34	952.46	54.66	13,663.3
1993	2,021.8	7,559.7	4,743.73	997.22	47.83	15,370.3
1994	1,730.3	6,129.7	4,905.12	1,098.26	43.80	13,907.2
1995	1,558.7	5,287.8	5,066.51	1,216.90	34.38	13,164.3
1996	1,156.9	3,316.8	5,227.90	1,247.58	42.40	10,991.6
1997	1,499.2	4,996.2	5,389.29	1,255.39	44.72	13,184.8
1998	1,597.7	5,479.4	5,550.67	1,268.48	48.83	13,945.1
1999	1,773.2	6,339.9	5,712.06	1,279.81	55.83	15,160.8
2000	2,071.8	7,804.8	5,873.45	1,315.76	64.40	17,130.2
2001	2,437.1	9,596.9	6,034.84	1,383.39	68.22	19,520.5

TABLE 13. CALCULATED AGGREGATE USAGE CO-EFFICIENTS (base year 1974)

SECTOR OF CONSTRUCTION	TOTAL REQUIREMENTS (Tonnes)	CONSTRUCTION EXPENDITURES (1971 dollars)	AGGREGATE USAGE CO-EFFICIENT
Residential Construction	2,933	610,200	.004807
Non-residential Construction	9,561	492,600	.019409
Provincial Road Construction	252,416	2,621,400	.096291
Municipal Road Construction	42,962	451,100	.095238
Other Engineering	1,090	17,600	.061932
TOTALS	308,962	4,192,900	

TABLE 14. FORECAST OF DEMANDS FOR SAND AND GRAVEL IN THE PAS AREA (tonnes)

Year	Residential Construction	Non-Residential Construction	Provincial Road Construction	Municipal Road Construction	Other Engineering	Total Demand
1975	4,744	48,195	177,055	47,403	2,016	279,413
1976	5,186	56,947	192,594	52,001	2,508	309,236
1977	6,812	89,150	208,134	52,409	2,322	358,827
1978	6,197	76,952	223,674	53,321	2,052	362,196
1979	5,308	59,361	239,215	54,064	1,858	359,806
1980	4,660	46,540	254,755	56,987	1,464	364,406
1981	3,357	20,717	270,295	58,234	1,283	353,886
1982	2,758	8,860	285,835	61,155	1,349	359,957
1983	2,977	13,181	301,375	64,078	1,450	383,061
1984	3,311	19,828	316,916	72,026	2,060	414,141
1985	5,330	59,802	332,455	76,623	3,391	477,601
1986	9,737	147,069	347,996	81,221	3,090	589,113
1987	8,738	127,301	363,536	82,467	2,086	584,128
1988	5,417	61,524	379,076	85,891	1,629	533,537
1989	3,905	31,555	394,616	86,469	2,141	518,686
1990	5,601	65,171	410,156	87,379	2,610	570,917
1991	7,150	95,838	425,697	88,291	3,016	619,992
1992	8,491	122,416	441,236	90,710	3,386	666,239
1993	9,719	146,724	456,776	94,973	2,963	711,155
1994	8,317	118,969	472,317	104,596	2,713	706,912
1995	7,493	102,629	487,857	115,896	2,130	716,005
1996	5,561	64,374	503,398	118,817	2,627	694,777
1997	7,207	96,969	518,938	119,561	2,770	745,445
1998	7,680	106,348	534,477	120,808	3,025	772,338
1999	8,524	123,049	550,018	121,886	3,458	806,935
2000	9,959	151,481	565,558	125,310	3,989	856,297
2001	11,715	186,262	581,099	131,752	4,226	915,054

TABLE 15. ANNUAL REQUIREMENTS — BASE FORECAST
('000 tonnes)

YEAR	THE PAS AREA	THE PAS REGION	YEAR	THE PAS AREA	THE PAS REGION
1976	309	344	2002	928	1030
1977	359	399	2003	941	1046
1978	362	403	2004	955	1061
1979	360	400	2005	969	1077
1980	365	405	2006	982	1091
1981	354	394	2007	996	1107
1982	360	400	2008	1018	1131
1983	383	425	2009	1041	1157
1984	415	460	2010	1064	1182
1985	478	531	2011	1089	1210
1986	590	655	2012	1113	1236
1987	584	649	2013	1136	1262
1988	533	593	2014	1160	1289
1989	519	576	2015	1182	1313
1990	571	634	2016	1207	1341
1991	620	689	2017	1229	1366
1992	667	740	2018	1253	1391
1993	711	790	2019	1276	1418
1994	707	785	2020	1299	1443
1995	716	796	2021	1322	1469
1996	695	772	2022	1344	1494
1997	746	828	2023	1367	1518
1998	773	858	2024	1390	1545
1999	807	897	2025	1414	1571
2000	856	951	2026	1435	1595
2001	915	1017			
			TOTALS	43 859	48 734

TABLE 16. ANNUAL REQUIREMENTS — ALTERNATE FORECAST ('000 tonnes)

YEAR	THE PAS AREA	THE PAS REGION	YEAR	THE PAS AREA	THE PAS REGION
1976	250	278	2002	752	835
1977	291	323	2003	763	847
1978	293	326	2004	773	860
1979	291	324	2005	785	872
1980	296	328	2006	795	884
1981	287	318	2007	806	896
1982	291	324	2008	824	916
1983	310	345	2009	844	937
1984	336	373	2010	862	958
1985	387	430	2011	883	980
1986	477	531	2012	902	1001
1987	473	525	2013	920	1022
1988	432	481	2014	940	1044
1989	420	467	2015	957	1063
1990	463	513	2016	978	1087
1991	502	558	2017	996	1107
1992	540	600	2018	1014	1127
1993	576	640	2019	1034	1148
1994	572	636	2020	1052	1169
1995	580	645	2021	1071	1190
1996	562	626	2022	1088	1210
1997	604	671	2023	1107	1230
1998	626	695	2024	1126	1252
1999	653	727	2025	1146	1273
2000	694	770	2026	1162	1292
2001	741	824			
			TOTALS	35 527	39 478

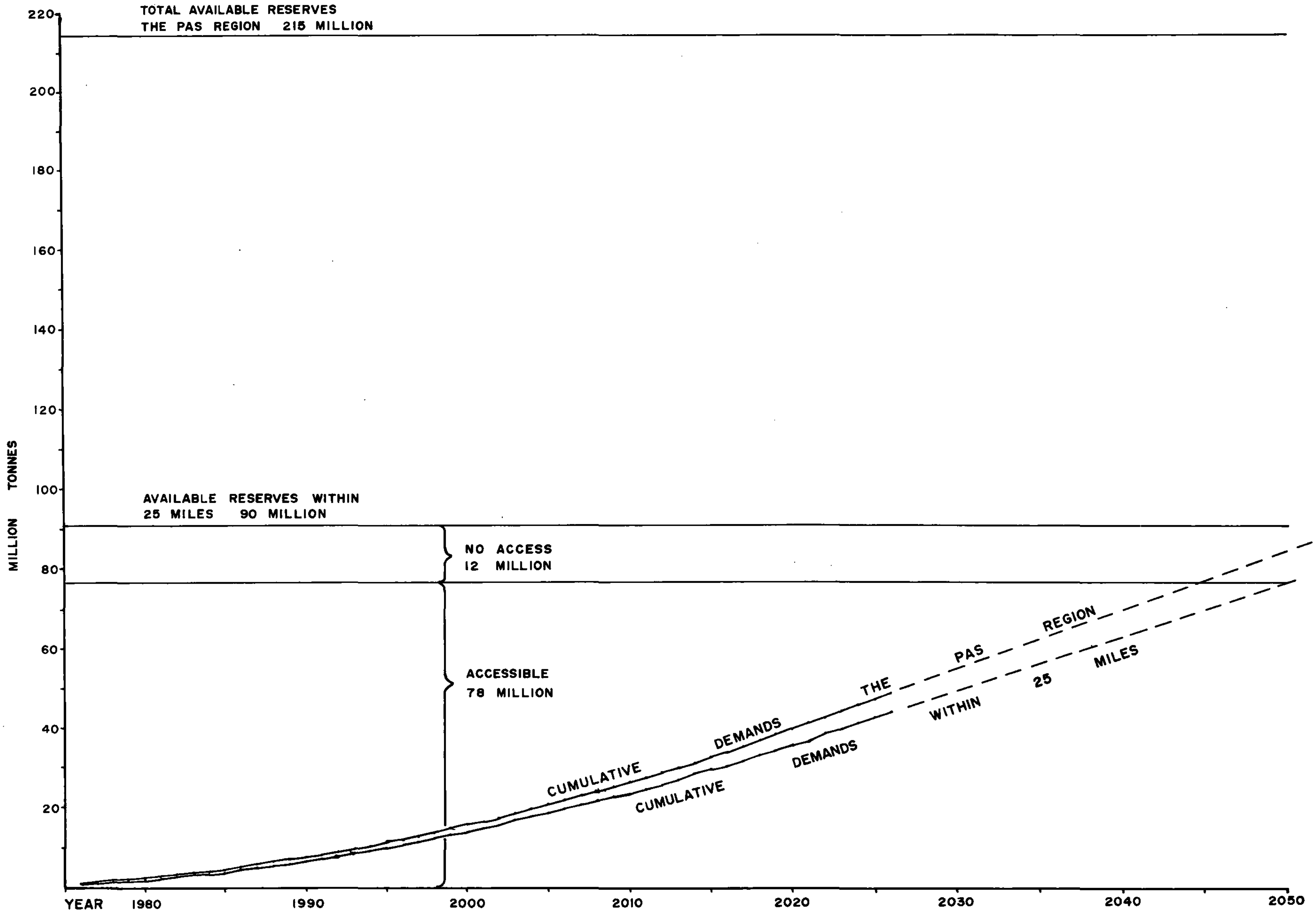


FIGURE 8. Life Expectancy of Sand and Gravel Reserves in The Pas Region — Base Forecast

