2022 Whitehorse Flood Mapping

LiDAR and Airphoto
Data Capture and Processing

LiDAR and Air Photo Report

Our File: 2611 19372-07

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1. Introduction

McElhanney Ltd (MCSL) performed a LiDAR and aerial photography acquisition for Whitehorse Flood Mapping areas shown in Figure 1.

The site was flown on June 19th, Agusut 15th, and August 16th, 2022. This report describes the acquisition, post-processing and quality control methodology used to produce the final elevation models.

2. Mission Plan

Project: Whitehorse Flood Mapping Project
Date: Mission 1: 2022-06-19; Mission 2: 2022-08-15; Mission 3: 2022-08-16
Location: Whitehorse, YT
Topography: low relief

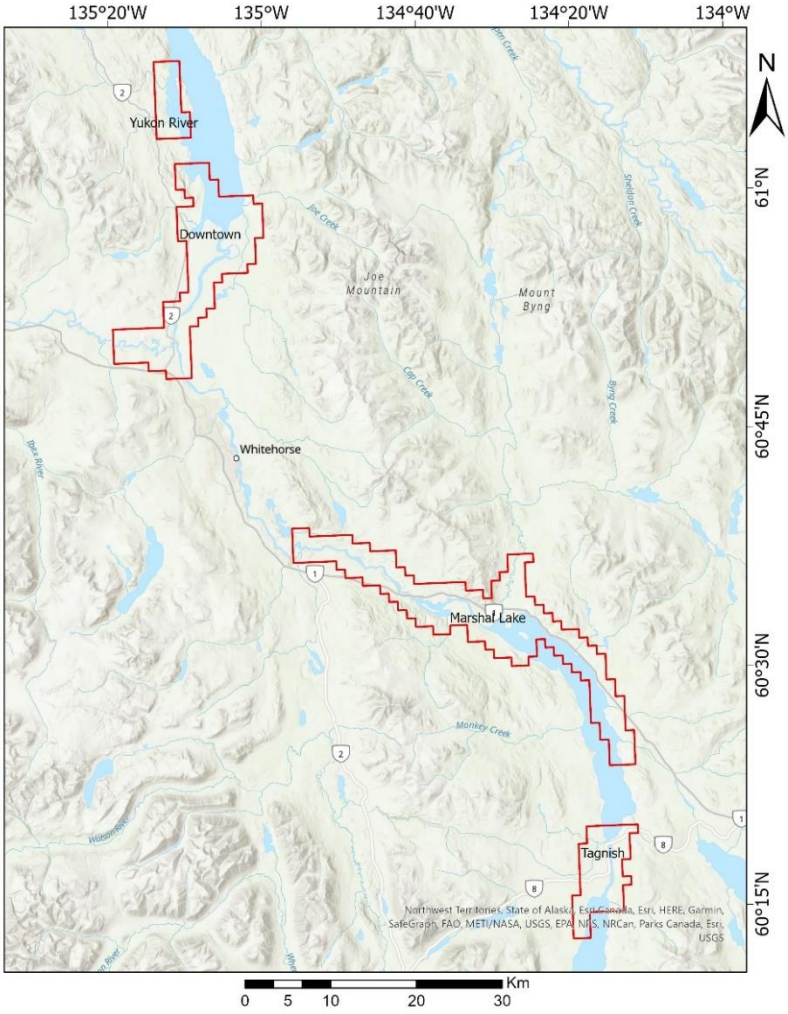

Figure 1 - LiDAR Survey Site

3. Equipment

McElhanney utilized the Leica Terrain Mapper -2 (TM2), Hyperion2+ system for LiDAR Capture (Figure 2).

For Product Specifications please see

https://leica-geosystems.com/products/airborne-systems/topographic-lidar-sensors/leica-terrainmapper-2

The LiDAR system is mounted on Piper Navajo fixed wing aircraft.

On-board camera is Leica MFC150 / Leica MFC150-NIR Camera Head - simultaneous capture.

Figure 2 - Leica TerrainMapper-2 system components

4. Flight Plan

Table 1 - Flight Parameters 2022-06-19

Flight Line Label	Swath Width [m]	Alt MSL [m]	Length [km]	Scan Pattern	Used Laser Pulse Rate [Hz]	Used Scan Rate [Hz]	FOV [deg]	Flown Line Direction [deg]	Line begin time [UTC]	Line end time [UTC]
007	1310	2452	10.7	Circle	2000000	150	40	18:32:41	18:35:11	007
008	1310	2455	11.1	Circle	2000000	150	40	18:36:56	18:39:32	008
009	1310	2455	17.6	Circle	2000000	150	40	18:42:35	18:46:49	009
010	1310	2455	10.8	Circle	2000000	150	40	18:48:49	18:51:29	010
011	1310	2455	10.3	Circle	2000000	150	40	18:53:08	18:55:41	011

