QUATERNARY GEOLOGY AND AGGREGATE POTENTIAL OF THE FORT NELSON AIRPORT AREA

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INTRODUCTION

A key component of the British Columbia Oil and Gas Development Strategy (OGDS) is a comprehensive road infrastructure plan aimed at promoting better access to resources through improved infrastructure. The completion of road infrastructure improvements, such as the upgrade of Sierra-Yoyo-Desan (SYD) Resource Road and construction of Clarke Lake By-Pass Road in the Fort Nelson area, northeast British Columbia (Fig. 1), are expected to promote longer drilling seasons, accelerate exploration and production programs, and increase industry and Provincial revenues. It has been estimated that 2,000,000 m^3 of aggregate material are needed for this initial road infrastructure improvement program. A study was conducted to evaluate existing local sources of aggregate material along SYD that could be used for this project (Thurber, 2000) and it was determined that existing aggregate reserves were largely depleted.

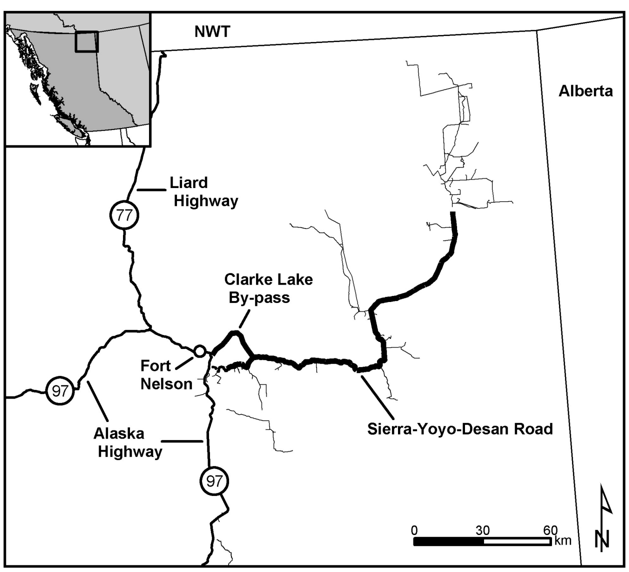

Figure 1: Location of Fort Nelson and major roadways in northeast British Columbia

To meet the aggregate needs for this initial improvement project, and to meet the needs of future resource and lease-road construction, a surficial mapping program was initiated to systematically explore for new, local aggregate sources in northeast British Columbia (see Levson *et al.*, this volume). Initial test pit programs were conducted in spring 2003, with follow-up work and reconnaissance-scale fieldwork and preliminary aerial photograph mapping conducted during summer 2003. To date, four main aggregate resources have been identified within the SYD Road corridor, with a total resource of approximately 5,000,000 m^3 of granular material. This effort has also identified numerous other areas that are believed to have potential to host granular deposits but that require further work to sufficiently evaluate.

One such area is within the Fort Nelson airport area, approximately 8 km northeast of Fort Nelson town-site (Figs. 2, 3). This area is of particular interest due to its proximity to the Clarke Lake By-Pass Road right-of-way. This report summarizes findings from detailed surficial mapping and test pitting conducted within Fort Nelson airport area.

PROJECT BACKGROUND

SYD Road is a high-grade, all weather road, located east of Fort Nelson, and is accessed from mile 293 of Alaska Highway. It extends 180 km to the east and northeast ending at the North Helmet airstrip in the Helmet District (Fig. 1). This resource road supports the majority of summer, and a good portion of winter, drilling, well tie-in, wellhead servicing, and well production activities in the area. As such, this road can experience high volumes of heavy, oil-field service traffic, which has been increasing due to increased oil and gas exploration and production activities in the area. The volume of traffic on the SYD is greater than on the Alaska Highway. Current plans include upgrading and widening of the SYD Road to meet increased demands of this critical resource road. SYD road provides access to resources that generate $200 to $300 million per year in direct revenue to the province.

As part of this infrastructure improvement project, a new 21 km road is to be constructed from Fort Nelson to the SYD, including a new two-lane bridge crossing of the Fort Nelson River – the Clarke Lake By-pass (Fig. 1). This will eliminate the need to use the narrow BC Rail train bridge and a set of switchbacks. This transportation project will improve safety and access, reduce travel time and reduce maintenance costs of the road and on vehicles using the road.

