Alberta
RESEARCH COUNCIL

SAND AND GRAVEL RESOURCES OF THE COLD LAKE AREA, ALBERTA

W.A.D. Edwards and J.C. Fox

August, 1980

Open File Report No. 1980-8

Alberta
RESEARCH COUNCIL

ERRATA

Figure 3: In the notes, the reference should be Edwards, 1977 and 1978 and J.C. Fox, 1978.

TABLE OF CONTENTS

ILLUSTRATIONS

Alberta
RESEARCH COUNCIL

Table of contents (continued)

TABLES

Table of contents (continued)

Alberta
RESEARCH COUNCIL

ABSTRACT

The major aggregate deposits (1,000,000 m^3 or more) in the Cold Lake study area are found as: intermediate level terraces in the Beaver River valley (six deposits), terraces in the Mooselake River valley (two deposits), and outwash deposits in the Elk Point area (three deposits). These deposits at present provide a fairly even distribution of aggregate throughout the region so that the major aggregate consumers (towns of St. Paul, Bonnyville, Grand Centre, Medley and Cold Lake; County of St. Paul; Municipal District of Bonnyville; and Alberta Transportation) have relatively convenient supplies of sand and gravel.

The greatest exploitation of the resource to date has occurred in the lower Beaver valley (east of the Sand River) and many of the deposits in this area are nearing depletion. Development has begun in the Mooselake River valley to supply aggregate to this northeast region. The outwash deposits are also undergoing development as major sources of aggregate for St. Paul and the southern half of the study area.

The substantial size of deposits and their distribution has prevented shortages of aggregate in most parts of the study area. Yet the resource is finite and dwindling. If oil sands development proceeds at a high rate the northeastern part of the study area will be depleted of gravel by 1997 and the entire region by the year 2032. A detailed, overall management plan should be followed if the remaining resource is to be efficiently used.

INTRODUCTION

This report is one of a series published by the Alberta Geological Survey, a department of the Alberta Research Council. The purpose of the report is to describe potentially useful sand and gravel deposits, provide a starting point for detailed exploration programmes, and aid land-use planning decisions.

The deposits described are mappable at a scale of 1:50,000, have a minimum thickness of 1 m and have a ratio of overburden to gravel and sand of no more than 1:1. Volume figures are general estimates based on a geological interpretation of the deposits and not detailed subsurface data.

ACKNOWLEDGMENTS

Funds for this project were supplied by Alberta Energy and Natural Resources.

The authors wish to thank G. Seve for assistance in the field; J. Meyer for help in the field and office; and P. Sham for technical assistance in the field, laboratory work and drafting. Thanks are also due B. Hudson for valuable comments during the course of this study, and B.N. Peterson, M.M. Fenton, and L.D. Andriashek, for their critical reading of the manuscript.

LOCATION OF STUDY AREA

The study area is located 200 km east-northeast of the city of Edmonton (Fig. 1).

Municipalities covered or partially covered in this study include the towns of St. Paul, Bonnyville, Elk Point, Grand Centre, and Cold Lake; the County of St. Paul (No. 19); the M.D. of Bonnyville (No. 87); and I.D. No. 18 (Fig. 2).

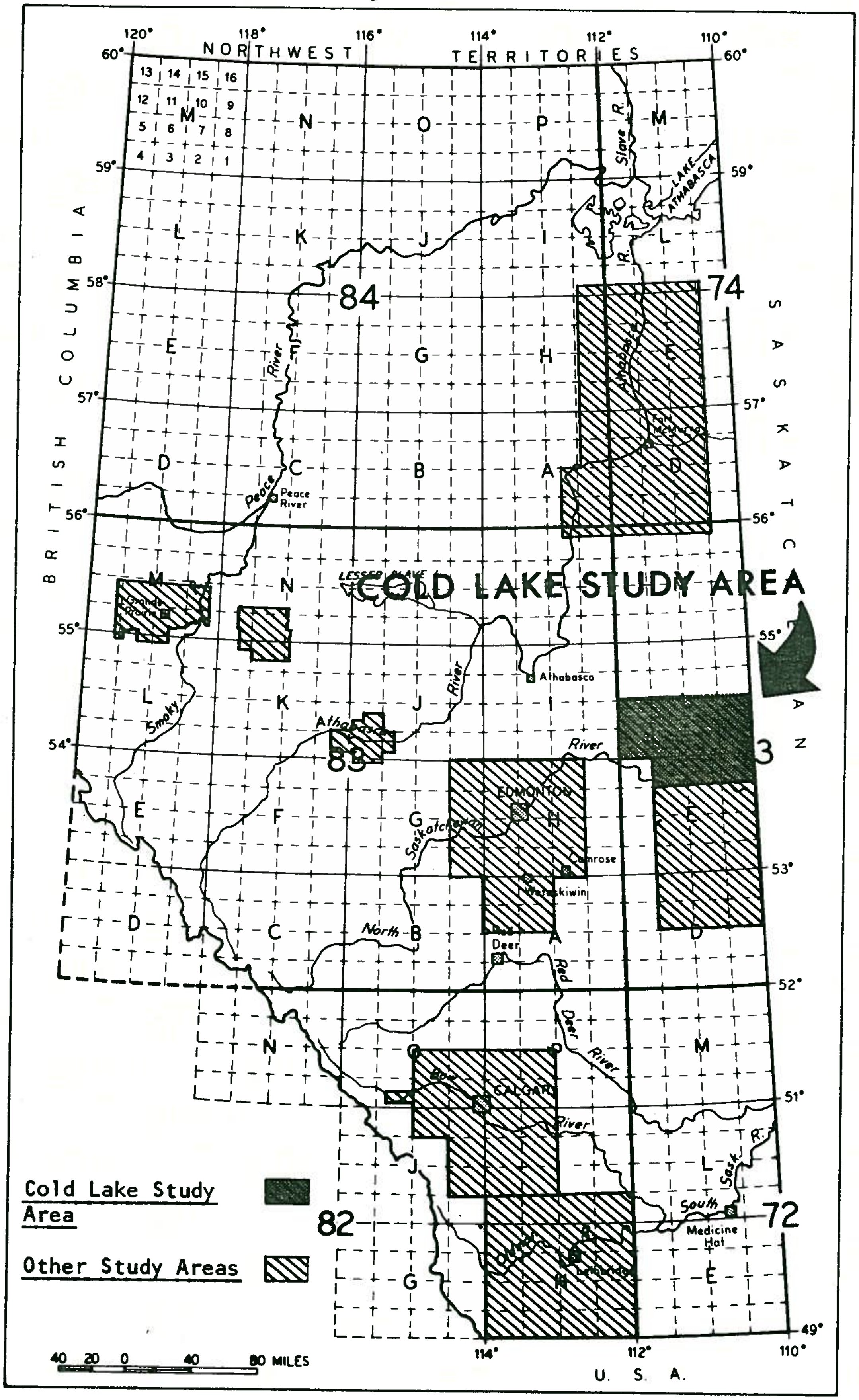


FIGURE 1. Sand and Gravel Inventory study areas.

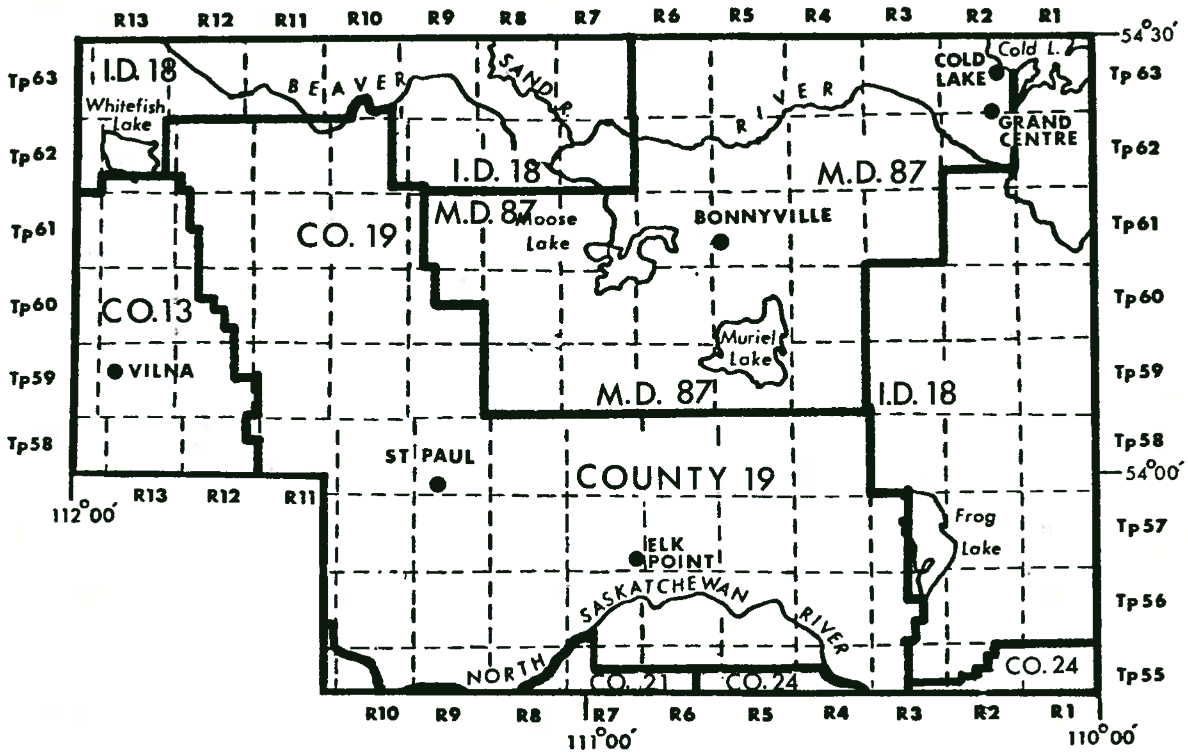


FIGURE 2. Detailed location of the Cold Lake study area.

PREVIOUS WORK

Published reports used in this study included a surficial geology map by Ellwood (1961), a soil survey report by Lindsay, Pawluk and Odynsky (1962), and a hydrogeology report by Currie and Zacharko (1975).

Water well logs on file at the Alberta Research Council and preliminary surficial geology information (Fenton and Andriashek, 1979) also provided useful data.

METHODS OF STUDY

The study began with the compilation and review of existing literature on the surficial and subsurface geology. A preliminary airphoto interpretation of the area was performed prior to field investigation from which a surficial geology map (Fig. 3) was derived.

Fieldwork formed the second phase of the study and was done during the summers of 1977 and 1978. This phase consisted of: (1) road and foot traverses to check and refine the airphoto interpretation; (2) describing sand and gravel pits and other exposures, collecting samples for lab analysis and field sieving of bulk samples; (3) subsurface testing (Geonics EM 31 and resistivity surveying, power-auger testhole drilling, and backhoe excavating) was used to gain further information on the quantity and quality of major deposits.

The final phase of the study consisted of analyzing samples (grain-size distribution and petrographic analyses), assessment of the data and production of this report.

A number of different systems are presently used in classifying rock fragments according to size. Fragments described by geologists are most commonly classified according to the Wentworth scale (Wentworth, 1922) shown in figure 4. Terms used in this report correspond to the industrial classification (Fig. 4).

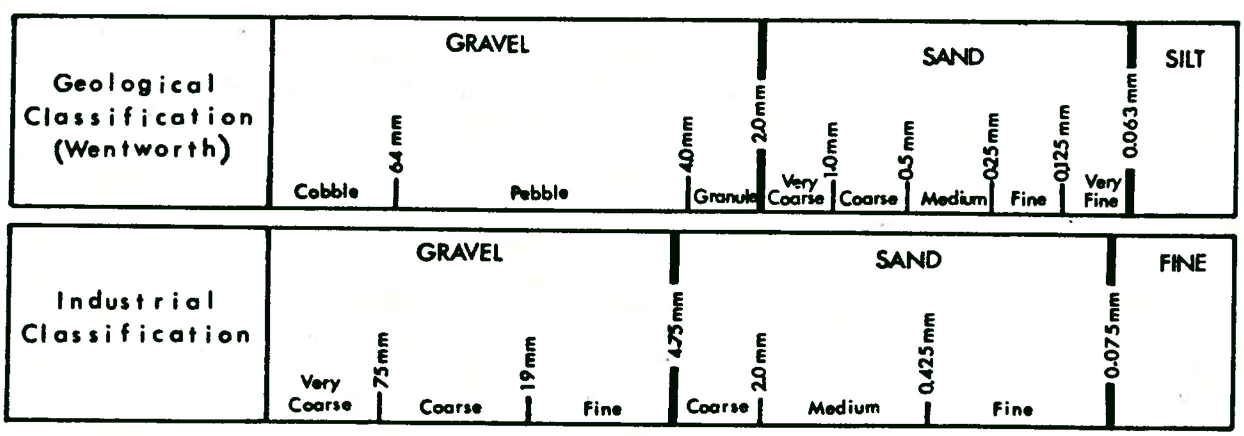


FIGURE 4. Geological and Industrial grain-size classifications.

Sediments are classified according to the abundance of fragments of different sizes. In this study all coarse-grained sediments (more than 50 percent, by weight, of the sediment having particle diameters in excess of .075 mm) are classified according to figure 5.

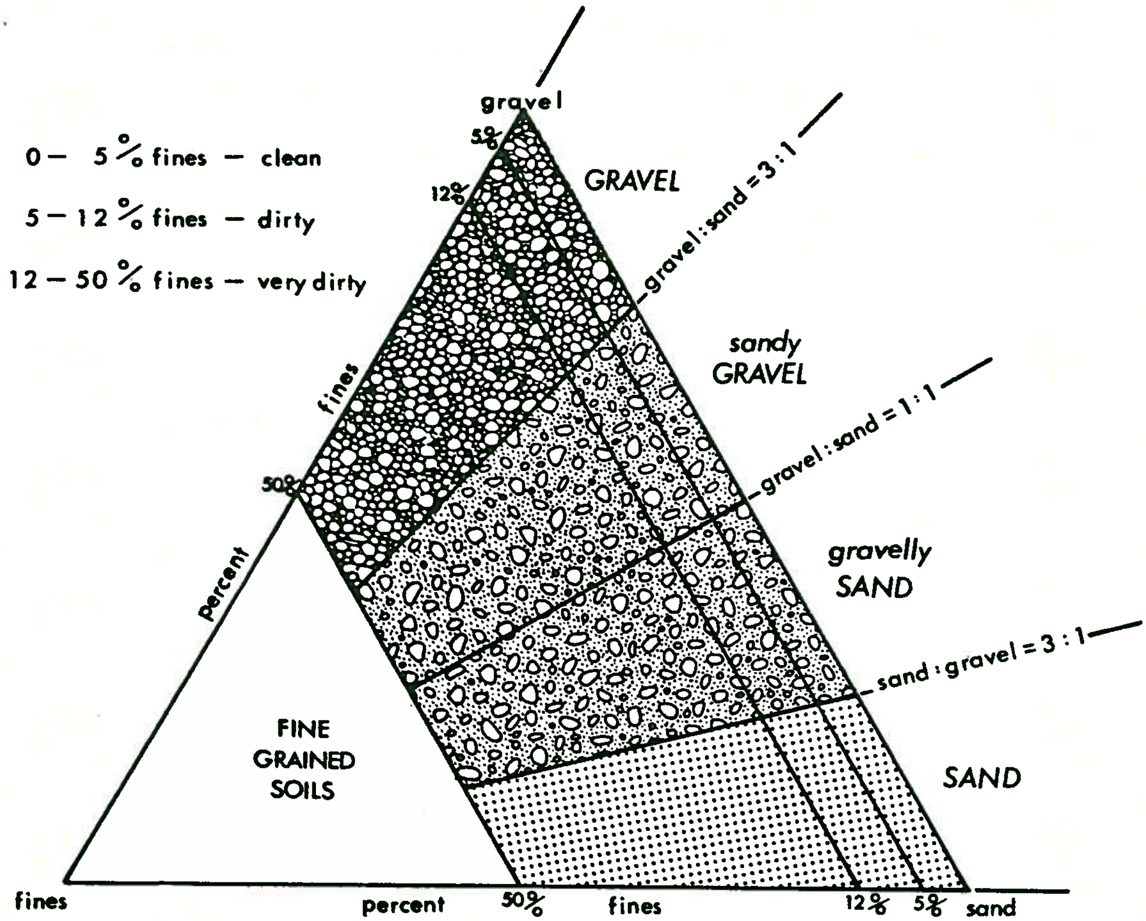


FIGURE 5. Classification of unconsolidated, coarse-grained sediments (after the Unified Soil Classification System).

Sand and gravel is a general term used for any coarse-grained sediment. Sand, gravelly sand, sandy gravel and gravel are specific terms defined in figure 5. The amount of fines in a coarse-grained sediment is indicated by the use of the appropriate modifier - clean, dirty or very dirty (Fig. 5) (for example, clean gravelly sand or very dirty gravel). If no modifier is used the sediment is assumed to be clean.

BEDROCK GEOLOGY

The northeastern part of the study area is underlain by the Cretaceous Lea Park Formation and the southwest by the Cretaceous Belly River Formation (Fig. 6) (Green, 1972; Currie and Zacharko, 1975; Ozoray, Wallick and Lytviak, 1979).

The bedrock within the area is not a source of aggregate. It is soft and easily comminuted and therefore does not form a major component of the sand and gravel in the area. Ironstone concretions from the Belly River Formation are the most resistant fraction of the local bedrock and form a small percentage of most sand and gravel deposits. The ironstone is considered a deleterious material.

The bedrock topography of the area (Yoon and Pluyn, 1974; Currie and Zacharko, 1975) indicates that three major bedrock valleys cross the area. These channels are infilled mainly by fluvial and glacial materials. The bases of these buried valleys often have a fill of sand and gravel but due to the considerable depth of burial these occurrences do not appear to have economic significance and were not investigated further.

SURFICIAL GEOLOGY

An understanding of the geological processes that were and are active in an area is important in the location and assessment of mineral aggregate deposits. In this study most deposits were the result of glaciofluvial and subsequent fluvial processes and thus an understanding of the surficial geology is valuable.

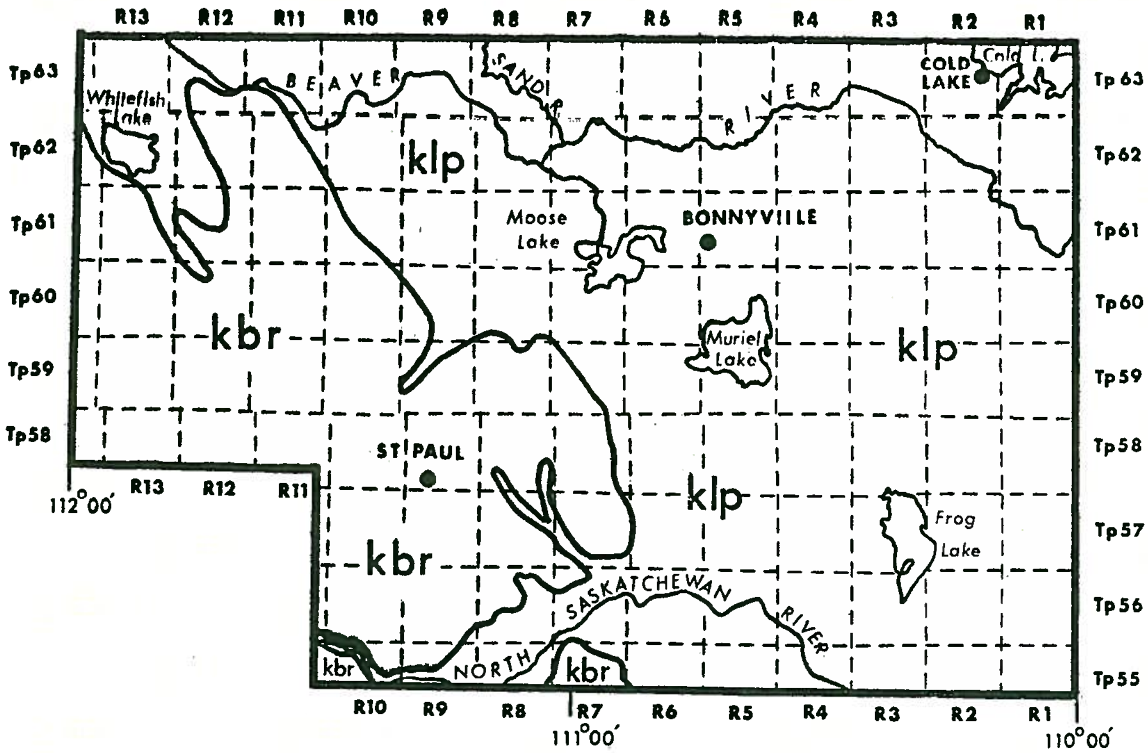


FIGURE 6. Bedrock geology of the Cold Lake study area (after Green, 1972; and Ozoray, Wallick and Lytviak, 1979): Kbr — Cretaceous Belly River Formation; Klp — Cretaceous Lea Park Formation.

Figure 3 shows the types and distribution of surficial deposits in the study area as determined through airphoto interpretation and limited field investigation. Most of the area is covered by moraine composed mainly of till. This has been divided into five units (Fig. 3) based on the morphology and genesis. Table 1 describes the landform and materials in each of the morainal units and indicates their potential as an aggregate source.

The moraine plain, fluted moraine and ice-thrust moraine (units 1, 2, and 3 respectively) were probably formed under conditions of active glacial movement. Areas of moraine plain and fluted moraine are unlikely localities for gravel deposits because glacial activity tends to mix sediment rather than sort it. Minor lenses of sand and/or gravel are common in the ice-thrust areas southeast of the Thérien Lakes and one deposit north of St. Paul may be a large ice-thrust block.

Table 1. Composition of the glacial units and their potential for aggregate use

Unit	Name	Description	Potential for Aggregate
1	Moraine Plain	a flat to rolling surface underlain principally by till.	LOW: may be small deposits in meltwater channels.
2	Fluted Moraine	a rolling surface formed of long flutes composed of till, sand or other glacially molded sediments.	LOW: may be incorporated sand or gravel lenses.
3	Ice-thrust Moraine	a hummocky to ridged surface formed of till, sand, gravel or bedrock thrust and deposited by ice.	MODERATE: small sand and gravel lenses common; large deposits rare.
4	Stagnant-ice Moraine	a rolling to hummocky suface formed of till hummocks, ice-contact deposits and meltwater channels.	LOW TO MODERATE: low potential in primarily till areas (doughnuts), moderate in areas with meltwater channels.
5	Water-modified Moraine	a flat to rolling surface formed of eroded till or thin lacustrine sediments over till.	LOW: may be small deposits in meltwater channels.

The stagnant-ice moraine (unit 4) was formed by the melting of a large mass of debris-rich stagnant ice. This unit can contain granular material. Complex networks of meltwater channels drained the areas of stagnant ice resulting in the transportation and deposition of coarse grained materials.

The water-modified moraine (unit 5) is moraine plain which has been modified slightly by later meltwaters. The action of meltwaters altered the morphology and airphoto expression of the moraine but generally did not deposit or accumulate sand and gravel.