012	1310	2483	8.3	Circle	2000000	150	40	18:57:41	18:59:49	012
021	1310	2464	15.2	Circle	2000000	150	40	187.7	18:20:55	18:24:51
022	1310	2455	15.3	Circle	2000000	150	40	7.8	18:26:19	18:29:50
023	1310	2448	15.4	Circle	2000000	150	40	7.7	19:07:24	19:11:05
024	1310	2454	15.4	Circle	2000000	150	40	187.7	19:12:49	19:16:45
025	1310	2447	12.2	Circle	2000000	150	40	7.7	19:18:52	19:21:45
026	1310	2455	12.3	Circle	2000000	150	40	187.8	19:23:30	19:26:36
027	1310	2455	12.3	Circle	2000000	150	40	7.7	19:28:08	19:30:57
028	1310	2455	14.7	Circle	2000000	150	40	187.9	19:33:09	19:36:46
029	1310	2455	9.1	Circle	2000000	150	40	187.7	19:01:22	19:03:37
030	1310	2430	10.8	Circle	2000000	150	40	354.2	17:48:47	17:51:23
031	1310	2428	10.9	Circle	2000000	150	40	174.3	17:43:50	17:46:47
032	1310	2421	13.3	Circle	2000000	150	40	354.2	17:38:45	17:42:13
033	1310	2388	13.2	Circle	2000000	150	40	174.3	17:33:33	17:36:52
034	1310	2418	13.1	Circle	2000000	150	40	354.2	17:28:52	17:32:06
035	1310	2421	10.9	Circle	2000000	150	40	174.2	17:24:14	17:26:51
036	1310	2422	19.2	Circle	2000000	150	40	359.3	22:46:31	22:50:47
037	1310	2414	20.5	Circle	2000000	150	40	179.4	22:52:19	22:57:23
038	1310	2411	20.6	Circle	2000000	150	40	359.4	22:58:46	23:03:24
039	1310	2409	20.8	Circle	2000000	150	40	179.3	23:05:01	23:10:21
040	1310	2409	19.7	Circle	2000000	150	40	359.4	23:12:00	23:16:46
041	1310	2411	17.8	Circle	2000000	150	40	179.3	23:18:42	23:23:19
042	1310	2423	13.5	Circle	2000000	150	40	359.3	23:24:33	23:27:38
043	1310	2428	11.9	Circle	2000000	150	40	179.3	23:29:25	23:32:29
044	1310	2425	11.0	Circle	2000000	150	40	359.4	23:33:49	23:36:28
045	1310	2427	11.1	Circle	2000000	150	40	179.3	23:38:05	23:41:02
046	1310	2428	10.9	Circle	2000000	150	40	359.4	23:42:29	23:45:13
047	1310	2506	10.0	Circle	2000000	150	40	179.4	23:46:44	23:49:35
048	1310	2537	5.7	Circle	2000000	150	40	359.3	23:50:54	23:52:10

061	1310	2436	27.8	Circle	2000000	150	40	329.7	20:46:18	20:52:14
062	1310	2435	28.3	Circle	2000000	150	40	149.8	20:53:57	21:00:45
063	1310	2432	28.5	Circle	2000000	150	40	329.7	21:02:14	21:08:36
064	1310	2432	28.5	Circle	2000000	150	40	149.8	21:10:29	21:17:15
065	1310	2428	28.2	Circle	2000000	150	40	329.7	21:18:41	21:25:29
066	1310	2428	27.6	Circle	2000000	150	40	149.8	21:27:20	21:33:59
067	1310	2428	27.4	Circle	2000000	150	40	329.7	21:35:31	21:41:52
068	1310	2428	26.7	Circle	2000000	150	40	149.8	21:43:41	21:50:13
069	1310	2422	26.4	Circle	2000000	150	40	329.7	21:52:07	21:58:17
070	1310	2425	27.2	Circle	2000000	150	40	149.7	21:59:45	22:06:27
071	1310	2418	27.4	Circle	2000000	150	40	329.7	22:07:53	22:14:15
072	1310	2412	27.1	Circle	2000000	150	40	149.7	22:15:55	22:22:27
073	1310	2409	26.7	Circle	2000000	150	40	329.8	22:24:21	22:30:41
074	1310	2409	25.4	Circle	2000000	150	40	149.7	22:32:26	22:39:06

