Lab 3 – Accuracy Assessment of LiDAR

REMS 6085 – LiDAR Systems and Processing

Reuben Walker

W094201

Table of Contents

Introduction

This report will outline the process of measuring and presenting accuracy statistics for a LiDAR survey. The points will be assessed to see if they fall within the Government of Canada's *Federal Airborne LiDAR Data Acquisition Guideline* CQL1 standards.

The study area of this project consists of the NSCC Centre of Geographic Sciences campus and the surrounding field in Lawrencetown, Nova Scotia. The data was captured on October 14, 2022.

The data was captured using a Zenmuse L1 sensor mounted on a DJI Matrice 300 RTK drone. These were the flight parameters:

- Height above ground level (relative to takeoff point): 80m
- Flight speed: 7.9 m/s
- Side overlap: 60%
- Returns: 3
- Sampling rate: 160 KHz
- Repetitive scanning mode
- RGB coloring enabled

The resulting point cloud had a point density of approximately 760 points per m^2. The The sensor also collected RGB imagery of the surface at the same time, with a spatial resolution of 2.18 cm/pixel. This means that the orthophoto accurately represents the area as it was when the point cloud was collected.

Survey Control

Real-Time Kinematic (RTK) survey control points were collected by Geomatics Engineering Technology (GETG) students in Fall 2022. These points were chosen to assess a variety of land cover types, broadly classified into two categories: Non-Vegetated Vertical Accuracy (NVA) and Vegetated Vertical Accuracy (VVA). NVA control points are taken on clear, flat, open areas without significant vegetation cover. These surfaces include gravel, pavement, flat bare soil, and very low grass (such as mowed lawns or golf courses). The survey area for a NVA point should have a minimum area of Altered surfaces (such a plowed fields) are not acceptable surfaces for NVA.

VVA control points are taken on vegetated areas, such as areas with tall grass, crops, and trees. VVA can also be used for any surface that is soft or not well defined, such as mud or soft dirt. The minimum survey area for

The minimum survey area for both NVA and VVA is *$(ANPS \times 5)^2$*. ANPS stands for Aggregate Nominal Pulse Spacing, which is the average lateral distance between pulses. For both NVA and VVA, the ground must also be reasonably flat with a slope of no more than 10 degrees.

In Figure 1, the study area with the control points are shown. The NVA points are displayed in red and the VVA points are shown in green. By comparing the location of the points to the orthophoto, it can be observed that the NVA points were captured on paved or barren areas and the VVA points were captured on vegetated areas.

Data processing

The study area was divided into 11 blocks as shown in Figure 1. Because of the high point density of the LiDAR data, 200 x 200 meter blocks were used in order to make processing faster & more reliable. Points were imported into the project from the supplied LAZ file and assigned to their corresponding blocks. Any points falling outside of the defined study area were deleted.

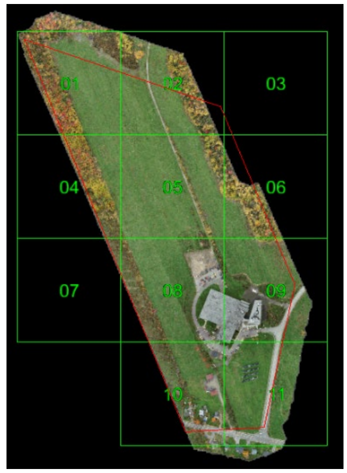


Figure 1. Study area (red) and project blocks (green) shown over the orthophoto

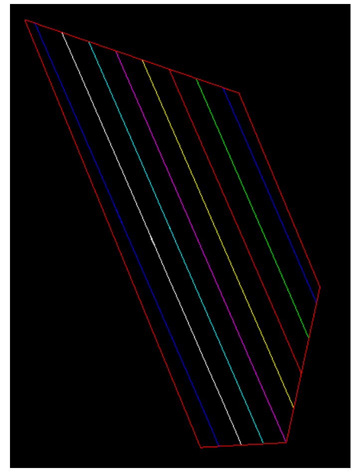


Figure 2. The eight flightlines extracted from the raw trajectory

The raw trajectory data was then imported. The take-off, landing, and turn-around portions of the trajectory were removed, resulting in 8 distinct flightlines cutting across the study area. (Figure 2) Then, a custom macro was used to assign flightline information to each LiDAR point, by matching the timestamp of each point with the timestamp of the flightline. Any points not associated with a flightline were deleted.

