

R-2582A Fitzhugh Borrow Pit

Summary of Project Area, Survey, & Flight

Project

- Description: CON - US 158/NC 46 FROM I-95/NC 46 IN ROANOKE RAPIDS TO SR 1312 (ST. JOHN CHURCH ROAD) IN NORTHAMPTON COUNTY. FITZHUGH PIT ORIGINAL FLIGHT

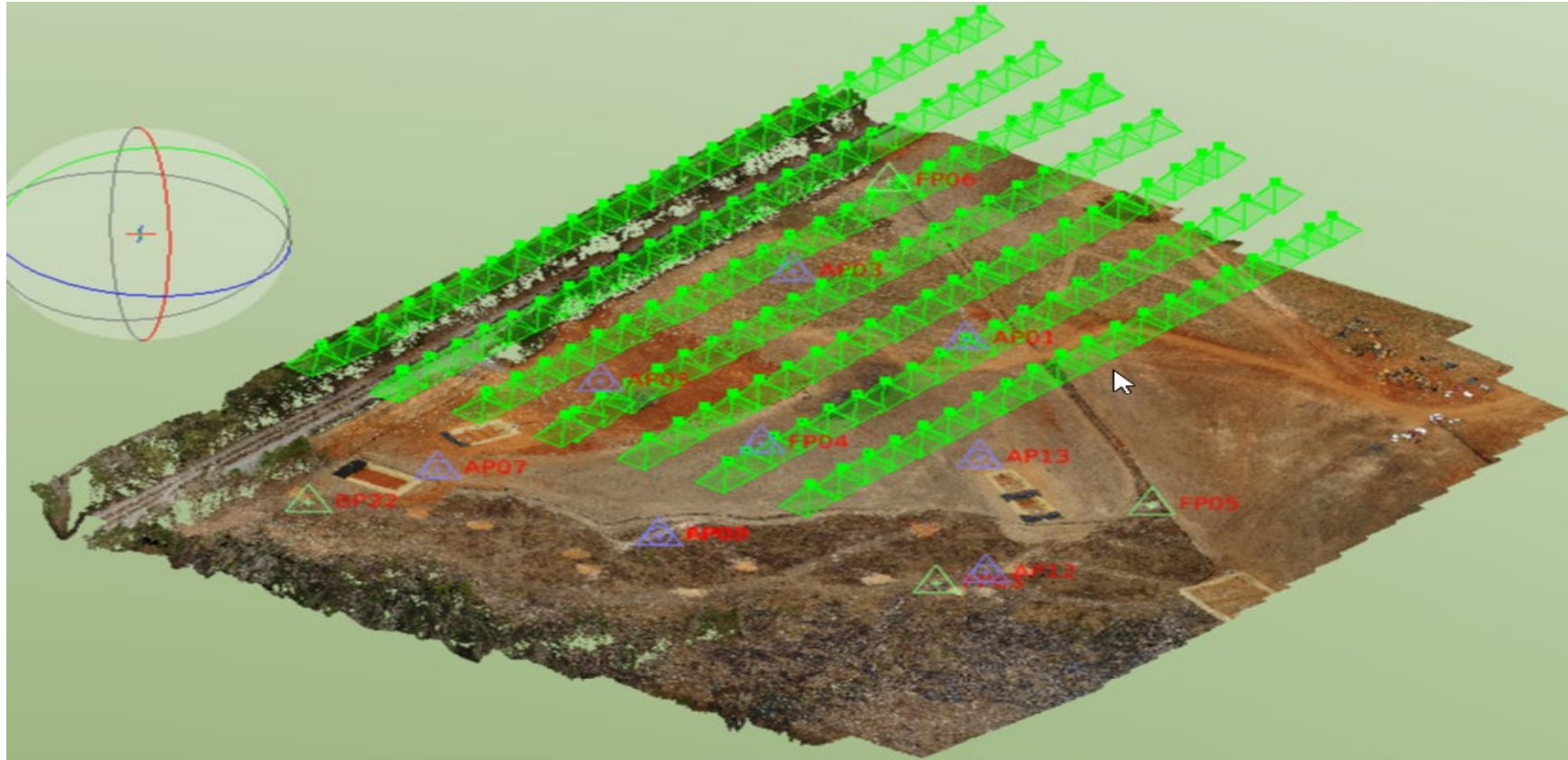
Image Acquisition

- ucs-744fp, DOP 03/18/20, DJI Inspire 2 Drone, DGI Zenmuse X4s camera, FL 8.8 mm, flying height 400ft AMGL
- long axis flown with a south/north direction of flight with nominal 0.111 ft GSD
- weather conditions were cool, fair, and windy
- manned aircraft flight – cs-747, DOP 03/20/20, Vexcel UltraCam Eagle M3 camera

