

# Accuracy Assessment of LiDAR over the Centre of Geographic Sciences and Delivery of Derived Products

Flight Mission – October 14, 2022

Project Report – March 3, 2026

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## **1. Introduction**

This report details the accuracy assessment of a drone-based LiDAR dataset acquired over the Centre of Geographic Sciences (COGS) campus October 14, 2022, at approximately 13:03 local time. The primary objective of this mission was to evaluate the absolute vertical and horizontal accuracy of the point cloud in accordance with the *Government of Canada's Federal Airborne LiDAR Data Acquisition Guidelines*.

By comparing the airborne data against high-precision Real-Time Kinematic (RTK) ground control points, this assessment categorizes vertical errors across various land cover types, including Non-vegetated Vertical Accuracy (NVA) and Vegetated Vertical Accuracy (VVA). The resulting analysis ensures the dataset meets the standards required for high-resolution topographic mapping and geospatial analysis.

## **2. Mission Information**

### **2.1 Coverage**

The project area is located within UTM Zone 20 North. All spatial data products, including the LiDAR point cloud and the resampled orthomosaic, are referenced to the following coordinate systems:

Horizontal Datum: NAD83 (CSRS)

Vertical Datum: CGVD2013

Units: Meters

## 2.2 Flight Details

The data was collected using a *DJI Matrice 300 RTK* unmanned aerial vehicle (UAV). To ensure optimal point density and surface penetration, the flight was executed using the specifications listed in the table below:

Item	Specification
Date	2022-10-24
Sensor	Zenmuse L1
UAV	DJI Matrice 300 RTK
Altitude	80 m AGL (Above Ground Level)
Flight Speed	7.9 m/s
Flight Speed	7.9 m/s
Side Overlap	60%
Scanning Mode	Repetitive
Positioning	Integrated RTK GNSS

Table 1: Flight Details and Specifications

## 2.3 Acquisition Details

The mission used the *Zenmuse L1* sensor, which integrates a LiDAR module, a high-accuracy IMU, and an RGB camera for simultaneous data capture.

- **LiDAR Sensor:** The system operated at a 160 KHz sampling rate with triple return capability, resulting in an high average point density of approximately 760 points/m<sup>2</sup>.
- **Imagery:** RGB coloring was enabled during the flight, allowing for the generation of a 5 cm resolution orthomosaic (resampled from the original 2.18 cm) to assist in the visual inspection of check points.
- **Trajectory Processing:** Post-processed trajectory data (SBET) was provided in WGS84 (ellipsoidal heights) to ensure the highest possible positional integrity for the point cloud generation.

- **Ground Truth:** RTK GNSS points were collected on both hard and soft surfaces, providing a 3D accuracy of less than 5 cm at a 95% confidence level for the final validation.

### 3. Survey Control

The horizontal and vertical accuracy of the LiDAR data is validated using Real-Time Kinematic (RTK) GNSS points collected by GETG students in the Fall of 2022. A total of 27 survey control points were used to validate the absolute vertical position of the LiDAR survey. These points serve as the ground truth and are accurate to within 5 cm (3D at 95% confidence).

Of these 27 points, 10 were collected in grassy fields to support the Vegetated Vertical Accuracy (VVA) assessment. The remaining 17 control points were collected over non-vegetated surfaces, including paved areas within the COGS parking lots, along Elliott Road, and on nearby gravel roads. The control points collected on the gravel road on the northern side of the COGS property are considered NVA due to the hard pack quality of the road. The distinctions of NVA vs VVA control points is as follows:

#### 3.1 Non-vegetated Vertical Accuracy (NVA)

- **Land Cover Types:** Hard surfaces (asphalt, concrete), bare earth, and very short grass.
- **Guideline Tie-in:** The NVA is the primary metric for calculating the RMSEz (Root Mean Square Error in the z-direction) to define the overall Vertical Accuracy class of the dataset.

#### 3.2 Vegetated Vertical Accuracy (VVA)

- **Land Cover Types:** Tall grass, crops, brush, and forested areas.
- **Guideline Tie-in:** Federal Standards require VVA testing because LiDAR often overestimates ground elevation in thick brush. The VVA is typically reported as the 95th percentile error, meaning errors in these areas are often not normally distributed.

The figure below illustrates the distribution of ground control points throughout the COGS property, along Elliott Road, and other nearby locations.