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Finding aggregate deposits that are local can generate great savings. Aggregates account for 30 to 50% of road construction and maintenance costs in northeast BC. As well, transportation costs of aggregate can be prohibitive. For example, for the SYD project, rail transportation costs of aggregate from Ft. St. John to Fort Nelson and truck transportation costs from Fort Nelson to the SYD are ~$85/m^3. Two million cubic metres of aggregate is needed for 180 km SYD road upgrade, totalling $170M. If transportation costs were lowered by just $1/m^3 a savings of $2 million could be generated. It is expected that if local sources of aggregate were found, total aggregate costs could be reduced significantly. Therefore to help minimize road construction costs, Quaternary geology and aggregate potential mapping was completed close to the Clarke Lake By-pass in the Fort Nelson airport area.

STUDY AREA

The study area includes part of the Fort Nelson airport area and is comprised of the area south and east of the main runway, down to the floodplain of Fort Nelson River below (Fig. 3). The study area is located within the Fort Nelson Lowland physiographic region, a flat to very gently rolling area with very little relief (Holland 1976).

The Fort Nelson airport area can be locally divided into three physiographic units: plain, valley side and valley bottom (inset, Fig. 3). Fort Nelson airport is situated on a near-level plain above Muskwa Valley. This plain continues north and west but has been incised by McChonachie Creek which flows east into Fort Nelson River just north of airport property. This plain is moderately well drained, typically supporting stands of white spruce (*Picea glauca*), and rare lodgepole pine (*Pinus contorta* var. *latifolia*), but does have areas where black spruce (*Picea mariana*) bogs dominate. Closer to the valley sides, trempling aspen (*Populus tremuloides)* is common. Valley sides are steep and terraced with terrace flats being typically 25 to 150 m wide and up to 1000 m long. Terrace flats and risers support white spruce and trembling aspen stands almost exclusively and typically are well drained. The valley bottom setting is flat and moderately to poorly drained. Trempling aspen and balsam poplar (*Populus balsamifera ssp. balsamifera*) stands are more common here, with large blocks having been logged in recent years.

The Fort Nelson airport has had a long and complex land-use history. During the early 1940's it served as a base for the United States Army and Air Force for various staging and training exercises. As a result, much of the area, although now grown over with trees and vegetation, has been disturbed. Evidence of disturbance includes overgrown roads, building foundations and excavations. These disturbances have made interpretation of aerial photographs and field observations challenging.

BEDROCK GEOLOGY

The Fort Nelson area is underlain by gently dipping marine shales and siltstones of the Lower Cretaceous Buckinghorse Formation, Fort St. John Group (Okulitch *et al.*, 2002; Thompson, 1977). This formation has a minor component of sandstone. There are no bedrock exposures within the study area. Buckinghorse Formation rocks can however be seen in steep cutbanks south of the Fort Nelson airport area along Fort Nelson River.

Grading laterally and vertically from these rocks are coarser grained, sandstones and siltstones of the Lower Cretaceous Sikanni Formation. To the north of Fort Nelson and northwest of the Fort Nelson airport, Sikanni Formation rocks form a topographic high. Exposures of these rocks are common in road cuts north of town and in areas cleared for agricultural purposes. A similar topographic high is seen east of the airport property, across Fort Nelson River. In both cases these prominent topographic features rise approximately 150 m above the surrounding area.

This sequence of rocks is interpreted to be a transgressive/regressive cycle from marine shales into alluvial-delatic sandstones, mudstones, conglomerates, and coal. This cycle is repeated three times in the stratigraphy and is attributed to orogenic activity within the Columbian Orogen (Stott, 1975; Thompson, 1977).

QUATERNARY HISTORY AND LANDFORMS

The last ice sheets to have covered northeastern British Columbia and adjacent Alberta have left a record of their presence in the existing landforms and surficial deposits: streamlined forms, meltwater channels, erratics and drift sheets, and traces of former ice dammed lakes (Mathews 1980). Many of these landforms have been unmodified since the close of the Late Wisconsinan glaciation.

