



## **2022 Whitehorse Flood Mapping Preliminary Report**

**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 19<sup>th</sup>, August 15<sup>th</sup>, and August 16<sup>th</sup>, 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

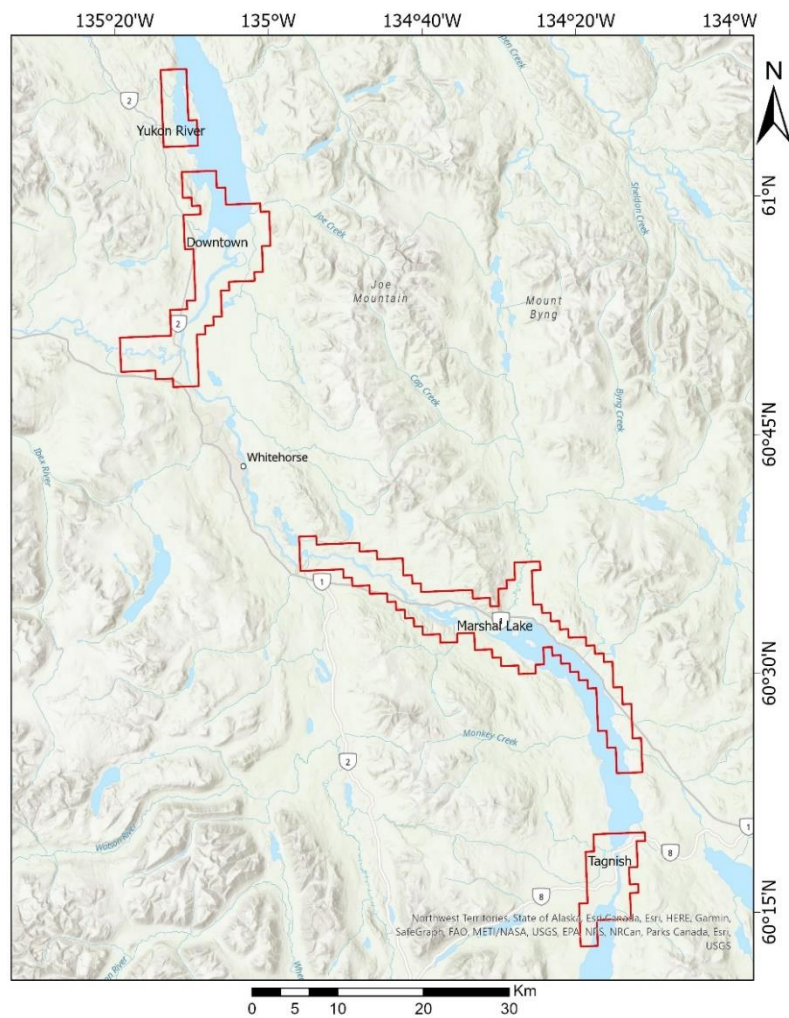


Figure 1 - LiDAR Survey Site

### 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.

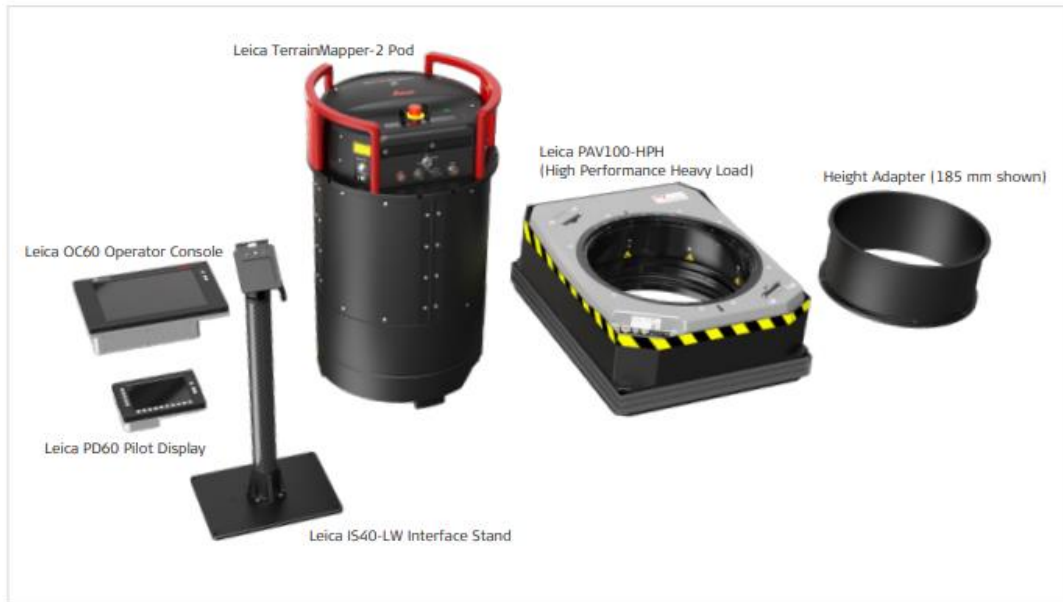


Figure 2 - Leica TerrainMapper-2 system components

### 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 <sup>2</sup> | Bare-earth pts/m <sup>2</sup> |
|--------------|--------------------------------|-------------------------------|
| 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

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

#### Area - 02

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

#### Area - 03

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

#### Area - 04

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

#### Area - 05

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

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 1,369 check points were used for this analysis. Figure 3 shows the location of the Check points for this project:

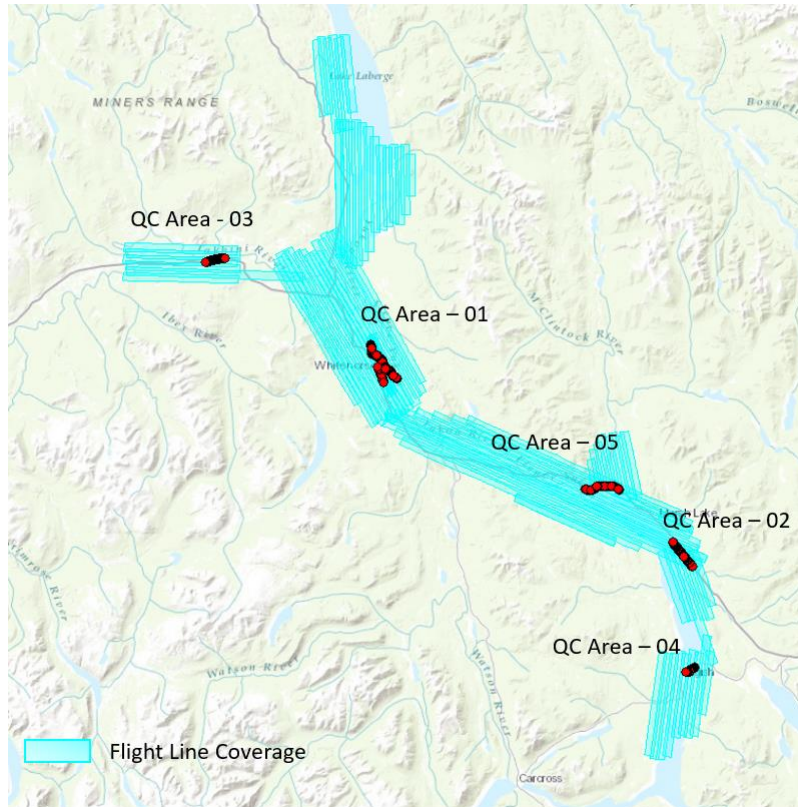


Figure 3 - Controls used for vertical check

#### 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 – 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 - 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 – 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= 108

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 Orthophoto - **TBD**