Identifying Granular Resources Using Thematic Mapper Imagery, Slave Geological Province, Northwest Territories

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ABSTRACT

The exploration for granular resources in northern Canada is of considerable importance where building materials are required for engineering applications associated with resource developments. A study was undertaken to determine the effectiveness of using Landsat Thematic Mapper (TM) imagery in the identification of granular resources in a large relatively unknown area, the Lac de Gras - Aylmer Lake region of the Slave Geological Province in the Northwest Territories.

Image processing focused on the use of the simple linear stretch, standard principal components analysis (PCA), and selective PCA. Standard PCA uses all available data bands as input to the transformation, while selective PCA uses subsets of the available data bands as input to the transformation. Detailed airphoto interpretation and field work were also performed.

Evaluation of results showed that TM band 3 and TM band 7 were the most effective single-band images to use for the extraction of granular resources (primarily esker landforms). The linear stretch was effective in delineating granular resources (which have a high reflectance value) which are surrounded by a less-reflective landscape, such as hummocky till or organic soils.

Further evaluation revealed that the first component of the TM2/TM3 selective PCA and the first component of the TM2/TM7 selective PCA were effective in the identification of granular resources. These components delineated the trunk eskers and tributaries (which were identified from linear stretch analysis) along with some eskers which were not identified from the linear stretch analysis.

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1. INTRODUCTION

1.1 OVERVIEW

The objective of this thesis is to determine the effectiveness of using Landsat Thematic Mapper (TM) imagery in the identification of granular resources in a large, relatively unknown area. In this project the study area is the Lac de Gras - Aylmer Lake region of the Slave Geological Province in the Northwest Territories. This area was selected primarily in response to development (both approved and proposed) occurring in this region. Figure 1 shows the approximate boundaries of the study area.

The purpose of this thesis is twofold. First, it is necessary to determine the reliability of satellite image analysis techniques as compared to the traditional method of airphoto interpretation in the identification of granular resources. The reliability of the satellite imagery is an issue because of the decrease in scale from airphotos and the lack of stereoscopic viewing. Second, it must be determined if certain mathematical transformations (principal components analysis) of the TM data provide for increased separability of granular deposits compared to the use of standard TM image bands. Two types of image enhancements have been applied to the TM imagery in an effort to extract information on potential granular resources. It was decided to use both the simple linear stretch and variations of the principal components transformation. The granular deposits identified from the linear stretch method were verified by comparison to a compilation of all deposits in the study area, determined from detailed airphoto interpretation and field work. The criteria used to identify potential granular deposits from the TM imagery are: orientation of the landform relative to ice flow direction; orientation of the landform relative to other similar features; shape of the landform; the landform's association with drainage features and relief (relief determined from a topographic map).

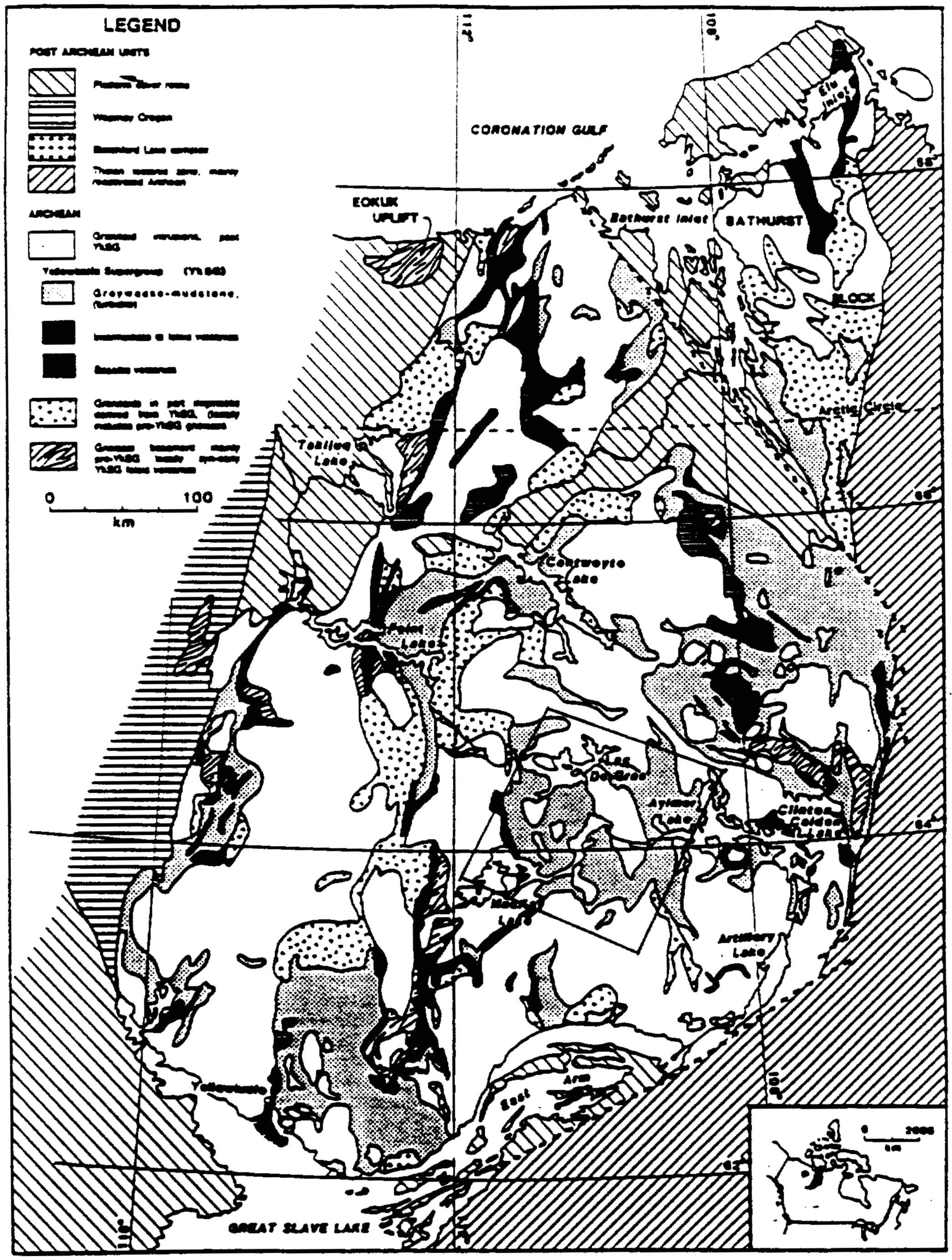

Figure 1: Approximate Limits of Study Area (GSC, 1990)

This thesis is the development of a project which was undertaken by the author while working on a co-operative education placement for the Land Management Division of the Department of Indian Affairs and Northern Development (DIAND). The Land Management Division is responsible, through its Granular Resources Program, for maintaining data on potential granular resources, along with existing pits and quarries, in the NWT and Yukon. The field work portion of the project was performed in conjunction with DIAND's NWT Regional Office, which was conducting an Esker Research Program to identify potential quarry locations within the study area. DIAND purchased the satellite imagery and some of the airphotos which were used in this project.

1.2 STUDY AREA

Located about 325 kilometres northeast of Yellowknife, the study area for this project is approximately enclosed by the following points:

- 63° 48' N , 108° 00' W
- 63° 48' N , 111° 53' W
- 65° 00' N , 110° 46' W
- 64° 34' N , 108° 00' W

The majority of this region is on the National Topographic Series (NTS) 1:250,000 topographic maps 76C (Aylmer Lake) and 76D (Lac de Gras). This area is north of the treeline in the tundra landscape, which is characterized by mosses, sedges, grasses, shrubs and dwarf trees. Generally, the northern half of the study area is within the zone of continuous permafrost and the southern portion is within the zone of discontinuous permafrost (Mollard and Mollard, 1994).

1.2.1 Bedrock Geology

This area is located within the Slave Geological Province in the south-central Canadian arctic. As part of the Canadian Shield, the age of the bedrock can be up to two billion years old (Meyerhoff, 1982). Many sections of the bedrock are exposed due to the scouring and polishing of the repeated glaciations over the last 2 million years. The bedrock distribution is very complex, but can be subdivided into two main categories (Dredge et al., 1994). Examples of rock types characteristic of these two categories are provided below (Lord and Barnes, 1954):

GRANITOID -- quartz diorite; biotite-hornblende; gabbro; pegmatite

YELLOWKNIFE SUPERGROUP -- basalt; slate; phyllites; quartz-mica schist

1.2.2 Surficial Geology

The Slave Geological Province was completely glaciated during the Wisconsinan glaciation, which ended some 9000 years ago. As a result, the landscape is dominated by glacial landforms and deposits. Till is the most extensive glacial deposit in the study area. The till ranges from a silty-sand to sand depending upon the bedrock source and amount of meltwater associated with deposition. Till derived from the granitoid rocks was sandier than that derived from the Yellowknife Supergroup, which was siltier in nature (Dredge et al., 1994). The majority of the till deposits are relatively thin (less than 5 metres of glacial drift). These areas contain some bedrock outcrops and generally conform to the underlying bedrock morphology. Some areas of till deposit are quite thick (up to 30 metres of drift) and form a hummocky topography with no bedrock outcrops.

There are several drumlin fields in the study area. Drumlins are not a worthwhile source of granular material, as they are composed of unsorted and unstratified till deposits. However, drumlins are an excellent indicator of ice flow direction. The long axis of the oval, streamlined hills is parallel to the direction of ice movement and the end facing the direction of the ice front is blunter and steeper than the tail end (Mollard, 1974). Glaciofluvial deposits, such as eskers and kames, are widespread throughout the study area but occupy a limited areal extent. Outwash deposits are very rare in this region

(Dredge et al., 1994). Eskers and kames are well-drained landforms and contain well-sorted and washed granular resources. Eskers are long, sinuous ridges formed from material deposited by meltwater flowing in tunnels near the bottom of a glacier. Eskers generally are formed parallel to the direction of ice movement. Figure 2 displays the ages, thickness and directions of the ice flows which occurred in the study area. Figure 2 also shows the location of the Sauvage Esker, a large trunk esker which receives a network of feeder eskers. Kames are conical hills or mounds formed when meltwater enters holes on

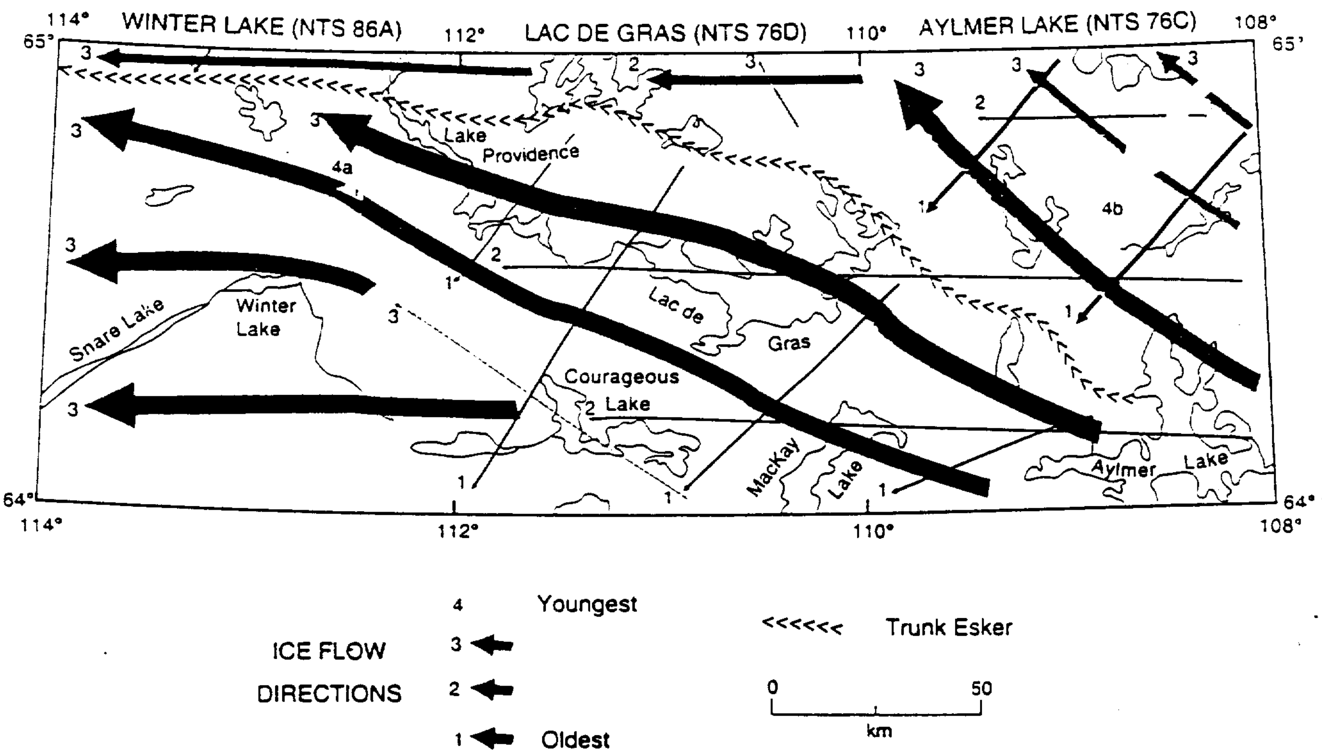

Figure 2. Summary ice flow diagram for the study area. Flow directions are numbered in order of decreasing age. Thickness of the line gives the relative affect of the flow on transport of debris and on modifying the landscape; thickest arrows represent the dominant flow (Dredge et al., 1994)

or inside stagnant glacier ice <u>or</u> at the margin of the glacier on the adjoining land surface (Mollard, 1974). It is these glaciofluvial landforms that the author made an effort to identify using TM imagery.

Organic deposits (primarily peat bogs) are geographically widespread throughout the study area, but limited in areal extent.

1.3 RESEARCH RATIONALE

The Slave Geological Province has been the host of several large-scale mining projects over the years; gold and base metals have been some of the resources traditionally extracted from this region. Just recently there has been a flurry of activity in the Slave Province (especially the Lac de Gras region) as several potentially profitable diamond-bearing kimberlite[1] pipes have been discovered. This has led to a rush of staking in the region, along with intense research being performed as developmental initiatives and environmental concerns converge. BHP Diamonds Inc., which has a large mineral claim north of Lac de Gras, is currently before the federal environmental assessment review board seeking approval for its projects. If approved, BHP is expected to start production of its mines as soon as 1998. Other mining companies are awaiting the outcome of the BHP assessment and then may begin their own applications for permission to begin production. If approved, each of these projects will require granular materials for all-weather and winter roads, landing strips, building pads, containment facilities, etc. (Harrison, 1994).

The traditional method of identifying granular resources has been airphoto interpretation followed by field-checking of potential deposits. This method of granular resource identification can be very effective owing to the stereoscopic nature of the airphotos and the level of detail which can be attained. Identifying granular resources with airphotos can also be a very expensive and time-consuming process, especially if the study area is large with a minimal amount of research having been performed there. This is the

[1] *Kimberlite* is an igneous rock that consists mainly of the mineral olivine and is found in volcanic pipes (BHP Diamonds Inc. and DIA MET Minerals Ltd., 1995)

situation in the remote Lac de Gras - Aylmer Lake region, where intense research has only been performed in the last few years due to the diamond potential of the area. If TM imagery proves to be reliable in the identification of potential granular resources, it would be very useful in areas such as this project's study area. A considerable amount of airphoto interpretation time could be saved if only the areas with granular resource potential (identified from the TM imagery) had to be analyzed in more detail with airphotos.

In this thesis we will attempt to determine the reliability of satellite image analysis techniques (linear stretch, principal components analysis) as compared to airphoto interpretation in the identification of granular resources. Additionally, an attempt will be made to determine if principal components analysis of the TM data provides for increased separability of granular deposits than the use of standard TM image bands. Every effort has been made to follow a logical and rational progression of steps in order to provide answers to these problems. A review of previous work performed in this field of study is provided, focusing upon the use of Landsat imagery in surficial geology mapping and granular resource identification. The methodology behind the project is described, divided into the following sections: satellite image analysis (utilizing linear stretches and principal components analysis), detailed airphoto interpretation, and field work. Both descriptive and statistical results of all analyses and field work are provided, followed by the conclusions of the thesis.

2. LITERATURE REVIEW

2.1 INTRODUCTION

The identification of granular resources through the use of remote sensing techniques is a field of study which has experienced rapid development in the recent past. For years, the interpretation of airphotos was the only reliable means by which sources of aggregate could be located. Yet with the evolution in the science of remote sensing to the increased use of satellite - based sensors, an entirely new set of techniques for identifying granular resources was made available for research.

This literature review will focus on selected research projects in which Landsat imagery is utilized either to map the surficial geology or to identify the granular resources within a certain area. A variety of different enhancement types and image classifications were used in these papers. Many other studies have been performed with the purpose of identifying sand and gravel deposits utilizing other types of imagery, such as Systeme Probatoire d'Observation de la Terre (SPOT) and MEISS-II Multispectral Airborne data. These papers will not be reviewed here, as the purpose of this thesis is the application of TM imagery to the location of aggregates.

2.2 PREVIOUS RESEARCH

Economically, granular resources are a high-volume, low-value material. Hence, one of the primary concerns for the mining companies when deciding to extract from a granular deposit is the transportation cost from quarry to job site. Many factors determine whether a deposit can be quarried including the location of the deposit, the quality and quantity of the material, the availability of the deposit for production, and the means of transporting the aggregate to market. If a problem is encountered in any of these factors, an otherwise excellent deposit of sand and gravel may be essentially worthless (Kneeler Jr. et al. 1994).

Along with the economic factors involved in the extraction of granular material there are also some ecological considerations, especially in the very fragile environment of the Canadian tundra. Eskers are considered to be a primary source of granular materials as they have relief, they are easily recognizable and distinct landforms, the material within the esker is well-sorted, and generally they are easily developed without drainage problems. Mueller (1994) concluded that eskers are also the most suitable habitat for denying for several types of animals (ground squirrels, foxes, wolves, grizzly bears) in the Canadian tundra. Developed soils and easily penetrated materials are relatively rare in shield regions of Canada, which are characterized by extensive bedrock outcrops and numerous lakes. The sands and grovels of eskers provide easy digging for animals, and because they are so well drained they remain unfrozen year round. Eskers are also used by wildlife as travel corridors (Jakimchuk and Carruthers, 1983) and as habitat for relief from insects. Mueller recommended that den sites should be identified and avoided; the disturbance of eskers should be minimized; quarry sites should be identified,; materials should be reclaimed after industrial use, and impacts on the use of eskers should be studied.

There have been several studies in the past on the use of Landsat imagery for surficial geology mapping and in the exploration of granular resources. Rencz and Shilts (1981) mapped the surficial geology of the Kaminak Lake area of the NWT using Landsat Multispectral Scanner (MSS) imagery. The overall accuracy of correctly classifying a pixel was 90 percent. The surficial geology map produced from Landsat data was comparable to maps produced by conventional techniques. The authors state that the advantage of this method over conventional techniques is the capability of rapidly reproducing low-cost derivative maps at any scale.