During deglaciation, 13,500 to 10,000 years before present, the Laurentide Ice Sheet (LIS) retreated generally to the northeast (Mathews 1980). A series of ice- and topographically-dammed glacial lakes and meltwater channels developed. Within the Fort Nelson area a number of meltwater channels and likely recessional moraines that have been mapped as part of this project record the retreat of the LIS (Fig. 2). Moraines are arcuate-shaped in planform with NW-SE to N-S orientations and with their concave sides facing NE to E. The recessional moraines are associated with a number of meltwater channels. A moderate-sized meltwater channel now occupied by Jackfish Creek (~25 km south of Fort Nelson) occurs on the NNE edge of a topographic high (Fig. 2). Presumably the position of this meltwater channel was related to the presence of ice to the NNE

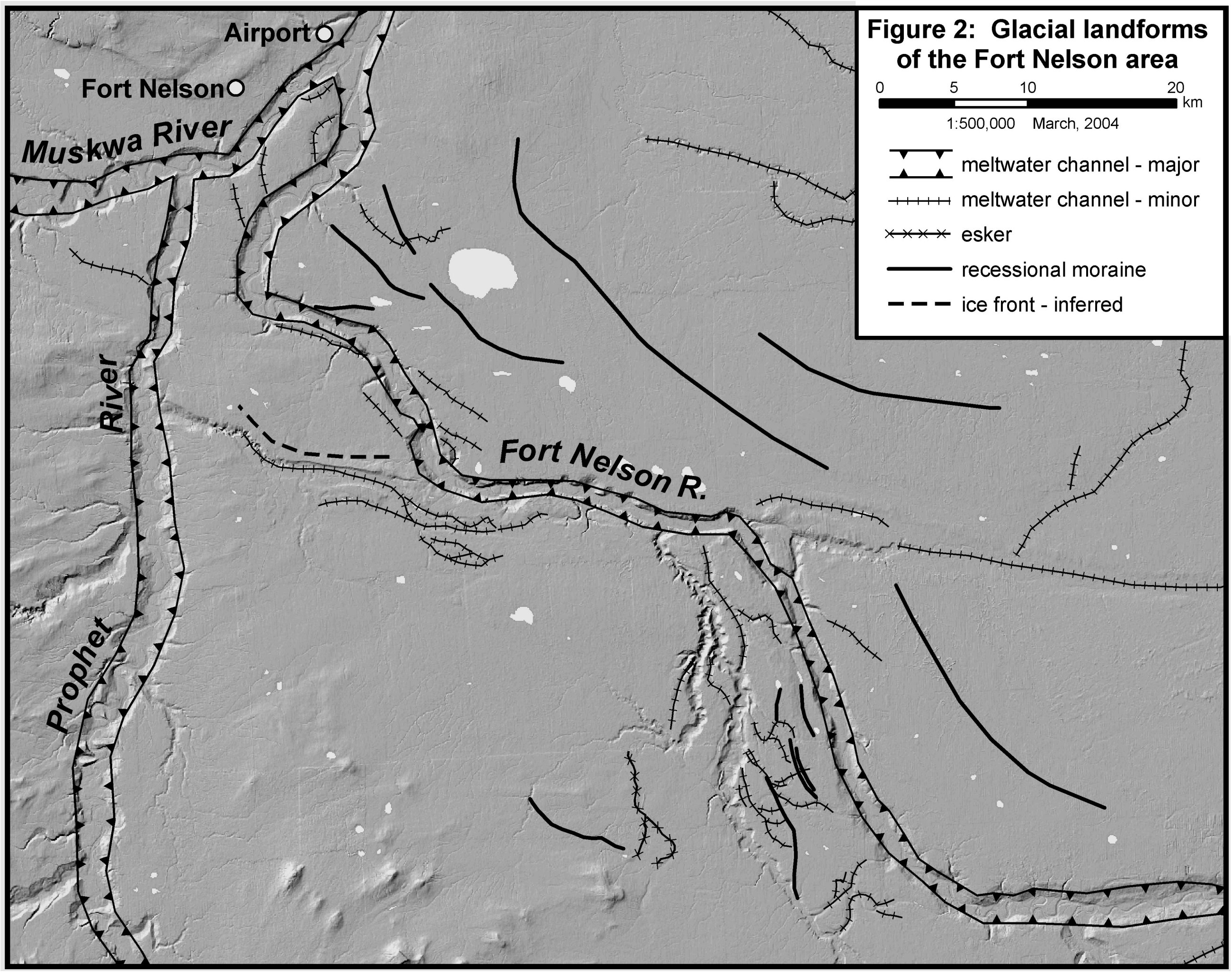

Figure 2: Glacial landforms of the Fort Nelson area

(mapped as a inferred ice front, Fig. 2), otherwise the channel would have developed at a lower elevation. Taken together these observations confirm the general NE retreat of the LIS within the Fort Nelson area and the importance of this pattern of retreat to the development of meltwater channels, some of which are being mined for aggregate.

