Comparison of Aerial Photographic Terrain Analysis with Investigation in Arctic Canada

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ABSTRACT: *During 1960–61 the Cambridge Research Laboratories of the U. S. Air Force sponsored a photogeologic study of Northern Canada to include all terrain north of the 65th parallel, a total of approximately 900,000 square miles (Figure 1).*

The object of the study was to locate and describe potential natural landing surfaces that would require a minimum of surface preparation to accommodate emergency landings by heavy, wheeled, transport aircraft. In addition to considering requirements for aircraft operation at each site such as runway length, surface roughness, and bearing strength as well as approaches and accessibility, such factors as bedrock and surficial geology, geomorphology, water resources and the availability of natural construction materials also were analyzed.

A total of 50 potential landing sites was located by stereoscopic analysis of the RCAF vertical air photographs covering the entire area of the project. To date only one of these sites has been checked by field examination. This paper compares the terrain analysis as interpreted by photogeologic methods . . . a view from 30,000 feet, with the actual field conditions as observed during an operation organized by the Defence Research Board of Canada.

INTRODUCTION

SINCE 1955 the U. S. Air Force has been studying the ice-free portions of the Arctic in order to understand more fully the problems inherent with aircraft operations on natural surfaces in this harsh environment. In the investigation of such remote areas, the general approach utilizes air photo interpretation extensively with the following procedure being commonly employed, (Needleman, 1962).

(a) The terrain is analyzed by photogeologic methods, making complete use of all available literature for background information.

(b) The most promising potential airstrip sites are tentatively selected and field-checked by small parties of earth scientists.

(c) The landing area is completely tested for its soil load-bearing strength and minor surface preparations of the strip, such as filling of small gullies and local levelling, are performed.

(d) The proposed landing area is marked and finally tested by repeated landings and takeoffs of heavy, wheeled aircraft, such as the C-130 (approximately 100,000 lbs.).

The above operation has been undertaken at several locations in Greenland with complete success (see references).

The initial phase, i.e., photogeologic interpretation supported by literature search, of the terrain analysis of the Canadian Arctic has already been completed (Pressman, *et al.*, 1961). Of the 50 most favorable sites located and described as potential emergency landing areas for heavy aircraft, only one has been field-checked to date (Hattersley-Smith, 1962, p. 46). It has been named Niagara Glacier Site by the Canadian Defence Research Board and is located in the north-central portion of Ellesmere Island, approximately 135 miles southwest of Alert Weather Station, Figure 1. An oblique photo of the area facing northwest, Figure 2, shows the view a pilot will have on the south eastern approach to this site. The Ellesmere ice-cap lines the horizon and the potential landing strip parallels the Lewis River Valley. Figure 3 is a stereogram of the Niagara Glacier Site. This photography which was used for the photogeologic interpretation is approximately 1:60,000, was taken in July 1959, and exhibits a great amount of detail.

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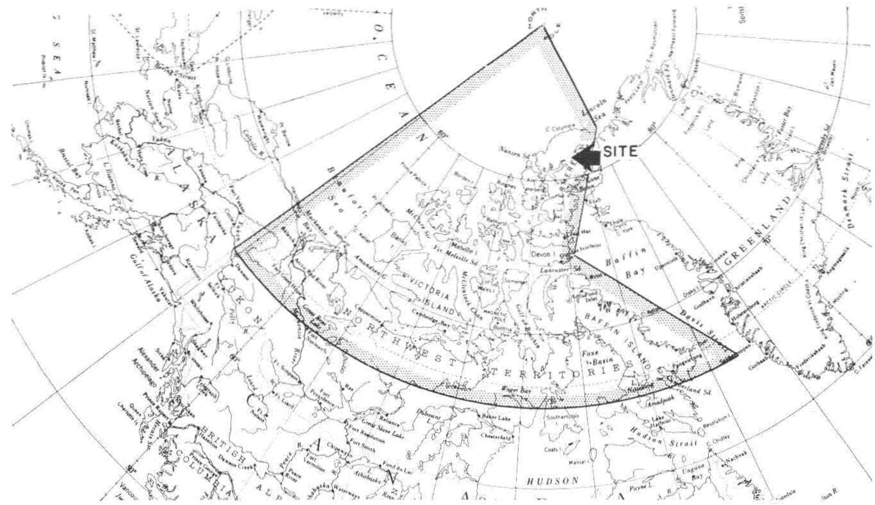


FIG. 1. Area covered by photogeologic study of Northern Canada. Location of Niagara Glacier Site is shown.