Hornsby (1983), working with a study area in the eastern NWT, determined that the primary limitation of using Landsat imagery for mapping surficial geology is the changes which occur in the spectral response patterns of similar features on the ground. While Landsat provided a feasible method of mapping surficial geology, classifications could not be extended more than a few tens of kilometers beyond the original classified image because of the spectral response changes.

In three contrasting geologic environments of Canada, Belanger and Rencz (1984) performed several enhancements, including principal components analysis (PCA) and unsupervised classifications, to evaluate the surficial geology of each area. It was found that in some areas where ground information concerning the surficial geology/vegetation relationship was available, a semi-supervised classification may yield the best results.

Mollard (1985) studied the utility of TM imagery for identifying large sand and gravel prospects in south-central Saskatchewan. Mollard determined that because TM imagery lacks the stereoscopic effect of airphotos the emphasis is placed on geological environment, geomorphic setting and land cover to identify granular prospects. It is also difficult to predict the average depth of recoverable granular material using TM imagery. Mollard states that the principal advantage of the satellite imagery is one of scale, since a large number of airphotos must be obtained in order to cover the area of one TM image.

Carswell (1986) utilized different enhancements of TM imagery to map the surficial geology of a portion of northwestern Ontario. Carswell performed linear stretches, PCA, and mathematically-derived enhancements (band products) of the data. It was found that a true-colour composite using a linear piecewise stretch offered the most control allowing for the maximum separability of surficial materials.

George et al. (1986) attempted to identify and map tonal anomalies caused by differing drainage patterns due to underlying granular deposits in Chatham, Ontario using multispectral imagery. They were working under the hypothesis that shallowly buried granular deposits would have better drained soils (hence differing spectral responses) developed over them. Excellent discrimination of the surficial materials was obtained from colour composites of visible and near-infrared bands and from band ratios.

Minor et al. (1988) conducted a geobotanical study in California employing remote sensing techniques using TM imagery to determine if vegetation could be used to discriminate parent materials for suitability as aggregate source material. Image processing techniques included band composites, band ratios, PCA and linear recombination. The most useful images were those composites that included bands from two of the techniques, such as a ratioed band with principal components bands. The alluvium best suited for aggregate source material was better drained and thus contributed to the premature desiccation (browning) of the overlying annual vegetation.

Gorecki et al. (1989) undertook a study to determine the utility of TM imagery for sand and gravel exploration in northwestern Alberta. A supervised classification was performed where the training sites consisted of known aggregate locations. Evaluation of results showed that a high percentage of test sites (known aggregate deposits that were not used for training) were identified as aggregate prone by means of this procedure.

Rencz, Aylsworth and Shilts (1989) digitally classified and compared a TM image of part of the District of Keewatin, NWT with a 1:125,000 surficial geology map produced from airphoto interpretation. They concluded that the classification results were similar to the surficial geology map and that the TM data should have a wide application to mapping surficial geology in other areas of the arctic. The discrepancies were due to human interpretation on the conventional map or overlap in the spectral signatures on the TM map.

Although their paper did not pertain to the extraction of granular resources, Chavez and Kwarteng (1989) utilized a type of data analysis which could be applied to TM imagery when searching for aggregates. As opposed to using a 'standard' PCA, in which all available data bands are used as input to the PCA, the authors performed a 'selective' PCA. Selective PCA means that only a subset of the available data bands are used as input to the PCA, with various criteria being used to select the subsets. Selective PCA can be used to enhance the spectral contrast between different regions of the electromagnetic spectrum, so that properties such as vegetation differences and moisture retention capability can be identified.

2.3 SUMMARY

The utilization of satellite imagery in the identification of granular resources is a tool which should continue to be refined because of the potential amount of time and money which can be saved in data analysis. There are still some flaws with the technology which must be solved. Two of the primary problems are related to the actual design of the TM sensor. First, it is generally not possible to view the TM imagery stereoscopically due to the path of the satellite, making it very difficult to predict the volume of a potential granular deposit. Because this is a very important factor to consider when identifying potential sources of aggregate, a method should be developed which predicts the volume. The use of RADARSAT imagery, with its stereoscopic abilities, could possibly solve this problem.

Secondly, the spatial resolution of the TM imagery makes it impossible to identify many smaller deposits which could contain high - quality, extractable material. In the future, newer satellite sensors with improved spatial resolution should provide more accurate methods for the identification of granular resources.

3. METHODOLOGY

3.1 INTRODUCTION

This methodology attempts to follow a logical progression of steps so that the thesis objectives can be met. Initially, image analysis of the TM data was performed utilizing linear stretch enhancements of the imagery to identify potential locations of granular material. Principal component transformations of the data were performed at a later stage following the original DIAND project. Following the linear stretch analysis, a detailed airphoto interpretation of the study area was performed to accurately assess probable sources of aggregate. To conclude the project, field tests and ground checks were carried out in the study area.

Several criteria have been defined (see Tables 2 and 3) in order to provide for a logical identification system in the extraction of potential granular resources from TM imagery or airphotos. Most of these criteria have been based on geomorphic principles which are characteristic of the landforms present in the study area. The geomorphic principles have been extracted from Easterbrook (1993).

3.2 SATELLITE IMAGE ANALYSIS

3.2.1 Type and date of Imagery

The type of imagery analyzed in this study was Landsat Thematic Mapper multispectral imagery. TM images have a 30 metre spatial resolution and seven bands of radiance data (band 6 has a 120 metre resolution). Table 1 outlines the seven TM bands, their principal applications and their positions in the electromagnetic spectrum. In this project, only five of the seven energy bands are utilized. Band 1 (blue visible) is not used because of its high sensitivity to haze and other atmospheric distortions. Band 6 (thermal infrared) is not used because of its spatial resolution of 120 metres.

Table 1: Thematic Mapper Spectral Bands (adapted from Lillesand and Kiefer, 1994)

Band	Wavelength (μm)	Nominal Spectral Location	Principal Applications
1	0.45 - 0.52	Blue	Designed for water body penetration, making it useful for coastal water mapping. Also useful for soil/vegetation discrimination, forest mapping, and cultural feature identification.
2	0.52 - 0.60	Green	Designed to measure green reflectance peak of vegetation for vegetation discrimination and vigor assessment. Also useful for cultural feature identification.
3	0.63 - 0.69	Red	Designed to sense in a chlorophyll absorption region, aiding in plant species differentiation. Also useful for cultural feature identification.
4	0.76 - 0.90	Near infrared	Useful for determining vegetation types, vigor, and biomass content, for delineating water bodies, and for soil moisture discrimination.
5	1.55 - 1.75	Mid - infrared	Indicative of vegetation moisture content and soil moisture. Also useful for differentiation of snow from clouds.
6	10.4 - 12.5	Thermal infrared	Useful in vegetation stress analysis, soil moisture discrimination, and thermal mapping applications.
7	2.08 - 2.35	Mid - infrared	Useful for discrimination of mineral and rock types. Also sensitive to vegetation moisture content.

* Bands 6 and 7 are out of wavelength sequence because band 7 was added to the TM late in the original system design process.

The TM image which was analyzed at the University of Waterloo was taken on August 2, 1994 and occupies part of NTS 1:250,000 map sheets 76C and 76D. The study area consists of the upper left portion of this scene, which can be referred to as Path 44, Row 15. The 1994 imagery was purchased by DIAND for use in their Granular Resources Program in the Slave Province. The TM image which was analyzed at DIAND headquarters (Hull, PQ) and the Government of Northwest Territories Centre for Remote Sensing (GNWTCRS, Yellowknife) was taken on July 26, 1989 and occupies the entire NTS 1:250,000 map sheet 76D. The EASI/PACE[2] image analysis system was used for the majority of the TM data analysis.

3.2.2 Linear Stretch Analysis

The bands of TM spectral data can be viewed independently as black and white images. Often a colour display of the satellite imagery aids in the discrimination of different land cover types and also provides for an aesthetically pleasing output. A true colour composite is produced when three bands of image data are used and the band assigned to the red, green and blue colour display guns are the actual red, green and blue spectral bands. A false colour composite is produced when the spectral bands (e.g. near infrared) are assigned to colour display guns of differing light intensity (e.g. red visible). When referring to colour composites, the bands will be listed in their RGB colour display order. Therefore, composite 432 means that band 4 is displayed in the red gun, band 3 is displayed in the green gun, and band 2 is displayed in the blue gun. Experimentation was done using several of the more common false colour composites, focusing on 432, 234 and 543. Composite 432 is commonly referred to as the "false colour infrared" composite because of its similarity to colour infrared film.

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[2] Any use of trade, product or firm names is for descriptive purposes only and does not imply endorsement by the author.

An image enhancement is the manipulation of the raw satellite spectral data in order to increase the amount of information that can be interpreted from the image. There is no single optimum enhancement -- usually several enhancements of the same image are required to adequately display all inherent information (PCI, 1993). Choosing the appropriate enhancement is often a matter of experimentation and data manipulation, combined with the operator's experience with the equipment and imagery.

Most satellite sensors were designed to accommodate a wide range of illumination conditions, from poorly lit arctic regions to high reflectance desert regions. Because of this, the pixel values in the majority of digital scenes occupy a relatively small portion of the possible range of image grey values (0 - 255). If the pixel values are displayed in their original form, only a small range of grey values will be used, resulting in a low contrast display on which similar features might be indistinguishable (PCI, 1993). A contrast stretch enhancement expands the range of pixel values so that they are displayed over a fuller range of grey values. One of the image enhancements utilized extensively in this project was the simple linear stretch, a type of contrast stretch. When a linear stretch is performed, the range of grey values in the image (e.g. 51 - 153) is expanded uniformly to fill the range of available display grey values (0 - 255). One drawback to the linear stretch is that it assigns as many grey display levels to the rarely occurring image values as to the frequently occurring values.

3.2.3 Identification of Targets

The imagery was carefully analyzed and the location of each potential deposit or glaciofluvial landform was recorded. The target identified on the imagery was associated with a certain kind of landform after comparing it to a checklist of distinguishing features (see Table 2). All available information pertaining to each target has been stored in a database entitled "features.dbf" (see Appendix A). The primary fields pertaining to the satellite image analysis that are contained within "features.dbf" are as follows:

- target number
- western point of target (latitude/longitude coordinates accurate to minutes; some targets are accurate to seconds)
- eastern point of target (latitude/longitude coordinates accurate to minutes; some targets are accurate to seconds)
- centre point of target (latitude/longitude coordinates accurate to minutes; some targets are accurate to seconds)
- the list of satellite imagery distinguishing features according to the lettered code as outlined in Table 2

3.2.4 Principal Components Analysis

Principal Components Analysis (PCA) provides an alternate means of displaying multispectral image data (like TM imagery) due to a set of mathematical transformations that generates a new set of uncorrelated image components (Richards, 1993). There are two main advantages of using PCA. First, unlike the original bands of spectral data which are often highly correlated (see Table 5), there is no mathematical correlation between the new components. Second, PCA may be used to compress the information content of a number of bands of imagery (e.g. 7 TM bands) into just two or three new components, thereby reducing redundancy in data processing and analysis (Richards, 1993).

The PCA procedure is graphically displayed in Figure 3. For ease of display, only a two-dimensional multispectral space is used, yet the relationship holds true for any number of dimensions in multispectral imagery.

Table 2: Satellite Image Analysis Distinguishing Features

FEATURE TYPE	POSSIBILITIES
ORIENTATION RELATIVE TO ICE FLOW DIRECTION	A. Parallel to ice flow B. Transverse to ice flow C. Lacking consistent orientation
ORIENTATION RELATIVE TO OTHER SIMILAR FEATURES	A. Oriented in the same direction as other similar features B. No orientation with other similar features, even when orientation is expected C. Orientation unknown
TONE/COLOUR *NOTE: TM3 (red visible) with a linear stretch	A. Light grey (almost white) B. Medium grey C. Dark grey D. Combination (mixed lighter/darker)
SHAPE	A. narrow and sinuous; relatively uniform width; low width/length ratio B. very narrow and curving; relatively uniform width; generally a low width/length ratio C. oval to cigar-shaped streamlined forms D. belt of material with variable widths E. variable in shape and size F. Deltaic
TONE/UNIFORMITY	A. Lineaments and fractures B. Uniform and smooth C. Mottled (vegetation) D. Other
ASSOCIATION WITH DRAINAGE FEATURES	A. Pass through lakes or weave through groups of lakes B. Parallel to shoreline (probable increased relief) C. Parallel to major streams D. No apparent association
ASSOCIATION WITH RELIEF * from comparisons with a topographic map	A. Run up and down slope B. Parallel to contour C. No apparent association

- When digital numbers from one band are plotted against those from another band near to it in the electromagnetic spectrum (e.g. TM2 v. TM3), the majority of the points lie on, or near to, a diagonal line passing through the origin of the graph (Drury, 1993). This results in an elliptical distribution (see Figure 3a). The closer the data are to the diagonal, the greater the degree of correlation.
- PCA begins by shifting the origin of the plot to the point defining the means of the two sets of data (see Figure 3b)(Drury, 1993).
- The axes are then rotated through an angle Ø so that one of the axes (PC1) is aligned with the maximum variance in the data. The second axis (PC2) is orthogonal to PC1 and therefore expresses the variance that cannot be expressed by PC1 (see Figure 3c)(Drury, 1993).

The principal components which are created are linear transformations of the original images, and have axes that are orthogonal to each other with no mathematical correlation. The sum of the variances in all of the components is equal to the total variance present in the original input image (ASP, 1983). The first component includes the largest percentage of the total scene variance. Succeeding components (PC2, PC3. . .PCn) each contain a decreasing percentage of the scene variance (Lillesand and Kiefer, 1994).

Two types of PCA were utilized in this thesis. Standard PCA means that all of the available input bands are used as input to the analysis. In this study, TM bands 2,3,4,5 and 7 were transformed into five new components. Each of the new components was

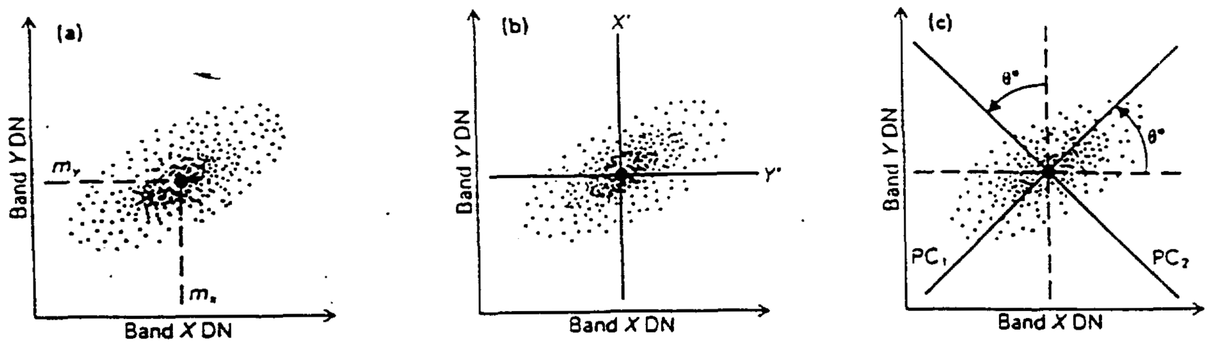

Figure 3: Principal Components Axes Shift and Rotation (Source: Drury, 1993)

analyzed independently in black and white. The fifth component was discarded, as it contained a high degree of image noise[3] and was uninterpretable.

Selective PCA means that only a subset of the available input bands are used as input to the analysis (Chavez and Kwarteng, 1989). In this thesis, the criteria used to select the subsets was based upon the degree of correlation between the bands. The following subsets were selected because of their higher degree of correlation: TM2/TM3 subset and TM5/TM7 subset, while the following subsets were selected because of their lower degree of correlation: TM2/TM5 subset and TM2/TM7 subset.

The method in which selective PCA uses only highly correlated subsets as input is useful for dimensionality reduction (Chavez et al., 1982; Chavez et al., 1984). By grouping the input bands in this manner, the PCA will map most of the variance or information into the first component. The method in which selective PCA uses subsets with a lower degree of

[3] Image noise is random or regular artifacts in data which degrade the information-bearing quality and are caused by defects in the recording device (Drury, 1993).

correlation is useful for identifying areas of spectral contrast (Chavez and Kwarteng, 1989). By using only two bands as input, the information that is common to both will be mapped to the first component and information that is unique to either one of the two input bands will be mapped to the second component (Chavez and Kwarteng, 1989). The subsets TM2/TM5 and TM2/TM7 were chosen because it was believed the moisture detection capabilities of the mid-infrared bands would aid in the identification of granular materials. Granular deposits are reasonably well-drained, therefore it was believed that they would contrast against the more poorly-drained surrounding landscape.

Each of the components created using the selective PCA procedure was analyzed independently in black and white

3.3 AIRPHOTO INTERPRETATION

The airphoto analysis is a necessary step in this project since it should either support or discard any speculations made about possible targets from the TM imagery. The airphoto analysis allows stereoscopic viewing of the topography of the targets. The improved resolution should also allow the vegetation cover of the targets and their surrounding areas to be distinguished, along with other finer details which were not distinguishable on the TM imagery. There were two sets of airphotos used in this project.

The airphotos used in the early stages of this project were 1956 black and white photographs at a scale of 1:60,000. They were borrowed from the Terrain Sciences Division of the Geological Survey of Canada. Airphotos were available for the entire 76D NTS map sheet of the Lac de Gras area. The roll numbers and photograph numbers for the photographs which were analyzed as part of this study are:

A15492 -- (1-25), (65-110), (160-181)
A15494 -- (1-25), (65-110)

A15495 -- (1-20), (50-90)

There were also colour airphotos available of the main BHP claim area in the Lac de Gras-Exeter Lake area. These photos were taken in August of 1993 at a scale of 1:20,000 by Eagle Mapping Services of Port Coquitlam, B.C. The roll numbers and photograph numbers for these photographs are:

G9308038 -- (1-164)
G9308037 -- (1-269)
G9308036 -- (1-283)

Every photo was carefully analyzed and the location of each potential deposit or glaciofluvial landform was recorded. The method of identifying the targets from the airphotos was generally the same method as used with the linear stretch technique, only the airphotos had increased resolution and stereoscopic abilities. The target identified on the airphoto was associated with a certain kind of landform after comparing it to a checklist of distinguishing features (see Table 3

The airphotos were also used in preparation for the field work portion of the project, so certain factors had to be considered to ensure that maximum use of the expensive helicopter time could be achieved. Each potential target was studied according to the following economic factors:

- approximate distance from Daring Lake camp (kilometres)
- relationship to major water bodies regarding development potential
- whether the prospect was in the zone of continuous or discontinuous permafrost
- approximate size of the deposit (category sizes are given below)

The categories which were used to classify the approximate size of each target were borrowed from "Compilation Inventory of Granular Material Resources Information Bordered by Latitude 63° and 68° and Longitude 102° and 112° in NWT" (Mollard 1994). The number range for each of these three categories is in cubic metres of material:

SMALL - tens of thousands to hundreds of thousands

MEDIUM - hundreds of thousands to millions

LARGE - millions to tens of millions

All available information pertaining to each target has been stored in the database entitled "features.dbf" (see Appendix A), which is described in Section 3.2.3. In addition to the fields described previously, the following fields pertaining to airphoto interpretation were included in the database:

- each of the economic factors considered when preparing for field work (except flight lines and photo numbers)
- the list of airphoto distinguishing features according to the lettered code as outlined in Table 3
- a reference as to whether the target is visible on both TM data and airphotos or on airphotos only

3.4 FIELD WORK

The preliminary TM linear stretch analysis and airphoto interpretation was verified by ground checks, short ground traverses and low-level helicopter surveys.

