Granular Resources Information Pertinent to MGP: Fort Good Hope to Mackenzie Delta



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ENVIRONMENTAL



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1.0 INTRODUCTION

Environmental Geosolutions, Inc. (EGI) of Exeter Ontario was contracted by Indian and Northern Affairs Canada (Contract #A7133-07-0008) to summarize, digitize and update selected, currently available granular resource information in the vicinity of the proposed Mackenzie Gas Project (MGP) within the Northwest Territories (NWT). Output from this project will be used to enhance the utility of the existing Mackenzie Valley on-line mapping tool. This report describes the digitizing of granular resource information for three distinct geographic areas within the MGP that was undertaken in this contract:

- ♦ Fort Good Hope to southern Mackenzie Delta (EBA, 1974)
- ♦ Fort Simpson to Fort Good Hope (PEMCAN, 1972)
- ♦ Tuktoyaktuk (R.M. Hardy, 1977)

This report describes the tasks performed to execute the contract, the resultant GIS and image files, and recommendations for the future. The Departmental Representative responsible for this contract is Robert J. Gowan.

2.0 BACKGROUND

The commodity-driven economy of the NWT is one of the fastest-growing in Canada, fueled by an array of resources including diamonds, oil, gold, uranium, and other base metals. The NWT also has one of the world's largest deposits of natural gas in the Mackenzie delta, resulting in plans to develop a pipeline south through the Mackenzie Valley (the Mackenzie Gas Project, or MGP) and potentially build a permanent road north to the Arctic Ocean. All of these on-going developments and proposed projects require another very important resource to form the basic infrastructure on which they are built – *granular resources*. The availability and proximity of granular resources for northern development projects can be a significant portion of a project's start-up costs, especially if granular materials have to be transported over long distances. There is an obvious need to provide information on the granular resources (location, amount, type) for a given area in an accessible and easy-to-use format. The management of granular resources is vital to ensure present reserves are used to their full potential and correctly allocated to prevent wasted resources. Proper management also ensures that the needs of future developments can also be reasonably accommodated.

Much work has already been done to develop products to distribute information on granular resources in Canada's north. The Northern Granular Resources Bibliographic Database (<u>http://www.aina.ucalgary.ca/ngr/</u>) contains citations and abstracts to over 1700 reports on granular resources in Canada's three northern territories and adjacent waters. This database has helped to provide a central point to search for granular information and provides many documents in downloadable formats. In addition to the database, two on-line mapping tools have been developed for the Mackenzie Valley (MV) and Inuvialuit Settlement Region (ISR; URLs withheld at request of INAC). These mapping products are the next logical step towards providing a usable and applied tool for stakeholders to obtain information about the granular resource information that exists for a certain area. Considerable information on granular

resources has been summarized and digitized in the past, but most of this has been in the ISR and the central MV (around Norman Wells). This contract has addressed gaps in digital information for the area between these regions.

There is a large amount of interest made evident at a recent workshop in Yellowknife (Terriplan Consultants, 2007) in providing even more detailed granular resource information to stakeholders through the on-line mapping tools. These tools can be an important component of the decision-making that deals with proposed and alternative locations of MGP facilities, and provide the spatial framework to contribute to a better understanding of the impact of the granular requirements of the MGP. The various groups involved with and affected by granular management planning are widely dispersed, resulting in travel and meetings that are expensive and difficult to arrange. Online tools provide an environment for data dissemination and dispersal and will be a critical component in the development of granular resource allocation plans which must involve an iterative process of recommendation and response.

3.0 SCOPE OF WORK

The contract document outlines the scope of work for this project as follows:

- 1. Obtain, through the Departmental Representative, and review, pertinent reports of granular resources in the vicinity of the proposed Mackenzie Gas Project between approximately Fort Good Hope and the southern Mackenzie Delta.
- 2. Prepare from the reports obtained through Task #1, above, information on the location, extent and type of granular resources, including geo-referencing of existing aerial photographs and map-based site plans, digitizing deposit boundaries, subsurface investigations (boreholes, test pits), test samples, etc.
- 3. Compile, process and summarize the granular resource information in maps, tables, etc., determined in consultation with the Departmental Representative.
- 4. Document source, compilation methods, etc for all above data using metadata consistent with current industry standards.
- 5. Prepare digital archives including spatial information, descriptive attributes and scanned images for granular resources sites processed as part of this study.
- 6. Document, in tables, maps and a report, the work undertaken and results obtained through this project.

