Open File 2009-43

Preliminary assessment of aggregate potential in Peel River basin (including parts of 106E, 106F, 106K, 106L, 116H and 116I)

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Front cover photograph:
View south of the Snake River in the eastern part of the map area. Photo by Tammy Allen.

INTRODUCTION

The Peel Basin aggregate potential study was initiated to provide an increased understanding of potential aggregate resources in the Peel River watershed. An improved understanding of regional aggregate potential will enhance project viability and encourage exploration investment in the Peel Watershed. The aim of this study was to remotely assess broad regions of the Peel River basin in Yukon for potential sources of aggregate materials.

Currently, the Peel Watershed Land Use Planning Commission is building a land use plan whose accuracy hinges on predicting likely access routes for future development. Surficial geology mapping, which is used to locate the aggregate required for future development, has only been partially completed for the planning region. To supplement the existing data, this study reports on new reconnaissance aggregate mapping and summarizes potentially valuable aggregate resources in previously mapped areas.

Aggregate-specific reconnaissance surficial geological mapping was accomplished via aerial photographic interpretation, with no field work component to ground-truth map units. Aggregate is generally plentiful in highlands of the planning region and aggregate mapping was not undertaken in the southern and western uplands of the Wernecke and Ogilvie mountains. The aggregate mapping area approximately follows the limit of the Laurentide Ice Sheet along the Wernecke Mountains, and extends west to encompass all of NTS map sheets 106F, 106E, 116H, 116I, 106L, and 106K where they lie within the boundaries of the Peel Watershed Land Use Planning region (Fig. 1). The resulting 1:400 000-scale map product (Open File 2009-43) can be used to identify areas of high aggregate potential for more detailed studies in the future.

REGIONAL SETTING

Physiography

The Peel Watershed Land Use Planning region encompasses the upper Peel River watershed including major tributaries such as the Snake, Bonnet Plume, Wind, Hart, Ogilvie and Blackstone rivers. Physiographic regions within the planning area include the Peel Plateau and Plain, Bonnet Plume Depression, Wernecke Mountains, Ogilvie Mountains, Kandik Basin, Richardson Mountains and Eagle Lowland (Fig. 2). Aggregate potential mapping has focussed on plateaus and lowlands due to scarcity of aggregate in these areas. The aggregate study area encompasses all or parts of the Richardson Mountains, Peel Plateau and Plain, Eagle Lowland, Bonnet Plume Depression, and Ogilvie Mountain physiographic regions. The Kandik Basin and large parts of the Ogilvie and Wernecke mountains have been excluded from this study.

Development potential

Three petroleum basins are present in the aggregate mapping region: Peel Plateau and Plain, Bonnet Plume Basin, and a small portion of Eagle Plain (Fig. 3). While Eagle Plain has significant potential for oil and gas development, it is largely outside of the study area and addressed in North Yukon planning documents. Significant gas potential is thought to occur beneath Peel Plateau and Plain and is currently being explored by industry (Active Dispositions, 2008 in Fig. 3). Similarly, extensive coal reserves in the Bonnet Plume Basin have high potential for economic development in the future. Just outside of the study area, in the Wernecke

Mountains, significant mineral potential exists, most notably in the form of the Crest Iron deposit and Wernecke Breccia copper-uranium showings.

Bedrock

Bedrock in the Peel Plateau and Plain is part of the Northern Interior Platform and characterized by relatively flat-lying sedimentary rocks typical of the Western Canadian Sedimentary Basin east of the Cordilleran Orogen deformation front. A poorly-understood Proterozoic succession is uncomfortably overlain by a westerly-thickening wedge of sedimentary rocks (up to 4.5 km thick) made up of Cambrian to Upper Devonian carbonates and shales; Upper Devonian to Carboniferous shale, sandstone, and lesser conglomerate; and Cretaceous mudstone, shale and minor sandstone deposits (Allen and Fraser, 2008). Adjacent to the Peel Plateau and Plain, the Bonnet Plume Basin is an intermontane, fault-bounded basin within the Northern Yukon Fold Complex. The basin contains extensive non-marine late Cretaceous to Tertiary sandstone, shale, conglomerate and coal (Norris, 1997).

The southern extension of the Richardson Mountains in the study area is the result of uplift of Paleozoic deep water sediments into a breached anticlinorium characterized by sandstone, limestone, and chert (Norris, 1997). The northern limit of the Mackenzie Mountains also occurs within the aggregate mapping region as the Wernecke and Ogilvie mountains. Part of the Cordilleran Foreland Fold and Thrust Belt, these sedimentary rocks are characterized by sandstone, siltstone, dolomite, shale, conglomerate, chert, and limestone (Norris, 1997).

Glaciation

The Laurentide Ice Sheet advanced across the Peel Plateau and Plain and into the Bonnet Plume Depression at least once (Fig. 4). Three well-defined Laurentide glacial limits lack robust chronological controls, but likely comprise a recessional sequence following the achievement of the ice sheet's maximum western position during the global Last Glacial Maximum (Dyke *et al.*, 2002). The Laurentide Ice Sheet made only minor advances into the Wernecke and Richardson mountains. Local ice in the region was limited to a small number of valley-constrained glaciers originating in high cirques in the Wernecke Mountains. The advance of the Laurentide Ice Sheet into the region was westward, against the regional pre-glacial east-flowing drainage pattern. Abrupt diversions in course, abandoned channels, and deeply incised canyons are common.

Transportation network

The land-based transportation network in the planning region is limited to one all-weather road and numerous trails (Fig. 5). It is expected that development of petroleum resources in the study area will require at least one major all-weather road, a pipeline link to the Dempster Highway corridor or Mackenzie River valley, and numerous drill pads. Development of other transportation networks (*i.e.*, airstrips) will also require access to high-quality aggregate.

PREVIOUS WORK

Surficial mapping

Surficial geological mapping for the Peel Watershed Land Use Planning Region is not yet complete (Fig. 6), however, 1:250 000-scale maps exist for the Trail River (106L; Duk-Rodkin and Hughes, 1992), Nadaleen River (106C; Ricker, 1974), Nash Creek (106D; Vernon and Hughes, 1965), and Larsen Creek (116A; Hughes and Vernon, 1965). In addition, surficial geological mapping at a scale of 1:100 000 has been completed for the Dempster Highway corridor (Thomas and Rampton, 1982a-d), including parts of 116I and 116H.