Comparison of Photogeology with Field Investigation

In order that an objective comparison may be made between the photogeologic interpretation and the actual field conditions, the original terrain analysis of the site will be quoted. A field report prepared in August 1961 is also presented.

"NIAGARA GLACIER SITE: ELLESMERE ISLAND, 81°30′N, 75°05′W (APPROX.)*

Photogeologic Site Interpretation

Landforms:

The strip is underlain by an outwash fan, which is one of a series extending from the "fronts" of numerous valley glaciers which are characteristic of the area. These fans are being deposited in a northwest trending valley, which at the site and the adjacent area, measures approximately $\frac{3}{4}$ mile in width. The normal fan at this location is dissected by gully action yielding rough surfaces; however, the portion of the fan underlying the strip is anomalous in that it is for the most part undissected and flat-lying. Meltwaters from the nearby glaciers feed Lewis River, a braided stream which flows southeast. Approximately 10 miles from the site it merges with Very River which in turn empties into Hazen Lake.

Bedrock Geology:

The site lies within the Central Ellesmere Fold Belt of the Innuition Region; bedrock in the adjacent area trends N80°W, dips vertically for the most part and reportedly consists of Carboniferous and Permian, sedimentary and volcanic deposits. Rock types known to occur near here include: argillite, cherty argillite, limestone, quartzite, andesite and volcanic breccia.

Surficial Geology: (see Figure 4)

The outwash fans, one of which underlies the landing strip, are glacio-fluvial in origin; i.e., materials have been transported by ice and later deposited by their meltwaters. These fans for the most part are built of poorly sorted and poorly stratified materials consisting mostly of coarse, sub-angular sand and gravel with finer grained materials towards the outer limits of the

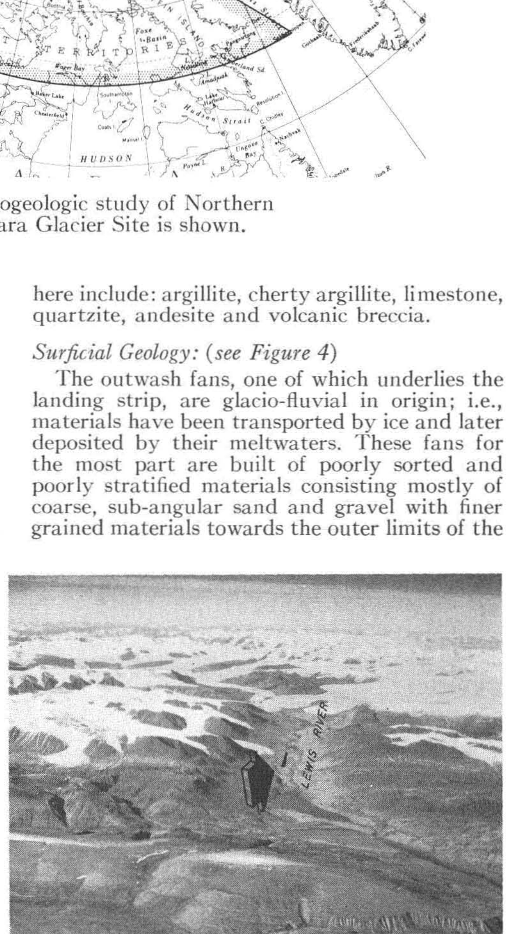


FIG. 2. This oblique aerial photograph shows the potential landing strip at the Niagara Glacier Site as it would be seen by a pilot approaching the site from the southeast. This site may also be approached from the northwest. Photo No. T490L (88), RCAF, 28 July 1952.

* Excerpt from, "Terrain Analysis of Ice-free Land Sites in Arctic Canada", A. E. Pressman, *et al.* Research sponsored by U. S. Air Force Cambridge Research Laboratories.