4.0 TASKS PERFORMED

The description of tasks performed will be separated into sub-sections according to the three geographic areas that are defined in Section 1.0.

4.1 Tuktoyaktuk

Granular resources for the Tuktoyaktuk area were inventoried by R.M. Hardy and Associates in 1977. EGI converted this inventory into digital format as part of an earlier INAC contract (A7133-06-00015) that covered much of the ISR area. However, this work was erroneously omitted from the final report for the earlier INAC contract (EGI, 2007) and thus is presented here. Several steps described below are required to transform the PDF-format inventory into a digital product that can be utilized on the on-line mapping tools.

4.1.1 Geo-referencing of Scanned Site Plan Photographs

The original granular inventory reports from the 1970s typically contain a series of individual site reports with 'site plans'. These site plans consist of a half-tone copy of a portion of a standard NAPL aerial photograph that is annotated with deposit boundaries and subsurface investigations (boreholes, test pits, outcrops). Geo-referenced versions of the site plan photographs from granular resource inventories could be a very useful source of information to users of the on-line mapping tools. Site plan photographs from R.M. Hardy's Tuktoyaktuk inventory were geo-referenced for inclusion in the ISR on-line mapping tool (Appendix C).

Site plan photographs were first saved as JPEGs (300 dpi) from the original PDF document. These images were cropped to the photo edges, removing the remainder of the page. Cropped JPEG photos were imported to Manifold GIS, and were geo-referenced using an average of 3-6 control points to tie to the base imagery using an affine transformation (Figure 1). The base imagery used was the orthophotography collected by Tarin Resource Services for the Mackenzie Delta area in the summer of 2000. Site plan photographs were geo-referenced to UTM Zone 8 (NAD83) to be compatible with the native projection of the ISR on-line mapping tool. Following the geo-referencing, site plan photographs were exported as TIFF files, the image format requested by the manager of the on-line granular resource mapping tools.

4.1.2 Digitizing of Granular Inventories

From the geo-referenced site plan photographs, the following components of the inventory was digitized in Manifold GIS and exported to ESRI shapefile format:

- granular deposit boundaries (polygons)
- boreholes (points)
- test pits (points)

For each individual deposit, test pit, or borehole, the unique identification number from the original inventory was included as an item in the shapefile. This item is used to relate the pit/borehole/deposit to the digital report pages which are provided as a pop-up option in the online mapping tool (described in more detail in the next section). Although Manifold GIS provides some auto-tracing features, these were not utilized in this project. The graininess and imperfections of the site plan photographs were not conducive to the auto-trace option, which detects line or polygon features with the same colour. Manual digitizing was performed for all polygons, tracing the centre of the hand-written boundary. A smoothing process was performed after digitizing to 'clean-up' the deposit boundaries to match the original hand-written versions as much as possible. Manifold's 'Spline' command smooths deposit boundaries by inserting additional midpoints and using a spline algorithm to replace sharp corners with curves.

The digitizing of the granular resource information (deposit boundaries, test pits, boreholes) will allow users to compare the original interpretations from the geo-referenced site plan photographs to the base imagery in the on-line mapping tool (Figure 2).

4.1.3 Inventory Report Pages

One of the features of the on-line granular resource mapping tools is the ability of the user to "drill-down" to access the digital inventory report pages that pertain to the item of interest (deposit, borehole, test pit). Upon user request, the on-line mapping site's reporting tool (Cold Fusion) delivers report pages to the screen through a pop-up interface. The report pages that are viewed by the user are actually a series of JPEG files (one JPEG per report page). The existing ISR mapping tool contains links to a set of JPEG report pages that were produced from INAC scanning of original paper inventory documents.

The existing scanned files lack much of the contrast and detail that was contained in the original inventory, particularly with regards to the site plan photographs. In the time since the original inventories were scanned, INAC retained the services of the engineering consultants who authored the reports to provide vastly improved digital versions. New JPEG files of the improved digital report pages were generated at 150 dpi.

Columns were added to the shapefile database files that represent the range of page numbers in the report (start and end) that pertain to the deposit, borehole or test pit. These page ranges are referenced by Cold Fusion to generate the report delivered to the on-line user.



Figure 1: Example from previous EGI report (EGI, 2007) of the base imagery (top panel) used to geo-reference the inventory site plan photographs (RKL, 1972), shown overlaid in the bottom panel.



Figure 2: An example of digitized granular resource information (deposit boundaries, test pits, boreholes) overlaid on the on-line mapping tool base image from previous EGI report (EGI, 2007).