While NTS map sheets 106C, 106D, and 116A are outside of the aggregate mapping region, much of the linework from existing mapping by Duk-Rodkin and Hughes (1992) in 106L (Trail River) and Thomas and Rampton (1982a and 1982b) in 116H and 116I have been used to compile polygons with high aggregate potential. The distribution of map units and associated grain size classifications were useful in predicting aggregate potential of unmapped units. Another important source of information has been the glacial limits map for Yukon (Duk-Rodkin, 1999). Linework including glacial limits, meltwater channels, eskers, and moraine ridges have been imported directly into the aggregate potential map.

Aggregate potential

No aggregate potential maps have been published in Yukon, however, they are becoming increasingly common in other jurisdictions. The British Columbia Geological Survey has undertaken a number of projects to convert existing surficial geological maps into aggregate specific products, and focussed surficial mapping in regions of limited aggregate resources. For example, a collaborative aggregate and surficial mapping project recently completed by the Geological Survey of Canada, the Alberta Geological Survey, the BC Ministry of Transportation, and a number of private organizations, has demonstrated how traditional surficial geological mapping can be seamlessly integrated with more focussed aggregate exploration and resource identification (Levson *et al.*, 2005). While completing surficial geology maps over the course of three field seasons, the project identified eight new major aggregate deposits, 25 new prospects and a large number of showings in a region previously considered to have little or no aggregate prospects (Levson *et al.*, 2005). Eleven of these deposits alone were valued at $120 M in direct royalty revenue to the Province of British Columbia (Levson *et al.*, 2005).

Aggregate assessments are generally conducted on either regional (smaller than 1:50 000 map sheet) or preliminary site investigation (1:50 000 or larger) scales. At a useable scale of 1:250 000, this study could be termed a ‘preliminary regional investigation’, providing only the most introductory overview to potential aggregate resources in the region. Typically, a map showing the distribution of potential aggregate sources is accompanied by field data describing the quality (physical and chemical properties) and quantity (inferred thicknesses) of mapped units (Langer and Knepper, 1998). Quantitatively-derived values from Alberta and British Columbia demonstrate groups of landforms with greater aggregate potential (Tables 1 and 2).

Table 1. *Modified from Bobrowsky and Manson (1998), categories and ultimate ranking (1 is highest potential, 11 is lowest potential) assigned in quantitative assessment of Vancouver Island aggregate potential based on observations of total volume, mean deposit volume, number of gravel pits, and the number of gravel pits per landform.*

Landform Family	Ranking
Undifferentiated Glaciofluvial	1
Glaciofluvial Fans	2
Glaciofluvial Terraces	3
Glaciofluvial Plains	4
Undifferentiated Fluvial	5
Fluvial Fans	6
Fluvial Terraces	7
Undifferentiated Marine	8
Undifferentiated Moraine	9
Undifferentiated Colluvium	10
Organics	11

Table 2. *From Dixon Edwards (1998) based on frequency of mined land types in Alberta.*

Feature	Aggregate Source	Suitability	Volume	Development Potential
Glaciofluvial				
Outwash plain	Very common	Very good	Very large	Excellent
Valley train	Very rare	Very good	Large	Poor
Meltwater channel	Very common	Good	Small	Excellent
Esker	Rare	Good	Small/medium	Good
Kame	Very common	Fair	Small	Excellent
Kame terrace	Very rare	Very good	Medium	Moderate/poor
Kame delta	Very rare	Good	Medium	Good
Crevasse	Very rare	Poor	Very small	Excellent
Fluvial				
River	Common	Very good	Medium/small	Poor
Terrace	Very common	Very good	Medium/small	Moderate/poor
Glaciolacustrine	**Very rare**	**Very good**	**Large**	**Good**
Eolian	**Common**	**Poor**	**Very large**	**Good/moderate**
Colluvial	**Common**	**Poor**	**Medium/small**	**Poor**

Tables 1 and 2 demonstrate that glaciofluvial materials are the most prospective surficial materials for aggregate development, followed by fluvial and morainic materials. The least suitable materials for aggregate development include colluvial, organic, and certain fluvial deposits. High quality aggregate is characterized by a range in grain size from sand to gravel, relatively equidimensional shapes, low porosity and chemical reactivity, as well as easy and abundant access (Langer and Knepper, 1998).

OBJECTIVE AND METHODS

The objective of this study was to produce an aggregate potential map for the Peel River basin that would broadly identify regions of high aggregate potential and make recommendations for future aggregate assessment work in the region.

Identification of aggregate resources was accomplished through the compilation of existing surficial geological maps and interpretation of aerial photographs where no mapping exists. Black and white aerial photography at scales between ~1:60 000 and 1:70 000 was obtained from the Yukon Government's Energy, Mines and Resources Library in Whitehorse. Coverage for the study area was complete, but derived from many different photo rolls flown between approximately 1950 and 1980 by the Government of Canada. Existing surficial geology mapping was available for ~50% of the field area. Most of this was at a scale of 1:250 000 (Duk-Rodkin and Hughes, 1992), with less extensive mapping at a scale of 1:100 000 (Thomas and Rampton, 1982a-d) along the Dempster Highway corridor.

In the process of mapping polygons, other geological features with potential development-related impacts such as landslides and thermokarst depressions were recorded. These appear on the map as point data locations and could be used to identify sites for future topical studies.

Unit boundaries were mapped at a scale of 1:100,000 and labeling is modified from the British Columbia Terrain Classification System (Howes and Kenk, 1997; summarized in Appendix 1). Based on the hierarchy of landform groups outlined in Tables 1 and 2, landforms with high potential for aggregate were identified, and assigned to a value of 1, 2, or 3 according to their likely suitability as aggregate sources for infrastructure development.

A qualitative ranking approach was used in place of field checking of individual aggregate units in this study. Higher rankings were assigned to landforms that appeared to be large, well-drained, and have relatively flat surfaces. Lower rankings were assigned to landforms that appeared to be poorly drained, to have hummoky or ice-rich surfaces (including thick organic soils), to be affected by upslope colluvial processes, or be overlain be fine-grained glaciolacustrine, aeolian or colluvial deposits.

This methodology was successful in broad-scale identification of landforms with high aggregate potential, however, there are a number of important limitations to this data. No grain size information can be gleaned from air photos, and units mapped as having high aggregate potential could very easily be composed entirely of a grain size of little use for aggregate development (*i.e.*, sand). Similarly, the lack of any field work to verify unit boundaries, compositions, or genetic processes place a major caveat on the reliability of this data set. This mapping should be used only as a guide for further investigation, rather than an indication of individual deposits.