The key purpose of this project was to determine the effectiveness of using TM imagery as a "first-look" to identify glaciofluvial features in a large, relatively unknown area. Therefore it was decided that the focus of the field work should be to identify and observe as many of the targets as possible from the air. After observing as many of the targets as

Table 3: Airphoto Interpretation Distinguishing Features

FEATURE TYPE	POSSIBILITIES
ORIENTATION RELATIVE TO ICE FLOW DIRECTION	A. Parallel to ice flow B. Transverse to ice flow C. Lacking consistent orientation
ORIENTATION RELATIVE TO OTHER SIMILAR FEATURES	A. Same direction as other similar features B. No orientation with other similar features C. Orientation unknown
TONE/COLOUR (Black and White Photos)	A. Light grey (almost white) B. Medium grey C. Dark grey D. Combination (mixed lighter/darker)
TOPOGRAPHY	A. Narrow, steep-sided ridges; considerable relief B. Lumpy, steep-sided mounds; considerable relief C. Hummocky, hilly topography in an almost featureless plain D. Rounded, oval-shaped hills; considerable relief E. Flat-topped, steep-sided extensions of narrow, steep-sided ridges F. Relatively level topography; slight slope downward G. Narrow, gentle-sided ridges; little relief
SHAPE	A. narrow and sinuous; relatively uniform width; low width/length ratio B. very narrow and curving; relatively uniform width; generally a low width/length ratio C. oval to cigar-shaped streamlined forms D. belt of material with variable widths E. variable in shape and size F. Deltaic G. Conical or elongated hills
COVER	A. Bare B. Mosses (mottled) C. Grasses/Shrubs D. Mixed (bare/vegetated)
TONE/UNIFORMITY	A. Lineaments and fractures B. Uniform and smooth C. Mottled (vegetation) D. Other

Table 3: Airphoto Interpretation Distinguishing Features

FEATURE TYPE	POSSIBILITIES
ASSOCIATION WITH DRAINAGE FEATURES	A. Pass through lakes or weave through groups of lakes B. Parallel to shoreline (probable increased relief) C. Parallel to major streams D. No apparent association
ASSOCIATION WITH RELIEF	A. Run up and down slope B. Parallel to contour C. No apparent association

possible, conclusions would be made as to why some of the targets appear on both TM imagery and airphotos while some targets are visible on airphotos only. The actual quality and composition of the granular material was also considered in this project.

Before embarking for the work in the field, much preparation had to be done in order to ensure a balance of maximum cost-effectiveness and target coverage. As mentioned in the airphoto interpretation methodology, there are several economic factors which were considered when performing the airphoto interpretation (these are contained in "features.dbf" database). It was also necessary to observe the largest amount of variation within the targets as possible. For instance, it was important to gain observations from the following subgroups of targets:

- targets identified on both satellite imagery and airphotos
- targets identified from airphotos only
- targets believed to be eskers
- targets believed to be kames
- targets within areas of exposed bedrock, boulder fields or thin till

- targets within areas of thicker till

The targets were manually plotted on NTS topographic maps and a schedule was developed to visit the optimal number of sites considering the aforementioned factors (both economic and target variability).

At each of the target sites observed by the air or the ground, detailed notes and/or photographs were taken. For each target, qualitative descriptions and observations were made on the following variables:

- detailed description of the landform shape
- the amount of vegetation present and where on the landform it occurs
- the amount of exposed granular material
- a general description of the surrounding landscape
- any other unique features of the landform (e.g. sinkholes)

Further to the observations made from the helicopter surveys and ground checks, eight sites were chosen out of the target list as sampling locations. These sites were chosen because of their apparent potential for granular extraction. Therefore, some of the factors considered when choosing the sampling sites were: location of the target relative to proposed developments; potential volume of target; well-defined slope for extraction purposes; well-graded exposed granular material. By sampling selected targets, it was hoped that an indication of the quality of the granular material in the study area would be obtained. Additionally, after gaining some knowledge of the material within the landform, analysis could be made regarding the surficial appearance of the landforms compared to the different kinds of material inside.

When sampling and testing the eskers, each pit had to be at least one metre deep. A tarpaulin was spread out beside the test pit, and a representation from each layer was placed on the tarpaulin at each successive shovel layer. Remaining material from each layer was discarded. Once a depth of at least one metre was reached, the sample on the tarpaulin was reduced to a size which would fit into a 20 litre pail. The sample was reduced using the "quartering" method, which ensures that a representative sample of the entire pit is collected. The samples were then sent to EBA Engineering Consultants, Ltd. (Yellowknife) for detailed analysis.

4. RESULTS

4.1 SATELLITE IMAGE ANALYSIS

4.1.1 Linear Stretch

The simple linear stretch was used extensively in order to enhance the following image bands and colour composites. When performing single band image analysis, band 3 (red visible) and band 7 (mid-infrared) were used the most frequently. Band 3 is regarded as an excellent indicator of non-vegetated features, as it senses areas of chlorophyll absorption. Since many glaciofluvial landforms contain extensive sections of non-vegetated exposed aggregate (this is especially so in the arctic tundra), band 3 is useful for revealing them. Band 7 is often used in the discrimination of mineral and rock types and moisture content identification. It was effective in revealing many of the same targets that band 3 identified. Band 2 (green visible), which measures the chlorophyll reflectance of vegetation, is very effective at differentiating between vegetated areas and non-vegetated areas. Band 2 reveals many of the same features as band 3, yet it is not recommended for use alone because of sensitivity to haze.

Although several colour composites were experimented with, composites 432, 234 and 543 were chosen to focus on. With composite 432 (false colour infrared), the vegetation appears red/pink and exposed surfaces (e.g. exposed granular, boulders, bedrock) appear white to pale blue. Therefore it is relatively easy to differentiate between these two types of land cover, and in areas with a low amount of exposed bedrock the esker landforms can be quite apparent. Composite 543 produces an image which is closer to real-life colours in appearance. The vegetation appears green, exposed surfaces appear purple/pink and water bodies appear blue. Composite 234 produces an image with excellent contrast between the dominant colours. Vegetation in this composite appears purple while the exposed surfaces appear yellow. Composite 234 is quite effective at revealing eskers in areas with a low amount of exposed bedrock.

In all, a total of 36 targets was identified from the TM imagery on the study area of NTS map sheet 76D. Every one of these targets is believed to be eskers, although there are some differences between them. Some of these eskers are well-defined on the imagery while others are difficult to distinguish -- some of the eskers even display beading tendencies on the TM imagery. A beaded esker has numerous bead like expansions and contractions in width, due to pauses in glacial retreat or the discharge of esker streams into temporary lakes (Mollard, 1974). The targets which were identified on the TM imagery were almost evenly distributed between the three deposit size classes used in the study (defined in the airphoto interpretation methodology). Of these targets, eight were classified as small deposits, seven were classified as medium deposits and six were classified as large deposits.

The majority of the 36 targets which were identified from the TM imagery had distinguishing features which were similar to one another and are characteristic of eskers in general. The following is a list of distinguishing features of eskers as interpreted from the TM imagery:

- oriented parallel to the known direction of ice flow
- oriented in the same direction as other eskers
- shape is narrow and sinuous; width is relatively uniform
- tone/uniformity of surrounding landscape is mottled
- pass through lakes or weave throughout groups of lakes
- most of the eskers have exposed granular material which is highly reflective; this results in a very light tone on many of the bands/composites analyzed

Generally, it was much easier to detect the eskers on the TM imagery in areas of thicker till, as opposed to areas of thinner till, exposed bedrock or boulder fields. On some occasions the esker seemed to "blend in" to the surrounding landscape if it was situated near a boulder field or exposed bedrock.

4.1.2 Principal Components Analysis

The analysis of the covariance matrix and the correlation matrix will be reviewed first, as both of these matrices apply to the entire TM data set. Following the review of the covariance matrix and correlation matrix statistics, the results of the analyses of each PCA and each new component will be discussed. Eigenvector loading values for each transformation and the amount of scene variance in each new component will be provided.

4.1.2.1 Covariance Matrix and Correlation Matrix

Before applying the PCA to the TM data, it was necessary to create the covariance matrix of the data set (see Table 4). The covariance matrix represents the means by which the

Table 4: Covariance Matrix for Thematic Mapper Input Bands

TM Band	2	3	4	5	7
2	172.48				
3	189.52	214.28			
4	320.20	372.39	715.69		
5	499.30	586.27	1108.81	1764.21	
7	217.39	255.07	470.38	756.61	329.80

scatter/spread of the pixels in multispectral space is described. If there is a high correlation between a pair of spectral bands, the corresponding off-diagonal element in the covariance matrix will be large by comparison to the diagonal element. If there is little correlation between the spectral bands, the off-diagonal terms will be close to zero (Richards, 1993). As is evident from analysis of Table 4, the spectral bands in this study's data set are highly correlated. All of the off-diagonal terms in the matrix are relatively large and none of the off-diagonal terms are close to zero. By applying Equation 4.1 to the covariance matrix, a correlation matrix of the TM spectral bands can be created (Richards, 1993),

$$Q_{ij} = V_{ij} / \text{sq.rt} (V_{ii} * V_{jj}) \qquad \text{(Equation 4.1)}$$

where Q_{ij} is an element of the correlation matrix and V_{ij}, etc. are elements of the covariance matrix; V_{ii} and V_{jj} are the variances of the *i*th and *j*th bands of data. The correlation matrix for the data set used in this thesis is displayed in Table 5. As was to be expected after analyzing the covariance matrix, the numerical correlation values are all

Table 5: Correlation Matrix for Thematic Mapper Input Bands

TM Band	2	3	4	5	7
2	1.0				
3	0.986	1.0			
4	0.912	0.951	1.0		
5	0.905	0.954	0.987	1.0	
7	0.912	0.959	0.968	0.992	1.0

quite high. A general trend of most multispectral data which can be observed in this correlation matrix is that bands which are closer to each other in the electromagnetic spectrum have greater correlation values.

4.1.2.2 Standard Principal Components Analysis

Table 6 contains the eigenvector loading values for the standard PCA, in which all available TM data bands were used as input to the analysis.

<u>Principal Component 1 -- 98.03% Scene Variance</u>

This component contains substantial positive loading values (ranging from 0.22 to 0.75) for all TM input bands. The image is generally an average of all input bands, and can be

Table 6: Eigenvector Loadings for Standard PCA

	TM2	TM3	TM4	TM5	TM7
PC1	0.22	0.25	0.47	0.75	0.32
PC2	0.76	0.55	-0.08	-0.34	-0.03
PC3	-0.02	0.10	-0.81	0.26	0.51
PC4	-0.26	0.14	0.33	-0.50	0.74
PC5	-0.56	0.77	-0.05	0.06	-0.28

referred to as the "brightness" index (Drury, 1993). This component was ineffective in the identification of granular resources. Because PC1 is an average of all input bands, the resulting image is quite "smooth" and lacking in contrast. There appears to be a limited amount of grey values/tones used in this image. The characteristics of the eskers (e.g. differing vegetation and moisture content than the surrounding landscape) which would make them evident in a PCA would not be detected until the later components.

Principal Component 2 -- 1.32% Scene Variance

PC2 contains strong positive loadings in the visible input bands (highest on TM2) and negative loading values in the near infrared and mid-infrared bands. Vegetation is a material that displays this contrast between the visible and infrared portions of the spectrum; therefore this component may be considered a "vegetation index". Because vegetation has higher reflectance levels in the infrared portions of the spectrum and these input bands have negative loading values, this image would display regions of vegetation contrast darker. This component was a poor indicator of granular resources, although they can be detected if some previous knowledge of their location is known. This component was best enhanced using a logarithmic contrast enhancement, a technique which is useful for enhancing dark features (Richards, 1993).

Principal Component 3 -- 0.56% Scene Variance

PC3 contains strong positive loadings in the mid-infrared bands and a strong negative loading in the near infrared band. The visible band loadings can be disregarded because the degree of the loadings is quite light. This component could be used as an indicator of vegetation. The very high negative loading for the near infrared band contrasted against the positive loadings for the mid-infrared bands would display areas of vegetation contrast with a dark tone. This component could also be used as an indicator of vegetation moisture content, as both of the mid-infrared bands contain water energy absorption zones (Drury, 1993). Eskers, boulder fields, exposed bedrock and flutings all appear very light on this image and can be difficult to distinguish from each other. Flutings are smooth straight parallel furrows worn in the surface of the rocks by glacial erosion (Mollard, 1974). Some eskers not detected from the linear stretch analyses were identified on this image, primarily in areas where there was little exposed bedrock, boulder fields or flutings. Areas of till appear darker. The contrast on this image between till and exposed rock surfaces is probably due to vegetation contrasts and moisture content. Regions with glacial till would have a greater amount of vegetation than the exposed rock surfaces of eskers, boulder fields, bedrock and flutings. This image was best enhanced using a linear stretch.

Principal Component 4 -- 0.06% Scene Variance

PC4 contains substantial negative loadings for TM2 and TM5 input bands, and substantial positive loadings for TM3, TM4 and TM7 input bands. Because of the complexity of the loading sequence, it was not possible to provide an exact explanation as to what this component displays. This image is quite noisy, although it is still interpretable. Organic soils/peat bogs appear very dark on this image and are well-defined. Eskers are also well-defined and appear very bright. There is good contrast between the eskers and other exposed rock surfaces -- they can be easily distinguished from each other. Some of the eskers only identified from airphoto analysis can be detected, but they are very difficult to extract owing to the amount of image noise present. These targets probably wouldn't be extracted if previous knowledge of them wasn't available. This image was best enhanced using a linear stretch.

Principal Component 5 -- 0.02% Scene Variance

This component was disregarded as the amount of scene variance it represents is negligible. The image was very noisy and uninterpretable.

4.1.2.3 Selective Principal Components Analysis

Principal Component 1 (TM2/TM3) -- 99.30% Scene Variance

Table 7 contains the eigenvector loading values for the selective PCA utilizing TM2 and TM3 as input bands for the analysis.

Table 7: Eigenvector Loadings for Selective PCA TM2/TM3

	TM2	TM3
PC1	-0.67	-0.74
PC2	-0.74	0.67

PC1 contains high negative loadings for both input bands, and can be considered the brightness component, or average of the two input bands. This is an excellent image for identifying eskers, as they appear very dark and well-defined. Some of the targets previously identified from airphotos - only can be extracted with ease. Eskers are easily separated from the larger, lighter boulder fields. Waterbodies are very light, while peat bogs/organic soils have a lighter tone than other soil types. The reason this component is so effective at displaying eskers is because it is basically an average of two input bands, which independently are also very effective at displaying eskers. This image was best enhanced using a logarithmic contrast enhancement.

Principal Component 2 (TM2/TM3) -- 0.70% Scene Variance

PC2 contains a high negative loading for the TM2 input band and a high positive loading for the TM3 input band. This image should display contrast between regions of chlorophyll reflectance (TM2) and chlorophyll absorption (TM3), but it is very difficult to interpret due to the high degree of noise. Eskers appear very light and are easily separated from the boulder fields, which were unidentifiable and blended into the landscape. Eskers which were previously identified on airphotos only were very difficult to extract due to the high amount of noise. This image was best enhanced using a linear stretch. This component is not recommended for use in granular resource identification.

Principal Component 1 (TM5/TM7) -- 99.79% Scene Variance

Table 8 contains the eigenvector loading values for the selective PCA utilizing TM5 and TM7 as input bands for the analysis.

Table 8: Eigenvector Loadings for Selective PCA TM5/TM7

	TM5	TM7
PC1	-0.92	-0.39
PC2	0.39	-0.92

PC1 contains a very high negative loading for the TM5 input band, and a smaller negative loading for the TM7 input band. This component should approximate an average of the two input bands, with more emphasis being placed on TM5 characteristics due to the high loading value. The overall tone of this image is quite dark, even with a logarithmic contrast stretch applied. This component delineates the organic soils/peat bogs very accurately with a dark tone. Eskers are well-defined and very dark, but can be difficult to distinguish due to the overall dark image tone. This component is not recommended for use in granular resource identification.

Principal Component 2 (TM5/TM7) -- 0.21% Scene Variance

PC2 contains a positive loading for the TM5 input band, and a very high negative loading for the TM7 input band. Eskers appear dark and very well-defined. Yet in areas with a large number of boulders (a substantial part of the study area), it is often difficult to extract the eskers as their tones are very close to the boulders. Some of the eskers previously identified on airphotos only can be identified, and flutings are also very apparent on this component. The till surfaces, which are generally light toned, contrast against the exposed rockfaces. The exposed rock faces probably appear dark on this image due to the high negative loading for TM7, a band which is used for discrimination of rock types in geological applications. The lighter-coloured till surfaces are probably due to the positive loading for TM5, a band which could sense the vegetation and soil moisture of the till. This component is recommended for use in granular resource identification with reservations, such as in areas with a low proportion of boulders and flutings present. This image was best enhanced using a linear stretch.

Principal Component 1 (TM2/TM5) -- 98.51% Scene Variance

Table 9 contains the eigenvector loading values for the selective PCA utilizing TM2 and TM5 as input bands for the analysis.

Table 9: Eigenvector Loadings for Selective PCA TM2/TM5

	TM2	TM5
PC1	-0.28	-0.96
PC2	-0.96	0.28

PC1 contains a negative loading for the TM2 input band and a very high negative loading for the TM5 input band. This component should approximate an average of the two input bands, with more emphasis being placed on TM5 characteristics due to the high loading value. The overall tone of this image is quite dark, even with a logarithmic contrast stretch applied. This component delineates the organic soils/peat bogs very accurately with a dark tone. Eskers are well-defined and very dark, but can be difficult to distinguish due to the overall dark image tone. This component is not recommended for use in granular resource identification.