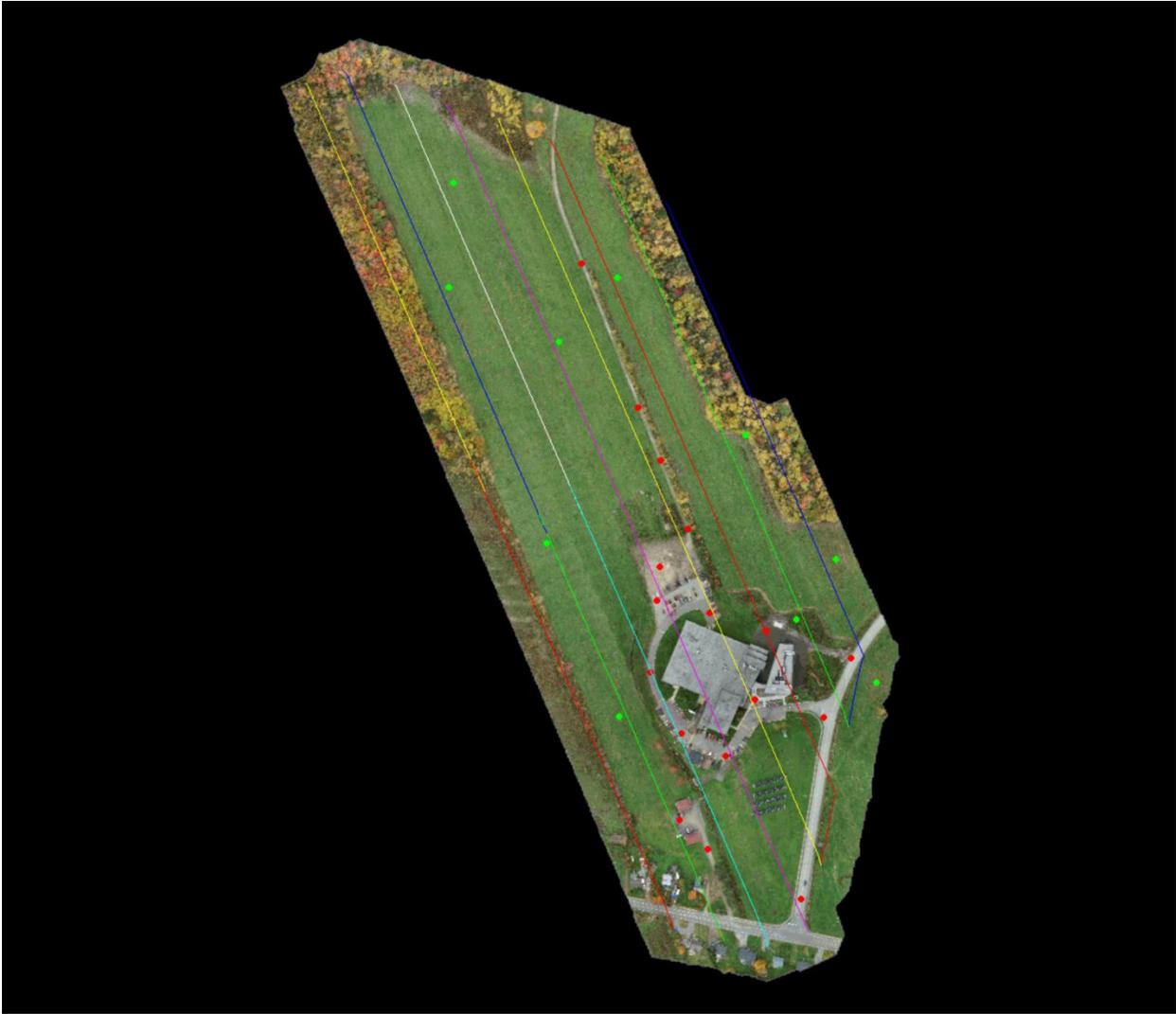


Figure 1: Study Area with Orthomosaic, Flight Trajectories and Control Points

## 4. Data Processing

### 4.1 Ingesting LiDAR

LiDAR data was imported in *Bentley MicroStation 2024* using the *Import Wizard* menu found in the *TerraScan* window. The project set up included the input of laser points (Orthometric), input of flight trajectories (Elipsoidal) and the choice of the Target System (Orthometric). Additionally, the Geoid model was changed from USA – GEOID18 to Canada – CGVD2013.

With the project now set up, ingestion of the LiDAR points was done using the *Process Drone Data* tool from the *Import Wizard* menu. The following procedures with their associated settings were as follows:

Procedure	Settings
<b>Split Trajectory</b>	Break at trajectory gaps Delete parts with no laser points Split at turns – Type: Sharp turn Delete short passes – Limit: 100.0m
<b>Match Passes</b>	Max xy mismatch: 1.00m Max z mismatch: 0.50m Per session correction parameters: -Heading -Roll -Pitch Per line correction parameters: -Lever Z Solve mirror angle correction: Correction for: Skip central part Skip from: -20 To: 20 deg
<b>Smoothen and remove noise</b>	Classify isolated points If fewer than: 3 other points Within 3.00m Smoothen surfaces Remove noise around surface Apply to: Non-vegetation only Vegetation limit: 0.05 visible band Temporary 1: 20 – Temporary 1 Temporary 2: 21 – Temporary 2 Noise: 22 - Noise
<b>Thin points to inactive</b>	Inactive class: 19 – inactive Spacing: 0.050m
<b>Classify height from ground</b>	Low vegetation: 0.250m from ground High vegetation: 2.000m from ground
<b>Classify above ground features</b>	Classify to classes Roof: 6 – Building roof Roof structure: 13 – Roof structure Pole: 18 – Pole Car: 17 – Car Use vegetation index Limit: 0.050 Temporary: 20 – Temporary 1

## 4.2 LiDAR Classification

Using the settings configured in the *Process Drone* tool, a macro script was generated to execute the first stage of LiDAR classification. Several key classification tasks were completed successfully within the point cloud, including the identification of low, medium, and high vegetation, as well as the roof class.

The car class was largely successful; however, some manual reclassification was required to correct misidentified features. In certain areas, vehicles were incorrectly classified as medium vegetation, particularly within the COGS parking lot. Conversely, portions of forest vegetation were mistakenly classified as cars. As a result, manual editing was most heavily concentrated on refining the car class. Minor adjustments were also necessary for poles and roof edges to ensure they were properly distinguished from the high vegetation class.

