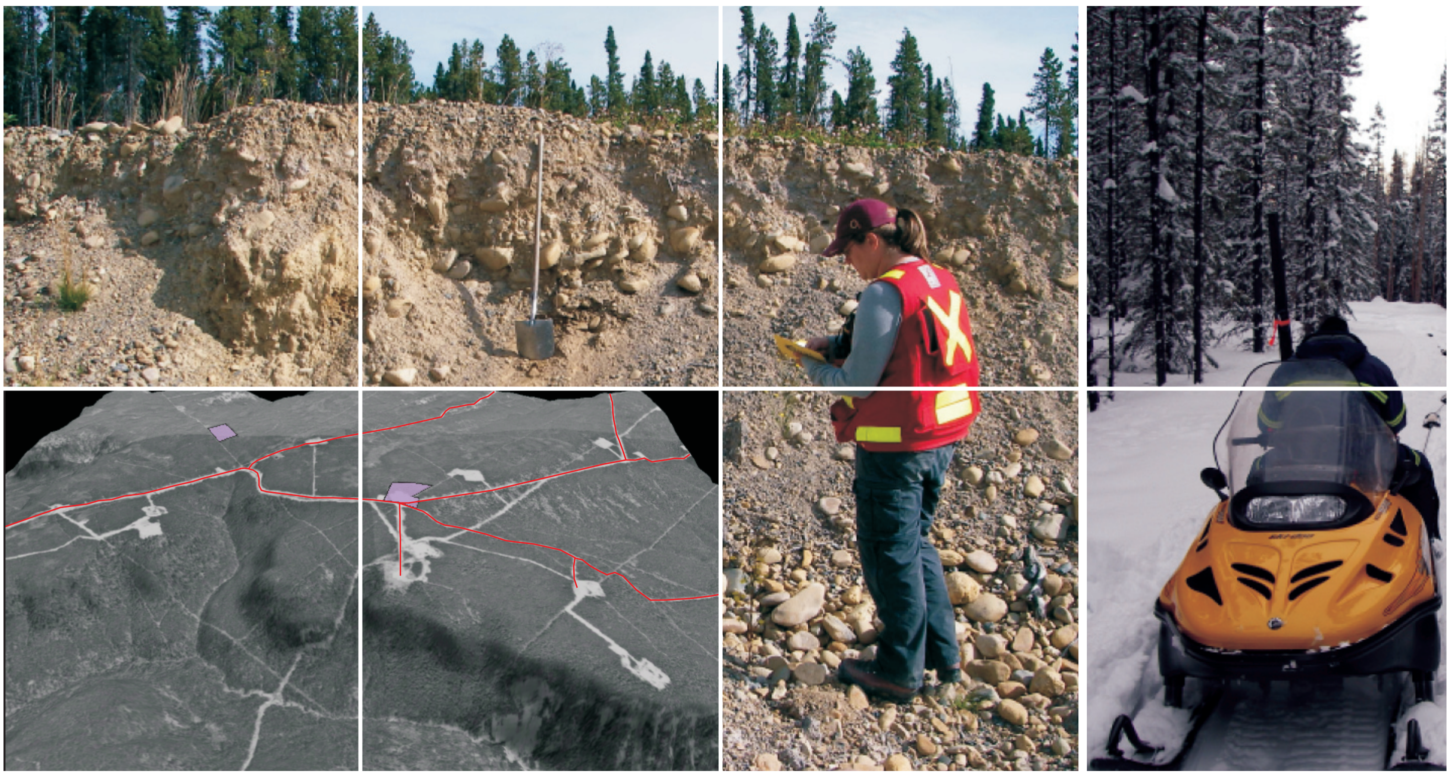
Oil And Gas

Aggregate Potential of Green Creek Area, Northeast British Columbia

Aggregate Prospecting Report 2009–2



Ministry of Energy, Mines and Petroleum Resources

Resource Development and Geoscience Branch

BRITISH COLUMBIA

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Table of Contents

Aggregate Potential of Green Creek Area, Northeastern British Columbia

AGGREGATE POTENTIAL OF GREEN CREEK AREA, NORTHEASTERN BRITISH COLUMBIA

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Key Words: Aggregate, sand and gravel, capacitively-coupled resistivity, road construction, oil and gas.

INTRODUCTION

Increased oil and gas industry activity in northeast British Columbia (NEBC) has resulted in a significant expansion of infrastructure. New roads are being built and existing roads are being upgraded to meet the demands of increased summer activity. In many cases the bulk of construction and maintenance costs are associated with the extraction and transport of aggregate. The British Columbia Ministry of Energy, Mines and Petroleum Resources (MEMPR) is currently conducting a program focused on identifying new, local sources of construction aggregate to reduce costs and support the development and maintenance of all season petroleum development roads (PDRs). This report summarises a preliminary assessment of the aggregate potential of portions of NTS map sheet 94G (Trutch). Specifically, near Green Creek, a tributary of the Sikanni Chief River, on the plateau area between the Buckinghorse and Sikanni Chief rivers, east of the Alaska Highway (Highway 97; Figure 1).

Many aggregate deposits in NEBC do not exhibit a clear surface expression. This can complicate exploration and limit the effectiveness of traditional remote sensing methods such as aerial photograph interpretation. To address this, MEMPR has employed other techniques such as geophysical surveys. In this study a surface-based capacitively-coupled resistivity (CCR) survey was used to delineate the lateral and vertical extent of granular material.

STUDY AREA LOCATION

Green Creek is located in NTS map sheet 94G/08 (Medana Creek), approximately 300 km northwest of Fort St. John, and roughly 40 km east of the Alaska Highway (Highway 97) on PDR 153 (Figure 1). It is accessible year round on all-season PDRs. In this study, two adjacent target areas are identified: Green Creek North and Green Creek South (Figure 2). The targets are situated on the plateau above the Sikanni Chief River Valley (Figure 3).

SCOPE OF STUDY

This study is a preliminary assessment of aggregate potential in the Green Creek area. The objective is to draw attention to the area as an aggregate prospect for further evaluation. Estimates of volume are tentative and the quality of material for road construction has not been considered, nor has the logistics or economics of mining.

PREVIOUS WORK

The Green Creek area has been included in one previous aggregate potential study and several Quaternary geology studies. Savinkoff (2004) mapped the aggregate potential for portions of NTS map sheets 94G and 94H, including the Green Creek area, but did not identify the area as a potential exploration target. Several aggregate tenures in the area are held by private operators, including one that hosts an active gravel pit (Figure 4).