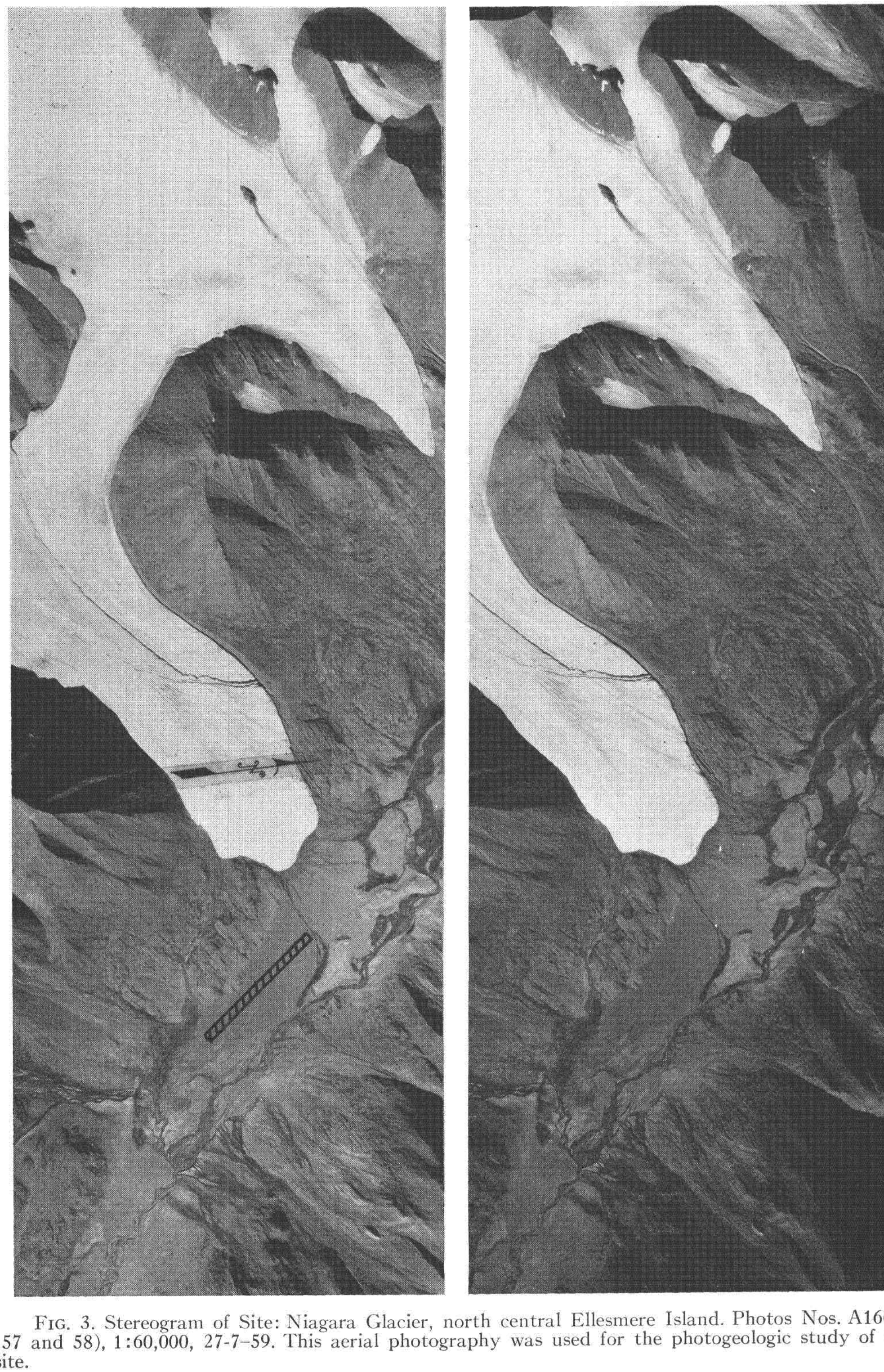
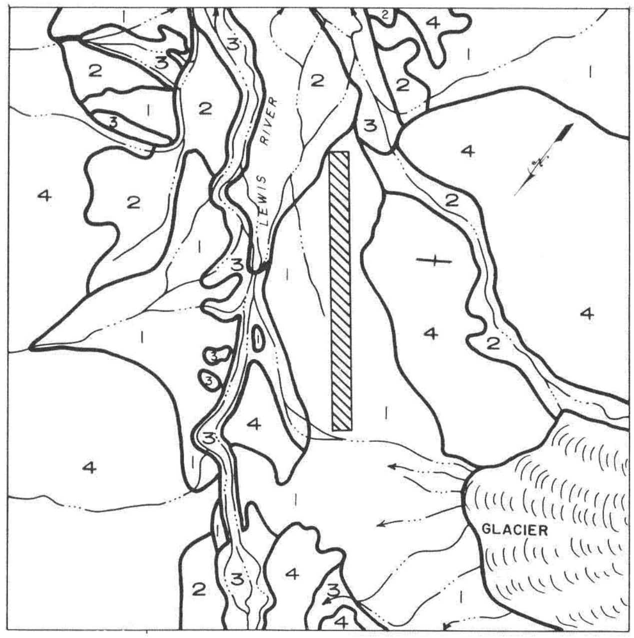