Any LiDAR points from locations where multiple flightlines overlap will then be removed. The Cut Overlap tool will be used to classify any points falling outside of a 40 degree corridor along each flightline to Class 12 – Overlap. This will allow us to keep the points but be able to ignore them in any future processing. Classifying out the overlapping points results in much more distinct band of points for each flightline, as seen in Figure 3.

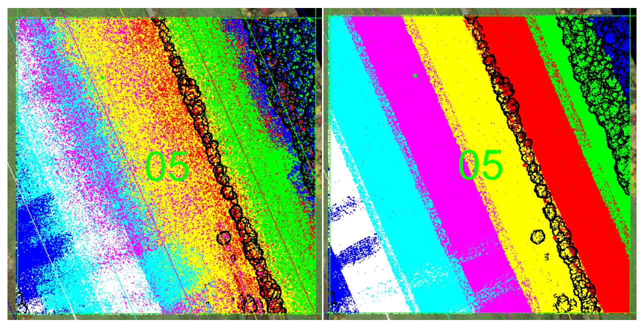


Figure 3. Points colored by flightline before (left) and after (right) removing overlap

All non-overlapping LiDAR points were then classified using a classification macro. Noise & low points were classified into a Low Point class, and then the remaining points were classified into ground, low vegetation, medium vegetation, high vegetation, and building classes. The following parameters were used for the 3 vegetation classes:

Class	Height above ground
Low vegetation	5 – 50 cm
Medium vegetation	0.5 – 2 m
High vegetation	2 – 50 m

The NVA and VVA check points were then imported into the project using the XYZ Text tool in MicroStation. This was done by making copies of the .csv files, and removing any data besides the XYZ values. Since this data was provided with the northing and the easting second, these two columns were swapped so that XYZ Text could read them in XYZ order. The NVA points and VVA points were each assigned to their own levels. The result of this can be seen in Figure 4.

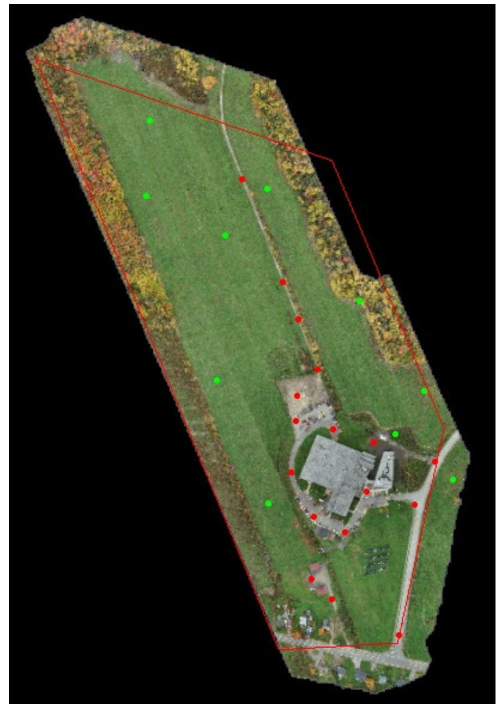


Figure 4. NVA and VVA control points overlaid on the orthophoto of the study area

Finally Global Mapper was used to create Digital Terrain Model (DTM) and Digital Surface Model (DSM) surfaces from the point cloud. The DTM was created from ground points only, and the DSM was created from all points except for the points classified to the Overlap and Low Point classes. Creating the DTM revealed that the classifier was not able to classify the points in blocks 3 and 7, likely because of the small amount of points in those blocks. Attempts to fix the classification macro by changing parameters such as the building size were unsuccessful, and it produced the same results regardless. The DTM is shown in Figure 5, and the DSM is shown in the map in Figure 6.