Regional mapping, conducted by Mathews (1978, 1980), provides a framework for the deglacial history of NEBC and northwest Alberta. The surficial geology of the Trutch map sheet (NTS 094/G) was investigated by Bednarski (2000). The mapping suggests portions of the Green Creek area have a glaciofluvial origin.The origin and nature of sediments in this region are described by Bednarski and Smith (2007). Trommelen (2005, 2006) completed mapping north of the study area. Other aggregate studies in NEBC include Dewar and Polysou (2003), Johnsen et al. (2004), Levson et al. (2004), Best et al. (2005), Ferbey et al. (2005), Levson et al. (2005), Smith et al. (2005) Demchuk et al. (2005), Best et al. (2006), Hickin (2006), and Ferbey (2008).

QUATERNARY HISTORY

Surficial materials in the area mostly are glacial in origin. The area was inundated by ice during the Late Wisconsinan (ca. 22 000 years ago). An ice sheet over much of British Columbia extended east of the Rocky Mountains

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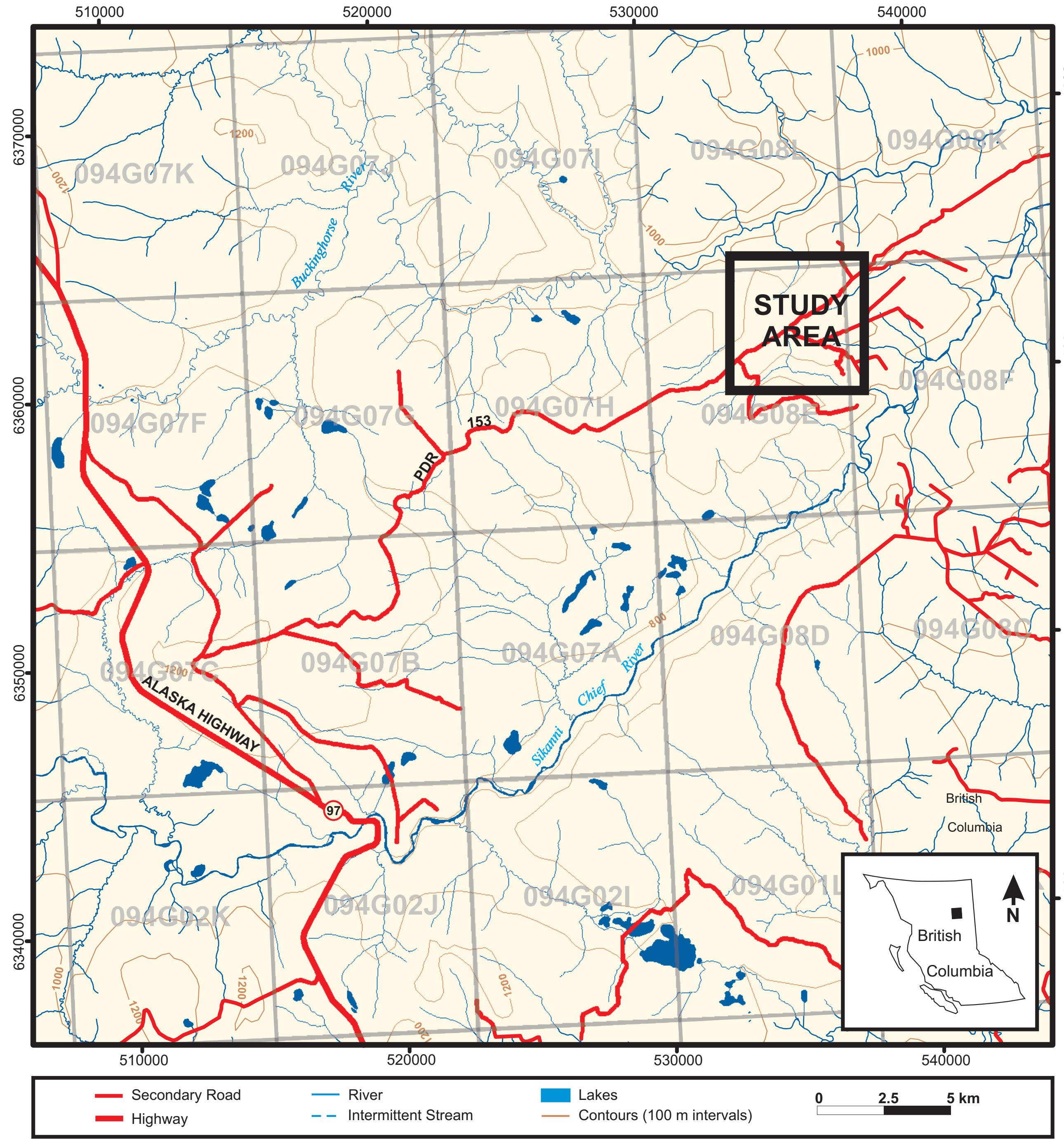

Figure 1. Location of the Green Creek study area.

(Cordilleran Ice Sheet) and coalesced with the continental Laurentide Ice Sheet in the vicinity of the study area (Mathews, 1980; Bednarski and Smith, 2007). By *ca.* 10 000 years ago deglaciation was well under way (Catto *et al*., 1996). At that time the Cordilleran Ice Sheet retreated west and the Laurentide Ice Sheet east, blocking regional drainage and impounding glacial lakes. During this phase of deglaciation, valleys were submerged, consequently outwash is generally rare at surface (Bednarski and Smith, 2007). As the Laurentide Ice Sheet retreated to the east, the glacial lakes receded from the area, following the moving ice margin. Subsequent erosion and incision from the Sikanni and Buckinghorse rivers has created the present-day landscape (Mathews, 1980; Bednarski and Smith, 2007).

