BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES COMPANY

OIL AND GAS COMMISSION

STAGE 1 REVIEW OF TERRAIN HAZARD ASSESSMENTS AND MAPPING IN NORTHEAST BRITISH COLUMBIA

FINAL REPORT

PROJECT NO: 0452-001-05
DATE: March 31, 2006

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BGC ENGINEERING INC.
AN APPLIED EARTH SCIENCES COMPANY

500 - 1045 Howe Street
Vancouver, BC
Canada V6Z 2A9
Telephone (604) 684-5900
Facsimile (604) 684-5909

March 31 2006

BGC Project Number: 0452-001-05

Mr. Peter McAuliffe
Oil and Gas Commission
Technical Services and Regulatory Affairs Branch
PO Box 9331 Stn Prov Gov't
5th Floor, 1675 Douglas St.
Victoria, BC V8W 9N3

Dear Peter:

Re: Stage 1 Review of Terrain Hazard Assessments and Mapping in Northeast British Columbia

Please find attached a final copy of our above referenced report and map dated March 31, 2006. In addition to this report we are providing two binders of hardcopy technical references, drill hole logs from Duke Energy, and landslide reports from MoT. A CD containing contents of the online database, PDF reports, and ArcGIS files is enclosed in the back of the report. Instructions on how to access the draft versions of the online database and ArcIMS mapping application are found in Appendix II of the report.

Should you have any questions or comments, please do not hesitate to contact me at the number listed above.

Best regards,

BGC ENGINEERING INC.
per:

Mark Leir

Mark Leir, P.Eng. P.Geo., LEG
Senior Geological Engineer

EXECUTIVE SUMMARY

The oil and gas sector is currently operating over a wide geographic area in northeastern British Columbia. In some instances, there are terrain hazards that are affecting or could potentially affect oil and gas activities. These hazards need to be inventoried, described, and understood so the development companies can avoid or manage the risk in these areas.

The purpose of this study was to:

- Describe the current state of knowledge on terrain hazard mapping and work completed to date.
- Include a summary of terrain hazards relevant to northeastern BC and to oil and gas development.
- Provide a synopsis of current information gaps and recommendations on how to best address the information needs.
- Include recommended methodologies for future terrain hazard assessment work.

The deliverables for this project include a report, hardcopy map (Figure 1) and accompanying prototype Internet database and linked online mapping application in Google Earth and ArcIMS. The database is accessible on the Internet and contains geologic hazard locations with linked references, photos, and co-ordinates. It currently contains about 100 named hazards, 1500 landslide points, and over 70 indexed documents and maps. Hardcopy papers, reports, and drill hole logs have been supplied in to binders and the reports indexed in the database.

The landscape features susceptible to landslide hazards that may be encountered during oil and gas resource development include:

- Glaciolacustrine surficial geology units that contribute to large rotational landslides, creep and settlement.
- Exposed Shaftsbury Bedrock Formation and portions of Ft. St. John Bedrock Group that contribute to large translational landsliding and creep deformation.
- Alluvial/Colluvial cones that are susceptible to creep deformation.
- Areas of degrading permafrost that contribute to differential settlement and triggering of landslides
- Valleys and gullies that expose Shaftsbury Formation and portions of Ft. St. John Group
- Slopes greater than 10° that contribute to landsliding

Prior to routing and construction, oil and gas development must be aware of problematic areas to ensure that facilities avoid these areas, are adequately designed, and are set back a sufficient distance from the valley crest. Access roads can be repaired and re-routed more easily than pipelines and drill pads. Hazard avoidance cannot be effectively done unless the location, potential extents, mechanics, and maximum velocity of the landslides are estimated prior to facility routing, design, and construction.

The OGC ultimately requires a permitting process that prioritises areas that are susceptible to landslide hazards. To identify these areas in an economical manner and at a practical scale we propose that a simple landslide susceptibility map be constructed.

A susceptibility map aggregates factors that contribute to landsliding, such as unfavourable geology, slope, and evidence of previous landsliding, in a systematic manner and defines areas that are currently or potentially unstable. This map could be classified into to 3 or 5 classes of landslide susceptibility and each class would require a set of due diligence criteria that an oil and gas development company would be encouraged to follow in order to minimise the risk to their facilities.

Initially, the map could be constructed using the mosaic of information assembled as part of this study. The map will be dynamic as it will become more accurate and detailed as larger scale information is added. Areas where key information gaps exist and oil and gas development is proposed can be made a priority for more detailed geology and landslide inventory.

At this time the following minimum information is required to build the susceptibility map.

- Cretaceous shale bedrock
- Glaciolacustrine surficial geology
- Documented landslide points
- Ground movement pipeline incidences
- Slopes greater than 8 to 10 degrees

This report lists a set of existing data sources that should be added to the resources assembled to date. This additional information is relatively easy to collect and provides a substantial improvement to the inputs in the proposed susceptibility map and reduces the current number of 1:,20,00 scale mapsheets requiring further study (See Figure 1)

The algorithm used to create the susceptibility map has not been finalised at this time. However simple algorithms and an awareness of the limitations in the input data often result in a cost effective landslide map. Additionally, a simple algorithm is easier to explain to the end users of the map resulting in an increased utility and confidence in the result.

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LIMITATIONS OF THE REPORT

BGC Engineering Inc. (BGC) prepared this report for the Resource Development and Geoscience Branch (RDGB) of the BC Ministry of Energy, Mines and Petroleum Resources (MEMPR) and the Oil and Gas Commission (OGC). The material in it reflects the judgement of BGC staff and their project partners in light of the information available to BGC at the time of report preparation. Any use a Third Party makes of this report or accompanying databases, or any reliance on decisions to be based on them, is the responsibility of such Third Parties. BGC accepts no responsibility for damages, if any suffered by any Third Party as a result of decisions made, or actions, based on this report.

As a mutual protection to our client, the public, and ourselves, all reports and drawings are submitted as confidential information for our client for a specific project. Authorization for use and/or publication of data, statements, conclusions or abstracts from or regarding our reports and drawings is reserved pending our written approval.

1.0 INTRODUCTION

The oil and gas sector is currently operating over a wide geographic area in northeastern British Columbia. In some instances, there are terrain hazards that may affect oil and gas activities. These hazards need to be identified, described, inventoried, and understood so the development companies can avoid or manage these areas more carefully.

There is currently insufficient knowledge with respect to the characteristics and extent of terrain units and landslides in northeastern BC. To date approximately 22% of the study area has been mapped at 1:20,000 scale; 34% at 1:50,000 scale, and 70% at 1:250,000 scale. This study is intended to determine the distribution and prevailing knowledge of problematic terrain units and geologic hazards that may impact or triggered by oil and gas activities.

This introduction provides background to the project and outlines the report organisation. The scope of work and the study area is described in Section 2.0 and the project results are provided in Section 3.0. Section 4.0 provides the conclusions and recommendations are discussed in Section 5.0. Appendix I contains the Figure 1 overview map; Appendix II contains notes made from interviewed contacts; Appendix III contains instructions on how to access the prototype online database and Google Earth/ArcIMS mapping application that accompanies this study; Appendix IV contains instruction on obtaining surficial geology information, and Appendix V contains 2 DVDs that include the landslide inventory, pipeline incidences, map layers, and reports.

2.0 SCOPE OF WORK

The purpose of the study, description of the study area, and the study scope are described in this Section.

2.1 Purpose

The purpose of this study was to:

- Prepare a summary of the existing information identified from a literature review and interviews of relevant experts to describe the current state of knowledge on terrain hazard mapping and work completed to date.
- Identify terrain units that are inherently unstable and hazardous to develop on.
- Summarize the prevailing knowledge on these problematic terrain units and their distribution in the region.
- Include a summary of terrain hazards relevant to northeastern BC and to oil and gas development.

- Estimate the risk of loss resulting from resource activities that may impact those landscape units.
- Provide a synopsis of current information gaps and recommendations on how to best address the information needs.
- Include recommended methodologies for terrain surveys and recommendations for future terrain hazard assessment work.

2.2 Study Area

In general, the northeast BC study area is bounded by the BC/Yukon border to the north, BC/Alberta border to the east, and Rocky Mountains to the south and west. More specially, the OGC defined the study area as the combination of the Peace and Fort Nelson Forest Districts, as shown in Figure 1 in Appendix I.

The project area lies on the western edge of the Alberta Plateau of the Great Plains (Bostock 1948, Holland 1964). The topography is subdued, reflecting the underlying Cretaceous bedrock, and includes northwesterly trending belts of rolling terrain with north and westerly directed drainage (Stott 1982). The region is dissected by deeply incised, integrated dendritic drainage systems such as the Hay, Fort Nelson, Liard and Peace Rivers.

2.3 Data Acquisition

This project started with a literature review and data gathering tasks that were conducted over the first three weeks of the project. Various personnel searched Internet indexes, mapping websites, library catalogues, in-house BGC resources, and interviewed contacts on the phone or in person. The results of this review is discussed below in Section 3.0.

2.4 Data Compilation

Data compilation involved reviewing the resources in order to assess the utility of each towards meeting the goals set by the OGC. Locating geologic hazards and pipeline facilities and identifying areas and geological units susceptible to landsliding were the main focus of data compilation. Data compilation also included “publishing” the data onto the Internet. This includes building the hazard and report database indexes and linked ArcGIS project and Internet mapping application. The results of data compilation are discussed below in Section 3.0.

2.5 Analysis

Analysis involved overlay GIS analysis to determine 1:20,000 scale mapsheets within the northeast that had not been studied but contained information gathered in the data acquisition task that suggests the area may be problematic. The results of the analysis is discussed below in Section 3.6.

2.6 Reporting

Reporting involved writing the report that accompanies the digital deliverables. It includes the results, conclusions and recommendations and a large format map.

3.0 RESULTS

3.1 Deliverables

The deliverables for this project include a report, hardcopy map and accompanying prototype Internet database and linked online mapping application in Google Earth and ArcIMS. The database is accessible on the Internet and contains geologic hazard locations with linked references, photos, and co-ordinates. It currently contains about 100 named hazards, 1500 landslide points, and over 70 indexed documents and maps. Hardcopy papers, reports, and drill hole logs have been supplied in to binders and are indexed in the database.

All digital maps collected for this study are included in an accompanying CD and has been added to an ArcGIS geodatabase and corresponding ArcIMS project at http://bgcengineering.info/website/htmlviewer/Generic/viewer.htm. Select map layers, such as the study area boundary, problematic bedrock and surficial geology units, pipeline infrastructure, and landslide locations are also included in a linked Google Earth application at http://www.bgcengineering.info/OGC. Instructions on how to access the database, ArcIMS and Google Earth mapping applications are provided in Appendix III. A listing of the resources in the database and mapping applications are listed in Section 3.2.

The landslide hazards in the database can be queried by name and region in order to find specific sites. Reports have been cross-referenced to the hazard location so background information on a specific landslide can be found. The database also contains a list of technical papers, reports, and maps that are not specific to a hazard site , but are useful for certain portions of the study area. This report index is very powerful, as one can search for documents in a number of ways, including author year, publication name, and keyword. Most of the documents that were published after 2000 are in PDF format and can be downloaded directly from the database an are also on the accompanying CD. Hardcopy reports and papers are contained in a binder and are organised by date of publication.