The most important units in terms of sand and gravel resources are the glaciofluvial deposits (Table 2) which are divided into ice-contact (unit 6) and outwash deposits (unit 7). Ice-contact deposits found in the study area include kames and eskers. They are scattered about the area but individually contain only small quantities of aggregate, generally sand. In this study the term outwash deposit includes outwash plain, pitted outwash plain, valley train and high-level terraces (particularly the Beaver and Mooselake River terraces). The outwash deposits are the best sources of aggregate in the Cold Lake study area.

Table 2. Composition and aggregate potential of the glaciofluvial units

Unit	Name	Description	Potential for Aggregate
6	Ice-contact	kame, esker, crevasse filling.	HIGH TO VERY HIGH: potential for occurrence of granular material very high; deposits may be poorly sorted, structurally deformed, low in volume and generally sand.
7	Outwash	outwash, pitted outwash, valley train; depositional terrace or bar (or eroded valley fill).	VERY HIGH: potential for occurrence of granular material very high, for coarse aggregate high; deposits generally clean, well-sorted, uniform and sometimes high in volume.

In situ bedrock (Unit 8, Fig. 3), as opposed to disturbed bedrock in thrust moraine, is found mainly in the valleys of the North Saskatchewan River, Kehiwin Channel and Beaver River. The potential of the bedrock for aggregate use is low (Table 3).

Recent (postglacial) deposits (Unit 9, Fig. 3) include present river channel deposits of sand, silt and clay and poorly drained depressional areas containing shallow organic material overlying till. Areas of Recent fluvial deposition are generally of low potential in this area (Table 3).

Table 3. Aggregate potential of the bedrock and Recent units

Unit	Name	Description	Potential for Aggregate
8	Bedrock	soft sandstone (Belly River Fm) or shale (Lea Park Fm), sometimes with ironstone concretions.	VERY LOW: sandstone is generally fine grained, poorly exposed.
9	Fluvial	alluvium (generally fine grained) and erosional terraces.	LOW: alluvium is generally sandy or muddy.
	Bog	organic material (bog, marsh and swamp).	VERY LOW

The surficial geology map (Fig. 3) provided with this report can be used for aggregate exploration by considering the geological units in terms of their aggregate potential (as shown in Tables 1, 2 and 3, and in Fig. 3).

SAND AND GRAVEL RESOURCES

The major present and potential sources of sand and gravel in the Cold Lake study area are: terraces and bars in the Beaver River and Mooselake River valleys, outwash plain deposits in the southeast portion of the area and scattered meltwater channel and ice-contact deposits.

The following sections will describe more fully these major categories and individual deposits within them. The terrace and bar deposits will be discussed under two headings: the *Beaver River terrace and bar deposits* and the *Mooselake River terrace, bar, and deltaic deposits*. The outwash plain and meltwater channel deposits will be described under *Outwash deposits* and the various ice-contact features will be considered under *Ice-contact deposits*. The sand and gravel deposits of the study area are shown at a scale of 1:50,000 in a series of maps (Figs. 17 to 27) included in the pocket. Each of these figures (17 to 27) has an index map.

A description of the present markets for aggregate in the area are given in the section on *Resource development*. Estimated rates of consumption and assumed total available quantities of aggregate are used in this section to provide a view of the use of the resource until its depletion in the study area.

BEAVER RIVER TERRACE AND BAR DEPOSITS

The Beaver River originates just west of the study area and flows eastward into Saskatchewan. In places the Beaver River valley is up to 40 m deep. The down-cutting which formed the valley was accompanied by the deposition of sediments as bars or floodplain deposits (Fig. 7). These sediments were deposited at various elevations (Fig. 8) and after partial erosion, now form terraces on the valley walls. These terraces are excellent sources of aggregate material.

The Beaver River was initially formed during the final stages of the last glacial period as glacial ice was melting from the area. It is likely that meltwater channels (high level channels) provided the initial incision that helped determine the course of the ancestral Beaver River. The direction and continuity of these early channels is uncertain but it appears that the meltwater of one system (including deposits 1, 3, 6, 11, 12 and 15 in Fig. 8) flowed west and the water in another system (including deposits 30, 34, 40, 42, 45, 48 and 50 in Fig. 8) flowed east. The material in these high level channels and fans, like the out-wash in the area, is primarily sand (Fig. 8).

The early Beaver River followed the same course as the present river (Fig. 7) and deposited granular material now seen as high level terraces (Fig. 8). These terraces are situated on the upper part of the valley from the edge to about 15 m below it. The deposits occasionally contain coarse aggregate (example, deposits 38 and 51, Fig. 8) but are generally composed of sand.

Clasts were eroded from the till forming the banks as the Beaver River continued downcutting. These clasts were concentrated into mid-channel or point bars situated 15 to 30 m below the valley edge. These deposits now form the intermediate level terraces (Fig. 8) which commonly contain gravel and are the major sources of aggregate in the northern part of the study area.

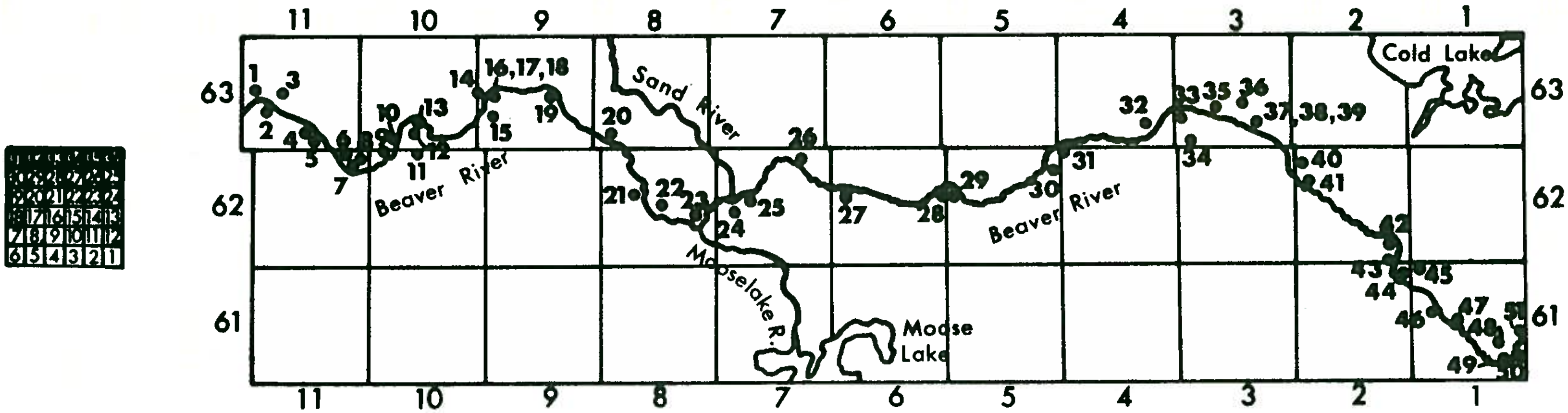


FIGURE 7. Location of sand and gravel deposits in the Beaver River valley.

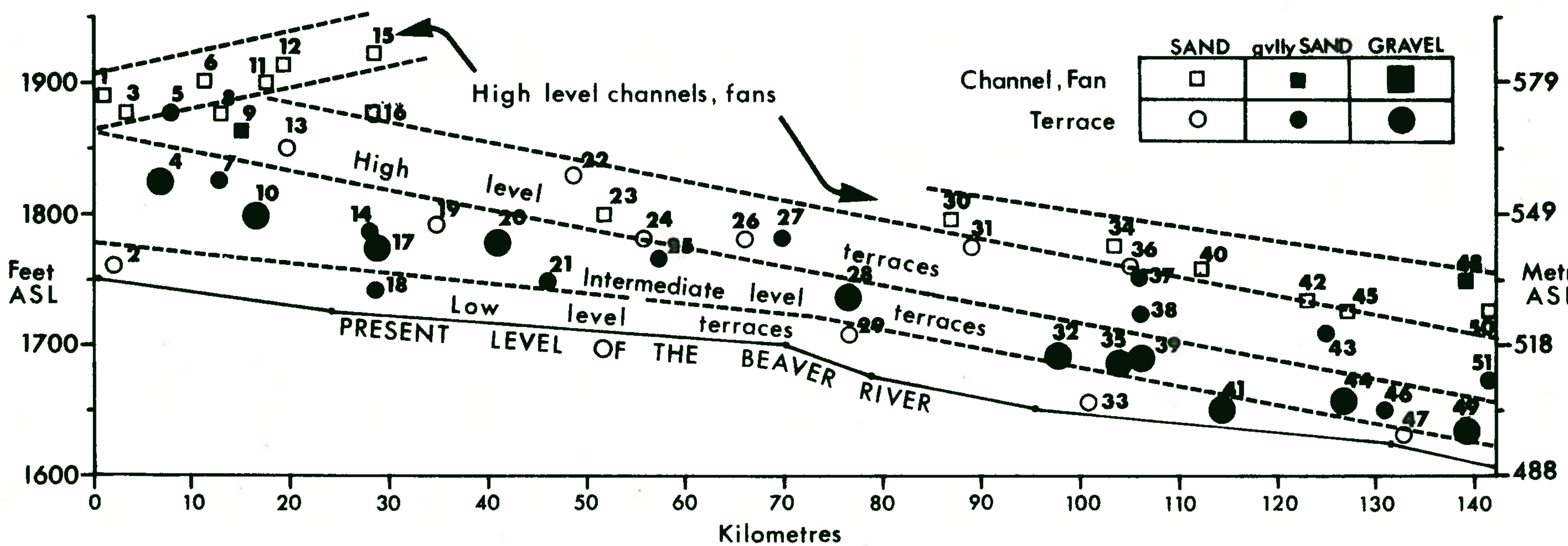


FIGURE 8. Elevation and composition of deposits in the Beaver River valley.

As the ice retreated from the area the amount of water available to the Beaver River was reduced. Incision continued but the river was less competent to carry and deposit coarse aggregate. Generally the terraces formed at this stage (low level terraces, Fig. 8) are finer and more poorly sorted than the intermediate level terraces. The present day river floodplain and channel deposits are mainly clay and silt with some sand; deposits of gravel are not being formed.

The three zones: i) upper level deposits; ii) intermediate level deposits; and iii) low level deposits, are described in more detail in the following sections.

Upper level deposits (Table 4)

The upper deposits are the result of several means of deposition:

High Level channels

High level channels are early meltwater channels cut off by later valley incision. They are generally infilled with medium sand and floored by till at depths of 3 m or more. The water table is often encountered just above the till. None of these deposits were being worked for aggregate at the time of fieldwork.

Terraces

Generally 2 to 5 m of sand and gravel cover the till with the water table most often just above the till. Most of the aggregate material on the terraces is clean medium sand with below 25 percent gravel content. Several deposits (5, 12, 13, 36, 38, 43, 51, Table 4) contain areas where gravelly sand is found. Deposit 12 consists of a high terrace composed mainly of sand and a lower terrace (13) of gravelly sand to gravel. This latter terrace is a good source of sand and gravel and will likely become a source of material for the local area south of the river when present supplies become depleted.

Table 4. Upper level Beaver Valley deposits.
(see Fig. 8 for the locations of the deposits)

Deposit	Area (ha)	Volume (m3)	Material	Landform	Status
1	3	140,000	medium sand	fan	pit
3,6,11,15, 23,30,34	?	?	barren or sandy	channel	occasional borrow pit
5	16	280,000	gravelly sand to medium sand	terrace	pit
8	29	793,000	medium sand	channel	undeveloped
9	8	200,000	gravelly sand	fan	pit
12	111	3,663,000	medium sand	terrace, channel	undeveloped
13	45	1,575,000	sandy gravel	terrace	undeveloped
16	4	50,000 (?)	sand	fan	undeveloped
22	40	1,000,000 (?)	sand (?)	terrace	undeveloped
24	62	700,000	sand	terrace	undeveloped
26	50	1,000,000 (?)	sand	terrace	undeveloped
27	45	?	sand	terrace	undeveloped
31	20	100,000 (?)	sand	terrace	undeveloped
36	48	500,000	sand to gravelly sand	terrace	inactive, gravelly sand mainly depleted
37	22	250,000	sand	terrace	depleted
38	50	450,000	sand to gravelly sand	terrace	mainly depleted
40	?	?	sand	fan	inactive
42	25	423,000	sand	terrace, fan	borrow pit
43	16	180,000 (?)	gravelly sand	terrace	inactive
45	100	2,700,000	medium sand	terrace, fan	pit
48	23	585,000	gravelly sand	fan	undeveloped
50	7	150,000	medium sand	channel	undeveloped
51	13	425,000	gravelly sand to sand	terrace	pit

? - Information uncertain or unknown

Alluvial fans

These fans are small and are associated with cut off channels or meltwater channels which intersected the ancestral Beaver Valley. They generally contain little material (250,000 m^3) and are mainly medium sand.

Deposits 9 and 48 do contain areas of gravelly sand. The water table was not encountered during exploration.

Most of the upper level deposits are of medium sand, occasionally dirty, with low gravel content. Of the total volume (about 15,384,000 m^3) less than 15 percent is gravel size. The gravels are mainly of Precambrian origin with some deleterious material.

Until the fall of 1978 only seven pits had been developed in these upper deposits. Four pits (deposits 1, 9, 42 and 45) were small and infrequently used by local farmers as fill. Two deposits (36 and 38) are essentially depleted of aggregate reserves. Thus only one upper level deposit (51) was actively supplying aggregate at this time.

Intermediate level deposits (Table 5)

All of the intermediate level deposits are terraces. These terraces are composed of the coarsest material within the valley and are located 15 to 30 m below the lip of the valley wall, often with very steep access. They range in size from 4 to 87 ha.

The material of the intermediate terraces is coarser than the upper level deposits. It varies between medium sand and coarse gravel and is predominantly gravelly sand to sandy gravel.

Considerable variation in thickness is encountered in individual terraces but they are generally thicker than the upper level deposits with the thinnest

Table 5. Intermediate level terraces in the Beaver River valley. (see Fig. 8 for the locations of the deposits)

Deposit	Area (ha)	Volume (m^3)	Material	Landform	Status
4	50	1,517,000	sandy gravel (lag)	terrace	undeveloped
7	4	143,000	gravelly sand	terrace	undeveloped
10	32	1,134,000	sandy gravel	terrace	undeveloped
14	30	50,000 (?)	gravelly sand	terrace	inactive pit
17	12	250,000 (?)	gravelly sand to gravel	terrace	undeveloped
19	25	200,000 (?)	sand	terrace	undeveloped
20	25	2,000,000	sandy gravel	terrace	pit
21	6	150,000 (?)	gravelly sand	terrace	inactive pit
25	50	1,000,000 (?)	gravelly sand	terrace	inactive pit
28	30	1,400,000	sand to gravel	terrace	pit
32	8	200,000 (?)	gravelly sand to gravel	terrace	mainly depleted
35	8	50,000 (?)	gravelly sand	terrace	mainly depleted
39	17	50,000	sand to sandy gravel	terrace	mainly depleted
44	34	304,000 (?)	sand to gravelly sand (?)	terrace	mainly depleted
46	16	92,000	gravelly sand	terrace	undeveloped
49	87	2,846,000	gravelly sand to sand	terrace	pit

? - information uncertain or unknown

portion (1 to 2 m) on the river side. Groundwater is likely to be encountered near the base of the aggregate, just above the till which generally forms the underlying layer.

These intermediate deposits contain the bulk of the sand and gravel pits within the Beaver River valley. Of the 16 deposits listed (Table 5), six were being actively excavated in 1978 (deposits 20, 28, 32, 39, 33 and 49) and two are already depleted (35 and 39). The remaining deposits appear to have good potential except for deposit 4 where 70 percent of the material is of a very coarse lag deposit (clasts up to 75 cm diameter) with the interstitial spaces filled with organic matter and fines. Deposit 7, although of small volume, could become an aggregate source for the area north of the river when the pit immediately south of Fork Lake is depleted.

Low level deposits (Table 6)

The low level deposits are few in number and generally small. Only a few of the largest (2, 29, 41, 47) were explored due to access difficulties. The aggregate materials range in size from fine or medium sand to sandy gravel. Difficult access and relatively small volumes make these deposits of low priority for further testing.

Table 6. Low level terraces in the Beaver River valley. (see Fig. 8 for the locations of the deposits)

Deposit	Area (ha)	Volume (m^3)	Material	Landform	Status
2	42	400,000 (?)	mainly sand	terrace	undeveloped
18	20	300,000	gravelly sand	terrace	undeveloped
29	15	450,000	sand	terrace	pit
33	25	500,000 (?)	fine sand	terrace	undeveloped
41	8	20,000 (?)	gravelly sand	terrace	depleted
47	?	?	sand	terrace	undeveloped

? - information uncertain or unknown

MOOSELAKE RIVER TERRACE, BAR AND DELTAIC DEPOSITS

The geological history of the Mooselake River system is not well understood. Although the few facts available fit a number of hypotheses, the authors have chosen to restrict the discussion in this report to only one.

The present Mooselake River flows south to north (Moose Lake to the Beaver River) but the early Mooselake River, in which the major aggregate deposits formed (Fig. 9), is believed to have flowed in the opposite direction. This interpretation is based on the decrease in elevation of the deposits from north to south (Fig. 10), a decrease in gravel to sand content and maximum clast size from north to south and eastward dipping cross beds at site 54.

The Mooselake River valley probably formed the downstream part of the early Beaver River and terminated in a much larger Moose Lake. The various fluvial bars and terraces in the Mooselake River valley are stratigraphically similar — sand and gravel resting on a relatively flat surface of clay till. This till surface provides a minimum elevation (about 541 m ASL) for the bottom of the Mooselake valley during this early stage. Extending the surface up the Beaver River valley (Fig. 10) indicates that the high level Beaver River terraces upstream from the Mooselake River may have formed as part of a Beaver River-Mooselake River system.

Flow was diverted from the Mooselake River valley into the lower Beaver valley when the height of land dividing the Beaver-Mooselake system and the lower Beaver River (SW-13-62-8, Fig. 9) was breached. The intermediate and low level Beaver River terraces were formed after the diversion.

The landforms in the Mooselake River system include fluvial bars (sites 52, 53, 54, 55, 56, 57, 62, 63 and 65; Table 7), terraces (sites 58 [?], 59, 60 and 61, Table 7) and a delta built into early Moose Lake (site 64; Table 7). The fluvial bars and terraces may all contain coarse aggregate. They occur as highs in

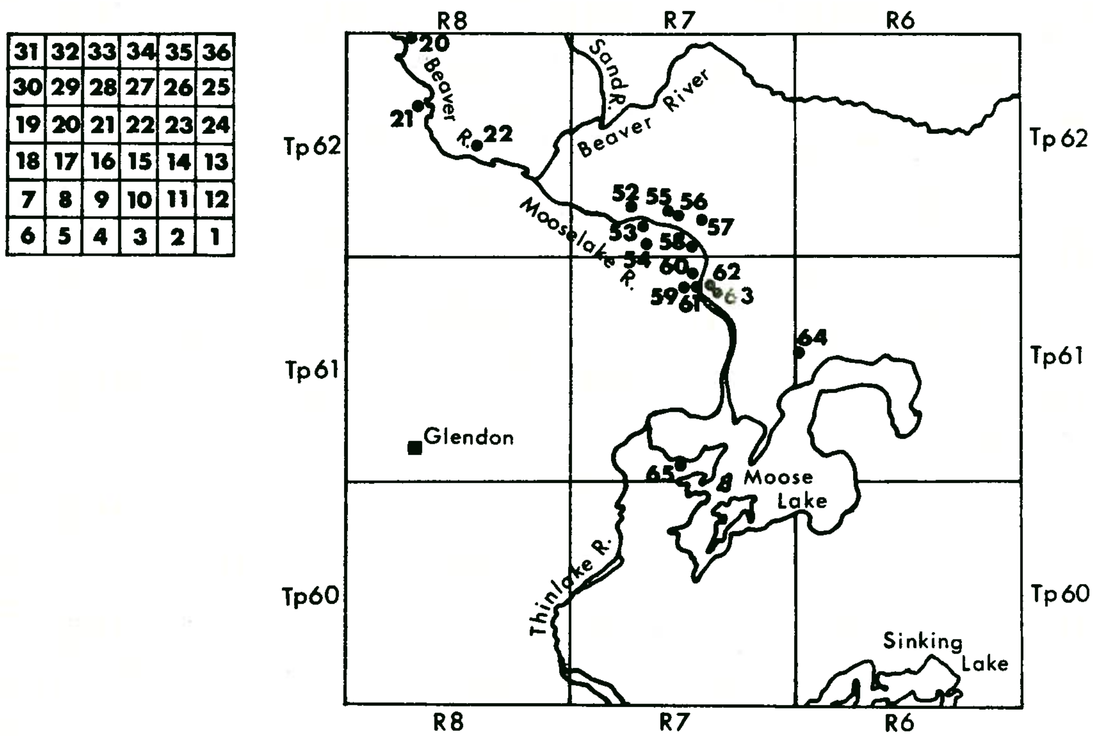


FIGURE 9. Location of sand and gravel deposits in the Mooselake River valley and the Moose Lake basin.

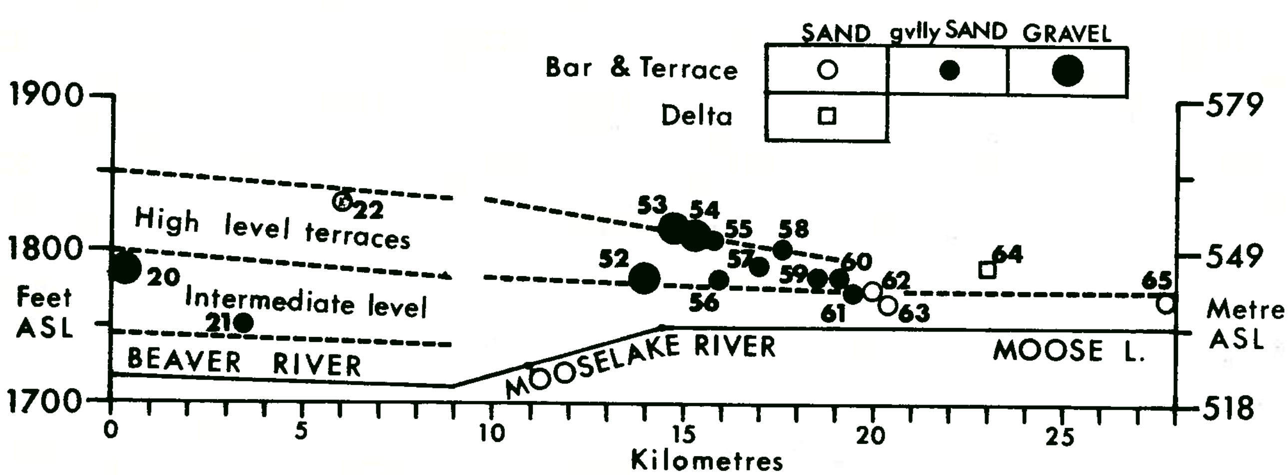


FIGURE 10. Elevation of deposits in the Mooselake River valley and the Moose Lake basin.