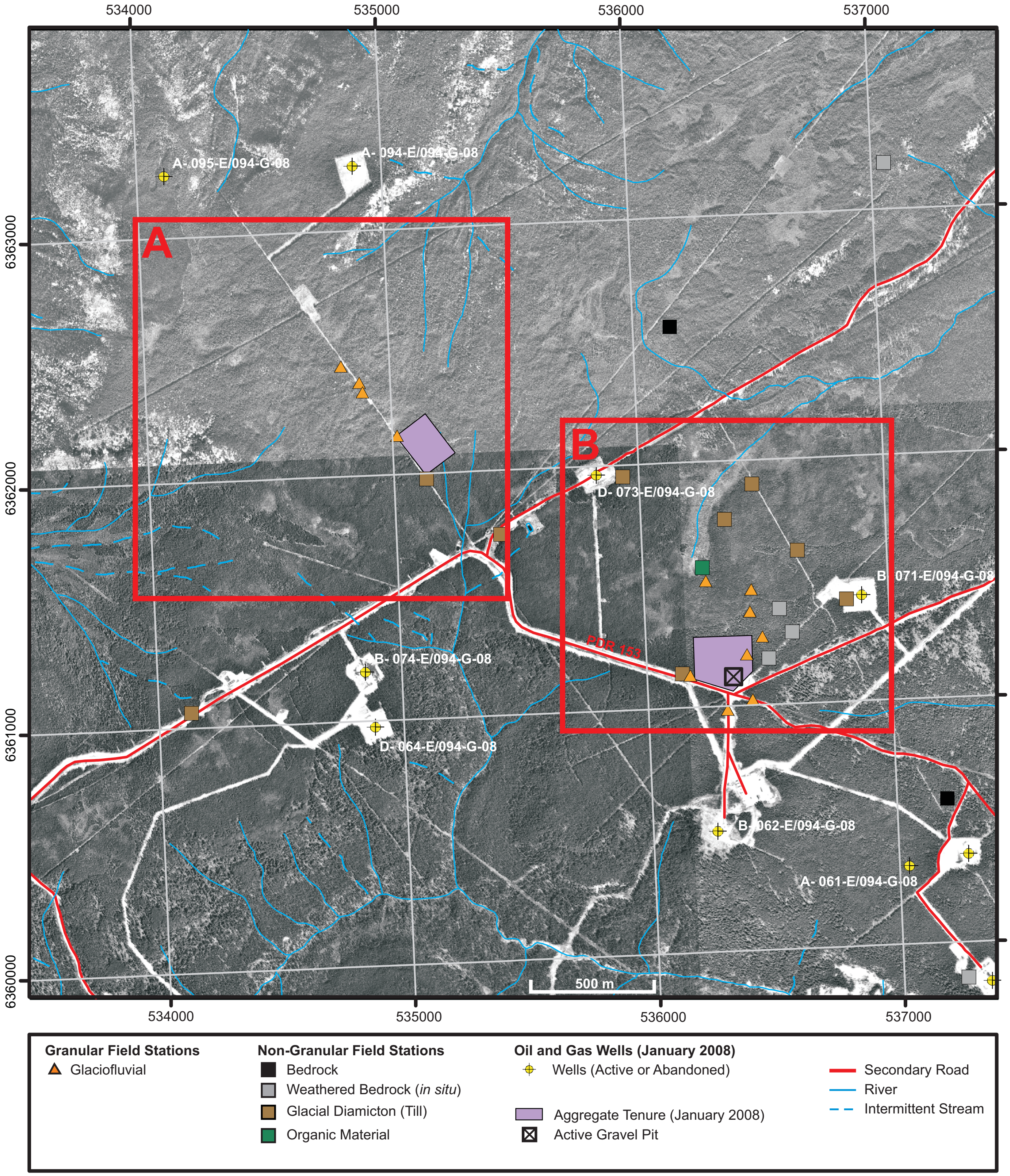

Figure 2. Two separate areas were evaluated in this study, Green Creek North (A) and Green Creek South (B). (refer to legend in Figure 1).

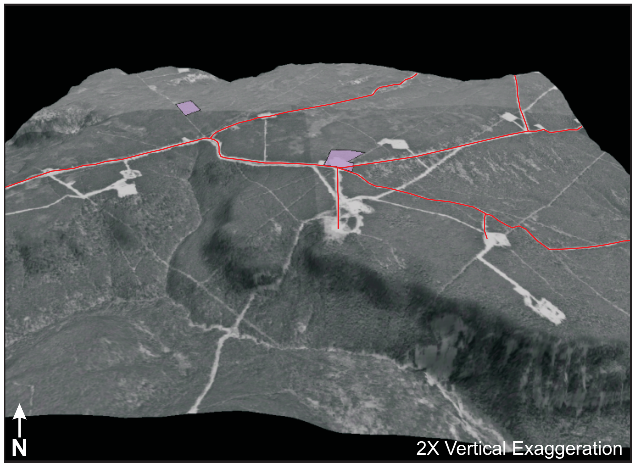

Figure 3. Orthophoto draped over SRTM DEM provides a three-dimensional view of study area (viewed to the northeast).

Figure 4. Cobble gravel in the existing gravel pit in the Green Creek South prospect area.

METHODOLOGY

Fieldwork was conducted in the summer of 2006 and winter of 2007. The summer program focused on reconnaissance investigation and evaluation through a hand dug test hole program. The following winter, the CCR survey was conducted to expand on summer findings.

Hand Dug Test Hole Program

Hand dug test holes, ranging in depth from 0.3 to 1.0 m, were used to identify surficial material (Figure 5). Twenty-five test holes were dug throughout the study area (Figure 6). At each test hole site, sediments were logged, photographed, and a preliminary interpretation of genesis made. Sites where granular material was encountered were evaluated and prioritized for follow-up work. Topography and landform analysis was performed using a Shuttle Radar Topography Mission digital elevation model (SRTM DEM; 90 m horizontal resolution).

Figure 5. Test holes were dug by hand throughout the study area.

CCR Survey

The objective of this program was to determine thickness and lateral extent of granular material and expand on the findings of the summer field program. A CCR survey was conducted using an OhmMapper™ instrument (Figure 7). This method provides an electrical model of the subsurface. Variations in modelled resistivity have been found to correspond to different sediment types (Archie, 1942; Keary and Brooks, 1984; Reynolds, 1997, Best, 2006). Granular materials such as sand and gravel typically have high resistivity values (>200 ohm-m), whereas fine-grained sediments such as silt, clay, and clay-rich diamictons commonly show lower resistivity values (1-200 ohm-m; Table 1).

Survey Design

The instrument configuration follows the manufacturers protocols (Geometrics 2001). Six lines totalling 4.6 km were collected on existing seismic lines and clearings (Figure 8). The Ohmmapper™ instrument was configured with one transmitter and five receivers (5 m dipole length) in a dipole-dipole array. By using several receivers at a variety of off-sets from the transmitter, a vertical, geometric pseudosection can be modelled. The first receiver was separated from the transmitter by a non-conductive rope set at either 5 m or 10 m. Each line was surveyed four times to stack