The Fort Nelson airport area is located at the confluence of two major meltwater channels (each ~2 km wide and ~90 m deep), now occupied by the Muskwa and Fort Nelson rivers (Mathews 1980; Fig. 2). These rivers are smaller in width, and much more sinuous, than the valleys they occupy. These channels once carried much larger volumes of water and sediment during deglaciation. These conditions led to the transport and deposition of gravel during deglaciation. Consequently there should be aggregate deposits associated with these meltwater systems particularly at higher elevations within the valleys and on the adjacent plain. Aggregate deposits and landforms on the plain may also be associated with earlier stages of glaciation when sediments were transported and deposited underneath (subglacial), within (englacial) or atop (supraglacial) former ice sheets. Shallow boreholes that were completed as part of an environmental baseline study for the Fort Nelson airport property indicate that drift thickness can be up to >7 m thick (Transport Canada 1998).

METHODS

Results from a previously conducted reconnaissance test pit program by Atco Airports Ltd. indicated the occurrence of granular material on Fort Nelson airport property. This information stimulated interest in this area as a host to an aggregate deposit(s). To further assess the area's potential to host such a deposit, British Columbia Ministry of Energy and Mines (MEM) personnel carried out detailed aerial photograph and field surveys.

MEM personnel made observations at 46 field stations, using hand augers and shovels. In areas of tree blowdown, natural exposures in tree root wads were also utilized to determine sub-surface sediment types. To characterize the study area and sub-surface sediments, various data were collected: topographic position; dominant tree, shrub and herb species; exposure height; unit thickness; and, sediment texture, structure, and paleoflow. Black and white, 1:10 000 and 1:40 000 scale aerial photographs were used throughout the various stages of this study.

Other data collected and compiled for this study included: test pit logs from the original test pit program conducted by Atco Airports Ltd.; subsurface borehole logs (Transport Canada 1998); and test pit results from an investigation of Clarke Lake By-Pass Road right-of-way (Thurber Engineering, unpublished). Following the methodology of Howes and Kenk (1997), detailed surficial geology mapping was completed using these data and 1:10,000 scale black and white aerial photographs.

A test pitting program was initiated in December 2003 to assess the aggregate potential of the area. Using a Kobelco 220LC tracked excavator, 2 to 5 metre deep pits were excavated at 18 sites on Fort Nelson airport property. Detailed descriptions of sediments were completed at each pit, and classified using both the Wentworth scale and the Modified Unified System of Soil Classification. Granular material was sampled from select sites for various laboratory analyses. Following procedures set by Cunningham (1990), sieve analyses, degradation (susceptibility of aggregates to mechanical breakdown), and sand equivalent tests (presence or absence of plastic fines) were completed on these samples.

RESULTS AND INTERPRETATION

Surficial geology

The results of surficial geology mapping are shown in Figure 3. Figure 4 summarizes test pit log data and is classified as indicating either granular or non-granular material. Granular material thinner than 1 metre thickness is mapped as non-granular. Granular sediments have grain sizes greater than and including fine sand (>125μm diameter, Wentworth scale).

The reader is referred to Howes and Kenk (1997) for detailed explanation of surficial geology map labels (Fig. 3). Due to the scale of mapping and limited data, considerable variation in sediments may occur that is not reflected in the mapping. More confidence in interpretation is given to those polygons containing field data.

Four main types of deposits are found: fluvial (F), glaciofluvial (F^G), organic (O) and morainal (M). Secondary types include colluvium (C) and anthropogenic (A) deposits. Given the long land use history of the study area, many additional areas could be labelled as anthropogenic.

The valley bottom physiographic area (inset, Fig. 3) includes active fluvial plains that contain flood channels, levees and scroll bars. The Muskwa River is boxed between valley walls causing the planform of meander loops to be boxed-shaped rather than gently looped-shaped. The area was visited during high water where dramatic rates of bank erosion were observed. Surface sediments within the fluvial plain are dominantly silt and sand. The Muskwa River is transporting and depositing gravel today and likely did so in the past. Thus, gravel deposited from previous positions of the Muskwa River channel generally occur beneath these finer grained deposits. Buried gravels were locally observed along the modern cut banks of the Muskwa River.