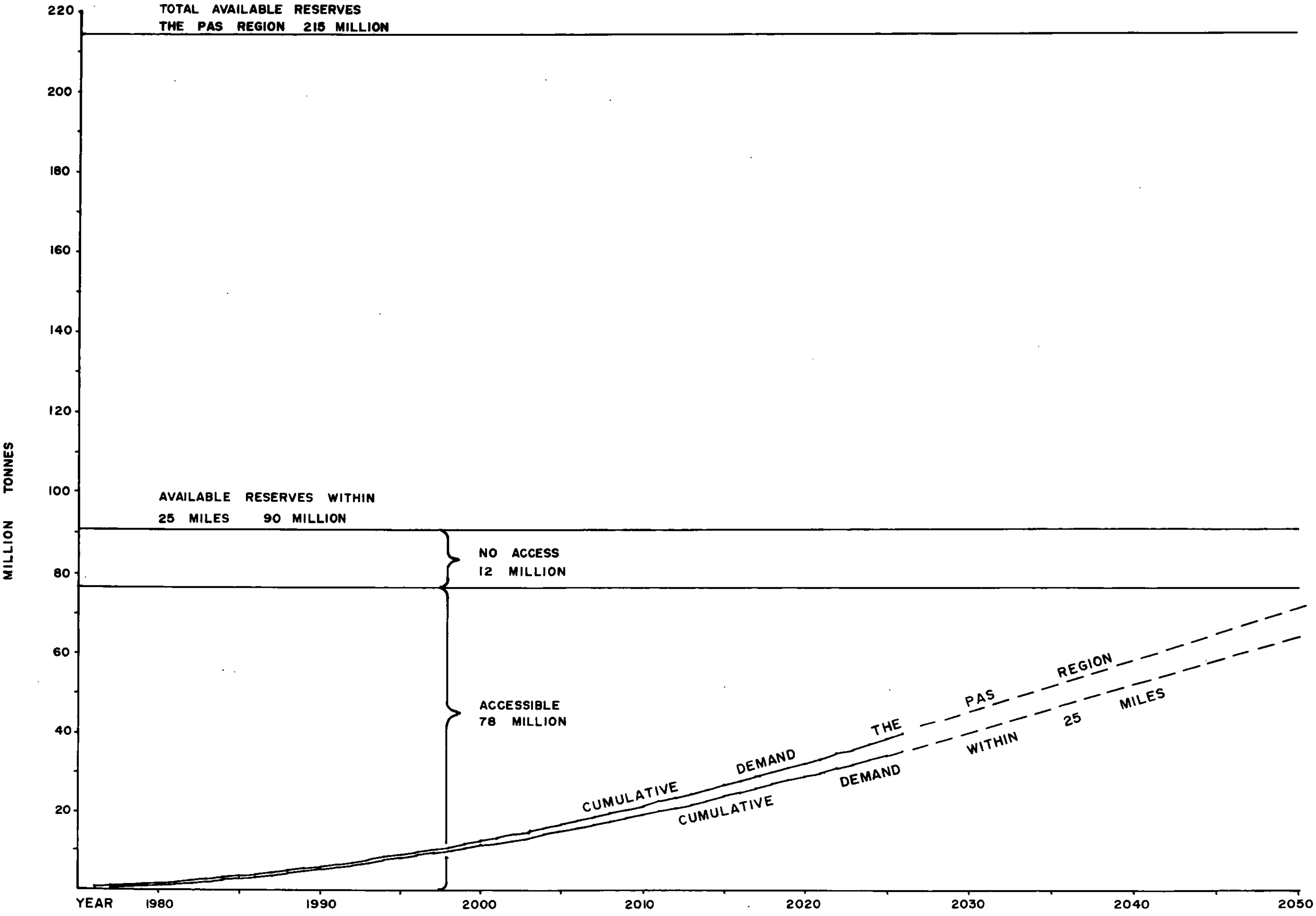


FIGURE 9. *Life Expectancy of Sand and Gravel Reserves in The Pas Region — Alternate Forecast*

CONCLUSIONS

The sand and gravel resource base in The Pas region will be able to meet future demands well beyond the year 2026. However the concentration of demands on individual deposits which are strategically located will result in their early depletion. Although accessible gravel reserves within a twenty-five mile radius of the Town are projected to last until the year 2044, there is already evidence of individual deposits reaching depletion. The Freshford and Westray pits, located in the southern sector of the area, have only limited supplies still available. The Big Eddy deposit has a life expectancy of fifteen to twenty years and its depletion will have an impact on the distribution of gravel demands in the area.

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APPENDIX A

PHOTOGRAPHS

PLATE 1A: Meander scroll in the Pasquia Basin

PLATE 1B: Flat surface of dolomitic bedrock north of Cormorant Lake

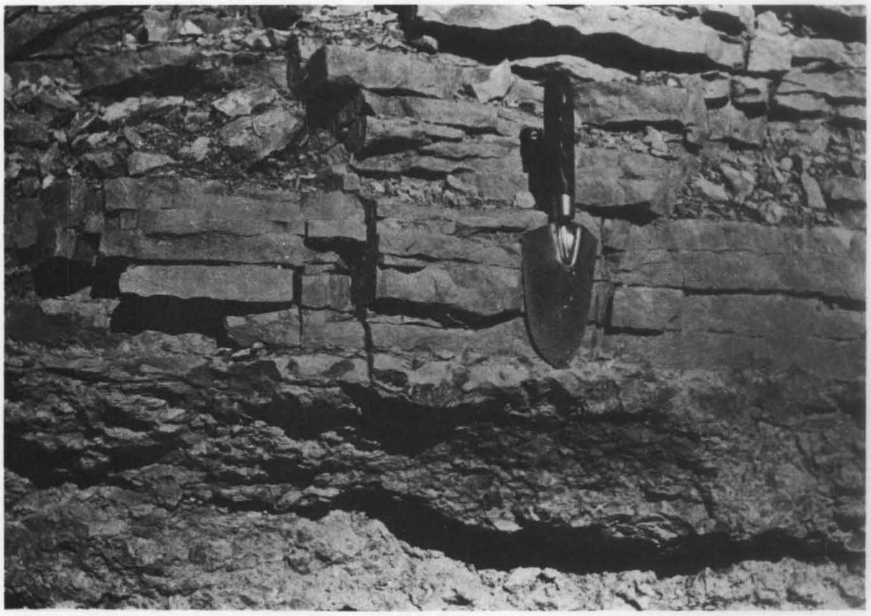

PLATE 2A: Thinly bedded Red River Formation exposed in the Wanless quarry (NE¼ 36-59-26W)

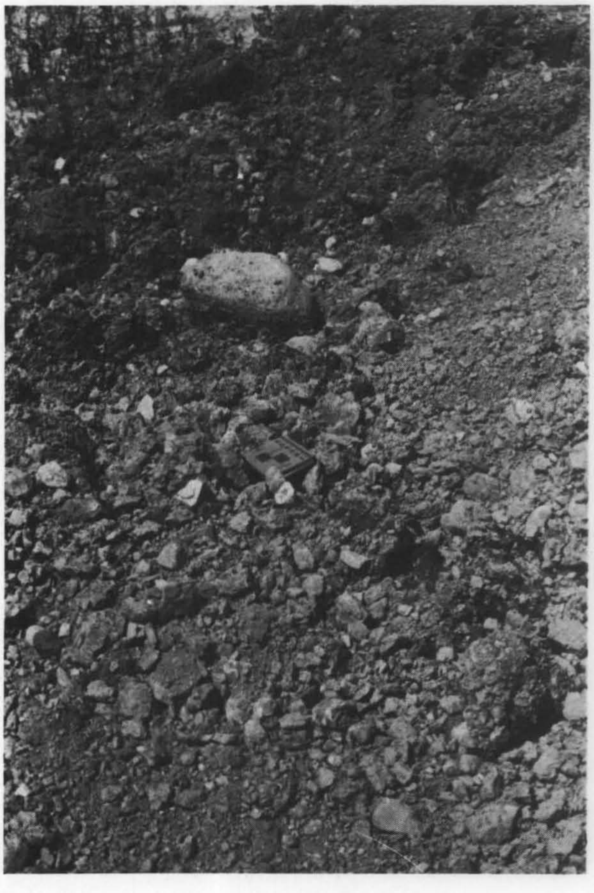

PLATE 2B: Clayey Till (Unit 2b)

PLATE 3A: Ablation till along the Clearwater Lake Road

PLATE 3B: Esker sediments at a gravel pit in NW¼ 25-62-27W

PLATE 4A: *Kame sediments in Deposit 31006*

PLATE 4B: *The "Melange" Deposit (33-57-24W): thin layer of sand and gravel over clayey till*