FIG. 3. Stereogram of Site: Niagara Glacier, north central Ellesmere Island. Photos Nos. A16694 (57 and 58), 1:60,000, 27-7-59. This aerial photography was used for the photogeologic study of the site.



SURFICIAL GEOLOGY MAP OF SITE

1000 0 1000 2000 3000 4000 5000 FT.

EKBLAW PASS Ellesmere Island, 81°30'N, 75°05'W (approx.).

FIG. 4. This surficial geology map of the Niagara Glacier Site was prepared solely by photogeologic methods using the 1:60,000 vertical air photos.

1—Outwash fans, poorly sorted, poorly stratified, sub-angular, coarse sand and gravel.
2—Sub-rounded sand and gravel, some sorting.
3—Coarse grained, rounded sand and gravel, some silt.
4—Exposed bedrock, reportedly sedimentary.

deposits. The river channels consist generally of somewhat rounded particles of coarse sand and gravel which exhibit some degree of sorting. Bedrock is widely exposed on both valley walls which rise to sharp peaks typical of valley-glaciated regions.

Water Resources:

Water is available in the warmer months from the many glacial meltwater channels and also from Lewis River. A 1×2 mile lake is located 4 miles downstream from the strip along Lewis River.

Construction Materials:

Abundant coarse, sub-angular sand and gravel is available from the various outwash fan deposits which underlie and surround the strip. Coarse, sorted materials are available from the channel deposits of Lewis River which lie adjacent to the strip. Bedrock is readily available from the valley walls, the closest source of which lies within 150 feet of the strip.

Engineering Considerations:

The strip is oriented northwest, measures approximately 4,500 feet in length and has ample width. The surface of the underlying outwash fan is smooth and slopes gently away from the glacier's edge. Due to its permeability, the fan should not pose excessive heaving problems in times of freeze and thaw, but it may occasionally be subjected to sheet flooding from glacial meltwaters.

Obstructions:

There are no obstructions to flight within necessary approach limits in a northwest direction along Lewis Valley (over ½ mile wide). A hill lies 5,000 feet southeast of the site along the approach, and it may be necessary to slightly re-orient the strip to avoid this obstruction. However, this will result in a decrease in the runway length.

Accessibility:

The site is accessible by float-equipped aircraft landings which may be possible on the nearby lakes (within 4–10 miles southeast and northwest of the strip) during summer. During winter, ski-equipped and wheeled aircraft have landed on Hazen Lake whose nearest shore is 25 miles northeast of the strip. Hazen Lake is reported to freeze to a smooth surface and is a prominent landmark."

FIELD INVESTIGATION*

"Initial survey of the site from the air re-

* The following is quoted from a statement by S. Windisch, McGill University. He has approved inclusion in this paper.