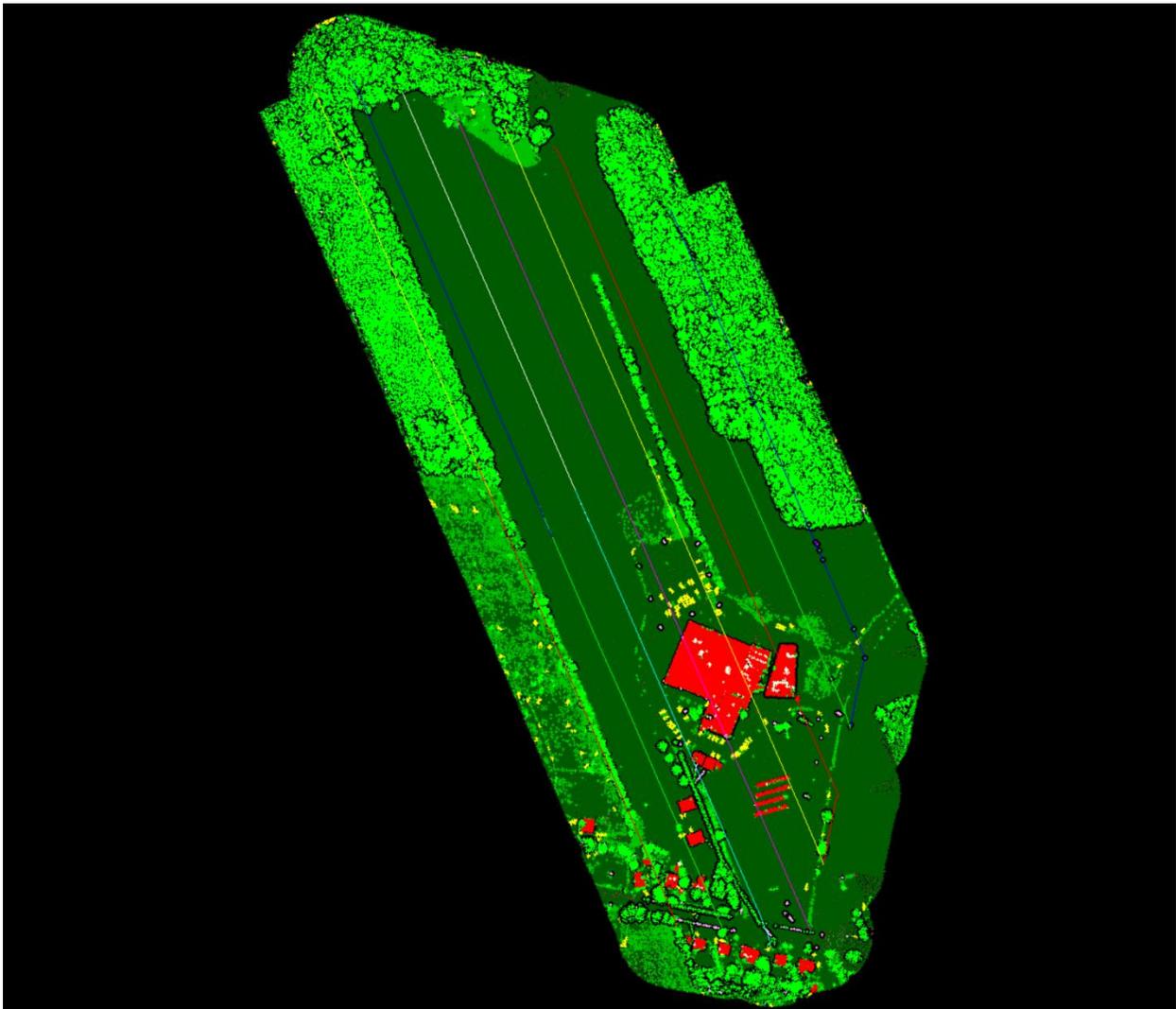
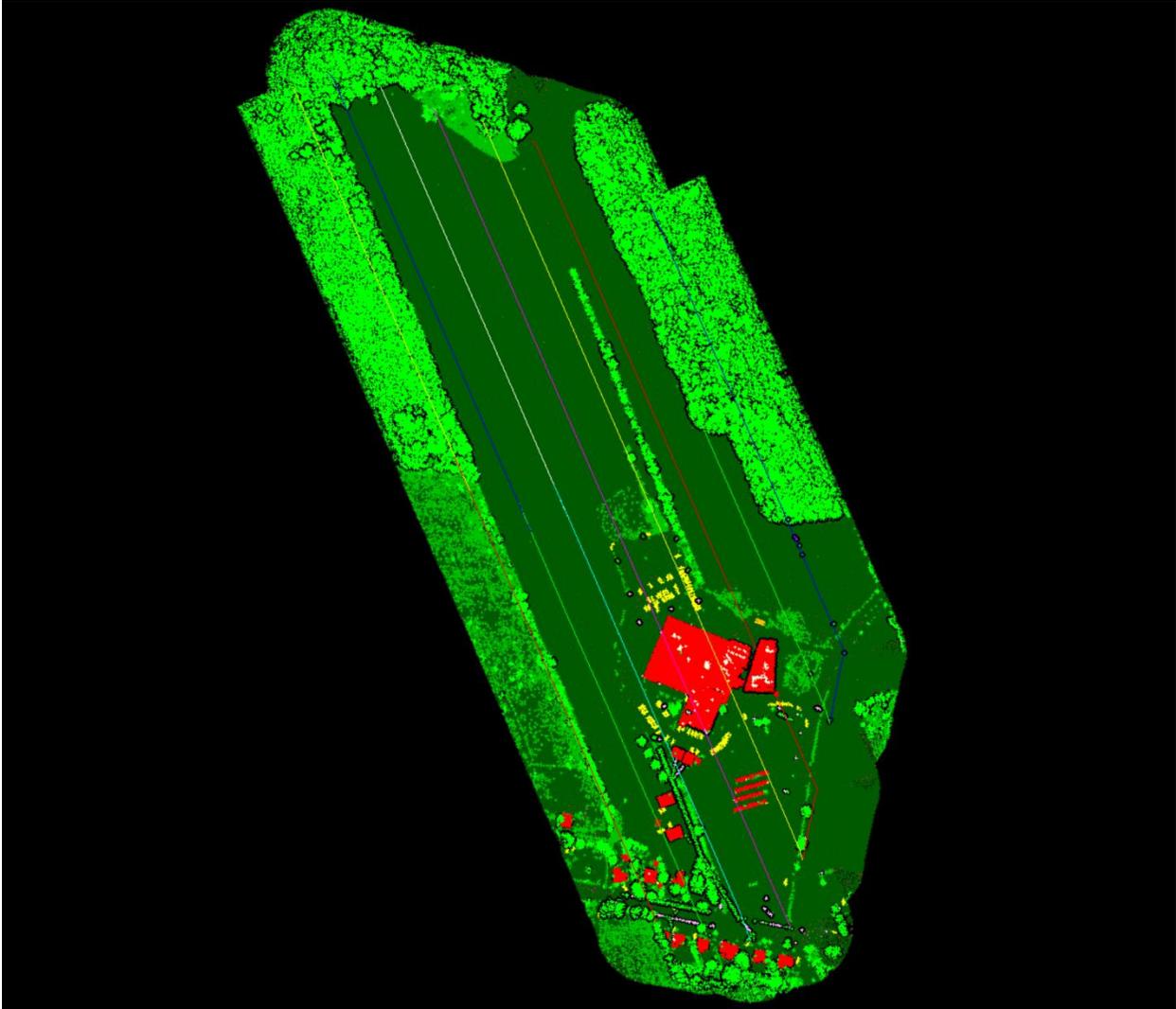