The digital deliverables are intended to be a test case to demonstrate what is possible for publishing the information internally at the OGC, within the provincial government, or to the public. BGC believes the construction of a database and mapping application was the most cost effective method of organising the materials and determining where the information gaps exist. Some work will be required to refine the functionality and content of the data and maps before it should be released to the public. BGC recommends that this be done, as many people and organisations that were contacted and were asked to contribute asked, in turn, if they could get access to the results of the compilation. The OGC will find that private organisations will be more forthcoming with their data if they are comfortable with where it will be published and how it will be used. Having access to information from private organisations will minimise the likelihood of conducting detailed studies in areas where private industry has already studied. Recommendations for database refinement and areas for further study are provided in Section 5.0.

3.2 Data Sources

The following is a list of data sources for this project. As described in Section 3.1 all of the reports and maps obtained for this study are indexed in the database or can be viewed online.

Figure 1 enclosed in Appendix I outlines areas within the study area that have been studied. As listed in the map legend this map shows;

- the study area,
- 1:250,000 scale bedrock or surficial geology studies
- 1:50,000 scale bedrock or surficial geology studies
- 1:50,000 scale mapsheets containing pipeline infrastructure
- 1:20,000 scale Terrain Stability Mapping
- 1:5 Million scale glaciolacustrine surficial geology
- 1:250,000 scale Shaftsbury Shale and Fort St. John Group bedrock geology, and
- Slopes angles > 10 degrees
- Documented landslides
- Located pipeline incidences

The reader is encouraged to have Figure 1 handy as this map is referred to often in this report.

3.2.1 Surficial Geology

The following highlights some of the Internet websites visited to obtain surficial geology data. A more comprehensive list of resources can be found in Appendix IV.

The 1:5 million scale digital surficial geology map GSC Map 1880A - Surficial Materials of Canada (Fulton, 1995) was downloaded from http://gsc.nrcan.gc.ca/map/1880a/index_e.php into the ArcIMS project. This was the only useful digital surficial dataset located so far because it was continuous and consistent over the entire study area. It was used to quickly highlight the problematic glaciolacustrine surficial geology as outlined in Figure 1.

Digital Terrain maps were available for download at http://www.em.gov.bc.ca/Mining/Geolsurv/MapPlace/MoreDetails/OF_13.htm. An Excel spreadsheet index from this website lists all 1:50,000 terrain maps available for BC. The following sheets in the study area were downloaded and tested for utility in ArcGIS:

093I 1 to 16
093I 053, 054, 063, 064, 073,074,
093M 069, 078, 079, 088 to 090, 096 to 100
093O 8, 9, 11 to 16
093P 2 to 5, 9, 10, 12 to 16
093P 002, 003, 012, 013
094A 1,2,7,8
094A 004, 014, 015, 003
094B 3,4,5,9,10,15
094C 1,2,7,8,9,10,11,14,15
094D 006, 008, 015 to 020, 026,027,035,036,045
094J NW
094O SE

The following sheets were listed in the Excel spreadsheet as available for download, but could not be found on the website.

093B 005, 015, 025, 033, 043
093I 006, 007,015 to 017,023 to 028, 031 to 037, 041 to 047, 054, 055
093O 10, 15
093O 002 to 005, 015, 016, 025, 026, 036, 037, 073, 074, 083, 084
093P 09 to 12
093P 039, 054, 055, 058, 059, 064, 065, 068, 069, 074, 075, 078,
094C 001 to 003, 005, 007, 017, 013, 015, 018, 023, 024, 031 to 034 to 037, 041 to 043, 044, 047, 048, 056 to 058, 067, 094
094F 004, 006, 007, 016, 017, 025 to 028, 035 to 039,
094O SW

Locating this information will reduce the number of 1:20,000 scale mapsheets that are proposed for further detailed study.

This terrain mapping data available to the public is organised into two categories called

Forest Renewal BC (FRBC) and Forest Practices Code (FPC). Both categories of data have been created using the Terrain Classification System for British Columbia (Howes and Kenk, 1997), both meet Resources Inventory Standards Committee (RISC standards), and both are in digital format. However, for some unknown reason, the terrain codes are provided to the public in different ways and affects the data utility. FRBC is difficult to query because the terrain codes were combined as a single character string. For example, polygons with glaciolacustrine units could not be identified without parsing the string into separate columns. The FPC terrain codes were divided into separate columns for each parameter and were easier to query.

Ryan Hinton, a student at the BC Ministry of Energy Mines and Petroleum Resources, contacted various departments within the ministries of Energy, Mines and Petroleum Resources; Environment; and Transportation for surficial mapping data. Canfor was also asked for terrain stability mapping resources. Canfor provided FRBC_48 and 96, and FPC 36 and 56. The following 1:50,000 scale raster-format soil maps were provided by the ministries:

093I 1 to 16
093P 12 to 16
094A 1 to 8
094B 9,10, 15, 16

The following URLs were also reviewed for soil data but no useful products for northeast BC were found.

http://srmwww.gov.bc.ca/soils/
http://srmwww.gov.bc.ca/terrain/
http:/www.landinformationbc.com

3.2.2 Bedrock Geology

Digital bedrock geology at 1:250,000 scale was downloaded from
http://www.em.gov.bc.ca/Mining/Geolsurv/Publications/catalog/bcgeolmap.htm.

This was the only useful digital bedrock dataset located so far because it was continuous and consistent over the entire study area. It was used to quickly outline the problematic Shaftsbury Formations and Fort St. John Group bedrock geology as shown in Figure 2

The bedrock geology also included a Quaternary geology layer, as described in
http://www.em.gov.bc.ca/Mining/Geolsurv/mapplace/Metadata/quaternary_bc_dd_meta.htm.
However, the layer does not differentiate between surficial geology units and therefore was not useful at this time.

The following URLs were also reviewed for bedrock data but no useful products were found.

http://www.em.gov.bc.ca/Mining/Geolsurv/MapPlace/themeMaps.htm

http://www.em.gov.bc.ca/Mining/Geolsurv/bedrock/index/vmapweld.htm

http://gsc.nrcan.gc.ca/map/1860a/index_e.php
GSC Map 1860A – Geology of Canada, 1:5,000,000 scale bedrock geology

http://gsc.nrcan.gc.ca/org/calgary/pub/1m_e.php
There is 1:1,000,000 geology data from the GSC, but it is not available in a digital GIS format.

http://gdr.ess.nrcan.gc.ca/english/explorer.jsp
A very slow ArcIMS website with hundreds of geology layers is available. No data exists for northeast BC at this website.

3.2.3 Technical Papers and Reports

Hardcopy and digital reports and technical papers were primarily obtained from:

- the online UBC library, http://www.library.ubc.ca/home/research.html;
- the GSC's Geoscan online index; http://ess.nrcan.gc.ca/esic/geoscan_e.php;
- CGRG Bibliography of Canadian Geomorphology, http://cgrg.geog.uvic.ca/cgi-bin/search.cgi; and
- BGC Engineering Inc.

Attempts were made to obtain digital copies of reports and maps and link them to the database. Hardcopy papers were not converted to digital format and resources in reference lists were not obtained unless they were available online.

Site specific hardcopy reports are likely located at private engineering consulting companies, such as Thurber, AMEC, and EBA and at pipeline and railway companies such as Duke Energy and CN Rail. These reports are more difficult or time consuming to access because a consulting companies' competitive advantage is their reports and knowledge of an area. Additionally, large companies like Duke and CN have trouble finding their old reports and are often reluctant to release them to the public, due to legal liability concerns. However, careful negotiation and inside contacts/relationships can overcome these challenges. Time and patience is also required to fully explore private company resources.

3.2.4 Pipeline Incidences Data

BGC obtained an Excel spreadsheet of pipeline ruptures in BC from Dana Warner at the OGC in Fort St. John. This data includes leaks and ruptures caused by 3rd party impact, corrosion, operating error, and ground movement from June 15, 1980 to January 29, 2004. BGC extracted a subset of the data that included leaks and ruptures caused by ground movement incidents in northeast BC. OGC provided geographic coordinates for this subset, so their spatial distribution could be estimated on a map. The resulting dataset are plotted on Figure 2 and are shown in the ArcIMS and Google Earth Internet mapping applications.

3.2.5 Seismic Epicentres

Earthquakes are being reconsidered as possible triggers for the flowslides in the northeast. Accordingly, we obtained the seismic epicentres from the Canadian National Earthquake Database and from the American Advanced National Seismic System Catalogue (for older data going back as far as there are seismic records). The data becomes sparse the further back in time one looks, with only major quakes registered in rough coordinates in the earliest data. The links to the two sources are:

http://www.seismo.nrcan.gc.ca/nedb/eq_db_e.php
http://www.ncedc.org/anss/

3.3 Interviewed Contacts

Contacts were made to:

- gauge the current state of knowledge,
- determine the areas and corridors that have been studied and mapped,
- determine information needs as perceived by industry and government , and,
- determine what they perceive the research priorities are.

A listing of contacted industry/agency/research specialists and their comments is provided in Appendix II.

The MLAWP and Duke Energy were interviewed in person in Fort St. John and BGC spent two days at the Ministry of Transportation office in Prince George to review their slope stability files and gain understanding of where they are affected. Approximately 40 landslide records were obtained but have not been added to the database. Engineering consulting groups in the Fort St. John area were also contacted and they provided insight into problem areas. CN Rail provided some geotechnical reports along its rail grade near Taylor, BC, and Terasen Gas provided a list of its geotechnical hazards along it pipeline near Fort Nelson. Duke Energy provided georeferenced hardcopy borehole logs and a digital centreline of their transmission system. We understand that a list of landslides affecting Duke Operations is also available from them.

Earth scientists at the Geological Survey of Canada, Ministry of Forests, and University of British Columbia were contacted and they provided insight into problem areas and significant ground movement hazards and process in the northeast.

BGC gratefully acknowledges the contributions these organisation and individuals made.

3.4 Current State of Knowledge

The occurrence of number of large landslides in northeast BC has been increasing over the last 30 years (Geertsema, 2006). Slow creep deformation is a common type of failure mode, in addition to rapid, catastrophic type failures. Understanding where the landslides are and their failure mechanisms is important to defining areas that can impact oil and gas development. The depth to landslide failure planes, possible landslide extents, velocity of failure, and the amount of deformation are also required in order to effectively avoid and/or prepare oil and gas facilities against these hazards.

The current state of knowledge suggests slope stability is controlled by two equally important groups; bedrock and surficial materials. The discontinuous permafrost through out northern British Columbia can also adversely affect both of these units. These problematic bedrock and surficial units are described below and are outlined in Figure 1 and the Google Earth mapping application.

3.4.1 Bedrock

Bedrock geology has been mapped in northeastern British Columbia at 1:500,000 scale by Stott (1982) and at a 1:250,000 scale by Thompson (Halfway River 94B, 1986; Beatton River (94H) and Fontas River (94I) (1975)). All 1:250,000 scale bedrock mapsheets for the northeast have been assembled to form Digital Geology Map Compilation of British Columbia (2005). Figure 1 shows the spatial distribution of these bedrock geology studies and outlines the problematic Shaftsbury Formation and Fort St. John Group described below.