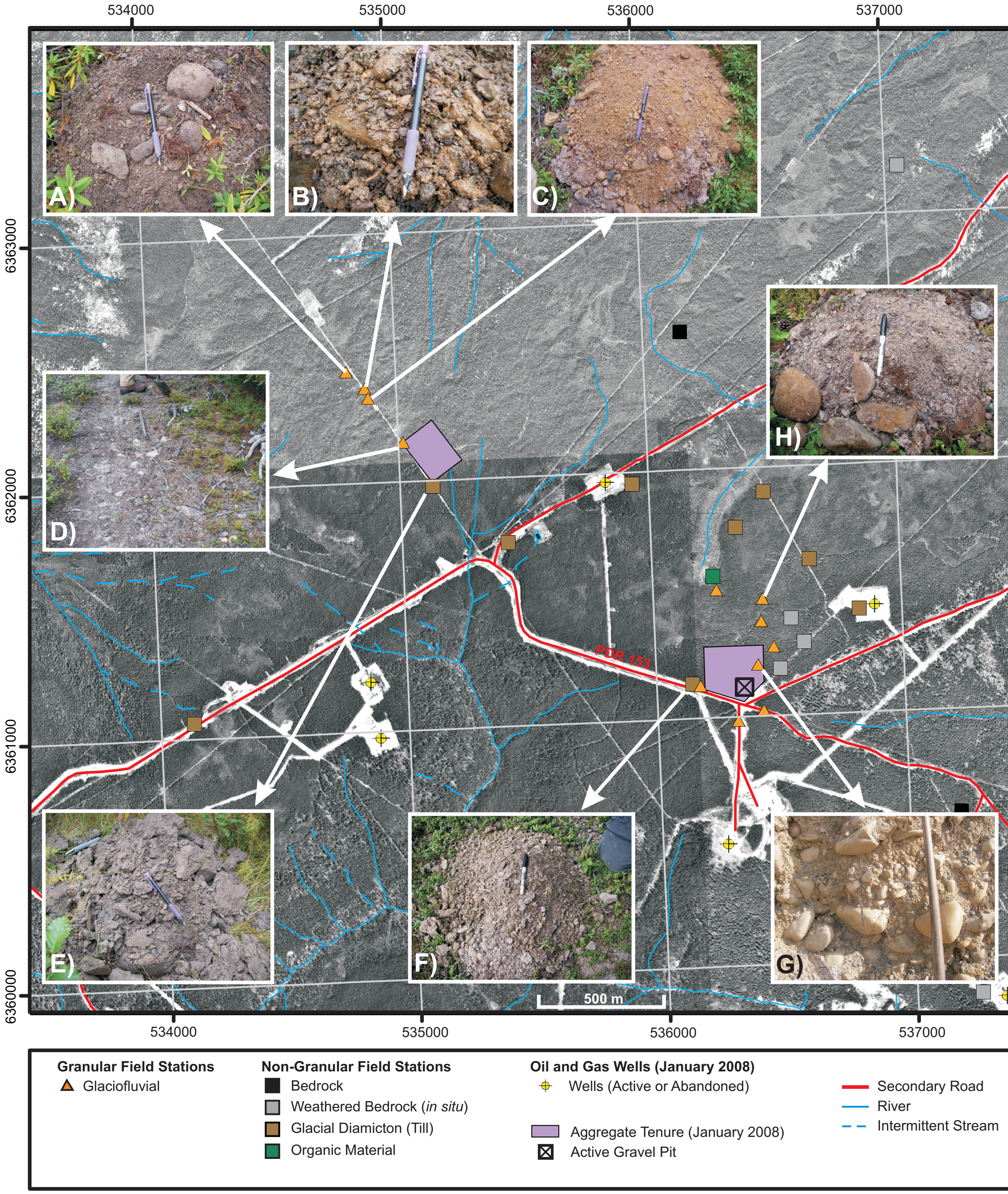

Figure 6. A variety of surficial materials were encountered in the test holes, including granular material (orange triangles), diamicton (brown squares), weathered bedrock (grey square) and organics (green squares). A and B) pebble gravel with silty-sandy matrix; C) sandy pebble gravel; D) angular pebble gravel observed at surface; E and F) diamicton with silty matrix; G) pit-run gravel from the existing gravel operation; H) pebbly cobble gravel with silty sandy matrix.

Figure 7. CCR Survey using OhmMapper™ instrument from Geometric. Five dipole-dipole receivers and a transmitter are towed behind a snowmobile.

the data and increase the signal to noise ratio: twice with a 5 m rope, and twice with a 10 m rope. This allowed the subsurface to be imaged to a modelled depth of 6 m below the surface of the snow. The array was towed behind a snowmobile travelling at approximately 5 to 7 km/h, with data recorded every 0.5 seconds. Continuous location information was simultaneously collected on a handheld global positioning system (GPS).

TABLE 1. RESISTIVITIES OF COMMON GEOLOGIC MATERIALS (AFTER REYNOLDS, 1997).

Material	Resistivity (ohm-m)
Clay	1 - 100
Alluvium and Sand	10 - 800
Moraine	10 - 5000
Boulder clay	15 - 35
Gravel (dry)	1400
Gravel (saturated)	100
Quaternary sands	50 - 100
Clayey sand	30 - 215
Sand and gravel	30 - 255
Permafrost	1000 - 10000

CCR Data Modelling

Multiple stages of processing were required to convert data collected by the OhmMapper™ into a realistic subsurface pseudosection. Once collected, data were inspected and erroneous points removed. Topographic data, obtained from the SRTM DEM, were incorporated into the resistivity data. The data were then modelled in Geotomo Software's RES2DINV inversion software. Finally, the modelled pseudosections were inspected for artefacts and geological plausibility prior to interpretation.

Display of Modelled CCR Data

In this report CCR results are displayed in two different ways (Figure 9 and 10). Both figures use the same graduated colour scheme that shows variations in apparent resistivity from 50 to 1137 ohm-m. Pseudosections were used to define the vertical extent of granular material. Figure 10 displays all the modelled data for the entire survey at six common depths below the surface, referred to as "depth slices". The depth slices are determined by the location of model blocks; the depths shown are 0.43 m, 1.28 m, 2.18 m, 3.17 m, 4.25 m, and 5.45 m below surface. These depth slices were used to determine the lateral extent of granular material.

Interpretation of CCR Data

To be an effective aggregate prospecting tool, CCR results require a well defined resistivity scale that distinguishes granular from non-granular material. In this study, results were compared to common expected resistivity values of different material types (Table 1). Four classes of apparent resistivity were defined. Below each pseudosection in Figure 9, interpretations are shown in shades of grey.

Aggregate Potential Assessment

The target areas were classified into moderate or high potential based on initial assessments of material encountered in hand dug test holes and the results of the CCR survey. Areas are considered to have high potential where granular material was encountered and CCR values are greater than 700 ohm-m. Moderate potential is assigned to areas where granular material was encountered and/or CCR values fall within the range of 400 to 700 ohm-m. The boundaries of the moderate and high potential prospects are left open (dashed) where there is insufficient data to constrain the extent of granular material. Area and volume calculations for available granular resources exclude tenured land (as of January 2008; Figure 2). The values presented in Table 3 should be considered estimates and require comprehensive test pit programs to confirm.

