McElhanney

September 5, 2013,

Our File:2611-10191-0

Transportation Engineering Branch
Government of the Yukon
Box 2703, Whitehorse, Yukon Y1A 2C6
Attention: Michael Kearney CLS, P.Eng

Re: Dawson City Airport and Dome Rd. YK LiDAR and Orthophoto

Dear Mr. Kearney,

Enclosed you will find McElhanney LiDAR Report for Dawson Airport and Dome Rd, YK project. This letter serves to certify that the LiDAR and survey work have been completed in accordance with ASPRS (American Society of Photogrammetry and Remote Sensing) and BC Specification and Guidelines for Control Surveys using GPS Technology and LiDAR specifications from (Integrated Land Management Bureau).

Should you have any question or require additional information, please contact me at 604-424-4784.

Yours Sincerely,

Azadeh Koohzare, PhD., PEng.
Project Manager
McElhanney Consulting Services Ltd.

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Enclosure: LiDAR report

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Dawson City Airport and Dome Rd. YK

LiDAR and Orthophoto
Data Capture and Processing

LiDAR Report

Our File:

2611 10191-0

Submitted To:

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September 5, 2013

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1. Introduction

McElhanney Consulting Services Ltd (MCSL) performed a LiDAR and aerial photography acquisition in the Dawson City, YK shown in Figure 1a and Figure 1b.

The acquisition was carried out on August 6th, 2013. This report describes the acquisition, post-processing and quality control methodology used to produce the final elevation models.