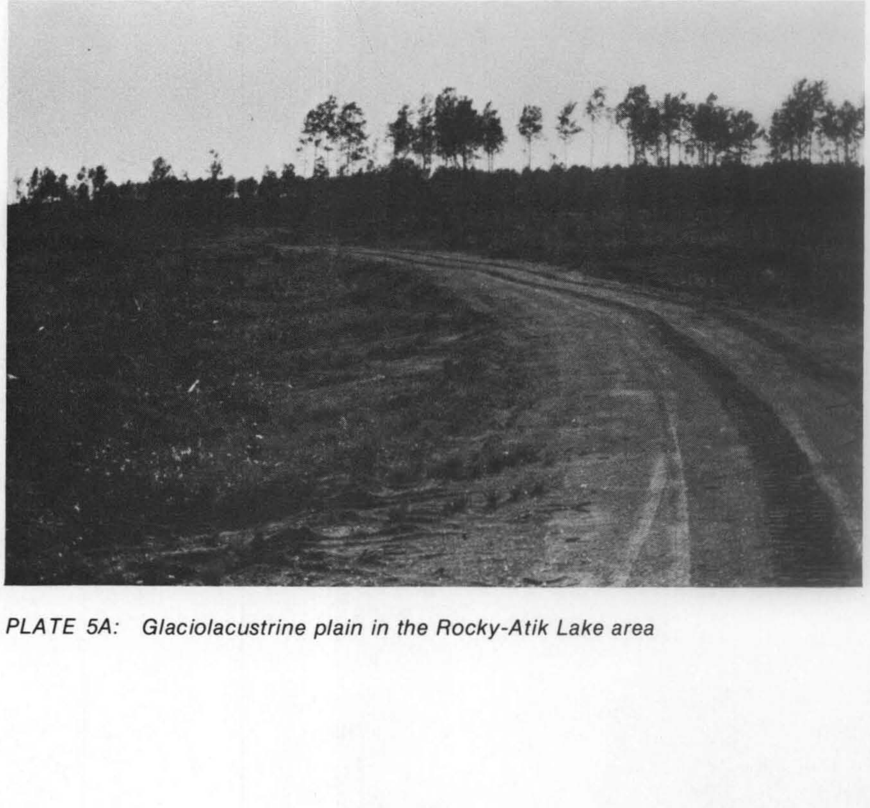

PLATE 5A: *Glaciolacustrine plain in the Rocky-Atik Lake area*

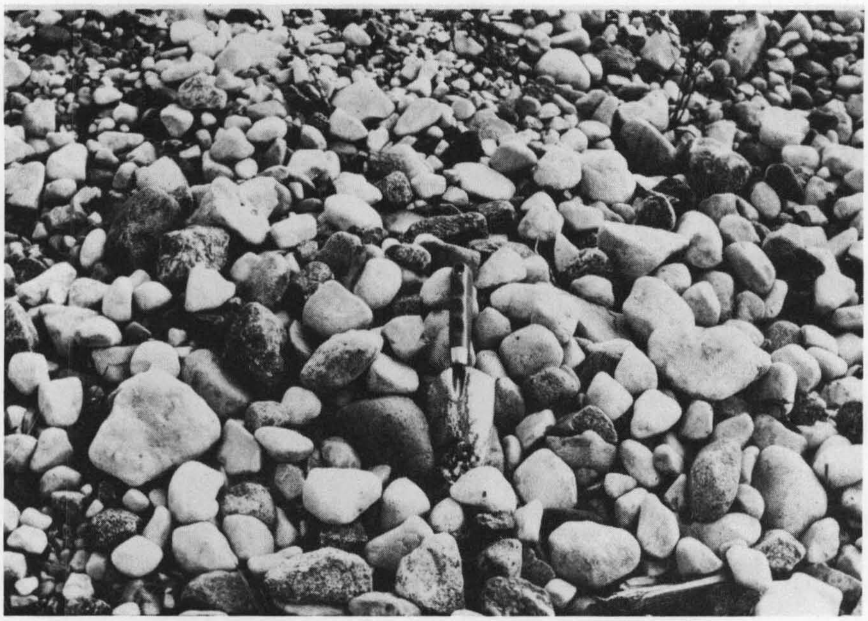

PLATE 5B: Morphology of beach gravel

PLATE 6A: Horizontal bedding of Lake Agassiz beach ridge

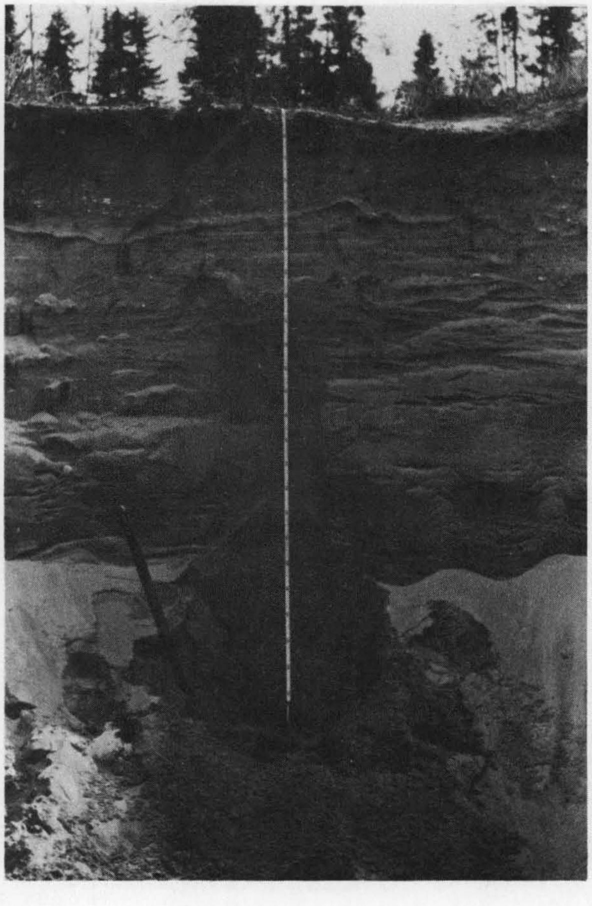

PLATE 6B: Beach sand and associated bedding

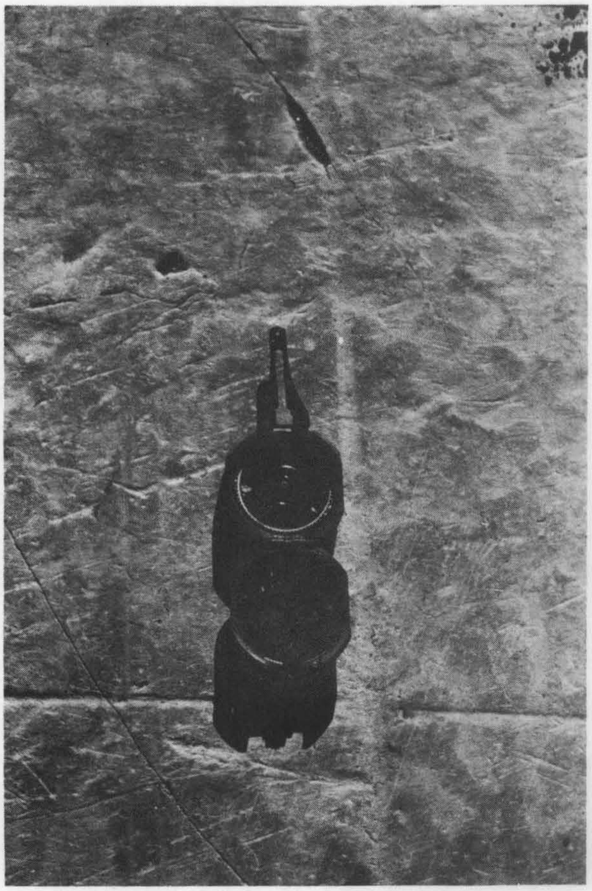

PLATE 7A: Striae at NE¼ 28-60-28W

PLATE 7B: Crescentic gouges west of Rocky Lake

PLATE 8A: Flutings east of The Pas moraine

APPENDIX B

LOGS OF SECTIONS AND DRILL HOLES

1. Measured Sections

Location (Section-Township-Range WPM)		Depth in Meters	Description
18-59-26	Freshford Beach Deposit (Pit Face)	0.0 — .13	Stony organic soil
		0.13 — .38	Fine sand (70%), pebbles (30%); rounded to subrounded, mildly calcareous, regular boundary, carbonate pebbles (95%), light yellowish brown
		0.38 — 0.40	Organic layer, 10YR 3/2
		0.40 — 0.54	Fine sand (70%), pebbles (30%), 10YR 6/4
		0.54 — 0.56	Root layer, some pebbles
		0.56 — 0.70	Fine sand (70%), pebbles (30%); carbonates (95%), Precambrian (5%), subrounded, 10YR 6/4
		0.70+	Pebbles (20%), granules (20%), sand (60%), (water table)
13-58-24	Finger Pit Outwash Deposit (Pit Face)	0.0 — 0.01	Granules and pebbles in organic horizon, 10YR 4/2
		0.01 — 0.06	Granules and pebbles in organic and fine sand matrix, horizontal organic lens 3 cm in thickness, 10YR 4/2
		0.06 — 0.08	Granules (90%), fine to coarse sand (5%); carbonates (80%), Precambrian (20%), mildly calcareous
		0.08 — 1.1	Granules and pebbles, lens of organic matter
		1.1 — 1.2	Pebbles and cobbles in fine sand
		1.2 — 1.4	Granules and pebbles
		1.4 — 1.5	Cobbles (95%), medium sand (5%)
		1.5 — 1.7	Medium sand (60%), coarse sand (40%)
		1.7 — 1.8	Granules
		1.8 — +	Pebbles, granules and cobbles in medium sand, carbonates (80%), Precambrian (20%), subrounded
13-58-24	Finger Pit Outwash Deposit (Backhoe Section)	0.0 — 0.1	Organic horizon
		0.1 — 0.3	Leached sand, 10YR 8/2
		0.3 — 0.8	Sand and granules, organic lens (4 cm)
		0.8 — +	Clayey till, calcareous, 10YR 7/2, (water table)
24-58-27	C.N.R. Pit North End, Beach Deposit (Pit Face)	0.0 — 0.09	Organic horizon
		0.09 — 0.2	Reddish fine sand, oxidized, 10YR 6/8
		0.2 — 0.47	Granules
		0.47 — 0.52	Organic layer
		0.52 — 0.72	Carbonate cobbles and fine sand

Location (Section-Township-Range WPM)		Depth in Meters	Description
24-58-27	C.N.R. Pit North End, Beach Deposit (continued)	0.72 — 1.10	Laminated fine sand lens in cobbles and granules
		1.10 — 1.45	Laminated fine sand, .5 cm laminae
		1.45 — 1.60	Pebble layer, subrounded, predominantly carbonates
		1.60 — 1.63	Coarse sand
		1.63 — +	Pebbles, cobbles in medium sand
31-51-26	Highways Pit	0.0 — 1.2	Interbedded fine sand and cobbles
		1.2 — 1.4	Rounded cobbles
		1.4 — 2.4	Interbedded pebbles and cobbles
		2.4 — 3.7	Sand and cobbles (water table)
29-57-26	Magazine Ridge	0.0 — 0.7	Interbedded sand and gravel, rounded pebbles and cobbles, graded bedding (water table)
32-49-23	Easterville Road Cut (Fluting)	0.0 — 0.2	Fine sand and pebbles, boundary regular, 10YR 3/4
		0.2 — 0.25	Pebbles and medium sand; boundary regular, 10YR 5/3
		0.25 — 0.35	Pebbles and granules, rounded to subrounded, 10YR 5/3
		0.35 — 0.55	Pebbles and granules and fine sand, rounded to subrounded, 10YR 6/3
		0.55 — 0.62	Pebbles and fine sand, carbonates (90%), Precambrian (10%), 10YR 5/3
		0.62 — +	Fine sand, Precambrian material, 10YR 6/3
25-50-25	Easterville Road Cut	0.0 — 0.2	Pebbles, coarse sand and organic matter, 10YR 2/2
		0.2 — 0.8	Pebbles, granules, coarse sand and fine sand, boundary regular
		0.8 — 1.05	Medium sand, 10YR 4/4
		1.05 — +	Clayey till, calcareous, 10 YR 5/3
26-50-25	Easterville Road Cut	0.0 — 0.2	Pebbles, coarse sand, 5YR 2.5/1
		0.2 — 0.35	Pebbles, granules and medium sand, 5YR 7/3
		0.35 — +	Clayey till, calcareous, 5YR 8/4
28-52-24	Connolly Lake Esker	0.0 — 0.07	Topsoil, 10YR 3/4
		0.07 — 0.14	Coarse sand, 10YR 5/6
		0.14 — 0.21	Coarse sand and gravel, rounded to subrounded, 10YR 4/4
		0.21 — +	Coarse to medium sand and pebbles, subrounded, 10YR 5/6
33-52-24	Connolly Lake Esker	0.0 — 0.01	Organic topsoil
		0.01 — +	Sand and gravel, subrounded, carbonates (80%), Precambrian (20%), 10YR 4/4