Figure 2: Study Area after running Macro



*Figure 3: Study Area after Manual Classification*

### **4.3 Check Points**

Before performing the accuracy assessment, the raw NVA and VVA check shots required reformatting in *Microsoft Excel* to ensure compatibility with *TerraScan* and *MicroStation*.

#### **4.3.1 File Reformatting**

The original GNSS acquisition files contained additional information such as Topography, Land Cover, and Class, which are not necessary for the accuracy assessment. To resolve this, two distinct versions of the control files were created:

- **For TerraScan:** The CSV files were trimmed to the *PXYZ format* (Point ID, Easting, Northing, and Elevation). This specific structure is required for the "Output Control Report" tool to correctly cross-reference known coordinates against the LiDAR point cloud.
- **For MicroStation:** To visually inspect the points within the DGN, the data was further reduced to a simple *XYZ format* (removing the Point ID).

#### 4.3.2 Import and Visualization

Once the data was cleaned, the *XYZ Text* tool was used within the *MicroStation* settings. Each set of check shots for both NVA and VVA were imported with distinctly different coloured symbology to avoid confusion, and an increased line weight to increase point sizes

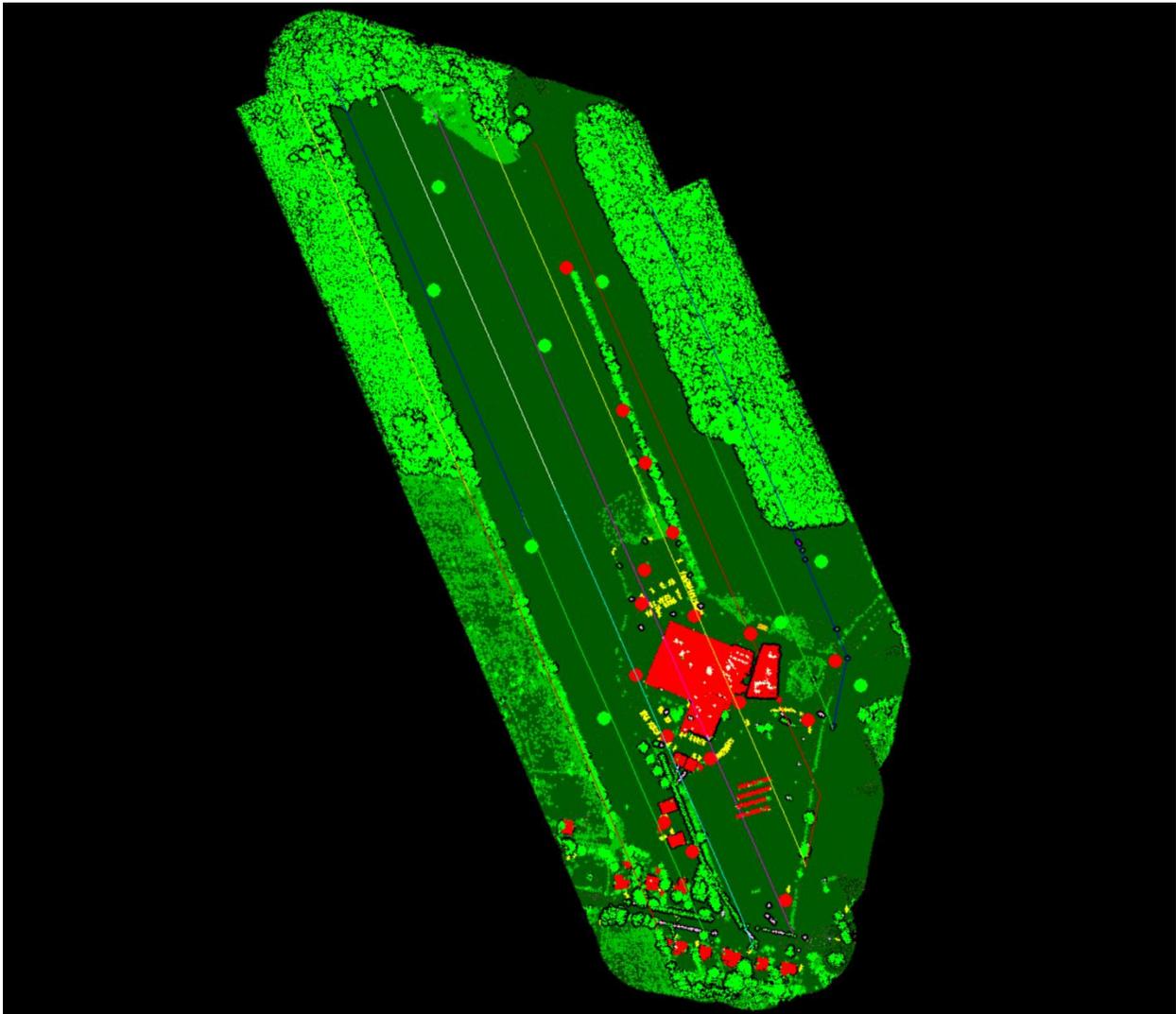


Figure 4: Study Area after Control Points imported

#### 4.4 Creation of Surfaces

The workflow begins by isolating Class 2 points for the DTM and all valid returns for the DSM within *TerraScan*. These filtered datasets are exported as .LAS files and imported into *Global Mapper*, where a TIN-based gridding algorithm interpolates the points into a continuous surface. The grid is set to a 0.5m spatial resolution and finalized as a GeoTIFF (.tif) export.