RESULTS

The frequency of mapped landform types and the overall rankings for each landform type are shown in Table 3. The highest ranking landforms are fluvial terraces (Ft), glaciofluvial landforms (F^G), and fluvial plains (Fp) (Open File 2009-43). The least prospective landforms are bedrock (R), glaciolacustrine (L^G), moraine (M), fluvial fans (Ff), and colluvium (C). Of the 1088 individually mapped units, 44% are ranked with the highest potential level (1), 32% are ranked with the middle potential level (2), and 24% are ranked with the lowest potential level (3). The most common landforms are fluvial plains (Fp), glaciofluvial terraces (F^Gt), colluvium (C), undifferentiated glaciofluvial complexes (F^Gptf), and fluvial terraces (Ft).

Table 3. *Total number of polygons in each landform type (or group of landform types), the percent of total mapped polygons for each landform type, and the average aggregate potential ranking (1-high; 3-low) for each landform type.*

Landform	# of Polygons	% of total	Avg. Ranking
Ft	119	11%	1.07
FGl	25	2%	1.16
Fp	209	19%	1.25
FGt	156	14%	1.39
FGptf	150	14%	1.65
Fptf	79	7%	2.22
FAp	16	1%	2.00
C	136	13%	2.49
Ff	79	7%	2.62
LG	22	2%	2.95
M	93	9%	2.80

The landform types summarized in Tables 3 are, in some cases, composed of a number of similar landforms as described below:

Ft: fluvial terraces

F^Gl: glaciofluvial deltas and kames

Fp: fluvial plains

F^Gt: glaciofluvial terraces

F^Gptf: glaciofluvial plains (F^Gp), fans (F^Gf), and other undifferentiated glaciofluvial complexes (F^Gptf)

Fptf: fluvial plains (Fp), terraces (Ft), and other undifferentiated fluvial complexes (Fptf)

Fp-A: active fluvial plains

C: colluvial aprons (Ca), fans (Cf), blankets (Cb), veneers (Cv), and other undifferentiated colluvial complexes (Cafb)

Ff: fluvial fans

L^G: glaciolacustrine veneers (L^Gv), and glaciolacustrine blankets (L^Gb)

M: moraine plains (Mp), veneers (Mv), hummocks (Mh), ridges (Mr), rolling terrain (Mm), blankets (Mb), and other undifferentiated moraine complexes (Mpvh)

In general, fluvial deposits are finer grained and less prospective for aggregate development than are glaciofluvial deposits. Glaciofluvial deposits are one of the most common sources of aggregate resources in Canada because of their ubiquitous presence, generally large volumes, frequent absence of silt and clay, and common presence of grain sizes between sand and cobbles.

Regional Summary

The Peel Plateau and Plain (Fig. 2; the northeastern half of the map area) has very few large units of high aggregate potential. Entirely within Laurentide glacial limits, much of the Peel Plateau and Plain is blanketed in moraine, obscuring potential channels and deposits beneath these relatively flat-lying and clay-rich sediments. Lower-ranked units in this area could have significant variation in composition. Detailed and intensive field work would be required to determine the precise location of aggregate deposits and the range of grain sizes present in individual landforms. Sub-surface imaging technologies such as LiDAR or GPR would be particularly useful prospecting tools in the aggregate-poor regions of the Peel Plateau and Plain. The application of this technology has been demonstrated in northern British Columbia and Alberta where a shortage of known aggregate resources has led to high infrastructure costs for the petroleum industry (Levson *et al.*, 2005). Cross-referencing this map (Open File 2009-43) with any available sub-surface data (*i.e.*, shothole logs or Quaternary stratigraphy) is recommended.

In the Bonnet Plume Depression (Fig. 2; generally the lower Wind and Bonnet Plume rivers) abundant polygons with high aggregate resource potential are the result of glacial meltwater deposits associated with limits or still-stands of the Laurentide Ice Sheet margins. Expansion of meltwater flow west and northward across the basin from channels previously pinned against the Wernecke Mountain front deposited abundant coarse gravel in the southern Bonnet Plume Basin. The glaciofluvial material was transported northward by the Wind and Bonnet Plume rivers and is distributed downstream along high terraces adjacent to and between the rivers. Both the original meltwater channels and the subsequently reworked terraces likely contain significant aggregate deposits. Detailed aggregate resource potentials could likely be produced for this region with minimal field work to estimate thicknesses, verify boundaries, and determine the physical and chemical properties of individual landforms and deposits.

In the westernmost unglaciated region of the map area (Fig. 2; Ogilvie Mountains, Eagle Lowland, and Richardson Mountains) unconsolidated aggregate resources are likely to be limited to fluvial and minor glaciofluvial deposits associated with glacially-induced base-level changes. The Laurentide Ice Sheet dammed many of the east-flowing streams in this area of the mapping region, resulting in thick lacustrine sediments in some valleys. While there may have been some contribution of coarse-grained aggregate from the nearby ice margin, the majority of aggregate deposits in this region are likely of limited volume, and finer-grained than those in the rest of the mapping region. Bedrock here is well-exposed and may be the most suitable source of aggregate for potential development.

The lithological composition of aggregate deposits is an important factor in assessing their potential for development. While no data exists to assess the lithologies of surficial deposits in this region, aggregate in the Peel River basin is likely predominantly composed of locally derived sedimentary and meta-sedimentary lithologies, with potentially significant contributions of glacially-transported crystalline rocks from the Canadian Shield.

CONCLUSIONS

The Peel Watershed Land Use Planning region contains significant economic and industrial development potential associated with petroleum and mineral reserves in the Peel Plateau and Plain, Bonnet Plume Basin, and Wernecke Mountains. Should these resources be developed, there will be a need for transportation of people, materials and products to and from active exploration and development sites in the region. It is expected that development of petroleum resources in the Peel Plateau will require at least one major all-weather road, a pipeline link to the Dempster Highway corridor or Mackenzie Valley, and numerous drill pads. Responsible and efficient development of this infrastructure will require the identification of high quality aggregate deposits.

The results of this preliminary study show there is significant potential for aggregate resource development in the region. Specifically, glaciofluvial deposits in the Bonnet Plume Basin will be important sources of high-quality aggregate. On the Peel Plateau and Plain, buried meltwater channels and ice-contact glaciofluvial deposits may be the most significant source of aggregate resources. These deposits are notoriously difficult to locate and assess. Development of the Peel Plateau and Plain would require detailed aggregate mapping specifically focussed around any potential development.