Location (Section-Township-Range WPM)		Depth in Meters	Description
34-52-27	South Beach Ridge	0.0 — 0.08	Organic topsoil
		0.08 — 0.40	Leached medium sand, 10YR 6/6
		0.40 — 0.60	Fine sand and gravel, rounded to subrounded, 10YR 7/4
		0.60 — +	Medium sand and gravel, rounded to subrounded, 10YR 6/4
20-53-26		0.0 — 0.50	Carbonate pebbles, 10% organic material, 10YR 3/3
		0.50 — +	Sand and gravel, 10YR 6/4
26-53-29	Drumlin #1	0.0 — 0.08	Topsoil
		0.08 — 1.2	Sandy lower oxidized till, 10YR 5/4
		1.2 — +	Angular carbonate boulders
14-53-29	Drumlin #2	0.0 — 1.3	Clayey oxidized till, subangular carbonate boulders, 10YR 6/4
27-56-25	Saskatchewan Flood Plain	0.0 — 1.3	Silt and clay, dark yellowish brown, non-calcareous, clay loam, 10YR 3/4
13-53-29	Gravel outwash over Drumlin	0.0 — 0.50	Pebbles and cobbles in organic material, rounded, predominantly carbonates, 10YR 3/2
		0.50 —	Oxidized calcareous till, 10YR 5/6
19-56-26	Big Eddy Deposit	0.0 — 0.6	Interbedded sand and pebbles
		0.6 — 1.80	Coarse sand, pebbles interbedded with granules (water table)
20-56-26	Big Eddy (Pit Face)	0.0 — 2.6	Interbedded sand and gravel with lens of organic matter, 1-3 cm in depth, pebbles, rounded to subrounded, carbonates (90%), Precambrian material (10%), non calcareous
18-58-26	C.N.R. Deposit (Pit Face)	0.0 — 0.4	Pebbles and cobbles in organic horizon
		0.4 — 0.5	Granules, carbonates (90%)
		0.5 — 0.53	Organic layer
		0.53 — 0.70	Coarse sand with pebbles
		0.70 — 0.74	Organic layer
		0.74 — 1.0	Medium to coarse sand
		1.0 — 1.10	Medium sand and pebbles in organic matter
		1.10 — 1.20	Garnet rich sand
		1.20 — 1.50	Coarse to medium sand and pebbles
		1.50 — 1.52	Pebbles
		1.52 — 1.70	Pebbles and medium sand
		1.70 — 3.85	Cobbles in medium sand, carbonates (90%), Precambrian material (10%), subrounded, graded bedding
		3.85 — 4.02	Fine sand, cross bedding
		4.02 — 4.25	Pebbles in fine sand

Location (Section-Township-Range WPM)		Depth in Meters	Description
18-58-26	C.N.R. Deposit Pit Face (cont)	4.25 — 4.80	Cobbles in medium to coarse sand
		4.80 — 5.50	Cobbles, pebbles and fine sand
19-58-27	C.N.R. Deposit North End (Backhoe Section)	0.0 — 0.1	Organic horizon
		0.1 — 1.2	Graded bedding, sand and gravel
		1.2 — +	Clayey till, calcareous, 10YR 7/2
31-56-26	Big Eddy (Pit Face)	0.0 — 2.1	Interbedded sand and gravel, graded bedding, cross bedding in some fine sand layers, organic lenses within beach strata, no cobbles, carbonates (85%), Precambrian (15%)
11-58-24	Pit 9B (Backhoe)	0.0 — 0.2	Pebbles in organic matter
		0.2 — 0.4	Interbedded sand and pebbles
		0.4 — 0.8	Clayey till, calcareous, 10YR 7/2
34-58-25	The Pas Moraine Clearwater Lake Road	0.0 — 1.2	Clayey till, rounded to subangular. Boulder (100 cm x 60 cm x 50 cm) calcareous, (water table), 10YR 7/2.
3-58-25	Airport Deposit (Pit Face)	0.0 — 1.5	Interbedded, sand and gravel within organic lenses, subrounded to subangular clasts, 80% carbonates, 20% Precambrian
		1.5 — 3.6	Cobbles and boulders in fine to coarser sand
32-49-23	Easterville Pit Beach Ridge	0.0 — 2.3	Mildly calcareous, interbedded, sand and gravel, graded bedding, cross bedding and laminated sand in lower layers. Pebbles are rounded to subrounded. Organic lens without some layers. 28 distinct layers with depth varying from 3 to 30 cm
31-56-26	Big Eddy Deposit	0.0 — 2.52	Mildly calcareous, interbedded sand and gravel, strata vary from 10 to 30 cm graded bedding; sandy upper layers and wet gravelly lower layers, carbonate pebbles (80%) rounded to subrounded

2. Drill Logs

Location (Section-Township-Range WPM)		Depth in Meters	Description
28-52-24	Connolly Lake Esker	0.0 — 0.45	Fine to coarse pebbles
		0.45 — 0.92	Coarse sand
		0.92 — +	Pebbles and granules
18-54-26	Freshford Deposit	0.0 — 1.2	Medium sand
		1.2 — 2.1	Medium sand to pebbles (water table)
		2.1 — +	Coarse sand, pebbles and cobbles
18-54-26	Freshford Deposit	0.0 — 0.6	Granules and fine sand
		0.6 — 1.5	Pebbles and coarse sand
		1.5 — +	Cobbles and pebbles

Location (Section-Township-Range WPM)	Depth in Meters	Description
20-54-26 Freshford Deposit	0.0 — 0.6	Medium sand and pebbles
	0.6 — 0.9	Coarse sand and pebbles
	0.9 — +	Clayey till
34-55-26 Beach Ridge (The Pas Moraine)	0.0 — 0.5	Medium to fine sand
	0.5 — 1.2	Fine sand
	1.2 — 2.6	Clayey till, 10YR 7/2
	2.6 — 5.4	Silt and clay
7-58-26 Root Lake North	0.0 — 0.5	Clayey till in organic matrix
	0.5 — +	Sandy clay
31-57-26 Highway's Deposit	0.0 — 0.3	Sand and pebbles
	0.3 — 0.5	Fine sand and cobbles
	0.5 — 0.9	Coarse sand and pebbles
	0.9 — 1.2	Fine to medium sand
	1.2 — 1.4	Fine sand and pebbles
	1.4 — +	Coarse sand and cobbles
33-57-26 The Pas Moraine (Fluting)	0.0 — 0.5	Medium sand and pebbles
	0.5 — 2.1	Clayey till (water table)
31-56-26 The Pas Moraine (Big Eddy)	0.0 — 0.6	Coarse sand and pebbles
	0.6 — 1.1	Coarse sand, pebbles and cobbles
	1.1 — 1.8	Medium sand and pebbles
	1.8 — 3.0	Granules and pebbles
	3.0 — +	Clayey till, 10YR 7/2
31-56-26 The Pas Moraine (Big Eddy)	0.0 — 0.8	Clayey till, 10YR 10/2
	0.8 — 1.9	Sandy, silty till
	1.9 — 2.4	Pebbles in sandy-silt-clay matrix
31-56-26 Big Eddy Deposit	0.0 — 0.5	Organic silty sand with pebbles
	0.5 — 1.8	Sand and gravel
30-56-26 Big Eddy Deposit	0.0 — 1.2	Sand and gravel
	1.2 — +	Clayey till, 10YR 7/2
30-56-26 The Pas Moraine	0.0 — 1.8	Fine sand and gravel
	1.8 — +	Coarse sand and pebbles

Location (Section-Township-Range WPM)		Depth in Meters	Description
9-56-26	Pasquia Flood Plain	0.0 — 1.8	Fine sand and silty clay
		1.8 — 2.5	Silty clay (water table)
8-56-26	Pasquia	0.0 — 0.5	Organic silty clay
		0.5 — 4.5	Soft sticky clay (water table)
17-56-26	Saskatchewan River Flood Plain, Rahls Island	0.0 — 5.4	Soft clay

