*Applications of Photogrammetry to the Design and Construction of the Quebec Cartier Mining Railway**

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ABSTRACT: *Photogrammetry and photo interpretation were used in practically every phase of the design and construction of the Quebec Cartier Mining Company railroad and its associated facilities. Apart from conventional topographic mapping at many scales, airphotos were used in the computation of earthwork quantities. Airphoto interpretation assisted the preliminary studies for site and route location, by delineating soil and muskeg boundaries. During construction airphoto studies were used extensively for the job access road location, to locate borrow pits, to locate sources of aggregate and to delineate drainage areas. The system and equipment employed in compiling earthwork quantities during construction are described along with the sequential use of airphotos.*

INTRODUCTION

DURING June 1952, airborne magnetometer explorations were commenced in the vicinity of Manicouagan Lake, Province of Quebec. These and subsequent air and ground explorations by Quebec Cartier Mining Company heralded a new chapter in the development of the iron ore regions of Canada which culminated in the completion, this year, of an open pit mine site, a concentrator and town site at Lac Jeannine, a harbour and town site at Port Cartier on the north shore of the Gulf of St. Lawrence, a railway 195 miles long from Port Cartier to Lac Jeannine and a hydroelectric plant to deliver 60,000 H.P. at the Hart-Jaune River 12 miles south of Lac Jeannine. Geographically, Lac Jeannine is at latitude 52°N and longtitude 68°W. Geologically, this region is part of a main structure generally termed the Labrador Trough. Physically, the area is rugged northern bushland where the temperature ranges from 60° below to 100° above through the year and where the total snowfall can be as much as 12 feet. Access to this rugged interior up to the time of construction, was by canoe, snowmobile or aircraft.

Air explorations, air photography and photogrammetry were used during virtually every phase of the development and construction of this project. It may be said that air surveys for exploration, mapping and route location were used more extensively here than on any other construction project in Canada to date. Furthermore, it is doubtful that the vast quantities of data gained from these surveys could have been obtained in the short time available by any other method.

PRECONSTRUCTION SURVEYS

As no suitable maps were available for the area in 1952, the explorations were carried out using the topographic and photo geological information afforded by the existing RCAF 1″=3333′ air photography. The photographs were used for navigation and at the beginning, rudimentary planimetric maps compiled from a photo mosaic of this photography were used as base maps on which to plot magnetic and geological data.

As explorations became more detailed better maps were required. The first maps compiled from the RCAF photography were 10′ form-line maps at a scale 1″=600′. The absolute accuracy of the elevations portrayed was very doubtful because time did not allow the

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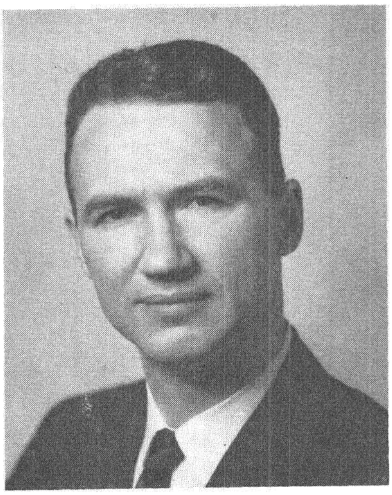
establishment of ground-control. The exploration area mapped in such a manner exceeded 40,000 acres.

During 1956 a preliminary topographic and photo interpretation study was conducted to select possible railroad and access routes from the proposed harbour site near Shelter Bay to the mine site Lac Jeannine. This study performed with the aid of existing 3333′ photography, covered an area of 25,000 square miles. It disclosed the major problems concerning soils, drainage and terrain to be encountered in the area. Based on this preliminary information a total of 13 routes were selected for investigation. All of these possible routes were then photographed at a scale of 1″=1 mile. Further detailed field checking and field photogeology studies using this photography enabled the location engineers, working closely with the photo interpreters, to narrow the selection to three main routes with their associated alternatives.

The third mapping step was the compilation of reconnaissance maps at a scale of 1″=3,000′ with 25′ contours. The vertical-control consisted of a few barometric elevations and the horizontal-control utilized relatively short distances that were measured across several of the larger lakes. These surveys were accomplished during the winter when the lakes were frozen. Surveyors were moved from lake to lake by small aircraft and all operations were conducted under most difficult conditions. Bridging of this sparse horizontal and vertical control was performed on the Wild A-7 Autograph.