2. Mission Plan

Project: Dawson City Airport LiDAR and Aerial photo Project

Date: August 6th, 2013

Location: Dawson City, YK

Total Days: 2

Total Acquisition Time (hrs): 3 hrs

Topography: moderate

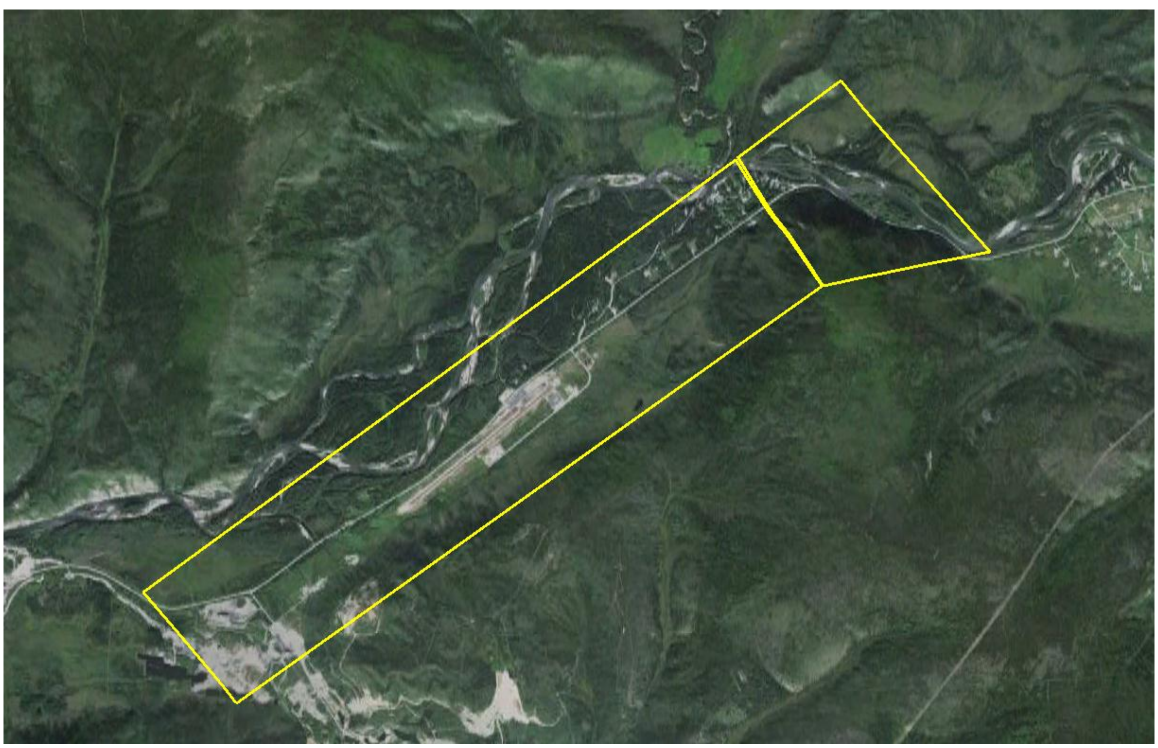

Figure 1a – LiDAR Survey Site-Dawson City Airport, YK

Figure 1b – LiDAR Survey Site-Dome Rd, Dawson City, YK

3. LiDAR Acquisition

McElhanney utilized the ALS70 Leica system (Figure 2).
For Product Specifications of Leica ALS70 please see
http://www.leica-geosystems.com/en/Leica-ALS70-Airborne-Laser-Scanner_57629.htm
The ALS70 was mounted on Piper Apache fixed wing Aircraft.

Figure 2 –ALS70 Leica components

4. Flight Plan

Each line was flown with an average point density of 4.3 pts /m² and with 60% average overlap to ensure that there are enough LiDAR returns, as required for the project. Table 1 show the flight parameters.

Table 1: Flight Parameters

Name	Length [m]	FOV [deg]	Swath Width [m]	Target Speed [kts]	Alt MSL [m]	Min Alt AGL [m]	Max Alt AGL [m]	Used Laser Pulse Rate [Hz]	Used Scan Rate [Hz]
001	20213.0000	39	1123.0000	140	1832.0000	1090.0000	1586.0000	344600.0000	50.4000
002	20815.0000	39	1130.0000	140	1842.0000	1100.0000	1596.0000	342400.0000	50.4000
003	21234.0000	39	1123.0000	140	1843.0000	1101.0000	1585.0000	344600.0000	50.4000
004	21640.0000	39	1126.0000	140	1855.0000	1113.0000	1589.0000	343600.0000	50.4000
005	21832.0000	39	1129.0000	140	1860.0000	1118.0000	1593.0000	343000.0000	50.4000
006	21918.0000	39	1127.0000	140	1879.0000	1137.0000	1591.0000	343400.0000	50.4000
007	22122.0000	39	1123.0000	140	1865.0000	1123.0000	1585.0000	344600.0000	50.4000
008	22047.0000	39	1123.0000	140	1829.0000	1087.0000	1585.0000	344600.0000	50.4000
009	21282.0000	39	1123.0000	140	1830.0000	1122.0000	1586.0000	344400.0000	50.4000
010	20463.0000	39	1124.0000	140	1830.0000	1207.0000	1587.0000	344200.0000	50.4000
011	19664.0000	39	1123.0000	140	1844.0000	1303.0000	1586.0000	344400.0000	50.4000
012	18732.0000	39	1123.0000	140	1844.0000	1291.0000	1586.0000	344400.0000	50.4000
013	17725.0000	39	1124.0000	140	1869.0000	1190.0000	1587.0000	344200.0000	50.4000
014	16787.0000	39	1123.0000	140	1893.0000	1151.0000	1586.0000	344400.0000	50.4000
015	9625.0000	39	1125.0000	140	1894.0000	1152.0000	1588.0000	344000.0000	50.3000

5. Data Processing

All GPS data was processed using GrafNav software v.8.4. IMU data was processed using Leica IPAS Pro v.1.3 and the laser data was extracted using ALS Post Processor v.2.68. The GPS antenna position in the airplane was calculated by post–processing the raw data at 1 second intervals for the entire flight.

We have set up one base station for the airborne GPS processing, and the coordinates were calculated in NAD83-CSRS.

Table 1: The coordinates of the base stations. The horizontal coordinates are in NAD83-CSRS and the orthometric heights are based on Ht2 geoid model.

Pt	Easting	Northing	Ellipsoidal height	Orthometric height
2035	591730.669	7103552.098	378.908	369.004

The airborne positions were combined with the post–processed platform (aircraft) attitude information to generate a time tagged position and orientation solution.

The standard deviation of the airborne GPS solution for using KAR (Kinematics Ambiguity Resolution) was estimated to be 0.04, 0.05 and 0.07m in East, North and height directions, respectively.