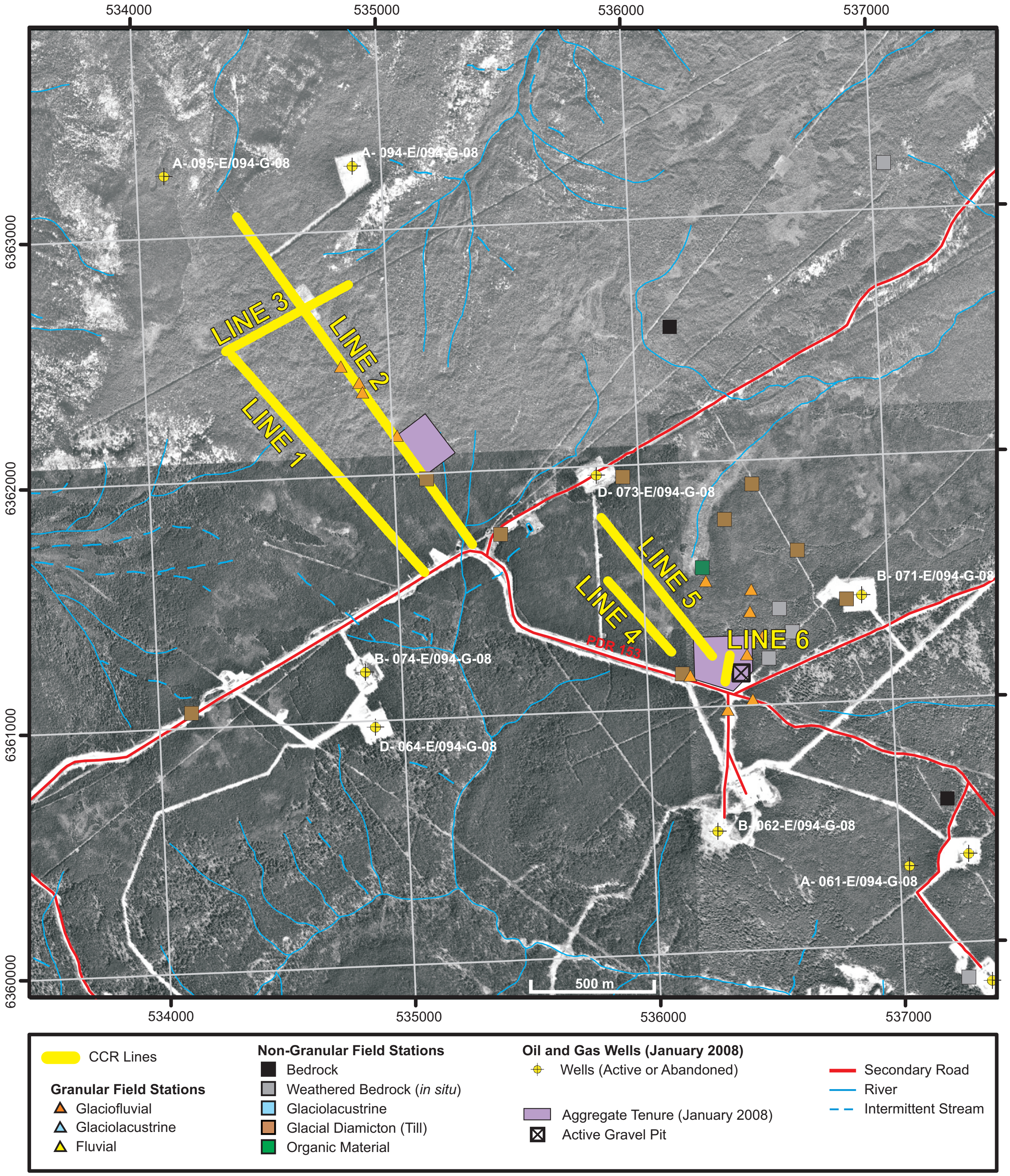

Figure 8. The six CCR survey lines were collected along existing seismic lines where data collection was unimpeded by vegetation.

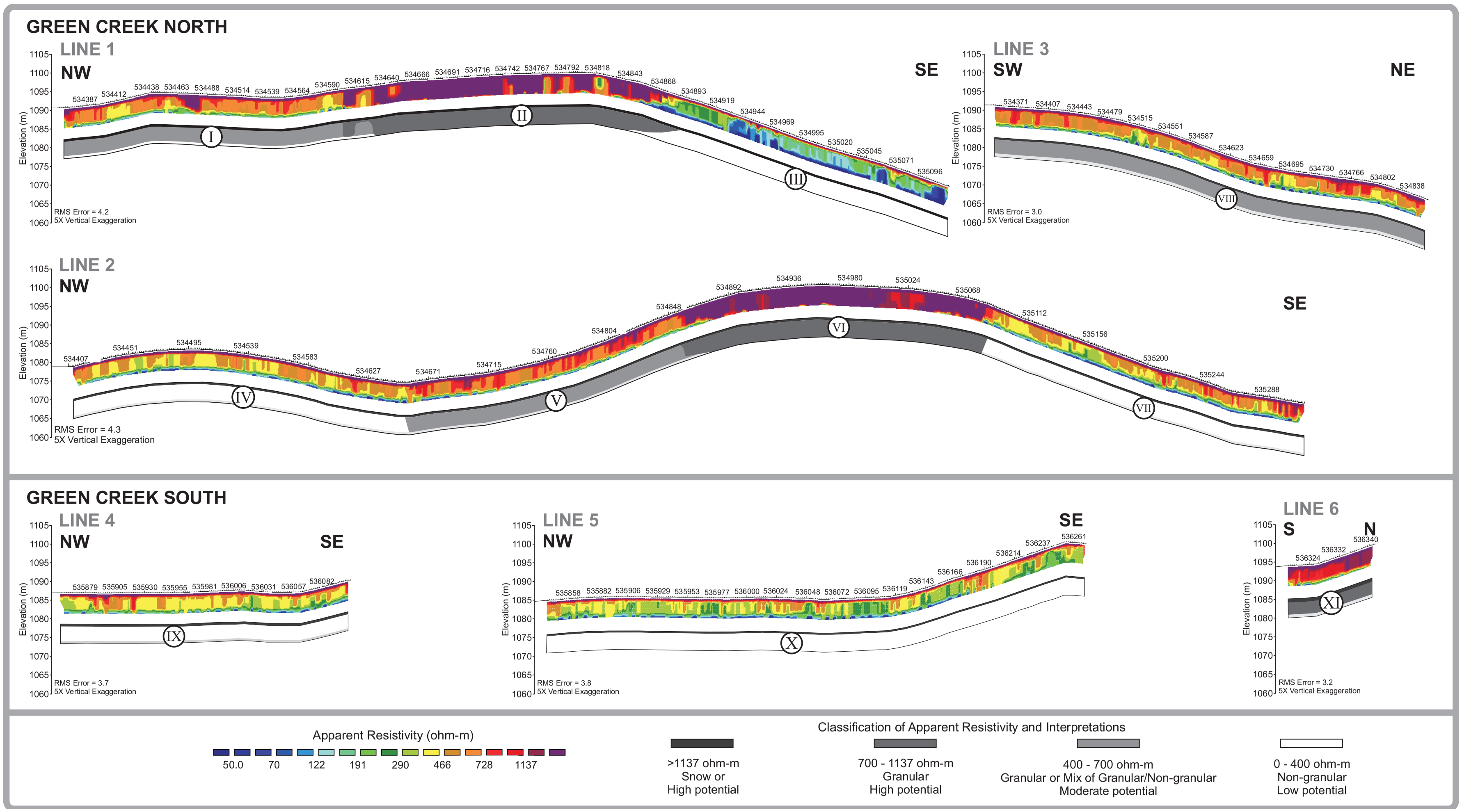

Figure 9. The modelled apparent resistivity data, displayed as pseudosections, images the electrical structure of the subsurface. Low resistivity values, representing conductive materials such as clay and silt rich diamict appear as cool colours (green and blue). High resistivity values associated with granular material appear as by warm colours (orange, red and purple). The Roman numerals refer to zones discussed in the text.