Problematic bedrock units in these regions consist of the Cretaceous clay shales and overconsolidated clays. Much work has already been done on the Shaftesbury Formation that outcrops along the Peace and Beatton Rivers (Sargent and Cornish 1985, Cornish and Moore, 1985, Hanna and Little, 1992). The Fort St. John Group, in which the Shaftesbury Formation is included, extends into the northeast and also outcrops along the Scatter and Liard Rivers (Stott, 1982). The Cretaceous clay shales contain bentonite and bentonitic-rich beds that allow the rock mass to fail at low angles (8° to 15°) (Severin, 2004). This means that, given the right conditions, slope angles as low as 8° may be susceptible to landsliding. Accordingly, slopes >10° are highlighted in Figure 1 and are used to help identify areas of northeast BC that require further study. The state of knowledge on the distribution and extent of these bentonite beds is incomplete.

The slope failure-type in bedrock is structurally controlled by the regional dip of bedrock (Severin, 2004). If the shale beds dip toward the bottom of the valley, the failures are commonly long, translational failures that often form a large landslide complex extending beyond the valley crest and incorporating several sections of the river valley slope. If the shale beds dip away from the bottom of the valley, the failure type tends to be shorter and have more of a rotational component to the slide. The river valleys that allow the bentonite and/or the clay shales to be undercut and be exposed in the valley walls are most susceptible to producing these large translational failures (Severin, 2004). These river valleys are highlighted in Figure 1 as areas with slopes greater that 10°.

The low angle bedrock failures in northeastern BC are common; however there are few technical reports on their failure mechanisms and, accordingly, failure mechanisms for these slope instabilities are still poorly understood. Bidwell (1999) revisits the 1957 Peace River Bridge failure on the north side of the Peace River near Taylor; Hungr has reviewed bedrock controlled slides as part of the BC Hydro Site C Dam study (1981) and in the Scatter River area (1984). Imrie (1991) wrote about how the Shaftsbury Shale responds when it is unloaded from construction or landslide movement. There are technical papers written on shale failures in the Albertan Prairies (Miller 2002, Miller and Cruden 2001, Miller, 2000, Cruden 1997 and 1995, Lu et al 1998, and Cruden et al, 1993., 1991, 1990 , Thompson and Morgenstern, 1979) that have concepts that may be applied to northeastern BC. A thorough review of these technical reports is recommended to further refine the proposed locations of more detailed study and setbacks from valley crests.

Along the western boundary of the study area along the eastern edge of the Canadian Cordilleran, mountain top deformation occurs. This deformation is slow downslope creep and sagging of mountain ridges and is independent of a particular rock formation. Downslope deformation can progressively load a pipeline to the point of rupture. Deformation also increases maintenance costs and the likelihood of fill failures along access roads. The slow mountain top deformation creates long linear cracks (sackung) and can be the precursor to rock and debris avalanches (Geertsema et al 2006) that entrain unconsolidated materials at the base of the slope. These debris avalanches can run out for long distances, up to 3 km. The process is very difficult to predict from terrain stability maps. Lineament mapping from airphotos is required to locate sackungen and evidence of deforming ridges.

3.4.2 Surficial Materials

Surficial geology has been mapped through the entire study area at to a scale of 1:5,000,000 (Fulton 1995) and in pockets throughout northeastern British Columbia, down to 1:20,000 scale. Figure 1 shows the spatial distribution of these surficial geology and terrain stability mapping studies. The 94A, 93I, 93O, 93P mapsheets have been mapped by Mathews (1978 and 1980) and the 94A mapsheet again by Reimchen (1980) and most recently by Hartman (2005). The 93N, 94B, and 94C mapsheets in the Williston Lake area have been mapped by Rutter (1977) and Bednarski (2005) has mapped the 94P12 and 94P13 1:50,000 scale mapsheets and the 1:250,000 scale 94G mapsheet (Bednarski, 2000). Description of surficial geology in 93P and 94A mapsheets provide surficial and glacial information to mining and industry (Bobrowsky et al, 1991; Bobrowsky and Smith, 1992).

Problematic surficial geology units in northeastern BC consist of the valley fill sediments, colluvial aprons and unconsolidated glacial lake (glaciolacustrine) clays. Valley-fill sediments consist of interbedded clay, silt and sand that were deposited in glacially ponded water. These units often have highly plastic clay interbeds that fail. Typically there are many different interbeds that fail, not one single distinct highly plastic layer, giving rise to multi-levelled failures with up to 4 or 5 distinct failure planes. These failures occur during initial downcutting of the river and may occur in stages or as a re-activation of old failures. The valley-fill units are usually located along the current water courses in northeastern BC; however, very little is known about the pre-glacial topography that controls the subsurface extents of the valley fill sediments. Understanding these extents, say through geophysical surveys, also helps define the potential horizontal and vertical extents of these slope instabilities.

Much work has already been done within the 94A NTS mapsheet, especially along the Peace River valley slopes. Thurber (1978, 1981, 1990) has reviewed the shoreline stability as part of BC Hydro's Site C Dam Study and Severin (2005) has mapped the landslides along the valley walls of the Peace, Beatton, Halfway, Pine, Moberly, and Blueberry Rivers. Jones (1999) has also reviewed the North Beatton River valley walls. Harbricht (1988, 1989, 1990a, 1990b, and 1991) and Raymond et al (2002) have investigated landslides affecting the highway in this mapsheet. Bidwell (1999) has also reviewed the 94A mapsheet and reviewed slope instabilities along the valley slopes opposite Taylor BC, slope instability near the Fort St. John sewage lagoons, and the 1974 failure at Mile 716.7 on the CN Rail mainline. Larger failures that have occurred in this valley-fill terrain unit include the Attachie (Fletcher et al., 2002; Evans et al, 1996; Hungr, 1982; and Thurber, 1973), Halfway Hill (Coulter, 1973), and the Big Bam Ski Hill (Zandbergen, 2000; Bidwell, 1999) slides.

Mapsheets 94G and 94J have been recently mapped for surficial geology by Dyke and Sladen of the GSC and will be published in 2006. In these mapsheets, the problematic terrain units are colluvial aprons found at the base of cliffs along the rivers. These colluvial aprons fail in a slow creep, but can move as much as 2 m/year. Future surficial geology mapping should include the mapping of these fans and cones.

Unconsolidated glacial lake clays have been mapped throughout northeastern BC. The clay deposited by Glacial Lake Peace is highly plastic and, when in contact with stiff till at depth, forms retrogressive earth flows that can extend beyond the limits of the valley crest. This type of failure has been identified by Geertsema et al (2006), Severin (2005), Geertsema and Schwab (2004), Bobrowsky and Smith.(1992) and by Geertsema and Clague (2006) in the Halden Creek area (mapsheet 94J)

In general terms, any glaciolacustrine units in northeastern BC should be considered susceptible to landsliding. Mapping the vertical and horizontal extents of the this soil type, especially near river valleys, will help define areas requiring further study and will help oil and gas development avoid or design through these challenging geological conditions.

3.4.3 Permafrost

Discontinuous permafrost and, due to changing climatic conditions, relict permafrost also exists in many areas of northern British Columbia. Degrading and relict permafrost has been identified as a cause of many low angle failures in surficial materials (Dyke personal communication; Bednarski, 2005). The excess water from the permafrost may also contribute to some bedrock failures. Although the extent of the discontinuous permafrost and fossil permafrost is unknown at this time, Geertsema (personal communication) suggests that northeast facing valley walls within the north and northwestern sections of the study may be relatively more susceptible to permafrost degradation. Like glaciolacustrine soils and Cretaceous clay shales, mapping the vertical and lateral extents of discontinuous and relict permafrost will help oil and gas development prepare for through these challenging geological conditions.

3.4.4 River Valleys

River valleys in northeastern BC, such as the Peace River, Beatton, Halfway, Sikanni, Buckinghorse, Scatter, and the Halden have down-cut into lacustrine soils and clay shale bedrock units exposing weak layers that form landslide failure planes (Thurber 1978, 1981, and 1990). The areas in and around any river valley that cuts into lacustrine materials and the clay shale bedrock should be considered susceptible to landsliding and creep failures (Carabetta and Leighton, 1984). Accordingly, the valleys and the terrain behind the valley crest need to be identified as potential problem areas so oil and gas development can avoid or design through these challenging geological environments.

3.5 Industry Management of Geohazards

CN Rail (formerly BC Rail) has documented numerous grade settlements and landslides along portions of its track that traverses into the river valleys of the Peace River. This includes the section of the Fort. St. John Subdivision that climbs up the Peace River valley slope near Taylor BC south of Fort St. John (Pritchard, 2005; Maber and Stewart, 1976). Due to the large problem-areas that the track traverses, CN is forced to adopt a reactive approach when dealing with these creeping ground conditions. Grade failures and settlement problems are fixed when required or maintained on an annual basis. It is not economically feasible to re-route the railway and avoid these ground movement problems.

Ministry of Transportation (MoT), like CN Rail, also adopts a reactionary approach when dealing with ground movement hazards. Many kilometres of highway traverse river valley slopes susceptible to landsliding. Some sections of highway have been, or could be, re-routed to avoid the geotechnical problems. MoT has expressed and interest in having these problem areas delineated to effectively plan the relocation of the roads. MoT has also expressed an interest in participating in and using a centralised online database and mapping application to help organize and delineate ground movement geohazards in northeastern BC.

Transmission pipeline companies such as Duke Energy and Terasen Gas are very susceptible to ground movement hazards because their pipelines are usually buried within the problematic ground. Slow and prolonged creep style ground movement, that progressively loads the pipeline, often does not provide significant evidence of its occurrence (such as cracks and scarps, etc.) nor does it require overly steep (>20 degree) slopes to occur within (Sladen and Dyke 2004; Cavers, 1998). Degrading permafrost also contributes to creep style ground deformation. Surficial geology type and landslide inventory maps are required to identify areas were landsliding and soil creep are most likely to be present.

3.6 Analysis of Acquired Data

Considering the state of knowledge described in Section 3.4 and the data available at the time of this study, an analysis was performed within a GIS to help identify 1:20,000 scale mapsheets in northeast BC requiring bedrock and/or surficial geology mapping and a landslide inventory.

The analysis consisted of identifying all 1:20:000 scale mapsheets that:

- are contained within the OGC study area, AND
- do not contain a Terrain Stability Mapping study, AND
- do not contain landslides from the Severin (2004) database, AND

- are contained within 1:50,000 scale mapsheets containing existing pipeline networks, AND
- contain slopes greater than 10°, AND

contain:

- a documented landslide, OR
- an existing ground movement related pipeline incident before January 29 2004, OR
- glaciolacustrine geology, OR
- Shaftsbury Shale, OR
- Cretaceous shale within the Fort St. John Group.