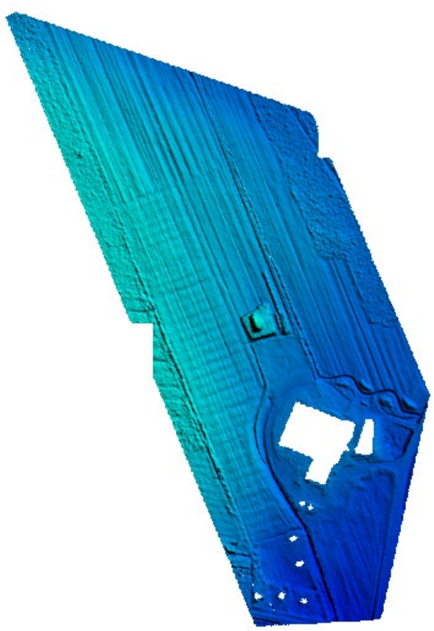


Figure 5. DTM generated from ground points

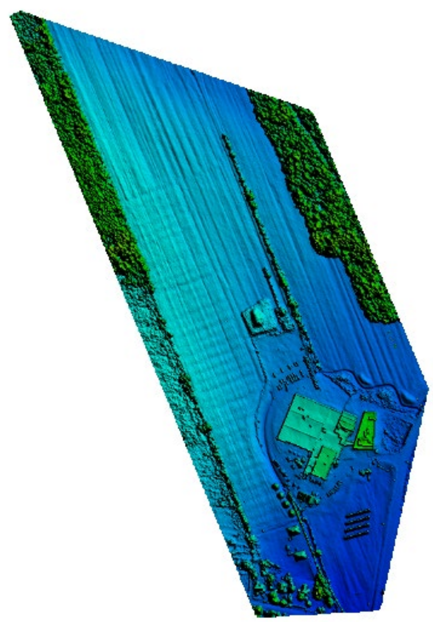
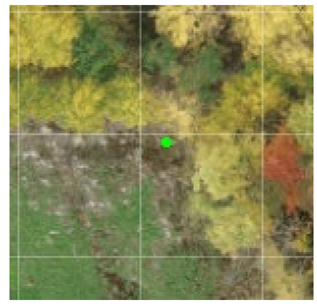


Figure 6. DSM generated from all valid points

Accuracy QA/QC

The RTK control points represent real points captured on the ground. Ideally, they can be used to evaluate the accuracy of the LiDAR points – since the RTK points represent definite physical points, if the LiDAR surface lines up closely with then then they are accurate. In reality, there could be errors or mistakes when capturing the RTK control points, such as multipath errors or capturing the point on an elevated surface that is not represented in the LiDAR ground surface. Points that might be problematic can be identified by making a control report, identifying any points with a high Dz value, investigating them, and evaluating their surroundings for any potential problems. For this project, an error of 10cm or more is considered worth investigating.

Using this method, I identified the following points that may have issues.



- VVA Point 207: Dz of -9cm, which is not exactly 10cm. However, the point was taken extremely close to the forest, (Figure 8) and the trees could have interfered with the GPS signal by blocking satellites or causing multipath error.
- VVA Point 213: Outside of bounds, automatically removed
- NVA Point 106: This point only had a Dz of -3.7cm, but it was taken directly next to two large buildings, which could introduce PDOP and multipath errors. Figure 9 shows the point's proximity to buildings.
- The following NVA points were flagged because of a similar error:
    - Point 100, Dz -9.7 cm
    - Point 103, Dz -9.1 cm
    - Point 104, Dz -9.9 cm
    - Point 105, Dz -9.6 cm
    - Point 107, Dz -9.8 cm
    - Point 108, Dz -12.8 cm
    - Point 115, Dz -11 cm

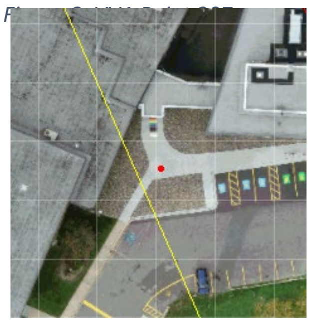


Figure 9. NVA Point 106

The error is as follows: many of these points were taken on paved roads, which are a hard ground surface. However, the classification macro classifies these surfaces as "low vegetation", likely because they are slightly raised compared to the ground surface constructed by the classifier. Since we are generating the control report by comparing the RTK points to the ground surface, this represents a systematic error. If a more advanced classification macro was used to identify and classify road surfaces as "ground" then these RTK points would be more accurate. An example of this error can be seen in Figure 10; the side view shows that the road surface is mis-classified as Low Vegetation (dark green), while the ground surface (orange) is much lower. Since the point was taken from the road surface, it appears to be much higher than the ground surface but lines up well with the Low

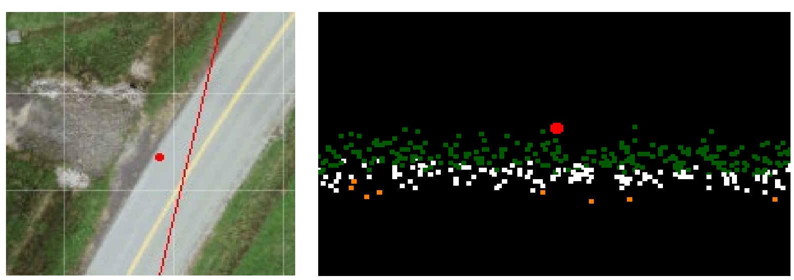


Figure 10. NVA Point 108 with side view profile

Vegetation points. However, none of these points were ultimately removed because they did not introduce significant enough errors to compromise the study.