4.2 Fort Good Hope to Southern Mackenzie Delta

Granular resources for this geographic area were inventoried as a 4-volume set by EBA Engineering Consultants in 1974 (one summary volume, three granular inventory volumes). The MV on-line mapping tool currently hosts digitized granular resource deposit boundaries for the complete EBA 1974 inventory. There is a minor offset (approximately 50 metres) that exists between the digitized deposits and the underlying base image. Completion of the EBA inventory required digitizing of borehole and test pit locations and geo-referencing of inventory aerial photographs. At the onset of the contract it was decided that deposit boundaries would be redigitized for two reasons:

- improved geo-locational accuracy that is possible by using Google Earth and Microsoft Virtual Earth imagery as the reference data
- ♦ to ensure consistency with the geo-referenced aerial photographs

The steps undertaken to convert the EBA inventories to digital format are the same as described in Section 4.1 for the Tuktoyaktuk inventory, with a couple of differences pertaining to the projection and the source of the base imagery. Because detailed orthophotography was not available to use as base imagery for this part of the MV, a link was established in Manifold to Google Earth or Microsoft Virtual Earth for use as the reference map. The Microsoft and Google products provide large-area imagery mosaics from high-resolution satellites, some of which rival the detail obtained from orthophotography (Appendix C). Site plan photographs were geo-referenced to UTM Zone 10 (NAD83) to be compatible with the native projection of the MV on-line mapping tool.

4.3 Fort Simpson to Fort Good Hope

Granular resources for this geographic area were inventoried as a 10-volume set by PEMCAN Services in 1972. The MV on-line mapping tool currently hosts digitized granular resources (deposit boundaries, borehole and test pit locations) for the complete PEMCAN 1972 inventory. Completion of the PEMCAN inventory required geo-referencing of inventory aerial photographs. The steps undertaken are the same as described in Section 4.1.1 for the Tuktoyaktuk inventory, with a couple of differences pertaining to the projection and the source of the base imagery. Because detailed orthophotography was not available to use as base imagery for this part of the MV, a link was established in Manifold to Google Earth or Microsoft Virtual Earth for use as the reference map (Appendix C). Site plan photographs were geo-referenced to UTM Zone 10 (NAD83) to be compatible with the native projection of the MV on-line mapping tool.

Site plan photographs from the following volumes were geo-referenced:

- ♦ Fort Norman community
- ♦ Fort Simpson community
- ♦ Norman Wells community
- ♦ Wrigley community
- ♦ Fort Norman Norman Wells inter-community
- ♦ Fort Simpson Wrigley inter-community
- ♦ Wrigley Fort Norman inter-community

Site plan photographs from the Fort Good Hope community volume and Norman Wells to Fort Good Hope inter-community volume were not completed due to the unavailability of PDF inventory files of an adequate quality to perform the geo-referencing.

5.0 FILE NAMING CONVENTION

The files generated in this project are named using a combination of site-specific variables (Table 1) including ASTIS record number, inventory code, and deposit number. Three sets of files were generated for each inventory: a) JPEG files of individual inventory report pages; b) geo-referenced site plan photographs; c) shapefiles of granular resource locations. For each inventory, separate shapefiles were generated for deposit boundaries, borehole locations, and test pit locations. The following file nomenclature was used:

INVENTORY	CODE	ASTIS RECORD			
RM Hardy (1977) – Tuktoyaktuk Area					
Tuktoyaktuk	ТК	33565			
EBA (1974) – Stage III (Fort Good Hope – Mackenzie Delta)					
Stage III - Volume 2	St3b	30383b			
Stage III - Volume 3	St3c	30383c			
Stage III - Volume 4	St3d	30383d			
PEMCAN (1972) – Fort Simpson – Fort Good Hope					
Fort Norman community	FN	30390			
Fort Simpson community	FS	37406			
Norman Wells community	NW	30391			
Wrigley community	WR	30388			
Fort Norman – Norman Wells	FN-NW	30386			
Fort Simpson – Wrigley	FS- WR	30385			
Wrigley – Fort Norman	WR-FN	30384			

 Table 1: The inventory-level codes used in the file naming nomenclature.