This project is a valuable base layer for development planning in the region and has potential to become a foundation-study for future work in the Peel Watershed. Most directly, a reconnaissance aggregate map provides a starting point for surficial geological mapping in the region. In addition, the significance of certain landscape characteristics such as landslides and permafrost are recognized through the course of aggregate mapping and can be pin-pointed for topical studies that should occur prior to development.

The identification of regional sand and gravel resources contributes to a long-term strategy for infrastructure capable of supporting future development demands. Future aggregate-related work in the Peel Watershed should be focussed on quantifying and qualifying areas of high aggregate potential through focussed field-based assessments. Detailed field work will be of particular importance in the petroleum-rich Bonnet Plume Basin and Peel Plateau and Plain should increased development in the region occur.

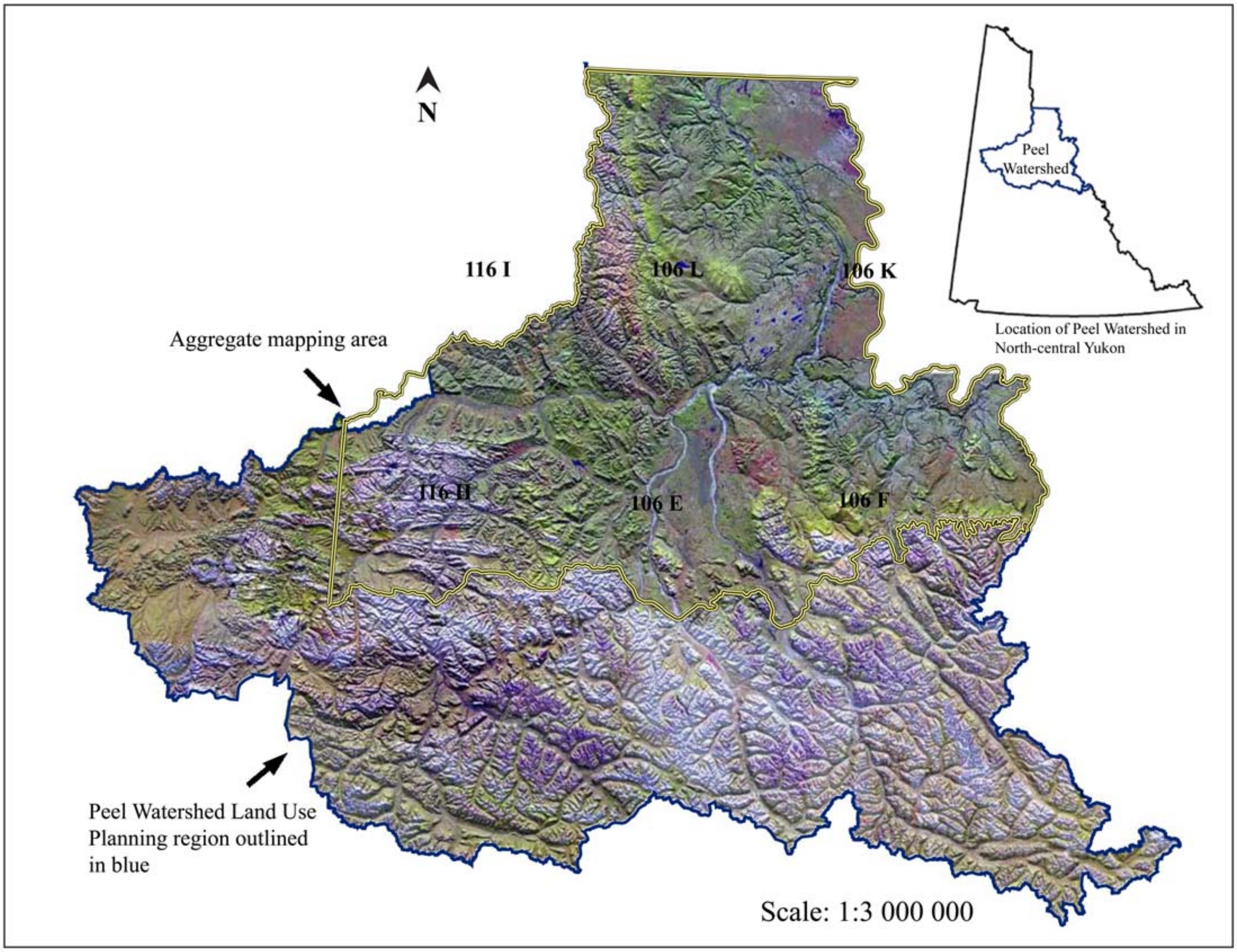

Figure 1. *Regional location map of aggregate mapping area within the Peel Watershed Land Use Planning region. The aggregate mapping area is outlined in yellow, and includes low-topography regions in the northern part of the Land Use Planning region.*