Principal Component 2 (TM2/TM5) -- 1.49% Scene Variance

PC2 contains a very high negative loading for the TM2 input band and a positive loading for the TM5 input band. The boundaries of peat bogs/organic soils are delineated very accurately and appear very light on the image. The peat bogs appear light on this image due to the positive loading for TM5, which senses soil moisture. Eskers can be identified, but they are poorly-defined and "blend in" to the rest of the landscape. It would be very difficult to identify the eskers if prior knowledge of their whereabouts was not known. This component is not recommended for use in granular resource identification. This image was best enhanced using a linear stretch.

Principal Component 1 (TM2/TM7) -- 96.03% Scene Variance

Table 10 contains the eigenvector loading values for the selective PCA utilizing TM2 and TM7 as input bands for the analysis.

Table 10: Eigenvector Loadings for Selective PCA TM2/TM7

	TM2	TM7
PC1	-0.57	-0.82
PC2	-0.82	0.57

PC1 contains substantial negative loadings for both TM2 and TM7 input bands. Eskers and boulder fields are both very dark-toned and well-defined. Some eskers identified previously from airphotos only and flutings can also be identified. This component is basically an average of the two input channels. Since both TM2 and TM7 are effective at defining eskers when used independently, the first component of this selective PCA will display eskers accurately. Additionally, the low moisture content of the eskers as compared to the surrounding landscape could be the cause for this contrast between TM2/TM7. TM7 is much more sensitive to moisture content than TM2. This image is best enhanced using a logarithmic contrast stretch. This component is recommended for use in granular resource identification.

Principal Component 2 (TM2/TM7) -- 3.97% Scene Variance

PC2 contains a substantial negative loading for the TM2 input band and a substantial positive loadings for the TM7 input band. It is very difficult to extract eskers from boulder fields and the remainder of the light-toned image. This image is best enhanced using a linear stretch. This component is not recommended for use in granular resource identification.

4.2 AIRPHOTO INTERPRETATION

In total ninety-two targets were identified in the study area bounded by NTS map sheet 76D. Thirty-six of these targets were identified from both the TM linear stretch analysis and airphotos. Fifty-six of these targets were identified from detailed airphoto analysis only. The targets which were identified on both TM data and airphotos were quite evenly distributed between the three deposit sizes. Of the targets which were identified on airphotos only (for which there was size data), the majority were classified as small deposits. Twelve targets (out of seventeen for which size data was available) were classified as small.

Most of the targets which were identified on airphotos only are within areas with a large amount of exposed bedrock or a very thin till cover. Like the TM imagery, the reflectance levels of exposed bedrock and exposed granular material on airphotos are often very similar. In many cases it is very difficult to distinguish glaciofluvial landforms in areas of exposed bedrock using only features such as tone and colour. Unlike the TM imagery, the ability to view airphotos stereoscopically allows the unique topography of the glaciofluvial landforms to be extracted from the surrounding g area. The majority of the remaining airphoto-only esker targets were too small for the satellite to detect because of its lower resolution.

The airphoto analysis was very effective at extracting finer details about the landforms which were visible on TM imagery, for which the satellite data provided little detail. On many of the larger, well-defined eskers there are areas where material "splay" away from the main esker body. These areas probably formed where there was an opening in the glacier and some of the meltwater sediments escaped. These formations can only be identified reliably from the airphotos. Another phenomenon which can be analyzed in detail from the airphotos is esker beading.

Groups of small mounds (probably kames) usually situated near large eskers were only identifiable on the airphotos. This is due to the size of the mounds, which were too small to be identified from the satellite imagery's lower resolution.

Some types of land cover are easier to distinguish on the airphotos than on the TM imagery. For example, areas with a large amount of organic material (e.g. peat bogs) appeared darker than thick till on the airphotos, yet lighter than water. Areas which are vegetated are also easier to distinguish on the airphotos, although it is possible to make quite accurate vegetation deductions from the TM imagery. The larger-scale colour airphotos were very effective at revealing vegetation, since real-life colour knowledge could be applied to the interpretation.

Along with the detailed glaciofluvial features (e.g. esker beading) which could only be identified from airphoto analysis, there were also certain types of landforms which could be identified from the airphotos only because of their topography; drumlins are a good example. Drumlins are composed of unstratified material and are generally a poor source of granular material, and therefore lack the excessive surface drainage that is characteristic of glaciofluvial landforms. Because drumlins are composed primarily of till they are often covered with vegetation. Being covered with vegetation, the reflectance values of drumlins on airphotos and satellite imagery is usually quite low. This makes it difficult to distinguish drumlins from the surrounding landscape using reflectance values alone. Drumlins can only be reliably identified using the stereoscopic abilities of airphotos. Within the study area there is a very large drumlin field south of Lac de Gras, and a smaller field to the northeast of Lac de Gras.

4.3 FIELD WORK

In total, 74 of the 92 targets identified from the TM linear stretch analysis and airphoto interpretation were observed. Fifteen of the remaining targets were omitted because their locations were either too distant relative to fuel supplies or were inaccessible. Misinterpretation of the landscape either during the field work or during the pre - field work analysis accounted for the remaining three target omissions.

The observed characteristics of eskers identified on both TM imagery and airphotos will be discussed first. In general, the eskers identified on the TM imagery were significantly larger in width, height and length than the eskers identified on airphotos only. The majority of these eskers had a relatively rounded top with very little crest. The top of these eskers is usually either sand or a mixture of sand and a thin cobbly "crust". Most of these landforms are vegetated by grasses and small plants along the sides, but have very little vegetation on the top. Most of these eskers appeared to be of a considerable relief of approximately ten metres or greater. In most cases, the landscape surrounding these targets was either thick glacial till (with vegetation) or water bodies. Finally, the eskers identified from the TM imagery, being larger, displayed more special features like sinkholes, esker terraces and ice-wedge polygons than their airphoto-identified counterparts.

The eskers which were identified on airphotos only are divided between those with rounded tops and those with sharper crests. The surface of these landforms is usually an exposed coarse-grained sand. Most of these eskers had some vegetation along the side slopes but had very little on the top, similar to the eskers identified on TM imagery. These eskers were divided between smaller relief (approximately ten metres or less) and greater relief (approximately ten metres or more), yet the vast majority of these eskers were not as wide as the targets identified from the TM data. Most of these targets are surrounded by a landscape consisting of a large proportion of exposed bedrock or boulders. Another general observation about eskers is that when they near a major water body or enter a water body the composition of the esker tends to become coarser and the crest becomes quite sharp. A possible explanation for this tendency is the flanks of the esker are being eroded and the finer materials washed away by the surrounding water body.

All of the kame targets in this project were identified on the airphotos only. They were all covered with well-graded granular material and a high percentage of cobbles. Most of the kames had only a very small amount of vegetation near the base. The majority of the kames had little relief, yet a few of them were a considerable size (five to ten metres).

Seven sample sites were chosen because of their potential suitability for granular resource extraction. Each of these sites have a rounded crest, except for one which has a flat surface, and all sites were well-drained. The vegetation cover on these eskers ranged from less than 15 percent to approximately 100 percent. The esker with the flat surface had the least amount of vegetation cover. The percent cobble and boulder cover ranged from zero to approximately 70 percent. The esker with the flat surface had approximately 15 percent cobble/boulder cover. Four of the six sample sites which had rounded crests were described as containing well-graded material, generally a mix of fine sand, coarse sand, pebbles and cobbles. Two of the sample sites with rounded crests were described simply as "sand and gravel". The sample site with the flat surface was found to contain poorly-graded material, consisting predominantly of sand and pebbles.

5. CONCLUSIONS

This thesis had two primary objectives to solve. First, it was necessary to determine the reliability of satellite image analysis techniques as compared to the traditional method of airphoto interpretation in the identification of granular resources. The reliability of the satellite imagery is an issue because of the decrease in scale from airphotos and the lack of stereoscopic viewing. Second, it must be determined if principal components analysis of the TM data provides for increased separability of granular deposits than the use of standard TM image bands.

The main purpose of the TM image analysis was to determine whether the imagery could be used to distinguish granular resources, and to identify some of the factors affecting this process. The two types of TM image analysis performed in this study enhance the TM data in very different manners, and therefore must be reviewed separately. When utilizing a linear stretch enhancement the highly-reflective exposed granular materials, which are a characteristic surface material for many large eskers, tend to appear bright or over-exposed. The tone surrounding most of the targets identified from the linear stretch analysis could be described as mottled. This tone is representative of areas with differing drainage patterns, most likely hummocky till or organic soils. This contrast in reflectance levels makes it possible to extract potential granular materials within areas of thicker till or organic soils. When performing stretches of single TM bands, TM3 and TM7 were found to be the most effective for revealing eskers. Figure 4 is a TM3 subset of the study area enhanced using a linear stretch. The image is approximately 20 kilometres by 18 kilometres in area. Eskers are easily delineated from the image as they are bright in tone. Also evident are the roads and airstrip of the BHP Minerals exploration site at the left-hand side of the image. When utilizing stretched colour composites of the TM data, RGB composites 432 and 234 were found to be the most effective.

Figure 4: Sample Enhancement: Linear Stretch of TM Band 3

Two variations of the PCA were performed in this study, both the standard PCA and the selective PCA. Standard PCA utilizes all of the available TM data bands as input to the analysis, while selective PCA uses only a subset of the available bands as input to the analysis. The subsets which were used as input to the selective PCA were: TM2/TM3, TM5/TM7, TM2/TM5, TM2/TM7. After performing the various principal component analyses, two of the new components were found to be very effective in the identification of granular resources, while two components were recommended for use with reservations. The first component of the TM2/TM3 selective PCA was very effective at delineating eskers because it is an average of two input bands which are very effective at displaying eskers when used independently. Figure 5 is the same subset of the study area as was used in Figure 4. The first component of the TM2/TM3 selective PCA is displayed in this image. Eskers are identified as the black lineal features occurring in an approximate east to west (left to right) pattern across the image. A boulder field can also be delineated as the dark region in the lower centre area of the image. The first component of the TM2/TM7 selective PCA was also very effective at revealing eskers for two reasons. Because it is an average of two input bands which are both effective at displaying eskers when used independently, this component is also effective. Additionally, the low moisture content of the eskers as compared to the surrounding landscape could be the cause for this contrast between TM2 and TM7. TM7 is much more sensitive to moisture content than TM2. The third component of the standard PCA and the second component of the TM5/TM7 selective PCA were recommended for use with reservations. Both of these components were very effective at revealing exposed rocks, ranging from granular material to boulders and bedrock. In areas with more than one type of exposed rock present, it is very difficult to distinguish between types. Therefore these components could be used to identify granular resources in areas with a low proportion of other exposed rock types.

Several factors indicate that the eskers identified on TM imagery are possibly trunk (main) eskers or tributaries thereof -- a large network of eskers feeding into the trunk. Most of these landforms are oriented parallel to the direction of ice flow and in the same direction as other similar features. Additionally, most of these eskers pass through lakes or weave throughout groups of lakes.

The airphoto interpretation accomplished two tasks, the first one being that finer details

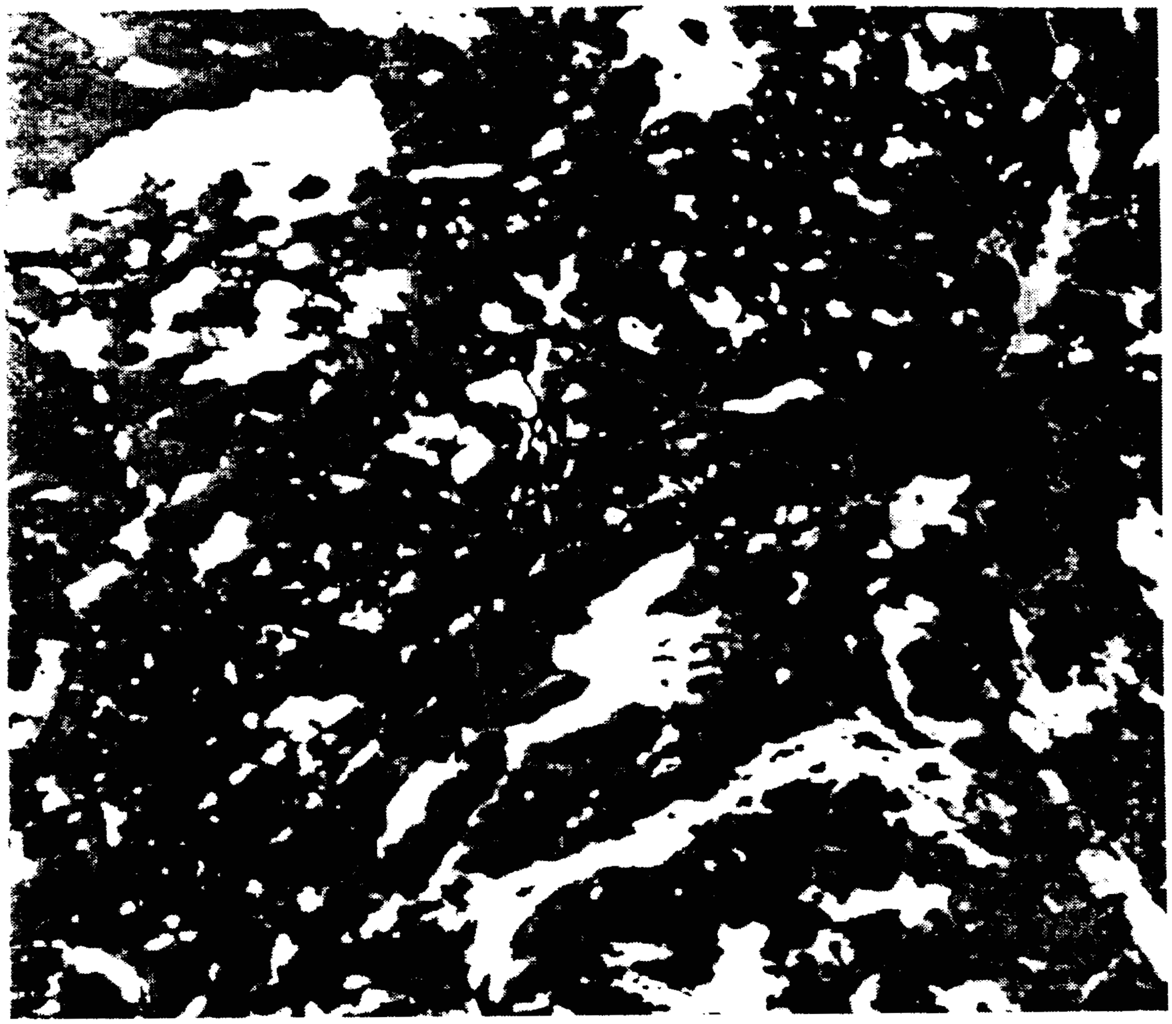

Figure 5: Sample Enhancement: PC1 of TM2/TM3 Selective PCA

(e.g. beading) of the eskers identified from the linear stretch analysis were revealed. The other major task accomplished is a number of new targets (eskers and kames) were identified which were not evident from the linear stretch analysis. According to Mollard (1994), most of the targets identified from the airphotos for which there are data are considered small prospects. There are two reasons why these targets were identified on airphotos only and not with the linear stretch analysis. First, most of the airphoto-only targets are within areas with a large amount of exposed bedrock and boulders. These landscapes have similar reflectance values to the exposed granular, and therefore other factors must be depended upon to identify the targets (e.g. relief). Second, these landforms are generally smaller in length and width than their counterparts identified on the TM imagery, and do not seem to be oriented in the same direction as the ice flow or each other. These clues seem to indicate that these are not trunk eskers or tributaries thereof -- they are likely smaller independent landforms which cannot be identified with the decreased resolution of the TM sensor.

The other main objective of this thesis was to determine if PCA of the TM data provides for increased identification of granular deposits than the use of linear stretches of standard TM bands. The eskers which were unidentifiable during the linear stretch analysis due to their size would also be unidentifiable in a PCA. This is due to the spatial resolution of the TM sensor, and not with the data enhancement techniques. However, the two components which were recommended for use in granular resource identification were very effective at delineating the trunk eskers and tributaries along with some of the eskers which were not identified from the linear stretch analysis. The first component of the TM2/TM3 selective PCA clearly identified some of the targets which were not evident from the linear stretch analysis. This component also provided a good deal of contrast between the eskers and other exposed rock faces, such as bedrock and boulder fields. The first component of the TM2/TM7 selective PCA also identified some of the eskers which were not extracted from the linear stretch analysis. A large number of glacial flutings were also evident using this component. For the most part, the effectiveness of this component is probably due to the moisture content sensitivity contrast between TM bands 2 and 7.

Figure 6 is a TM7 subset of the study area enhanced using a linear stretch. The image is approximately 20 kilometres by 18 kilometres in area. This subset is located on the south side of Lac de Gras in an area where eskers were not identified during linear stretch analysis. However, further analysis of the area with airphotos revealed potential granular deposits in the upper-right portion of the image. Although it is possible to faintly delineate the small SE-NW tending esker, the boundaries of the landform are so poorly defined that a judgment made solely on the basis of this image would have to be questioned. The degree of tone variance within this image is very poor; excluding waterbodies, the grey levels are relatively uniform throughout. Figure 7 is the same subset of the study area as was used in Figure 6. The first component of the TM2/TM7 selective PCA is displayed in this image. Along with the faintly recognizable esker observed in the upper right portion of Figure 6, other SE-NW tending eskers can be delineated in Figure 7. They are very dark in tone and their boundaries are better defined than in Figure 6. The remainder of the Figure 7 image has a greater contrast in grey levels than Figure 6, providing for easier extraction of the potential granular resources.

The main esker systems of the region were generally identifiable using linear stretch analysis, and were predominantly located within areas of thicker till. Eskers identified on airphotos only were generally located within areas with high amounts of bedrock or boulders or were too small to be detected by the TM sensor. Kame targets were unidentifiable on the TM imagery due to the TM resolution. The first components of selective PCAs TM2/TM3 and TM2/TM7 both provided accurate delineation of the main esker systems, and also identified some of the eskers which were not extracted from the linear stretch analysis in areas of exposed bedrock and boulder fields.