JPEG files of individual inventory report pages

Nomenclature: ASTIS Record_Page_*n*.jpg, where *n* = page 1 to the last page of the inventory

Example: 30383b_Page_07.jpg = Page 7 of volume 2 of EBA inventory

Georeferenced site plan photographs

Nomenclature: InventoryCode_Deposit#.tif

Example: St3b_1001.tif = Deposit 1001 of volume 2 of EBA inventory

Shapefiles

Nomenclature: InventoryCode_borehole.shp InventoryCode_deposit.shp InventoryCode_testpit.shp

Example: St3b_deposit.shp = Deposit boundaries (polygons) of volume 2 of EBA inventory

6.0 RESULTS

The work completed in this contract for each granular resource inventory is summarized in Table 2. Detailed site maps are provided for the Tuktoyaktuk and EBA inventory areas in Appendix B. Sample geo-referenced site plan photographs from all granular resource inventories (RM Hardy, EBA, PEMCAN) is provided in Appendix C. A regional index map (Figure 3) shows the approximate location of all inventories that are referenced in this report.

Inventory	Deposits	Boreholes	Test Pits	Site Plan	Scanned
Volume				Photographs	Inventory Pages
Tuktoyaktuk	124		48	24	256
Stage III Volume 2	100	30	80	55	363
Stage III Volume 3	66	56	60	50	333
Stage III Volume 4	69	58	64	43	319
Fort Norman				31	
Fort Simpson				13	
Norman Wells				21	
Wrigley				20	
FN - NW				26	
FS - WR				59	
WR - FN				100	
Total	359	144	252	442	1271

Table 2: Inventory-level summary of work performed in this contract, including digitized granular resource information (deposits, test pits, boreholes), site plan photographs, and scanned inventory pages. Note that the deposit column represents the number of polygons digitized, which may be more than the number of deposits due to multi-polygon deposits.

7.0 METADATA

For each granular resource inventory, metadata was generated in FGDC format for each of the individual shapefiles (deposits, boreholes, test pits). A program called Corpsmet 95 (<u>http://corpsgeo1.usace.army.mil/</u>) was used to develop the template metadata format, an example of which is provided as Appendix A.

8.0 DISCUSSION AND RECOMMENDATIONS

This contract resulted in a complete digital version of the EBA 1974 granular resource inventory and a set of geo-referenced site plan photographs for most volumes of the 1972 PEMCAN granular resource inventory. In addition, as part of this contract EGI assessed the existing PEMCAN digital granular resource data (produced by AggMapr) that is available on the MV on-line mapping tool. EGI assessed the data for both spatial agreement and completeness relative to the geo-referenced site plan photographs:



Figure 3: Index map to show the approximate locations of the digital granular resource inventories in this report. The black box is the boundary of the PEMCAN inventory. The red box is the boundary of the EBA inventory. The yellow box is the boundary of the R.M. Hardy Tuktoyaktuk inventory. Map is courtesy of Google Maps.

Spatial Agreement: There is some spatial discrepancy between the digital granular deposit boundaries produced by AggMapr and the geo-referenced photographs that were generated in this contract. The shift is irregular and not easily fixed, as it varies in both length and direction (not a constant easting or northing shift). The disagreement between the two data sources is understandable when the age of the source data and the different methods for digitizing them are considered. Even with the spatial discrepancy, it is recommended that INAC publish both PEMCAN data products (AggMapr and EGI) on the MV on-line mapping tool until the decision is made to re-digitize the granular resource data using the geo-referenced site plan photographs as the base imagery.

Completeness: As opposed to the lack of spatial agreement, a more immediate and pressing concern with the AggMapr dataset is the number of PEMCAN sites that: a) lack digitized features, and b) contain digitized features that do not represent the actual landscape.

Of the 315 total PEMCAN sites in the 10-volume inventory, 76 (over 24%) are missing from the AggMapr dataset. The photographs from these missing sites have been geo-referenced as part of this contract, therefore the digitizing of the missing sites can be accomplished relatively easily in the near future.

The AggMapr dataset contains a layer called 'Polylines' which represents granular deposits that extended beyond the edge of the site plan photograph or map that they were being digitized from. As opposed to interpreting the true boundary of the granular deposit through analysis of land features on the base imagery, AggMapr digitized the photograph or map edge, resulting in a digital boundary that is not representative of the actual boundary. There are 43 sites that contain these features. With access to detailed collections of base imagery through Manifold's links to Google Earth and Virtual Earth, the ability to interpret deposit boundaries that extend beyond the photograph edge is greatly improved.