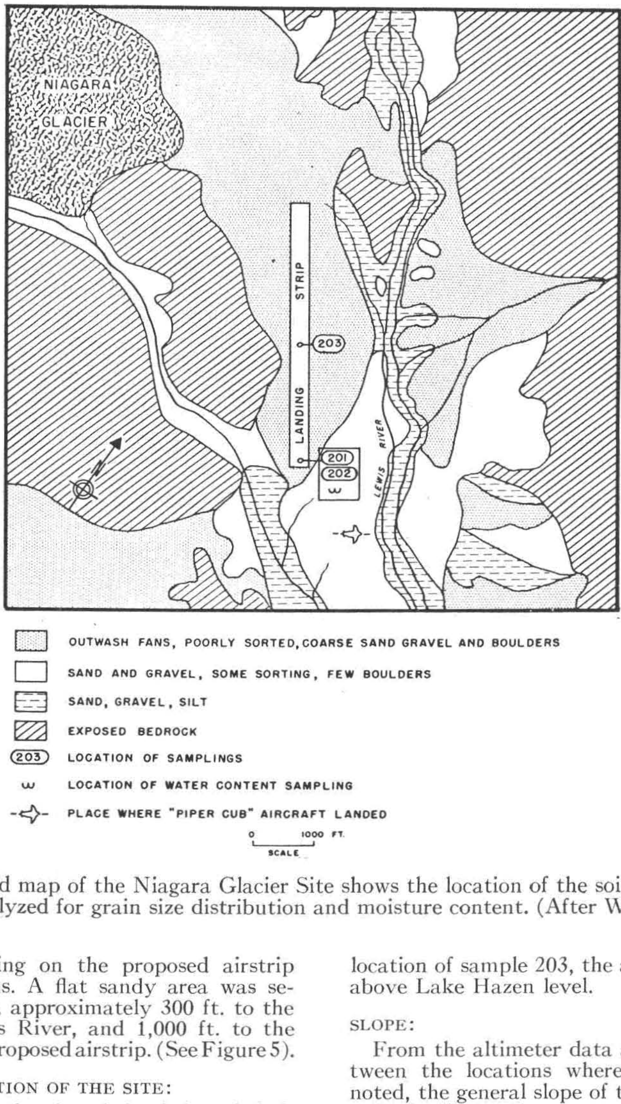


FIG. 5. This field map of the Niagara Glacier Site shows the location of the soil samples which were analyzed for grain size distribution and moisture content. (After Windisch.)

vealed that landing on the proposed airstrip was too hazardous. A flat sandy area was selected for landing, approximately 300 ft. to the west of the Lewis River, and 1,000 ft. to the south-east of the proposed airstrip. (See Figure 5).

GENERAL DESCRIPTION OF THE SITE:

The area where the aircraft landed, and similar sandy areas, present a relief composed of a few 5–10 ft. high sand or gravel dunes on a generally flat surface. Minor irregularities are within 6 inches and have the aspect of not well-identified polygon channels.

The exposed bedrock between the Niagara Glacier and the proposed landing strip is broken into angular blocks varying in size up to 5 ft. and greater. The general aspect of this bedrock is that of a pile of rocks, approximately 100 ft. high with 15°–25° slopes.

The valley, having an average width of 1.5 miles at its base, runs between mountains of an approximate height of 2,000 ft. with 30°–35° slopes.

ELEVATION:

The elevation above Lake Hazen level was determined by a pocket size altimeter. Where samples 201 and 202 were collected, the elevation was established as approximately 750 ft. above Lake Hazen level. (See Figure 5.) At the location of sample 203, the altimeter read 780 ft above Lake Hazen level.

SLOPE:

From the altimeter data and the distance between the locations where the readings were noted, the general slope of the proposed landing strip, in the north-west to south-east direction, is estimated to be 1.5%.

However, the area is also sloping towards the Lewis River in a direction perpendicular to the area mentioned above.

SAMPLES:

Three surface samples were taken for grain-size analysis: Nos. 201 and 202 at the south end and No. 203 at the middle of the proposed landing strip.

Angular and subangular boulders are predominant in the outwash fan and their maximum size is about 12″. However, the samples were limited to the fraction of the grains smaller than 2″.

Two samples for water-content determination were taken at 11 in. from the surface, at the same location as samples 201 and 202.

GRAIN SIZE ANALYSIS:

The grain-size distributions of the samples were obtained by standard sieve analysis. The results are shown graphically in Figure 6.

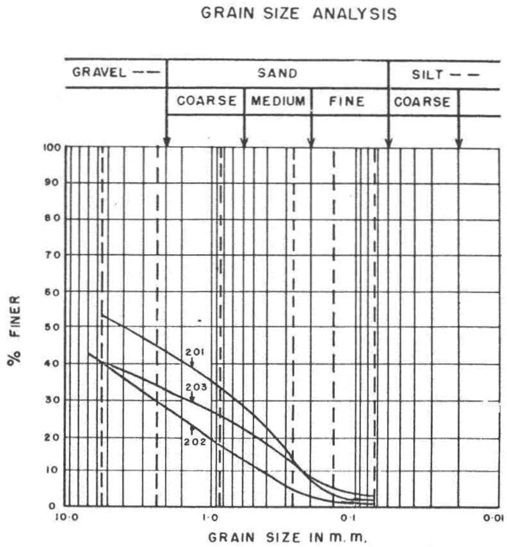


FIG. 6. Grain size distribution of soil samples obtained at the Niagara Glacier Site. The average content of fines is approximately 3%. (After Windisch.)