Table 7. Deposits in the Mooselake River valley and Mooselake basin. (see Fig. 9 for the locations of the deposits)

Deposit	Area (ha)	Volume (m^3)	Material	Landform	Status
52	30	150,000 (?)	sandy gravel	bar	undeveloped
53	26	980,000	sandy gravel	bar	pit
54	80	3,430,000	sandy gravel	bar	pit
55	7	50,000 (?)	gravelly sand (?)	bar	undeveloped
56	5	25,000 (?)	gravelly sand (?)	bar	undeveloped
57	12	100,000 (?)	gravelly sand (?)	bar	undeveloped
58	13	100,000 (?)	gravelly sand (?)	terrace (?)	undeveloped
59,60,61*	42	287,000	gravelly sand	terraces	undeveloped
62	30	125,000 (?)	sand (?)	bar	undeveloped
63	12	50,000 (?)	sand (?)	bar	undeveloped
64,65	1000+	10,000,000+	sand, rarely with gravelly sand lenses	delta and bar, lacustrine	essentially

? - information uncertain or unknown
* - Hardy, 1979

otherwise low, marshy terrain. The thickness of sand and gravel approximates the height of the landform above the surrounding terrain and ranges from about 6 m (sites 53 and 54; Fig. 9) to as little as 1 m (site 52; Fig. 9). The deltaic part of the system is composed of 6 to 15 m of medium to fine-grained sand over till.

The grain size distribution varies with position in the system. The upstream (northern) sites (52, 53 and 54; Fig. 9) contain a high percentage of gravel (Table 7). The downstream (southern) terraces contain less gravel (sites 59, 60 and 61; Table 7) and the deltaic part of the system is essentially sand, occasionally with an upper 2 or 3 m of gravelly sand (site 65; Fig. 9).

In general the coarse gravel in the system is composed of hard, durable quartzite to quartz sandstone (site 54 – 52 percent) and granite (site 54 – 47 percent) (Hardy, 1979). The fine gravel contains more granite (site 54 – 55 percent), less quartzite (site 54 – 32 percent) and more deleterious metamorphic rock (site 53 – 6 percent). The coarse gravel can produce a good to excellent material for concrete (site 54 – petrographic numbers range from 106.4 to 119.8) (Hardy, 1979) and because the upstream (northern) sites (52, 53 and 54; Fig. 9) are highest in coarse gravel they are the most valuable in terms of high quality construction material. The more downstream (southern) sites (59, 60 and 61; Fig. 9) contain less coarse gravel and thus the quality of the aggregate rates as poor for concrete (site 61 - petrographic number 148.4) (Hardy, 1979).

The fine aggregate shows a similar decrease in quartz and sandstone grain frequencies from north to south (site 54 – 79 percent; site 61 – 55 percent) and an increase in igneous and metamorphic rock (site 54 – 20 percent; site 61 – 37 percent) (Hardy, 1979). The suitability of the sand for concrete purposes decreases from fair in the upstream sites to unsuitable at the downstream terrace sites (Hardy, 1979).

The large volume (Table 7), high percentage of gravel and good quality of aggregate at sites 53 and 54 makes them valuable sources of aggregate. Although the smaller downstream (southern) terraces (sites 59, 60 and 61; Table 7) contain less gravel and poorer quality material, they still must be considered to be significant resources. The deltaic area contains an immense volume of material (sites 64 and 65; Table 7) but the fine nature of the aggregate and the high water table will probably prevent its utilization.

OUTWASH DEPOSITS

The term outwash is used to define any deposit composed of material carried by glacial meltwater but not deposited directly in contact with the ice. In this study it includes outwash plain deposits, and meltwater channel deposits (i.e., terraces and fluvial bars). The terraces and bars of the Beaver and Mooselake River systems are described separately.

Deglaciation of the study area was dominated by the stagnation of large masses of ice and the formation of extensive networks of meltwater channels. Outwash deposits are thus common and widespread throughout the area.

The outwash plain deposits found in the study area formed when meltwater flowing within stagnant ice or in a meltwater channel spread out onto a relatively flat, unconfined plain. The decrease in the flow velocity of the water resulted in the deposition of coarse-grained sediments.

The outwash plain deposits (sites 66, 67 and 68; Fig. 11 and Table 8) all contain coarse sediments (20 to 30 percent gravel), aggregate thicknesses in excess of 5 m and volumes greater than 10,000,000 m^3. These deposits occur in the southern part of the study area and represent the greatest accumulation of exploitable aggregate in the Cold Lake area.

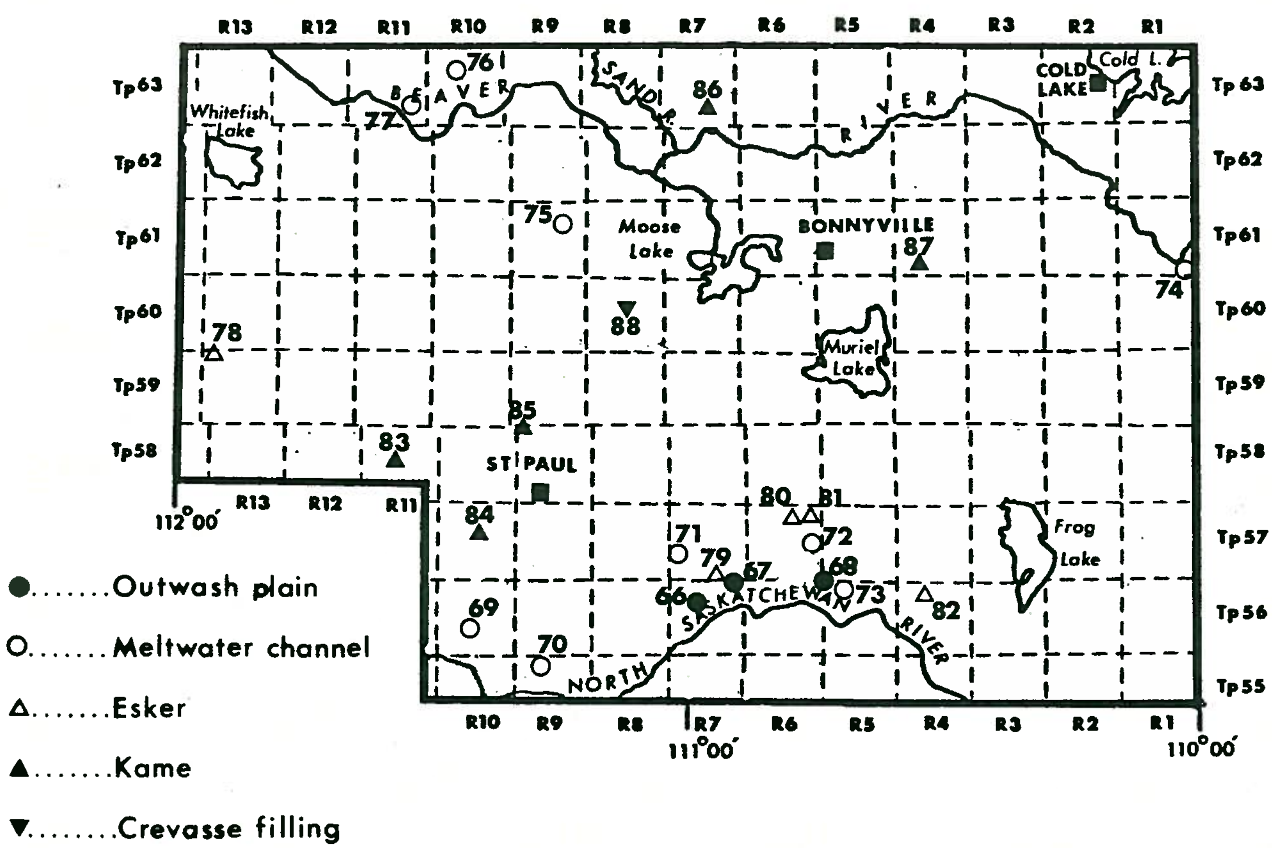


FIGURE 11. Location of outwash and ice contact deposits.

Table 8. Outwash plain and meltwater channel deposits. (see Fig. 11 for the locations of the deposits)

Deposit	Area (ha)	Volume (m^3)	Material	Landform	Status
66	209	11,547,000	gravelly sand	outwash plain	pits
67	186	11,756,000	sand to gravelly sand	outwash plain	pits
68	629	34,000,000	sand to gravelly sand	outwash plain	pits
69	68	1,020,000	gravelly sand	meltwater channel	pits
70	4	102,000	gravelly sand	meltwater channel	pit
71	25	1,530,000	gravelly sand	meltwater channel	undeveloped
72	20	751,000	gravelly sand	meltwater channel	undeveloped
73	591	31,230,000	sand	meltwater channel	undeveloped
74	146	5,800,000	sand	meltwater channel	undeveloped
75	30	300,000	sand	meltwater channel	pit
76	31	930,000	sand	meltwater channel	pit
77	57	1,700,000	sand	meltwater channel	pit

The meltwater channel deposits (sites 69, 70, 71, 72, 73, 74, 75, 76 and 77; Fig. 11) are composed of sediments in the form of terraces and point-bars which were deposited in channels immediately following the last glaciation. In terms of grain-size distribution the meltwater channel deposits can be divided into two types: 1) gravelly sand deposits containing about 30 to 45 percent gravel (sites 69, 70, 71 and 72; Table 8); and 2) sand deposits containing less than 10 percent gravel and more than 45 percent medium grained sand (sites 73, 74, 75, 76 and 77; Table 8).

The gravelly channel deposits all occur in the southern half of the study area in close proximity to the outwash plain deposits. They range in volume from about 100,000 m^3 to 1,500,000 m^3 (Table 8) and in thickness from 1 to 5 m.

Groundwater is often encountered near the surface of the deposits because of their valley location. Relatively small volumes, small thicknesses and a high water table are factors which limit the usefulness of the gravelly meltwater channel deposits.

Sandy meltwater channel deposits are scattered throughout the study area. They are variable in volume, containing from a few thousands to many millions of cubic metres of sand. An abandoned channel often marks the course of the former meltwater flow (e.g., sites 74 and 75; Fig. 11). In some cases the abandoned meltwater channel is not visible. These disassociated outwash deposits (sites 76 and 77; Fig. 11) are detectable on airphotos but not by tracing the abandoned meltwater channels. The lack of coarse aggregate and the general fine to medium grained nature of the sand are the major factors which have curtailed greater exploitation of these often large deposits.

ICE-CONTACT DEPOSITS

Ice contact deposits are formed of sediments deposited in contact with glacial ice. The ice-contact landforms found in this area include eskers, kames and crevasse fillings.

Five eskers (sites 78 to 82; Fig. 11) were identified in the study area of which two (sites 78 and 79; Fig. 11) have been exploited for aggregate. The volume of material found is generally small (Table 9) and the sediments are principally in the form of sand. The ridge form and the absence of overburden (site 78 is an exception) allows easy extraction of material from eskers.

The esker at site 78 has a 1 to 5 m thick till cap. This cap was formed when poorly sorted debris slumped from surrounding stagnant ice and buried the well-sorted, coarse-grained sediments that had been deposited in a subglacial channel. The other four eskers all occur in the Elk Point area, north of the outwash plain deposits. They represent the upstream, ice-confined part of the meltwater systems which formed the outwash plains.

Table 9. Ice-contact deposits. (see Fig. 11 for the locations of the deposits)

Deposit	Area (ha)	Volume (m^3)	Material	Landform	Status
78	5	250,000	sand to gravelly sand	esker	pit
79	3	120,000	sand to gravelly sand	esker	pit
80	22	500,000 (?)	sand (?)	esker	undeveloped
81	2	80,000	sand (?)	esker	undeveloped
82	20	500,000 (?)	sand (?)	esker	undeveloped
83	12	480,000	sand to gravelly sand	kame	pit
84	28	500,000	sand	kame	pits
85	11	700,000	sandy gravel	kame	pit
86	5	100,000 (?)	sandy gravel to gravelly sand	kame	pit
87	?	?	sand to sandy gravel	kame	pit
88	20	100,000 (?)	sand to sandy gravel	crevasse filling	pit

? - information uncertain or unknown

Kame and crevasse filling deposits are scattered about the area (sites 83 to 88; Fig. 11). The kames (sites 84 to 86) are irregular hills composed of gravelly sand and sand usually with a till cap. A system of crevasse fillings was identified by airphoto interpretation in the central part of the study area. The largest crevasse filling (site 88; Fig. 11) has been worked for sand and gravel. Both the kames and crevasse fillings are highly variable in structure and content and only detailed testing can define the amount and quality of aggregate within them. Generally the volume of aggregate is small and the quality fair to poor (Table 9).

The ice-contact deposits are scattered across the area, north of the outwash plain deposits. This suggests that meltwater drainage in the northern and central parts of the area was initially confined within the stagnant ice mass and resulted in the formation of the ice-contact deposits.

RESOURCE DEVELOPMENT

There is an estimated 147 million cubic metres of sand and gravel presently available in the Cold Lake study area (Table 10) of which about 122 million cubic metres is sand and 25 million cubic metres is coarse aggregate. The coarse aggregate (gravel) can be generally divided into material suitable for concrete (termed construction gravel in this study) and material useful for road maintenance and construction or fill (termed road gravel here). In this area there are approximately 19 million cubic metres of construction quality gravel and 6 million cubic metres of road gravel (Table 10). All construction quality gravel is also suitable for road gravel. The intermediate Beaver River terraces, the northern deposits in the Mooselake River valley and the outwash plain deposits, are assumed to contain construction quality gravel. Detailed testing and sample analyses are necessary to confirm these assumptions and will probably alter the amount of construction gravel estimated in this study.

The consumption of aggregate varies from place to place and with time (Table 11). Per capita consumption in 1976 among the provinces varied from 4.1 m^3 in P.E.I. to 12.5 m^3 in Quebec. Edmonton had a per capita consumption of 7.2 m^3 in 1976 and an average annual per capita consumption of 7.8 m^3 from 1972 to 1976. Annual consumption will probably reach 11.2 m^3 per capita in Edmonton and other expanding regions in the near future (Table 11). In this study a value of about 10 m^3 per capita annual consumption (18 tons) was used in the gravel consumption projections.

Population projections have been done for the Cold Lake region (Alberta Department of Municipal Affairs, 1978). Four possible projections, based on various assumptions, were made for part of the study area until 1999. Three of these

Table 10. Estimated amounts of aggregate available in the study area.

Deposits	Sand (m^3)	Gravel (road) (m^3)	Gravel (construction) (m^3)	Total (m^3)
Beaver River valley:				
upper level	12,564,000	2,600,000	-	15,164,000
intermediate terraces	6,849,000	-	4,540,000	11,389,000
low terraces	1,372,000	298,000	-	1,670,000
Mooselake River valley	11,739,000	1,226,000	2,333,000	15,298,000
Outwash plain	44,984,000	-	12,318,000	57,302,000
Meltwater channel	41,795,000	1,568,000	-	43,363,000
Ice-contact	2,245,000	586,000	-	2,831,000
	121,548,000	6,278,000	19,191,000	147,017,000

projections (Fig. 12) are used in this study: 1) a projection based on existing population and increased growth (at 3.79 percent annually) assuming no major resource development (oil sands); 2) a projection based on a low rate of oil sands development; and 3) a projection based on a high rate of oil sands development. The population of an area outside of the Municipal Affairs study area but within the scope of this study (including Vilna, St. Paul, Elk Point and the County of St. Paul) was added to the Municipal Affairs total, but projected at only 1.59 percent annually — the historical increase of the Cold Lake region with no major interference (Municipal Affairs, 1978). Beyond 1999 population growth was projected at 1.59 percent.

Table 11. Examples of annual per capita consumption rates for aggregate.

Area	Year or average of years	Aggregate (tons)	Consumption per capita[1] (m^3)	Reference
Newfoundland	1976	11.0	6.2	The Canadian Mineral Aggregate Industry, 1978
Nova Scotia	1976	13.3	7.4	The Canadian Mineral Aggregate Industry, 1978
Prince Edward Island	1976	7.4	4.1	The Canadian Mineral Aggregate Industry, 1978
New Brunswick	1976	14.2	10.0	The Canadian Mineral Aggregate Industry, 1978
Quebec	1976	22.3	12.5	The Canadian Mineral Aggregate Industry, 1978
Ontario	1976	12.9	7.2	The Canadian Mineral Aggregate Industry, 1978
Manitoba	1976	19.9	11.1	The Canadian Mineral Aggregate Industry, 1978
Saskatchewan	1976	10.3	5.8	The Canadian Mineral Aggregate Industry, 1978
Alberta	1976	14.9	8.3	The Canadian Mineral Aggregate Industry, 1978
British Columbia	1976	16.7	9.4	The Canadian Mineral Aggregate Industry, 1978
Edmonton	1972 to 1976	13.9	7.8	Edmonton Regional Aggregate Study, 1978
Edmonton	1976	12.9	7.2	Edmonton Regional Aggregate Study, 1978
Dauphin, Manitoba	1976	28.5	16.0	Sand and Gravel Resources of the Dauphin Region, 1978
Edmonton[2]	early 1980's	20	11.2	Edmonton Regional Aggregate Study, 1978
Winnipeg, Manitoba[2]	1981	11.6	6.5	Aggregate Resources of the Winnipeg Region, 1976
Brandon, Manitoba[2]	1981	15.7 to 17.3	8.8 to 9.7	Calculated from data in: Sand and Gravel Resources of the Brandon Region, 1977
Winnipeg, Manitoba[2]	1996	12.9	7.2	Aggregate Resources of the Winnipeg Region, 1976
Brandon, Manitoba[2]	1996	18.5 to 20.5	10.4 to 11.5	Calculated from data in: Sand and Gravel Resources of the Brandon Region, 1977

[1]May include crushed stone in some areas.

[2]Figures determined from projected population and consumption data.

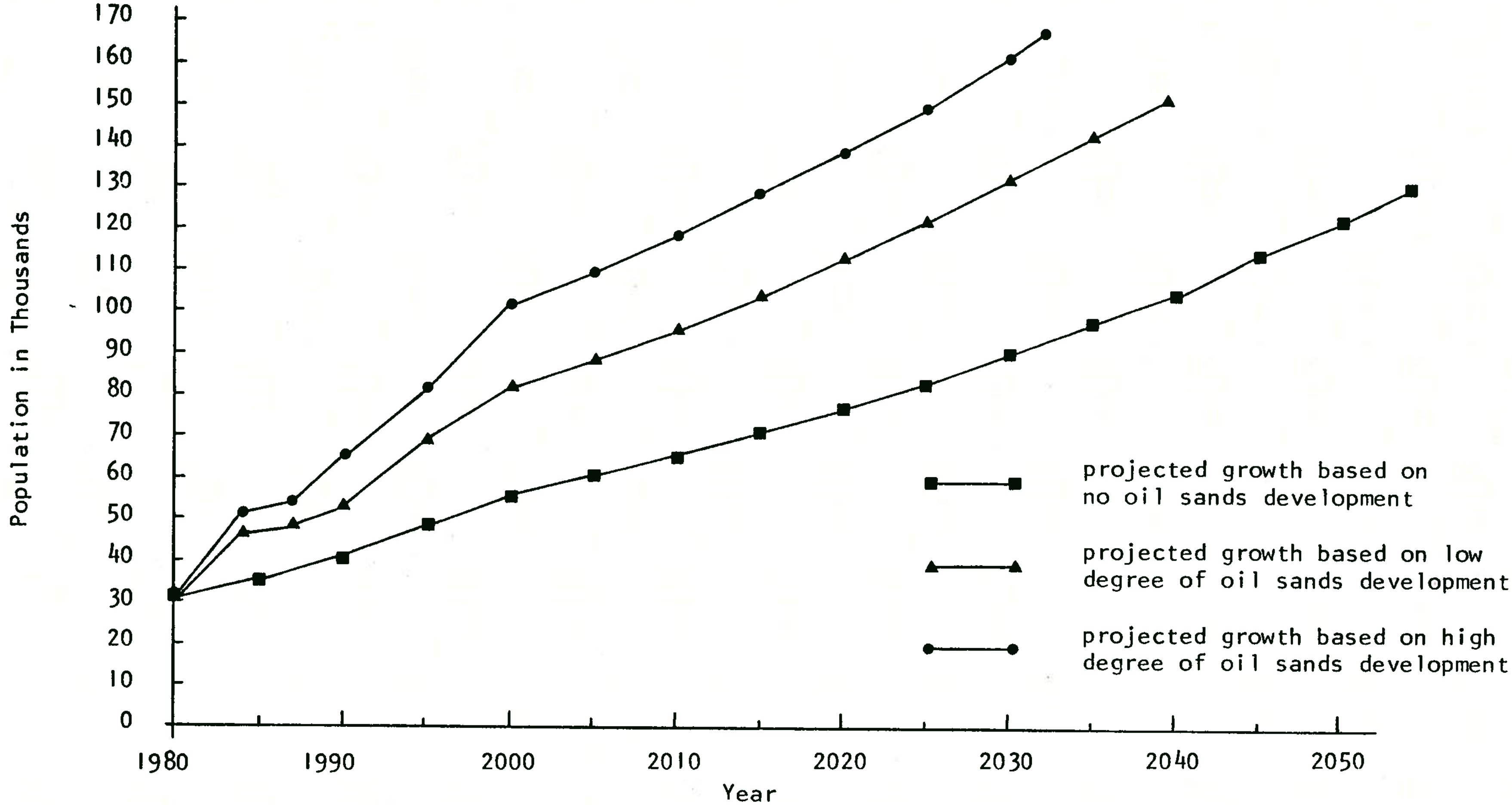


FIGURE 12. Projected population for study area (after Alberta Municipal Affairs, 1978).

Based on a population growth with no oil sands development and an assumed annual aggregate consumption of 10 m^3 per capita[1] the aggregate resource within the study area (Table 10) will meet demand from within the study area well beyond the year 2050. However, the major proportion of the aggregate in the study area is sand and therefore the critical commodity is gravel. Assuming that 45 percent of all aggregate consumed is gravel[2] then the available gravel will be consumed by the year 2054 (Fig. 13). If a growth rate assuming a low degree of oil sands development is used, the available gravel will be depleted by the year 2039 (Fig. 14). If a growth rate assuming a high degree of oil sands development is used, the available gravel will be used by the year 2032 (Fig. 15).

These projections involve uncertainties because we are dealing with assumed figures and an area which could receive aggregate from outside the study area or could supply aggregate to external and/or unforeseen users.

Some aggregate from north of the study area (north of Ethel Lake) is already being used in the Grand Centre area and new deposits on the Medley River are being developed. Also the deposits on which the supply data was based may not be developed because of inaccessibility, poor mining conditions, land conflicts or other reasons. Alternatively, new deposits within the study area could be found which would increase the available supply. One important, and often deceiving, complication about aggregate consumption in an area is the fact that usually both the aggregate supply and market areas are not evenly distributed around the study area. Figure 16 shows the distribution of gravel by township within the study area, the present major markets and the zone from which they draw aggregate.

The major markets are St. Paul with about 19 percent of the population of the study area, Bonnyville with about 15 percent of the population, and Cold Lake -

---

[1] A survey of consumers in the study area in 1980 indicated that the 1979 consumption had already exceeded 10 m^3 per capita.

[2] The 1980 survey indicated that as much as 60 percent of the aggregate consumed (and recorded) was gravel.