The valley side physiographic area (inset, Fig. 3) includes abandoned river terrace flats and terrace risers of the Muskwa River. These landforms were created during Muskwa River incision. The slopes of terrace risers vary considerably. Terrace flats vary in width from ~25 to 150 metres. Gravel was observed at the bases of blown down trees in the southwestern-most terrace flat and indicates that when the Muskwa River was at this elevation it was transporting gravel. Elsewhere on the same terrace flat two small swamps (Op) were observed in aerial photographs suggesting that the sediments immediately underlying these swamps are fine grained. It is unknown if these fine-grained sediments are underlain by coarse-grained sediments. Fluvial terraces in the middle and northwest portion of the study area that are at a somewhat similar elevation maybe contain gravel and/or sand.

The terrace that is crossed by the Clarke Lake By-pass is composed of very fine-grained surficial sediments, likely overbank fines from the ancient Muskwa River. Swamps (Op) on this terrace further suggests that most of the feature is surfaced by fine-grained sediments. The slope above this terrace flat is composed dominantly of morainal material (till). Some of this material appears to have been reworked by mass wasting processes.

The plain physiographic area is an area of very low relief and contains glaciofluvial (F^G), organic (O), till (M) and anthropogenic (A) sediments. Deposits of glaciofluvial sediments are discontinuous and occur as elongate deposits rather than as continuous sheets. Portions of these deposits also have a gentle elongate hill morphology with hill crests aligned SW-NE. These observations suggest that these sediments were deposited by water flows in conduits within glacial ice.

Glaciofluvial deposits are surrounded by organic sediments (bogs). Presumably these organic deposits are underlain by till or thin beds of sand and gravel overlying