The final results of the accuracy assessment are as follows:

	NVA	VVA	CQL1 Standards
Average dz	-7.4 cm	0.8 cm	-
Minimum dz	-12.8 cm	-9.0 cm	-
Maximum dz	-2.9 cm	8.3 cm	-
Average magnitude	7.4 cm	4.0 cm	-
Root mean square	7.9 cm	4.9 cm	≤ 10 cm
Std deviation	2.9 cm	5.1 cm	-
95% Confidence	15.484 cm	N/A	≤ 19.6 cm
95% Percentile	N/A	8.72 cm	≤ 30 cm

All values have been converted into centimeters. The full output control report and control point information tables can be found in the appendices section.

After comparing the accuracy assessment against the CQL1 standards, we can see that this LiDAR survey does fall within CQL1 guidelines.

Summary

This project involved importing a LiDAR point cloud, dividing it into flightlines, removing overlap, and classifying the points using the macro. Then, the LiDAR points were compared against RTK points captured on the ground in order to assess their accuracy, using the Canadian Federal LiDAR Data CQL1 guidelines. Some of the RTK points had potential multipath issues due to being captured close to buildings and trees. Another set of RTK points that were captured on roadways were found to be unusable because the classification macro classified the roadways as Low Vegetation points that were above the ground surface. However, these errors were not significant enough to warrant removal, and the output control report revealed that the LiDAR points did fall within the CQL1 guidelines. A potential improvement to the process for next time would to be to develop a classification method that classifies the road surfaces properly, so that RTK points taken on the road surface can be used.

Appendices

Equipment Used

Hardware:

- Zenmuse L1 Sensor
- DJI Matrice 300 RTK drone

Software:

- Bentley Microstation CONNECT Edition with TerraScan and TerraMatch extensions
- Blue Marble Geomatics Global Mapper 24.1
- Microsoft Excel

Datums Used

- CGVD 2013 vertical datum

Lidar Files, Metadata & Sources

Supplied data:

Folder \ Filename	**Description**	**Source**
`Reference\AOI.dgn`	Microstation DGN for the survey area of interest, used to clip points and flightlines	Rob Hodder
`Lidar\COGS_L1_nad83CSRSutmz20_cgvd2013.laz`	LAZ file for the project. 760 points/m^2 with RGB information embedded	Rob Hodder
`Ortho\ortho_shifted.tif`	RGB orthomosaic from drone flight. Approx. 2cm Resolution	Rob Hodder
`RTK\NVA.csv`	RTK points taken from non-vegetated surfaces	GETG Students
`RTK\VVA.csv`	RTK points taken from vegetated surfaces	GETG Students
`sbet\ DJI_20221014130323_0001_Zenmuse-L1-mission_sbet.out`	Raw SBET flightline data	Rob Hodder

Derived data:

Folder \ Filename	**Description**	**Source**
`Lab3\COGS_L1.dgn`	Final DGN containing labeled tile layout, AOI boundaries, sbet, flightlines, NVA points, and VVA points	Reuben Walker
`Lab3\blocks\CG#.las`	Final classified .las tiles, 11 blocks. Numbered from 000001 to 000011.	Reuben Walker
`Lab3\blocks\Lab3_COGS.prj`	Terrascan Project	Reuben Walker
`Lab3\trajectories\*.trj`	Cut trajectories per flight line	Reuben Walker
`Lab3\macros\deduceFlightlines.mac`	Macro used to deduce flightlines.	Reuben Walker
`Lab3\macros\classifyOL_40.mac`	Macro used to classify overlap, using a 40 degree corridor.	Reuben Walker
`Lab3\macros\finalClassification.mac`	Macro used to classify points into low, ground, low-high vegetation, and building classes	Reuben Walker
`Lab3\reports\import_points.txt`	Report generated from importing points into project	Reuben Walker
`Lab3\reports\deduceFlightlines.txt`	Report generated from deduce flightlines macro	Reuben Walker
`Lab3\reports\cutOL.txt`	Report generated from classify overlap macro	Reuben Walker
`Lab3\reports\finalClassification.txt`	Report generated from final classification macro	Reuben Walker
`Lab3\RTK\NVA_pxyz.csv` `Lab3\RTK\VVA_pxyz.csv`	Terrascan "known point" files for NVA and VVA formatted to work in TerraScan	GETG students, edited by Reuben Walker
`Lab3\RTK\NVA_ControlReport.txt` `Lab3\RTK\VVA_ControlReport.txt`	Output control reports from TerraScan for NVA and VVA	Reuben Walker
`Lab3\RTK\accuracy_assesment.xlsx`	Excel file containing accuracy assessment results, including 95% confidence and 95th percentile.	Reuben Walker
`Lab3\surfaces\block#_DTM.tif`	BareEarth surface of the project area, 1 surface per block. 0.5m spatial resolution. Numbered from 000001 to 000011.	Reuben Walker
`Lab3\surfaces\block#_DSM.tif`	FullEarth surface of the project area, 1 surface per block. 0.5m spatial resolution. Numbered from 000001 to 000011.	Reuben Walker