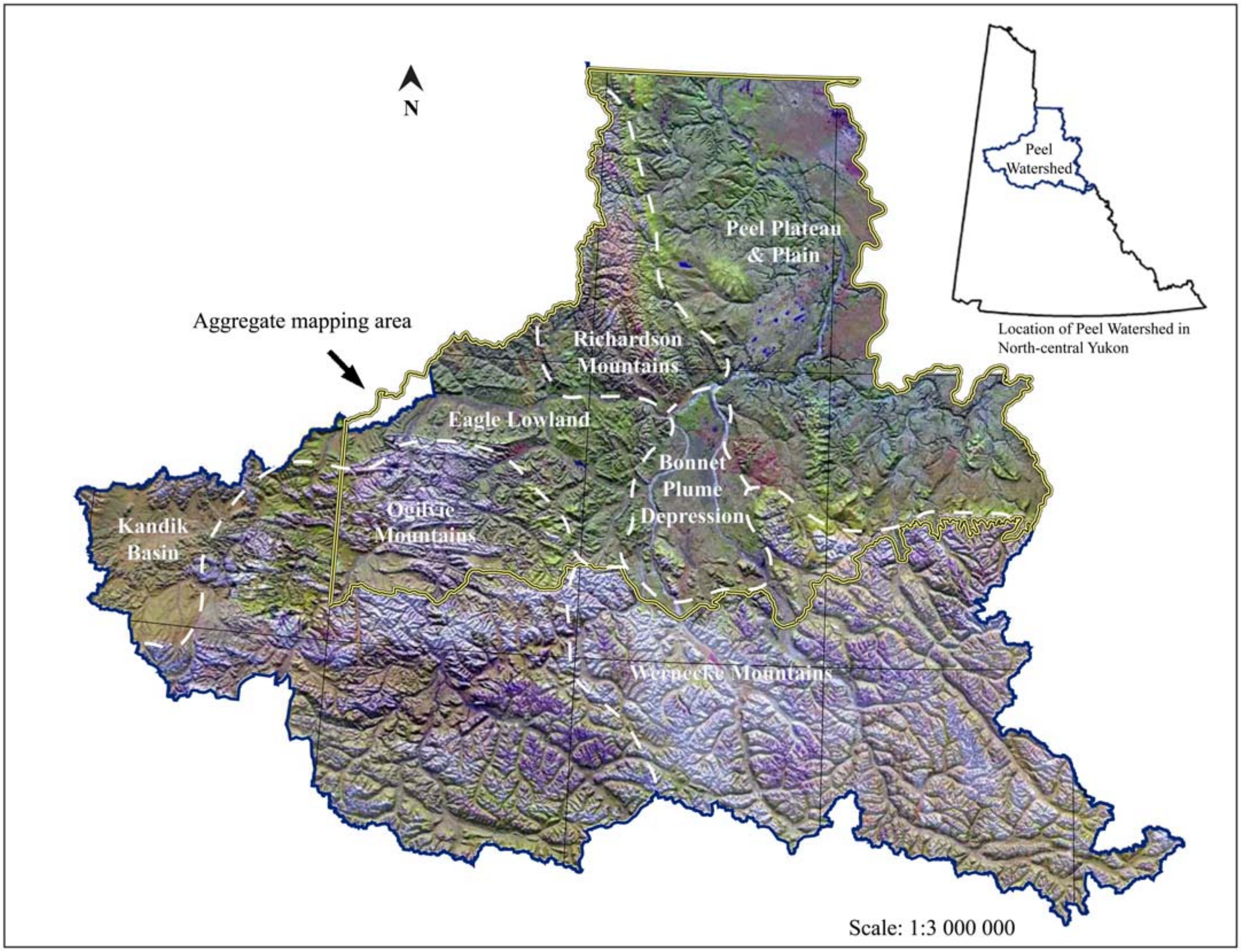

Figure 2. *Regional physiographic setting of the study area. Physiographic regions within the study area include the Peel Plateau and Plain, Richardson Mountains, Bonnet Plume Basin, Eagle Lowland, and parts of the Ogilvie Mountains.*

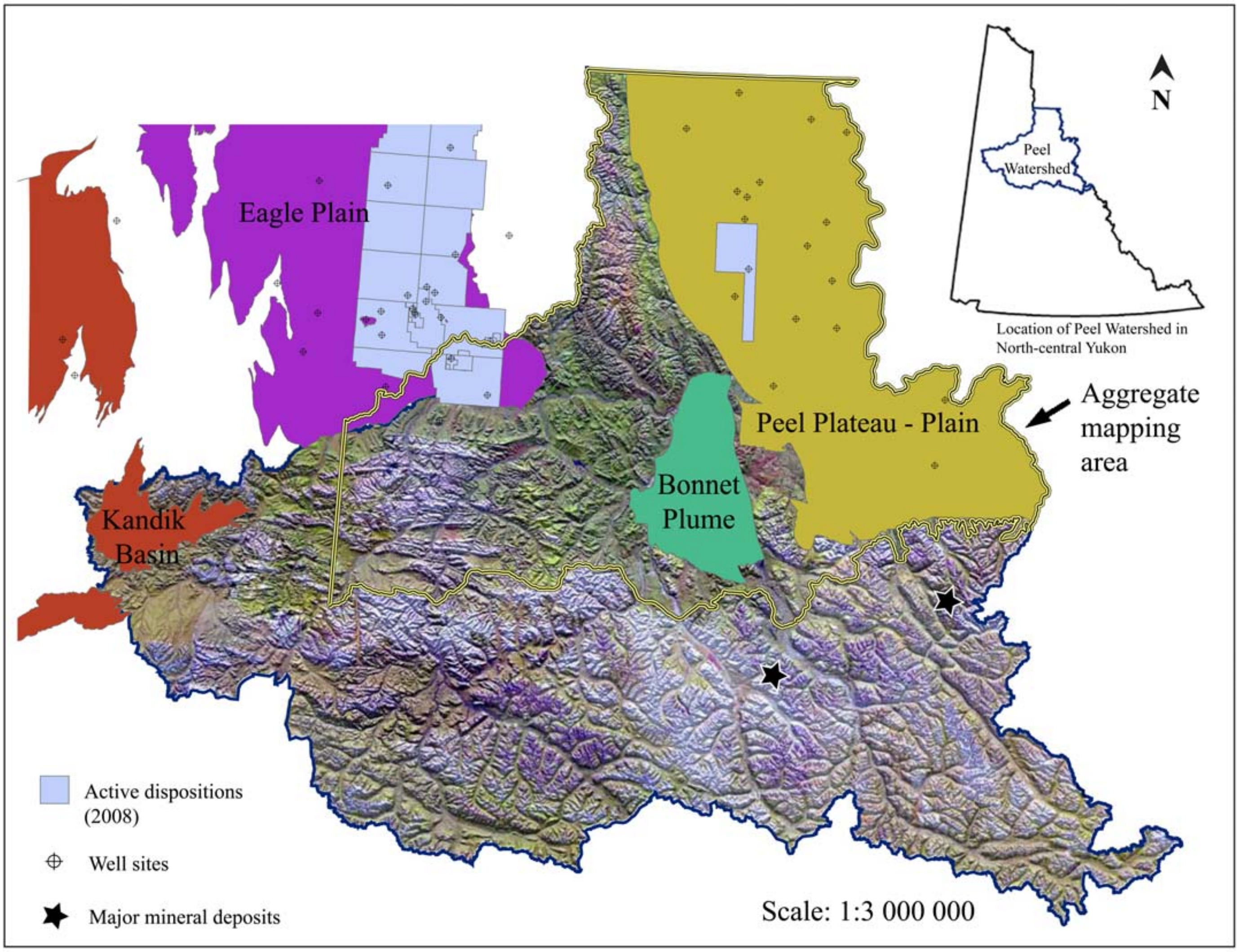

Figure 3. *Petroleum basins, dispositions and well locations in the Peel Watershed. Active oil and gas exploration dispositions, as well as numerous exploration well sites are found within the Peel Plateau and Plain.*