APPENDIX C
SEDIMENT ANALYSES

Location	Identifier	% Gravel	% Sand	% Silt & Clay	Folk & Ward Statistics of sand fractions in Phi Units				Munsell Colour	Pebble Lithology		Pebble Morphology	Acid Reaction
					MZ	Sorting	Skewness	Kurtosis		% Carbonates	% Precambrian Material		
32-50-25 SPIA	South Beach Ridge	66.33	29.00	3.87	0.71	0.43	1.04	0.68	10YR5/1	98	2	Subangular-subrounded	Mild
32-50-25 SPIB	South Beach Ridge	75.70	23.31	1.08	1.15	0.99	0.87	0.70	10YR4/2	99	1	Subangular-subrounded	Mild
32-50-25 SPIC	South Beach Ridge	37.67	61.26	1.07	0.49	0.29	1.40	0.55	10YR7/4	98	2	Subangular-subrounded	Mild
32-50-25 SPID	South Beach Ridge	86.48	12.03	1.48	0.02	0.45	3.62	0.35	10YR7/2	98	2	Subangular-subrounded	Mild
32-50-25 SPIF	South Beach Ridge	64.94	34.05	1.02	0.48	0.39	1.35	0.58	10YR7/2	99	1	Subangular-subrounded	Mild
32-50-25 SPIG	South Beach Ridge	85.32	12.66	2.02	0.56	0.63	1.33	0.58	10YR7/2	96	4	Subrounded	Strong
32-50-25 SPIH	South Beach Ridge	69.93	29.20	1.16	1.86	0.02	3.08	0.07	10YR7/2	98	2	Subangular-subrounded	None
32-50-25 SPII	South Beach Ridge	92.0	47.50	2.34	0.77	0.89	1.20	0.58	10YR8/3	98	2	Subangular-subrounded	Strong
32-50-25 SPIJ	South Beach Ridge	78.49	20.57	0.94	-3.92	0.27	3.89	0.33	10YR8/3	99	1	Subrounded	Mild
32-50-25 SPIK	South Beach Ridge	93.76	3.99	2.25	0.59	0.95	1.66	0.37	10YR8/3	96	4	Subangular-subrounded	Strong
32-50-25 SPIL	South Beach Ridge	93.00	5.64	1.00	0.09	0.68	3.57	0.26	10YR8/3	90	10	Subangular-subrounded	Mild
32-50-25 SPIM	South Beach Ridge	45.60	53.20	0.62	0.30	0.22	2.15	0.31	10YR8/3	92	8	Subangular-subrounded	None
32-50-25 SPIN	South Beach Ridge	95.06	4.20	0.70	0.82	0.85	1.10	0.50	10YR8/3	90	10	Subangular-subrounded	Mild
32-50-25 SPIO	South Beach Ridge	92.32	6.73	0.95	0.37	0.72	1.95	0.43	10YR8/3	98	2	Subangular	Strong
32-50-25 SPIP	South Beach Ridge	91.18	7.98	0.84	0.46	0.57	1.55	0.51	10YR8/3	99	1	Subangular-subrounded	Strong
32-50-25 SPIQ	South Beach Ridge	84.85	14.47	0.68	0.73	0.50	0.98	0.63	10YR8/3	96	4	Subangular-subrounded	Mild
02-60-26 3A	Root Lake N.	81.70	15.28	3.02	1.12	0.84	-0.05	0.77	10YR6/2	95	5	Subangular-subrounded	Mild
3B	Root Lake N.	70.66	29.34	0.00	1.13	0.66	-2.2	0.75	10YR7/3	90	10	Subrounded	Mild
3C	Root Lake N.	77.35	21.33	1.36	1.02	0.61	0.45	0.49	10YR7/3	50	50	Subangular-subrounded	None
3D	Root Lake N.	92.39	5.27	2.34	1.24	0.88	0.44	0.65	10YR8/3	90	10	Subangular-subrounded	Mild
3E	Root Lake N.	69.20	30.57	0.23	1.25	0.49	0.20	0.52	10YR8/3	60	40	Subangular-subrounded	None
30-56-26 2A	Big Eddy Beach Ridge	1.37	95.70	2.93	1.67	0.69	0.11	1.33	10YR6/3	94	6	Subrounded	Mild
30-56-26 2B	Big Eddy Beach Ridge	88.36	9.28	2.36	0.80	0.89	1.10	0.62	10YR4/2	96	4	Subrounded	Mild
30-56-26 2C	Big Eddy Beach Ridge	30.52	68.86	0.62	0.50	0.36	1.33	0.61	10YR7/4	95	5	Subangular-subrounded	Mild
30-56-26 2D	Big Eddy Beach Ridge	56.01	43.07	0.91	1.41	0.85	0.49	0.64	10YR6/4	94	6	Subangular-subrounded	Mild
30-56-26 2E	Big Eddy Beach Ridge	24.61	74.64	0.75	1.75	0.79	0.05	0.76	10YR7/4	95	5	Subangular-subrounded	Mild
30-56-26 2F	Big Eddy Beach Ridge	71.52	28.20	0.28	0.14	0.38	5.11	0.24	10YR7/3	97	3	Subangular-subrounded	Mild
30-56-26 2G	Big Eddy Beach Ridge	73.40	26.51	0.09	1.28	0.69	0.26	0.67	10YR7/3	96	4	Subangular-subrounded	Mild
30-56-26 2H	Big Eddy Beach Ridge	59.80	39.87	0.34	1.61	0.88	-0.04	0.84	10YR7/2	93	7	Subangular-subrounded	Mild
30-56-26 SPIB	Big Eddy Beach Ridge	86.75	7.71	5.54	1.12	0.99	0.87	0.70	10YR8/3	95	5	Subrounded	Strong

Location	Identifier	% Gravel	% Sand	% Silt & Clay	Folk & Ward Statistics of sand fractions in Phi Units: MZ	Sorting	Skewness	Kurtosis	Munsell Colour	Pebble Lithology: % Carbonates	% Precambrian Material	Pebble Morphology	Acid Reaction
30-56-26 SPIC	Big Eddy Beach Ridge	94.24	4.60	1.16	0.44	0.53	0.17	0.72	10YR8/3	96	4	Subrounded	Strong
30-56-26 SPID	Big Eddy Beach Ridge	88.79	10.22	1.00	0.36	0.41	1.75	0.50	10YR7/1	90	10	Subrounded	Strong
30-56-26 SPIE	Big Eddy Beach Ridge	90.81	8.07	1.12	0.30	0.56	2.02	0.55	10YR8/2	91	9	Subrounded	Strong
26-59-26 1A	Root Lake Beach Ridge	66.76	25.83	7.41	1.26	0.90	0.70	0.64	01YR5/1	95	5	Subangular-subrounded	Strong
26-59-26 1B	Root Lake Beach Ridge	91.71	6.21	2.08	0.85	0.91	1.12	0.49	10YR7/3	95	5	Subangular-subrounded	Strong
26-59-26 1D	Root Lake Beach Ridge	17.10	82.52	0.38	-0.35	0.14	24.9	0.12	10YR5/1	90	10	Subrounded	Strong
26-59-26 1E	Root Lake Beach Ridge	81.54	17.33	1.13	0.52	0.55	1.29	0.79	10YR7/3	95	5	Subangular-subrounded	None
26-59-26 1A	Root Lake Beach Ridge	86.54	12.12	1.33	0.53	0.55	1.26	0.78	10YR7/3	94	6	Subangular-subrounded	None
26-59-26 1G	Root Lake Beach Ridge	93.66	4.67	1.68	0.64	0.78	1.30	0.64	10YR7/2	95	5	Subangular-subrounded	Strong
9-64-24 1D	Outwash	21.16	72.55	6.29	1.42	0.85	0.12	0.77	10YR6/3	40	60	Subangular-subrounded	None
9-64-24 1E	Outwash	2.62	95.83	1.54	1.59	0.74	0.03	1.32	10YR7/3	—	—	—	None
9-64-24 1F	Outwash	20.27	75.65	4.08	1.54	0.79	0.01	1.38	10YR7/3	40	60	Subrounded	None
9-64-24 1G	Outwash	2.40	98.43	1.53	1.70	0.75	0.05	1.16	10YR7/3	—	—	—	None
9-64-24 1H	Outwash	14.91	82.75	2.35	1.44	0.74	0.12	0.91	10YR7/3	40	60	Subangular-subrounded	None
9-64-24 1I	Outwash	1.12	97.64	0.33	1.56	0.76	0.02	1.33	10YR7/3	—	—	—	None
9-64-24 1J	Outwash	12.67	85.65	1.68	1.56	0.76	0.11	0.82	10YR7/3	40	60	Subangular	None
9-64-24 1K	Outwash	0.84	98.16	1.00	1.78	0.62	0.22	0.90	10YR7/3	—	—	—	Mild
3-58-25 1A	Kame I	79.02	10.20	1.78	1.00	0.69	0.70	0.59	10YR7/3	95	5	Subangular-subangular	Mild
3-58-25 1B	Kame I	83.20	15.19	1.61	0.93	0.70	0.79	0.63	10YR6/2	98	2	Subangular-subangular	Mild
3-58-25 1C	Kame I	88.31	10.91	0.79					10YR6/4	95	5	Subrounded	Mild
3-58-25 1D	Kame I	88.30	11.00	0.70	0.96	0.69	0.71	0.55	10YR7/3	95	5	Subrounded	Mild
3-58-25 1E	Kame I	63.86	35.50	0.64	0.93	0.67	0.72	0.54		95	5	Subangular-subrounded	Mild
12-61-27 CP	Kame II	80.22	17.46	2.23					10YR6/4	60	40	Angular	Mild
12-61-27 CP	Kame II	46.24	48.82	4.94					10YR7/2	56	44	Angular	Mild
30-56-26 3A	Big Eddy Beach Ridge	1.98	94.75	3.26	1.69	0.69	0.11	1.34	10YR6/6				None
30-56-26 3B	Big Eddy Beach Ridge	78.74	19.36	1.90	1.23	0.69	0.51	0.69	10YR5/2	89	11	Subrounded	Mild
30-56-26 3C	Big Eddy Beach Ridge	79.56	19.73	0.71	1.71	0.90	0.37	0.68	10YR6/3	83	17	Rounded	Mild
30-56-26 3D	Big Eddy Beach Ridge	79.76	19.19	1.05	0.79	0.73	0.96	0.70	10YR6/2	95	5	Subrounded	Mild