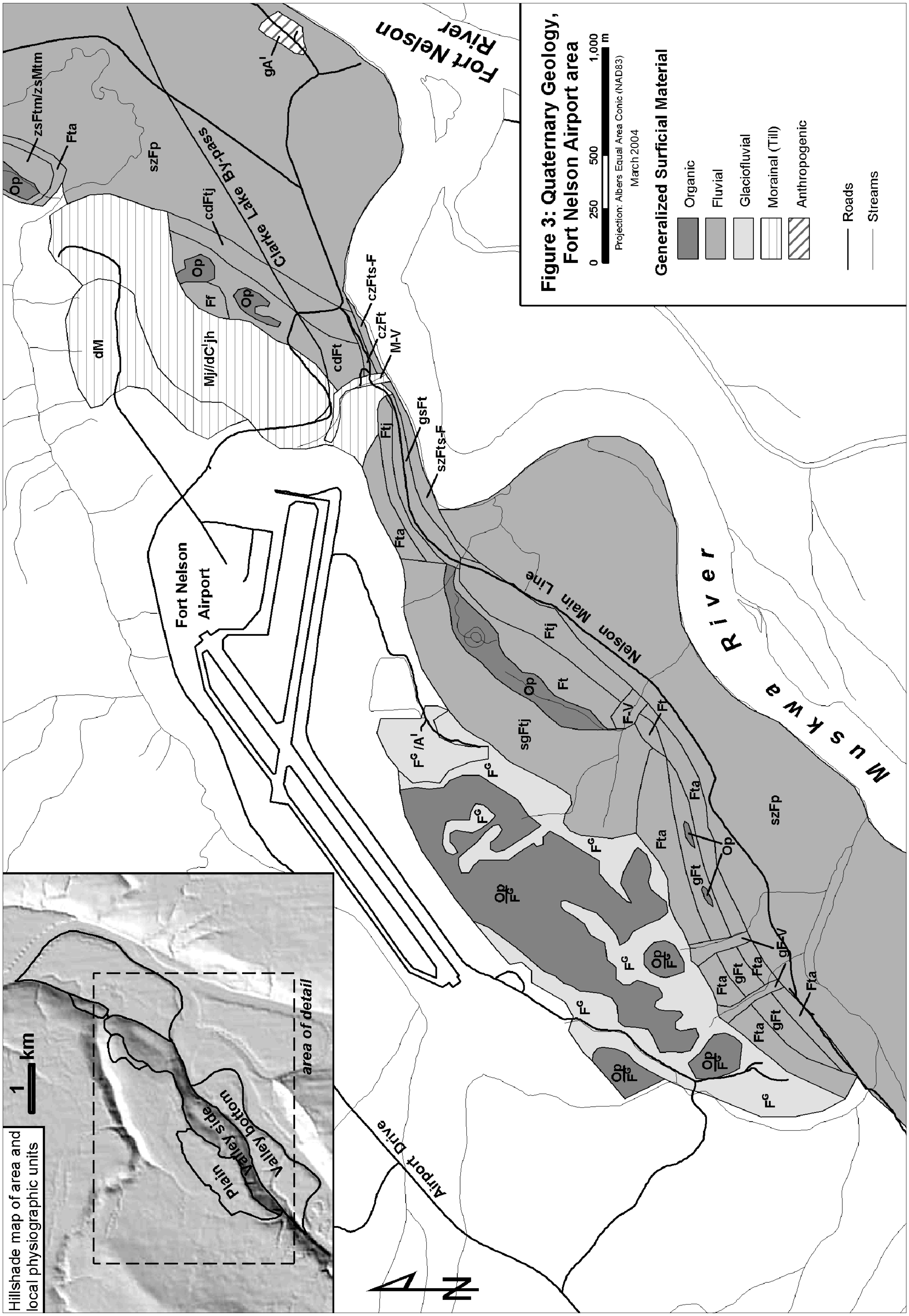

Figure 3: Quaternary Geology, Fort Nelson Airport area

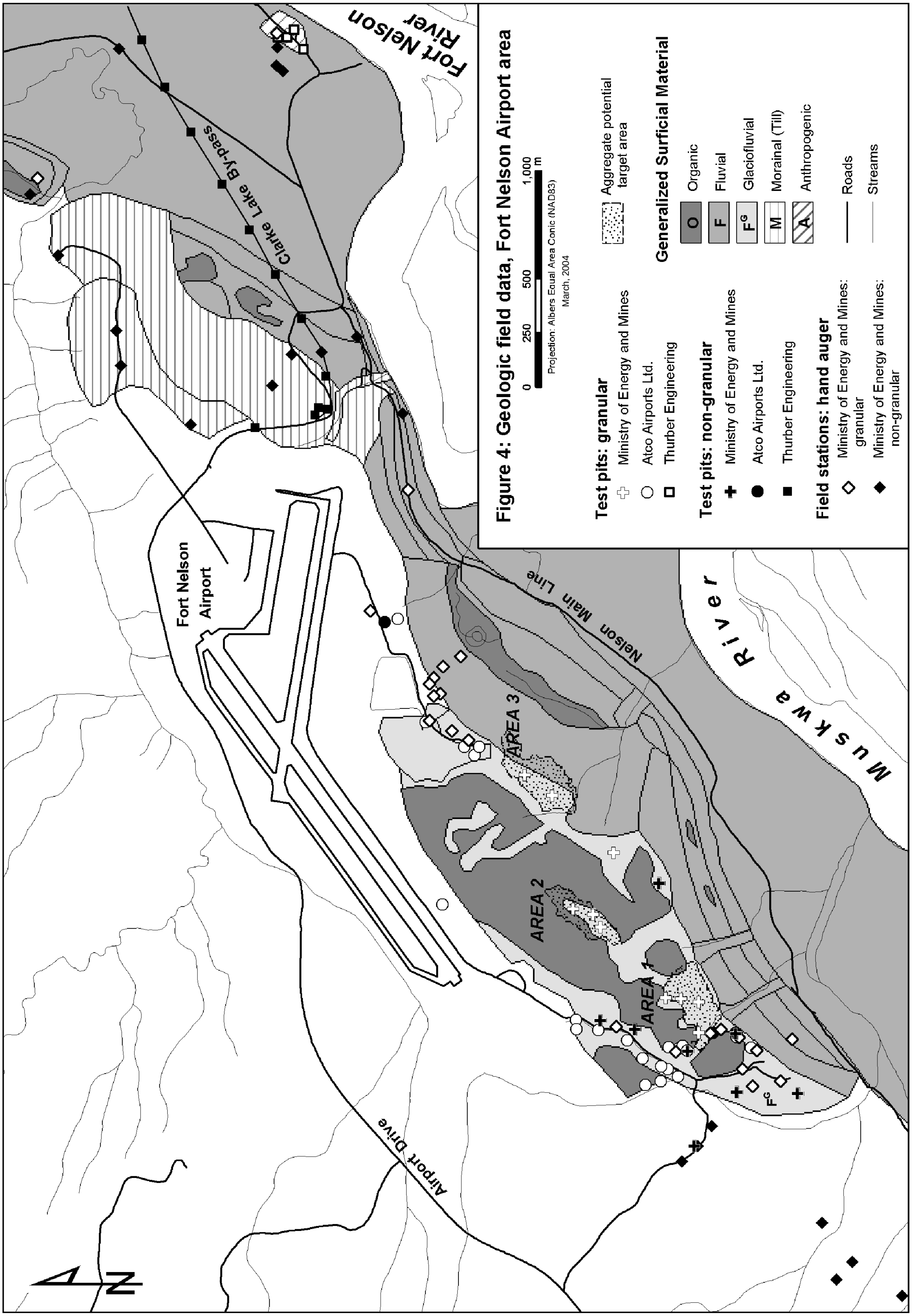

Figure 4: Geologic field data, Fort Nelson Airport area

till. Till is at the surface in the northeast portion the study area. It is relatively clast rich, massive, with a silty-clay matrix. Elsewhere till was observed to underlie glaciofluvial sediments (MEM test pits 3, 5, 8, 9, 11, 13, 15, 23, 53, 56, 57). Anthropogenic deposits are more common than indicated in Figures 3 and 4. Deposits of this type include: piles of overburden, granular material and buried garbage.

DISCUSSION ON GRANULAR DEPOSITS

Test pits were concentrated in the plain physiographic area as this area (i) has known gravel deposits, and (ii) has numerous roads that provide relatively easy access for an excavator.

A total of eighteen test pits were completed over three days (Fig. 4, Table 1). Seven samples were collected for analysis: gradation, degradation and sand equivalent tests (Cunningham 1990). Based on test pit data and lab analyses three areas have been identified that may be of interest for mining granular material: Area 1 includes MEM test pits 11 and 12; Area 2 includes MEM test pits 20, 54 and 56; and, Area 3 includes test pits 32 and 57 (Fig. 4).

Area 1

Test pits 11 and 12 in Area 1 lie above and northeast of an old pit face ~3 m high, 100 m long with a southeast aspect. Adjacent and southeast of this old pit face is evidence of an old clearing that was likely the site of previous aggregate mining. Area 1 had 2.6 m, >2.1 m and 0.5 m of horizontally stratified gravel in test pits 11, 12 and 53, respectively (Table 1).

Results from degradation and sand equivalent tests indicate that material from test pit 11 meets MOT specifications for all granular materials. Based on four gradation curves, the granular material in Area 1 is best suited for use as select granular sub-base (SBSG, Ministry of Transportation 2000). Due to disturbances related to land-use history it is difficult to estimate the volume of granular material in Area 1 (Fig. 4).

Area 2