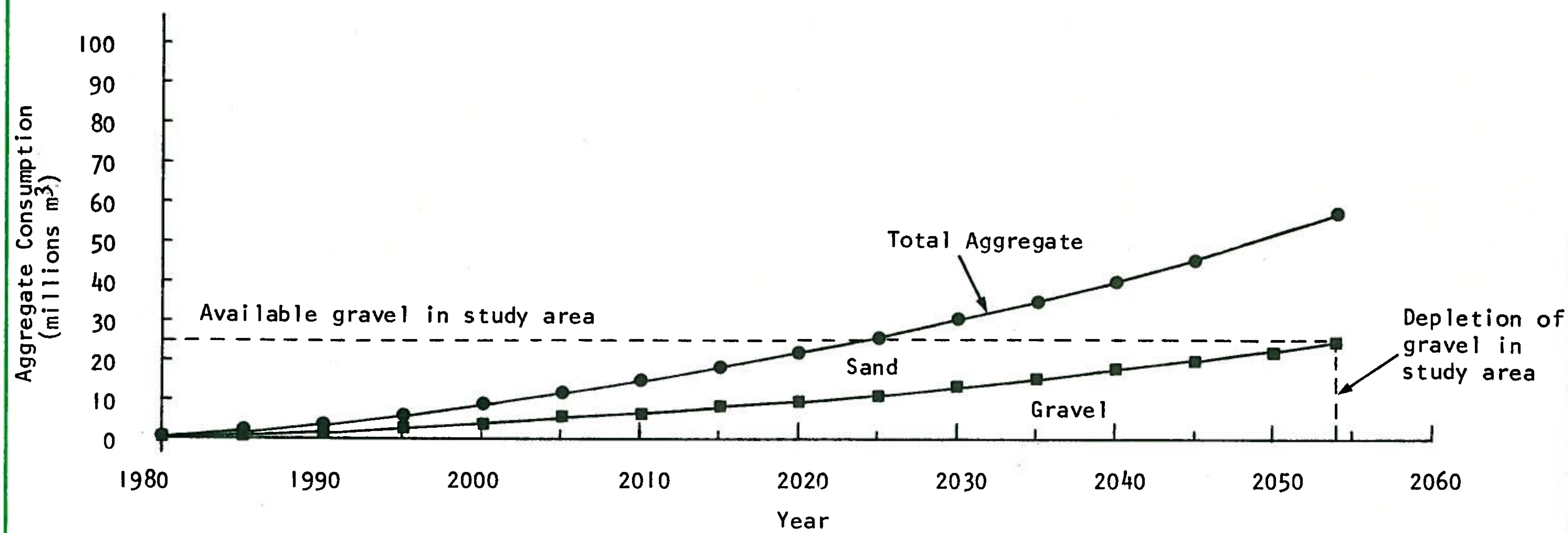


FIGURE 13. Cumulative aggregate consumption (m^3) based on population projections with no oil sands development and per capita consumption of 10 m^3 annually.

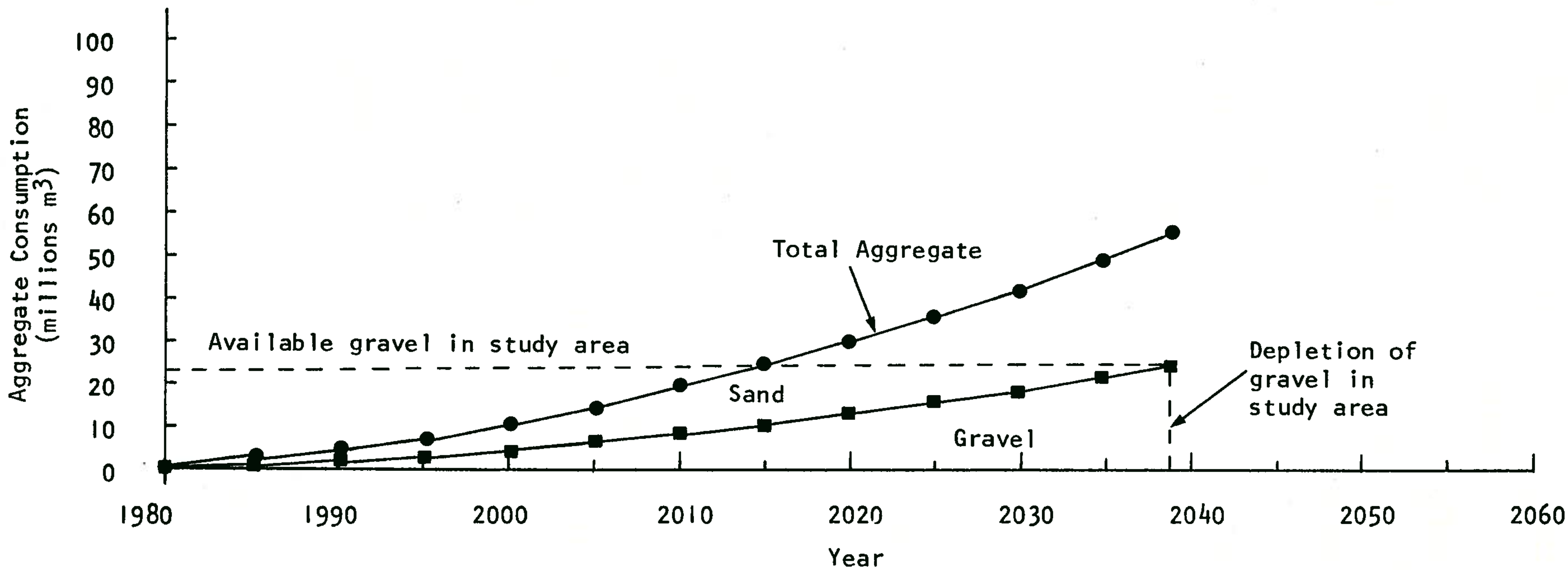


FIGURE 14. Cumulative aggregate consumption (m^3) based on population projections with a low degree of oil sands development and per capita consumption of 10 m^3 annually.

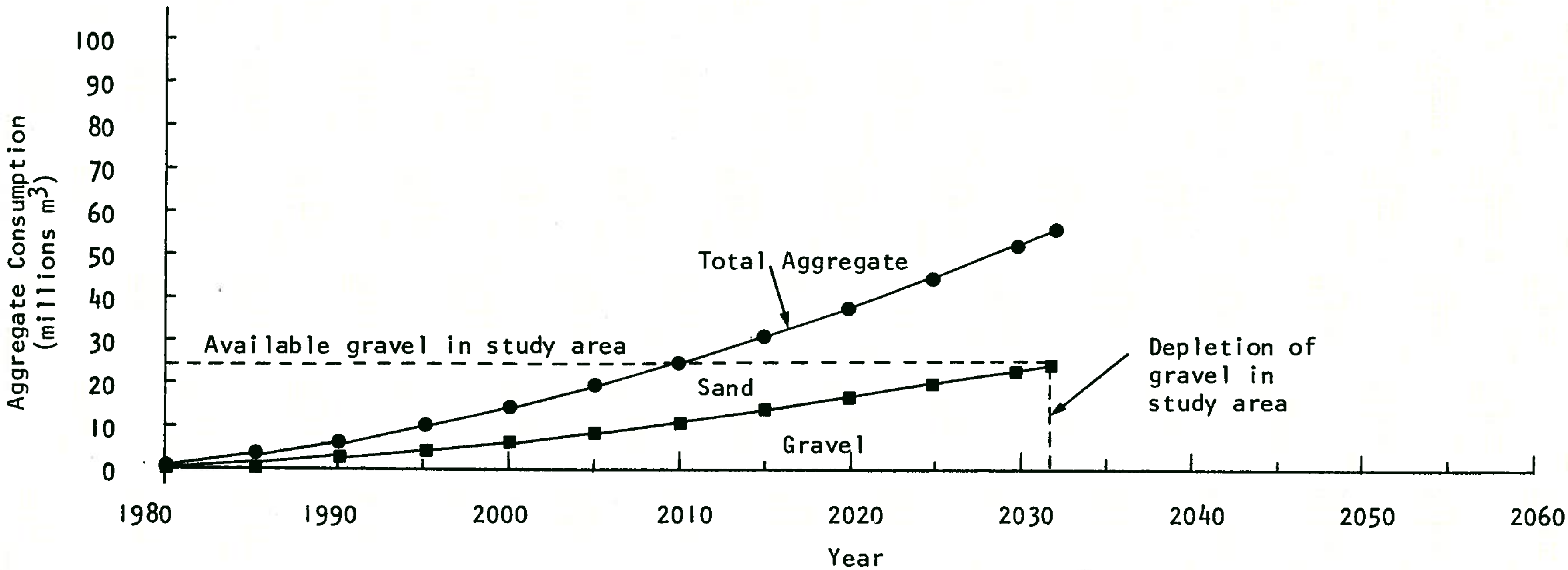


FIGURE 15. Cumulative aggregate consumption (m^3) based on population projections with a high degree of oil sands development and per capita consumption of 10 m^3 annually.

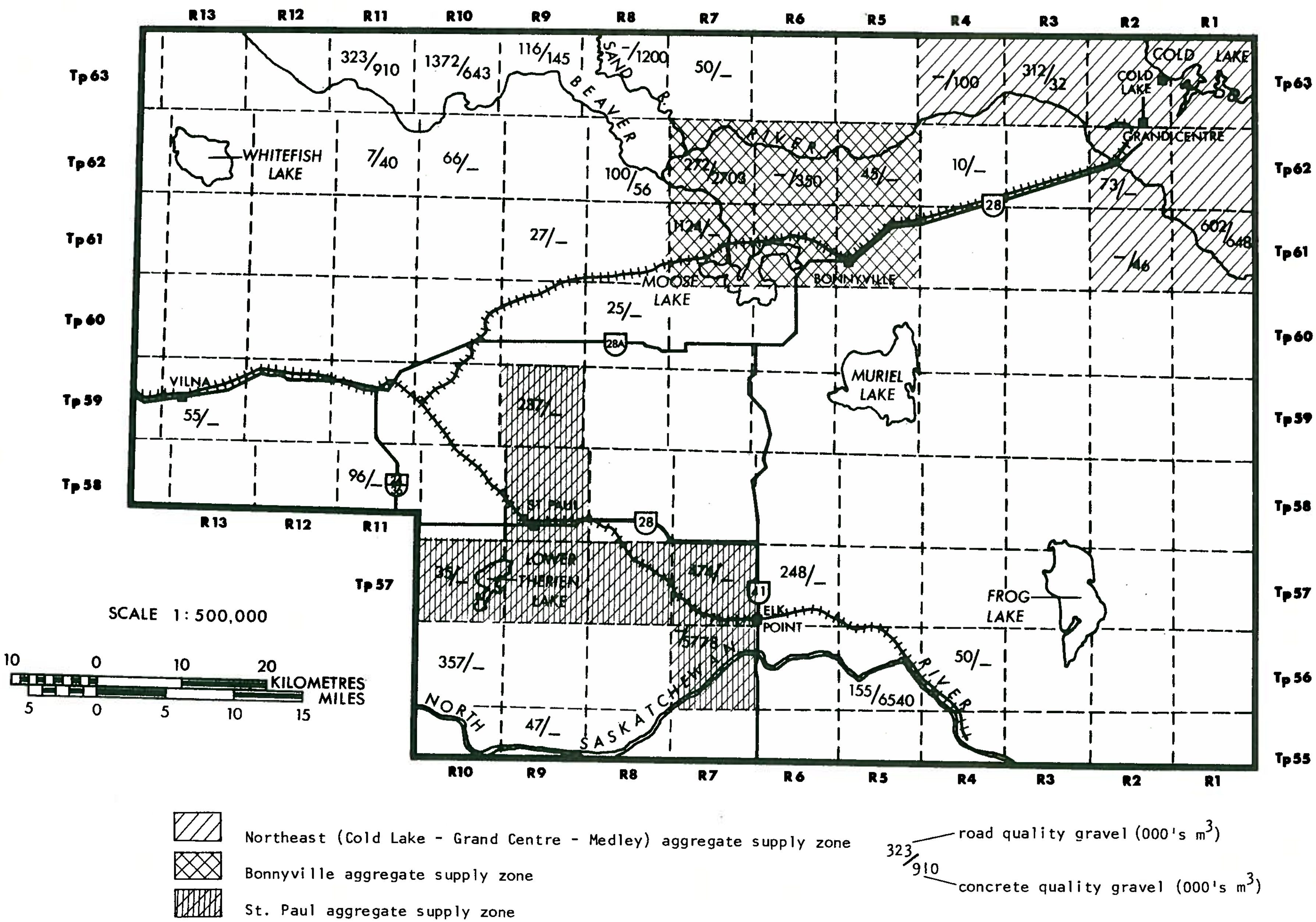


FIGURE 16. Distribution of gravel resources and major aggregate supply zones in the Cold Lake area.

Grand Centre - Medley (hereafter called the Northeast market) with about 40 percent of the population. If the population distribution remains the same in the future then the Northeast market will consume aggregate at the greatest rate. Unfortunately the Northeast aggregate supply zone also contains the least aggregate of the three major zones.

Based on population growth with no oil sands development, the Northeast market will deplete the road gravel in its present supply zone by the year 2000 and all gravel by 2003. The nearest source would then be the Bonnyville supply zone which, after 2003, would supply both the Bonnyville and Northeast markets. The Bonnyville area would be depleted by the year 2022 and the Northeast and Bonnyville markets would be forced to draw on the western Beaver River terraces and the Elk Point outwash deposits. These deposits would not be depleted until about the year 2054, but would require a haul distance of about 100 km to Grand Centre.

Based on population growth with a low degree of oil sands development, the Northeast market will deplete the gravel in its present supply zone by the year 1998. The Northeast and Bonnyville markets, combined after 1998, would deplete the Bonnyville supply zone by 2013 and then would have to use the western Beaver River terraces and the Elk Point outwash deposits until the year 2039 when the entire Cold Lake region would be depleted.

If the population grows according to projections based on a high degree of oil sands development, then the Northeast aggregate supply zone will be depleted of gravel by the year 1997. The combined Bonnyville and Northeast markets would deplete the Bonnyville supply zone by the year 2009. The three major markets plus the rural consumption would then consume the remaining gravel by the year 2032.

These projections and depletion dates are based on numerous assumptions and are, at best, useful estimates. Even so this assessment clearly illustrates that the resource is finite. To make the most efficient use of the dwindling aggregate supply it is necessary that: 1) a sound data base, at 1:50,000 scale or larger, be established similar to, but more detailed than, the maps (Figs. 17 to 27) used in this report; 2) an efficient government policy on aggregate is developed; and 3) a comprehensive resource management plan is produced. The resource is dynamic with constantly shifting areas of availability and of need so that continual monitoring and revision of the data base would be required and active, flexible management would be essential.

REFERENCES

Alberta Department of Municipal Affairs, 1978, Cold Lake Regional Plan, Population: Projected Growth, Planning Branch, 76 p.

Canadian Transport Commission, 1978, The Canadian Mineral Aggregate Industry, Traffic and Tariffs Branch, Traffic and Tarriff Studies Division, Ottawa, 150 p.

City of Edmonton, 1978, Edmonton Regional Aggregate Study, Engineering Department, Materials and Testing Section, 65 p.

Currie, D.V. and Zacharko, N., 1976, Hydrogeology of the Vermilion area, Alberta, Alberta Research Report 75-5, 15 p.

Ellwood, R.B., 1961, Surficial geology of the Vermilion area, Alberta, Canada, Thesis (Ph.D.), University of Illinois, 131 p.

Fenton, M.M. and Andriashek, L.D., 1979, Surficial geology of the Sand River area, Alberta, Alberta Research Council, Open File Report 1979-6, 16 maps.

Gartner Lee Associates Ltd. and Proctor and Redfern Ltd., 1978, Sand and Gravel Resources of the Dauphin Region, prepared for the Mineral Resources Division, Department of Mines, Resources and Environmental Management, Winnipeg, Manitoba, 2 volumes.

Green, R., 1972, Geological map of Alberta, Alberta Research Council.

Hardy, R.M. & Associates Ltd. (J. Rennie), 1979, Esso Resources Canada Ltd., Aggregate Survey, Cold Lake data, final report.

Lindsay, J.D., Pawluk, S. and Odynsky, W., 1962, Exploratory soil survey of 74-M, 74-L, 74-E and 73-L, accompanies R.C.A. Preliminary Soil Survey Report 63-1.

Ozoray, G.F., Wallick, E.I. and Lytviak, A.T., 1979, Hydrogeology of Sand River, 1:250,000 map, Alberta Research Council.

Underwood McLellan & Associates Ltd., 1976, Aggregate resources of the Winnipeg region, prepared for the Mineral Resources Division, Department of Mines, Resources and Environmental Management, Winnipeg, Manitoba.

Underwood McLellan & Associates Ltd., 1977, Sand and Gravel Resources of the Brandon region, prepared for Department of Mines, Resources and Environmental Management, Winnipeg, Manitoba, 2 volumes.

Wentworth, C.K., 1922, A scale of grade and class terms of clastic sediments: Journal of Geology, v. 30, p. 377-392.

Yoon, T.N. and Vander Pluyn, H., 1974, Buried channels in the Edmonton, Lac La Biche, Cold Lake area, Department of the Environment, 99 p.

GLOSSARY

aggregate - any of several hard, inert, construction materials (such as sand, gravel, crushed stone, slag, or other mineral), or combinations thereof, used for mixing in various-sized fragments with a cementing or bituminous material to form concrete, mortar, plaster, etc., or used alone as in railroad ballast or in various manufacturing processes (such as fluxing). Syn: mineral aggregate; coarse aggregate — the portion of an aggregate with diameters greater than 4.75 mm; fine aggregate — the portion of an aggregate in which the particle diameters are smaller than 4.75 mm and larger than 0.075 mm.

alluvial fan - a flat to gently sloping stream deposit shaped like a fan, formed wherever a constriction in a valley abruptly ceases or the gradient of the stream suddenly decreases.

alluvium - material deposited during relatively recent geological time by running water; includes clay, silt, sand, or gravel in stream beds, floodplains, terraces, alluvial fans, etc.

bar - see fluvial bar.

bedrock - in-place pre-Quaternary material exposed at the surface or underlying the surficial material.

clast - an individual constituent, grain, or fragment produced by the physical disintegration of rock.

clay - a rock or mineral fragment or detrital particle of any composition having a diameter less than 0.004 mm (Wentworth scale).

clean - said of sand and/or gravel that contains less than 5 percent fines.

cobble - gravel having a diameter in the range of 75 to 250 mm.
Syn: very coarse gravel.

Cretaceous - the final period of the Mesozoic era, thought to have covered the span of time between 136 and 65 million years ago.

crevasse filling - a short, straight ridge of stratified sand and gravel and till believed to have been deposited in a crevasse of a wasting glacier and left standing after the ice melted; a variety of kame.

cross-bedding - an internal arrangement of layers in stratified material characterized by minor beds or laminae inclined to the original depositional surface and produced by swift currents of air or water.

deleterious rock (type) - a rock fragment which when used as aggregate will break or crumble into smaller sized fragments or react with the cementing agent or fluids within the mix to expand, shrink or breakdown to weaken the mixture (such as soft sandstone, weathered gneiss, and some chert).

delta - the low, nearly flat alluvial deposit at the mouth of a river resulting from the accumulation in a wider body of water (e.g. lake) of sediment supplied by the river; partly subaerial and partly below water.

deposit (sand, gravel, aggregate) - an accumulation of sand and/or gravel left by a natural process of agent, usually wind, water or gravity.

dirty gravel - said of gravel that contains between 5 and 12 percent fines (Fig. 5).

dirty sand - said of sand that contains between 5 and 12 percent fines (Fig. 5).

doughnut (moraine) - a small, well developed circular closed ridge composed of till, glaciolacustrine or rarely glaciofluvial sediments and believed to have been formed as a result of stagnant-ice conditions.

durable rock (type) - a rock fragment which is hard and inert and can be used as aggregate without breaking, crumbling or reacting with the cementing material (such as quartzite, fresh granite or limestone).

esker - a narrow ridge, often long and sinuous, composed of sand and/or gravel deposited by a meltwater stream flowing in or on glacier ice.

fan - see alluvial fan.

fines - sediment with particle diameters less than .075 mm (Fig. 4).

fluted moraine - a rolling surface formed of long flutes composed of till, sand or other glacially molded sediments.

fluvial - pertaining to rivers or streams.

fluvial bar - a ridge-like accumulation of sand, gravel or other alluvial material formed in the channel (or former channel) of a stream where a decrease in velocity induces deposition.

glacial - pertaining to distinctive features and materials produced by or derived from glaciers and ice sheets.

glaciofluvial (deposits) - material deposited by streams flowing from, on or within melting glacier ice, generally composed of sorted, stratified sand and gravel; includes outwash, kame, esker, etc.

granite - a coarse grained, plutonic rock composed principally of quartz and alkali feldspar; forms a good aggregate material unless deeply weathered when it may crumble.

granular material - natural occurring mineral sediment in which more than 50 percent of the sediment is greater than .075 mm in size. Syn: sand and gravel.

gravel - naturally occurring rock or mineral fragments larger than 4.75 mm in diameter; an unconsolidated, natural accumulation of granular material which contains more than 3 parts gravel for every part sand (Figs. 4 and 5).

gravelly sand - an unconsolidated, naturally occurring granular material which contains a ratio of sand to gravel between 3:1 and 1:1 (50 to 75 percent sand) (Fig. 5).

headwaters - the upper (upstream) drainage basin and source of a stream.

ice-contact (deposit) - material deposited in contact with glacier ice by meltwater; includes kames, eskers, and kame terraces.

ice-thrust moraine - a ridge or block of material (usually arcuate) formed by the thrusting or pushing of ice.

igneous rock - a rock formed from molten material (magma); includes granites and volcanic rocks.

ironstone - a hard, banded sedimentary rock of ferruginous composition, often found as a compact, rounded, subspherical mass (concretion); although hard ironstone tends to fracture and break when used as aggregate (deleterious).

kame - a steep-sided hill, knob, hummock or short irregular ridge composed chiefly of poorly sorted and stratified sand and gravel deposited by a subglacial or supraglacial stream as an alluvial fan or delta against or upon a glacier or ice sheet.

lag (gravel) - a residual accumulation of coarse, usually hard rock fragments left behind after currents have winnowed or washed away the finer material.

meltwater channel - a watercourse or abandoned watercourse used by water derived from melting glacier ice and often marked by accumulations of gravel and sand derived from the ice.

metamorphic rock - a rock derived from pre-existing rocks in response to the temperature, pressure and chemical changes encountered with burial in the earth's crust; includes gneisses and schists.

moraine - an area formed by glacial processes and composed predominantly of till.

moraine plain - a flat to gently undulating surface composed primarily of till.

outwash - a glaciofluvial deposit formed in front of the margin of glacier ice; a pitted outwash deposit is a deposit whose otherwise flat surface is marked by many irregular shallow depressions.

outwash plain - see outwash.

overburden - the soil, silt, till or other unconsolidated material overlying a gravel or sand deposit which must be removed prior to mining.

pebble - a small, roundish rock fragment having a diameter in the range of 4 to 64 mm (Wentworth scale) (Fig. 4). Syn: gravel.

petrographic analysis - the description and systematic classification of rock fragments (esp. gravel) by unaided eye or microscopic examination for the purpose of determining the origin of the fragments and their quality (durability) when used as aggregate. Syn: pebble count.

petrographic number - an empirical value representing the quality of the aggregate based on the number and type of pebbles or grains present. The petrographic number allows certain numerical limits to be defined on a petrographic basis for aggregate specifications. Petrographic number ranges from 100 upwards — the smaller the petrographic number the higher the quality of the aggregate.

point par - see fluvial bar.

poorly sorted - said of a sediment that is not sorted or consists of particles of many sizes mixed together in any unsystematic manner so that no one size class predominates.

quartzite - a sedimentary or metamorphic rock consisting of quartz grains or crystals cemented with secondary silica such that the rock breaks across or through the grains rather than around them; an excellent aggregate material, highly resistant to weathering and very hard.

sand - naturally occurring rock or mineral fragments larger than 0.75 mm in diameter and smaller than 4.75 mm; an unconsolidated, natural accumulation of granular material which contains more than 3 parts sand for every part gravel (Fig. 4).

sand and gravel - see granular material.

sandstone - a clastic sedimentary rock composed principally of fragments of sand size (usually quartz) united by a cementing material (commonly silica, iron oxide, or calcium carbonate); an excellent to poor aggregate material depending on the strength of the cementing bond, and the amount of weathering it has been subjected to, and the reaction of the rock to weathering.

sandy gravel - an unconsolidated naturally occurring granular material which contains a ratio of gravel to sand between 3:1 and 1:1 (50 to 75 percent gravel) (Fig. 5).

shale - a fine-grained sedimentary rock formed by the consolidation of clay, silt or mud and characterized by a finely stratified structure, shale is generally soft but sufficiently indurated so that it will not fall apart on wetting; a poor aggregate material because of its softness and fissility.

silt - a rock or mineral fragment or detrital particle having a diameter in the range of 0.004 to 0.063 mm (Wentworth scale).

stagnant ice (moraine) - the landform formed by ablating ice that is no longer flowing forward; characterized by hummocky topography (mounds or hummocks) formed of till or glaciolacustrine sediments, doughnuts, ice-contact deposits and meltwater channels.

subglacial channel - see esker.

terrace - a large bench or step-like ledge breaking the continuity of a slope and marking a former water level; terrace commonly denotes an aggradational form contained in a valley and composed of unconsolidated material, often sand and gravel.

till - unsorted and unstratified sediment deposited directly by glacier ice.

valley train - outwash confined within a valley.

well-sorted - said of a sorted sediment that consists of particles all having approximately the same size.

water-modified moraine - a flat to rolling surface formed of eroded till or thin lacustrine sediments over till.