Location	Identifier	% Gravel	% Sand	% Silt & Clay	Folk & Ward Statistics of sand fractions in Phi Units				Munsell Colour	Pebble Lithology		Pebble Morphology	Acid Re-action
					MZ	Sorting	Skew-ness	Kurtosis		% Carbo-nates	% Pre-cambrian Material		
30-56-26 3E	Big Eddy Beach Ridge	84.14	15.20	0.66	0.86	0.66	0.85	0.59	10YR3/3	83	17	Rounded-subrounded	Mild
30-56-26 3F	Big Eddy Beach Ridge	67.36	30.54	2.11	1.17	0.79	0.60	0.58	10YR6/3	76	24	Subrounded	Mild
30-56-26 3G	Big Eddy Beach Ridge	74.65	25.24	0.11	0.97	0.55	0.41	0.41	10YR7/3	80	20	Subrounded	None
30-56-26 3H	Big Eddy Beach Ridge	77.08	22.67	0.25	0.51	0.53	1.42	0.47	10YR7/3	89	11	Subrounded	Mild
30-56-26 3I	Big Eddy Beach Ridge	71.01	28.67	0.32	1.07	0.64	0.60	0.61	10YR7/3	82	28	Subrounded	Mild
30-56-26 3J	Big Eddy Beach Ridge	82.85	15.70	1.72	0.13	0.35	3.13	0.31	10YR7/2	71	29	Subrounded	Mild
30-56-26 3K	Big Eddy Beach Ridge	90.84	8.93	0.18	0.32	0.44	1.97	0.41	10YR7/3	90	10	Subrounded	Mild
30-56-26 3L	Big Eddy Beach Ridge	71.01	28.66	0.23	0.12	0.35	3.16	0.31	10YR7/2	80	20	Subrounded	Mild
30-56-25 2D	Big Eddy Beach Ridge	32.00	66.91	0.43	0.46	0.42	1.42	0.56	10YR7/3	81	19	Subrounded	Mild
	Big Eddy Beach Ridge	56.73	43.08	0.18	0.34	0.40	1.88	0.43	10YR7/3	89	11	Subrounded	Mild
13-61-26 2A	Root Lake N.	22.83	67.83	9.34	0.98	0.84	0.22	0.78	10YR5/2	95	5	Subrounded	Mild
13-61-26 2B	Root Lake N.	13.48	77.15	9.37	1.36	1.17	0.20	0.62	10YR6/1	90	10	Subrounded	Mild
13-61-26 2C	Root Lake N.	41.20	51.61	7.19	1.43	1.17	0.16	0.04	10YR5/6	89	1	Subrounded	Mild
13-61-26 2D	Root Lake N.	86.46	9.96	3.58	1.31	1.01	0.82	0.74	10YR4/3	75	26	Subangular	Mild
13-61-26 2E	Root Lake N.	79.47	18.92	1.61	0.07	0.50	3.21	0.37	10YR6/3	90	10	Subrounded	Mild
27-55-26 1A	Aeolin Sand	0	76.27	3.73	1.75	0.56	0.27	1.06	10YR6/4	—	—	—	None
28-52-24 2B	Esker I	55.65	41.4	2.78	0.40	0.52	1.50	0.47	10YR7/6	85	15	Subangular-subrounded	Mild
28-52-24 2C	Esker I	78.40	19.41	2.19	1.50	0.85	0.25	0.54	10YR7/6	80	20	Subangular-subrounded	Mild
28-52-24 2D	Esker I	77.70	20.85	1.45	1.20	0.85	0.56	0.52	10YR7/6	87	13	Subangular-subrounded	Mild
02-63-26	Esker II	69.22	30.57	0.19	1.26	0.49	0.20	0.52	10YR7/6	60	40	Subangular-subrounded	None
12-50-23 1A	S. Beach Ridge	89.05	7.14	3.81	1.46	1.18	0.61	0.48	10YR8/3	100	0	Subrounded	None
12-50-23 1B	S. Beach Ridge	93.84	4.66	1.50	1.88	1.35	-0.08	0.56	10YR7/3	100	0	Subrounded	Mild
12-50-23 1C	S. Beach Ridge	83.65	11.59	4.40	1.72	1.33	0.04	0.61	10YR7/6	100	0	Subrounded	Mild
12-50-23 1D	S. Beach Ridge	76.91	8.67	14.14	1.66	1.16	0.53	0.56	10YR7/6	100	0	Subrounded	Mild
12-50-23 2A	S. Beach Ridge	76.56	21.92	1.53	0.63	0.67	1.21	0.65	10YR8/3	100	0	Subrounded	None
12-50-23 2B	S. Beach Ridge	45.83	51.31	2.86	0.84	0.65	0.96	0.97	10YR7/6	88	2	Subrounded	None
12-50-23 2D	S. Beach Ridge	43.64	54.54	1.81	0.21	0.33	2.62	0.37	10YR7/3	95	5	Subrounded	Mild
12-50-23 2E	S. Beach Ridge	82.58	15.70	1.72	0.54	0.57	1.26	0.83	10YR7/6	100	0	Subrounded	Mild
20-53-26 4A	S. Beach Ridge	75.50	20.23	4.30	0.60	0.85	1.30	0.54	10YR7/6	98	2	Subrounded	Mild
20-53-26 4B	S. Beach Ridge	45.24	52.56	2.20	0.17	0.41	2.70	0.35	10YR7/6	98	2	Subrounded	Mild

Location	Identifier	% Gravel	% Sand	% Silt & Clay	Folk & Ward Statistics of sand fractions in Phi Units				Munsell Colour	Pebble Lithology		Pebble Morphology	Acid Reaction
					MZ	Sorting	Skewness	Kurtosis		% Carbonates	% Precambrian Material		
36-57-25	Sandy Outwash	5.53	92.4	1.73	1.88	0.64	0.18	0.77	10YR7/3	—	—	—	None
01-58-27	Gravelly Outwash	78.31	19.91	1.78	0.94	0.75	0.83	0.64	10YR6/2	95	5	Subrounded	None
6-58-26	Gravelly Outwash	79.82	18.94	1.32	1.05	0.70	0.65	0.62	10YR7/3	90	10	Angular	Mild
9-64-29 1A	Sandy Outwash	33.26	64.29	2.16	1.53	0.82	0.14	0.71	10YR5/6	30	70	Subangular-subrounded	None
9-64-29 1B	Sandy Outwash	40.94	55.16	3.90	1.23	0.97	0.13	0.69	10YR6/4	10	90	Subangular	None
9-64-29 1C	Sandy Outwash	1.16	98.52	0.33	1.66	0.72	0.07	0.26	10YR8/3	—	—	—	None
6-58-26 3A		44.87	49.51	5.62	1.04	0.88	1.16	0.75	10YR4/3	90	10	Subangular	Mild
6-58-26 3B		28.79	69.71	1.50	1.37	0.63	0.03	1.01	10YR6/4	92	8	Subangular	Mild
6-58-26 3C		86.75	10.47	2.77	1.36	1.05	0.11	0.84	10YR6/4	88	12	Subangular	Mild
6-58-26 3D		37.06	62.26	0.66	0.68	0.44	1.02	0.60	10YR7/3	80	20	Subangular	Mild
6-58-26 3E		83.25	15.15	1.21	1.05	0.70	0.65	0.62	10YR6/4	80	20	Subangular	Mild
6-58-26 3F		90.88	8.59	0.53	0.70	0.57	1.05	0.84	10YR7/3	98	2	Subangular	Mild
31-57-26 1A		69.77	26.14	4.09	0.76	0.73	1.05	0.80	7.5YR8/4	88	1$2	Subrounded	Mild
31-57-26 1B		73.38	25.55	1.07	0.38	0.39	1.71	0.49	10YR8/2	80	20	Subrounded	Mild
31-57-26 1C		86.80	11.86	1.34	1.08	0.70	0.80	0.70	10YR8/3	77	23	Subrounded	None
31-57-26 1D		6.76	92.55	0.69	1.14	0.80	0.09	0.90	10YR7/2				None
12-61-26 1A	Root Lake N.	25.21	67.20	7.59	1.12	0.78	0.65	0.58	10YR3/2	90	10	Subangular	Mild
12-61-26 1B	Root Lake N.	62.66	34.61	2.73	0.40	0.59	0.67	0.59	10YR2/2	71	29	Subangular	None
12-61-26 1D	Root Lake N.	75.15	23.74	1.11	0.73	0.60	1.03	0.87	10YR6/3	80	20	Subangular	Mild
12-61-26 1G	Root Lake N.	48.12	49.22	2.66	0.20	0.58	2.44	0.47	10YR7/3	95	5	Subangular	Mild
12-61-26 1H	Root Lake N.	95.62	3.46	0.92	0.90	0.88	1.00	0.78	10YR8/5	90	10	Angular	Mild
12-61-26 1J	Root Lake N.	78.81	18.38	2.81	0.57	0.72	1.27	0.87	10YR7/2	82	15	Angular	Mild
01-57-26 10C		83.34	13.68	2.98	0.86	0.72	0.94	0.84	10YR7/1	90	10	Subangular	None
01-57-26 10D		45.06	53.07	1.88	1.15	0.56	1.01	0.72	10YR8/3	65	35	Rounded	Mild
01-57-26 10E		70.51	22.71	6.77	1.47	1.14	0.71	0.70	10YR7/2	90	10	Subangular	Strong
17-57-26 2A		8.43	91.04	0.53	1.90	0.70	0.22	0.84	10YR7/3	—	—	—	None
		41.33	57.64	1.04	1.35	0.96	-0.07	0.89	10YR7/4	90	10	Subangular	None
		2.76	96.99	0.26	1.54	0.52	0.05	1.38	10YR7/2	—	—	—	None
14-53-28 4A	Westray Beach Ridge	3.02	94.81	2.17	1.75	0.75	0.08	1.12	10YR6/6	—	—	—	None
14-53-28 4B	Westray Beach Ridge	83.70	51.41	0.89	0.59	0.48	1.11	0.57	10YR7/3	70	30	Subangular-subrounded	None
14-53-28 4C	Westray Beach Ridge	64.6	93.17	0.36	1.85	0.71	0.20	0.93	10YR7/3	—	—	—	None
13-54-29 3A	Drumlin Gravel	85.09	9.80	5.10	1.54	1.07	0.49	0.58	10YR7/4	95	5	Subangular	Mild