Control Point Information Tables

NVA			
Point #	Easting	Northing	Elevation (m)
118	328631.1	4972837	27.489
117	328683.2	4972705	27.865
116	328703.6	4972656	27.574
115	328728.5	4972592	27.1
114	328702.9	4972558	27.085
113	328700.5	4972526	27.141
112	328694.6	4972460	26.623
111	328723.2	4972404	26.487
110	328749.1	4972515	26.732
109	328800.9	4972499	26.313
108	328878.8	4972473	26.316
107	328853.5	4972419	25.98
106	328790.8	4972435	26.846
105	328763.2	4972383	26.236
104	328720.9	4972324	25.606
103	328746.9	4972297	25.309
100	328832.9	4972252	24.739

VVA			
Point #	Easting	Northing	Elevation (m)
213	328902.1	4972451	25.517
211	328665.4	4972420	27.757
210	328598.7	4972579	28.745
209	328828.9	4972509	26.004
208	328865.5	4972565	26.14
207	328782.1	4972679	26.845
206	328663.9	4972824	27.297
205	328610.5	4972765	28.336
204	328508.3	4972816	28.828
203	328513	4972912	27.662

Output Control Reports

All units are in meters.

NVA:

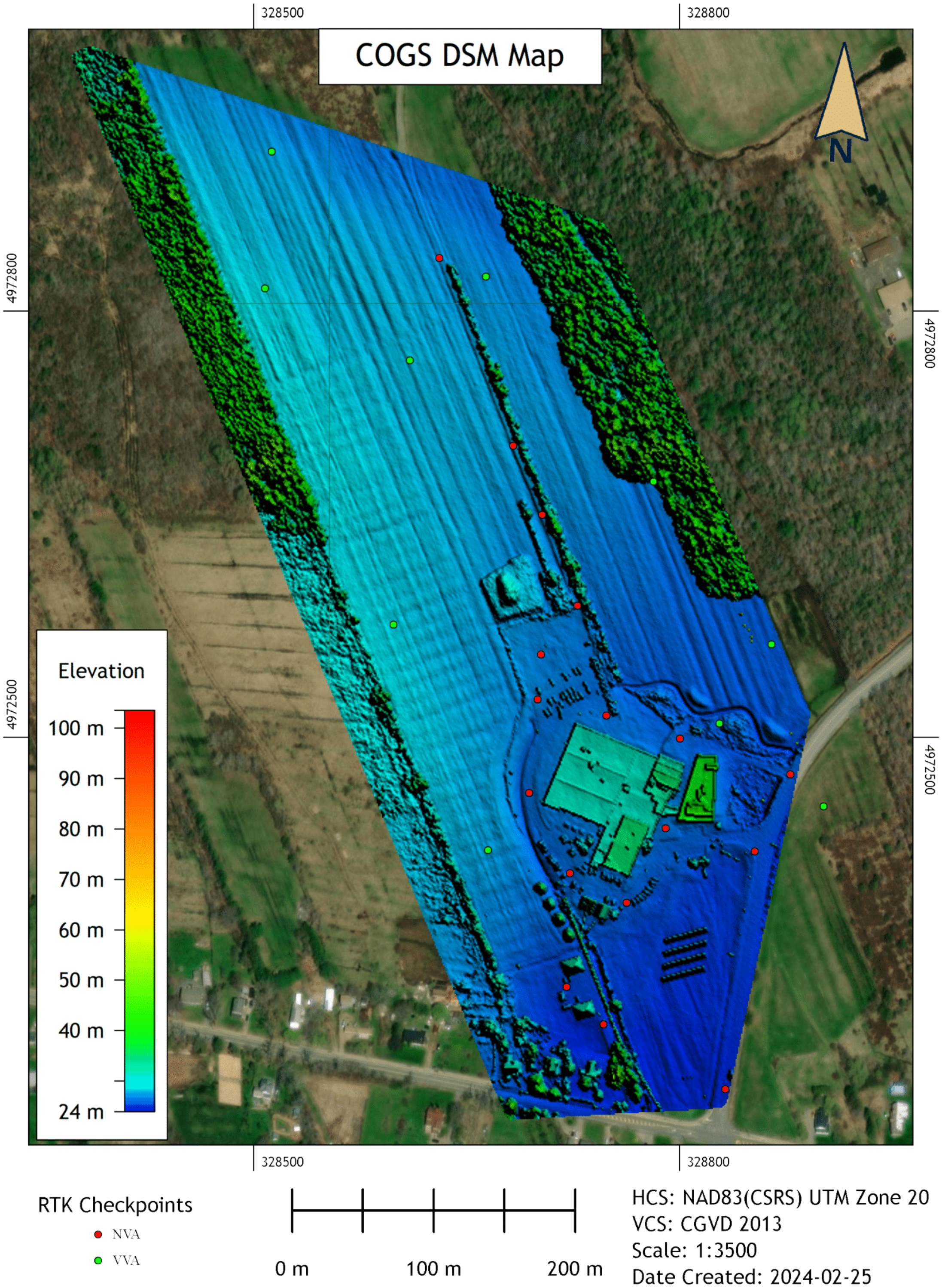
Number	Easting	Northing	Known Z	Laser Z	Dz	Dz (abs)
118	328631.1	4972837	27.489	27.46	-0.029	0.029
117	328683.2	4972705	27.865	27.833	-0.032	0.032
116	328703.6	4972656	27.574	27.521	-0.053	0.053
115	328728.5	4972592	27.1	26.99	-0.11	0.11
114	328702.9	4972558	27.085	27.014	-0.071	0.071
113	328700.5	4972526	27.141	27.064	-0.077	0.077
112	328694.6	4972460	26.623	26.566	-0.057	0.057
111	328723.2	4972404	26.487	26.413	-0.074	0.074
110	328749.1	4972515	26.732	26.675	-0.057	0.057