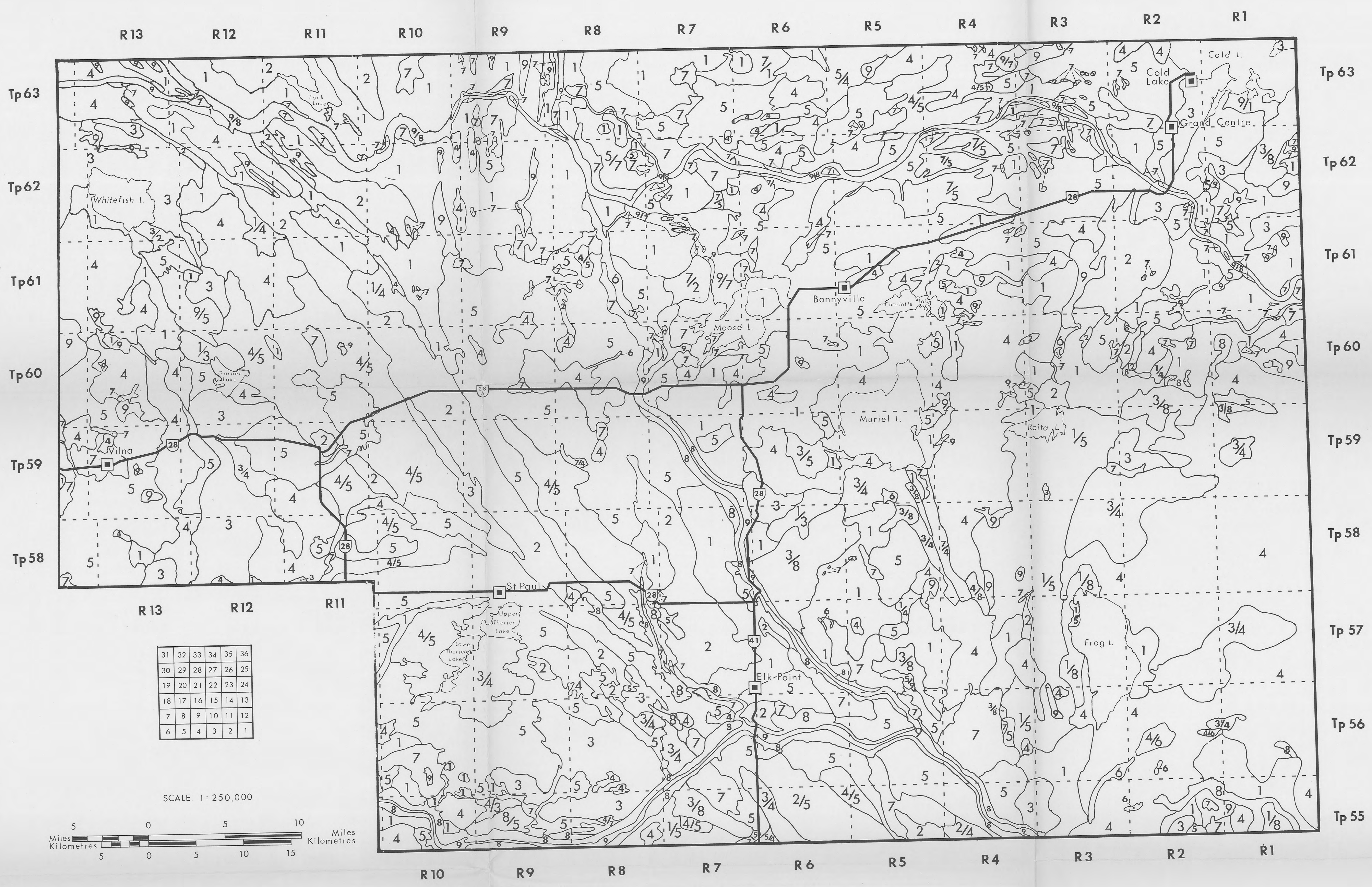
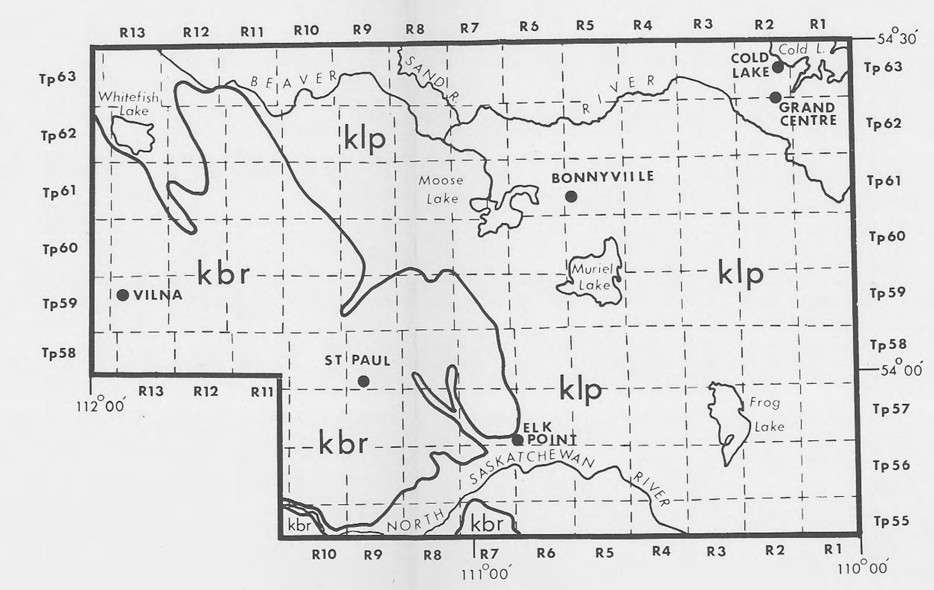


FIGURE 3. SURFICIAL GEOLOGY OF THE COLD LAKE STUDY AREA



LEGEND

CRETACEOUS

Kbr — Belly River Formation; soft sandstone

Klp — Lea Park Formation; shale

Approximate geological contact (after Green, 1972)

LEGEND

GLACIAL DEPOSITS AND FEATURES	POTENTIAL FOR AGGREGATE
1 Moraine Plain: a flat to rolling surface underlain principally by till.	LOW: may be small deposits in meltwater channels.
2 Fluted Moraine: a rolling surface formed of long flutes composed of till, sand or other glacially molded sediments.	LOW: may be incorporated sand or gravel lenses.
3 Ice-thrust Moraine: a hummocky to ridged surface formed of till, sand, gravel or bedrock thrust and deposited by ice.	MODERATE: small sand and gravel lenses common; large deposits rate.
4 Stagnant-ice Moraine: a rolling to hummocky surface formed of till hummocks, ice-contact deposits and meltwater channels.	LOW TO MODERATE: low potential in primarily till areas (doughnuts), moderate in areas with meltwater channels.
5 Water-modified Moraine: a flat to rolling surface formed of eroded till or thin lacustrine sediments over till.	LOW: may be small deposits in meltwater channels.
GLACIOFLUVIAL DEPOSITS	
6 Ice-contact: kame, esker, crevasse filling.	HIGH TO VERY HIGH: potential for occurrence of granular material very high; deposits may be poorly sorted, structurally deformed, low in volume.
7 Outwash: outwash, pitted outwash, valley train; depositional terraces or bar (or eroded valley fill).	VERY HIGH: potential for occurrence of granular material very high, for coarse aggregate high; deposits generally clean, well-sorted, uniform and sometimes high in volume.
BEDROCK	
8 Outcrop, Thinly Covered Bedrock or Slumped Bedrock: soft sandstone (Belly River Fm) or shale (Lea Park Fm), sometimes with ironstone concretions.	VERY LOW: sandstone is generally fine grained, poorly exposed.
RECENT DEPOSITS AND FEATURES	
9 Fluvial: alluvium (generally fine grained) and erosional terraces.	LOW: alluvium is generally sandy or muddy.
9 Bog: bog, marsh, swamp.	VERY LOW

Approximate geological contact.

Contacts between units were derived from airphoto interpretation. Multiple designations (e.g. 7/2 indicate that both units are present, the first unit being the most common. Sediment type was determined by field investigation. The designation of potential for occurrence of aggregate is a relative assessment. Specific areas may have a lower or higher potential and should be assessed in a more detailed manner. Geology by W.A.D. Edwards, 1977 and 1978. Some units after Fenton and Andriashek, 1979.

LEGEND

UNIT — DESCRIPTION — POTENTIAL FOR AGGREGATE

Glacial Deposits

[4] ....Stagnant-ice Moraine: *a rolling to hummocky surface formed of till hummocks, ice-contact deposits and meltwater channels.* — [4] ....LOW TO MODERATE: *low potential in primarily till areas (doughnuts), moderate in areas with meltwater channels.*

[5] ....Water-modified Moraine: *a flat to rolling surface formed of eroded till or thin lacustrine sediments over till.* — [5] ....LOW: *may be small deposits in meltwater channels.*

Glaciofluvial Deposits

[6] ....Ice-Contact: *kame, esker, crevasse filling.* — [6] ....HIGH TO VERY HIGH: *potential for occurrence of granular material very high; deposits may be poorly sorted, structurally deformed, low in volume.*

[7] ....Outwash: *outwash, pitted outwash, valley train; depositional terrace or bar (or eroded valley fill).* — [7] ....VERY HIGH: *potential for occurrence of granular material very high, for coarse aggregate high; deposits generally clean, well-sorted, uniform and sometimes high in volume.*

Recent Deposits

Fluvial: *alluvium (generally fine grained) and erosional terraces.* — LOW: *alluvium is generally sandy or muddy.*

[9] .... Bog: *bog, marsh, swamp.* — [9] .... VERY LOW

s7 ....*Prefix describes the overall grain size composition of the deposit; s = sand, gs = gravelly sand, sg = sandy gravel, g = gravel; see inset diagram for explanation of grain-size terms; units with no prefix have not been investigated.*

7/9 ....*Multiple designations indicate that both units are present, the first unit being the most common.*

....*Active pit.*

....*Inactive pit.*

▲ ....*Site.*

....*Approximate geologic contract.*

NOTES

The boundaries of the deposits shown on this map were derived from airphoto interpretation. Additional information on individual deposits can be found in the report. Units with an (*) from Fenton and Andriashek, 1979 (ARC), other geology by Edwards, 1977 and 1978, and Fox, 1978.

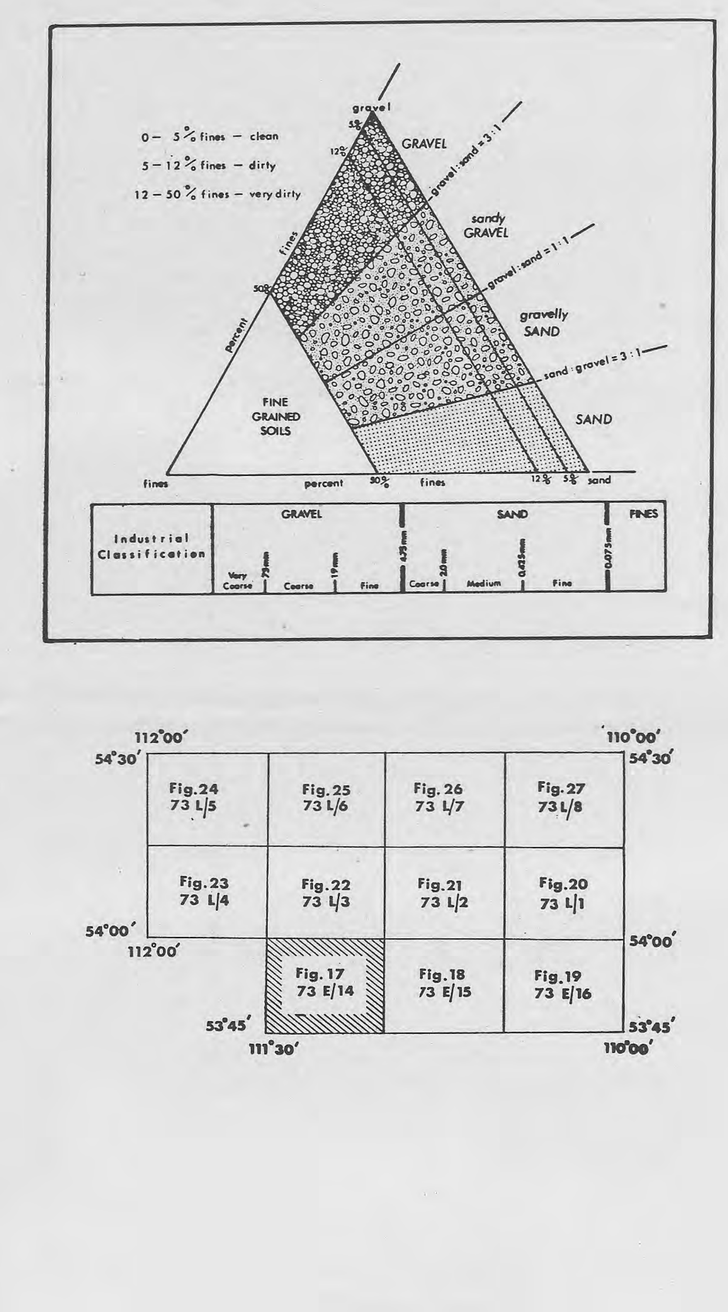
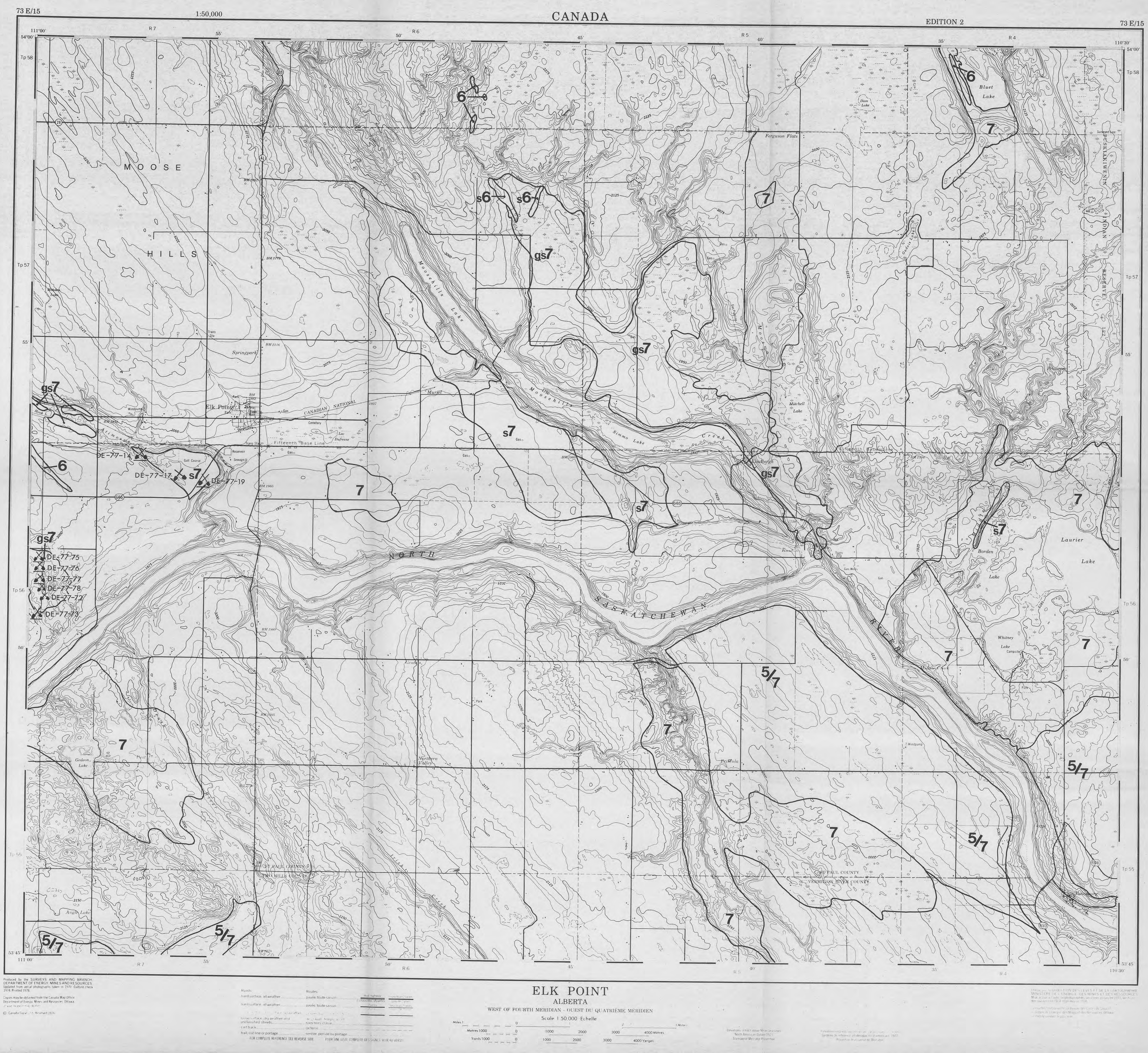


FIGURE 17. SAND AND GRAVEL DEPOSITS IN MAP 73 E/14



LEGEND

UNIT	DESCRIPTION	POTENTIAL FOR AGGREGATE
Glacial Deposits		
4	....Stagnant-ice Moraine: *a rolling to hummocky surface formed of till hummocks, ice-contact deposits and meltwater channels.*	4 ....LOW TO MODERATE: *low potential in primarily till areas (doughnuts), moderate in areas with meltwater channels.*
5	....Water-modified Moraine: *a flat to rolling surface formed of eroded till or thin lacustrine sediments over till.*	5 ....LOW: *may be small deposits in meltwater channels.*
Glaciofluvial Deposits		
6	....Ice-Contact: *kame, esker, crevasse filling.*	6 ....HIGH TO VERY HIGH: *potential for occurrence of granular material very high; deposits may be poorly sorted, structurally deformed, low in volume.*
7	....Outwash: *outwash, pitted outwash, valley train; depositional terrace or bar (or eroded valley fill).*	7 ....VERY HIGH: *potential for occurrence of granular material very high, for coarse aggregate high; deposits generally clean, well-sorted, uniform and sometimes high in volume.*
Recent Deposits		
	Fluvial: *alluvium (generally fine grained) and erosional terraces.*	LOW: *alluvium is generally sandy or muddy.*
9	.... Bog: *bog, marsh, swamp.*	9 .... VERY LOW

s7 ....*Prefix describes the overall grain size composition of the deposit; s = sand, gs = gravelly sand, sg = sandy gravel, g = gravel; see inset diagram for explanation of grain-size terms; units with no prefix have not been investigated.*

7/9 ....*Multiple designations indicate that both units are present, the first unit being the most common.*

....*Active pit.*

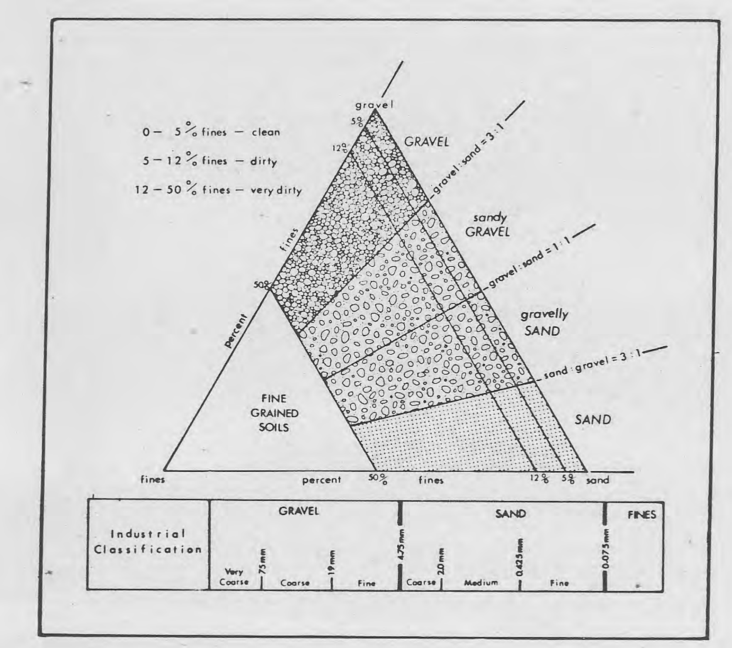
....*Inactive pit.*

▲ ....*Site.*

....*Approximate geologic contract.*

NOTES

The boundaries of the deposits shown on this map were derived from airphoto interpretation. Additional information on individual deposits can be found in the report. Units with an (*) from Fenton and Andriashek, 1979 (ARC), other geology by Edwards, 1977 and 1978, and Fox, 1978.