All samples contained at least 55% gravel, and none had more than 4% silt.

It must be remembered that the samples represented only the fraction of the existing grain-sizes smaller than 2 in. A total representative sample would yield a distribution curve shifted to a lower percent of finer values.

Coarse gravel and boulders were present in increasing quantities towards the north end of the proposed landing strip and near the snout of the Niagara Glacier.

WATER CONTENT:

The samples taken from the lowest part of the landing strip area (at 11 in. from surface) contained only 1.7% water, although the area is close to the glacier and only slightly above the river level.

PILOT'S REMARKS:

The pilot of the "Piper Cub" responsible for transporting the field party noted that the valley was too narrow for "instrument landing." Added to the restriction in approach, the curving of the valley at the south-east may cause difficulties for the take-off of high speed or heavily loaded aircraft.

CONCLUSION ON SITE INVESTIGATION:

In its present condition, the site has a rough surface. Dry melt water channels, polygon channels and boulders up to 12 inches diameter present relief variations ranging up to 3 ft. The surface becomes rougher towards the north-east."*

EVALUATION OF THE PHOTOGEOLOGIC ANALYSIS

Although the field trip to the site was a reconnaissance investigation, (Hattersley-Smith, 1962, p. 47) it did yield valuable data which supported the photogeologic predictions about some of the more important factors that are normally considered in selecting sites for use as potential natural airstrips. These factors are:

1. Runway dimensions and slope
2. Surface smoothness
3. Soil characteristics and properties
4. Approaches

In addition, other natural variables such as meteorological conditions, availability of water and natural construction materials also are analyzed. However, if any of the above listed factors are not favorable, no test landing or take-off by heavy transport aircraft is considered. It is interesting to note that every airstrip site chosen and field analyzed in Greenland has been successfully tested by at least two perfect landings and take-offs. (See References.)

RUNWAY DIMENSIONS AND SLOPE:

Under Engineering Considerations of the photogeologic report, the potential runway length at Niagara Glacier site is listed as 4,500 feet and its width is considered adequate, i.e., over 200 feet. The reconnaissance field map (Figure 5) shows no major discrepancy, and until the detailed field studies and preparations are performed the actual usable length of runway cannot be determined.

All slopes had to be estimated because no high-order topographic maps of the area exist. The potential strip lies on the southeast flank of an outwash fan situated in a valley with a gentle southeast gradient. The glacier front—the source of outwash materials—rests northwest of the strip at a minor elevation above the floor of the valley. By considering location, gradient, and relief, it was deduced that the slope of the potential strip was gentle to the southeast, although the vertical exaggeration in the stereogram (Figure 5) causes the slope to appear rather steep. Ground altimeter readings taken during the field investigation determined the slope to be about 1.5% to the southeast, in very close agreement with photogeologic predictions.

SURFACE SMOOTHNESS:

The outwash fan displayed less microrelief than terraces or any of the other landforms in the area potentially suitable for a natural airstrip. In addition, the surface of this fan was the least dissected of any fans in the vicinity. Because there were no features of

* End of quotation from Windisch statement.

known height on or near the fan to compare with the minor surface irregularities along the landing site, heights and depths of natural obstacles could not be estimated with any degree of accuracy.

If field investigations should show that the surface of this least dissected fan is too rough for use as an airstrip, then all other fans in the surrounding area need not be considered. Although this type of information from photo interpretation does not answer the question "Is this site usable?", it may eliminate, on the basis of one field trip, costly and unnecessary investigations of other areas containing similar landforms.

According to the photogeologic interpretation the surface was considered to be, "for the most part undissected and flat-lying." The on-site evaluation is that the surface contains, "relief variations ranging up to 3 feet."