### 5. Accuracy QA/QC

The Real-Time Kinematic (RTK) points served as the ground truth benchmark to validate the LiDAR dataset. The accuracy assessment relied on both statistical analysis and visual check if the point cloud ground class was lined up with the ground truth.

#### 5.1 Vertical Error Calculation (Dz)

The primary method for assessing accuracy was the calculation of the Dz error. This represents the vertical distance between the known elevation of the RTK point and the elevation of the LiDAR surface at the exact horizontal (x, y) location.

- **TIN Interpolation:** Since a LiDAR point rarely hits the exact center of an RTK survey pin, *TerraScan* creates a Triangulated Irregular Network (TIN) from the ground-classified LiDAR points.
- **Calculation:** The software interpolates the elevation of the TIN at the RTK coordinate and subtracts it from the RTK's known elevation.
- **Interpretation:** A Dz value near zero indicates high agreement. Large positive or negative values highlight areas where the LiDAR sensor may have failed to reach the ground, which is common in VVA areas.

#### 5.2 Statistical Methodology

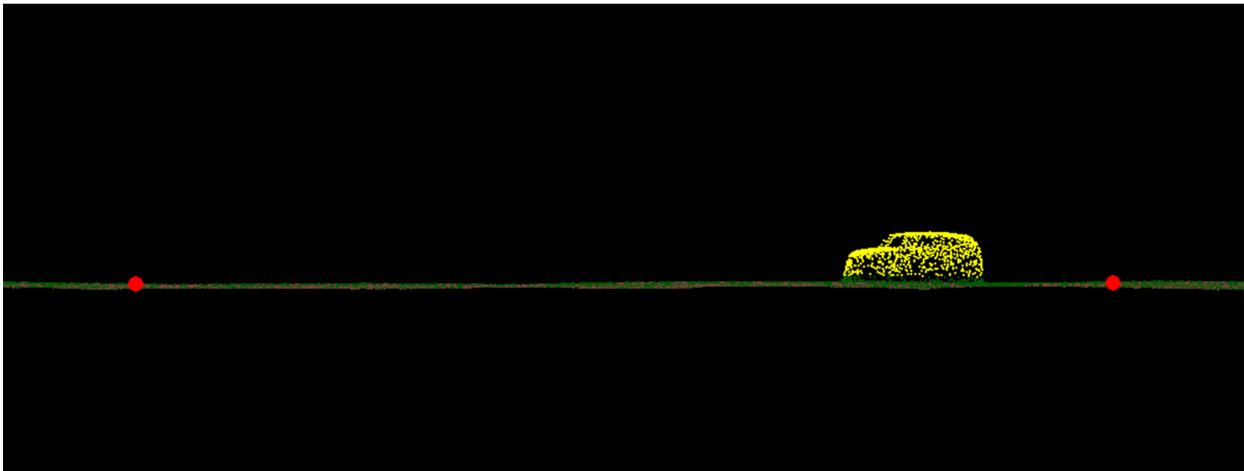
The project utilized two distinct calculations to define vertical accuracy based on land cover:

- **NVA (95% Confidence):** On flat, open surfaces where error is normally distributed, accuracy is derived from the Root Mean Square Error ( $RMSEz * 1.9600$ ). Our result of 0.0768 m is well within the  $< 0.196$  m threshold.
- **VVA (95th Percentile):** In rugged terrain, the 95th Percentile of absolute Dz values is used to account for non-normal error distribution. This resulted in a VVA of 0.0865 m