The identified 1:20,000 scale mapsheets are outlined in red in Figure 1. There are approximately 160 mapsheets, however, some additional data acquisition and review of the acquired literature would reduce this number, and accordingly, this is recommended before any 1:20,000 scale mapsheets are commissioned for further study. The purpose of further study would be to map the lacustrine geology and characterise the landslides within the identified mapsheets in order to refine the results of a preliminary landslide susceptibility map proposed in Section 5.0.

4.0 CONCLUSIONS

As described in Section 3.4landscape features susceptible to landslide hazards that may be encountered during resource development include:

- Glaciolacustrine surficial geology units that contribute to large rotational landslides, creep and settlement.
- Exposed Shaftsbury Formation and portions of Ft. St. John Group that contribute to large translational landsliding and creep deformation.
- Alluvial/Colluvial cones that contribute to creep deformation.
- Areas of degrading permafrost that contribute to differential settlement and triggering of landslides
- Valleys and gullies that contribute to exposing Shaftsbury Formation and portions of Ft. St. John Group
- Slopes greater than 10° that contribute to landsliding

Prior to routing and construction, oil and gas development must be made aware of problematic areas to ensure that facilities avoid problematic areas and are set back a sufficient distance from the valley crest. It is important to know the vertical and horizontal extents of these key geological units and geomorphic landforms to effectively commission more detailed studies and/or build a useful development zoning or landslide susceptibility map. A discussion around the development of this map is provided below.

The current list of 1:20,000 scale mapsheets missing information such as more detailed geology, landslides or a pipeline incident is considerable and it may be unaffordable to map the surficial geology or conduct a landslide audit in all of these sheets. The number of 1:20,000 scale mapsheets outlined in red in Figure 1 can be reduced if the more information is included and the GIS analysis is performed again. The list of this additional information is provided below in Section 5.1.5.

5.0 RECOMMENDATIONS

The OGC ultimately requires a permitting process based on prioritised areas within northeast BC that are susceptible to landslide hazards. To identify these areas in an economical manner we propose that a simple landslide susceptibility map be constructed.

5.1 Landslide Susceptibility Map

A susceptibility map aggregates factors that contribute to landsliding, such as unfavourable geology, slope, and evidence of previous landsliding, in a systematic manner and defines areas that are currently, or potentially, unstable. This map could be classified into to 3 or 5 classes of landslide susceptibility and each class would require a set of due diligence criteria that an oil and gas development company would be encouraged to follow in order to minimise the impacts on ,and risk to their, development.

5.1.1 Map Scale

Currently the northeast is covered with a mosaic of geology and landslide information at varying scales and accuracies. Ideally, a susceptibility map at 1:20,000 scale is required as this scale is relatively practical to construct and affords the greatest utility to the oil and gas developer. However a map at this scale requires data at 1:20,000 scale, and at this time, that level of detail or accuracy is not available throughout in the northeast. Fortunately, in the short term, a susceptibility map can be built with the data currently at hand. Some areas of the susceptibility map may rely on1:5 million scale surficial geology data as input and some areas will use surficial geology derived from current 1:20,000 scale Terrain Stability Mapping. Areas where smaller scale data is used can be commissioned for further detailed study if the susceptibility is medium to high or the level data accuracy is unacceptable.

5.1.2 Map Inputs

At this time the following minimum information is required to build the susceptibility map.

- Cretaceous shale bedrock
- Glaciolacustrine surficial geology
- Documented landslide points
- Ground movement pipeline incidences
- Slopes greater than 8 to 10 degrees

As more information at a larger scale becomes available, or new contributing factors become apparent, such as the presence of permafrost, then the boundaries within the susceptibility will change, become more accurate, and the map can be reclassed. The map will be dynamic with improved accuracy as more information is added to it.

5.1.3 Landslide Susceptibility Algorithm

Landslide susceptibility mapping, hazard mapping, and more recently risk mapping have gained popularity since the introduction of personal computer and GIS in the early 1990's. There are a number of approaches to building and classifying the maps. The approaches used can be subjective or objective, empirical or deterministic, and qualitative or quantitative. Some approaches create landslide density or distribution maps, landslide susceptibility or hazard maps and in rarer cases, landslide risk maps (Leir et al 2004). In BGC's experience, simple algorithms combined with an awareness of the limitations in the input data are the most cost effective approaches to landslide mapping. Additionally, a simple algorithm is easier to explain to the users of the map resulting in an increased utility of the map and confidence in the result.

At this time we propose a simple index overlay approach for building the susceptibility map. Table 1 below provides and example of how a susceptibility map relates to the permitting process. In general the greater the number unfavourable conditions exist in given area the greater the landslide susceptibility and the stricter the requirement are for permitting. Details of this approach are not considered here at this time and require further discussion with the OGC.

Table 1 – Example of how landslide susceptibility can relate to permitting requirements

<table>
<tr><th>Susceptibility</th><th>Slopes > 10°,</th><th>Unfavourable Glaciolacustrine Geology</th><th>Unfavourable Bedrock Geology</th><th>Documented Landslide Nearby</th><th>Pipeline Incident Nearby</th><th>Permitting Action</th></tr>
<tr><td>very high</td><td>yes</td><td>yes</td><td>yes</td><td>yes</td><td>yes</td><td>Detailed Assessment</td></tr>
<tr><td>high</td><td>yes</td><td>yes</td><td>yes</td><td colspan="2">yes OR yes</td><td>Detailed Assessment</td></tr>
<tr><td>medium</td><td>yes</td><td colspan="2">yes OR yes</td><td colspan="2">yes OR yes</td><td>none</td></tr>
<tr><td>low</td><td>yes</td><td colspan="2">yes OR yes</td><td>no</td><td>no</td><td>none</td></tr>
<tr><td>very low</td><td>no</td><td>no</td><td>no</td><td>no</td><td>no</td><td>none</td></tr>
</table>

This simple approach can be applied at all map scales and can be started at 1:250,000 scales. The boundaries of soil units and more landslides and indecent can be added as information become available.

The development of a hardcopy landslide susceptibility map and preliminary permitting protocols would require approximately 200 person hours (2 months) and $20,000 to complete.

5.1.4 Including Setback Distance

Landslides in the northeast can become larger by retrogressing upslope or back into the valley plateau. Oil and gas development should avoid encroaching into areas where a landslide may retrogress. The length of the maximum retrogression is controlled by site-specific factors and usually requires a slope stability analysis to predict its limits. We do not recommend modelling a regional set back distance using GIS. However a conservative approach may be adopted where a setback is defined subjectively from a review of the landslide literature and encroachment into the setback zone would then trigger a more detailed site-specific deterministic analysis that could, in turn, refine the preliminary setback distance.

The addition of a regional set back distance would require approximately 100 person hours (1 months) and $10,000 to complete.

5.1.5 Further Data Acquisition

The accuracy and usefulness of a susceptibly map is increased as larger scale and more accurate information is added to the susceptibility model. As mentioned earlier, susceptibility map can be built at any scale but the accuracy is dependent on the scale and accuracy of the information. We recommend that the following list of data inputs be added to the current information base prior to starting the construction of a susceptibility map. Acquiring this information is practical and affordable and will also reduce the number of 1:20,000 scale mapsheets with information gaps, as discussed in Section 3.6

- FPC and FRBC terrain stability mapping listed as publicly available but could not be located as per Section 3.2.1
- Polygons of surficial geology digitized from hardcopy surficial geology maps.
- A more continuous pipeline map layer showing larger diameter transmission pipelines
- A digital map layer of existing and potential gas fields to determine areas impacted and potentially impacted by oil and gas development
- Updated (>January 2004) pipeline incident data with GPS coordinates for each incident
- Extents of discontinuous permafrost and relict permafrost
- Geohazard locations and problem areas identified by Duke Energy and MoT
- Drill hole data supplied by Duke Energy
- Surficial geology maps and reports from BC Hydro.
- Terrain Stability Data from Canfor
- A more thorough review of documents assembled during the Data Acquisition Task of this study
- Geo reference the Ministry of Environment raster soils maps and attempt to use them in the analysis
- Digital vector versions of Bednarski (2005) maps
- Digital vector versions of the new Dyke 2006 surficial geology maps.
- Larger scale (1:20,000 or 1:50,000 scale) Digital Elevation Model (DEM)

We propose that this data acquisition be completed prior to building a susceptibility map and refining the list of 1:20,000 scale map sheet requiring stud, as defined in Section3.6.

The data acquisition task would require 200 person hours (2 months) costing approximately $20,000 to complete.

5.2 Publishing

The OGC should consider providing the public with access to the OGC Database and Google/ArcIMS mapping applications. Access to these resources will encourage private organisations to share their information and experiences with the OGC and their feedback will help steer the direction of future OGC initiatives in this area. Many organisations contacted during this project expressed a need/desire to have access to the literature review and data sources obtained in this study. At this time these website resources provide industry, universities, and government with convenient access to a literature review about the northeast. It is an excellent starting point for future research development projects and with the OGC or its partner as the database custodian, positions the OGC to be involved with these projects from the start.

The databases should reside on a web server and the custodian of the database should have a genuine stake in the functionality and content of the product. Diligent maintenance of the database is required to provide a quality service and product to the public. The custodian's reputation will be linked to this website. The custodian should be prepared to communicate with many stakeholders and consistently solicit requests for information updates from the industry and government with interest in the northeast. The success of the published website should be gauged by how much information is downloaded from the website.

The task would require $15,000 (150 hours) to refine the current OGC database and Google Earth/ArcIMS mapping application and 8 person hours per week to maintain it.

6.0 CLOSURE

We trust this report meets your requirements and provides the OGC with a positive step towards an oil and gas permitting process. If you have any questions about the content of this report, please contact Mark Leir.

Yours sincerely,

BGC ENGINEERING INC.

per:

Jordan Severin, M.Sc., G.I.T.
Engineering Geologist

Reviewed by

Mark Leir, P.Eng., P.Geo.
Senior Geological Engineer

REFERENCES

Alexander, S. 1998. Preliminary Geotechnical Report - Canyon Road Slides, BC MoT, file # M44-16-31.

BC Hydro, 1990. Peace River - Site C Project, Reservoir Slopes, Task CL70, File #, H2243, 17p.

BC MoT, 1968. Report on Slide Activity, Slope Stability Factors and Remedial Measures at the Beatton River Slide.

Bednarski, J.M., 2000. 1:250,000 scale surficial geology of the Trutch mapsheet, GSC OF 3885.

Bednarski, J.M., 2005. 1:50,000 scale surficial geology of the Estsine mapsheet, GSC OF 4825.

Bednarski, J.M., 2005. 1:50,000 scale surficial geology of the Gote Creek mapsheet, GSC OF 4846.

Bidwell, A.K. 1999. Engineering geology of the Fort St. John area, M. Eng. Thesis., University of Alberta, 101p.

Bobrowsky P.T., Catto, N., and Levson, V. 1991. Reconnaissance Quaternary geological investigations in Peace River District, British Columbia, Geological Fieldwork 1990, BCGS Paper 1991-1, , pp.345-358.

Bobrowsky, P.T. and Smith, C.P. 1992. Quaternary studies in the Peace River district, 1990: Stratigraphy, mass movements and glaciation limits, Geological Fieldwork 1991, BCGS Paper 1992-1, p 363-374.