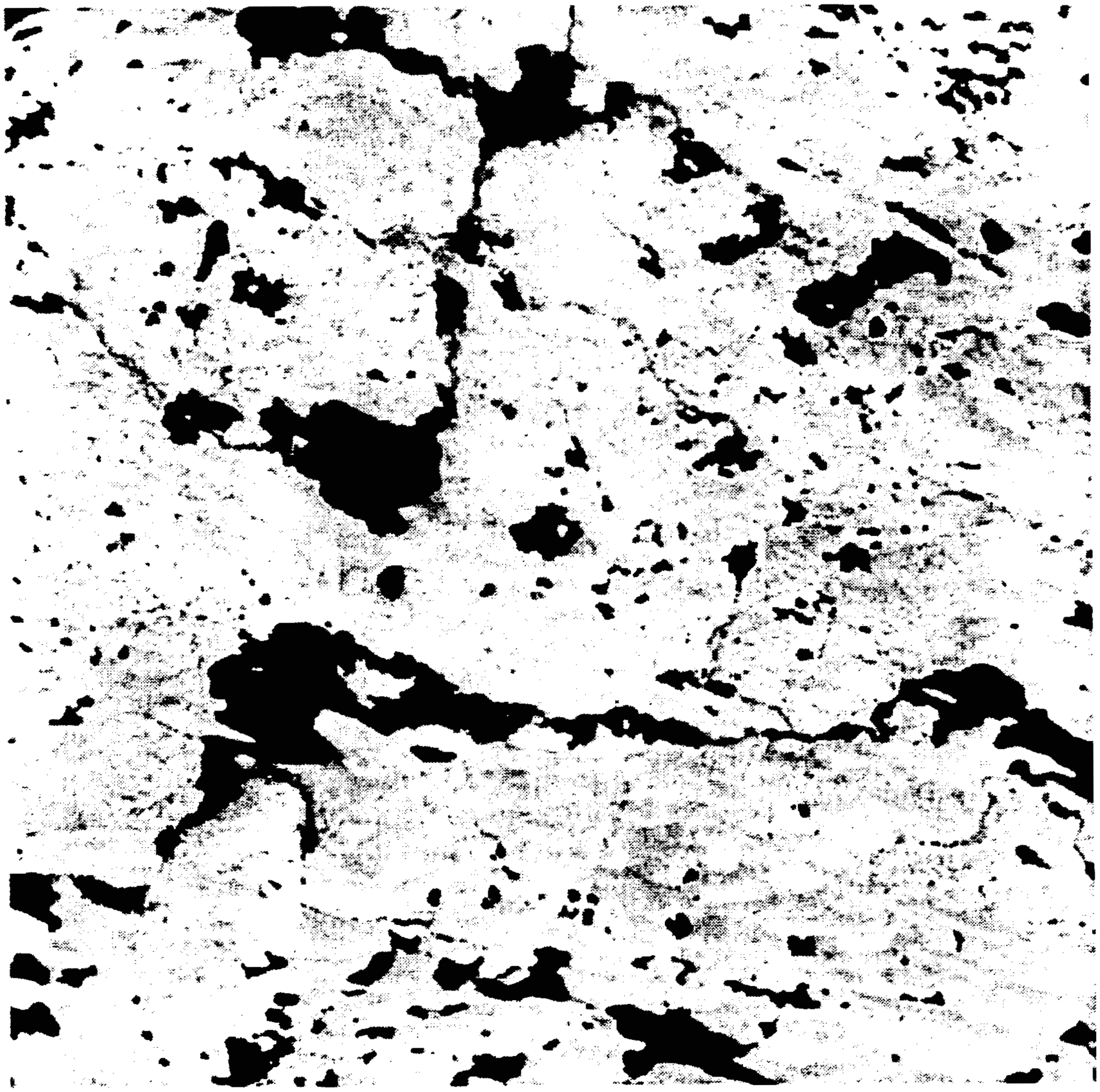

Figure 6: Sample Enhancement: Linear Stretch of TM Band 7

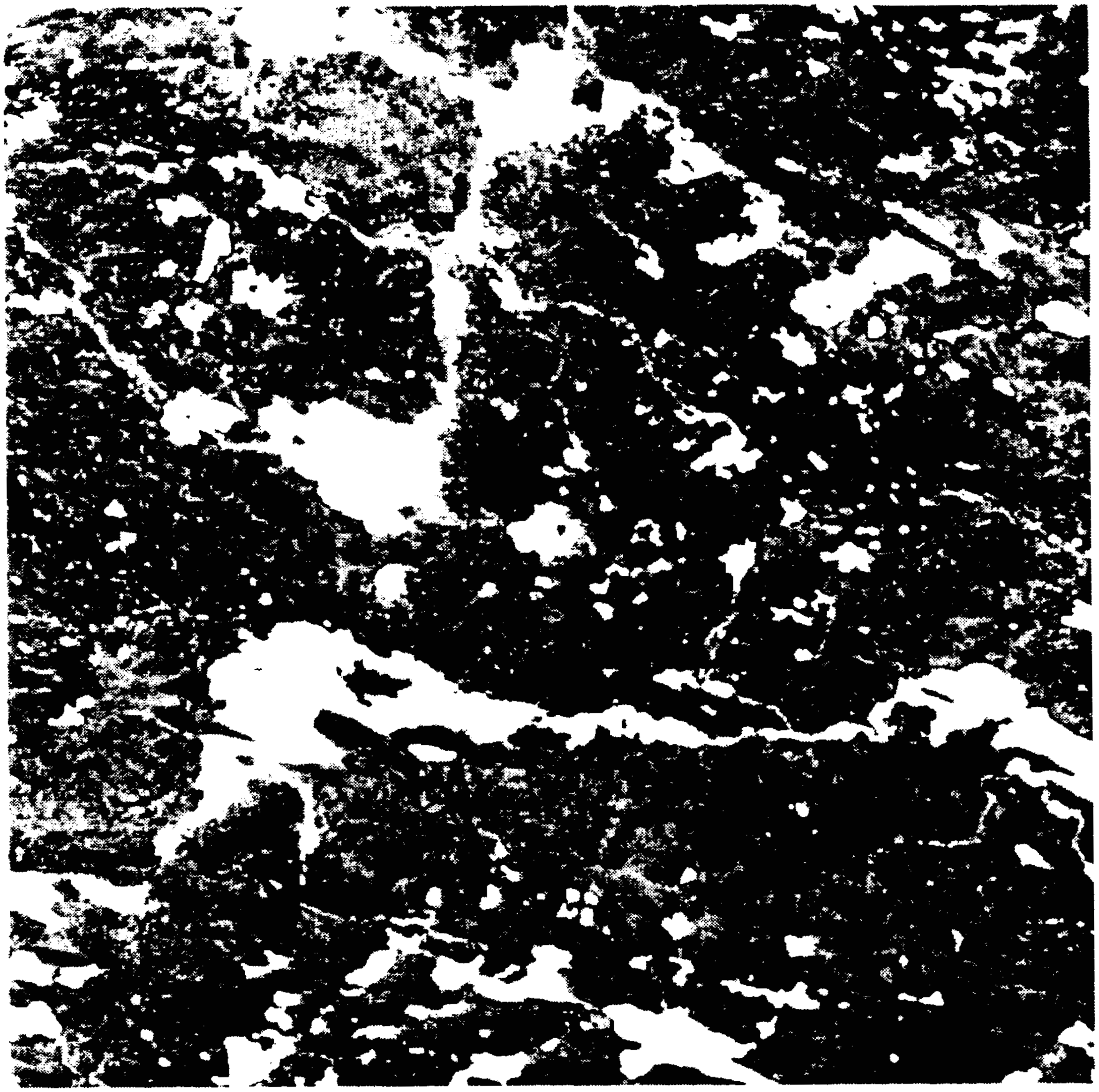

Figure 7: Sample Enhancement: PC1 of TM2/TM7 Selective PCA

6. PROJECT LIMITATIONS

Although every effort has been made to keep this methodology logical and accurate, it is inevitable that some limitations occur. First and foremost, it must be noted that image analysis techniques which are effective in the tundra ecosystem may not be as effective when analyzing a different landscape due to changes in the landforms, vegetation, etc.

The experience of the author with both the equipment and imagery could have an influence on the quality of analysis which is performed with the data. Increased experience could result in a larger amount of targets being identified through such analyses as rock-type discrimination and geobotanical applications.

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APPENDIX "A"

NUMBER	WESTERN POINT LAT. (North)	WESTERN POINT LONG. (West)	EASTERN POINT LAT. (North)	EASTERN POINT LONG. (DEG)	CENTRE POINT LAT. (North)	CENTRE POINT LONG. (West)	SIZE	DISTANCE TO FIELD CAMP (KM)	DISTANCE TO SAUVAGE ESKER (KM)
1a	64d36m28s	108d43m23s	64d36m50s	108d34m26s	0.00	0.00			
1b	64d36m28s	108d43m23s	64d35m15s	108d40m17s	0.00	0.00			
2	64d37m33s	108d51m59s	64d36m43s	108d45m33s	0.00	0.00			
3a	64d36m4s	109d8m31s	64d33m55s	109d2m15s	0.00	0.00			
3b	64d33m55s	109d2m15s	64d33m8s	108d56m37s	0.00	0.00			
3c	64d33m55s	109d2m15s	64d31m42s	108d58m32s	0.00	0.00			
4	64d31m27s	108d53m9s	64d26m58s	108d47m47s	0.00	0.00			
5	64d35m10s	109d16m29s	64d34m21s	109d13m52s	0.00	0.00			
6a	64d47m24s	110d52m	64d46m	110d38m	0.00	0.00	L	42.50	14.00
6b	64d46m	110d38m	64d45m30s	110d27m	0.00	0.00		52.50	0.00
6c	64d45m30s	110d27m	64d44m	110d11m	0.00	0.00		62.25	0.00
6d	64d44m	110d11m	64d41m	110d	0.00	0.00	M	72.50	14.00
6e	64d41m	110d	64d32m30s	109d45m	0.00	0.00			
6f	64d32m30s	109d45	64d27m30s	109d30m	0.00	0.00			
6g	64d27m30s	109d30m	64d26m	109d15m	0.00	0.00			
6h	64d26m	109d15m	64d20m30s	109d	0.00	0.00			
6i	64d20m30s	109d	64d17m	108d55m	0.00	0.00			
6j	0.00	0.00	0.00	0.00	64d45m	110d24m			
6k	0.00	0.00	0.00	0.00	64d43m	110d6m		72.00	14.00
6l	0.00	0.00	0.00	0.00	64d42m	110d4m		73.75	16.00
7a	64d45m6s	110d26m33s	64d43m	110d18m30s	0.00	0.00	S	60.00	5.00
7b	64d43m	110d18m30s	64d41m	110d14m	0.00	0.00		64.75	5.75
7c	0.00	0.00	0.00	0.00	64d43m	110d22m			
8a	64d37m27s	110d12m20s	64d33m51s	110d8m5s	0.00	0.00	M	73.75	15.00
8b	64d39m30s	110d14m	64d37m30s	110d12m	0.00	0.00		70.50	11.00
8c	0.00	0.00	0.00	0.00	64d35m30s	110d11m		74.00	16.00
9a	64d32m8s	109d58m23s	64d29m	109d45m	0.00	0.00			
9b	64d29m	109d45m	64d25m	109d35m	0.00	0.00			
9c	64d24m	109d33m	64d22m4s	109d29m37s	0.00	0.00			

NUMBER	WATER HINDER	CONTINUOUS PERMA.	AF1	AF2	AF3	AF4	AF5	AF6	AF7	AF8	AF9	SF1	SF2	SF3	SF4	SF5	SF6	SF7
1a												A	A		A	D	A	B
1b																		
2												A	A		A	D	A	B
3a																		
3b																		
3c																		
4																		
5																		
6a	TRUE	TRUE	A	A	D	A	A	D	D	A	B	A	A	A	A	D	A	C
6b	FALSE	TRUE	A	A	D	A	A	D	D	A	B	A	A	D	A	D	A	C
6c	FALSE	TRUE	A	A	D	A	A	D	C	A	C	A	A	A	A	C	A	A
6d	TRUE	TRUE	A	A	D	A	A	D	C	A	B	A	A	A	A	C	A	C
6e																		
6f												A	A	A	A	C	A	B
6g																		
6h																		
6i																		
6j			B	A	A	F	F	A	D	D	C							
6k	TRUE	TRUE	C	C	D	B	G	D	D	D	C							
6l	TRUE	TRUE	C	A	D	E	E	D	D	D	B							
7a	FALSE	TRUE	A	A	D	A	A	D	C	A	B	A	A	A	A	C	A	C
7b	TRUE	TRUE	A	A	D	A	A	D	C	A	B	A	A	D	A	C	A	B
7c			C	C	A	F	E	A	D	D	C							
8a	FALSE	TRUE	A	A	D	A	A	D	A	A	A	A	A	A	A	A	A	B
8b	FALSE	TRUE	A	A	D	A	A	D	D	A	B							
8c	FALSE	TRUE	C	C	A	B	G	A	D	D	C							
9a																		
9b												A	A	A	A	C	A	B
9c																		

NUMBER	WESTERN POINT LAT. (North)	WESTERN POINT LONG. (West)	EASTERN POINT LAT. (North)	EASTERN POINT LONG. (DEG)	CENTRE POINT LAT. (North)	CENTRE POINT LONG. (West)	SIZE	DISTANCE TO FIELD CAMP (KM)	DISTANCE TO SAUVAGE ESKER (KM)
10a	64d49m46s	110d44m32s	64d49m30s	110d37m30s	0.00	0.00		42.50	5.75
10b	64d49m30s	110d37m30s	64d49m30s	110d30m	0.00	0.00		48.00	6.25
10c	64d49m30s	110d30m	64d49m30s	110d16m	0.00	0.00	M	60.00	8.25
10d	64d49m30s	110d16m	64d50m30s	110d5m	0.00	0.00	S	66.75	10.50
10e	0.00	0.00	0.00	0.00	64d49m30s	110d36m		47.25	10.50
11	64d49m9s	109d53m2s	64d48m53s	109d51m28s	0.00	0.00			
12a	64d51m8s	110d50m3s	64d53m	110d37m	0.00	0.00	S	39.25	9.50
12b	64d53m30s	110d33m	64d56m26s	110d22m47s	0.00	0.00	S	55.00	17.50
14a	64d22m38s	110d7m3s	64d18m18s	110d5m2s	0.00	0.00	S	91.75	42.75
14b	64d29m	110d7m30s	64d22m30s	110d1m30s	0.00	0.00	S	86.25	32.50
15	0.00	0.00	0.00	0.00	64d24m57s	109d36m22s			
16	0.00	0.00	0.00	0.00	64d42m3s	108d47m28s			
17	0.00	0.00	0.00	0.00	64d36m5s	109d8m44s			
18	64d47m43s	109d10m30s	64d38m36s	108d56m15s	0.00	0.00			
19	64d2m57s	109d48m39s	64d3m6s	109d24m	0.00	0.00			
20	0.00	0.00	0.00	0.00	64d11m20s	109d51m12s			
21	65d14m10s	109d2m17s	65d12m18s	109d1m29s	0.00	0.00			
22a	65d20m42s	109d37m20s	65d14m37s	109d21m3s	0.00	0.00			
22b	0.00	0.00	0.00	0.00	65d16m12s	109d24m56s			
23	65d23m52s	110d5m42s	65d8m40s	109d10m	0.00	0.00			
24a	0.00	0.00	0.00	0.00	65d26m15s	110d27m56s			
24b	0.00	0.00	0.00	0.00	65d24m29s	110d19m32s			
24c	0.00	0.00	0.00	0.00	65d24m5s	110d16m35s			
24d	0.00	0.00	0.00	0.00	65d23m15s	110d13m43s			
24e	0.00	0.00	0.00	0.00	65d21m7s	110d5m27s			
25	65d29m3s	110d39m18s	65d28m28s	110d35m41s	0.00	0.00			
26	65d32m9s	110d47m25s	65d25m51s	110d35m21s	0.00	0.00			
27	0.00	0.00	0.00	0.00	65d26m26s	110d33m36s			
28	65d36m36s	111d46m26s	65d33m6s	111d21m58s	0.00	0.00			
29	0.00	0.00	0.00	0.00	65d2m4s	109d12m54s			

NUMBER	WATER HINDERANCE	CONTINUOUS PERMAFROST	AF1	AF2	AF3	AF4	AF5	AF6	AF7	AF8	AF9	SF1	SF2	SF3	SF4	SF5	SF6	SF7
10a	FALSE	TRUE	A	A	D	G	A	D	C	A	B	A	A	A	A	C	A	B
10b	TRUE	TRUE	A	A	D	G	A	D	A	A	B	A	A	A	A	A	A	B
10c	FALSE	TRUE	A	A	D	G	A	D	C	A	B	A	A		A	C	A	B
10d	TRUE	TRUE	A	A	D	G	A	D	D	A	B							
10e	FALSE	TRUE	C	C	D	E	E	D	C	A	C							
11																		
12a	TRUE	TRUE	C	A	A	G	A	A	C	A	B	C	C		A	C	A	C
12b	FALSE	TRUE	C	A	D	A	A	D	C	A	C	C	C		A	C	A	C
14a	FALSE	TRUE	A	A	D	G	A	D	D	A	B							
14b	FALSE	TRUE	C	A	D	G	A	D	D	A	A							
15											C	C	A	F	C	D	A
16											C	C		F	D	D	C
17																		
18																		
19																		
20																		
21																		
22a																		
22b																		
23																		
24a																		
24b																		
24c																		
24d																		
24e																		
25																		
26																		
27																		
28																		
29																		

NUMBER	WESTERN POINT LAT. (North)	WESTERN POINT LONG. (West)	EASTERN POINT LAT. (North)	EASTERN POINT LONG. (DEG)	CENTRE POINT LAT. (North)	CENTRE POINT LONG. (West)	SIZE	DISTANCE TO FIELD CAMP (KM)	DISTANCE TO SAUVAGE ESKER (KM)
31	65d28m	111d37m30s	65d12m32s	110d31m	0.00	0.00			
32	64d42m6s	110d36m2s	64d39m3s	110d33m25s	0.00	0.00		53.00	11.25
33	0.00	0.00	0.00	0.00	65d24m53s	111d48m48s			
34	65d18m21s	112d4m13s	65d19m11s	111d46m20s	0.00	0.00			
35	65d2m19s	112d11m30s	65d3m3s	112d9m9s	0.00	0.00			
36a	64d51m	111d41m	64d52m	111d35m30s	0.00	0.00	L	0.00	57.50
36b	64d52m	111d35m30s	64d53m	111d23m	0.00	0.00	L	0.00	52.50
36c	64d53m	111d23m	64d51m30s	111d11m	0.00	0.00			
36d	64d52m	111d8m30s	64d51m30s	111d6m	0.00	0.00		26.25	30.00
36e	0.00	0.00	0.00	0.00	64d52m	111d43m		6.25	61.25
36f	0.00	0.00	0.00	0.00	64d51m	111d1m30s			
37a	64d50m30s	111d45m32s	64d47m30s	111d40m30s	0.00	0.00		10.00	61.00
37b	64d47m30s	111d40m30s	64d42m14s	111d37m42s	0.00	0.00	S	12.50	57.50
37c	64d43m	111d37m30s	64d42m	111d36m	0.00	0.00		18.50	56.50
38	64d53m21s	111d36m34s	64d52m26s	111d34m38s	0.00	0.00		0.00	56.25
39a	64d53m33s	111d23m25s	64d55m3s	111d20m6s	0.00	0.00	S	11.25	47.50
39b	64d55m42s	111d12m47s	64d56m11s	111d8m47s	0.00	0.00			
40	64d52m58s	112d14m17s	64d56m23s	112d1m42s	0.00	0.00			
41	64d52m47s	112d10m26s	64d51m6s	111d46m15s	0.00	0.00	L	13.75	67.50
41b	0.00	0.00	0.00	0.00	64d51m30s	111d56m		16.25	71.50
43	64d35m57s	110d36m16s	64d42m6s	110d36m5s	0.00	0.00	M	55.00	16.25
44a	63d52m9s	109d40m4s	63d52m8s	109d39m6s	0.00	0.00			
44b	63d52m9s	109d40m4s	63d52m	109d38m48s	0.00	0.00			
45	63d52m22s	109d35m35s	63d53m5s	109d29m3s	0.00	0.00			
46	64d10m26s	109d23m23s	64d7m8s	109d2m47s	0.00	0.00			
47a	64d10m1s	110d54m15s	64d10m	110d47m	0.00	0.00	M	85.00	67.50
47b	64d10m	110d47m	64d11m	110d44m	0.00	0.00		85.50	66.75
47c	64d12m	110d33m	64d12m30s	110d20m30s	0.00	0.00		93.75	63.00
47d	64d12m30s	110d20m30s	64d11m50s	110d12m26s	0.00	0.00	L	97.00	63.00
48a	64d10m22s	110d46m42s	64d9m30s	110d44m	0.00	0.00		87.50	68.00