Recommendations:

It is recommended that INAC invest in the remaining steps that are needed to complete the digitizing of the PEMCAN inventory. Once completed, this will result in a complete digital record of granular resources that extends from Fort Simpson to the Mackenzie Delta. INAC is advised to undertake these steps in the following order of priority:

- *Re-scanning of remaining volumes.* Two of the volumes from the PEMCAN inventory (Fort Good Hope community, Fort Good Hope to Norman Wells inter-community) do not have digital versions of their site plan photographs/maps or granular resource data. This is largely due to poor quality PDF versions of these volumes. The original volumes should be re-scanned so that the PDF files that are needed to generate the individual site plan images are of improved quality
- ♦ *Geo-referencing of remaining volumes' site plan images.* The remaining volumes of the inventory should have their re-scanned site plan maps or photographs geo-referenced so that the full inventory is available to users
- Digitize sites that are missing or require interpretation. The combination of sites that are either missing data or require further interpretation (the 'Polyline' sites) represent over 35% of all PEMCAN sites. With the availability of both geo-referenced site plan photographs (produced in this contract) and extensive base imagery to aid in interpretation, INAC is advised to invest in the digitizing of these sites.
- ♦ *Re-digitize existing sites.* With the improved spatial accuracy that is now available with the geo-referenced site plan photographs, ultimately it would be advised to invest in a new digital version of the entire PEMCAN inventory that matches the photographs.

9.0 REFERENCES

- EBA Engineering Consultants Ltd., 1974. Granular Materials Inventory, Stage III. 4 Volumes. ASTIS Record 30383.
- EGI, 2007. Digitize Selected Granular Resources Information Pertinent to the MGP. A Final Report for INAC Contract A7133-06-0015.
- PEMCAN Services, 1972. Granular Materials Inventory. 10 Volumes. ASTIS Record 30393.
- R.M. Hardy and Associates, 1977. Granular Materials Inventory, Tuktoyaktuk, NWT. ASTIS Record 33565.
- Ripley, Klohn, and Leonoff (RKL) International Ltd, 1972. Community Granular Resources Inventory: Inuvik, NWT. Volume 3 of a 9 volume set. ASTIS Record 30396.
- Terriplan Consultants, 2007. "The NWT Granular Users Forum Summary Report: September 27 & 28, 2006, Yellowknife, NT" April 2007.

10.0 CONTRACTOR QUALIFICATIONS

Environmental Geosolutions Inc. is a federally-incorporated entity with a mandate to develop custom geospatial products and tools for targeted user groups that lead to more applied uses of geospatial data. Stephen Boles, the founder and president of Environmental Geosolutions, has been active in the computer modeling and GIS communities for over a decade, including several years as a research scientist at the University of New Hampshire. Boles began his geomatics career in the early 1990s as a University of Waterloo co-op student working for DIAND on an assignment to assess the utility of using Landsat satellite data for granular resource identification in the Slave Geological Province of the NWT. Later in his career, Boles continued to gain extensive experience working on remote sensing projects pertaining to circumpolar regions (Alaska, Russia). Because of these years of experience working on remote sensing applications in the North, Boles is well poised to contribute to the continued development and refinement of the on-line mapping tools for northern granular resources.