Using these maps and a detailed air photo analysis it was possible to designate one principal route along with two possible alternatives. With the area of interest narrowed down to these more reasonable confines it was then practical to commence the large-scale mapping program required for a more detailed study for location and design. This was started in early 1956. Control traverses were established between Shelter Bay and Lac Jeannine, and bench levels were run to maintain vertical datum. The control traverse, commencing at a Canadian government triangulation station on the coast, was run north to the mine site at Lac Jeannine, a distance of 200 miles. Here the traverse was tied and adjusted to another government triangulation station. For survey purposes the line was divided in three sectors. The traverse parties working in each sector checked distances by double chaining, and azimuth by astronomic observations every five miles.



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Bench levels were run simultaneously by two parties so that each loop could be checked at the end of each day. Traverses were run to an accuracy of 1:5,000 while the bench levels were run to obtain a closure of 0.1 multiplied by the square root of the distance in miles. This ground-control in conjunction with 1″=1,600′ photo was used to compile maps at 1″=200′ with 5′ contours. The strip map so produced for the route was about 1.7 miles wide for the complete 200 mile route. It was possible to complete this mapping in the short time of five months after receiving the ground-control by using four Wild A-8 Autographs on double shift.

The center-line of the railway was projected on these 1″=200′ maps during the winter of 1956–57 so that surveying the *P* line or preliminary line could be commenced in the Spring of 1957. This *P* line was transferred from paper to the ground by ties established to the 1956 control traverse. Profile and cross-sections taken at frequent intervals along the *P* line were used to correct the topographic maps. This step was necessary because a substantial part of the route mapped was heavily wooded, and variable tree heights and densities caused variation in the contours. The trees were usually higher in the wet hollows than on the higher ground. Our maps tended to smooth out these features.

Using these supplemental field data a strip map 600′ wide was compiled. The design drawings in plan and profile showed the coordinates of *PI*'s and the bearings of tangents; grades and all drainage and construction details were developed from these strip maps. Design earthwork quantities were obtained by interpolating cross-sections from the strip map contours.

Detailed surveys were carried out at a total of 22 bridges and trestle sites so that topographic plans at 1″=20′ with 1′ contours could be compiled for these locations.

Other preconstruction photogrammetric surveys included mapping at 1″=200′ of the new town site at Port Cartier (near Shelter Bay), the railroad yards and dock site at Port Cartier, the town site of Gagnon (7 miles north of Lac Jeannine), the mine site and concentrator site at Lac Jeannine and the mapping at 1″=100′ with 2′ contours of the Hart-Jaune River hydro development.

Photo interpretation studies provided information required for soil studies, aggregate searches, drainage studies and access road location problems.

Construction Surveys

During August 1958 survey crews again entered the area to commence the staking out of the railway center-line, right-of-way, grading, drainage and terminal yards ahead of construction. For construction surveys and supervision, the line was divided into eight residencies, approximately 25 miles in length. Surveys within each residency were accomplished mainly by two, eight man survey parties. Surveys connected with structure, track and yard layout were performed by independent parties. Residency survey parties under the overall supervision of a resident engineer were responsible for the layout of center-line, right-of-way, grades and drainage structures. Earthwork quantity estimates were compiled in each residency and were based upon cross-sections taken of the ground after grubbing operations.

A complete photogrammetric electronic computation program was established with which to handle the computations required for earthwork quantity control and estimates. This system was not used because of the difficulty in obtaining original ground photography after grubbing, and before this ground was disrupted by construction equipment. However, enough photogrammetric cross-sectioning was done to refine the system and to obtain comparisons with ground surveys. The field units of this system included a photo lab for developing, a Kelsh plotter with which to check diapositives, and a complete printing set-up so that prints could be obtained immediately in the field for annotation and identity purposes, plus a teletype hook-up between the field office and the main office for the transmittal each way of field and earthwork data. The main office units were composed of the photo lab, compilation co-ordination center and the A-8 plotter section from which cross-sections were received. From the A-8, cross-sections were received in machine co-ordinates on punch tape via the EK-3 attachment and an IBM tape to card converter. All of these data were entered into an IBM 650 computer programmed for the design templates and specifications peculiar to this contract. The IBM program furnished the co-ordinates of each ground cross-section in cut and fill per station, the template catch points, the vertical curve data, the design earthwork quantities. The co-ordinates of each cross-section in cut and fill referred to center-line grade elevations received from the computer were then processed through an electro dataplotter which delivered the plotted cross-sections in ink.