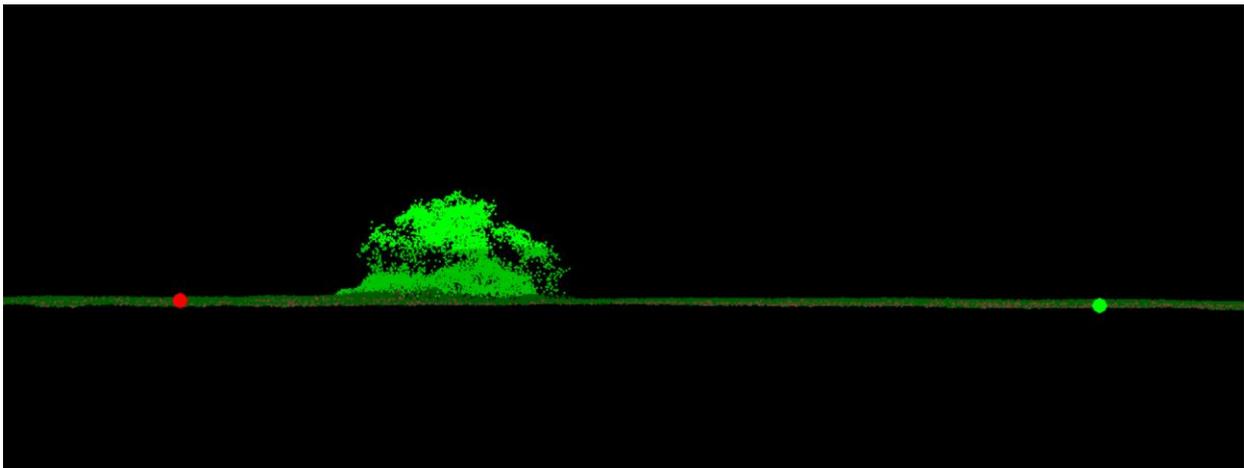
### 5.3 Evaluation of Control Point Errors

Upon review of the *TerraScan* Control Report, no manual edits or deletions were applied to the LiDAR point cloud or the control point datasets. Every surveyed check shot was retained to maintain the statistical integrity of the assessment.

- **NVA Performance:** The largest vertical error (Dz) was -0.080 m (Point 115). While this represents the "highest off" value for the non-vegetated class, it is still well below the common project threshold of 19.6 cm. The average Dz of -0.042 m suggests a slight, consistent downward bias in the LiDAR surface compared to the RTK points.
- **VVA Performance:** The largest vertical error was -0.095 m (Point 207). It is expected that VVA errors would be slightly higher than NVA errors because the complex terrain (tall grass, brush) makes it harder for the laser to reach the true ground and for the RTK surveyor to place the rod exactly on the mineral soil.



*Figure 5: Side view of two NVA Control Points*



*Figure 6: Side view of one NVA and one VVA Control Points*

#### 5.4 NVA Accuracy Assessment Results

Number	Easting	Northing	Known Z	Laser Z	Dz	Dz (Abs)
118	328631.079	4972836.763	27.489	27.47	-0.019	0.019
117	328683.237	4972704.668	27.865	27.84	-0.025	0.025
116	328703.557	4972656.107	27.574	27.51	-0.064	0.064
115	328728.544	4972592.256	27.1	27.02	-0.08	0.08
114	328702.908	4972557.771	27.085	27.04	-0.045	0.045
113	328700.451	4972526.112	27.141	27.12	-0.021	0.021
112	328694.645	4972460.396	26.623	26.58	-0.043	0.043
111	328723.16	4972403.856	26.487	26.44	-0.047	0.047
110	328749.111	4972514.847	26.732	26.71	-0.022	0.022
109	328800.873	4972498.535	26.313	26.29	-0.023	0.023
108	328878.75	4972473.444	26.316	26.24	-0.076	0.076
107	328853.459	4972419.116	25.98	25.94	-0.04	0.04
106	328790.772	4972435.331	26.846	26.81	-0.036	0.036
105	328763.233	4972383.064	26.236	26.17	-0.066	0.066
104	328720.882	4972323.928	25.606	25.58	-0.026	0.026
103	328746.915	4972297.341	25.309	25.27	-0.039	0.039
100	328832.891	4972251.754	24.739	24.69	-0.049	0.049
Average dz		-0.042				
Minimum dz		-0.08				
Maximum dz		-0.019				
Average magnitude		0.042				
Root mean square		0.046				
Std deviation		0.019				
95% Confidence		0.0768				

Table 3: NVA Accuracy Assessment Report

## 5.5 VVA Accuracy Assessment Results

Number	Easting	Northing	Known Z	Laser Z	Dz	Dz (abs)
213	328902.122	4972450.809	25.517	25.45	-0.067	0.067
211	328665.41	4972420.072	27.757	27.78	0.023	0.023
210	328598.704	4972578.976	28.745	28.74	-0.005	0.005
209	328828.852	4972509.233	26.004	26.08	0.076	0.076
208	328865.453	4972564.896	26.14	26.08	-0.06	0.06
207	328782.117	4972679.418	26.845	26.75	-0.095	0.095
206	328663.918	4972823.901	27.297	27.3	0.003	0.003
205	328610.469	4972764.86	28.336	28.37	0.034	0.034
204	328508.292	4972815.608	28.828	28.82	-0.008	0.008
203	328512.992	4972911.766	27.662	27.69	0.028	0.028
Average dz		-0.007				
Minimum dz		-0.095				
Maximum dz		0.076				
Average magnitude		0.04				
Root mean square		0.05				
Std deviation		0.053				
95th percentile		0.08645				

Table 4: VVA Accuracy Assessment Report

## 6. Summary

On October 14, 2022, at 13:03, a high-density LiDAR survey was conducted over the COGS campus using a *DJI Matrice 300 RTK* and *Zenmuse L1* sensor. Flown at 80m AGL, the mission achieved a point density of 760 points/m<sup>2</sup>, significantly exceeding the CQL1 (Data Quality Level 1) requirements.