Bostock, H.S. 1948. Physiography of the Canadian Cordillera with special reference to the area north of the 55th parallel. Geological Survey of Canada. Memoirs 247.

Carabetta, D.G., and Leighton, J.C. 1984. Elleh Creek Landslide on B.C. Railway's Fort Nelson Subdivision, Proceedings, 37th Canadian Geotechnical Conference, pp, 65-73.

Cavers, D.S. and McClarty, E.A. 1998. Use of surface pipeline segments to mitigate slide problems on the Fort Nelson natural gas mainline, 1998 International Pipeline Conference, ASME, pp 151-158.

Cornish, L.J. and Moore, D.P. 1985. Dam foundation investigations for a project on soft shale, . BC Hydro, pp 171-178.

Coulter, T.S. 1973. Report on the Stability of the South Bank of the Peace River near Halfway River, BC MoT, File # L4-MG8-336.

Coulter, T.S. 1988. Beatton River Crossing, Detailed Geotechnical Investigation, Thurber, File # 17-604-40.

Cruden, D.M., Keegan, T.R., and Thompson, S. 1993. The landslide dam on the Saddle River near Rycroft, Alberta, Canadian Geotechnical Journal, 30, pp1003-1015.

Cruden, D.M., Keegan, T.R., Thompson, S., and McKlung, J.E. 1991. The landslide dam on the Saddle River near Rycroft, Alberta, Proceedings, 44th Canadian Geotechnical Conference pp. 25-1 - 25-8.

Cruden, D.M., Lu, Z-Y., and Thomson 1997. The 1939 Montagneuse River landslide, Alberta, Canadian Geotechnical Journal, 34, pp 799-810.

Cruden, D.M., Lu, Z.-Y., Thompson, S. and Weimer, N. 1995. Alberta's Largest Historic Landslide, Proceedings, 48th Canadian Geotechnical Conference, pp. 893-900.

Cruden, D.M., Ruel, M., and Thompson, S. 1990. Landslides along the Peace River, Alberta, Proceedings, 43rd Canadian Geotechnical Conference, 1, pp.61-67.

Evans, S.G., Hu, X-Q., and Enegren, E.G. 1996. The 1973 Attachie Slide, Peace River Valley, near Fort St. John, British Columbia, Canada: A landslide with a high-velocity flowslide component in Pleistocene sediments, Landslides, Balkema, Rotterdam,

Fletcher, L., Hungr, O. and Evans, S.G. 2002. Contrasting failure behaviour of two large landslides in clay and silt, Canadian Geotechnical Journal 39, pp. 46-62.

Fulton, R.J. 1995. 1:5,000,000 Scale Surficial Materials of Canada, GSC Map 1880A.

Geertsema, M. and Clague, J.J. 2006. 1000-year record of landslide dams at Halden Creek, In-Press, Hydromorphic hazards in northern British Columbia, 29 pp.

Geertsema, M. and Schwab, J.W. 2004. Challenges with terrain stability mapping in northern British Columbia - the special case of large complex landslides, Proceedings, 57th Canadian Geotechnical Conference, 4C, pp 11-18.

Geertsema, M., Clague, J.J., Schwab, J.W., and Evans, S.G. 2006. An overview of recent large catastrophic landslides in northern British Columbia, Canada, Engineering Geology, 83, pp.120-143.

Geertsema, M., Hungr, O., Schwab, J.W. and Evans, S.G. 2006. A large rockslide-debris avalanche in cohesive soil and Pink Mountain, northeastern British Columbia, Canada, Engineering Geology, 83, pp 64-75.

Hanna, A. and Little, T.E. 1992. An estimate of rebound potential of the Shaftesbury Shale at a damsite in British Columbia, Proceedings, 38th Canadian Geotechnical Conference, 29, pp. 375-392.

Harbricht, T.N. 1988. Stability Investigation - Cache Creek Hill Slide, BC MoT, file # M44-16–02.

Harbricht, T.N.1989. Report on Stability Investigation for 0.9 km Slide, BC MoT, file # M44-16-40.

Harbricht, T.N 1990. Report on Stability Investigation, Montney Hill Slide, BC MoT, file # M44-16-28.

Harbricht, T.N. 1990. Stability Investigation for Peace View Hill Slide, BC MoT

Harbricht, T.N. 1991. Report on Stability Investigation for Upper Montney Hill Slide Area, North Peace District, BC MoT, file # M44-16-33.

Hartman, G., 2005. M. Sc. Thesis Simon Fraser University

Holland, S.S. 1964. Landforms of British Columbia, a physiographic outline. B.C. Department of Mines and Petroleum Resources. Bulletin 48, 138 p.

Hungr, O. 1981. Site C Reservoir, A Review of the Mobility of Bedrock Landslides, Thurber, file # 15-2-169, 27p.

Hungr, O. 1982. Feasibility of stabilizing the Attachie slide and adjacent areas, Site C reservoir, Thurber, file # 15-2-169.

Hungr, O., Gerath, R.F., and Morgan, G.C. 1984. Landslides of the Scatter River area, northeastern British Columbia, Proceedings, 37th Canadian Geotechnical Conference. pp 113-119.

Imrie, A.S. 1991. Stress-Induced Response from both Natural and Construction-related Processes in the deepening of the Peace River Valley, B.C., Canadian Geotechnical Journal, 28, pp 719-728.

Jones, I. 1999. North Beatton River Valley Wall Instabilities, Geotechnical Assessment, Geo-Engineering.

Leir, M., Mitchell, A.M. and Ramsay, S. Regional landslide susceptibility mapping for pipelines in British Columbia. Proceedings, 57th Canadian Geotechnical conference, Quebec City, CGS, 5C, p 19-27.

Lu, Z.Y., Cruden, D.M., and Thomson, S. 1998. Landslides and preglacial channels in the western Peace River lowland, Alberta, Proceedings, 51st Canadian Geotechnical Conference, pp 267-274.

Maber, C.T., and Stewart, P.. 1976. The Peace River Hill Landslide, Proceedings, 29th Canadian Geotechnical Conference, IV, pp 33-47.

Mathews, W.H. 1978. 1:250,000 scale surficial geology, Charlie Lake (94A), British Columbia Map, GSC Map 1460A.

Mathews, W.H. 1978. Quaternary stratigraphy and geomorphology of Charlie Lake (94A) map-area, British Columbia, GSC Paper 76-20, 21p.

Mathews, W.H. 1980. 1:250,000 scale surficial geology, Dawson Creek (093P), British Columbia, GSC Map 1467A.

Mathews, W.H. 1980. Retreat of the last ice sheets in northeastern British Columbia and adjacent Alberta, GSC Bulletin 331, 22p.

Miller, B.G.N. 2000. Two landslides and their dams, Peace River lowlands, Alberta, M.Sc. Thesis. University of Alberta, 149p.

Miller, B.G.N., and Cruden, D.M. 2001. Landslides, landslide dams, and the geomorphology of tributaries in the Peace River Lowland, Alberta, Proceedings, 54th Canadian Geotechnical Conference, pp 363-370.

Miller, B.G.N., and Cruden, D.M. 2002. The Eureka River landslide and dam, Peace River lowlands, Alberta, Canadian Geotechnical Journal, 39, 863-878 p.

Pritchard, M. 2005. Site Inspection, CN Fort St. John Subdivision, Mile 716.2 and 720.0, .

BGC Engineering file # 0034-1943, 2p.

Raymond, E.L., Evans, S.G., and Couture, R. 2002. Geological log of two boreholes at 2001 Cecil Lake Road landslide, near fort St. John, British Columbia, GSC OF 4294.

Reimchen, T.H.F. 1980. 1:250,000 scale surficial geology, Dawson Creek (093P), British Columbia, GSC Map 1467A.

Rutter, N.W. 1977. Multiple glaciation in the area of Williston Lake, British Columbia, GSC Bulletin 273.

Sargent, D. W. and Cornish, L.J. 1985. Water susceptibility of Shaftsbury shale, Proceedings, 38th Canadian Geotechnical Conference, pp 1-10.

Severin, J. 2004. Landslides in the Charlie Lake Map Sheet, Fort St. John, M. A. Sc. Thesis, UBC.

Sladen, W.E. and Dyke, L.D. 2004. Rainfall, pore water pressure, and slope movement in silts and shales near Fort St. John, British Columbia, Proceedings, 57th Canadian Geotechnical Conference, 1C, pp 38-44.

Stott, D.F. 1982. Lower Cretaceous Fort St. John Group and Upper Cretaceous Dunvegan Formation of the Foothills and Plains of Alberta, British Columbia, District of Mackenzie, and Yukon Territory. Geological Survey of Canada, Bulletin 328, 124p.

Thurber, 1973. Inspection of the Attachie Landslide.

Thurber, 1978. Site C Reservoir, Shoreline Stability Assessment, File # 15-2-62, 75p.

Thurber, 1981. A report on field inspection of overburden landslides, Site C Reservoir, File #15-2-169-A.

Thompson, R.I. 1975. Bedrock geology of the Beatton River (94H), Fontas River (94I), and Petitot River (96P) Map Areas, Northeastern British Columbia, GSC Paper 75-11.

Thompson, R.I. 1986. 1:250,000 scale bedrock geology, Halfway River, British Columbia, GSC Map 1634A.

Thompson, S. and Morgenstern, N.R. 1979. Landslides in Argillaceous Rock, Prairie Provinces, Canada, in Rockslide and Avalanches, Elsevier Press, Amsterdam, The Netherlands, pp 515-540.

Zandbergen, J. 2000. Investigation of the slope failure at the Big Bam ski hill near Taylor, British Columbia, B. Sc. Thesis, UBC, 66 p.