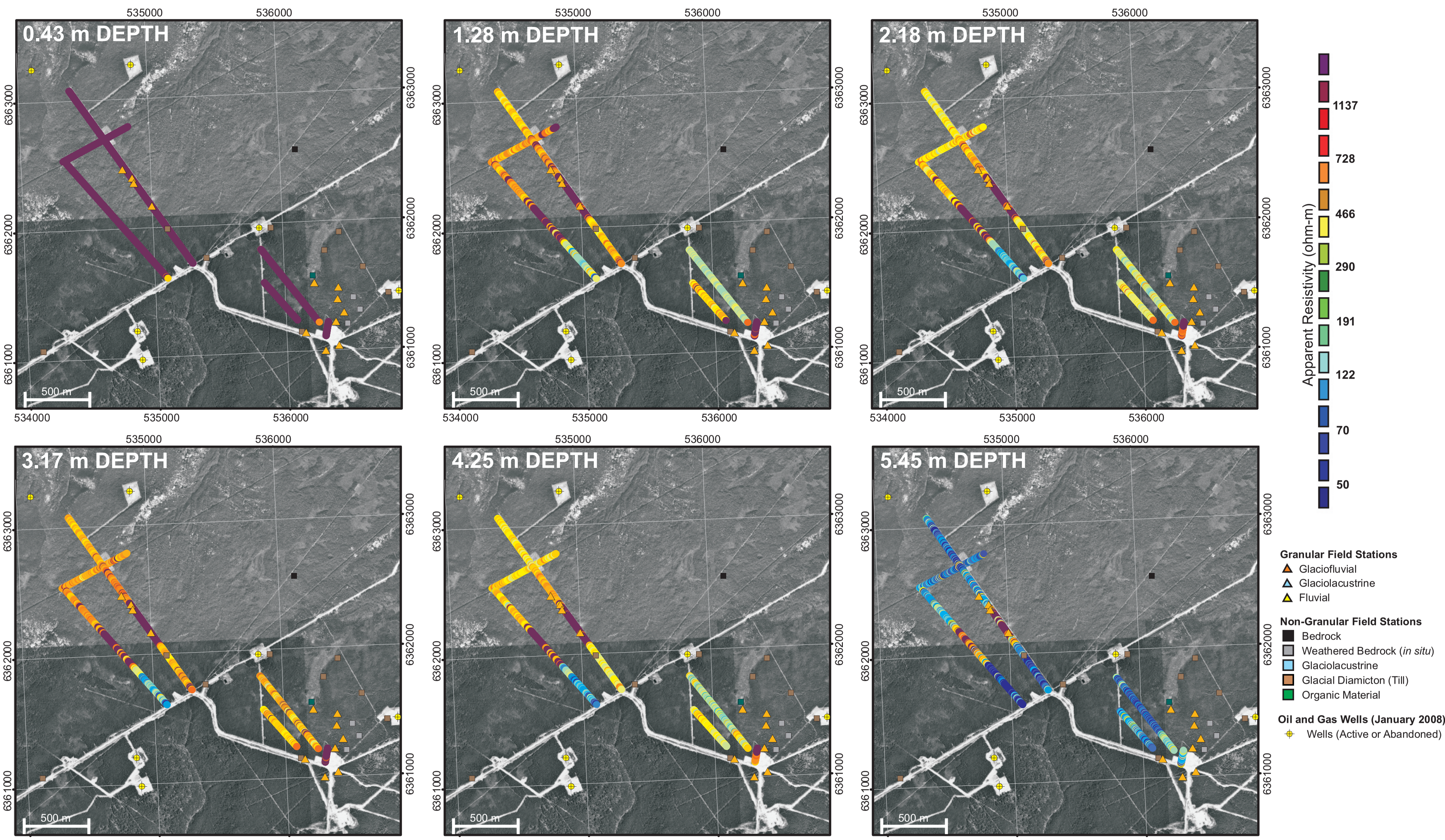

Figure 10. Depth slices extracted from the pseudosections are shown. The slice at 0.43 m consists only of high apparent resistivity values and is associated with snow. The lateral extent of granular material appears as warm colours such as orange, red, and purple. Non-granular material is represented by yellow, green and blue.

TABLE 2. AGGREGATE POTENTIAL BASED ON APPARENT RESISTIVITY.

Apparent Resistivity (Ohm-m)	Aggregate Potential
>1137	snow (if less than 1m depth) or granular, high potential
700 – 1137	granular, high potential
400 – 700	granular, moderate potential
0 – 400	non-granular, low potential

RESULTS AND INTERPRETATIONS

Green Creek North

Green Creek North hosts two prospects (Figure 11). Overall, Prospect A shows high potential for hosting an aggregate deposit and Prospect B shows moderate potential. The results from the field programs are presented here followed by interpretations and a discussion of aggregate potential.

Hand Dug Test Holes

Six hand dug test holes were dug in the Green Creek North target area. Four of these holes contained gravel at surface and the remaining two, diamicton (Figure 6). The holes containing gravel were clustered in the center of CCR Line 2 (Figure 8).

Field observations suggest the granular material is pebble-sized gravel with clast content ranging from 15 to 30 percent, in a mild oxidized, silty fine-grained sand matrix. Clast size range from granules to cobbles and are typically subrounded to subangular consisting primarily of locally derived shale and sandstone lithologies.

Diamicton in the non-granular holes contains approximately 5 percent clasts ranging in size from granules to pebbles, though most clasts are pebble sized. The matrix is silt and minor sand. Clasts were subrounded to subangular and derived from local lithologies.

CCR Survey

CCR Lines 1, 2, and 3 cover portions of Green Creek North. All of these lines have a high resistivity horizon in the upper metre and an inconsistent resistivity horizon at the base of the pseudosection. The upper horizon (0 to 1 m depth) typically shows very high apparent resistivity values (>1137 ohm-m, purple) that is interpreted as snow (Figure 9). All lines also show a non-uniform horizon from depths of 5 to 6 m. This horizon is at the limit of the model (i.e. confidence in these data are low and they are likely an artefact of data processing.) The zones described below are generalizations of the data for the purposes of predicting aggregate potential. The psuedosections data is generally variable reflecting noisy data and interpretations are based on the dominant apparent resistivity values within each zone.