Location	Identifier	% Gravel	% Sand	% Silt & Clay	Folk & Ward Statistics of sand fractions in Phi Units: MZ	Sorting	Skewness	Kurtosis	Munsell Colour	Pebble Lithology: % Carbonates	% Pre-cambrian Material	Pebble Morphology	Acid Reaction
12-54-29 2A	Drumlin Till	26.56	58.19	21.24	1.58	1.11	0.20	0.67	10YR7/4	90	10	Angular	Strong
02-55-29	Drumlin Till	26.83	55.05	18.09	1.52	1.14	0.16	0.71	10YR5/6	85	15	Angular	Strong
18-61-25	Ablation Till	31.73	49.58	18.09	1.93	1.11	0.14	0.59	2.5Y6/4	90	10	Angular	Strong
28-59-26	Lower Till	40.99	23.06	35.94	1.70	1.00	0.34	0.60	10YR5/4	85	15	Angular	Strong
28-59-26 2B	Lower Till	74.05	15.69	9.44	1.30	0.99	0.67	0.75	10YR7/4	90	10	Angular	Strong
30-57-26 1E	Upper Till	20.93	55.6	23.5	1.49	1.19	0.17	0.66	10YR7/2	90	10	Angular	Strong
30-57-26	Upper Till	19.10	23.10	57.80	1.93	1.31	-0.13	0.63	10YR7/2	95	5	Angular	Strong
33-57-26	Upper Till	15.88	19.31	64.79	1.94	1.05	0.23	5.63	10YR7/2	98	2	Angular	Strong
21-57-26	Upper Till	14.67	20.96	64.9	1.85	1.31	-0.13	0.65	10YR7/2	95	5	Angular	Strong
33-57-26 4B	Upper Till	39.50	11.50	48.48	1.50	0.97	-0.1	0.65	10YR7/2	95	5	Angular	Strong
10-61-25	Ablation Till	24.23	56.16	10.16	1.04	0.80	0.21	0.77	10YR7/2	70	30	Angular	Strong
26-57-25 5A	Silica Sand	2.65	94.50	2.86	1.18	0.64	0.18	0.77	10YR8/2				None
16-57-26	Glaciolacustrine	8.32	5.56	86.29	1.84	1.10	0.25	0.58	2.5Y6/2	98	2	Angular	None
16-61-27	Glaciolacustrine	6.80	16.70	76.50	1.52	1.08	0.13	0.70	2.5Y6/2	50	50	Angular	None

APPENDIX D: PEAT ANALYSIS

Sample	Location	Depth	% Sphagna	% Reed & Sedge	% Wood Fragments	% Humified	pH	Absorptive Value Dry Basis	Absorptive Value 25% Moisture Basis	Notes
V-50-25-28-PB-1A	SW¼23-50-25W	0 — 1 foot	79	9	4	8	6.3	17.39	12.79	med. — dark brown
V-50-25-28-PB-1B	SW¼23-50-25W	1 — 2 feet	7	30	30	33	6.8	12.56	9.17	dark med. brown
V-50-25-28-PB-1C	SW¼23-50-25W	2 — 2.6 feet	3	76	12	9	6.6	9.57	6.18	med. brown; other plants
V-50-25-28-PB-2A	SW¼23-50-25W	0 — 1 foot	95+	5			6.2	26.64	19.71	very light brown, whole plants
V-50-25-28-PB-2B	SW¼23-50-25W	1 — 1.5 feet	75*	15	4	6	6.5	24.29	17.98	whole plants*, may be 1/3 hypnum (?)
V-56-26-30-3A	?	—	1	59	20	20	4.3	7.81	5.61	med. — dark brown; silt grains
V-50-25-29-3A	SW¼28-50-25W	channel sample	55	35	5	5	6.5	12.65	9.24	H. sphag. + dark reed and sedge
V-50-25-15-4A	NE¼10-50-25W	0 — 1 foot	98	1	1	—	6.6	27.17	20.33	tan; excellent sphagnum
V-50-25-15-4B	NE¼10-50-25W	1 — 1.5 feet	80	8	7	5	6.5	16.20	11.89	light — med. brown
V-50-25-15-4C	NE¼10-50-25W	1.5 — 2 feet	2	48	5	45	6.7	8.80	6.35	med. — dark brown; 20% fibre
V-49-25-33-5A	SE¼33-49-25W	0 — 1 foot	1	65	15	20	6.6	8.22	5.92	med. — dark brown; may be other moss than sphagnum
V-49-25-33-5B	SE¼33-49-25W	1 — 1.5 feet	15?	45	10	30	6.8	9.24	6.68	med. — dark brown
V-49-25-33-5C	SE¼33-49-25W	1.5 — 2 feet	10	50	20	20	6.7	8.31	5.98	med. — brown; sphagnum
V-CP-3	?	—	27	63	3	7	6.2	13.45	9.83	med. brown
V-DRAGLINE	?	—	20	20	5	55	6.4	7.79	5.59	med. — dark brown; humified silt grains

APPENDIX E

GEOPHYSICAL SURVEYS

Ground geophysical investigations involving seismic refraction and resistivity techniques were carried out during the summer of 1976 in order to determine the approximate thicknesses of sand and gravel and other sediments in the area around The Pas.

SEISMIC REFRACTION SURVEYS

Seismic refraction surveys are based on the property that seismic waves are refracted at the interface of materials having different densities. In order for refraction to take place, the density of the underlying material should be higher than the material above. The time interval between the initiation of the waves and the first arrivals of these waves at a geophone placed a certain distance away is recorded on a seismograph. This time interval is dependent on (i) the velocities of the waves through the various materials, (ii) the depths to the refracting interfaces and (iii) the distance of the geophone from the point of initiation of the waves.

The time intervals versus the distance of the geophone from the point of initiation of the waves are plotted graphically. From these graphs the velocities of the waves through the various materials and the thicknesses can be calculated. Figure E-1a shows an example of a two layer case where the first layer consists of sand and the second layer, clayey till. The velocities of the materials were determined by fitting the derived curves to a set of standard velocity curves, while the thicknesses of materials were determined by using a multilayer seismic refraction nomogram (Meidau 1968; Figure E-1b). A pocket SEIS Engineering Seismograph, model ES-1A, was used to record the time intervals.

Results:

The following are generalized velocities of seismic waves obtained from 36 surveys (Table E-1) carried out at near surface sand and gravel locations:

Material	Seismic velocities
Sand and Gravel	410 — 1300 metres/second
Clayey Till	1300 — 2600 metres/second
Dolomite	2600 — 5000 metres/second

Results from the seismic surveys carried out over the Big Eddy, Root Lake and C.N.R. deposits (numbers 31001, 31003 and 31005 respectively) coincide closely with drill logs and pit information collected during the same field season.

Since the maximum depth of penetration employing a hammer shock source in an area of glacial till is approximately 12 m, it was not possible to establish the total thickness of till on the crest of The Pas Moraine. However, dolomite bedrock is indicated at six locations (Table E-1), two of which occur within the Big Eddy Reserve at NE 24-56-27W and SW 01-58-27W, approximately 5.6 metres from surface. At Prospector (SE 01-58-27W), Render Lake (NE 31-58-26W), Clearwater Lake (SE 34-57026W), and Root Lake (SE 21-59-26W) drift thickness varies from 4.1 to 6.0 m.

Because of the speed and ease of operation the seismic refraction techniques provides a useful reconnaissance tool in the determination of depth to bedrock. In addition, it provides valuable information on thicknesses of sand and gravel deposits.

RESISTIVITY SURVEY

Resistivity surveys are based on the property that different materials have different electrical resistivities. Therefore if a known current is introduced into the subsurface by means of two current electrodes and the resulting potentials measured by two separate potential electrodes the apparent resistivities of the subsurface materials can be calculated.

The Wenner configuration was generally employed during fieldwork. With this configuration 4 electrodes (2 current and 2 potential) are placed at equal intervals along a straight line with the current electrodes at the outside. Increasing the separation between the electrodes increases the depth of penetration of the current and hence the depth of investigation.

The apparent resistivities versus the electrode separations are plotted graphically on double logarithmic paper. The curve thus arrived at is compared with master curves (Orellana and Mooney, 1966) until a close fit is obtained. The resistivities and thicknesses of the different materials are derived from the master curves.

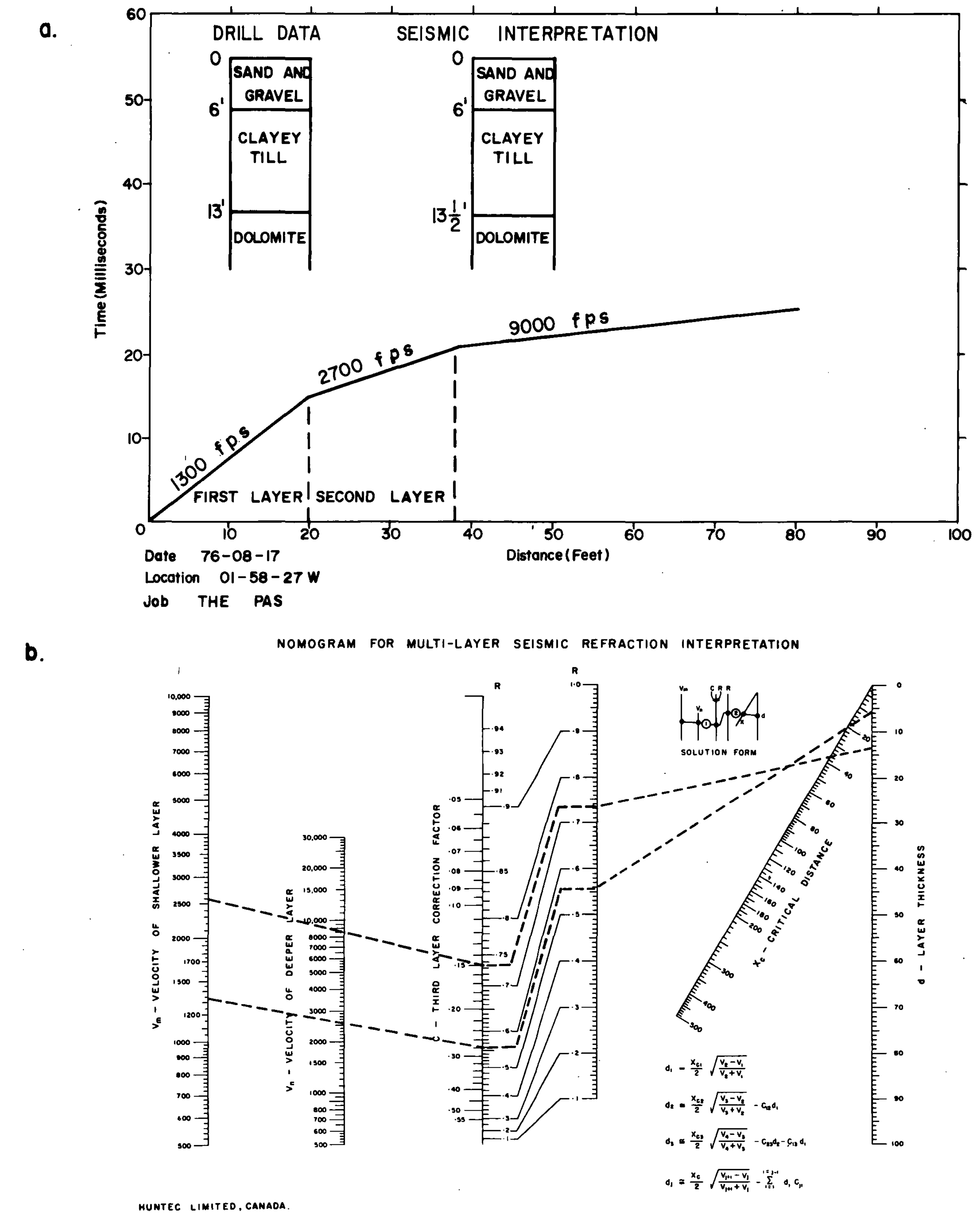

FIGURE E-1: Interpretation Procedures for Seismic Refraction Data (after Meidau, 1968)