APPENDIX I

FIGURE 1 OVERVIEW MAP

APPENDIX II

CONTACTS AND INTERVIEW RESULTS

<table>
<tr><th>Contact</th><th>Company</th><th>BGC</th></tr>
<tr><td>Peter Bobrowsky
Peter.Bobrowsky@nrcan-rncan.gc.ca
613-947-0333</td><td>Geological Survey of Canada, Ottawa</td><td>JS,
March,
2006</td></tr>
<tr><th colspan="3">Information</th></tr>
<tr><td colspan="3">
The GSC has a landslide database, suggests we use some of that.
Peter has compiled some of Thurber’s work, says either Adrian Hickin or Ray Lett may have them, gave numbers
Gave Number for GSC GIS guy, Alan Grignon (613) 947-8773 and mentioned to call
Says all glaciolacustrine units, not just Peace River , where ponding occurred due to ice dams are unstable, ranging from Fort St. John to Yukon border
Low angle detachment flows in permafrost
Clay shale beds are a problem
</td></tr>
<tr><th colspan="3">Follow-up Tasks</th></tr>
<tr><td colspan="3">
BGC contacted the GSC to obtain landslide information from their database, but due to “legal”? reasons Alan Grignon at the GSC said the GSC cannot release any details for each landslide – no names, type, nothing…just coordinates….
</td></tr>
</table>

<table>
<tr><th>Contact</th><th>Company</th><th>BGC</th></tr>
<tr><td>Dean Daniel
Area Manager (Roads)
dean.daniel@gov.bc.ca
(250) 787-3335</td><td>Ministry of Transportation, Peace District, Fort St John.</td><td>JB,
March 3,
2006</td></tr>
<tr><th colspan="3">Information</th></tr>
<tr><td colspan="3">
FSJ office in charge of roads and highways in region (generally south and east-west of FSJ) , Public Works is in charge of the Alaska Highway north of approx. Wonowon
Provided contact at the PWGSC in Ft. Nelson
Most slope stability issues occur in FSJ region and south, west and east. There are many sites along the Peace River towards Hudson's Hope
Slope stability issues revolve around pore water pressures, no note of seismic triggers.
Failures may occur during rainstorms with high pore water pressures or during dry weather
Failure planes tend to be surficial however there are many deep seated slides; failure planes are generally within the glacial lacustrine in the region, a layer of bentonite near the contact with bedrock, or at the contact with shale or sandstone
2001 was a heavy rainfall year with various landslides; noted that various scientists from around the world visited the region during this time
Provided ground photos (jpg) of several major slides in the region and does have more available with UTM coordinates
Provided contact info. for Ian Harder of Harder Associates – a geotechnical engineer used as a contactor for MoT in the region based out of FSJ
Provided contact information for the MoT geotechnical Engineers for MoT in Prince George; this office has all engineering and geotechnical information for the entire north half of the province from Prince George northward.
Provided photos and UTM coordinates of the Beatton slide and the Cecil Lake slide that took out road corridors
</td></tr>
<tr><th colspan="3">Follow-up Tasks</th></tr>
<tr><td colspan="3">
Contact MoT in Prince George for geotechnical report, landslide site info and locations
Bill Eisbrenner (Geo/ Mat Eng 250-565-6680
Heidi Evensen (Geotech Design Eng) 250-565-6681
Gordon Hunter (Geotech Design Eng) 250-565-6684
Contact PWGSC in Ft. Nelson
Paddy Whidden (Superintendent of Highways) 250 774-6956
Contact Ian Harder of Harder Associates in Fort St. John
May provide insight into the geohazard problems in the region and possibility of obtaining reports
</td></tr>
</table>

Contact	Company	BGC
Larry Dyke Larry.Dyke@nrcan-rncan.gc.ca (613) 996-1967	Geological Survey of Canada, Ottawa	JS, March, 2006

Information

- He conducting a landslide/Terrain Mapping/Pipeline interaction study for Mapsheets 94J and 94G at 1:50,000
- They will be done and published by June and will be happy to share the information
- He says the big problem in these areas is colluvial aprons at base of slopes. These are the main units affecting pipeline stability
- Fail by slow creep, not catastrophic, but up to 2 m a year
- Permafrost detachment failures in Trutch (094G) mapsheet are also a big problem
- Lacustrine units near Prophet River are Peace-like and fail similarly but not as complex
- Says we should get a copy of Greg Hartman thesis at SFU

Follow-up Tasks

- Obtain Greg Hartman thesis at SFU
- Obtain from GSC the results of 1:50,000 scale surficial geology mapping for mapsheets 94J and 94G

Contact	Company	BGC
Steven Garner, P.Eng Geotechnical Dam Engineer steve.garner@bchydro.com 604-528-2236	BC Hydro, Burnaby	JS, March 2006

Information

- Gave contact for seismic hazards (Tim Little, 604-528-2464)
- Seismic issues in this area have gone up over past years·
- Reservoir stability has responded to seismic issues·
- Reservoir related slides in Peace Canyon·
- Big issue is weak shale beds with bentonite interbeds along Peace River and others
- Can follow shale bed Marker from Peace River to Scatter River (using geophysics). He would like to see this delineated

Follow-up Tasks

- Contact John Psutka and Martin Lawrence at BC Hydro
- Visit their office to obtain copies of report and maps, if possible.
- BC Hydro may have some information on Peter Jordan's rerouting of the Alaska highway for the Scatter River Dam

Contact	Company	BGC
Marten Geertsema, P.Geo Regional Geomorphologist Marten.Geertsema@gov.bc.ca (250)-565-6923	Ministry of Forests Prince George, BC	JS, March 17, 2006
Information		
• provided several of his several engineering geology papers • Terrain stability mapping is a real challenge in northeast BC as described in his paper presented in Quebec City, 2005 • Need a better understanding of bedrock topography, permafrost locations, fossil permafrost locations, of slide mechanisms of undrained loading when rock falls on soil, and slow moving creep deformation • Indicates that mountain deformation is a problem and the number of large landslides is increasing • Mentions that the Tetsa River has permafrost so number of other northeast facing slopes likely will likely have permafrost problems too. • Would like to see temperature profiling		
Follow-up Tasks		

Contact	Company	BGC
Bob Gerath, P.Geo Senior Engineering Geologist rgerath@van.thurbergroup.com (604)684-4384	Thurber Engineering Ltd., Vancouver	JS, March 2006
Information		
• Conducted an extensive Terrain Mapping Exercise with O. Hungr (UBC) of the Scatter River Area for BC Hydro • Low angle failures at Beaver Crow, along Halfway and Toad Rivers • Flowslides in Liard Basin • Both Rock and Quaternary failures in Liard Basin • Permafrost melting W/NW of Fort Nelson • Says BC Hydro has bound atlases with report - Thurber has hard copy if we get permission from Hydro to release the report		
Follow-up Tasks		
• Obtain permission form Hydro to obtain reports from Thurber		

<table>
<tr><th>Contact</th><th>Company</th><th>BGC</th></tr>
<tr><td>Ian H. Harder, P.Eng.
Phone: (250) 785-4972
Fax: (250) 785-9083
Cell: (250) 261-1052
www.harderassociates.ca</td><td>Harder Associates Engineering Consulting Inc.
11927 - 242 Grandhaven Road
P.O. Box 6488
Fort St. John, British Columbia
V1J 4H9</td><td>JB,
March 4,
2006</td></tr>
<tr><th colspan="3">Information</th></tr>
<tr><td colspan="3">
Every substantial hillside and valley in the Peace Country is a geohazard. It would be very difficult to identify which slopes are stable and which pose a threat to potential movements. Most river valleys are the result of valley fill (Till of various consistencies and residual soils) following six or seven glacial events. The bedrocks consist of clay shale, siltstone or sandstone and are very indurated, weak and water bearing. Depending on the type of winter, the vadose zone can vary significantly and is very instrumental in instigating a lot of shallow slips and translational movements.
There is a saying in northeast BC: “Everything is flat in the Peace country, and whatever isn’t, really wants to be”. Having said this, I think most substantial slopes need to be investigated, analyzed and engineered individually because of the every varying and changing site boundary conditions. Most major rivers (Peace, Pine, Beatton, Halfway, Fort Nelson, Petitot, Graham, Cypress) in the western Canadian Sedimentary Basin are highly susceptible to slope failure and the smaller rivers, creek and streams are suspect as well.
He is a little apprehensive about a data base system and lean more to a site specific approach.
</td></tr>
<tr><th colspan="3">Follow-up Tasks</th></tr>
<tr><td colspan="3"></td></tr>
</table>

<table>
<tr><th>Contact</th><th>Company</th><th>BGC</th></tr>
<tr><td>Oldrich Hunger, P.Eng.
Professor
ohungr@eos.ubc.ca
604-822-8471</td><td>UBC, Vancouver</td><td>JS,
March 3,
2006</td></tr>
<tr><th colspan="3">Information</th></tr>
<tr><td colspan="3">
Has conducted several investigations in the Peace River Area for Thurber on shoreline stability and slope stability
Conducted a terrain analysis study on Scatter River for BC Hydro. He has a copy and will give it to us with BC Hydro permission
He suggests that the OGC should determine the locations of the slide and the mechanisms. We need to understand mechanisms in order to apply it to larger areas
</td></tr>
<tr><th colspan="3">Follow-up Tasks</th></tr>
<tr><td colspan="3">
Obtain permission form Hydro to obtain Scatter river reports/maps from Thurber
</td></tr>
</table>

Contact	Company	BGC
Peter Jordan, Regional Geomorphologist Peter.Jordan@gov.bc.ca 250 825-1119	Ministry of Forests Nelson, BC	JS, March 17, 2006
Information		
• Peter did a small job for BC Hydro for an area near Alaska Highway in 1985 but it was simply a reworking of Bob Gerath's work. Only ranked corridors for the highway. No new work was done. Project was done by Terra Environmental Consultants.		
Follow-up Tasks		

Contact	Company	BGC
Frank Maximchuk, P.Eng Senior Geotechnical Engineer fmaximchuk@geonorth.ca 250-564-4304	Geonorth Engineering Ltd.	AJ, March 2006
Information		
• Has completed the majority of his Peace work experience in the Southern Peace Region as subcontractor for MoT in Prince George • He Provided contact information for the MoT Geotechnical Engineers in Prince George • Slope stability issues caused by high pore water pressures • High pore water pressures (especially in June 2005) reactivated many existing creeps/slumps and caused some catastrophic failures • Noted movements typically occurred in overburden (interbedded glaciolacustrine and till (CI-CH)) or weak shale bedrock		
Follow-up Tasks		

Contact	Company	BGC
Brendan Millar P.Geo. MSc. Land Officer, Regional Client Services Brendan.Millar@gov.bc.ca 250-787-3481	Integrated Land Management Bureau, Ministry of Agriculture and Lands, Fort St. John	JB, March 3, 2006

Information

- Provided his Master's thesis on CD and 2 peer reviewed papers on the region
- His department is responsible for overseeing/permitting construction, mitigation and other land management issues for Federal and Provincially regulated pipelines, some roads and highways, river and flooding related issues, flare sites, quarries
- He suggested we contact Martin Geertsema (PhD on slope stability) working for MoF or Cato; Bobrowsky
- Data source suggestions:
  - Canadian Landslide Database (GSC)
  - Integrated Land and Resource Registry;
- Companies that he has dealt with in the region (possible sources for geotechnical reports):
  - Provident Energy
  - West Coast Energy
  - Duke Energy
  - Maurader Resources
  - KXL Resources
  - Encana (HDD)
  - Enbridge
- Geotechnical consulting companies that have worked in the region:
  - Thurber
  - EBA

Follow-up Tasks

- Integrated Land and Resource Registry: http://srmapps.gov.bc.ca/apps/mapview/
- Find a registry of oil and gas companies in the region and contact for data/ info contributions
- Contact EBA and Thurber to see if they can provide any information or leads (contacts to obtain permission for proprietary information)

Contact	Company	BGC
Ed McClarty Geotechnical Engineering Specialist emcclarty@duke-energy.com 250-262-3463	Duke Energy, Integrity, Technical Services, Fort St. John	JB, March 3, 2006

Information

- Duke Energy is regulated by the NEB not the OGC, therefore Duke may be willing to contribute information and data if there is a benefit to them (i.e. will the database be accessible to Duke?)
- Duke has LiDAR and orthorectified air photos for their RoWs.
- They may be willing to share air photos
- They have database of all slide locations in GIS and terrain mapping from original construction of ROW
- 1951 slide on a Peace River Crossing failed on bentonite layer
- Note that the majority of slides occur in the lacustrine clays or the clay-shale contact
- Duke has slope monitoring equipment in various locations
- They have done geotechnical drilling in at least 16 locations. This may be available.
- Duke suggested we contact AMEC in Ft. St. John because they do a lot of the geotechnical work in the region
- When asked about seismic data, he mentioned that most of the oil and gas exploration companies do the seismic surveys