NUMBER	WATER HINDERANCE	CONTINUOUS PERMAFROST	AF1	AF2	AF3	AF4	AF5	AF6	AF7	AF8	AF9	SF1	SF2	SF3	SF4	SF5	SF6	SF7
31																		
32	FALSE	TRUE	C	C	D	A	A	D	C	A	A	C	C	A	A	A	A	C
33																		
34																		
35																		
36a	FALSE	FALSE	A	A	D	A	A	D	A	A	B	A	A	A	A	C	B	B
36b	FALSE	TRUE	A	A	D	A	A	D	A	B	A	A	A	D	A	C	B	B
36c												A	A		A	C	A	C
36d	FALSE	TRUE	A	A	D	G	A	D	D	A	B	A	A		A	D	C	C
36e	FALSE	FALSE	C	C	D	B	G	D	D	D	C							
36f			A	C	D	B	G	D	D	D	C							
37a	FALSE	FALSE	B	B	D	A	A	D	A	A	C	C	A	A	A	A	A	C
37b	FALSE	FALSE	B	B	D	G	A	D	A	A	A							
37c	TRUE	FALSE	B	B	D	A	A	D	A	A	A							
38	TRUE	TRUE	B	B	D	A	A	D	B	A	C	C	A	A	A	C	B	A
39a	TRUE	TRUE	B	B	D	G	A	D	D	A	B	B	B		A	D	A	B
39b												B	B		A	C	A	A
40																		
41	FALSE	FALSE	A	A	D	G	A	D	A	D	C	A	A	A	A	A	A	A
41b	FALSE	FALSE	C	C	B	B	G	D	A	D	C							
43	FALSE	TRUE	B	B	D	A	A	D	D	A	B	B	B	A	A	A	A	B
44a																		
44b																		
45																		
46																		
47a	FALSE	FALSE	A	A	D	G	A	D	C	A	C							
47b	FALSE	FALSE	A	A	D	G	A	D	C	A	B							
47c	FALSE	FALSE	A	A	A	A	A	A	C	C	B							
47d	FALSE	FALSE	A	A	A	A	A	D	D	C	C	A	A		A	C	A	B
48a	FALSE	FALSE	A	A	A	A	A	A	D	D	C							

NUMBER	WESTERN POINT LAT. (North)	WESTERN POINT LONG. (West)	EASTERN POINT LAT. (North)	EASTERN POINT LONG. (DEG)	CENTRE POINT LAT. (North)	CENTRE POINT LONG. (West)	SIZE	DISTANCE TO FIELD CAMP (KM)	DISTANCE TO SAUVAGE ESKER (KM)
48b	64d9m	110d38m	64d9m12s	110d25m46s	0.00	0.00	L	95.50	67.50
49a	64d8m20s	111d39m7s	64d9m	111d34m30s	0.00	0.00	M	81.25	89.00
49b	64d9m30s	111d32m30s	64d9m	111d15m	0.00	0.00		80.50	82.00
49c	64d8m	111d11m30s	64d7m	111d1m	0.00	0.00	S	87.00	78.75
49d	64d6m30s	110d55m	64d5m	110d42m	0.00	0.00		94.00	75.00
49e	64d4m	110d37m30s	64d3m	110d28m	0.00	0.00	M	105.00	79.25
49f	0.00	0.00	0.00	0.00	64d9m	111d30m		80.00	83.75
49g	0.00	0.00	0.00	0.00	64d8m	111d11m		86.75	78.50
49h	0.00	0.00	0.00	0.00	64d6m	110d44m		97.25	75.50
50	64d16m30s	112d	64d16m	111d53m30s	0.00	0.00	S	69.50	90.00
51	64d29m	112d	64d27m	111d52m30s	0.00	0.00		48.75	78.00
52	64d33m	112d	64d31m30s	111d53m	0.00	0.00		41.25	74.50
53	64d19m	111d43m30s	64d17m30s	111d36m	0.00	0.00	M	63.25	76.75
54a	64d24m	111d40m30s	64d23m	111d39m30s	0.00	0.00		52.50	70.00
54b	64d25m	111d40m	64d25m	111d37m	0.00	0.00		51.25	68.50
55	64d35m30s	111d49m 30s	64d33m	111d47m	0.00	0.00	S	34.50	67.50
56	64d45m	111d50m	64d44m	111d45m30s	0.00	0.00		18.00	63.00
57	64d5m	111d37m	64d5m	111d31m30s	0.00	0.00	S	88.00	92.00
58	64d22m	111d36m	64d21m	111d35m	0.00	0.00		57.50	70.00
59	64d29m	111d30m30s	64d28m30s	111d26m30s	0.00	0.00	S	43.75	57.00
60a	64d40m	111d33m	64d38m	111d32m	0.00	0.00	S	25.50	53.75
60b	64d44m30s	111d35m	64d42m30s	111d33m30s	0.00	0.00		16.25	53.75
61a	64d46m	111d25m30s	64d41m30s	111d22m	0.00	0.00	S	18.75	45.50
61b	64d41m30s	111d22m	64d38m	111d15m	0.00	0.00	S	27.00	42.50
62	64d47m	111d34m	64d45m	111d30m30s	0.00	0.00		12.00	51.50
63	64d22m30s	111d18m	64d21m	111d11m	0.00	0.00	S	59.50	58.50
64	64d36m30s	111d12m	64d35m	111d8m30s	0.00	0.00		36.25	39.50
65a	64d45m30s	111d15m	64d41m30s	111d8m	0.00	0.00		25.00	35.00
65b	64d41m30s	111d8m	64d38m	111d4m	0.00	0.00		32.50	33.00
65c	64d38m	111d4m	64d35m30s	110d58m	0.00	0.00	L	39.00	32.50

NUMBER	WATER TOLERANCE	CONTINUOUS PERMA[illegible]	AF1	AF2	AF3	AF4	AF5	AF6	AF7	AF8	AF9	SF1	SF2	SF3	SF4	SF5	SF6	SF7
48b	FALSE	FALSE	A	A	A	A	A	A	D	A	A							
49a	FALSE	FALSE	A	A	D	A	A	D	A	C	B							
49b	TRUE	FALSE	A	A	D	A	A	D	D	C	C							
49c	TRUE	FALSE	A	A	D	A	A	D	D	C	C							
49d	TRUE	FALSE	A	A	D	A	A	D	D	C	A							
49e	FALSE	FALSE	A	A	D	A	A	D	D	C	B							
49f	FALSE	FALSE	C	C	D	B	G	D	A	D	C							
49g	FALSE	FALSE	C	C	A	B	G	A	D	D	C							
49h	FALSE	FALSE	C	C	D	B	G	D	D	D	C							
50	FALSE	FALSE	A	A	D	G	A	D	C	A	C							
51	FALSE	FALSE	A	A	D	A	A	D	A	A	B							
52	FALSE	FALSE	A	A	D	G	A	D	A	A	C							
53	FALSE	FALSE	A	A	D	A	A	D	C	A	B							
54a	FALSE	FALSE	A	A	D	A	A	D	C	C	B							
54b	FALSE	FALSE	A	A	D	G	A	D	C	A	A							
55	FALSE	FALSE	A	A	D	G	A	D	A	A	C							
56	FALSE	FALSE	A	A	D	G	A	D	A	C	A							
57	FALSE	FALSE	A	A	D	A	A	D	C	A	B							
58	FALSE	FALSE	A	A	D	G	A	D	C	A	B							
59	FALSE	FALSE	A	A	D	A	A	D	A	A	C							
60a	TRUE	FALSE	B	B	D	A	A	D	A	A	A							
60b	FALSE	FALSE	B	B	D	G	A	D	A	D	C							
61a	FALSE	FALSE	B	B	D	A	A	D	A	A	B							
61b	FALSE	FALSE	C	C	D	G	A	D	A	A	A							
62	FALSE	FALSE	B	B	A	A	A	A	A	A	C							
63	FALSE	FALSE	A	A	D	A	A	D	A	A	B							
64	TRUE	FALSE	A	A	D	G	A	D	A	A	A							
65a	TRUE	TRUE	A	A	D	A	A	D	C	A	B							
65b	FALSE	TRUE	A	A	D	A	A	D	A	A	B							
65c	FALSE	FALSE	A	A	D	A	A	D	A	D	B							

NUMBER	WESTERN POINT LAT. (North)	WESTERN POINT LONG. (West)	EASTERN POINT LAT. (North)	EASTERN POINT LONG. (DEG)	CENTRE POINT LAT. (North)	CENTRE POINT LONG. (West)	SIZE	DISTANCE TO FIELD CAMP (KM)	DISTANCE TO SAUVAGE ESKER (KM)
1a	64d36m28s	108d43m23s	64d36m50s	108d34m26s	0.00	0.00			
1b	64d36m28s	108d43m23s	64d35m15s	108d40m17s	0.00	0.00			
2	64d37m33s	108d51m59s	64d36m43s	108d45m33s	0.00	0.00			
3a	64d36m4s	109d8m31s	64d33m55s	109d2m15s	0.00	0.00			
3b	64d33m55s	109d2m15s	64d33m8s	108d56m37s	0.00	0.00			
3c	64d33m55s	109d2m15s	64d31m42s	108d58m32s	0.00	0.00			
4	64d31m27s	108d53m9s	64d26m58s	108d47m47s	0.00	0.00			
5	64d35m10s	109d16m29s	64d34m21s	109d13m52s	0.00	0.00			
6a	64d47m24s	110d52m	64d46m	110d38m	0.00	0.00	L	42.50	14.00
6b	64d46m	110d38m	64d45m30s	110d27m	0.00	0.00		52.50	0.00
6c	64d45m30s	110d27m	64d44m	110d11m	0.00	0.00		62.25	0.00
6d	64d44m	110d11m	64d41m	110d	0.00	0.00	M	72.50	14.00
6e	64d41m	110d	64d32m30s	109d45m	0.00	0.00			
6f	64d32m30s	109d45	64d27m30s	109d30m	0.00	0.00			
6g	64d27m30s	109d30m	64d26m	109d15m	0.00	0.00			
6h	64d26m	109d15m	64d20m30s	109d	0.00	0.00			
6i	64d20m30s	109d	64d17m	108d55m	0.00	0.00			
6j	0.00	0.00	0.00	0.00	64d45m	110d24m			
6k	0.00	0.00	0.00	0.00	64d43m	110d6m		72.00	14.00
6l	0.00	0.00	0.00	0.00	64d42m	110d4m		73.75	16.00
7a	64d45m6s	110d26m33s	64d43m	110d18m30s	0.00	0.00	S	60.00	5.00
7b	64d43m	110d18m30s	64d41m	110d14m	0.00	0.00		64.75	5.75
7c	0.00	0.00	0.00	0.00	64d43m	110d22m			
8a	64d37m27s	110d12m20s	64d33m51s	110d8m5s	0.00	0.00	M	73.75	15.00
8b	64d39m30s	110d14m	64d37m30s	110d12m	0.00	0.00		70.50	11.00
8c	0.00	0.00	0.00	0.00	64d35m30s	110d11m		74.00	16.00
9a	64d32m8s	109d58m23s	64d29m	109d45m	0.00	0.00			
9b	64d29m	109d45m	64d25m	109d35m	0.00	0.00			
9c	64d24m	109d33m	64d22m4s	109d29m37s	0.00	0.00			

NUMBER	WATER HINDER	CONTINUOUS PERMA.	AF1	AF2	AF3	AF4	AF5	AF6	AF7	AF8	AF9	SF1	SF2	SF3	SF4	SF5	SF6	SF7
1a												A	A		A	D	A	B
1b																		
2												A	A		A	D	A	B
3a																		
3b																		
3c																		
4																		
5																		
6a	TRUE	TRUE	A	A	D	A	A	D	D	A	B	A	A	A	A	D	A	C
6b	FALSE	TRUE	A	A	D	A	A	D	D	A	B	A	A	D	A	D	A	C
6c	FALSE	TRUE	A	A	D	A	A	D	C	A	C	A	A	A	A	C	A	A
6d	TRUE	TRUE	A	A	D	A	A	D	C	A	B	A	A	A	A	C	A	C
6e																		
6f												A	A	A	A	C	A	B
6g																		
6h																		
6i																		
6j			B	A	A	F	F	A	D	D	C							
6k	TRUE	TRUE	C	C	D	B	G	D	D	D	C							
6l	TRUE	TRUE	C	A	D	E	E	D	D	D	B							
7a	FALSE	TRUE	A	A	D	A	A	D	C	A	B	A	A	A	A	C	A	C
7b	TRUE	TRUE	A	A	D	A	A	D	C	A	B	A	A	D	A	C	A	B
7c			C	C	A	F	E	A	D	D	C							
8a	FALSE	TRUE	A	A	D	A	A	D	A	A	A	A	A	A	A	A	A	B
8b	FALSE	TRUE	A	A	D	A	A	D	D	A	B							
8c	FALSE	TRUE	C	C	A	B	G	A	D	D	C							
9a																		
9b												A	A	A	A	C	A	B
9c																		

NUMBER	WESTERN POINT LAT. (North)	WESTERN POINT LONG. (West)	EASTERN POINT LAT. (North)	EASTERN POINT LONG. (DEG)	CENTRE POINT LAT. (North)	CENTRE POINT LONG. (West)	SIZE	DISTANCE TO FIELD CAMP (KM)	DISTANCE TO SAUVAGE ESKER (KM)
10a	64d49m46s	110d44m32s	64d49m30s	110d37m30s	0.00	0.00		42.50	5.75
10b	64d49m30s	110d37m30s	64d49m30s	110d30m	0.00	0.00		48.00	6.25
10c	64d49m30s	110d30m	64d49m30s	110d16m	0.00	0.00	M	60.00	8.25
10d	64d49m30s	110d16m	64d50m30s	110d5m	0.00	0.00	S	66.75	10.50
10e	0.00	0.00	0.00	0.00	64d49m30s	110d36m		47.25	10.50
11	64d49m9s	109d53m2s	64d48m53s	109d51m28s	0.00	0.00			
12a	64d51m8s	110d50m3s	64d53m	110d37m	0.00	0.00	S	39.25	9.50
12b	64d53m30s	110d33m	64d56m26s	110d22m47s	0.00	0.00	S	55.00	17.50
14a	64d22m38s	110d7m3s	64d18m18s	110d5m2s	0.00	0.00	S	91.75	42.75
14b	64d29m	110d7m30s	64d22m30s	110d1m30s	0.00	0.00	S	86.25	32.50
15	0.00	0.00	0.00	0.00	64d24m57s	109d36m22s			
16	0.00	0.00	0.00	0.00	64d42m3s	108d47m28s			
17	0.00	0.00	0.00	0.00	64d36m5s	109d8m44s			
18	64d47m43s	109d10m30s	64d38m36s	108d56m15s	0.00	0.00			
19	64d2m57s	109d48m39s	64d3m6s	109d24m	0.00	0.00			
20	0.00	0.00	0.00	0.00	64d11m20s	109d51m12s			
21	65d14m10s	109d2m17s	65d12m18s	109d1m29s	0.00	0.00			
22a	65d20m42s	109d37m20s	65d14m37s	109d21m3s	0.00	0.00			
22b	0.00	0.00	0.00	0.00	65d16m12s	109d24m56s			
23	65d23m52s	110d5m42s	65d8m40s	109d10m	0.00	0.00			
24a	0.00	0.00	0.00	0.00	65d26m15s	110d27m56s			
24b	0.00	0.00	0.00	0.00	65d24m29s	110d19m32s			
24c	0.00	0.00	0.00	0.00	65d24m5s	110d16m35s			
24d	0.00	0.00	0.00	0.00	65d23m15s	110d13m43s			
24e	0.00	0.00	0.00	0.00	65d21m7s	110d5m27s			
25	65d29m3s	110d39m18s	65d28m28s	110d35m41s	0.00	0.00			
26	65d32m9s	110d47m25s	65d25m51s	110d35m21s	0.00	0.00			
27	0.00	0.00	0.00	0.00	65d26m26s	110d33m36s			
28	65d36m36s	111d46m26s	65d33m6s	111d21m58s	0.00	0.00			
29	0.00	0.00	0.00	0.00	65d2m4s	109d12m54s			

NUMBER	WATER HINDERANCE	CONTINUOUS PERMAFROST	AF1	AF2	AF3	AF4	AF5	AF6	AF7	AF8	AF9	SF1	SF2	SF3	SF4	SF5	SF6	SF7
10a	FALSE	TRUE	A	A	D	G	A	D	C	A	B	A	A	A	A	C	A	B
10b	TRUE	TRUE	A	A	D	G	A	D	A	A	B	A	A	A	A	A	A	B
10c	FALSE	TRUE	A	A	D	G	A	D	C	A	B	A	A		A	C	A	B
10d	TRUE	TRUE	A	A	D	G	A	D	D	A	B							
10e	FALSE	TRUE	C	C	D	E	E	D	C	A	C							
11																		
12a	TRUE	TRUE	C	A	A	G	A	A	C	A	B	C	C		A	C	A	C
12b	FALSE	TRUE	C	A	D	A	A	D	C	A	C	C	C		A	C	A	C
14a	FALSE	TRUE	A	A	D	G	A	D	D	A	B							
14b	FALSE	TRUE	C	A	D	G	A	D	D	A	A							
15												C	C	A	F	C	D	A
16												C	C		F	D	D	C
17																		
18																		
19																		
20																		
21																		
22a																		
22b																		
23																		
24a																		
24b																		
24c																		
24d																		
24e																		
25																		
26																		
27																		
28																		
29																		