Table 2 - Flight Parameters 2022-08-15

Flight Line Label	Swath Width [m]	Alt MSL [m]	Length [km]	Scan Pattern	Used Laser Pulse Rate [Hz]	Used Scan Rate [Hz]	FOV [deg]	Flown Line Direction [deg]	Line begin time [UTC]	Line end time [UTC]
013	1310	2471	3.5	Circle	2000000	150	40	348.8	16:09:56 tt	16:10:48 tt
014	1310	2445	4.8	Circle	2000000	150	40	168.9	16:05:42 tt	16:06:53 tt
015	1310	2445	6.5	Circle	2000000	150	40	348.2	16:00:34 tt	16:02:01 tt
016	1310	2445	7.9	Circle	2000000	150	40	168	15:55:33 tt	15:57:26 tt
017	1310	2445	8.4	Circle	2000000	150	40	348.4	15:49:54 tt	15:51:45 tt
018	1310	2444	8.9	Circle	2000000	150	40	168.1	15:44:49 tt	15:46:55 tt
019	1310	2455	9.2	Circle	2000000	150	40	348.3	15:39:11 tt	15:41:12 tt
020	1310	2455	9.1	Circle	2000000	150	40	167.8	15:33:50 tt	15:35:55 tt
055	1310	2428	50.7	Circle	2000000	150	40	294.1	17:10:40 tt	17:22:18 tt
056	1310	2428	50.3	Circle	2000000	150	40	113.9	16:56:07 tt	17:07:05 tt
057	1310	2428	48.5	Circle	2000000	150	40	294.2	16:41:03 tt	16:52:37 tt

058	1310	2428	38	Circle	2000000	150	40	114.1	16:28:06 tt	16:36:22 tt
059	1310	2477	15.7	Circle	2000000	150	40	294.3	16:17:15 tt	16:20:51 tt

Table 3 - Flight Parameters 2022-08-16

Flight Line Label	Swath Width [m]	Alt MSL [m]	Length [km]	Scan Pattern	Used Laser Pulse Rate [Hz]	Used Scan Rate [Hz]	FOV [deg]	Flown Line Direction [deg]	Line begin time [UTC]	Line end time [UTC]
049	1310	2445	34.5	Circle	2000000	150	40	294.1	15:12:04 tt	15:19:35 tt
050	1310	2445	37.8	Circle	2000000	150	40	114.1	15:23:09 tt	15:31:42 tt
051	1310	2443	41.2	Circle	2000000	150	40	294.1	15:35:20 tt	15:44:21 tt
051	1310	2443	41.2	Circle	2000000	150	40	114.2	16:56:45 tt	16:57:48 tt
052	1310	2417	43.7	Circle	2000000	150	40	120.1	15:47:46 tt	15:47:48 tt
052	1310	2417	43.7	Circle	2000000	150	40	114.1	15:52:11 tt	16:01:52 tt
053	1310	2417	47.5	Circle	2000000	150	40	294.1	16:05:54 tt	16:16:21 tt
054	1310	2417	49.4	Circle	2000000	150	40	114.1	16:20:02 tt	16:30:52 tt
055	1310	2428	50.7	Circle	2000000	150	40	294.1	16:34:50 tt	16:45:55 tt

5. Data Processing

All GPS and IMU data was processed using Inertial Explorer v8.9 software. The laser data was extracted using Leica HxMap 3.6 software. The GPS antenna position in the airplane was calculated by post-processing the raw data at one (1) second intervals for the entire flight. We have used Precise Point Position (PPP) to process the trajectories, and the coordinates were calculated in NAD83(CSRS).

6. Point Density

Bare earth point density varies with canopy closure, understory density and topographic features. Mean density of the point cloud and bare-earth was measured and can be seen in the following table for each area.

Table 4 - Measured point density for project sites

Area	Point-cloud pts/m^2	Bare-earth pts/m^2
Yukon River	36.52	9.56
Downtown	36.52	12.52
Tagnish	25.13	10.12
Marshal Lake	37.02	10.30

7. Calibration

System: Leica TM-2

LiDAR Calibration flight:

Calibration Date: April 24, 2022 Location: Abbotsford, BC

Base station used for calibration (in NAD83(CSRS) v4e2002):

- BCAB N 49° 03’ 7.81125” W 122° 19’ 46.2715” 72.996m

The LiDAR system calibration was flown over calibration site. The lever arms (offset between GPS antenna IMU and Laser Mirror), were calibrated based on 31 ground survey points.