This area is an elongate ridge of ~2 m relief, trending SW-NE and includes test pits 20, 54 and 56. Test pit 20 contained >4.4 m cross-bedded sandy gravel, test pit 54 contained 2.0 m sandy gravel overlying 0.5 m sand and silt, and test pit 56 contained 1.3 m sandy, pebbly gravel overlying till (Table 1). This landform is possibly an esker as (i) it has an elongate, hill morphology, (ii) it is composed of granular material some of which is cross-bedded (~30° dip), and (iii) it is located on the plain. Alternatively the ridge could be a fluvial bar related to high elevation deposition from the Muskwa River during deglaciation. A number of pine trees indicating a relatively dry site occur at test pit 20. This is also the pit with thickest gravels in the study area. The water table was not encountered.

Results from degradation and sand equivalent tests indicate that gravel from test pit 11 meets MOT specifications for all granular materials and appears best suited for use as SBSG. This classification is based on only two gradation curves, not the mean of four as required by provincial standard (Ministry of Transportation 2000). Fracture count data (i.e. the number of fractured or naturally occurring angular clasts in specific grain-size fractions) is not required for classifying SGSB material as this material can be produced by direct excavation (i.e. pit-run). However, other MOT granular material classifications such as high fines granular surfacing aggregate (HFGSA) or 25 mm well-graded base coarse aggregate (WGCBA) require minimum 50% fracture count after processing. Fracture count tests were not conducted on Area 2 samples. It is therefore not known if Area 2 sediments would meet the minimum fracture count requirement for these other granular material classifications.

A preliminary granular material volume estimate of 20,000 m^3 has been calculated. This volume was derived using the average thickness of gravels in the three test pits (2.3 m) and a conservative area estimate.

Area 3

Test pits 32 and 57 are located on a broad elongate ridge, trending SW-NE. Sediments in test pit 32 and 57 are composed of >4.6 m and 2.0 m of cross-bedded fine sand, respectively (Table 1). As there was no gravel in these pits, degradation and sand equivalent tests were not completed. Based on one gradation curve, the granular material in Area 3 is not suitable for SBSG. Further testing and additional gradation results may therefore prove Area 3 sediments appropriate for use as SGSB material.

A highly preliminary granular material volume estimate of 50,000 m^3 has been calculated using the average thickness of granular material in two test pits (3.3 m) and a conservative area estimate.