### 6.1 Key Findings

- **Data Refinement:** RTK control files were cleaned of non-coordinate metadata (Topography, Land Cover, Class) to meet PXYZ and XYZ formatting standards for TerraScan and MicroStation.
- **Vertical Accuracy:** The dataset was validated against high-precision ground truth points. For NVA (hard surfaces), accuracy was confirmed using the 95% Confidence Level ( $1.9600 * RMSEz$ ). For VVA (vegetated areas), the 95th Percentile was applied to account for the complex, non-normal error distribution caused by tall grass and canopy.
- **Surface Integrity:** Visual cross-sections confirmed that the RTK "known" elevations aligned accurately with the Ground Class (Class 2), proving the sensor's triple-return capability successfully penetrated rugged vegetation.

### 6.2 Conclusion

The mission successfully met all federal guidelines for high-resolution mapping. With superior point density and verified vertical precision, the resulting point cloud is a survey-grade product suitable for professional engineering and topographic analysis.

## 7. Appendices

### 7.1 Equipment Used

- **UAV Platform:** DJI Matrice 300 RTK
- **LiDAR Sensor:** Zenmuse L1 (Integrated LiDAR, IMU, and RGB camera)
- **Ground Control:** RTK GNSS Rover/Base Station (accurate to < 5 cm)

### 7.2 Datums Used

- **Horizontal Datum:** NAD83 (CSRS)
- **Vertical Datum:** CGVD2013
- **Coordinate System:** UTM Zone 20 North
- **Units:** Meters (m)

### 7.3 List of Deliverables

- **Nearing\_lab3\_report.pdf:** Digital copy of the final technical report.
- **Lab3\Nearing\_lab3.dgn:** Final MicroStation design file including trajectories, NVA points, and VVA points assigned to proper levels.
- **Lab3\lidar\COGS\_L1\_nad83CSRSutmz20\_cgvd2013.laz:** Final, classified LiDAR point cloud file.
- **Lab3\L3\_TScan\_Project\trajectory\\*.trj:** Cut trajectories organized per flightline.
- **Lab3\L3\_TScan\_Project\nearing\_lab3.ptc:** TerraScan class color configuration file.
- **Lab3\Macro\Nearing\_L3\_DroneMacro.mac:** Macro documenting all automated processing steps performed.
- **Lab3\RTK\xVA\_pnez.csv:** TerraScan "known point" files (Point ID, X, Y, Z) for NVA and VVA classes.
- **Lab3\RTK\xVA\_nez.csv:** Simplified coordinate files used for MicroStation import.
- **Lab3\RTK\xVA\_ControlReport.txt:** Exported Output Control Reports from TerraScan for both NVA and VVA.
- **Lab3\RTK\accuracy\_assessment.xlsx:** Excel workbook compiling all assessment results, including 95% confidence and 95th percentile calculations.
- **Lab3\Surfaces\Nearing\_DTM.tif:** Digital Terrain Model (BareEarth) at 0.5m spatial resolution.
- **Lab3\Surfaces\Nearing\_DSM.tif:** Digital Surface Model (FullEarth) at 0.5m spatial resolution.

## 7.4 Class Description in Use

- **Class 1 (Unclassified):** All processed points including vegetation, structures, and noise.
- **Class 2 (Default):** Points identified as the bare-earth surface via automated filtering.
- **Class 3 (Ground):** Refined bare-earth surface points.
- **Class 4 (Low Vegetation):** Grass or brush directly above the ground surface.
- **Class 5 (Medium Vegetation):** Mid-level shrubbery and lower canopy.
- **Class 6 (High Vegetation):** Tree canopy and tall vegetation.
- **Class 7 (Building Roof):** Primary roof surfaces of structures.
- **Class 8 (Low Points):** Error points located significantly below the ground surface.
- **Class 14 (Roof Structure):** Supplemental structural elements on rooftops.
- **Class 18 (Car):** Vehicles captured during the flight.
- **Class 19 (Pole):** Utility poles or vertical light standards.
- **Class 21 (Temporary 1):** Placeholder for interim processing steps.
- **Class 22 (Temporary 2):** Placeholder for interim processing steps.