NUMBER	WESTERN POINT LAT. (North)	WESTERN POINT LONG. (West)	EASTERN POINT LAT. (North)	EASTERN POINT LONG. (DEG)	CENTRE POINT LAT. (North)	CENTRE POINT LONG. (West)	SIZE	DISTANCE TO FIELD CAMP (KM)	DISTANCE TO SAUVAGE ESKER (KM)
31	65d28m	111d37m30s	65d12m32s	110d31m	0.00	0.00			
32	64d42m6s	110d36m2s	64d39m3s	110d33m25s	0.00	0.00		53.00	11.25
33	0.00	0.00	0.00	0.00	65d24m53s	111d48m48s			
34	65d18m21s	112d4m13s	65d19m11s	111d46m20s	0.00	0.00			
35	65d2m19s	112d11m30s	65d3m3s	112d9m9s	0.00	0.00			
36a	64d51m	111d41m	64d52m	111d35m30s	0.00	0.00	L	0.00	57.50
36b	64d52m	111d35m30s	64d53m	111d23m	0.00	0.00	L	0.00	52.50
36c	64d53m	111d23m	64d51m30s	111d11m	0.00	0.00			
36d	64d52m	111d8m30s	64d51m30s	111d6m	0.00	0.00		26.25	30.00
36e	0.00	0.00	0.00	0.00	64d52m	111d43m		6.25	61.25
36f	0.00	0.00	0.00	0.00	64d51m	111d1m30s			
37a	64d50m30s	111d45m32s	64d47m30s	111d40m30s	0.00	0.00		10.00	61.00
37b	64d47m30s	111d40m30s	64d42m14s	111d37m42s	0.00	0.00	S	12.50	57.50
37c	64d43m	111d37m30s	64d42m	111d36m	0.00	0.00		18.50	56.50
38	64d53m21s	111d36m34s	64d52m26s	111d34m38s	0.00	0.00		0.00	56.25
39a	64d53m33s	111d23m25s	64d55m3s	111d20m6s	0.00	0.00	S	11.25	47.50
39b	64d55m42s	111d12m47s	64d56m11s	111d8m47s	0.00	0.00			
40	64d52m58s	112d14m17s	64d56m23s	112d1m42s	0.00	0.00			
41	64d52m47s	112d10m26s	64d51m6s	111d46m15s	0.00	0.00	L	13.75	67.50
41b	0.00	0.00	0.00	0.00	64d51m30s	111d56m		16.25	71.50
43	64d35m57s	110d36m16s	64d42m6s	110d36m5s	0.00	0.00	M	55.00	16.25
44a	63d52m9s	109d40m4s	63d52m8s	109d39m6s	0.00	0.00			
44b	63d52m9s	109d40m4s	63d52m	109d38m48s	0.00	0.00			
45	63d52m22s	109d35m35s	63d53m5s	109d29m3s	0.00	0.00			
46	64d10m26s	109d23m23s	64d7m8s	109d2m47s	0.00	0.00			
47a	64d10m1s	110d54m15s	64d10m	110d47m	0.00	0.00	M	85.00	67.50
47b	64d10m	110d47m	64d11m	110d44m	0.00	0.00		85.50	66.75
47c	64d12m	110d33m	64d12m30s	110d20m30s	0.00	0.00		93.75	63.00
47d	64d12m30s	110d20m30s	64d11m50s	110d12m26s	0.00	0.00	L	97.00	63.00
48a	64d10m22s	110d46m42s	64d9m30s	110d44m	0.00	0.00		87.50	68.00

NUMBER	WATER HINDERANCE	CONTINUOUS PERMAFRO	AF1	AF2	AF3	AF4	AF5	AF6	AF7	AF8	AF9	SF1	SF2	SF3	SF4	SF5	SF6	SF7
31																		
32	FALSE	TRUE	C	C	D	A	A	D	C	A	A	C	C	A	A	A	A	C
33																		
34																		
35																		
36a	FALSE	FALSE	A	A	D	A	A	D	A	A	B	A	A	A	A	C	B	B
36b	FALSE	TRUE	A	A	D	A	A	D	A	B	A	A	A	D	A	C	B	B
36c												A	A		A	C	A	C
36d	FALSE	TRUE	A	A	D	G	A	D	D	A	B	A	A		A	D	C	C
36e	FALSE	FALSE	C	C	D	B	G	D	D	D	C							
36f			A	C	D	B	G	D	D	D	C							
37a	FALSE	FALSE	B	B	D	A	A	D	A	A	C	C	A	A	A	A	A	C
37b	FALSE	FALSE	B	B	D	G	A	D	A	A	A							
37c	TRUE	FALSE	B	B	D	A	A	D	A	A	A							
38	TRUE	TRUE	B	B	D	A	A	D	B	A	C	C	A	A	A	C	B	A
39a	TRUE	TRUE	B	B	D	G	A	D	D	A	B	B	B		A	D	A	B
39b												B	B		A	C	A	A
40																		
41	FALSE	FALSE	A	A	D	G	A	D	A	D	C	A	A	A	A	A	A	A
41b	FALSE	FALSE	C	C	B	B	G	D	A	D	C							
43	FALSE	TRUE	B	B	D	A	A	D	D	A	B	B	B	A	A	A	A	B
44a																		
44b																		
45																		
46																		
47a	FALSE	FALSE	A	A	D	G	A	D	C	A	C							
47b	FALSE	FALSE	A	A	D	G	A	D	C	A	B							
47c	FALSE	FALSE	A	A	A	A	A	A	C	C	B							
47d	FALSE	FALSE	A	A	A	A	A	D	D	C	C	A	A		A	C	A	B
48a	FALSE	FALSE	A	A	A	A	A	A	D	D	C							

NUMBER	WATER [illegible]ANCE	CONTINUOUS PERMAF[illegible]	AF1	AF2	AF3	AF4	AF5	AF6	AF7	AF8	AF9	SF1	SF2	SF3	SF4	SF5	SF6	SF7
48b	FALSE	FALSE	A	A	A	A	A	A	D	A	A							
49a	FALSE	FALSE	A	A	D	A	A	D	A	C	B							
49b	TRUE	FALSE	A	A	D	A	A	D	D	C	C							
49c	TRUE	FALSE	A	A	D	A	A	D	D	C	C							
49d	TRUE	FALSE	A	A	D	A	A	D	D	C	A							
49e	FALSE	FALSE	A	A	D	A	A	D	D	C	B							
49f	FALSE	FALSE	C	C	D	B	G	D	A	D	C							
49g	FALSE	FALSE	C	C	A	B	G	A	D	D	C							
49h	FALSE	FALSE	C	C	D	B	G	D	D	D	C							
50	FALSE	FALSE	A	A	D	G	A	D	C	A	C							
51	FALSE	FALSE	A	A	D	A	A	D	A	A	B							
52	FALSE	FALSE	A	A	D	G	A	D	A	A	C							
53	FALSE	FALSE	A	A	D	A	A	D	C	A	B							
54a	FALSE	FALSE	A	A	D	A	A	D	C	C	B							
54b	FALSE	FALSE	A	A	D	G	A	D	C	A	A							
55	FALSE	FALSE	A	A	D	G	A	D	A	A	C							
56	FALSE	FALSE	A	A	D	G	A	D	A	C	A							
57	FALSE	FALSE	A	A	D	A	A	D	C	A	B							
58	FALSE	FALSE	A	A	D	G	A	D	C	A	B							
59	FALSE	FALSE	A	A	D	A	A	D	A	A	C							
60a	TRUE	FALSE	B	B	D	A	A	D	A	A	A							
60b	FALSE	FALSE	B	B	D	G	A	D	A	D	C							
61a	FALSE	FALSE	B	B	D	A	A	D	A	A	B							
61b	FALSE	FALSE	C	C	D	G	A	D	A	A	A							
62	FALSE	FALSE	B	B	A	A	A	A	A	A	C							
63	FALSE	FALSE	A	A	D	A	A	D	A	A	B							
64	TRUE	FALSE	A	A	D	G	A	D	A	A	A							
65a	TRUE	TRUE	A	A	D	A	A	D	C	A	B							
65b	FALSE	TRUE	A	A	D	A	A	D	A	A	B							
65c	FALSE	FALSE	A	A	D	A	A	D	A	D	B							

NUMBER	WESTERN POINT LAT. (North)	WESTERN POINT LONG. (West)	EASTERN POINT LAT. (North)	EASTERN POINT LONG. (DEG)	CENTRE POINT LAT. (North)	CENTRE POINT LONG. (West)	SIZE	DISTANCE TO FIELD CAMP (KM)	DISTANCE TO SAUVAGE ESKER (KM)
1a	64d36m28s	108d43m23s	64d36m50s	108d34m26s	0.00	0.00			
1b	64d36m28s	108d43m23s	64d35m15s	108d40m17s	0.00	0.00			
2	64d37m33s	108d51m59s	64d36m43s	108d45m33s	0.00	0.00			
3a	64d36m4s	109d8m31s	64d33m55s	109d2m15s	0.00	0.00			
3b	64d33m55s	109d2m15s	64d33m8s	108d56m37s	0.00	0.00			
3c	64d33m55s	109d2m15s	64d31m42s	108d58m32s	0.00	0.00			
4	64d31m27s	108d53m9s	64d26m58s	108d47m47s	0.00	0.00			
5	64d35m10s	109d16m29s	64d34m21s	109d13m52s	0.00	0.00			
6a	64d47m24s	110d52m	64d46m	110d38m	0.00	0.00	L	42.50	14.00
6b	64d46m	110d38m	64d45m30s	110d27m	0.00	0.00		52.50	0.00
6c	64d45m30s	110d27m	64d44m	110d11m	0.00	0.00		62.25	0.00
6d	64d44m	110d11m	64d41m	110d	0.00	0.00	M	72.50	14.00
6e	64d41m	110d	64d32m30s	109d45m	0.00	0.00			
6f	64d32m30s	109d45	64d27m30s	109d30m	0.00	0.00			
6g	64d27m30s	109d30m	64d26m	109d15m	0.00	0.00			
6h	64d26m	109d15m	64d20m30s	109d	0.00	0.00			
6i	64d20m30s	109d	64d17m	108d55m	0.00	0.00			
6j	0.00	0.00	0.00	0.00	64d45m	110d24m			
6k	0.00	0.00	0.00	0.00	64d43m	110d6m		72.00	14.00
6l	0.00	0.00	0.00	0.00	64d42m	110d4m		73.75	16.00
7a	64d45m6s	110d26m33s	64d43m	110d18m30s	0.00	0.00	S	60.00	5.00
7b	64d43m	110d18m30s	64d41m	110d14m	0.00	0.00		64.75	5.75
7c	0.00	0.00	0.00	0.00	64d43m	110d22m			
8a	64d37m27s	110d12m20s	64d33m51s	110d8m5s	0.00	0.00	M	73.75	15.00
8b	64d39m30s	110d14m	64d37m30s	110d12m	0.00	0.00		70.50	11.00
8c	0.00	0.00	0.00	0.00	64d35m30s	110d11m		74.00	16.00
9a	64d32m8s	109d58m23s	64d29m	109d45m	0.00	0.00			
9b	64d29m	109d45m	64d25m	109d35m	0.00	0.00			
9c	64d24m	109d33m	64d22m4s	109d29m37s	0.00	0.00			

NUMBER	WESTERN POINT LAT. (North)	WESTERN POINT LONG. (West)	EASTERN POINT LAT. (North)	EASTERN POINT LONG. (DEG)	CENTRE POINT LAT. (North)	CENTRE POINT LONG. (West)	SIZE	DISTANCE TO FIELD CAMP (KM)	DISTANCE TO SAUVAGE ESKER (KM)
10a	64d49m46s	110d44m32s	64d49m30s	110d37m30s	0.00	0.00		42.50	5.75
10b	64d49m30s	110d37m30s	64d49m30s	110d30m	0.00	0.00		48.00	6.25
10c	64d49m30s	110d30m	64d49m30s	110d16m	0.00	0.00	M	60.00	8.25
10d	64d49m30s	110d16m	64d50m30s	110d5m	0.00	0.00	S	66.75	10.50
10e	0.00	0.00	0.00	0.00	64d49m30s	110d36m		47.25	10.50
11	64d49m9s	109d53m2s	64d48m53s	109d51m28s	0.00	0.00			
12a	64d51m8s	110d50m3s	64d53m	110d37m	0.00	0.00	S	39.25	9.50
12b	64d53m30s	110d33m	64d56m26s	110d22m47s	0.00	0.00	S	55.00	17.50
14a	64d22m38s	110d7m3s	64d18m18s	110d5m2s	0.00	0.00	S	91.75	42.75
14b	64d29m	110d7m30s	64d22m30s	110d1m30s	0.00	0.00	S	86.25	32.50
15	0.00	0.00	0.00	0.00	64d24m57s	109d36m22s			
16	0.00	0.00	0.00	0.00	64d42m3s	108d47m28s			
17	0.00	0.00	0.00	0.00	64d36m5s	109d8m44s			
18	64d47m43s	109d10m30s	64d38m36s	108d56m15s	0.00	0.00			
19	64d2m57s	109d48m39s	64d3m6s	109d24m	0.00	0.00			
20	0.00	0.00	0.00	0.00	64d11m20s	109d51m12s			
21	65d14m10s	109d2m17s	65d12m18s	109d1m29s	0.00	0.00			
22a	65d20m42s	109d37m20s	65d14m37s	109d21m3s	0.00	0.00			
22b	0.00	0.00	0.00	0.00	65d16m12s	109d24m56s			
23	65d23m52s	110d5m42s	65d8m40s	109d10m	0.00	0.00			
24a	0.00	0.00	0.00	0.00	65d26m15s	110d27m56s			
24b	0.00	0.00	0.00	0.00	65d24m29s	110d19m32s			
24c	0.00	0.00	0.00	0.00	65d24m5s	110d16m35s			
24d	0.00	0.00	0.00	0.00	65d23m15s	110d13m43s			
24e	0.00	0.00	0.00	0.00	65d21m7s	110d5m27s			
25	65d29m3s	110d39m18s	65d28m28s	110d35m41s	0.00	0.00			
26	65d32m9s	110d47m25s	65d25m51s	110d35m21s	0.00	0.00			
27	0.00	0.00	0.00	0.00	65d26m26s	110d33m36s			
28	65d36m36s	111d46m26s	65d33m6s	111d21m58s	0.00	0.00			
29	0.00	0.00	0.00	0.00	65d2m4s	109d12m54s			

NUMBER	WESTERN POINT LAT. (North)	WESTERN POINT LONG. (West)	EASTERN POINT LAT. (North)	EASTERN POINT LONG. (DEG)	CENTRE POINT LAT. (North)	CENTRE POINT LONG. (West)	SIZE	DISTANCE TO FIELD CAMP (KM)	DISTANCE TO SAUVAGE ESKER (KM)
1a	64d36m28s	108d43m23s	64d36m50s	108d34m26s	0.00	0.00			
1b	64d36m28s	108d43m23s	64d35m15s	108d40m17s	0.00	0.00			
2	64d37m33s	108d51m59s	64d36m43s	108d45m33s	0.00	0.00			
3a	64d36m4s	109d8m31s	64d33m55s	109d2m15s	0.00	0.00			
3b	64d33m55s	109d2m15s	64d33m8s	108d56m37s	0.00	0.00			
3c	64d33m55s	109d2m15s	64d31m42s	108d58m32s	0.00	0.00			
4	64d31m27s	108d53m9s	64d26m58s	108d47m47s	0.00	0.00			
5	64d35m10s	109d16m29s	64d34m21s	109d13m52s	0.00	0.00			
6a	64d47m24s	110d52m	64d46m	110d38m	0.00	0.00	L	42.50	14.00
6b	64d46m	110d38m	64d45m30s	110d27m	0.00	0.00		52.50	0.00
6c	64d45m30s	110d27m	64d44m	110d11m	0.00	0.00		62.25	0.00
6d	64d44m	110d11m	64d41m	110d	0.00	0.00	M	72.50	14.00
6e	64d41m	110d	64d32m30s	109d45m	0.00	0.00			
6f	64d32m30s	109d45	64d27m30s	109d30m	0.00	0.00			
6g	64d27m30s	109d30m	64d26m	109d15m	0.00	0.00			
6h	64d26m	109d15m	64d20m30s	109d	0.00	0.00			
6i	64d20m30s	109d	64d17m	108d55m	0.00	0.00			
6j	0.00	0.00	0.00	0.00	64d45m	110d24m			
6k	0.00	0.00	0.00	0.00	64d43m	110d6m		72.00	14.00
6l	0.00	0.00	0.00	0.00	64d42m	110d4m		73.75	16.00
7a	64d45m6s	110d26m33s	64d43m	110d18m30s	0.00	0.00	S	60.00	5.00
7b	64d43m	110d18m30s	64d41m	110d14m	0.00	0.00		64.75	5.75
7c	0.00	0.00	0.00	0.00	64d43m	110d22m			
8a	64d37m27s	110d12m20s	64d33m51s	110d8m5s	0.00	0.00	M	73.75	15.00
8b	64d39m30s	110d14m	64d37m30s	110d12m	0.00	0.00		70.50	11.00
8c	0.00	0.00	0.00	0.00	64d35m30s	110d11m		74.00	16.00
9a	64d32m8s	109d58m23s	64d29m	109d45m	0.00	0.00			
9b	64d29m	109d45m	64d25m	109d35m	0.00	0.00			
9c	64d24m	109d33m	64d22m4s	109d29m37s	0.00	0.00			