The preliminary field study did not yield specific data on the density of microrelief of the surface. Therefore until further field tests are undertaken a final decision cannot be made on the suitability of this site for landings. As previously stated, a minor amount of surface preparation would fulfill the requirement for potential natural landing strips. Furthermore, most existing natural airstrips shown to be suitable in Greenland did require minor surface modifications. It is the opinion of earth scientists who have long been involved in this problem area that with the possible exception of some features such as dry lake beds (playas) and beach terraces, there are no known landforms that can be utilized without any surface preparation to satisfy optimum test conditions for landings of heavy, transport aircraft (Needleman, personal communication).

SOIL CHARACTERISTICS AND PROPERTIES:

These two factors are treated as one category because a soil property (of these natural surfaces) such as bearing strength is completely dependent on the soil's characteristics, e.g., grain size distribution etc. The bearing strength of soil surfaces cannot be predicted with a sufficient degree of accuracy by conventional stereoscopic analysis of aerial photographs. What can be determined is the composition of the surface material and a relative estimate of moisture content which ultimately leads to an approximation of the soil bearing strength.

A comparison of the Surficial Geology Map (Figure 4) prepared solely by photogeologic interpretation with the map of the site compiled from field investigations (Figure 5) shows excellent agreement especially with respect to soil constituents and boundaries of individual soil types. The sole discrepancy in the photogeologic analysis occurs with the boulders that were not identified in soil types numbered 1 and 2 nor included in the site description. (See Figure 4.)

In Arctic areas where frost problems are so prevalent, it is of utmost importance that soils contain a minimum amount of moisture if they are to be used for foundations. For this reason the finer grained materials, i.e., silt and clay, which are distinguished by high moisture retention capabilities, should comprise only a very small percentage of the soil.

After airphoto identification of the geomorphic feature on which the potential landing area is situated and a thorough consideration of its geologic history of formation, it was estimated that the soil surface of the Niagara Glacier Site would present a minimum of frost heaving problems. This would be due to the high permeability of the natural material (predominantly sand and gravel) allowing moisture to drain from the upper soil layers. In this case, the favorable conditions were believed to be present because of the very minor amounts of fine particles near the surface.

These photogeologic interpretations are substantiated in the Grain Size Analysis of the field samples (Figure 6). The average content of "fines" is approximately 3%. Further verification lies in the fact that soil samples taken 11 inches below the surface, "contained only 1.7% water, although the area is close to the glacier and only slightly above river level."

Unfortunately no bearing-strength tests were performed at the Niagara Glacier Site. However, low moisture content near the surface coupled with the presence of a favorable grain size distribution in the soil profile does indicate that this potential landing strip will possess high bearing-strength.

APPROACHES:

There is no particular difficulty involved in formulating a preliminary assessment of the approach zones to landing areas. The final assessment however must consider the pertinent flight characteristics of the various aircraft which may use the airstrip as well as the local meteorological conditions. At this site, for example, due to the effect of the nearby glacier a strong westerly wind may occasionally enter Lewis Valley. If this does occur, aircraft using the northwest approach will be subjected to dangerous cross-winds. Conclusions on "meteorological hazards" should be considered valid only after extensive field data have been collected and analyzed.

In an attempt to determine the presence of natural obstacles in the approach zones, the stereo-view alone is not conclusive as it yields a highly exaggerated portrayal of relief. This can be seen by comparing the stereoview of the site (Figure 3) with the oblique view (Figure 2). A few "relative spot elevations" measured by photogrammetric methods on the potential strip and pertinent hilltops etc. would help solve this problem in these remote area surveys. These measurements also may possibly be used to determine the slope of the landing areas.

From the remarks of the pilot of the Piper Cub who visited the site, the approach from the northwest seems to be more favorable because the southeast portion of the valley curves.

Conclusions

The field investigations were in very close agreement with the photogeologic predictions particularly in the following major factors which are evaluated in remote area surveys for natural surface airstrips.

1. Runway dimensions and slope
2. Soil characteristics and properties
3. Approaches

The one significant discrepancy found during the field investigations was the presence of microrelief features ranging up to 3 feet in height on the potential airstrip surface. These features could not be ascertained on the conventional 1:60,000 scale aerial photographs in spite of their excellent quality.

It is quite possible that these minor surface irregularities could be resolved on larger scales of about 1:10,000. However, for reasons of cost and speed it is highly desirable that scales of 1:60,000 or smaller be utilized.

A definite need does exist for image sensing systems which are capable of resolving microrelief features of 6 inches or less at scales of 1:60,000 or smaller.

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