## 7.5 Control Point Information Tables

### NVA Table

Number	Easting	Northing	Known Z	Laser Z	Dz	Dz (Abs)
118	328631.079	4972836.763	27.489	27.47	-0.019	0.019
117	328683.237	4972704.668	27.865	27.84	-0.025	0.025
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109	328800.873	4972498.535	26.313	26.29	-0.023	0.023
108	328878.75	4972473.444	26.316	26.24	-0.076	0.076
107	328853.459	4972419.116	25.98	25.94	-0.04	0.04
106	328790.772	4972435.331	26.846	26.81	-0.036	0.036
105	328763.233	4972383.064	26.236	26.17	-0.066	0.066
104	328720.882	4972323.928	25.606	25.58	-0.026	0.026
103	328746.915	4972297.341	25.309	25.27	-0.039	0.039
100	328832.891	4972251.754	24.739	24.69	-0.049	0.049

### VVA Table

Number	Easting	Northing	Known Z	Laser Z	Dz	Dz (abs)
213	328902.122	4972450.809	25.517	25.45	-0.067	0.067
211	328665.41	4972420.072	27.757	27.78	0.023	0.023
210	328598.704	4972578.976	28.745	28.74	-0.005	0.005
209	328828.852	4972509.233	26.004	26.08	0.076	0.076
208	328865.453	4972564.896	26.14	26.08	-0.06	0.06
207	328782.117	4972679.418	26.845	26.75	-0.095	0.095
206	328663.918	4972823.901	27.297	27.3	0.003	0.003
205	328610.469	4972764.86	28.336	28.37	0.034	0.034
204	328508.292	4972815.608	28.828	28.82	-0.008	0.008
203	328512.992	4972911.766	27.662	27.69	0.028	0.028

### 7.6 Control Point Information Tables

#### NVA

Average dz	-0.042
Minimum dz	-0.08
Maximum dz	-0.019
Average magnitude	0.042
Root mean square	0.046
Std deviation	0.019
95% Confidence	0.0768

#### VVA

Average dz	-0.007
Minimum dz	-0.095
Maximum dz	0.076
Average magnitude	0.04
Root mean square	0.05
Std deviation	0.053
95th percentile	0.08645

# 8. Project Map

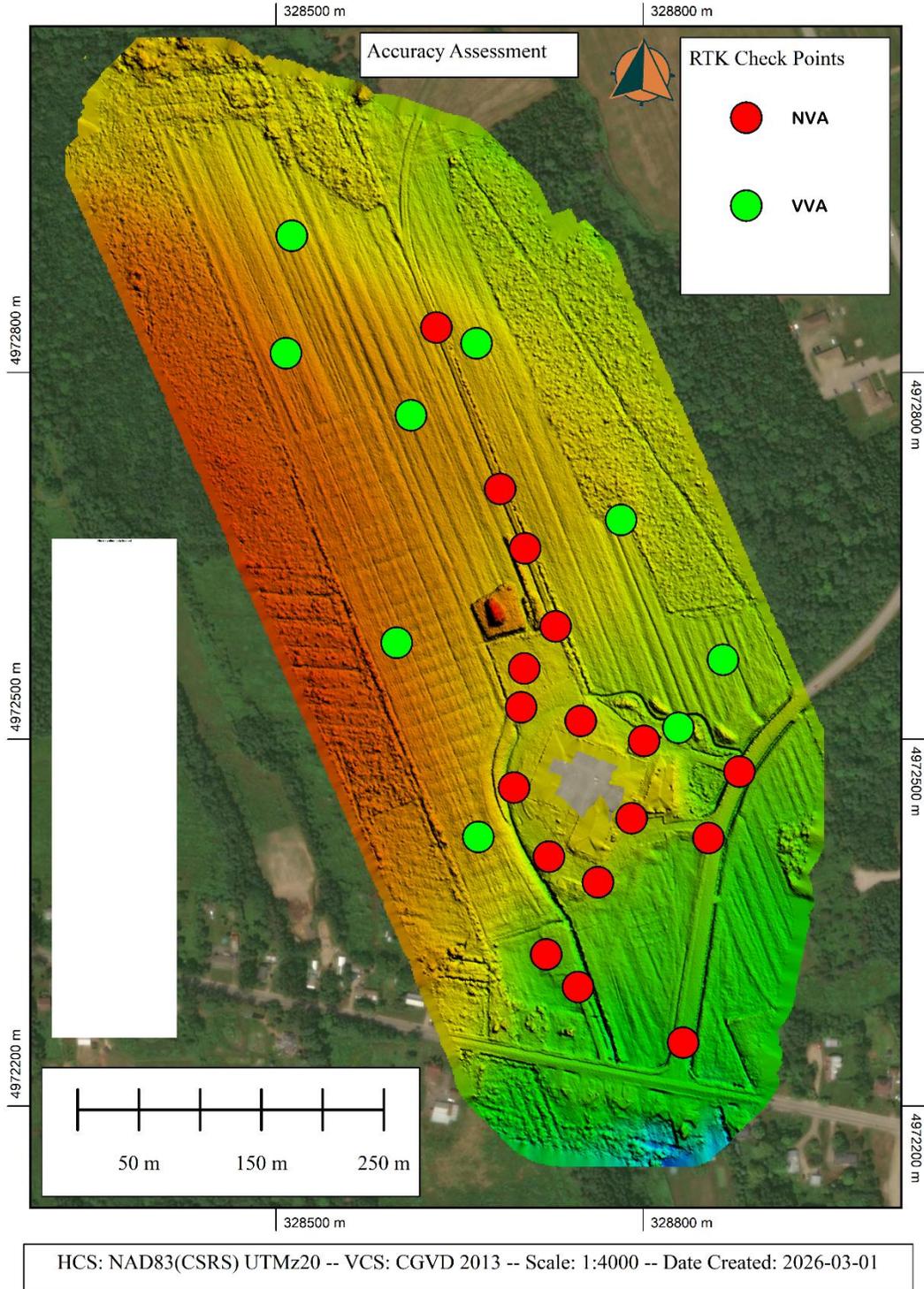


Figure 7: Study Area Map