Each line is described in the following section and refers to Figure 9. Line 1 consists of three visually distinct segments:

- Zone I has apparent resistivity values ranging between approximately 300 and 1000 ohm-m (yellow to red) and the distribution of values is non-uniform. These values suggest granular material, but because the majority of the values are at the lower end of the range, the material is likely a mix of fine to coarse sand and possibly minor gravel. Because this zone appears to have a relatively high proportion of fine grained granular material, rather than gravel, it is considered to have only moderate aggregate potential.
- Zone II shows consistently elevated values (>1370 ohm-m, purples). These values suggest sand or gravel and are interpreted to have high potential for granular material.
- Zone III is characterized by modest values (<200 ohm-m, blues and greens), indicating non-granular material.

Line 2 consists of four visually distinct segments (Figure 9):

- Zone IV generally has modest apparent resistivity values that ranges from approximately 300 to 700 ohm-m with the majority falling in the lower end of the range (yellow and brown). This suggests mainly non-granular material or a mix of non-granular and sand.
- Zone V has intermediate apparent resistivity values that suggest granular material, but may not contain gravel, therefore this zone is considered to have only moderate potential.
- Zone VI consists of elevated values (>1137 ohm- m, purple), interpreted as gravel with high potential for granular material.
- Zone VII shows predominantly modest to intermediate apparent resistivity values (400 to 750 ohm-m, yellow to orange), indicating low potential for granular material.

Apparent resistivity values in Line 3 are laterally homogeneous (Figure 9). Zone VIII shows intermediate apparent resistivity values (300 to 750 ohm-m, yellow to orange) throughout the entire line. This suggests moderate potential for granular material.

The depth slices define the lateral extent of prospective material (Figure 10). At 0.43 m depth apparent resistivity values are elevated (>1137 ohm- m, purple), representing snow. The centers of Lines 1 and 2 also have elevated apparent resistivity values (>1137 ohm-m, purple). This corresponds to Zones II and VI in pseudosections and suggest granular material to a depth of approximately 5 m. The northwest part of Green Creek North shows moderate potential (400 to 750 ohm-m, yellow to orange); however,

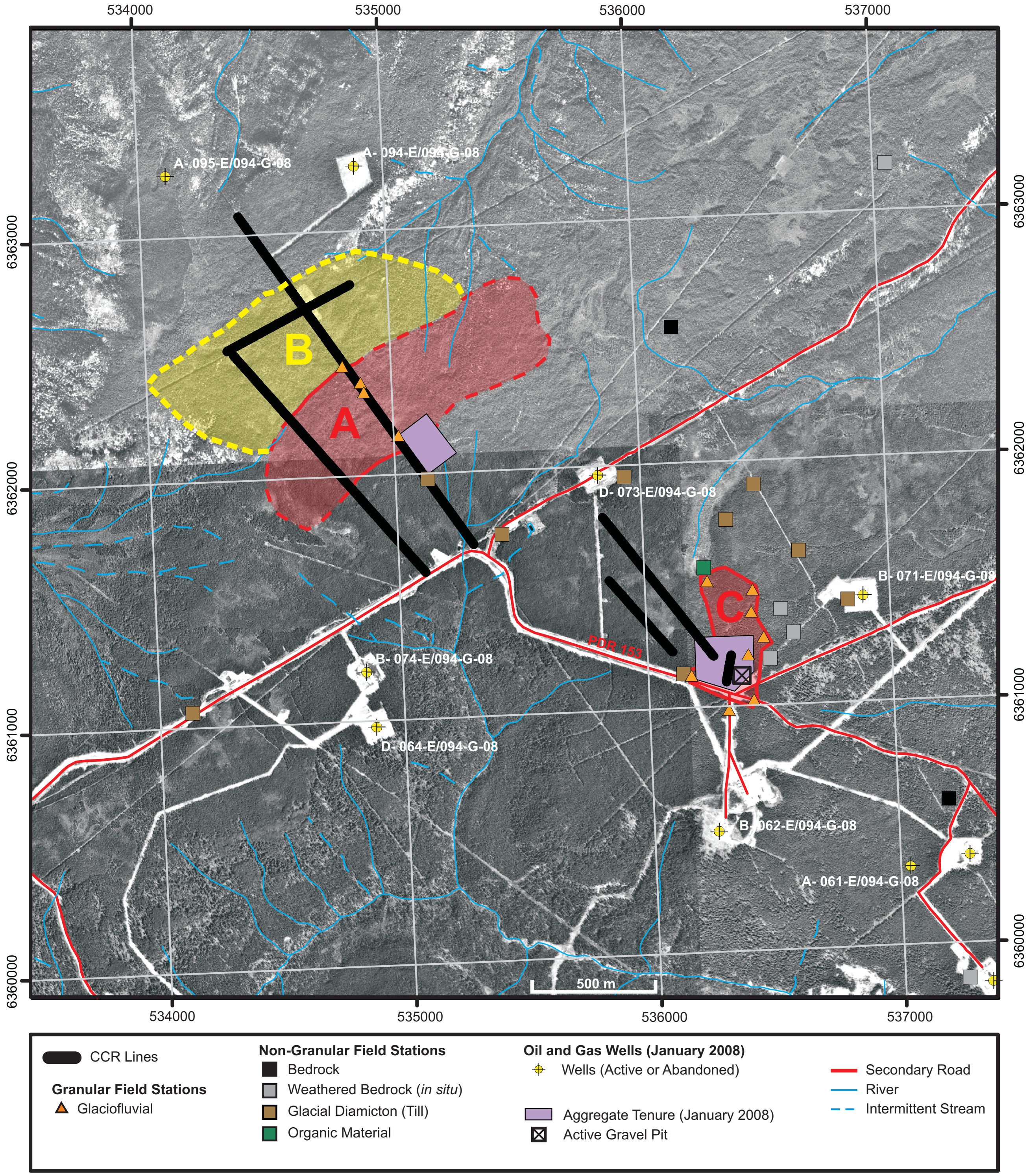

Figure 11. Aggregate potential of the Green Creek study area. In the Green Creek North (Figure 2), Prospect A has high potential and Prospect B has moderate potential to host an aggregate deposit. In Green Creek South, Prospect C has high potential to host a deposit.

the abundance of yellow (modest to intermediate resistivity values) indicates that the fine grained material likely dominates this area. The southeast portion of Green Creek North shows minimal potential, with modest apparent resistivity values (<50 to 200 ohm-m, blues and greens). At 5.45 m depth apparent resistivity is predominantly low (50 to 150 ohm-m, blues) but likely represent processing artefacts caused by an edge effect in the interpolation.