109	328800.9	4972499	26.313	26.257	-0.056	0.056
108	328878.8	4972473	26.316	26.188	-0.128	0.128
107	328853.5	4972419	25.98	25.882	-0.098	0.098
106	328790.8	4972435	26.846	26.809	-0.037	0.037
105	328763.2	4972383	26.236	26.14	-0.096	0.096
104	328720.9	4972324	25.606	25.507	-0.099	0.099
103	328746.9	4972297	25.309	25.218	-0.091	0.091
100	328832.9	4972252	24.739	24.642	-0.097	0.097
Average dz	-0.074					
Minimum dz	-0.128					
Maximum dz	-0.029					
Average magnitude	0.074					
Root mean square	0.079					
Std deviation	0.029					
95% Confidence	0.15484					

VVA:

Number	Easting	Northing	Known Z	Laser Z	Dz	Dz (abs)
213	328902.1	4972451	25.517	outside	*	
211	328665.4	4972420	27.757	27.774	0.017	0.017
210	328598.7	4972579	28.745	28.725	-0.02	0.02
209	328828.9	4972509	26.004	26.087	0.083	0.083
208	328865.5	4972565	26.14	26.09	-0.05	0.05
207	328782.1	4972679	26.845	26.755	-0.09	0.09
206	328663.9	4972824	27.297	27.28	-0.017	0.017
205	328610.5	4972765	28.336	28.372	0.036	0.036
204	328508.3	4972816	28.828	28.787	-0.041	0.041
203	328513	4972912	27.662	27.669	0.007	0.007

Average dz	-0.008
Minimum dz	-0.09
Maximum dz	0.083
Average magnitude	0.04
Root mean square	0.049
Std deviation	0.051
95% Percentile	0.0872

Project Map


COGS DSM Map
N
328500
328800
4972800
4972500
Elevation
100 m
90 m
80 m
70 m
60 m
50 m
40 m
24 m
RTK Checkpoints
NVA
VVA
0 m
100 m
200 m
HCS: NAD83(CSRS) UTM Zone 20
VCS: CGVD 2013
Scale: 1:3500
Date Created: 2024-02-25