Follow-up Tasks

- Find out if the OGC plans to make this site accessible to Duke Energy – if yes, Duke will likely be willing to contribute airphotos, drill holes logs, landslide database
- Contact AMEC in FSJ for information

<table>
<tr><th>Contact</th><th>Company</th><th>BGC</th></tr>
<tr><td>Heather Narynski, P.Eng.
Geotechnical Engineer (Northern Region)
Heather.Narynski@gov.bc.ca
(250) 565-6679</td><td>Ministry of Transportation, Northern Region
213-1011 Fourth Avenue
Prince George, BC V2L 3H9</td><td>ST,
March 15,
2006</td></tr>
<tr><th colspan="3">Information</th></tr>
<tr><td colspan="3">
Heather invited BGC to the Prince George office to review the geotechnical road files for information on natural landslides in the North Peace and South Peace districts.
Most file information pertained to road cut or road fill/shoulder failures along paved and/or government roads.
MoT does not have any systematic information, such as databases, to help manage their hazards.
None of the major road corridors have been systematically studied, to her knowledge.
MoT office does not do pre-emptive studies or surveys; rather they respond to reported road failures on a case-by-case basis. They do not have the mandate or the funds to do pre-emptive work.
They have walls of files and a computer listing of file title and file number but they do not have any database of locations of incidents. If they have an incident, they would go to their files and see if there was a record of previous problems. They have a large collection of historical air photos that cover most of the roads in their purview.
Critical landscape features susceptible to hazards that may be encountered by MoT are: steep slopes, silt- and clay-rich soils, migrating streams and cutbanks beneath road right-of-ways.
BGC demonstrated the OGC database with linked Google Earth to Heather and Gord Hunter.
</td></tr>
<tr><th colspan="3">Follow-up Tasks</th></tr>
<tr><td colspan="3">
Provide Heather and Gord Hunter with the link to access the completed OGC database.
BGC chatted briefly with Bill Eisbrenner, P.Eng., Regional Geotechnical & Materials Engineer, who is the manager of the MoT office. He was on his way out of the office and referred me to Heather and Gordon for the information we sought.
Heidi Evensen was not in the office. She has done a lot of work in the area and would be a good source to follow up with.
Bill Eisbrenner, P.Eng., Regional Geotechnical & Materials Engineer, Geotechnical & Materials Engineering Northern Region, #213 – 1011 Fourth Avenue, Prince George, BC, V2L 3H9; Tel (250) 565-6680; Fax (250) 565-6928; Cell (250) 960-9353; Email: Bill.Eisbrenner@gov.bc.ca
Gordon Hunter, P.Eng., Geotechnical Engineer (Northern Region), 250-565-6684
</td></tr>
</table>

Attempted calls as of March 17, 2006.

Steve Amonso –MoF	Left a message
Mike Bovis – UBC	Left a message
Caribou Road Services	Left a message
Drum Cavers – AMEC	Left a message
Dave Cruden – U of A	Left a message
Steve Evans – U of Waterloo	Left a message
Shane Kelly – AMEC (PG)	Left a message
Martin Lawrence – BC Hydro	Left a message
Nick Polysou – AMEC (PG)	Left a message
John Psutka – BC Hydro	Left a message
June Ryder	Left a message
Kevin Turner – MoF	suggested talking to Marten Geertsema

Danny Way	Peace District Forestry; provided phone number for resident engineer

APPENDIX III

INSTRUCTIONS FOR ACCESSING THE INTERNET DATABASE AND MAPPING APPLICATIONS

OGC Landslide Database

URL: http://www.bgcengineering.info/OGC
un: guest
pw: user

This database is where the landslide locations, jpg photos and GPS points of landslides, and relevant PDF reports are organised and stored.

Setting up a link between the OGC Landslide Database and Google Earth

Below are the instructions on how to link the above OGC Landslide database to your Google Earth software.

1. Open Google Earth.
2. Under "My Places", create a "Network Link". You can do this by right-clicking on My Places and selecting New Network Link.
3. In the Location textbox on the Network Link form enter:
   http://www.bgcengineering.info/OGC/kml_hazards.asp
4. In the Name textbox, enter "OGC Landslide Database".
5. The most current landslides and other layers should appear on the Google Map.

OGC Landslide Database in ArcIMS

URL: http://bgcengineering.info/website/htmlviewer/Generic/viewer.htm

1. Select "OGC" at the bottom of the screen and click on "Load"
2. Pan and zoom functionality is available on the upper left of the screen.
3. One can turn layers on and off by clicking on the check boxes on the right of the screen and then clicking refresh button on the extreme lower right of the screen (scrolling to the bottom of the legend is required to see the "Refresh" button)
4. A layer must be made "active" before one can use the "i" information button to view text information about a selected object. For example, to see information about a landslide point, click on the "active" check box in the grey legend in the right of the screen, click the "i" icon on the left of the screen and then click on the landslide point.

APPENDIX IV

SOURCES OF TERRAIN AND SOILS MAPPING INFORMATION

Sources of Terrain and Soils Mapping and Information:

Terrain Mapping and Digital Standards and Guidebooks:

Links to terrain mapping and digital data standards, user guides and other related information are listed at: http://srmwww.gov.bc.ca/tib/fia/terrainstabmap.htm.

Soil and Terrain Map Library (MapPlace):

Digital soils and terrain (and terrain stability, surficial geology and related) map files are available for interactive viewing or download (free of charge) in .e00/.shp (GIS formats) and/or as .Tiff (raster image) files from the Soil and Terrain Map Library at: http://www.em.gov.bc.ca/Mining/Geolsurv/Terrain&Soils/Default.htm (select 'interactive and downloadable Terrain and Terrain Stability Maps')

> Tip: To use this site, you'll need the MapGuide plug-in. See First Time Users at: http://www.em.gov.bc.ca/Mining/Geolsurv/MapPlace/default.htm to download the free plug-in and for tips on using ' The MapPlace.
>
> Tip: Check all the layers, as the maps have not been consistently catalogued. Only the uppermost selected layer is an active layer that can be queried.
>
> Tip: Zoom into your area of interest and review projects available. Double click on projects of interest (must be uppermost active map layer) to open a new window which provides details about the project. Use the interactive map link of this window (not available for raster files) to open a new interactive mapping window. Zoom in until the polygon linework shows up. Cursor over the polygon of interest to view an attribute code. (Only one attribute is displayed. The downloadable files should contain the full suite of polygon attributes).
>
> Tip: Use the right mouse button for printing the map window, for viewing reports, measuring distances, etc.

Other terrain and related mapping:

The Southern Interior Region (MSRM) has some digital terrain/terrain stability mapping available for interactive viewing and/or download via: http://srmapps.gov.bc.ca/apps/sir/

Terrain stability mapping for the Williams Lake MoF region is available from: ftp://ftpwml.env.gov.bc.ca/dist/geology/terrstab/ Please contact Soilterrain@victoria1.gov.bc.ca if you require the full project data and reports that correspond to this data.

The Soils/Terrain program has recently received some terrain stability mapping project data for the Skeena region. This data is currently being catalogued. Please contact Soilterrain@victoria1.gov.bc.ca.

Bioterrian mapping is a variant of terrain mapping. Bioterrain mapping is commonly a component of Terrestrial Ecosystem Mapping (TEM). Typically, full terrain attributes are collected following the same RISC standards as for terrain mapping, though some polygons boundaries may have been influenced by ecosystem considerations. For more information and access to TEM data, see: http://srmwww.gov.bc.ca/ecology/tem/index.html

Tip: See: Bioterrain Mapping, Data Access (PEM/TEM index maps under 'About the Data', EcoCat & ftp)).

Surficial Geology maps contain information about surficial materials and landforms. (In a sense, surficial geology mapping was a precursor to the 'Terrain' mapping and terrain classification standards.) To access in index of surficial geology maps for BC see: http://www.em.gov.bc.ca/Mining/Geolsurv/MapPlace/MoreDetails/of_13.htm.

Note: This index lists published hardcopy surficial geology maps. See the 'Soils and Terrain Map Library' above to access digital data.

Tip: When querying the surficial geology projects on the interactive map site, use the right mouse click to access information about each project (map name, date, author, etc.)

Note: These surficial geology maps are are available only in hardcopy from map sales outlets or on loan from a variety of libraries. See links below.

Aggregate Potential Mapping is typically based on terrain or surficial geology mapping and this information may be included in the project datasets. Aggregate potential mapping projects have been completed for Prince George, Okanagan, Nanaimo, Sea-to-Sky, Sunshine Coast, North Coast and Northeast BC. See: http://www.em.gov.bc.ca/Mining/Geolsurv/MapPlace/MoreDetails/aggregate.htm

Soil Mapping and Digital Standards and Guidebooks:

The '**Soil Inventory Methods for BC**' manual provides common standards and methods that are proposed as Provincial requirements for all soil inventory conducted in the Province. See: http:://srmwww.gov.bc.ca/risc/pubs/teecolo/soil/index.htm

Field Inventory Site and Soil Description data collection and data capture should follow the standards set out in the **Describing Ecosystems in the Field** manual available (downloadable html or .pdf formats, or hardcopy) via: http://srmwww.gov.bc.ca/ecology/dteif/index.html

Tools to assist with data capture are available via: http://srmwww.gov.bc.ca/ecology/tem/forms.html

The following **Canadian Soil Mapping and Soil Classification Standards** manuals are available from: http://sis.agr.gc.ca/cansis/publications/manuals/index.html

- A Soil Mapping System for Canada: Revised
- Analytical Methods Manual
- Land Suitability Rating System for Agricultural Crops
- Manual for Describing Soils in the Field
- Soil Survey Handbook
- The Canadian System of Soil Classification (1st Edition)
- The Canadian System of Soil Classification (2nd Edition)
- **The Canadian System of Soil Classification (3rd Edition)** is available from: http://sis.agr.gc.ca/cansis/references/1998sc_a.html

For information about **Humus Forms**, see 'Taxonomic Classification of Humus Forms in Ecosystems of British Columbia: First Approximation' available via: http://www.for.gov.bc.ca/hfd/pubs/Docs/Mr/Lmr008.htm and 'Towards a taxonomic classification of humus forms' available from the Ministry of Forests Library (link below).

Many other reference materials are available via:
http://sis.agr.gc.ca/cansis/references/index.html

The Soil Landscapes of BC report is available via our soils website at:
http://srmwww.gov.bc.ca/soils/index.html.

Soil Landscapes of Canada (interactive map) is available via:
http://sis.agr.gc.ca/cansis/systems/online_maps.html.