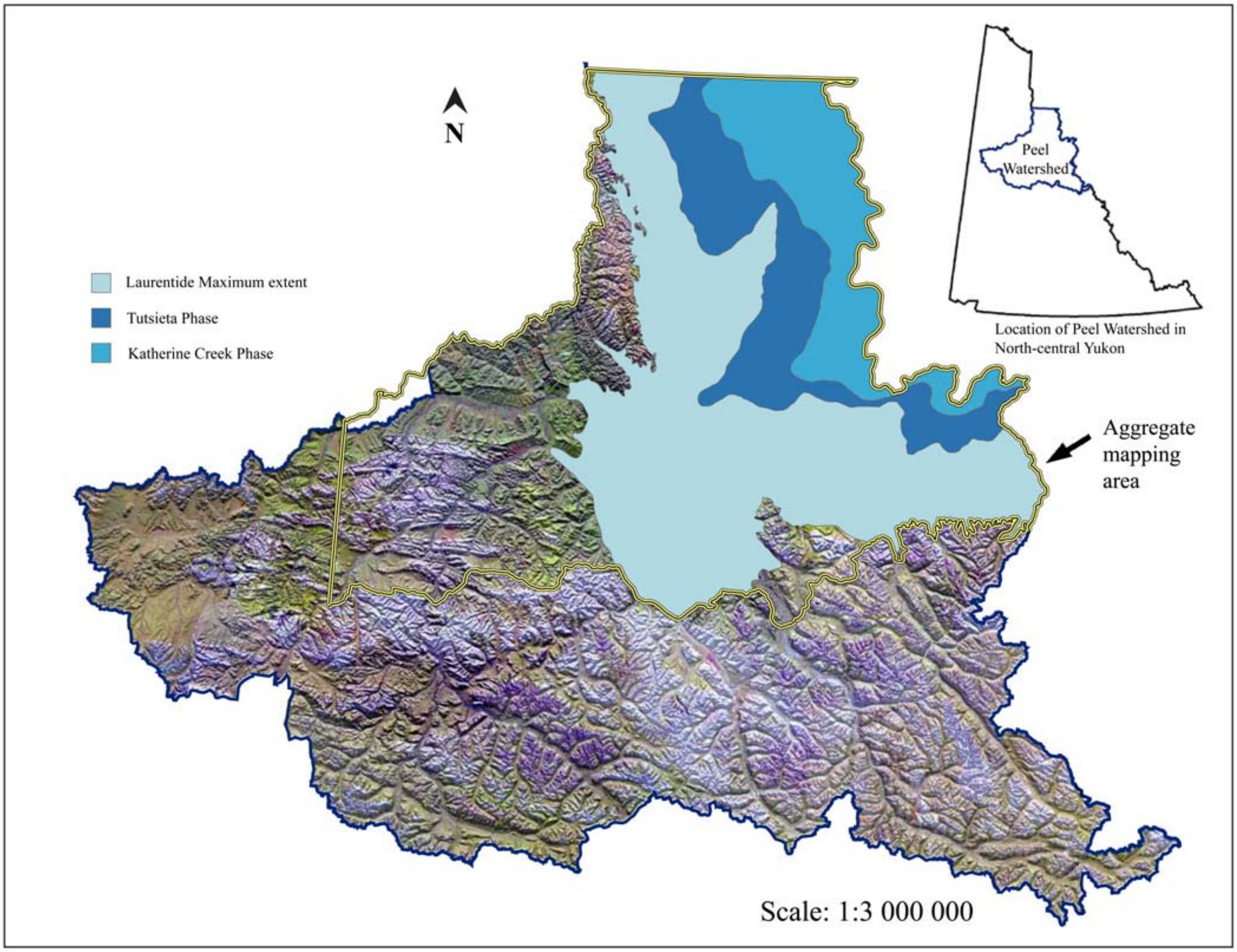

Figure 4. *Laurentide Ice Sheet glacial limits in the Peel Watershed. The distribution of landforms with high aggregate potential are controlled by the locations of former ice margins (Ice limits from Duk-Rodkin, 1999).*