EVALUATION OF MAPPING

Based on test pit information, only minor changes were required to the surficial geology mapping. Many locations in the plain physiographic area were disturbed indicating that anthropogenic activity was more common than is indicated in Figure 3 and 4. Historical activity included aggregate mining, as indicated above.

Table 1: Summary of Ministry of Energy and Mines test pit data

Test Pit #	Depth (m)	Granular material (m) [1]	Description of granular material [2]	Overburden thickness (m)	Water table depth (m)	Sample collected
1	4.0	none	n/a	n/a	none	
3	4.0	0.3-0.8	sandy silty gravel (CL-GM)	0.3 soil	none	
5	3.5	0.6-1.6	pebble cobble gravel (GP)	0.6 soil and fine sand	none	
8	2.0	0-0.5	sandy gravel (GW)	none	none	
9	3.4	1-3.4	0.5 m silty sandy gravel (GP) underlain by 0.8 m pebble gravel (GP)	1.0 road fill and organics	2.3	yes
10	2.5	none	n/a	n/a	none	
11	3.0	0.2-2.8	pebbly cobble gravel (GM)	0.2 soil	2.5	yes
12	2.5	0.4->2.5	sandy gravel (GM)	0.4 soil	2.5	yes
13	2.0	0.5-1.0	silty sandy gravel (GM)	0.5 soil	none	
15	2.5	0.5-1	sandy gravel (GM)	0.5 soil	none	
20	4.5	0.1->4.5	sandy gravel (GM)	0.1 soil	~3.5	yes
23	2.8	0.2-4.5	silty fine sand (SM)	0.2 soil	none	
32	4.8	0.2->4.8	fine sand (SW)	0.2 soil	none	yes
53	2.8	1.8-2.3	silty sandy gravel (GM)	1.8 silt	2.3	yes
54	2.8	0.2-2.2	sandy gravel (GM)	0.2 soil	1.8	
55	2.0	0.4->2.0	gravelly coarse sand (SP)	0.4 soil	1.5	
56	2.0	0-1.3	sandy pebble gravel (GP)	none	none	yes
57	2.5	0.3-2.3	fine sand (SP-GM)	0.3 soil	none	

[1] Depth range

[2] Description after Wentworth grain size classification. Codes in brackets follow the Modified Unified Soil Classification System

CONCLUSIONS

The Fort Nelson airport area is host to sediments deposited during and following the last glaciation. These sediments are of morainal, glaciofluvial, fluvial, organic and anthropogenic origin. Reconnaissance test pit results suggest that three areas on the Fort Nelson airport property have potential to host aggregate deposits. Detailed air photo mapping, ground surveys, and a high density test pit program are required to further assess the quality and volumes of granular material present in these areas. As well, there may be other areas within the Fort Nelson airport area that warrant further aggregate potential investigations – for example, the area north of Area 3, and fluvial terrace flats on the valley side.

ACKNOWLEDGEMENTS

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REFERENCES

Cunningham, D., Editor. 1990. Manual of test procedures, soils and mineral aggregates. British Columbia Ministry of Transportation and Highways.

Howes, D.E. and Kenk, E. 1997. Terrain classification system for British Columbia (version 2): a system for the classification of surficial materials, landforms and geological processes of British Columbia. Ministry of Environment, Lands and Parks, Province of British Columbia, 101 p.

Holland, S.S. 1976. Landforms of British Columbia, a physiographic outline. Bulletin 48. British Columbia Department of Mines and Petroleum Resources. 138 p.

Mathews, W.H. 1980. Retreat of the last ice sheets in northeastern British Columbia and adjacent Alberta.

Geological Survey, Bulletin 331. Geological Survey of Canada. 22 p.

Ministry of Transportation. 2000. Section 202 – granular surfacing, base and sub0bases, *In* Standard Specifications for Highway Construction, Volume 1, 586 p.

Stott, D.F. 1975. The Cretaceous system in northeastern British Columbia, *In* Caldwell, W.G.E. (ed.) The Cretaceous system in the Western Interior of North America – selected aspects. Geological Association of Canada, Special Paper 13: 441-467.

Thompson, R.I. 1977. Geology of Beatton River, Fontas River and Petitot River map-areas, northeastern British Columbia. Geological Survey of Canada, Paper 75-11, 8 p.

Transport Canada. 1998. Fort Nelson airport environmental baseline study: Volume 2. Completed by Beatty Franz and Associated Ltd.