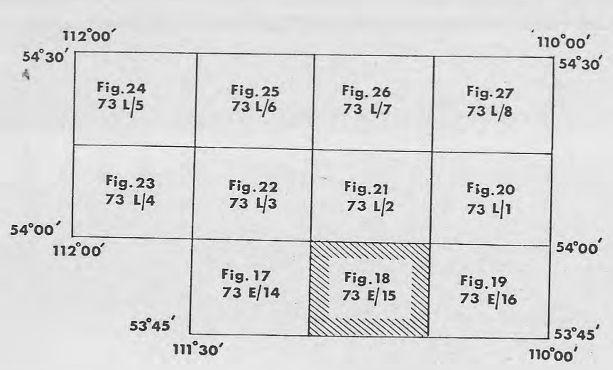


FIGURE 18. SAND AND GRAVEL DEPOSITS IN MAP 73 E/15

LEGEND

UNIT	DESCRIPTION	POTENTIAL FOR AGGREGATE
Glacial Deposits		
4	....Stagnant-ice Moraine: *a rolling to hummocky surface formed of till hummocks, ice-contact deposits and meltwater channels.*	4 ....LOW TO MODERATE: *low potential in primarily till areas (doughnuts), moderate in areas with meltwater channels.*
5	....Water-modified Moraine: *a flat to rolling surface formed of eroded till or thin lacustrine sediments over till.*	5 ....LOW: *may be small deposits in meltwater channels.*
Glaciofluvial Deposits		
6	....Ice-Contact: *kame, esker, crevasse filling.*	6 ....HIGH TO VERY HIGH: *potential for occurrence of granular material very high; deposits may be poorly sorted, structurally deformed, low in volume.*
7	....Outwash: *outwash, pitted outwash, valley train; depositional terrace or bar (or eroded valley fill).*	7 ....VERY HIGH: *potential for occurrence of granular material very high, for coarse aggregate high; deposits generally clean, well-sorted, uniform and sometimes high in volume.*
Recent Deposits		
	Fluvial: *alluvium (generally fine grained) and erosional terraces.*	LOW: *alluvium is generally sandy or muddy.*
9	.... Bog: *bog, marsh, swamp.*	9 .... VERY LOW

s7 ....*Prefix describes the overall grain size composition of the deposit; s = sand, gs = gravelly sand, sg = sandy gravel, g = gravel; see inset diagram for explanation of grain-size terms; units with no prefix have not been investigated.*

7/9 ....*Multiple designations indicate that both units are present, the first unit being the most common.*

....*Active pit.*

....*Inactive pit.*

▲ ....*Site.*

....*Approximate geologic contract.*

NOTES

The boundaries of the deposits shown on this map were derived from airphoto interpretation. Additional information on individual deposits can be found in the report. Units with an (*) from Fenton and Andriashek, 1979 (ARC), other geology by Edwards, 1977 and 1978, and Fox, 1978.

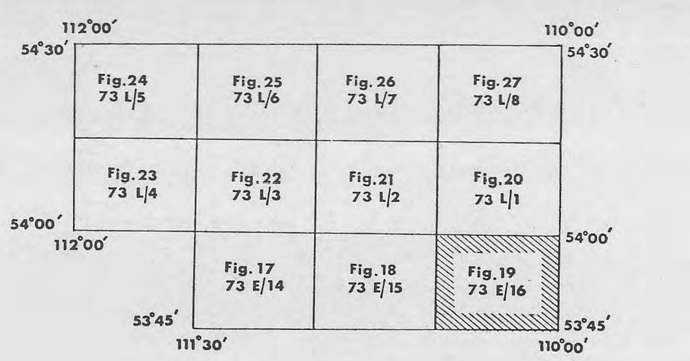
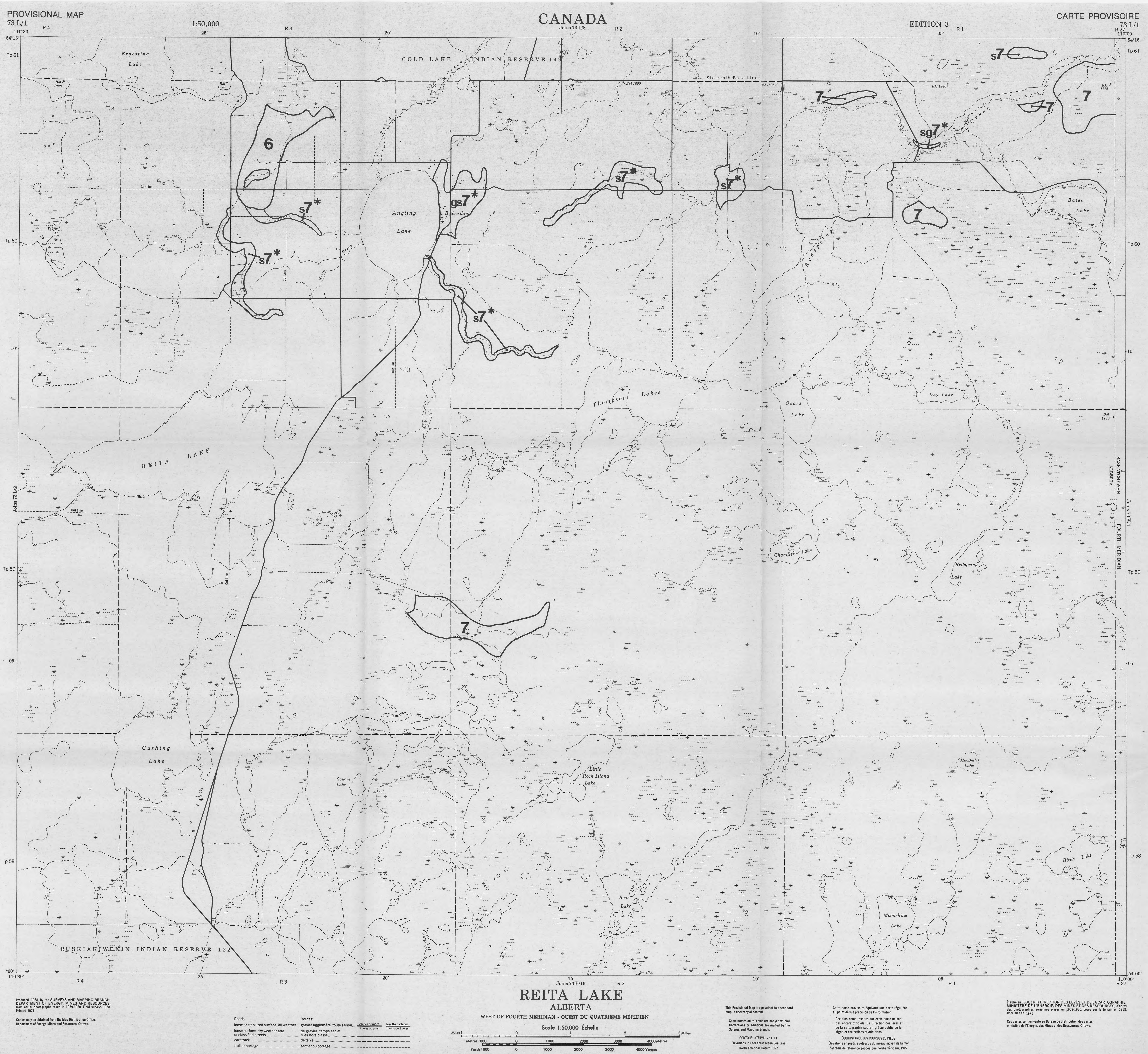


FIGURE 19. SAND AND GRAVEL DEPOSITS IN MAP 73 E/16

FROG LAKE
73 E/16
EDITION 2



LEGEND

UNIT	DESCRIPTION	POTENTIAL FOR AGGREGATE
Glacial Deposits		
4	....Stagnant-ice Moraine: *a rolling to hummocky surface formed of till hummocks, ice-contact deposits and meltwater channels.*	4 ....LOW TO MODERATE: *low potential in primarily till areas (doughnuts), moderate in areas with meltwater channels.*
5	....Water-modified Moraine: *a flat to rolling surface formed of eroded till or thin lacustrine sediments over till.*	5 ....LOW: *may be small deposits in meltwater channels.*
Glaciofluvial Deposits		
6	....Ice-Contact: *kame, esker, crevasse filling.*	6 ....HIGH TO VERY HIGH: *potential for occurrence of granular material very high; deposits may be poorly sorted, structurally deformed, low in volume.*
7	....Outwash: *outwash, pitted outwash, valley train; depositional terrace or bar (or eroded valley fill).*	7 ....VERY HIGH: *potential for occurrence of granular material very high, for coarse aggregate high; deposits generally clean, well-sorted, uniform and sometimes high in volume.*
Recent Deposits		
	Fluvial: *alluvium (generally fine grained) and erosional terraces.*	LOW: *alluvium is generally sandy or muddy.*
9	.... Bog: *bog, marsh, swamp.*	9 .... VERY LOW

s7 ....*Prefix describes the overall grain size composition of the deposit; s = sand, gs = gravelly sand, sg = sandy gravel, g = gravel; see inset diagram for explanation of grain-size terms; units with no prefix have not been investigated.*

7/9 ....*Multiple designations indicate that both units are present, the first unit being the most common.*

....*Active pit.*

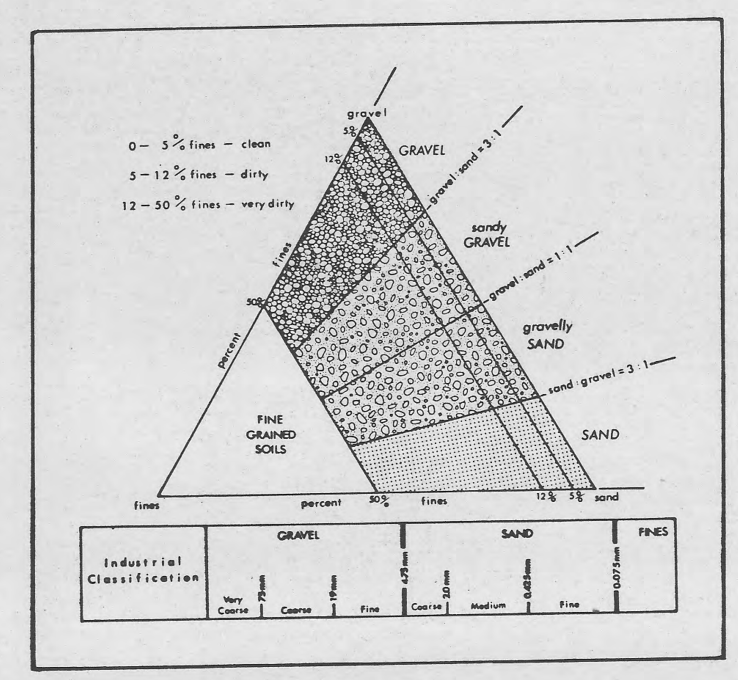
....*Inactive pit.*

▲ ....*Site.*

....*Approximate geologic contract.*

NOTES

The boundaries of the deposits shown on this map were derived from airphoto interpretation. Additional information on individual deposits can be found in the report. Units with an (*) from Fenton and Andriashek, 1979 (ARC), other geology by Edwards, 1977 and 1978, and Fox, 1978.



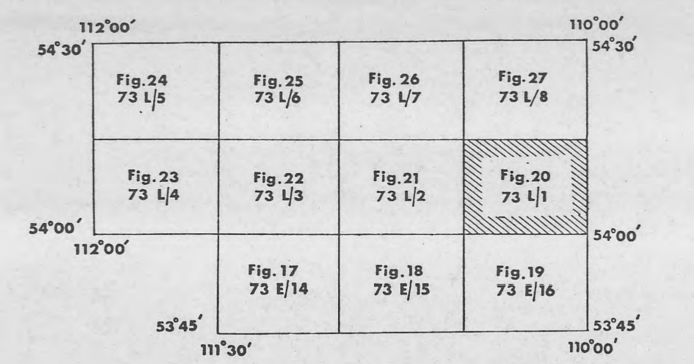
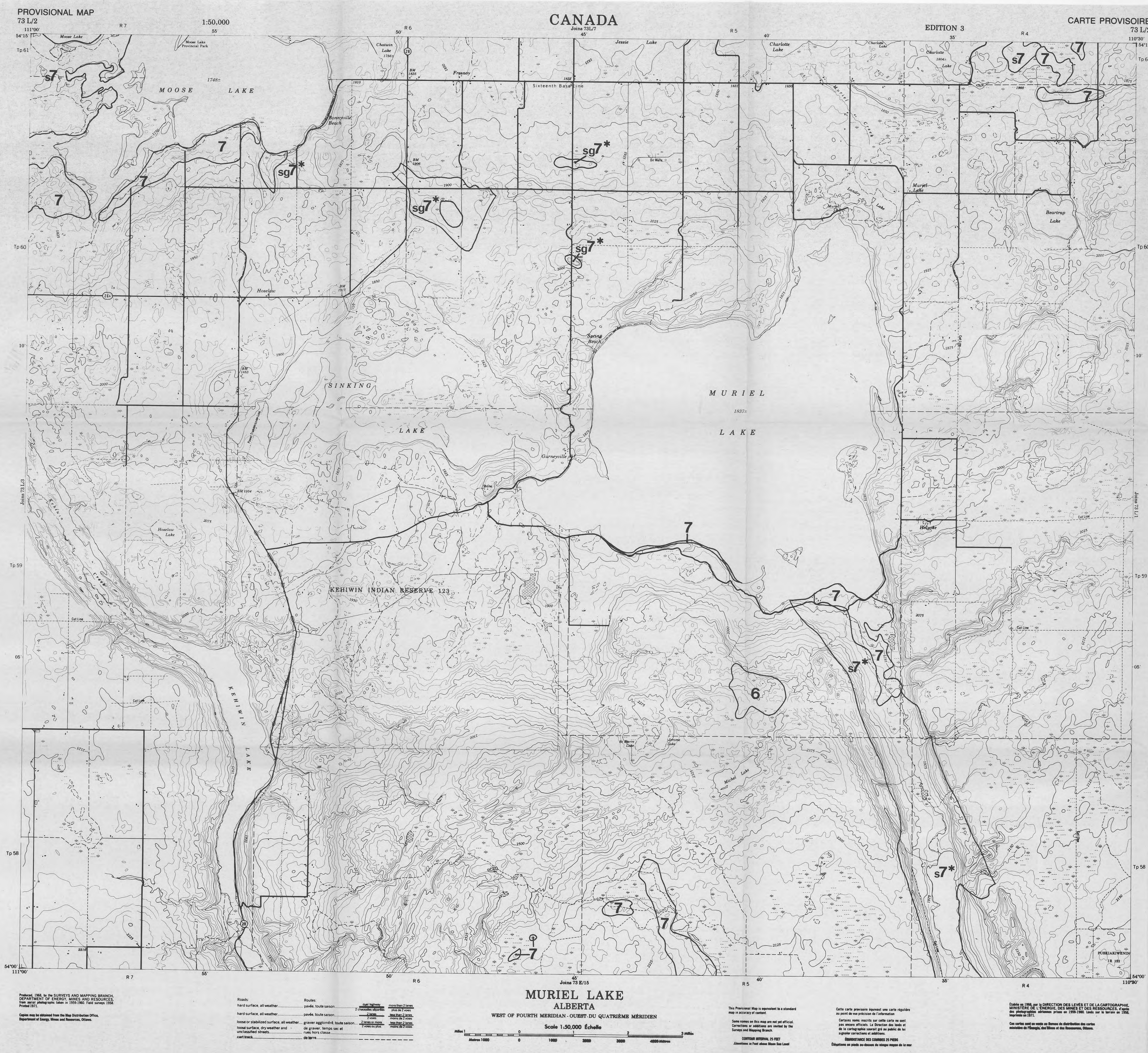


FIGURE 20. SAND AND GRAVEL DEPOSITS IN MAP 73 L/1



LEGEND

UNIT	DESCRIPTION	POTENTIAL FOR AGGREGATE
Glacial Deposits		
4	....Stagnant-ice Moraine: *a rolling to hummocky surface formed of till hummocks, ice-contact deposits and meltwater channels.*	4 ....LOW TO MODERATE: *low potential in primarily till areas (doughnuts), moderate in areas with meltwater channels.*
5	....Water-modified Moraine: *a flat to rolling surface formed of eroded till or thin lacustrine sediments over till.*	5 ....LOW: *may be small deposits in meltwater channels.*
Glaciofluvial Deposits		
6	....Ice-Contact: *kame, esker, crevasse filling.*	6 ....HIGH TO VERY HIGH: *potential for occurrence of granular material very high; deposits may be poorly sorted, structurally deformed, low in volume.*
7	....Outwash: *outwash, pitted outwash, valley train; depositional terrace or bar (or eroded valley fill).*	7 ....VERY HIGH: *potential for occurrence of granular material very high, for coarse aggregate high; deposits generally clean, well-sorted, uniform and sometimes high in volume.*
Recent Deposits		
	Fluvial: *alluvium (generally fine grained) and erosional terraces.*	LOW: *alluvium is generally sandy or muddy.*
9	....Bog: *bog, marsh, swamp.*	9 ....VERY LOW

s7 ....*Prefix describes the overall grain size composition of the deposit; s = sand, gs = gravelly sand, sg = sandy gravel, g = gravel; see inset diagram for explanation of grain-size terms; units with no prefix have not been investigated.*

7/9 ....*Multiple designations indicate that both units are present, the first unit being the most common.*

....*Active pit.*

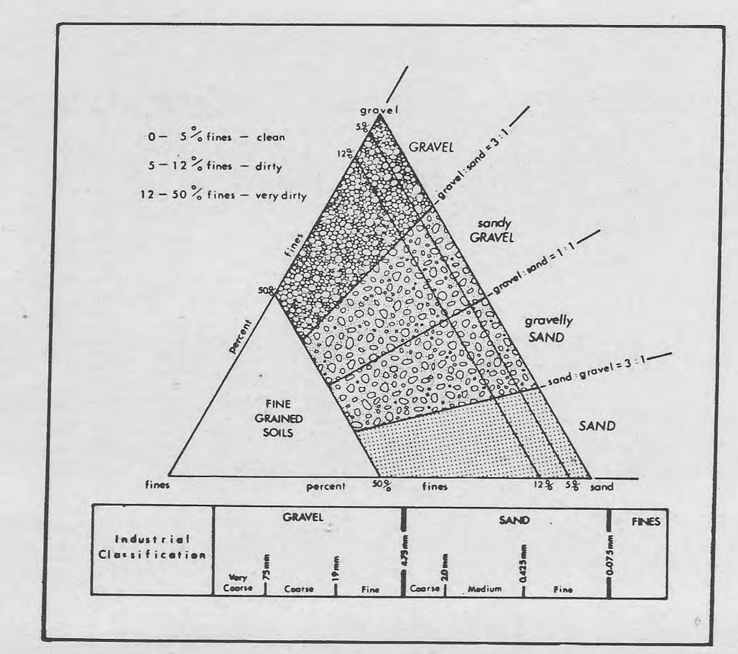
....*Inactive pit.*

▲ ....*Site.*

....*Approximate geologic contract.*

NOTES

The boundaries of the deposits shown on this map were derived from airphoto interpretation. Additional information on individual deposits can be found in the report. Units with an (*) from Fenton and Andriashek, 1979 (ARC), other geology by Edwards, 1977 and 1978, and Fox, 1978.



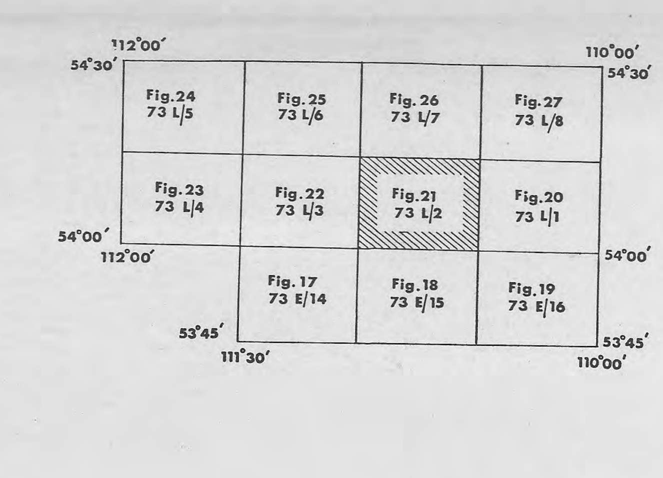
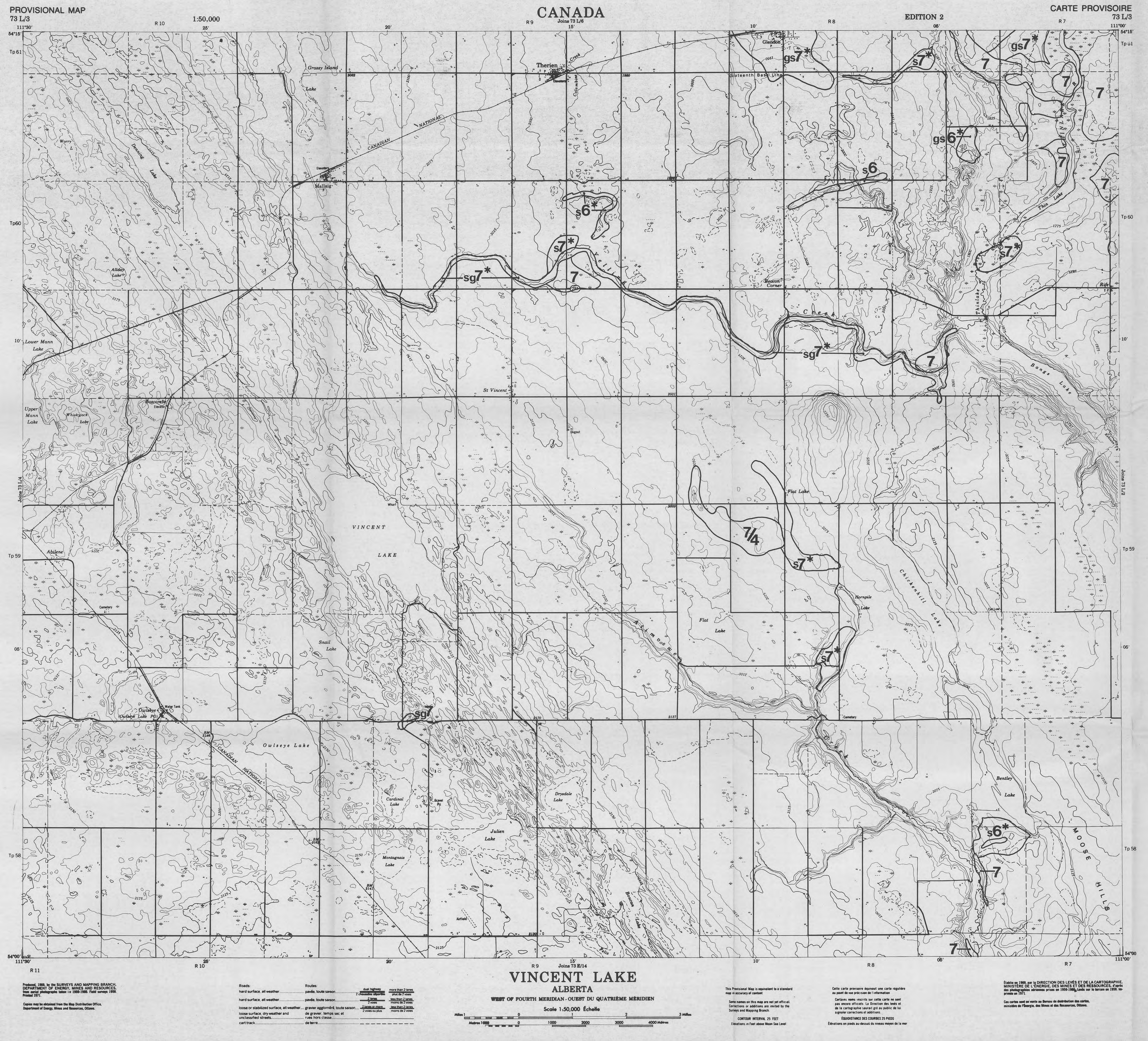