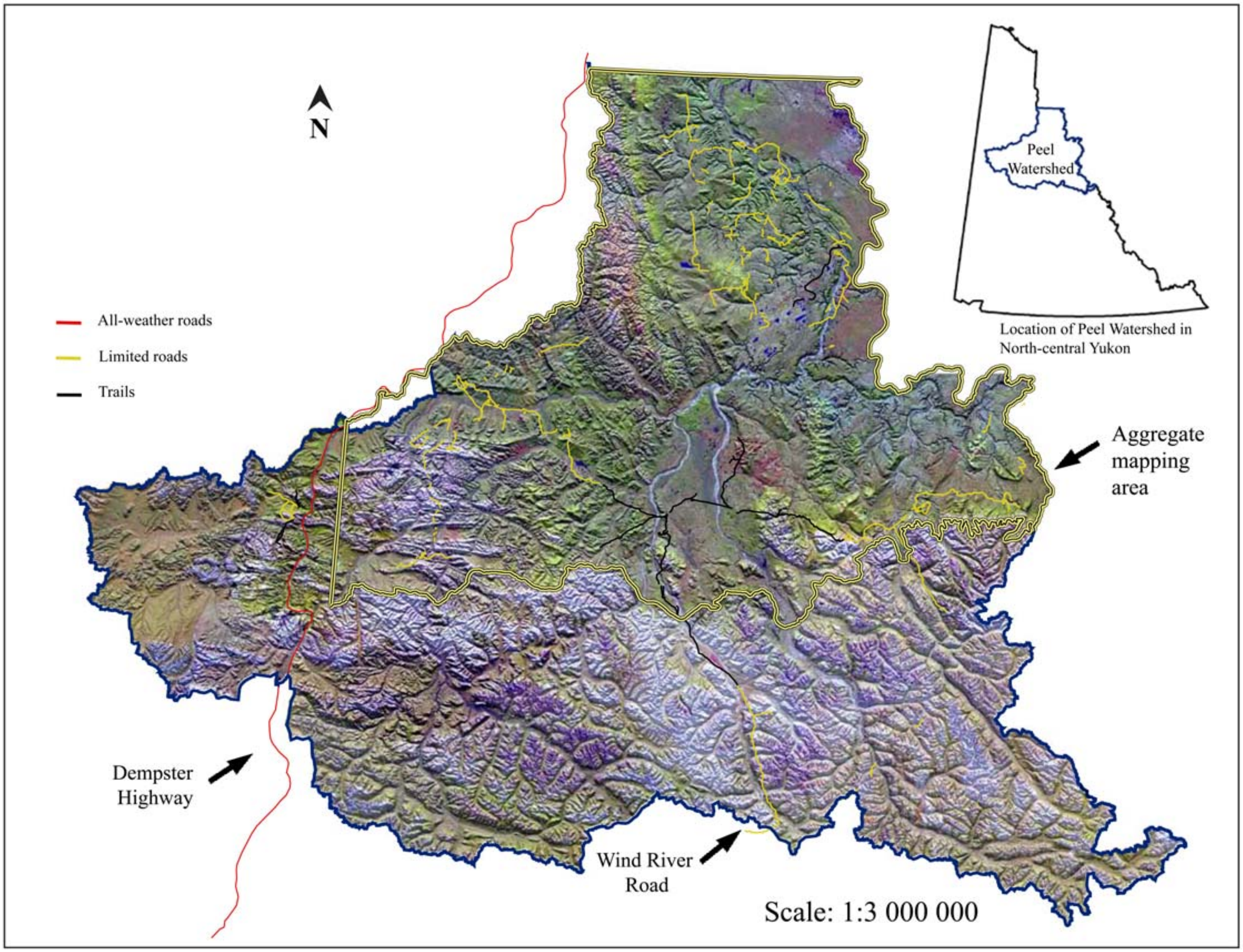

Figure 5. *Existing transportation network in the Peel Watershed is limited to one all-weather gravel road (the Dempster Highway), a small number of seasonal and limited use roads (such as the Wind River Road), and numerous trails. There are no all-weather roads within the aggregate study area.*

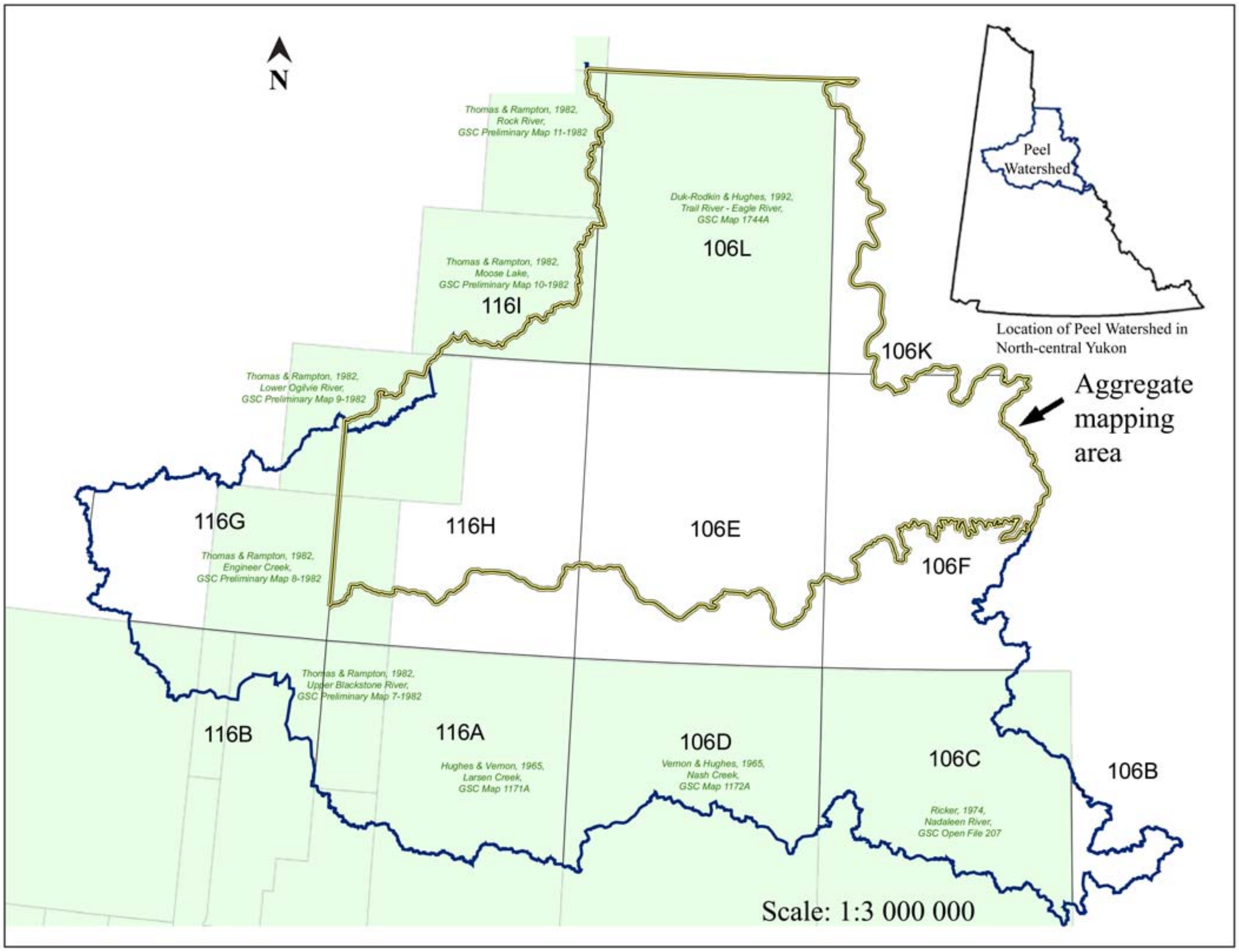

Figure 6. *Existing surficial geological mapping covers only ~50% of the Peel Watershed. There is no surficial geological mapping available for much of the Bonnet Plume Basin and Peel Plateau and Plain.*

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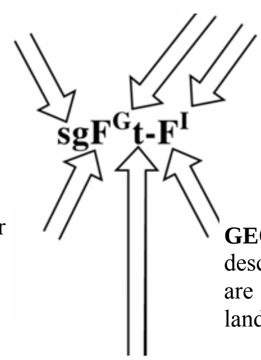
Appendix 1: Legend modified from the BC Terrain Classification System (Howes and Kenk, 1997)

Information is portrayed on a terrain map by a terrain symbol which is composed of a group of letters. These letters provide information about the character of the terrain and are arranged in a manner such that each letter position represents a particular characteristic of the terrain. Information provided by a terrain symbol includes texture and type of surficial material, surface expression, geomorphologic processes, and qualifiers.

QUALIFIERS are used where appropriate to provide information about surficial materials and geomorphologic processes.

TEXTURE not available for this product.



SURFICIAL MATERIAL (one upper case letter) is classified according to its mode of deposition.

GEOMORPHOLOGICAL PROCESSES describes geomorphological processes that are modifying either surficial materials or landforms.

SURFACE EXPRESSION (one to three lower case letters) describes the form (shape) of the land surface or the thickness of the materials.