Aggregate Potential of Prospect A

Prospect A is classified as high potential (Figure 11). Results from both the CCR survey and the hand dug test hole program indicate granular material occurs along CCR Line 1. In both CCR Lines 1 and 2 a topographic slope break marks the edge of the area of high potential. By using the SRTM DEM to map the slope break, a boundary (solid red line in Figure 11) can be extrapolated between CCR Lines 1 and 2. It is likely that the deposit extends to the northeast and southwest beyond the seismic lines, unfortunately there is no data to constrain the extent of granular material. The boundary is shown with a dashed line at the edge of the slope break where the boundary is inferred but unknown. Therefore the minimum area for the high potential region of the Prospect A must be >100 000 m^2. With a thickness of 4.25 m inferred from the pseudosections, the estimated granular resource for this area is >425 000 m^3.

Aggregate Potential of Prospect B

Prospect B is classified as moderate potential (Figure 11). The CCR data from Lines 1, 2, and 3 all suggest the presence of low to moderately prospective granular material. As there are no test holes in this region additional ground truthing is necessary to confirm surficial material. The boundary shown is drawn from a line of common elevation, suggesting one possible prospect configuration (Figure 11). No area or volume estimates are given due to insufficient control on prospect extent.

Green Creek South

Green Creek South hosts Prospect C. This prospect shows high potential and is an excellent candidate for further exploration. CCR Lines 4, 5, and 6 help delineate the west edge of the prospect, and the hand dug test holes help define the north, east and south edges of the prospect.

Hand Dug Test Holes

A total of 18 hand dug test holes were completed in the target area to delineate the boundary of the deposit. Eight holes revealed gravel, six contained diamicton, three exposed weathered bedrock, and one was dug in organics (Figure 6). The active gravel pit located within Prospect C was also examined (Figure 4).

Gravel in hand dug holes range from 40 to 60 percent clasts. Relative clast content decreases to north and south of the existing gravel pit. Clasts are up to 30 cm in diameter with an average at 5 cm. Clasts are rounded to subangular. The matrix is mainly silt with minor fine-grained sand.

Predominantly cobble-size gravel is exposed in the 3 to 4 m vertical section in the existing pit wall (Figure 4). The material is massive and matrix supported with occasional crudely stratified discontinuous beds. Clasts size ranges from 0.5 cm to 50 cm in diameter, averaging approximately 15 cm. Clasts are subrounded to rounded, mildly oxidized, and derived from local sandstones and siltstones. The matrix is silty fine to medium-grained sand. Rare open-framework lenses are exposed above and below larger clasts. The base of the gravel pit is a silty fine-grained sand, 4 m below the top of the excavation.

Test holes containing silty diamicton have less than 5 percent clasts. Clasts are up to 20 cm in diameter and average 2 cm. Clasts are subrounded to subangular and derived from local sedimentary lithologies. The matrix is silt with minor clay and fine-grained sand. Diamicton was encountered in the northern portion of the target area. Weathered bedrock found in test holes consists of fine and dense weathered mudstone, which broke easily into blocks. This material was encountered to the east of the gravel pit. Organic material found in one hole consisted of poorly drained peat, with minor silt and was located northwest of the gravel pit near the edge of the prospect.

CCR Survey

CCR Lines 4, 5, and 6 have some common features. In all pseudosections the upper horizon (approximately 0 to 1 m depth) of elevated apparent resistivity (>1137 ohm-m, purple) is present and is interpreted to be snow (Figure 9). All lines also contained a processing artifact in the bottom metre of the pseudosection.

Lines 4 and 5 display non-uniform apparent resistivity values between 70 and 700 ohm-m (green to orange) though the values in Line 4 are consistently higher. These values are relatively modest and suggest that sand and/or diamict is the dominant surficial material. Consequently, zones IX and X are assigned low potential.

Line 6 is located within the gravel pit and shows elevated apparent resistivity values (700 to >1137 ohm-m, orange to red) in Zone XI. This line was conducted over 2-3 m of gravel and was used to calibrate resistivity values for gravel in this study.

The depth slices define the lateral extent of granular material (Figure 10). Depth slices between 1.28 and 4.25 m on Lines 4 and 5 show moderate to low apparent resistivity varying from 70 to 700 ohm-m (green to orange) , though typically on the lower end of the range. This indicates low potential for aggregate. Line 6 has high apparent resistivity (700 to 1137 ohm-m, orange to red) for the length of the line, indicating granular material, likely gravel.

Aggregate Potential of Prospect C

Prospect C has high potential (Figure 11), a small portion of which is tenured. CCR Lines 4 and 5 have apparent resistivity values that suggest non-granular material, therefore, they were unable to detect the edge of the deposit. The deposit boundary is inferred to occur between the end of the CCR survey lines and gravel observed in test holes. To the north, east, and south, the deposit boundary is inferred based on the hand dug test hole program. The northern portion of the deposit encompasses an area of 56 000 m^2 and, if of similar thickness as the gravel pit (4 m), an inferred volume of approximately 224 000 m^3 of potential granular material remains untenured.

CONCLUSIONS

Both Green Creek North and South have the potential to host granular material. Two high potential areas (Prospect A and C) and one moderate potential area (Prospect B) are identified and recommended for further evaluation (Table 3). Prospect A in Green Creek North is the most prospective new area to host an aggregate deposit. High resistivity values in the CCR survey data and the presence of granular material at surface suggest this area may contain sand and gravel. The high potential area is constrained, in part, by the CCR survey and hand dug test hole data along two seismic lines that run approximately northwest-southeast. However there is potential for the prospect to extend perpendicular to these seismic lines to the northeast and southwest. This prospect has a preliminary resource volume estimate of >425 000 m^3 based on a thickness of 4.25 m, as indicated by the CCR data. Prospect B, also in Green Creek North, has moderate potential based on the CCR survey results. More work is, however, required to confirm the nature of the material in this area and assess its potential as an aggregate source. Prospect C in Green Creek South includes an area with an existing aggregate operation and the deposit is well constrained by hand dug test holes and is estimated to contain a maximum of 224 000 m^3 of granular resource if the observed thickness of 4 m in the gravel pit is maintained throughout the prospect area.

ACKNOWLEDGEMENTS

The authors would like to thank Travis Ferbey and Vic Levson for reviewing an early version of this report. The British Columbia Ministry of Energy, Mines, and Petroleum Resources funded this study through the Northeast British Columbia Aggregate and Surficial Geology Mapping Program.

TABLE 3. PRELIMINARY GRANULAR MATERIAL ESTIMATES FOR SELECTED PORTIONS OF GREEN CREEK NORTH AND SOUTH.

Location	Aggregate Potential	Area (m^2)*	Depth Estimate (m)	Preliminary EstimatedGranular Resource (m^3)**
Area A; Green Creek North	High	100 000	4.25	425 000
Area B; Green Creek North	Moderate		No Estimates Given	
Area C; Green Creek South	High	56 000	4.00	224 000

*All tenured portions of prospective polygons were removed from area calculations.
** Estimate based on depth inferred from CCR results, no consideration made for aggregate quality, gradation, or economics.

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