APPENDIX A – Metadata Sample

```
Identification_Information:
       Citation:
               Citation_Information:
                      Originator: Stephen Boles(ed.)
                      Publication_Date: Unpublished material
                      Publication_Time: Unknown
                      Title: Digital Granular Deposit Boundaries, Stage 3, Volume 2,
                      1974
                      Edition: 1.0
                      Geospatial_Data_Presentation_Form: map
       Description:
              Abstract:
                      Indian and Northern Affairs Canada acquired digital versions
                      of several granular resource inventories performed in Canada's
                      Arctic in the 1970s and 1980s. The original granular inventory
                      reports from the early 1970s typically contain a series of
                      individual site reports with 'site plans'. These site plans
                      consist of a half-tone copy of a portion of a standard NAPL
                      aerial photograph that is annotated with deposit boundaries
                      and subsurface investigations (boreholes, test pits, outcrops).
                      All site plan photographs were georeferenced to an orthophotograph
                      base image. Deposit boundaries and subsurface investigations
                      could then be digitized. Deposit boundaries were manually
                      digitized and a smoothing algorithm was applied after. The
                      following citation references the source publication for this
                      data:
                      Digital granular resource deposit boundaries from Volume 2 of the
                      Stage III Granular Materials Inventory,
                      1974
                             /
                      EBA Engineering Consultants, Ltd., 1974.
                      ASTIS record 30383b.
                      English
                       //pubs.aina.ucalgary.ca/gran/30383b.pdf
                      Granular Materials Inventory, Stage III (Volume 2), NWT
               Purpose:
                      The digital granular resource boundaries will be used to enhance
                      the utility of the Mackenzie Valley on-line mapping tool.
       Time_Period_of_Content:
              Time_Period_Information:
                      Single_Date/Time:
                              Calendar_Date: 20080331
               Currentness_Reference: Publication Date
       Status:
               Progress: Complete
               Maintenance_and_Update_Frequency: None planned
       Spatial Domain:
               Bounding_Coordinates:
                      West_Bounding_Coordinate: -130.66
                      East_Bounding_Coordinate: -127.66
                      North Bounding Coordinate: +67.50
                      South_Bounding_Coordinate: +66.33
       Keywords:
              Theme:
                      Theme_Keyword_Thesaurus: granular deposit
                      Theme_Keyword: Volume 2
                      Theme_Keyword: inventory
       Access_Constraints: None
       Use Constraints: None
       Point_of_Contact:
              Contact_Information:
                      Contact_Person_Primary:
                              Contact_Person: Robert J. Gowan
                              Contact_Organization: DIAND, Land Programs
                      Contact Organization Primary:
                      Contact_Position: Manager
                      Contact_Address:
                              Address_Type: mailing and physical address
```

```
Address:
                                     Les Terrasses de la Chaudière,
                                     15-25 Eddy St
                              City: Gatineau,
                              State_or_Province: QC
                              Postal_Code: K1A 0H4
                              Country: Canada
                      Contact_Voice_Telephone: 819-994-7464
                      Contact_Facsimile_Telephone: 819-997-7623
                      Contact_Electronic_Mail_Address: gowanb@inac.gc.ca
Spatial_Data_Organization_Information:
       Spatial_Reference_Information:
               Horizontal_Coordinate_System_Definition:
                      Planar:
                              Grid_Coordinate_System:
                                      Grid_Coordinate_System_Name: Universal Transverse Mercator
                                      Universal_Transverse_Mercator:
                                             UTM_Zone_Number: 10 North
                                             Transverse_Mercator:
                                                     Scale_Factor_at_Central_Meridian: 0.9996
                                                     Longitude_of_Central_Meridian: -123.000000
                                                     Latitude_of_Projection_Origin: +00.000000
                                                     False Easting: 500000
                                                     False_Northing: 0
                      Geodetic_Model:
                              Horizontal_Datum_Name: North American Datum of 1983
Metadata_Reference_Information:
       Metadata_Date: 20080331
       Metadata_Contact:
               Contact_Information:
                      Contact_Person_Primary:
                              Contact_Person: Stephen Boles
                      Contact_Address:
                              Address_Type: mailing address
                              Address: 38 John Street East
                              City: Exeter
                              State_or_Province: Ontario
                              Postal_Code: NOM 1S6
                              Country: Canada
                      Contact_Voice_Telephone: 519-235-6250
                      Contact_Electronic_Mail_Address: sboles@enviro-geo.com
       Metadata_Standard_Name: FGDC Content Standards for Digital Geospatial Metadata
       Metadata_Standard_Version: 1994
```

APPENDIX B – Inventory Site Maps



Tuktoyaktuk Area Inventory – RM Hardy and Associates (1977) – red polygons represent deposits and yellow circles represent test pit locations. Base image (50% opacity) courtesy Google Earth.



EBA Inventory (1974) – **Volume 2** – red polygons represent deposits, yellow circles represent test pit locations, and blue circles represent borehole locations. Base image (50% opacity) courtesy of Microsoft Virtual Earth.



EBA Inventory (1974) – **Volume 3** – red polygons represent deposits, yellow circles represent test pit locations, and blue circles represent borehole locations. Base image (50% opacity) courtesy of Microsoft Virtual Earth.



EBA Inventory (1974) – **Volume 4** – red polygons represent deposits, yellow circles represent test pit locations, and blue circles represent borehole locations. Base image (50% opacity) courtesy of Microsoft Virtual Earth.

APPENDIX C – Geo-referenced Site Plan Photography



Geo-referenced site plan photograph from R.M. Hardy's 1977 Tuktoyaktuk inventory (overlaid on a Google Earth image)



Geo-referenced site plan photograph from Volume 2 of EBA's 1974 Stage III inventory (overlaid on a Virtual Earth image)



Geo-referenced site plan photograph from the Fort Norman (now Tulita) community volume of PEMCAN's 1972 granular inventory (overlaid on a Google Earth image)