Delimiters indicate the relative amount of each surficial material type represented in a composite symbol. The delimiter symbols are a point sign (·), a single or double slash (/, //), or backslash (\).

Map Symbol	*Definition*
.	components on either side of the symbol are of approximately equal proportion.
/	the component in front of the symbol is more extensive than the one that follows; can also be used to indicate a discontinuous covering of material.
//	the component in front of the symbol is considerably more extensive than the component that follows.
\	the component in front of the symbol stratgraphically overlies the component following the symbol.

SURFICIAL MATERIALS

Surficial materials are defined as non-lithified, unconsolidated sediments. Surficial materials are classified according to their mode of formation. Specific processes of erosion, transportation, deposition, mass wasting and weathering produce materials that have specific sets of physical characte ristics. Surficial materials displaying direct evidence that glacier ice exerted a strong, but s econdary or indirect control, upon thei r mode of origin are indicated by a qualifier symbol, superscript "G".

Material Name	*Map Symbol*	*Formative Process*	*Description*
Colluvium	**C**	active	Colluvium is material that was transported and directly deposited by down-slope, gravity-driven processes such as creep, landslides and snow avalanches. The texture and composition of colluvium vary more than any other material in the map area, depending on the parent material and the mechanism and distance transported. The utility of colluvium as aggregate material is generally low.
Fluvial Material	**F**	inactive	Fluvial materials are transported and deposited by modern streams and rivers. Most of these deposits are limited to valley-bottom floodplains, terraces and fans. These features have potential to contain well-sorted and stratified deposits of sand and gravel.
Glaciofluvial Material	$\mathbf{F}^{G}$	inactive	Glaciofluvial materials have been deposited directly by glacial meltwater. These deposits can form supra-, en- or subglacially, as well as in front of, or adjacent to, a glacier. They are deposited in meltwater channels, eskers, terraces, plains and deltas. Glaciofluvial materials commonly contain well-sorted and stratified gravel and sand.
Glaciolacustrine Material	$\mathbf{L}^{G}$	inactive	Glaciolacustrine materials have been deposited in a lake on, in, under or beside a glacier. These deposits are generally thin in the map area, and can mask underlying units with higher aggregate potential.
Morainal Material (Till)	**M**	inactive	Morainal describes diamicts deposited by either primary glacial processes such as lodgement, deformation and melt-out, or secondary glacial processes caused by gravity and water. Potential aggregate resources are likely poorly sorted, limited in volume and variable in lateral and vertical extent.
Bedrock	**R**	–	The bedrock surficial material label is used for areas where bedrock outcrops or is covered by a thin veneer of sediment. Bedrock outcrops occur as hummocks and ridges on valley bottoms and sides.

SURFACE EXPRESSION

Surface expression refers to the form (assemblage of slopes) and pattern of forms expressed by a surficial material at the land surface. This three-dimensional shape of the material is equivalent to "landform" used in a non-genetic sense (e.g., ridges, plain). Surface expression symbols also describe the manner in which unconsolidated surficial materials relate to the underlying substrate (e.g., veneer).

Material Name	*Map Symbol*	*Description*
Apron	**a**	Wedge-like slope-toe complex of laterally coalescent colluvial fans and blankets. Longitudinal slopes are generally less than 15° (26%) from apex to toe with flat or gently convex/concave profiles.
Blanket	**b**	Layer of unconsolidated material thick enough (>1 m) to mask minor irregularities of the surface of the underlying material, but still conforms to the general underlying topography; outcrops of the underlying unit are rare.
Fan	**f**	Sector of a cone with a slope gradient less than 15° (26%) from apex to toe; longitudinal profile is smooth and straight, or slightly concave/convex.
Hummock	**h**	Steep sided hillock(s) and hollow(s) with multidirectional slopes dominantly between 15-35° (26-70%) if composed of unconsolidated materials, whereas bedrock slopes may be steeper; local relief >1 m; in plan, an assemblage of non-linear, generally chaotic forms that are rounded or irregular in cross-profile; commonly applied to morainal and glaciofluvial knob-and-kettle terrain.
Delta	**l**	Landform created at the mouth of a river or stream where it flows into a body of water. Deltas have gently sloping surfaces between 0-3° (0-5%), and moderate to steeply sloping fronts between 16-35° (27-70%). Glaciofluvial deltas in the map area are typically coarse-grained with steep sides and gently inclined kettled or channeled surfaces.
Rolling	**m**	Elongate hillock(s); slopes dominantly between 3-15° (5-26%); local relief >1 m; in plan, an assemblage of parallel or sub-parallel linear forms with subdued relief.
Plain	**p**	Level or very gently sloping, unidirectional (planar) surface with slopes 0-3° (0-5%); relief of local surface irregularities generally <1 m; applied to (glacio)fluvial floodplains, lacustrine deposits and till plains.
Ridge	**r**	Elongate hillock(s) with slopes dominantly 15-35° (26-70%) if composed of unconsolidated materials; bedrock slopes may be steeper; local relief is >1 m; in plan, an assemblage of parallel or sub-parallel linear forms; commonly applied to drumlinized till plains, eskers, morainal ridges, crevasse fillings and ridged bedrock.
Terrace	**t**	A single or assemblage of step-like forms where each step-like form consists of a scarp face and a horizontal or gently inclined surface above it; commonly applied to fluvial and glaciofluvial terraces.
Veneer	**v**	Layer of unconsolidated materials too thin to mask the minor irregularities of the surface of the underlying material; 10 cm - 1m in thick; outcrops of the underlying unit are common.

GEOMORPHOLOGICAL PROCESSES

Geomorphological processes are natural mechanisms of weathering, erosion and deposition that result in the modification of the surficial materials and landforms at the earth's surface.

The status of all geomorphological processes in this classification is assumed to be "active", except for the geomorphological processes "channeled by meltwater" and "kettled", which have an assumed status of "inactive".

Process Name	*Map Symbol*	*Description*
Lanslides	**L**	Downslope movement by falling, rolling, sliding or flowing of dry, moist or saturated debris derived from surficial material and/or bedrock.
Permafrost Processes	**X**	Processes controlled by the presence of permafrost, and permafrost aggradation or degradation.
Channeled by meltwater	**E**	Erosion and channel formation by meltwater alongside, beneath, or in front of a glacier or ice sheet.
Kettled	**H**	Depressions in surficial materials resulting from the melting of buried or partially buried glacier ice.
Ice Contact	**T**	Sediments deposited in contact with a glacier or ice sheet.