FIGURE 21 SAND AND GRAVEL DEPOSITS IN MAP 73 L/2



LEGEND

UNIT	DESCRIPTION	POTENTIAL FOR AGGREGATE
Glacial Deposits		
4	....Stagnant-ice Moraine: *a rolling to hummocky surface formed of till hummocks, ice-contact deposits and meltwater channels.*	4 ....LOW TO MODERATE: *low potential in primarily till areas (doughnuts), moderate in areas with meltwater channels.*
5	....Water-modified Moraine: *a flat to rolling surface formed of eroded till or thin lacustrine sediments over till.*	5 ....LOW: *may be small deposits in meltwater channels.*
Glaciofluvial Deposits		
6	....Ice-Contact: *kame, esker, crevasse filling.*	6 ....HIGH TO VERY HIGH: *potential for occurrence of granular material very high; deposits may be poorly sorted, structurally deformed, low in volume.*
7	....Outwash: *outwash, pitted outwash, valley train; depositional terrace or bar (or eroded valley fill).*	7 ....VERY HIGH: *potential for occurrence of granular material very high, for coarse aggregate high; deposits generally clean, well-sorted, uniform and sometimes high in volume.*
Recent Deposits		
	Fluvial: *alluvium (generally fine grained) and erosional terraces.*	LOW: *alluvium is generally sandy or muddy.*
9	.... Bog: *bog, marsh, swamp.*	9 .... VERY LOW

s7 ....*Prefix describes the overall grain size composition of the deposit; s = sand, gs = gravelly sand, sg = sandy gravel, g = gravel; see inset diagram for explanation of grain-size terms; units with no prefix have not been investigated.*

7/9 ....*Multiple designations indicate that both units are present, the first unit being the most common.*

....*Active pit.*

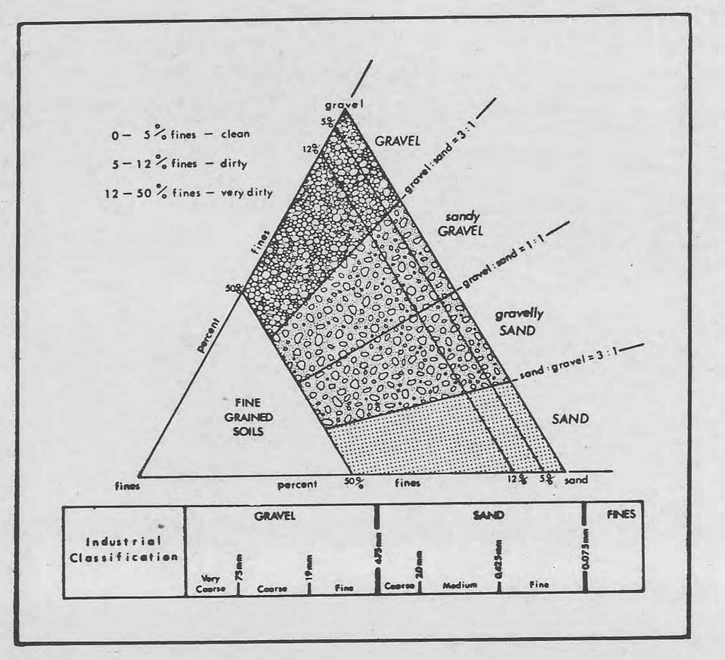
....*Inactive pit.*

▲ ....*Site.*

....*Approximate geologic contract.*

NOTES

The boundaries of the deposits shown on this map were derived from airphoto interpretation. Additional information on individual deposits can be found in the report. Units with an (*) from Fenton and Andriashek, 1979 (ARC), other geology by Edwards, 1977 and 1978, and Fox, 1978.



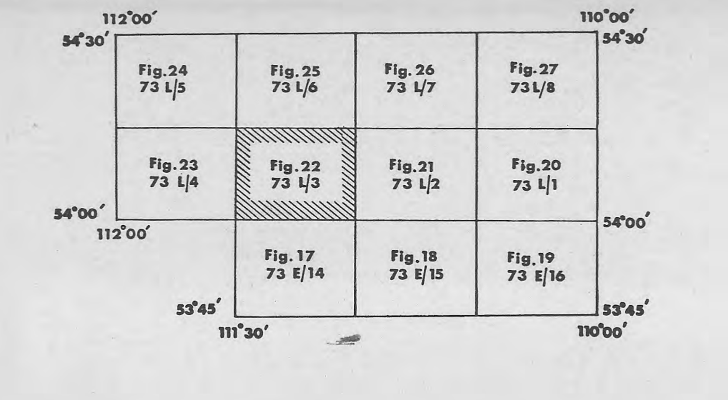
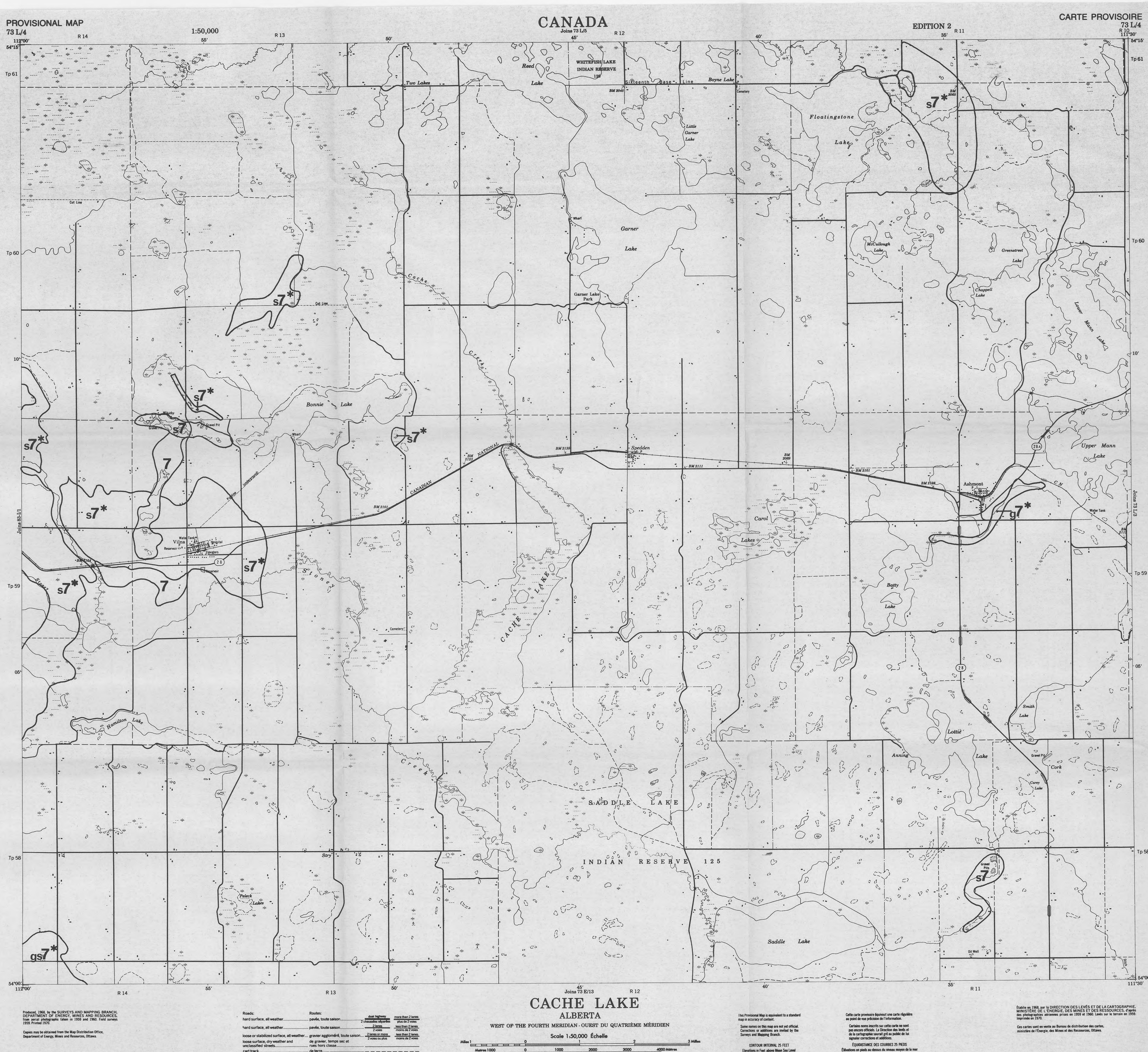


FIGURE 22. SAND AND GRAVEL DEPOSITS IN MAP 73 L/3



LEGEND

UNIT	DESCRIPTION	POTENTIAL FOR AGGREGATE
Glacial Deposits		
4	....Stagnant-ice Moraine: *a rolling to hummocky surface formed of till hummocks, ice-contact deposits and meltwater channels.*	4 ....LOW TO MODERATE: *low potential in primarily till areas (doughnuts), moderate in areas with meltwater channels.*
5	....Water-modified Moraine: *a flat to rolling surface formed of eroded till or thin lacustrine sediments over till.*	5 ....LOW: *may be small deposits in meltwater channels.*
Glaciofluvial Deposits		
6	....Ice-Contact: *kame, esker, crevasse filling.*	6 ....HIGH TO VERY HIGH: *potential for occurrence of granular material very high; deposits may be poorly sorted, structurally deformed, low in volume.*
7	....Outwash: *outwash, pitted outwash, valley train; depositional terrace or bar (or eroded valley fill).*	7 ....VERY HIGH: *potential for occurrence of granular material very high, for coarse aggregate high; deposits generally clean, well-sorted, uniform and sometimes high in volume.*
Recent Deposits		
	Fluvial: *alluvium (generally fine grained) and erosional terraces.*	LOW: *alluvium is generally sandy or muddy.*
9	.... Bog: *bog, marsh, swamp.*	9 .... VERY LOW

s7 ....*Prefix describes the overall grain size composition of the deposit; s = sand, gs = gravelly sand, sg = sandy gravel, g = gravel; see inset diagram for explanation of grain-size terms; units with no prefix have not been investigated.*

7/9 ....*Multiple designations indicate that both units are present, the first unit being the most common.*

X ....*Active pit.*

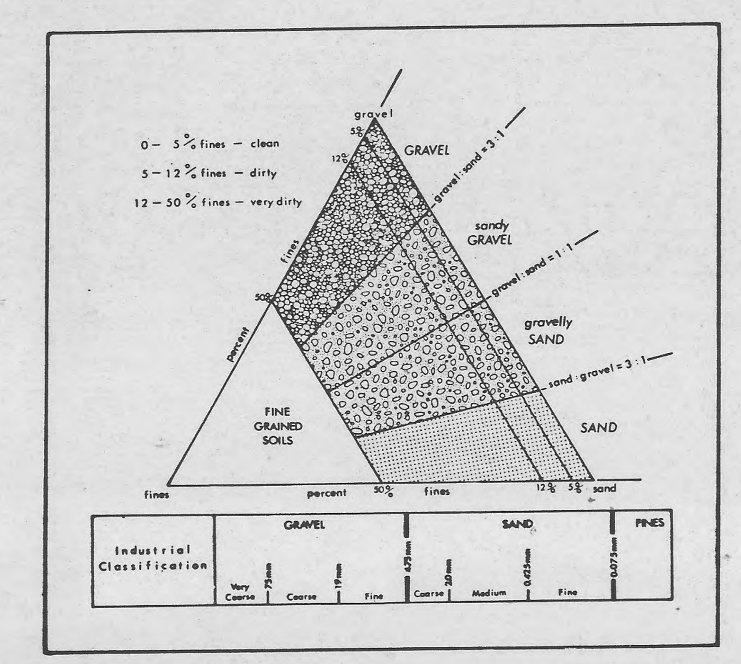
X ....*Inactive pit.*

▲ ....*Site.*

~ ....*Approximate geologic contract.*

NOTES

The boundaries of the deposits shown on this map were derived from airphoto interpretation. Additional information on individual deposits can be found in the report. Units with an (*) from Fenton and Andriashek, 1979 (ARC), other geology by Edwards, 1977 and 1978, and Fox, 1978.



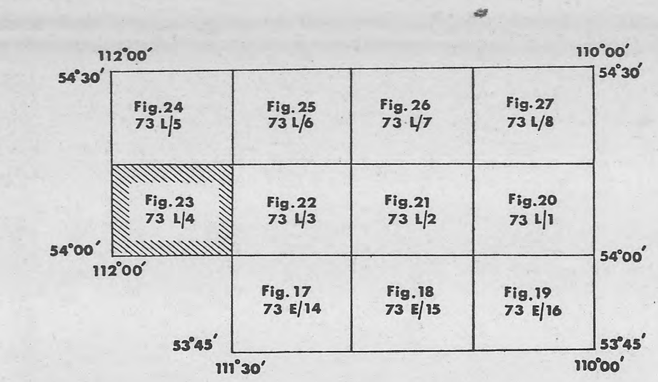
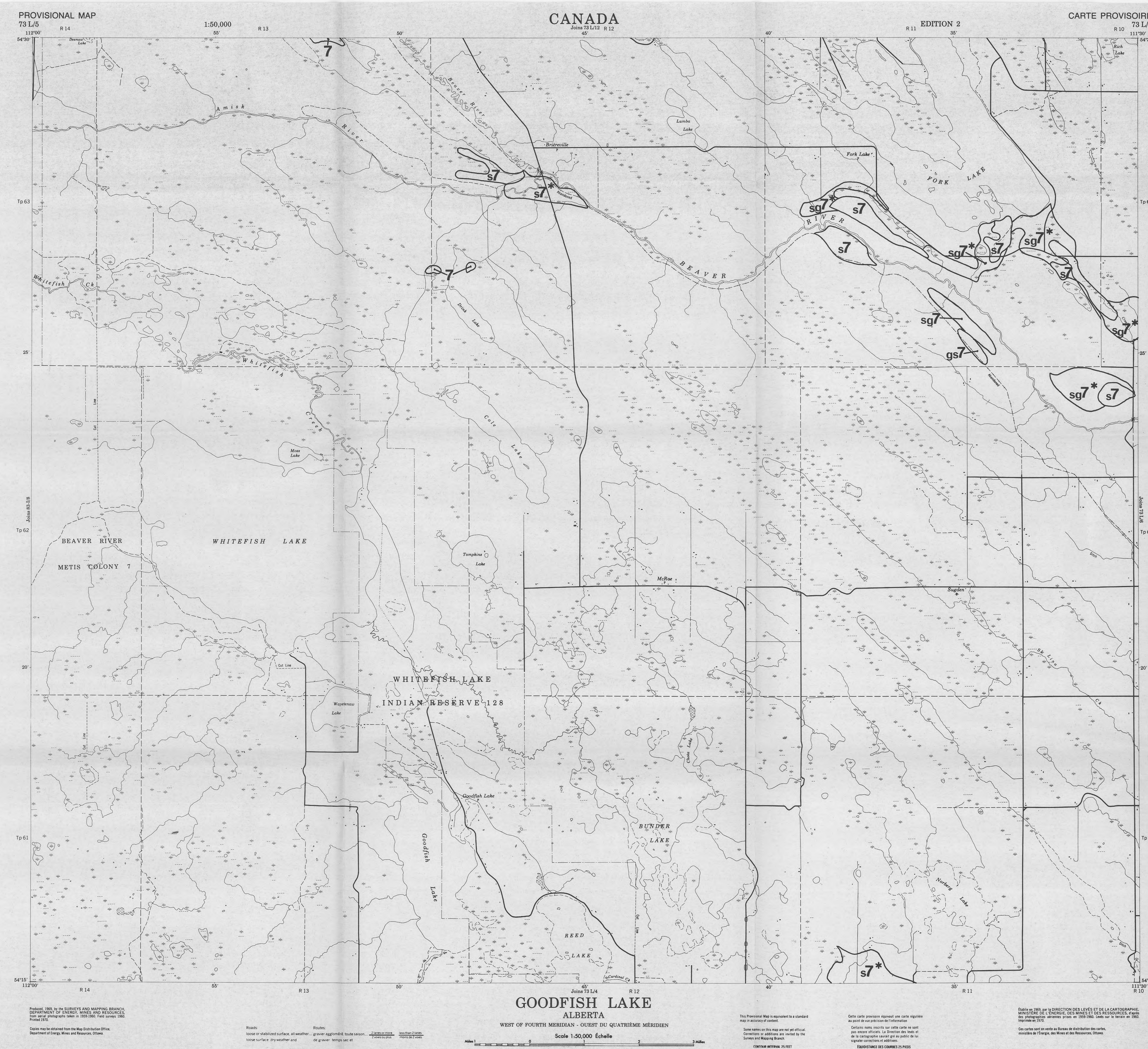


FIGURE 23. SAND AND GRAVEL DEPOSITS IN MAP 73 L/4



LEGEND

UNIT	DESCRIPTION	POTENTIAL FOR AGGREGATE
Glacial Deposits		
4	....Stagnant-ice Moraine: *a rolling to hummocky surface formed of till hummocks, ice-contact deposits and meltwater channels.*	4 ....LOW TO MODERATE: *low potential in primarily till areas (doughnuts), moderate in areas with meltwater channels.*
5	....Water-modified Moraine: *a flat to rolling surface formed of eroded till or thin lacustrine sediments over till.*	5 ....LOW: *may be small deposits in meltwater channels.*
Glaciofluvial Deposits		
6	....Ice-Contact: *kame, esker, crevasse filling.*	6 ....HIGH TO VERY HIGH: *potential for occurrence of granular material very high; deposits may be poorly sorted, structurally deformed, low in volume.*
7	....Outwash: *outwash, pitted outwash, valley train; depositional terrace or bar (or eroded valley fill).*	7 ....VERY HIGH: *potential for occurrence of granular material very high, for coarse aggregate high; deposits generally clean, well-sorted, uniform and sometimes high in volume.*
Recent Deposits		
	Fluvial: *alluvium (generally fine grained) and erosional terraces.*	LOW: *alluvium is generally sandy or muddy.*
9	.... Bog: *bog, marsh, swamp.*	9 .... VERY LOW

s7 ....*Prefix describes the overall grain size composition of the deposit; s = sand, gs = gravelly sand, sg = sandy gravel, g = gravel; see inset diagram for explanation of grain-size terms; units with no prefix have not been investigated.*

7/9 ....*Multiple designations indicate that both units are present, the first unit being the most common.*

....*Active pit.*

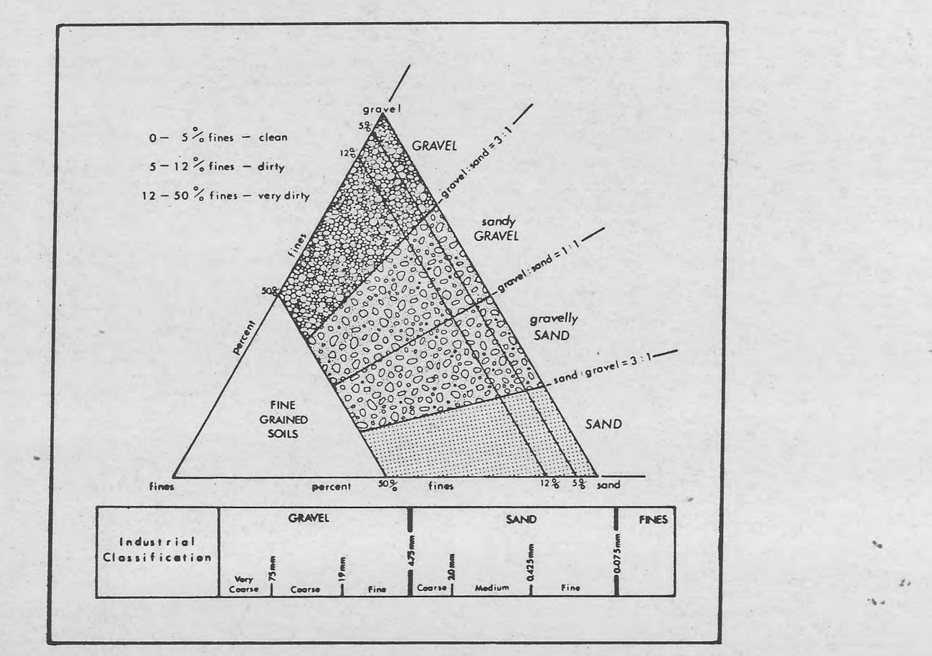
....*Inactive pit.*

▲ ....*Site.*

....*Approximate geologic contract.*

NOTES

The boundaries of the deposits shown on this map were derived from airphoto interpretation. Additional information on individual deposits can be found in the report. Units with an (*) from Fenton and Andriashek, 1979 (ARC), other geology by Edwards, 1977 and 1978, and Fox, 1978.