NUMBER	WESTERN POINT LAT. (North)	WESTERN POINT LONG. (West)	EASTERN POINT LAT. (North)	EASTERN POINT LONG. (DEG)	CENTRE POINT LAT. (North)	CENTRE POINT LONG. (West)	SIZE	DISTANCE TO FIELD CAMP (KM)	DISTANCE TO SAUVAGE ESKER (KM)
10a	64d49m46s	110d44m32s	64d49m30s	110d37m30s	0.00	0.00		42.50	5.75
10b	64d49m30s	110d37m30s	64d49m30s	110d30m	0.00	0.00		48.00	6.25
10c	64d49m30s	110d30m	64d49m30s	110d16m	0.00	0.00	M	60.00	8.25
10d	64d49m30s	110d16m	64d50m30s	110d5m	0.00	0.00	S	66.75	10.50
10e	0.00	0.00	0.00	0.00	64d49m30s	110d36m		47.25	10.50
11	64d49m9s	109d53m2s	64d48m53s	109d51m28s	0.00	0.00			
12a	64d51m8s	110d50m3s	64d53m	110d37m	0.00	0.00	S	39.25	9.50
12b	64d53m30s	110d33m	64d56m26s	110d22m47s	0.00	0.00	S	55.00	17.50
14a	64d22m38s	110d7m3s	64d18m18s	110d5m2s	0.00	0.00	S	91.75	42.75
14b	64d29m	110d7m30s	64d22m30s	110d1m30s	0.00	0.00	S	86.25	32.50
15	0.00	0.00	0.00	0.00	64d24m57s	109d36m22s			
16	0.00	0.00	0.00	0.00	64d42m3s	108d47m28s			
17	0.00	0.00	0.00	0.00	64d36m5s	109d8m44s			
18	64d47m43s	109d10m30s	64d38m36s	108d56m15s	0.00	0.00			
19	64d2m57s	109d48m39s	64d3m6s	109d24m	0.00	0.00			
20	0.00	0.00	0.00	0.00	64d11m20s	109d51m12s			
21	65d14m10s	109d2m17s	65d12m18s	109d1m29s	0.00	0.00			
22a	65d20m42s	109d37m20s	65d14m37s	109d21m3s	0.00	0.00			
22b	0.00	0.00	0.00	0.00	65d16m12s	109d24m56s			
23	65d23m52s	110d5m42s	65d8m40s	109d10m	0.00	0.00			
24a	0.00	0.00	0.00	0.00	65d26m15s	110d27m56s			
24b	0.00	0.00	0.00	0.00	65d24m29s	110d19m32s			
24c	0.00	0.00	0.00	0.00	65d24m5s	110d16m35s			
24d	0.00	0.00	0.00	0.00	65d23m15s	110d13m43s			
24e	0.00	0.00	0.00	0.00	65d21m7s	110d5m27s			
25	65d29m3s	110d39m18s	65d28m28s	110d35m41s	0.00	0.00			
26	65d32m9s	110d47m25s	65d25m51s	110d35m21s	0.00	0.00			
27	0.00	0.00	0.00	0.00	65d26m26s	110d33m36s			
28	65d36m36s	111d46m26s	65d33m6s	111d21m58s	0.00	0.00			
29	0.00	0.00	0.00	0.00	65d2m4s	109d12m54s			

NUMBER	WATER HINDERANCE	CONTINUOUS PERMAFROST	AF1	AF2	AF3	AF4	AF5	AF6	AF7	AF8	AF9	SF1	SF2	SF3	SF4	SF5	SF6	SF7
10a	FALSE	TRUE	A	A	D	G	A	D	C	A	B	A	A	A	A	C	A	B
10b	TRUE	TRUE	A	A	D	G	A	D	A	A	B	A	A	A	A	A	A	B
10c	FALSE	TRUE	A	A	D	G	A	D	C	A	B	A	A		A	C	A	B
10d	TRUE	TRUE	A	A	D	G	A	D	D	A	B							
10e	FALSE	TRUE	C	C	D	E	E	D	C	A	C							
11																		
12a	TRUE	TRUE	C	A	A	G	A	A	C	A	B	C	C		A	C	A	C
12b	FALSE	TRUE	C	A	D	A	A	D	C	A	C	C	C		A	C	A	C
14a	FALSE	TRUE	A	A	D	G	A	D	D	A	B							
14b	FALSE	TRUE	C	A	D	G	A	D	D	A	A							
15												C	C	A	F	C	D	A
16												C	C		F	D	D	C
17																		
18																		
19																		
20																		
21																		
22a																		
22b																		
23																		
24a																		
24b																		
24c																		
24d																		
24e																		
25																		
26																		
27																		
28																		
29																		

NUMBER	WESTERN POINT LAT. (North)	WESTERN POINT LONG. (West)	EASTERN POINT LAT. (North)	EASTERN POINT LONG. (DEG)	CENTRE POINT LAT. (North)	CENTRE POINT LONG. (West)	SIZE	DISTANCE TO FIELD CAMP (KM)	DISTANCE TO SAUVAGE ESKER (KM)
31	65d28m	111d37m30s	65d12m32s	110d31m	0.00	0.00			
32	64d42m6s	110d36m2s	64d39m3s	110d33m25s	0.00	0.00		53.00	11.25
33	0.00	0.00	0.00	0.00	65d24m53s	111d48m48s			
34	65d18m21s	112d4m13s	65d19m11s	111d46m20s	0.00	0.00			
35	65d2m19s	112d11m30s	65d3m3s	112d9m9s	0.00	0.00			
36a	64d51m	111d41m	64d52m	111d35m30s	0.00	0.00	L	0.00	57.50
36b	64d52m	111d35m30s	64d53m	111d23m	0.00	0.00	L	0.00	52.50
36c	64d53m	111d23m	64d51m30s	111d11m	0.00	0.00			
36d	64d52m	111d8m30s	64d51m30s	111d6m	0.00	0.00		26.25	30.00
36e	0.00	0.00	0.00	0.00	64d52m	111d43m		6.25	61.25
36f	0.00	0.00	0.00	0.00	64d51m	111d1m30s			
37a	64d50m30s	111d45m32s	64d47m30s	111d40m30s	0.00	0.00		10.00	61.00
37b	64d47m30s	111d40m30s	64d42m14s	111d37m42s	0.00	0.00	S	12.50	57.50
37c	64d43m	111d37m30s	64d42m	111d36m	0.00	0.00		18.50	56.50
38	64d53m21s	111d36m34s	64d52m26s	111d34m38s	0.00	0.00		0.00	56.25
39a	64d53m33s	111d23m25s	64d55m3s	111d20m6s	0.00	0.00	S	11.25	47.50
39b	64d55m42s	111d12m47s	64d56m11s	111d8m47s	0.00	0.00			
40	64d52m58s	112d14m17s	64d56m23s	112d1m42s	0.00	0.00			
41	64d52m47s	112d10m26s	64d51m6s	111d46m15s	0.00	0.00	L	13.75	67.50
41b	0.00	0.00	0.00	0.00	64d51m30s	111d56m		16.25	71.50
43	64d35m57s	110d36m16s	64d42m6s	110d36m5s	0.00	0.00	M	55.00	16.25
44a	63d52m9s	109d40m4s	63d52m8s	109d39m6s	0.00	0.00			
44b	63d52m9s	109d40m4s	63d52m	109d38m48s	0.00	0.00			
45	63d52m22s	109d35m35s	63d53m5s	109d29m3s	0.00	0.00			
46	64d10m26s	109d23m23s	64d7m8s	109d2m47s	0.00	0.00			
47a	64d10m1s	110d54m15s	64d10m	110d47m	0.00	0.00	M	85.00	67.50
47b	64d10m	110d47m	64d11m	110d44m	0.00	0.00		85.50	66.75
47c	64d12m	110d33m	64d12m30s	110d20m30s	0.00	0.00		93.75	63.00
47d	64d12m30s	110d20m30s	64d11m50s	110d12m26s	0.00	0.00	L	97.00	63.00
48a	64d10m22s	110d46m42s	64d9m30s	110d44m	0.00	0.00		87.50	68.00

NUMBER	WATER HINDERANCE	CONTINUOUS PERMAFRO	AF1	AF2	AF3	AF4	AF5	AF6	AF7	AF8	AF9	SF1	SF2	SF3	SF4	SF5	SF6	SF7
31																		
32	FALSE	TRUE	C	C	D	A	A	D	C	A	A	C	C	A	A	A	A	C
33																		
34																		
35																		
36a	FALSE	FALSE	A	A	D	A	A	D	A	A	B	A	A	A	A	C	B	B
36b	FALSE	TRUE	A	A	D	A	A	D	A	B	A	A	A	D	A	C	B	B
36c												A	A		A	C	A	C
36d	FALSE	TRUE	A	A	D	G	A	D	D	A	B	A	A		A	D	C	C
36e	FALSE	FALSE	C	C	D	B	G	D	D	D	C							
36f			A	C	D	B	G	D	D	D	C							
37a	FALSE	FALSE	B	B	D	A	A	D	A	A	C	C	A	A	A	A	A	C
37b	FALSE	FALSE	B	B	D	G	A	D	A	A	A							
37c	TRUE	FALSE	B	B	D	A	A	D	A	A	A							
38	TRUE	TRUE	B	B	D	A	A	D	B	A	C	C	A	A	A	C	B	A
39a	TRUE	TRUE	B	B	D	G	A	D	D	A	B	B	B		A	D	A	B
39b												B	B		A	C	A	A
40																		
41	FALSE	FALSE	A	A	D	G	A	D	A	D	C	A	A	A	A	A	A	A
41b	FALSE	FALSE	C	C	B	B	G	D	A	D	C							
43	FALSE	TRUE	B	B	D	A	A	D	D	A	B	B	B	A	A	A	A	B
44a																		
44b																		
45																		
46																		
47a	FALSE	FALSE	A	A	D	G	A	D	C	A	C							
47b	FALSE	FALSE	A	A	D	G	A	D	C	A	B							
47c	FALSE	FALSE	A	A	A	A	A	A	C	C	B							
47d	FALSE	FALSE	A	A	A	A	A	D	D	C	C	A	A		A	C	A	B
48a	FALSE	FALSE	A	A	A	A	A	A	D	D	C							

NUMBER	WATER [illegible]ANCE	CONTINUOUS PERMAF[illegible]	AF1	AF2	AF3	AF4	AF5	AF6	AF7	AF8	AF9	SF1	SF2	SF3	SF4	SF5	SF6	SF7
48b	FALSE	FALSE	A	A	A	A	A	A	D	A	A							
49a	FALSE	FALSE	A	A	D	A	A	D	A	C	B							
49b	TRUE	FALSE	A	A	D	A	A	D	D	C	C							
49c	TRUE	FALSE	A	A	D	A	A	D	D	C	C							
49d	TRUE	FALSE	A	A	D	A	A	D	D	C	A							
49e	FALSE	FALSE	A	A	D	A	A	D	D	C	B							
49f	FALSE	FALSE	C	C	D	B	G	D	A	D	C							
49g	FALSE	FALSE	C	C	A	B	G	A	D	D	C							
49h	FALSE	FALSE	C	C	D	B	G	D	D	D	C							
50	FALSE	FALSE	A	A	D	G	A	D	C	A	C							
51	FALSE	FALSE	A	A	D	A	A	D	A	A	B							
52	FALSE	FALSE	A	A	D	G	A	D	A	A	C							
53	FALSE	FALSE	A	A	D	A	A	D	C	A	B							
54a	FALSE	FALSE	A	A	D	A	A	D	C	C	B							
54b	FALSE	FALSE	A	A	D	G	A	D	C	A	A							
55	FALSE	FALSE	A	A	D	G	A	D	A	A	C							
56	FALSE	FALSE	A	A	D	G	A	D	A	C	A							
57	FALSE	FALSE	A	A	D	A	A	D	C	A	B							
58	FALSE	FALSE	A	A	D	G	A	D	C	A	B							
59	FALSE	FALSE	A	A	D	A	A	D	A	A	C							
60a	TRUE	FALSE	B	B	D	A	A	D	A	A	A							
60b	FALSE	FALSE	B	B	D	G	A	D	A	D	C							
61a	FALSE	FALSE	B	B	D	A	A	D	A	A	B							
61b	FALSE	FALSE	C	C	D	G	A	D	A	A	A							
62	FALSE	FALSE	B	B	A	A	A	A	A	A	C							
63	FALSE	FALSE	A	A	D	A	A	D	A	A	B							
64	TRUE	FALSE	A	A	D	G	A	D	A	A	A							
65a	TRUE	TRUE	A	A	D	A	A	D	C	A	B							
65b	FALSE	TRUE	A	A	D	A	A	D	A	A	B							
65c	FALSE	FALSE	A	A	D	A	A	D	A	D	B							

NUMBER	WESTERN POINT LAT. (North)	WESTERN POINT LONG. (West)	EASTERN POINT LAT. (North)	EASTERN POINT LONG. (DEG)	CENTRE POINT LAT. (North)	CENTRE POINT LONG. (West)	SIZE	DISTANCE TO FIELD CAMP (KM)	DISTANCE TO SAUVAGE ESKER (KM)
65d	0.00	0.00	0.00	0.00	64d35m30s	110d59m30s		41.75	32.00
66a	64d22m	111d0m30s	64d22m	110d58m	0.00	0.00		63.50	50.50
66b	64d21m30s	110d56m30s	64d20m30s	110d51m	0.00	0.00		65.50	48.75
67	64d27m	110d55m	64d24m	110d47m	0.00	0.00	L	57.00	39.75
68a	64d2m	110d40m	64d1m30s	110d35m30s	0.00	0.00	L	104.50	82.25
68b	64d1m30s	110d35m30s	64d1m30s	110d26m30s	0.00	0.00		108.50	83.25
69	64d33m	110d50m	64d31m	110d44m	0.00	0.00	S	57.00	29.25
70	64d46m	110d39m	64d45m30s	110d37m30s	0.00	0.00		47.50	8.25
71	64d20m30s	110d37m30s	64d20m30s	110d35m	0.00	0.00		74.00	45.50
72	64d35m30s	110d34m30s	64d34m30s	110d34m	0.00	0.00		58.50	20.50
73	64d43m30s	110d29m30s	64d41m30s	110d28m	0.00	0.00		55.50	5.50
74	64d6m30s	111d20m30s	64d6m30s	111d16m30s	0.00	0.00		87.00	83.00
75	0.00	0.00	0.00	0.00	64d51m	110d22m		57.25	11.00
76	0.00	0.00	0.00	0.00	64d49m	110d25m		55.50	7.25
77	64d31m30s	110d20m20s	64d30m	110d17m	0.00	0.00	S	73.50	29.00
78a	64d5m30s	110d9m	64d5m	110d1m	0.00	0.00	S	113.50	76.75
78b	0.00	0.00	0.00	0.00	64d5m	110d7m30s		113.50	76.75
78c	0.00	0.00	0.00	0.00	64d5m	110d4m30s		113.50	76.75
79	0.00	0.00	0.00	0.00	64d23m	110d53m		62.00	45.50
80	0.00	0.00	0.00	0.00	64d17m	110d37m		80.00	53.50
81a	0.00	0.00	0.00	0.00	64d50m	110d41m		43.00	14.50
81b	0.00	0.00	0.00	0.00	64d49m30s	110d38m		46.00	11.50
82	64d49m	111d23m	64d46m30s	111d21m	0.00	0.00		14.00	43.50
83	64d25m30s	111d15m	64d24m	111d10m30s	0.00	0.00	L	55.00	52.50

NUMBER	WESTERN POINT LAT. [illegible]	WESTERN POINT LONG. (West)	EASTERN POINT LAT. [illegible]	EASTERN POINT LONG. (DEG)	CENTRE POINT LAT. (North)	CENTRE POINT LONG. (West)	SIZE	DISTANCE TO FIELD CAMP (KM)	DISTANCE TO SAUVAGE ESKER (KM)
65d	0.00	0.00	0.00	0.00	64d35m30s	110d59m30s		41.75	32.00
66a	64d22m	111d0m30s	64d22m	110d58m	0.00	0.00		63.50	50.50
66b	64d21m30s	110d56m30s	64d20m30s	110d51m	0.00	0.00		65.50	48.75
67	64d27m	110d55m	64d24m	110d47m	0.00	0.00	L	57.00	39.75
68a	64d2m	110d40m	64d1m30s	110d35m30s	0.00	0.00	L	104.50	82.25
68b	64d1m30s	110d35m30s	64d1m30s	110d26m30s	0.00	0.00		108.50	83.25
69	64d33m	110d50m	64d31m	110d44m	0.00	0.00	S	57.00	29.25
70	64d46m	110d39m	64d45m30s	110d37m30s	0.00	0.00		47.50	8.25
71	64d20m30s	110d37m30s	64d20m30s	110d35m	0.00	0.00		74.00	45.50
72	64d35m30s	110d34m30s	64d34m30s	110d34m	0.00	0.00		58.50	20.50
73	64d43m30s	110d29m30s	64d41m30s	110d28m	0.00	0.00		55.50	5.50
74	64d6m30s	111d20m30s	64d6m30s	111d16m30s	0.00	0.00		87.00	83.00
75	0.00	0.00	0.00	0.00	64d51m	110d22m		57.25	11.00
76	0.00	0.00	0.00	0.00	64d49m	110d25m		55.50	7.25
77	64d31m30s	110d20m20s	64d30m	110d17m	0.00	0.00	S	73.50	29.00
78a	64d5m30s	110d9m	64d5m	110d1m	0.00	0.00	S	113.50	76.75
78b	0.00	0.00	0.00	0.00	64d5m	110d7m30s		113.50	76.75
78c	0.00	0.00	0.00	0.00	64d5m	110d4m30s		113.50	76.75
79	0.00	0.00	0.00	0.00	64d23m	110d53m		62.00	45.50
80	0.00	0.00	0.00	0.00	64d17m	110d37m		80.00	53.50
81a	0.00	0.00	0.00	0.00	64d50m	110d41m		43.00	14.50
81b	0.00	0.00	0.00	0.00	64d49m30s	110d38m		46.00	11.50
82	64d49m	111d23m	64d46m30s	111d21m	0.00	0.00		14.00	43.50
83	64d25m30s	111d15m	64d24m	111d10m30s	0.00	0.00	L	55.00	52.50

NUMBER	WATER IMPEDIANCE	CONTINUOUS PERMAFROST	AF1	AF2	AF3	AF4	AF5	AF6	AF7	AF8	AF9	SF1	SF2	SF3	SF4	SF5	SF6	SF7
65d	FALSE	FALSE	C	C	D	F	E	D	A	D	C							
66a	FALSE	FALSE	A	A	A	G	A	A	C	C	B							
66b	FALSE	FALSE	A	A	A	G	A	A	C	C	B							
67	FALSE	FALSE	A	A	A	A	A	A	C	A	C							
68a	FALSE	FALSE	A	A	D	G	A	D	C	A	A							
68b	FALSE	FALSE	A	A	A	A	A	A	C	C	C							
69	TRUE	TRUE	A	A	D	G	A	D	A	B	B							
70	FALSE	TRUE	A	A	A	F	D	D	D	A	C							
71	FALSE	FALSE	C	C	D	G	D	D	C	D	B							
72	TRUE	TRUE	B	B	D	A	A	D	D	A	B							
73	FALSE	TRUE	B	B	D	A	A	D	C	A	A							
74	TRUE	FALSE	A	A	D	A	A	D	C	A	C							
75	TRUE	TRUE	C	C	B	B	G	B	D	D	C							
76	FALSE	TRUE	C	C	B	B	G	B	D	D	C							
77	TRUE	TRUE	C	C	D	A	A	D	A	A	C							
78a	FALSE	FALSE	A	A	A	A	A	D	C	A	C							
78b	FALSE	FALSE	C	C	D	B	G	D	C	D	C							
78c	FALSE	FALSE	C	C	D	B	G	D	C	D	C							
79	FALSE	FALSE	C	C	B	B	G	D	C	D	C							
80	FALSE	FALSE	A	A	B	B	G	B	C	D	C							
81a	FALSE	TRUE	A	A	B	B	G	D	C	D	C							
81b	FALSE	TRUE	C	C	A	B	G	D	C	D	C							
82	FALSE	TRUE	B	A	D	A	A	D	A	A	C							
83	FALSE	FALSE	A	A	D	G	A	D	A	A	B							