The ground control established for photogrammetric cross-section compilation consisted of center-line stationing for scale, center-line profile and at least four wing points per model for vertical-control. The center-line stakes were identified by targets of cardboard 1′ square placed over each center-line stake while the wing points, which were about 200′ each side of the center-line and about 500′ apart, were identified by wooden crosses 6′ on a side. These targets were either white or black depending on the contrast required for the season and background.

The air photography taken of the right-of-way after grubbing was at a negative scale of 1″=350′ using an RC-8 camera with Aviogon lens. This equipment was installed in an Apache aircraft capable of flying at speeds as low as 100 m.p.h. Although the air photo for the most part had to be taken whenever construction conditions and progress demanded, it was found that the best photography for measurement purposes was obtained under overcast conditions using aperture openings of f 5.6. This was even true of snow covered ground. In this way the dark shadows inherent to deep rock excavation and high fills were panned out. The film used was Super XX Aerographic. The results of these photogrammetric trials may be best expressed numerically by saying that excavation quantities measured by photogrammetry agreed within 1% with the surveys performed by conventional ground methods. However, variations of up to 3% were experienced in the measurements of jagged rock fills.

Problems connected with obtaining the desired results through using photogrammetric methods were mainly physical. The photogrammetric equipment and the associated electronic digitizing and computing equipment have proved satisfactory and are now in relatively widespread use. The main problem as earlier suggested is that of obtaining the ground photography after grubbing and before the ground is disturbed. In other words, the railway or highway right-of-way must be cleared, grubbed and staked well in advance of construction.

Weather does not present a problem except during snow-flurries when even a light snowfall is sufficient to cover and obscure the ground-control targets. Normal haze, ice crystals, or rain do not present a problem from a photographic standpoint. As a matter of fact, much of the large-scale photography for measurement purposes was obtained under these conditions.

All of this 1″=350′ progress photography served as a permanent record of clearing, access and haul roads, grading and borrow pits, drainage ditches, culverts and other construction features.

In addition, photography at a scale of 1″=1,500′ of the right-of-way and access road was used continuously through the project to check drainage access road locations, possible sources of borrow and ballast materials.

The advantages of using an integrated photogrammetric electronic-computer method for construction design, terrain measurements and associated studies are many. The main advantage of such a system is that it provides a permanent and indisputable record of the ground before construction is commenced. Secondly, the information provided is complete in that the photography shows all details, some of which would be impossible or impractical to obtain, or which at the time of original ground cross-sectioning might not seem relevant. Then, of course, there is the question of accuracy. The accuracy of cross-section terrain measurements by conventional ground methods varies with the terrain. They are less accurate and less complete in very steep and rugged terrain when performed in extreme climatic conditions such as ice, snow and extreme cold. These factors naturally do not affect the accuracy of the photogrammetric measurements. The presentation and versatility of the data as obtained from an electronic-computer is far easier to keep to a standard than the data received from several survey parties; thus the overall quantity and quality control becomes easier and more economical. Last but not least, there are the side benefits of the every-day use of the air photography which is used by the soils, drainage, structural, engineering, estimating and construction departments; such use saves many field trips and for the most part portrays as much or more information as can be obtained on the ground.

In summary, air photography and photogrammetry was integrated here with exploration and construction studies to provide the engineer with a variety of information including:—

for reconnaissance and exploration

1. reconnaissance maps for navigation and access,
2. base maps for geological data compilation,
3. data derived from photogeology.

for preconstruction studies

1. photo studies to select possible road and railway routes, mill and harbour sites.
2. photo interpretation studies to delineate
   a) major soils and geologic features
   b) possible sources of borrow, ballast and aggregate materials
   c) vegetation characteristics including muskeg and other organic deposits
   d) drainage details and drainage areas required for culvert, bridge and hydro design.
3. topographic plans at various scales for route and site locations, construction quantity computation and design.

and during construction

1. for locating access roads, haul roads and construction camps,
2. for the location of communication transmitters,
3. to locate sources of borrow, ballast and concrete aggregate,
4. to measure clearing and grubbing,
5. to compute excavation quantities,
6. ballast stock piles inventory.

Following the completion of construction, there are many additional valuable aids afforded by air photographs and photogrammetry. These include the computations of open-pit ore excavations and stock piles at the mine, and the charting of the formation and flow of sea ice in the Gulf of St. Lawrence to aid in maintaining an all-year shipping lane to Port Cartier.