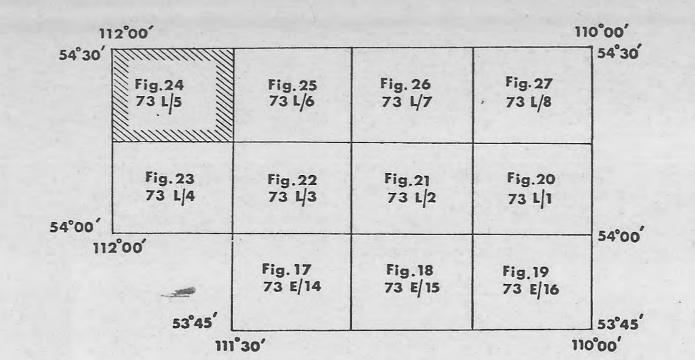
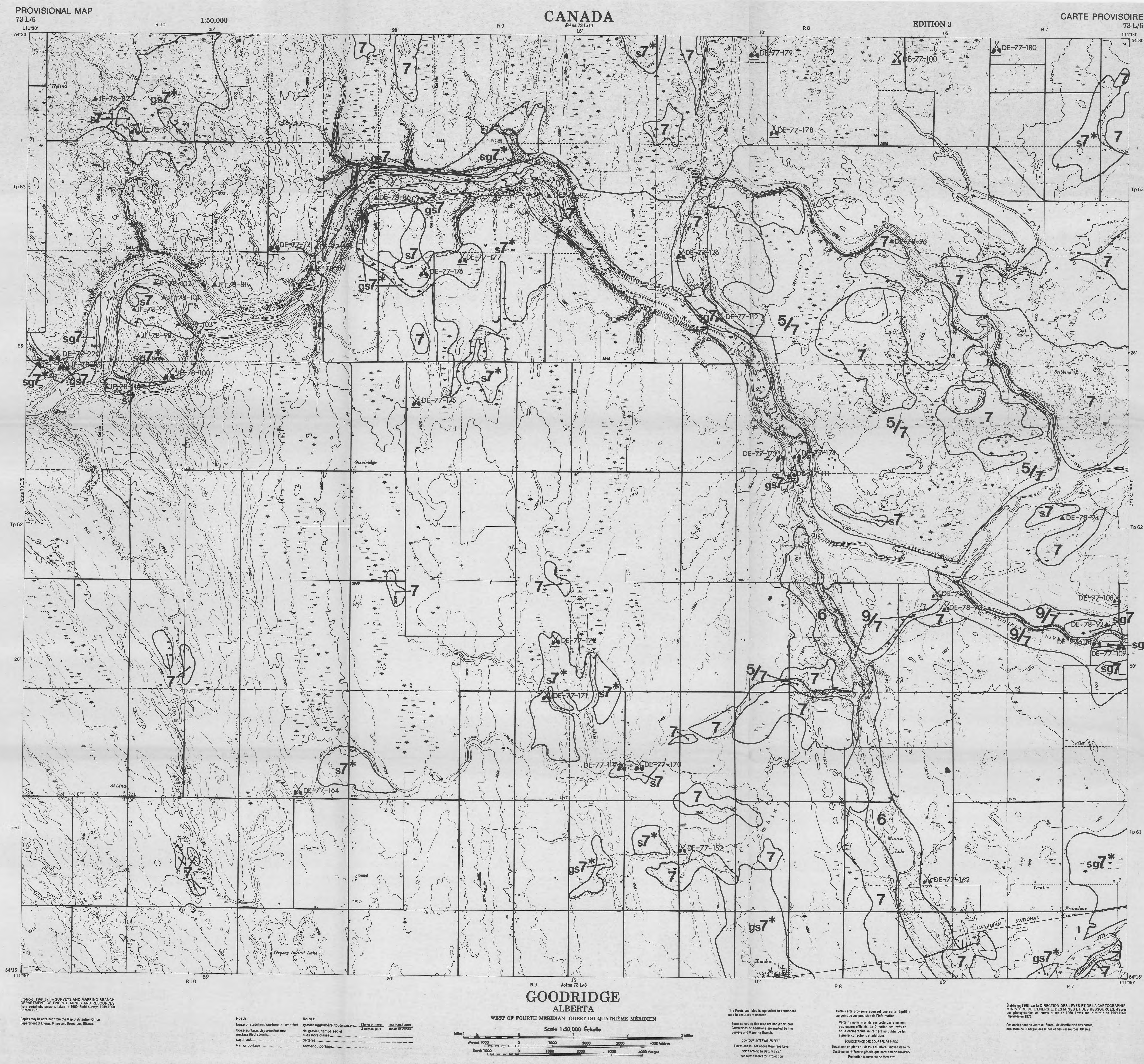


FIGURE 24. SAND AND GRAVEL DEPOSITS IN MAP 73 L/5



LEGEND

UNIT	DESCRIPTION	POTENTIAL FOR AGGREGATE
Glacial Deposits		
4	....Stagnant-ice Moraine: *a rolling to hummocky surface formed of till hummocks, ice-contact deposits and meltwater channels.*	4 ....LOW TO MODERATE: *low potential in primarily till areas (doughnuts), moderate in areas with meltwater channels.*
5	....Water-modified Moraine: *a flat to rolling surface formed of eroded till or thin lacustrine sediments over till.*	5 ....LOW: *may be small deposits in meltwater channels.*
Glaciofluvial Deposits		
6	....Ice-Contact: *kame, esker, crevasse filling.*	6 ....HIGH TO VERY HIGH: *potential for occurrence of granular material very high; deposits may be poorly sorted, structurally deformed, low in volume.*
7	....Outwash: *outwash, pitted outwash, valley train; depositional terrace or bar (or eroded valley fill).*	7 ....VERY HIGH: *potential for occurrence of granular material very high, for coarse aggregate high; deposits generally clean, well-sorted, uniform and sometimes high in volume.*
Recent Deposits		
	Fluvial: *alluvium (generally fine grained) and erosional terraces.*	LOW: *alluvium is generally sandy or muddy.*
9	.... Bog: *bog, marsh, swamp.*	9 .... VERY LOW

s7 ....*Prefix describes the overall grain size composition of the deposit; s = sand, gs = gravelly sand, sg = sandy gravel, g = gravel; see inset diagram for explanation of grain-size terms; units with no prefix have not been investigated.*

7/9 ....*Multiple designations indicate that both units are present, the first unit being the most common.*

....*Active pit.*

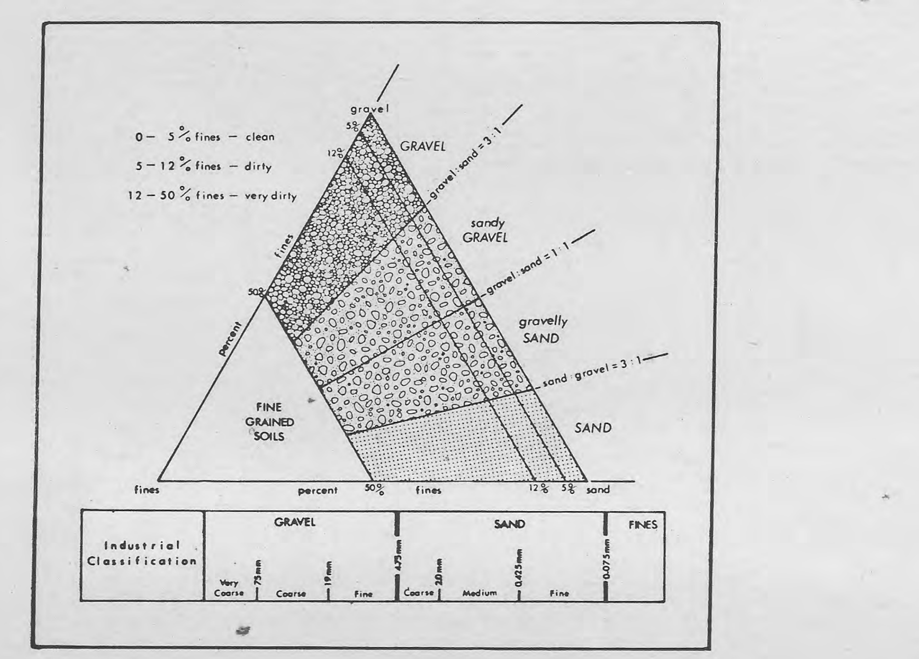
....*Inactive pit.*

▲ ....*Site.*

....*Approximate geologic contract.*

NOTES

The boundaries of the deposits shown on this map were derived from airphoto interpretation. Additional information on individual deposits can be found in the report. Units with an (*) from Fenton and Andriashek, 1979 (ARC), other geology by Edwards, 1977 and 1978, and Fox, 1978.



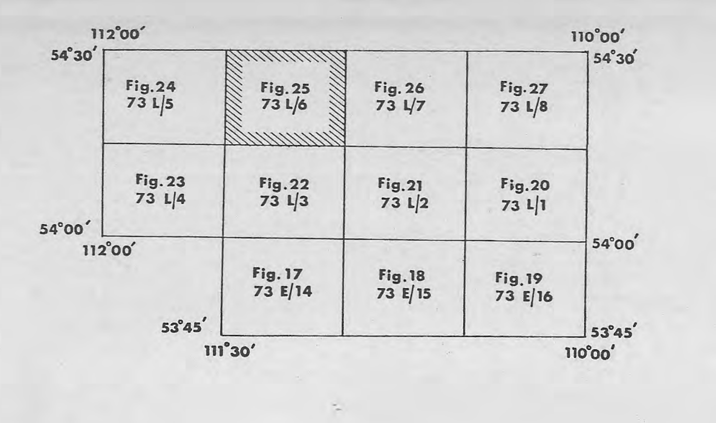
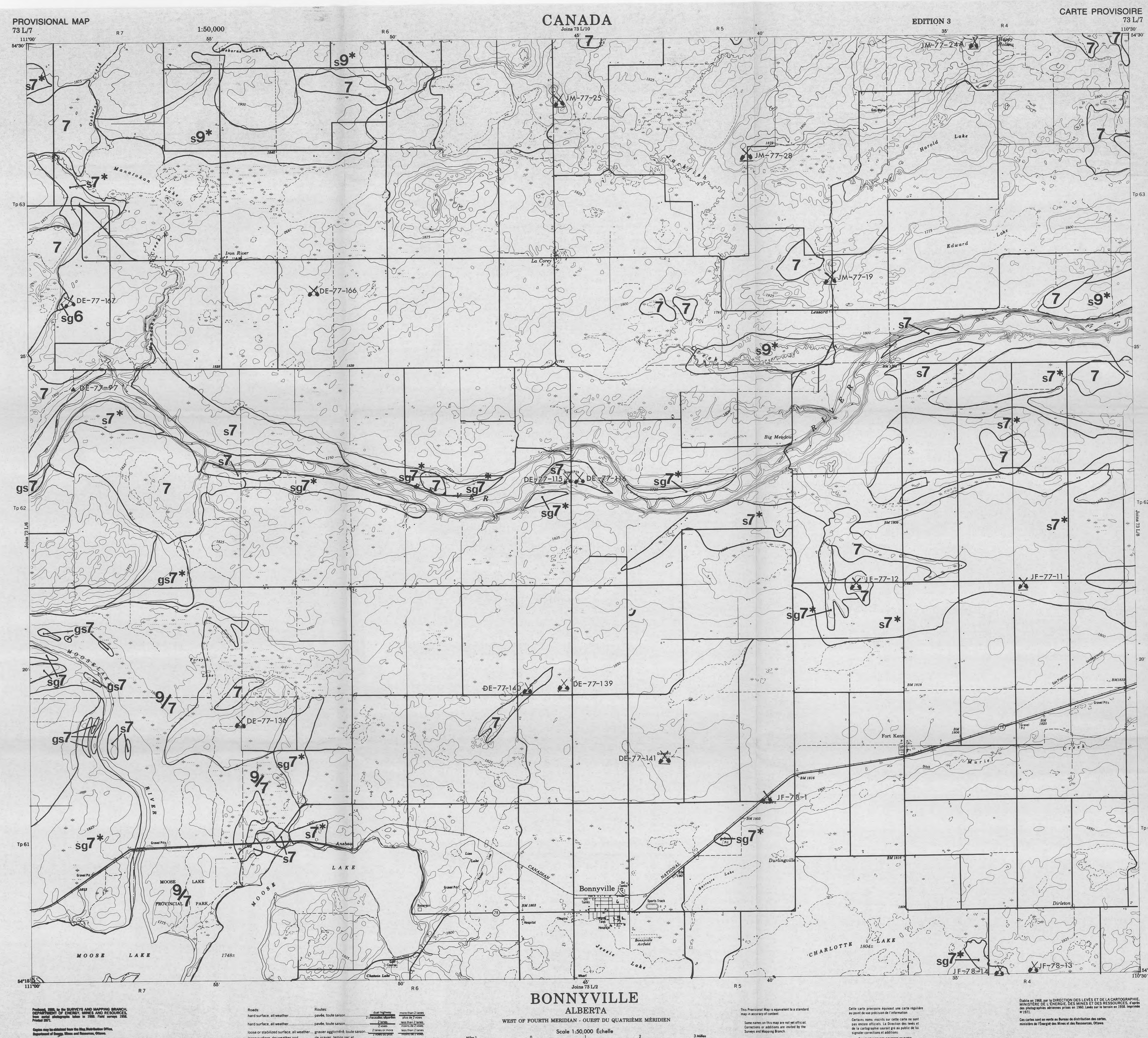


FIGURE 25. SAND AND GRAVEL DEPOSITS IN MAP 73 L/6

73 L/6
EDITION 3



LEGEND

UNIT	DESCRIPTION	POTENTIAL FOR AGGREGATE
Glacial Deposits		
4	....Stagnant-ice Moraine: *a rolling to hummocky surface formed of till hummocks, ice-contact deposits and meltwater channels.*	4 ....LOW TO MODERATE: *low potential in primarily till areas (doughnuts), moderate in areas with meltwater channels.*
5	....Water-modified Moraine: *a flat to rolling surface formed of eroded till or thin lacustrine sediments over till.*	5 ....LOW: *may be small deposits in meltwater channels.*
Glaciofluvial Deposits		
6	....Ice-Contact: *kame, esker, crevasse filling.*	6 ....HIGH TO VERY HIGH: *potential for occurrence of granular material very high; deposits may be poorly sorted, structurally deformed, low in volume.*
7	....Outwash: *outwash, pitted outwash, valley train; depositional terrace or bar (or eroded valley fill).*	7 ....VERY HIGH: *potential for occurrence of granular material very high, for coarse aggregate high; deposits generally clean, well-sorted, uniform and sometimes high in volume.*
Recent Deposits		
	Fluvial: *alluvium (generally fine grained) and erosional terraces.*	LOW: *alluvium is generally sandy or muddy.*
9	.... Bog: *bog, marsh, swamp.*	9 .... VERY LOW

s7 ....*Prefix describes the overall grain size composition of the deposit; s = sand, gs = gravelly sand, sg = sandy gravel, g = gravel; see inset diagram for explanation of grain-size terms; units with no prefix have not been investigated.*

7/9 ....*Multiple designations indicate that both units are present, the first unit being the most common.*

X ....*Active pit.*

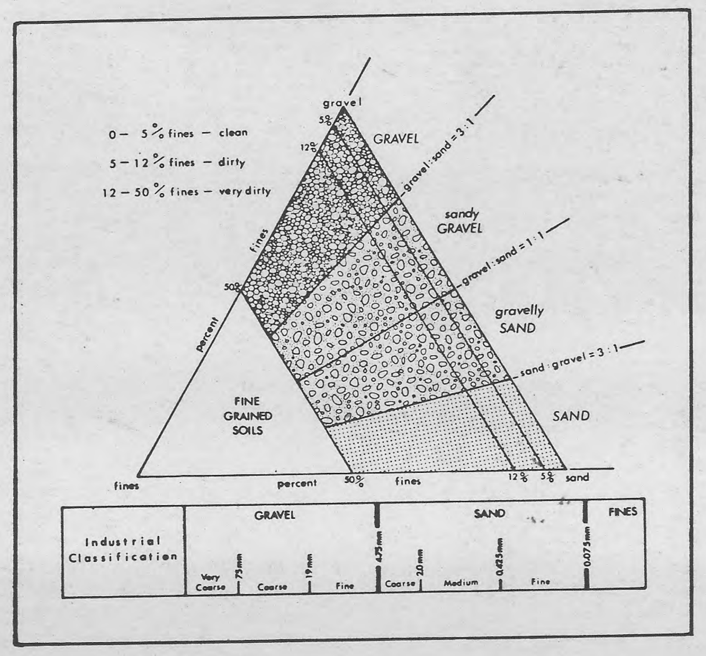
X ....*Inactive pit.*

▲ ....*Site.*

~ ....*Approximate geologic contract.*

NOTES

The boundaries of the deposits shown on this map were derived from airphoto interpretation. Additional information on individual deposits can be found in the report. Units with an (*) from Fenton and Andriashek, 1979 (ARC), other geology by Edwards, 1977 and 1978, and Fox, 1978.



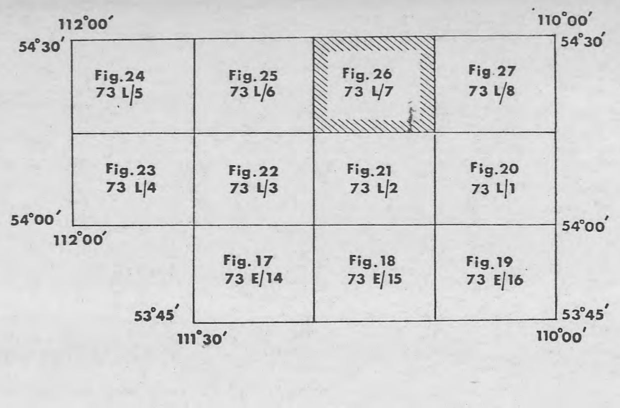


FIGURE 26. SAND AND GRAVEL DEPOSITS IN MAP 73 L/7

PROVISIONAL MAP
73 L/8

CANADA

1:50,000

EDITION 3

CARTE PROVISOIRE
73 L/8

LEGEND

UNIT — DESCRIPTION — POTENTIAL FOR AGGREGATE

Glacial Deposits

4 ....Stagnant-ice Moraine: *a rolling to hummocky surface formed of till hummocks, ice-contact deposits and meltwater channels.*
4 ....LOW TO MODERATE: *low potential in primarily till areas (doughnuts), moderate in areas with meltwater channels.*

5 ....Water-modified Moraine: *a flat to rolling surface formed of eroded till or thin lacustrine sediments over till.*
5 ....LOW: *may be small deposits in meltwater channels.*

Glaciofluvial Deposits

6 ....Ice-Contact: *kame, esker, crevasse filling.*
6 ....HIGH TO VERY HIGH: *potential for occurrence of granular material very high; deposits may be poorly sorted, structurally deformed, low in volume.*

7 ....Outwash: *outwash, pitted outwash, valley train; depositional terrace or bar (or eroded valley fill).*
7 ....VERY HIGH: *potential for occurrence of granular material very high, for coarse aggregate high; deposits generally clean, well-sorted, uniform and sometimes high in volume.*

Recent Deposits

Fluvial: *alluvium (generally fine grained) and erosional terraces.*
LOW: *alluvium is generally sandy or muddy.*

9 .... Bog: *bog, marsh, swamp.*
9 .... VERY LOW

s7 ....*Prefix describes the overall grain size composition of the deposit; s = sand, gs = gravelly sand, sg = sandy gravel, g = gravel; see inset diagram for explanation of grain-size terms; units with no prefix have not been investigated.*

7/9 ....*Multiple designations indicate that both units are present, the first unit being the most common.*

X ....*Active pit.*

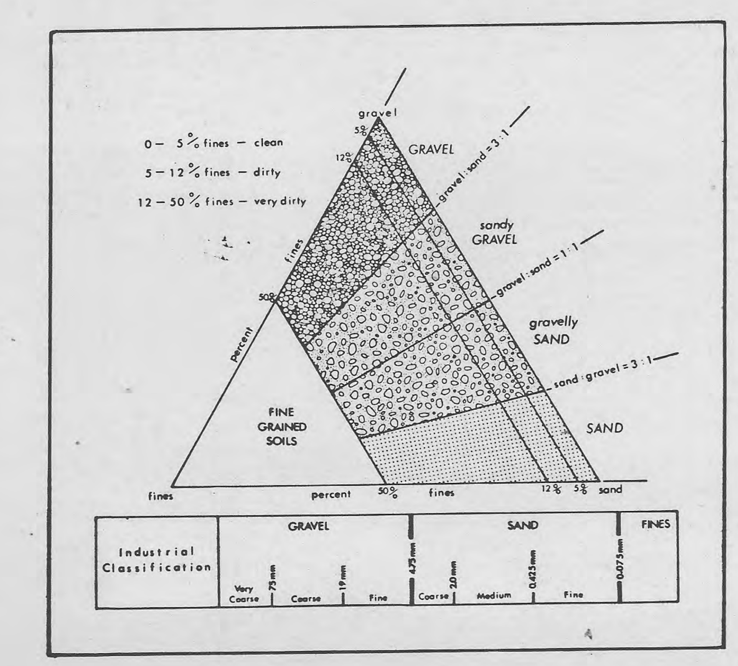
X ....*Inactive pit.*

▲ ....*Site.*

~ ....*Approximate geologic contract.*

NOTES

The boundaries of the deposits shown on this map were derived from airphoto interpretation. Additional information on individual deposits can be found in the report. Units with an (*) from Fenton and Andriashek, 1979 (ARC), other geology by Edwards, 1977 and 1978, and Fox, 1978.



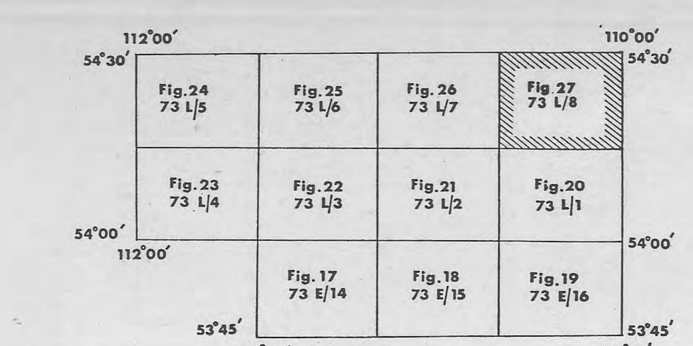


FIGURE 27. SAND AND GRAVEL DEPOSITS IN MAP 73 L/8

COLD LAKE
ALBERTA - SASKATCHEWAN

Produced, 1968, by the SURVEYS AND MAPPING BRANCH, DEPARTMENT OF ENERGY, MINES AND RESOURCES, from aerial photographs taken in 1960. Field surveys 1958. Printed 1971.

Copies may be obtained from the Map Distribution Office, Department of Energy, Mines and Resources, Ottawa.

Roads: / Routes:
hard surface, all weather........ pavée, toute saison........ dual highway / 2 chaussées séparées; more than 2 lanes / plus de 2 voies
hard surface, all weather........ pavée, toute saison........ 2 lanes / 2 voies; less than 2 lanes / moins de 2 voies
loose or stabilized surface, all weather... gravier aggloméré, toute saison... 2 lanes or more / 2 voies ou plus; less than 2 lanes / moins de 2 voies
loose surface, dry weather and unclassified streets........ de gravier, temps sec et rues hors classe........

Scale 1:50,000 Échelle

This Provisional Map is equivalent to a standard map in accuracy of content.

Some names on this map are not yet official. Corrections or additions are invited by the Surveys and Mapping Branch.

CONTOUR INTERVAL 25 FEET
Elevations in Feet above Mean Sea Level
North American Datum 1927
Transverse Mercator Projection

Cette carte provisoire équivaut une carte régulière au point de vue précision de l'information

Certains noms inscrits sur cette carte ne sont pas encore officiels. La Direction des levés et de la cartographie saurait gré au public de lui signaler corrections et additions.

ÉQUIDISTANCE DES COURBES 25 PIEDS
Élévations en pieds au-dessus du niveau moyen de la mer
Système de référence géodésique nord-américain, 1927
Projection transverse de Mercator

Établie en 1968, par la DIRECTION DES LEVÉS ET DE LA CARTOGRAPHIE, MINISTÈRE DE L'ÉNERGIE, DES MINES ET DES RESSOURCES, d'après des photographies aériennes prises en 1960. Levés sur le terrain en 1958. Imprimée en 1971

Ces cartes sont en vente au Bureau de distribution des cartes, ministère de l'Énergie, des Mines et des Ressources, Ottawa.