CANSIS Soil Surveys:

Soil Survey reports (.pdf) and maps (.e00 and/or .jpg) are available (at no cost) via Detailed Soil Survey Index at: http://sis.agr.gc.ca/cansis/systems/online_maps.html (Tip: this site uses an interactive mapping application to help users locate the soil surveys in their area of interest)

> Technical information is available from: http://sis.agr.gc.ca/cansis/nsdb/detailed/intro.html
>
> Tools: The Soil Mapper extension for Arcview (a tool that works with ArcView software to facilitate importing and mapping of detailed soil survey data) is available via: http://sis.agr.gc.ca/cansis/systems/soilmap/
>
> Shortcut: If you know which soil survey report you are interested in, use: http://sis.agr.gc.ca/cansis/publications/bc/index.html

CAPAMP:

CAPAMP digital soil map files (.e00) for the Lower Mainland, Southeast Vancouver Island, and the Okanagan)at 1:20,000 scale) are available from: ftp://fshftp.env.gov.bc.ca/pub/outgoing/Soil_Data/ (These same soils maps and additional derived theme maps are available as hardcopy prints - see below).

Documentation regarding the digital CAPAMP data capture/validation is available via the Ecological Data Catalogue (EcoCat) at: http://srmapps.gov.bc.ca/apps/acat/ (search for the term 'CAPAMP')

Agriculture Capability Mapping

Agriculture Capability maps (GIS format .e00) are available via the Canada Land Inventory topic from the CANSIS site at: http://sis.agr.gc.ca/cansis/systems/online_maps.html

> (Note: These files represent an incomplete set of CLI data (see next link), converted by CANSIS from the original CLI datasets to a component based file structure format.)

CLI Soil Capability maps (Agriculture capability, forestry capability, etc) in GIS format and raster images (.wmf) are available via: http://geogratis.cgdi.gc.ca/CLI/frames.html

> Technical information is available via: http://sis.agr.gc.ca/cansis/nsdb/cli/index.html

Hardcopy soils, agriculture capability and other theme maps are available (at a range of scales) for areas with agricultural potential. See topic: Hardcopy Maps below.

For **City Agriculture Capability** mapping (large cities), see the GeoConnections Discovery Portal at: http://geodiscover.cgdi.ca/gdp/index.jsp?language=en

- Tip: search the catalogue for: Location = BC, Subject = Soil, and Keywords = City.

Agriculture capability classification standards for BC are available via: http://www.alc.gov.bc.ca/alr/ag_cap_details.htm. (The referenced documents are available via the Ministry of Forests library.(see below)).

Canadian Soil mapping and Agriculture capability manuals and information are also available via: http://geogratis.cgdi.gc.ca/CLI/frames.html (see CLI Reports) and http://sis.agr.gc.ca/cansis/publications/manuals/index.html

Derived Maps

Other soils related derivative maps are available in several of the areas of BC, typically where soils surveys have been conducted at 1:20,000 scale (e.g. the CAPAMP mapping). (These derivative maps are available in Hardcopy format only). In addition to soils mapping, related themes include:

-Land capability for agriculture
-Agriculture Soil Management Groups
-Soil drainage
-Soils affected by flooding and/or high water table
-Surface soil erosion potential
-Irrigation water requirement
-Soil suitability for septic tank effluent absorption
-Soil suitability for residential development

See hardcopy map listing for a complete list of available maps.

Documentation regarding the algorithms used to derive some of the above theme maps is available via: http://www.for.gov.bc.ca/hfd/library/documents/bib94911/bib94911.htm

Climate Capability Maps:

Climate related mapping, including climate capability, climatic moisture deficit/surplus, freeze free period, growing degree days, and May to September precipitation, is available for some areas in BC. See the hardcopy **Map List** below.

Reports describing the Climate Capability Classification methodology are available (free download) via the Ministry of Forests Library (http://www.for.gov.bc.ca/hfd/library/index.htm)

Tip: search the catalogue for 'Climate Capability Classification'

Information about the 'Growing Degree days' methodology is available via: http://sis.agr.gc.ca/cansis/nsdb/ecostrat/egdd.html

An updated Plant Hardiness Map (2000) is available via: http://sis.agr.gc.ca/cansis/systems/online_maps.html

Soil Analyses:

Soil Analyses (BCSIS) are available via: http://srmwww.gov.bc.ca/soils/provsoil/index.html (Data is available via an interactive map-based query application. Query results include site and soil horizon information.)

The full attribute BCSIS database (including lab analyses) and documentation, are available for download from: ftp://fshftp.env.gov.bc.ca/pub/outgoing/Soil_Data/BCSIS/ (The BCSIS database is in MSAccess 98 format. The data tables contained in the database are also available as .xls or .csv files in the folder: BCSIS_exported_Tables, for users with an earlier version of MSAccess or other applications.)

Hardcopy (print-on-demand) Maps:

A listing the available hardcopy (print-on-demand) terrain, soils and related mapping can be viewed or downloaded via our ftp site at: ftp://fshftp.env.gov.bc.ca/pub/outgoing/Soil_Data/Terrain_Soils_MapList/ (The **Map List** is available in .pdf or .xls formats.)

> Note: The Map List is based on the mylars in our map cabinets. The list does not include mapping available in digital formats only or reports without hardcopy maps. We have attempted to flag corresponding available digital data and reports, however, this information is likely incomplete. Please report any errors or omissions to soilterrain@victoria1.gov.bc.ca in order that we may update the list.

If you are not familiar with the system of mapsheet naming and map locations, see below for tips on how to identify the mapsheets of interest.

Ordering print-on-demand maps:

Hardcopy (print-on-demand) soils and terrain and related (e.g. agriculture capability, soil drainage, etc.) maps (as listed on our Map List) can be ordered from: mailto:soilterrain@victoria1.gov.bc.ca. These maps are $5 per map plus shipping and taxes.

When ordering, please supply contact information including a street and mailing address. The reproduction company will then contact you by phone for billing information (a credit card number) and shipping instructions (mail or courier). Please allow at least 2 weeks for delivery of maps, to allow for pulling of mylars from our inventory, transfer of maps to the reproduction company, the reproduction company's workload and shipping to you.

> Note: Please contact your local printing or reproduction company for plotting of maps from downloaded digital files (e.g. from CANSIS or MapPlace). This service is not available from the Soil/Terrain program.

Other sources of Soil/Terrain reports and maps:

Published hardcopy soils reports and terrain/soils maps can also be ordered (at a cost) from the Pacific Regional Society of Soil Sciences: http://www.prsss.ca/default.shtml (Note: response time may vary)

Several Soil Survey reports are available print-on-demand (at a cost) from Trafford via: http://srmwww.gov.bc.ca/soils/project/report.html

BC Publications has a few Soil Survey reports and other soils and terrain related publications as well as a diverse range of there products. See : http://www.publications.gov.bc.ca/ (Tip: use keyword: 'terrain' or 'soil' to search for publications).

BC Geological Survey Branch (GSB) publications (maps/reports): http://www.em.gov.bc.ca/Mining/Geolsurv/Publications/default.htm

Crown Publications (including many GSB publications): http://www.crownpub.bc.ca/

The Ecological Report Catalogue (EcoCat) application provides access to reports, maps, digital data for Bioterrian and many other ecosystem, hydrometric and fish related projects) (free downloads:) See: http://srmapps.gov.bc.ca/apps/acat/

Some soil, surficial geology, terrain reports and data (as well as a vast array of other data) are available for discovery, download or viewing via the Land and Resource Information Data Warehouse at: www.lrdw.ca Tip: Search for 'Soil' or 'Surficial' etc. in the Title or All Fields; and uncheck the 'Theme View' option. (Note: MoE will be loading Terrain/Terrain Stability Mapping project data to the LRDW, commencing during 2006.)

Links to Libraries

BC Ministry of Forests and Range Library: http://www.for.gov.bc.ca/hfd/library/index.htm

GSC Pacific (Vancouver) - Geoscience Research Library:
http://gsc.nrcan.gc.ca/org/vancouver/library/index_e.php

Ministry of Energy and Mines Library: http://www.em.gov.bc.ca/Publicinfo/Library/default.htm

> Note: if you do not live in the Vancouver or Victoria areas, the materials from the above libraries can be borrowed via inter-library load through your local library.

Finding the Mapsheet(s) of interest:

Here are several options for finding the mapsheets of interest:

a) If you don't know which mapsheet is the correct one, you can view the 1:20,000 (e.g. 92F.065) and 1:50,000 (e.g. 92F/11) or 1:250,000 (e.g. 92F) mapsheet grids interactively on the web via:

'Make a Map' at: www.landinformationbc.com. (There's a tutorial, if you haven't used this before).
> Tip: Select Map Layers: Imagery & Base Maps / Base Maps (Reference Grids)

Or, visit The MapPlace: www.mapplace.ca (see First Time Users and download the MapGuide Plug-in.
> Tip: Zoom in to the general area of interest and turn on the grid layers and labels from the list.)

b) If you have a legal lot description, and want to know which mapsheet the property is on, you can view cadastre data online via: http://srmwww.gov.bc.ca/sgb/IMF/index.html (if you haven't used this site before, there is a tutorial).

> Tip: After you've zoomed in close in the area of interest, turn on 'layers' and :
> 1) (optional) check the "i" button under 'Tantalis Layers/Survey Parcels to confirm the lot identification, and
> 2) under Base - auto scaling, check the "**i**" button for Grids, and click on the parcel again - this will tell you the mapsheet number.

c) To find the NTS mapsheet that a geographic feature is located on, search the BC Geographical Names Information System database at: http://srmwww.gov.bc.ca/bcnames/.

NOTE: the Agriculture Capability mapping for the Langley-Vancouver area is based on the 1:25,000 grid. The 1:50,000 scale map grid is split into 8 letter blocks as follows:

```
 __________
| E | F |G | H |   92G/02    In this example, 92G/02 is the 1:50,000 scale map grid
|__ |__|__|_  |
| D | C | B| A |
|__ |__|__|_  |    The NE quadrant of 92G/02 would consist of 92G/02G and 92G/02H.
```

Terrain Listserv:

The Terrain Listserv has been implemented as a communications tool for the terrain mapping, inventory and terrain information community. The MoE provincial terrain information specialists will be using this listserv to communicate and consult with subscribers about:

- proposed changes to standards/guidelines/procedures,
- newly available data/information,
- education and professional development opportunities, and
- other initiatives related to access and management of terrain information.

To review the Listserv Policy and/or sign-up to the listserv, visit:
http://srmwww.gov.bc.ca/terrain/listserv.html

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Please report any broken hyperlinks and make suggestions regarding other sources of information or reference materials that are potentially of interest to terrain and soils data users.

Feel free to contact me if I can be of further assistance, or to order hardcopy (print-on-demand) maps.

Maija Finvers, P. Geo.

Terrain Information Specialist
Ecosystem Information Section*, Ecosystem Branch
Environmental Stewardship Division
Ministry of Environment
Phone: (250) 387-9474
Mailto:Soilterrain@Victoria1.gov.bc.ca
http://srmwww.gov.bc.ca/soils/
http://srmwww.gov.bc.ca/terrain/ (to be updated soon to include all of the above information and more!)
http:/www.landinformationbc.com

(* Formerly: Resource Information Branch
Land Information BC, MSRM)

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APPENDIX V

2 DVDS OF DIGITAL DATA, MAP LAYERS, AND REPORTS