Lever Arms

GPS Lever arms in (m):

X = -0.218 m Y = -0.224 m Z = 1.298 m

IMU Lever arms in (m):

x: 0 y: 0 z: 0

8. Quality Control

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

Comparison of Bare Earth LiDAR data with Existing LiDAR Ground Points

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

Area - 01

$$RMSE_z = Sqrt[\sum (Z_{Lidar(i)} - Z_{check(i)})^2 / n] = 0.027\text{m}$$

Area - 02

$$RMSE_z = Sqrt[\sum (Z_{Lidar(i)} - Z_{check(i)})^2 / n] = 0.031\text{m}$$

Area – 03

$$RMSE_z = Sqrt[\sum (Z_{Lidar(i)} - Z_{check(i)})^2 / n] = 0.103\text{m}$$

Area – 04

$$RMSE_z = Sqrt[\sum (Z_{Lidar(i)} - Z_{check(i)})^2 / n] = 0.022\text{m}$$

Area – 05

$$RMSE_z = Sqrt[\sum (Z_{Lidar(i)} - Z_{check(i)})^2 / n] = 0.059\text{m}$$

Where the ”Check” refers to the ground truth (in this project, we used existing LiDAR ground points) and *n* is the number of check points. A total of 2,014 check points were used for this analysis. Figure 3 shows the location of the Check points for this project:

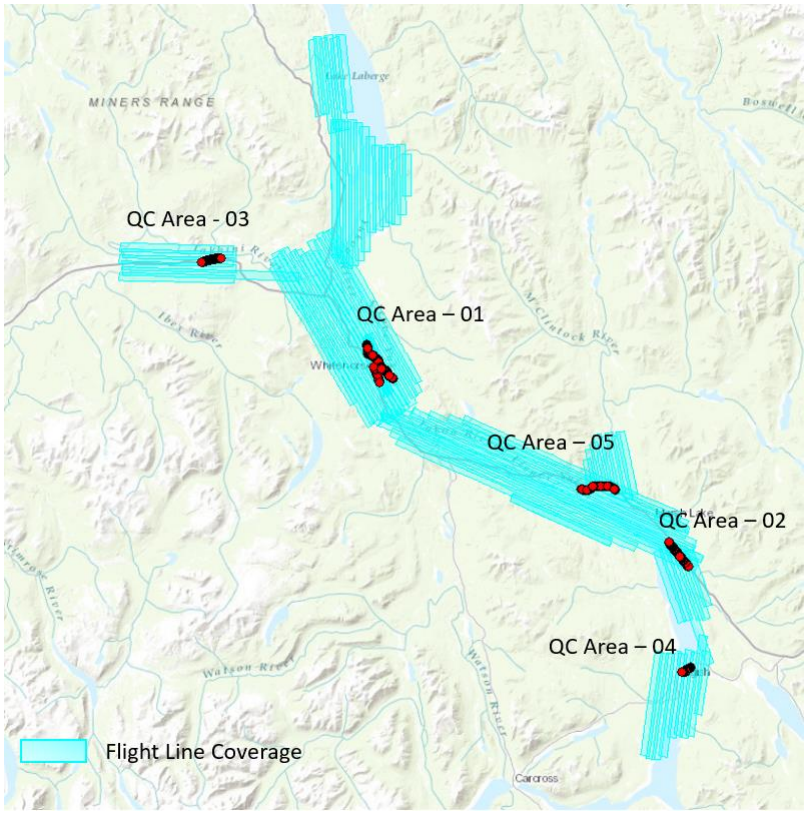

Figure 3 - Controls used for vertical check

QC Area – 01

N=308
Average dz +0.018 m
Minimum dz -0.048 m
Maximum dz +0.064 m
Average magnitude 0.023 m
Root mean square 0.027 m
Std deviation 0.020 m

QC Area - 02

N= 538
Average dz +0.017 m
Minimum dz -0.077 m
Maximum dz +0.100 m
Average magnitude 0.024 m
Root mean square 0.031 m
Std deviation 0.026 m

QC Area – 03

N= 415
Average dz -0.063 m
Minimum dz -0.240 m
Maximum dz +0.122 m
Average magnitude 0.085 m
Root mean square 0.103 m
Std deviation 0.082 m

QC Area – 04

N= 108
Average dz +0.044 m
Minimum dz -0.003 m
Maximum dz +0.097 m
Average magnitude 0.044 m
Root mean square 0.049 m
Std deviation 0.022

QC Area – 05

N= 645
Average dz +0.055 m
Minimum dz -0.023 m
Maximum dz +0.129 m
Average magnitude 0.055 m
Root mean square 0.059 m
Std deviation 0.021 m

9. Deliverables

Final output data is provided in NAD83CSRS UTM Zone 8 and the elevations are based on CGVD28 HT2 and CGVD13 geoid models. The deliverables include:

- Bare Earth & Thinned model key points in las, xyz
- Non Bare Earth in las format
- Index map
- 20 cm Orthophto