TABLE E-1 RESULTS OF SEISMIC SURVEYS

Location		Seismic Velocities fps	Depth (ft.)	Material Descriptions	Field Data
NE27-52-27W	(1)	1300	0 — 3	Topsoil, organic material and loose sand	Sand and gravel at surface
	(2)	2500	3 — 9	Sand and gravel	
	(3)	5000	9 — 35	Clayey till	
NE30-52-27W	(1)	1300	0 — 8	Sand and gravel	Sand and gravel at surface
	(2)	5000	8 — 35	Clayey till	
NE20-54-26W	(1)	1550	0 — 11	Sand and gravel	Freshford Deposits (Ridge B)
	(2)	6500	11 — 31	Clayey till	
SE20-54-26W	(1)	1200	0 — 6	Sand and gravel	Sand and gravel at surface
	(2)	4900	6 — 28	Clayey till	Freshford Deposit
NE17-54-26W	(1)	1450	0 — 4	Sand and gravel	Sand and gravel at surface
	(2)	6000	4 — 18	Clayey till	Freshford Pit
NE27-55-26W	(1)	1100	0 — 7	Sand	Sand at surface: north of cemetery
	(2)	4500	7 — 36	Clayey till	
SE22-55-26W	(1)	1000	0 — 4	Sand, gravel and soil	Pit run at surface. Young's
	(2)	3600	4 — 18	Clayey till	Point. Depleted pit
NE19-56-26W	(1)	1200	0 — 6	Soil and sand	Big Eddy Reserve
	(2)	5000	6 — 30	Clayey till	Settlement area
NE24-56-27W	(1)	2000	0 — 10	Sand and gravel	Big Eddy Reserve
	(2)	5000	10 — 16	Clayey till	Gravel Pit
	(3)	8000	16 — 24	Dolomite bedrock	
SW25-56-27W	(1)	1100	0 — 8	Sand and gravel	Big Eddy Reserve
	(2)	4000	8 — 17	Clay till	Gravel Pit
	(3)	10000	8 — 17	Bedrock	
NE25-56-27W	(1)	2800	0 — 9	Sand and gravel	Big Eddy Reserve
	(2)	5000	9 — 30	Clay till	Gravel Pit
	(3)	7000			
SE25-56-27W	(1)	1600	0 — 9	Sand and gravel	Sand and gravel pit
	(2)	6000	9 — 35	Clay till	Big Eddy Reserve
NE18-56-26W	(1)	1000	0 — 5	Loose soil and sand	Big Eddy Reserve
	(2)	3050	5 — 12	Sand and gravel	Settlement area
	(3)	6000	12 — 33	Clayey till	
SW12-56-26W	(1)	1200	0 — 13	Wet soil and clayey till (water table)	The Pas Moraine
	(2)	5000	13 — 35	Clayey till	Grace Lake
NE18-56-26W	(1)	2000	0 — 6	Loose wet sand and gravel	Magazine Ridge
	(2)	5500	6 — 34	Clayey till	
NW19-56-26W	(1)	1400	0 — 3	Loose soil and sand	Big Eddy Reserve
	(2)	2000	3 — 8	Sand and gravel	Settlement area
	(3)	6000	8 — 22	Clayey till	
SW19-56-26W	(1)	1200	0 — 1	Soil	
	(2)	1250	1 — 11	Wet sand and gravel	Kennedy's Gas Station
	(3)	5500	11 — 31	Clayey till	
SW17-56-26W	(1)	1250	0 — 7	Sand and gravel	Big Eddy Reserve
	(2)	7000	7 — 30	Clayey till	Settlement area
SE34-57-26W	(1)	1700	0 — 9	Clay till (water table)	Clearwater Lake Road
	(2)	5000	9 — 18	Clay till (compact)	
	(3)	15000	9 — 18	Dolomite bedrock	
NE06-58-26W	(1)	1350	0 — 5	Soil and sand	
	(2)	2500	5 — 13	Sand and gravel	Prospector Deposit
	(3)	7000	13 — 31	Clay till	

Location	Seismic Velocities	fps	Depth (ft.)	Material Descriptions	Field Data
SW07-58-26W	(1)	1250	0 — 4	Soil and loose sand	C.N.R. Deposit — Prospector
	(2)	2000	4 — 11	Sand and gravel	
	(3)	6000	11 — 33	Clayey till	
NW07-58-26W	(1)	2000	0 — 14	Sand and gravel	C.N.R. Deposit — Prospector
	(2)	4500	14 — 32	Clayey till	
SW18-58-26W	(1)	1100	0 — 4	Soil and loose sand	C.N.R. Deposit — Prospector
	(2)	2500	4 — 18	Sand and gravel	
	(3)	5000	18 — 36	Clayey till	
SE04-58-25W	(1)	800	0 — 6	Soil, wet sand and gravel	Airport Deposit
	(2)	7000	6 — ?	Dolomite bedrock	
SE03-58-25W	(1)	1500	0 — 15	Soil, sand and gravel	Airport Deposit
	(2)	15000	15 — ?	Dolomite bedrock	
SE01-58-27W	(1)	1250	0 — 7	Soil, sand and gravel	Prospector Deposit
	(2)	4500	7 — 26	Clayey till	
SW07-58-26W	(1)	2500	0 — 20	Sand and gravel	C.N.R. Deposit — Prospector
	(2)	5500	20 — 35	Clayey till	
NE31-58-26W	(1)	1100	0 — 5	Loose sand	Render Lake East
	(2)	3500	5 — 16	Clayey till	
	(3)	8000	16 — ?	Dolomite bedrock	
SE01-58-27W	(1)	1300	0 — 6	Sand and gravel	Prospector Deposit
	(2)	2700	6 — 13	Clayey till	
	(3)	9000	13 — ?	Dolomite bedrock	
SE13-50-27W	(1)	1700	0 — 6	Sand and gravel	C.N.R. Deposit — Prospector
	(2)	5000	6 — 31	Clayey till	
NE24-58-27W	(1)	1100	0 — 4	Sand	C.N.R. Deposit — Prospector
	(2)	4000	4 — 22	Clayey till	
SE21-59-26W	(1)	1350	0 — 11	Sand and gravel	Root Lake Deposit
	(2)	5000	11 — 20	Clayey till	
	(3)	13000	20 — ?	Dolomite bedrock	
SE27-59-26W	(1)	1200	0 — 10	Sand and gravel	Root Lake Deposit
	(2)	4000	10 — 33	Clayey till	
SE34-59-26W	(1)	1700	0 — 10	Sand and gravel	Root Lake Deposit
	(2)	6000	10 — 31	Clayey till	
SE21-59-26W	(1)	1250	0 — 5	Sand and gravel	Root Lake Deposit
	(2)	6500	5 — 12	Clayey till	
SW23-60-26W	(1)	1200	0 — 11	Sand and gravel	Root Lake Deposit
	(2)	6000	11 — 22	Clayey till	

(1) = Seismic velocity of 1st layer (2) = Seismic velocity of 2nd layer (3) = Seismic velocity of 3rd layer

Results:

Table E-2 shows the resistivity values and approximate thicknesses of 14 near surface sand and gravel deposits derived from the resistivity survey. The results indicate that resistivity values vary considerably with the type of material and the amount of moisture contained therein. Well drained, near surface sand and gravel deposits have the highest resistance, varying from 1300 to 10,000 ohm-feet. At sites where values ranged between 1300 and 2500 ohm-feet, 75 percent of the material was found to be sandy. Values from 2500 to 10,000 ohm-feet occured when more than 50 percent of the underlying material was in the pebble-cobble size. At NE¼ 27-59-26W, where the sediment is entirely beach sand, resistivity values are less than 1000 ohm-feet. Clayey till has relatively low values ranging from 95 to 1820 ohm-feet. At two locations, SE¼ 20-54-26W (Freshford) and SE¼ 33-57-26W (Reader Lake), the near surface water table accounts for the lowest resistivity values of the clayey till deposits surveyed.

TABLE E-2 RESULTS OF RESISTIVITY SURVEYS

LOCATION		P_1 OHM ft.	d_1 ft.	MATERIAL	P_2 OHM ft.	MATERIAL
SE20-54-26W	Freshford Pit	1300	4.0	Sand and Gravel	260	Clayey Till
SE33-57-26W	Reader Lake Road	1900	4.9	Sand and Gravel	95	Clayey Till
NW19-58-26W	C.N.R. Deposit	4500	12.0	Sand and Gravel	585	Clayey Till
NE22-59-26W	Root Lake Deposit	8500	7.0	Sand and Gravel	850	Clayey Till
SE34-59-26W	Root Lake Deposit	3000	12.0	Sand and Gravel	900	Clayey Till
NE27-59-26W	Root Lake Deposit	650	6.0	Sand	812	Clayey Till
NE34-59-26W	Root Lake Deposit	2800	6.5	Sand and Gravel	1820	Clayey Till
SE26-60-26W	Root Lake Deposit	10000	10.5	Sand and Gravel	2000	Clayey Till
NW11-60-26W	Root Lake Deposit	5500	4.5	Sand and Gravel	550	Clayey Till
NW14-60-26W	Root Lake Deposit	2500	3.5	Sand and Gravel	810	Clayey Till
SW14-60-26W	Root Lake Deposit	6000	4.5	Sand and Gravel	1200	Clayey Till
NE26-60-26W	Root Lake Deposit	2300	3.5	Sand and Gravel	920	Clayey Till

P_1 = Resistivity of First Layer

d_1 = Depth of First Layer

P_2 = Resistivity of Second Layer