The estimated values for the GPS antenna position were used with the laser ranges and platform angles to compute all the individual X, Y, and Z coordinates for each laser return in each flight line. The result is a processed point cloud containing all measured points.

6. Point Density

Bare earth point density varies with canopy closure, understory density and topographic features. Mean density of the point cloud was measured at 10 pts/m^2 .

7. Calibration

The LiDAR system calibration was flown over our BCIT calibration site in Burnaby, BC. The lever arms (offset between GPS antenna IMU and Laser Mirror), were measured as:

Lever Arms
GPS Lever arms in (m):
x: -0.163 y: -0.141 z: -1.419

IMU Lever arms in (m):
x: -0.450 y: 0.159 z: -0.169

There were a total number of 5 flight lines for calibration: 4 basic lines for Attune software analysis and 1redundant line for better accuracy. The lines were planned as follow:

- 2 orthogonal at low altitude
- 2 orthogonal at higher altitude
- 1 parallel lines at higher altitude

The calibration values used for this project are as follows:

Roll correction: -0.003044591 rad
Pitch correction: -0.003291501 rad
Heading correction: -0.003227494 rad

8. Quality Control

The LiDAR data consistencies have been checked between the flight lines using Terrascan software.

Comparison of Bare Earth LiDAR data with Ground Survey Values

According to ASPRS guidelines, the vertical accuracy of LiDAR is as follows:

$$RMSE_z = Sqrt[\sum (Z_{Lidar(i)} - Z_{check(i)})^2 / n] = 0.02 \text{ m}$$

Where the "Check" refers to the ground truth (In this project, we used survey points which are at least three times more accurate than the individual LiDAR points) and *n* is the number of check points. We have a total of 322 check points.

Average dz -0.02 m
Minimum dz -0.17 m
Maximum dz +0.50 m
Average magnitude 0.10 m
Std deviation 0.16 m

9. Deliverables

Final output data is provided in NAD83CSRS UTM 7 and the elevations are based on Ht2 geoid model. The digital data are delivered on WD portable hard drive in phases. The deliverables include:

- Classified LiDAR bare earth and non-bare earth in LAS
- Classified LiDAR filtered model key points in ASCII XYZ
- 1 m contour map in dwg
- Orthophoto image in TIFF and ECW format
- LiDAR Report

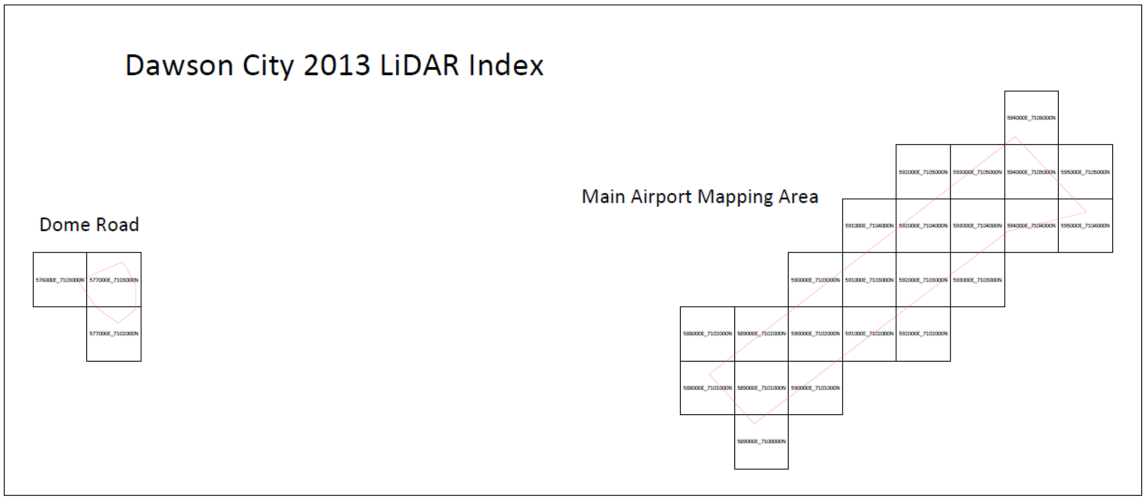

Figure 3- Index Map2012