Survey/Control

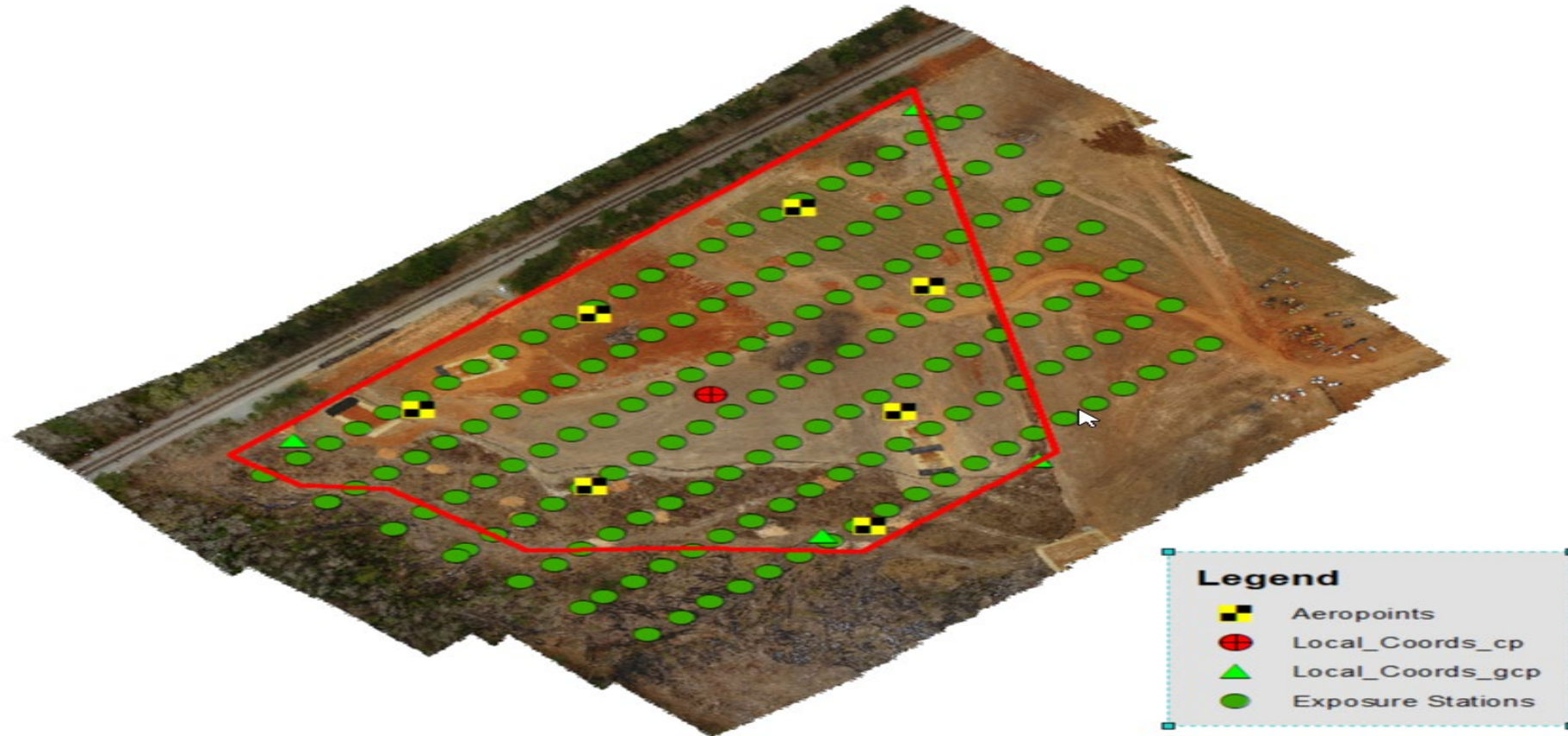
- GNSS exposure station data available via GeoCue Loki ASP system
- horizontal datum NAD 1983 (Conus), vertical datum NAVD 88, geoid G09NC, centroid localization point
- no control issues

Project Graphic with Image Background



- March 18, 2020 UAS Flight (UCS-744FP)
- Long axis (south/north) oriented nadir flight lines
- 160 images (planned 80% forward and side overlap)

Ground Control Points and Checkpoints Locations



- Orthophoto with 4 field surveyed ground control points, 8 independent checkpoints consisting of Aeropoints and field surveyed checkpoints, exposure stations, & original project boundary

Classified Ground Boundary

(from 03-18-20 UAS Flight)



Classified Ground Boundary = 19.18 Acres

Image Alignment Results

Independent Checkpoint Accuracy 4 GCP Only

	Point ID	X error (ft)	Y error (ft)	Z error (ft)
No. Points =		8	8	8
Min (ft) =		-0.065	-0.056	-0.202
Max (ft) =		0.045	0.092	-0.006
Mean (ft) =		-0.014	0.031	-0.117
Std Dev (ft) =		0.041	0.050	0.079
RMSE (ft) =		0.041	0.056	0.139
FVA (ft) =				0.271
RMSE R (ft) =		0.069		
Case 1 95% CE(ft) =		0.120		
Case 2 ~ CE(ft) =		0.119		

Independent Checkpoint Accuracy 4 GCP + Exposure Stations

	Point ID	X error (ft)	Y error (ft)	Z error (ft)
No. Points =		8	8	8
Min (ft) =		-0.101	-0.110	-0.118
Max (ft) =		-0.008	-0.052	0.033
Mean (ft) =		-0.058	-0.075	-0.059
Std Dev (ft) =		0.037	0.020	0.050
RMSE (ft) =		0.067	0.078	0.076
FVA (ft) =				0.149
RMSE R (ft) =		0.103		
Case 1 95% CE(ft) =		0.178		
Case 2 ~ CE(ft) =		0.177		

No GNSS Block Shift applied

Dense Point Cloud Accuracy Results

Vertical RMS Summary Statistics for Check Points using Classified Point Cloud

The following table provides a summary of the vertical RMS statistics for all Check point measurements taken from the classified Point Cloud data.

Check Point RMS Statistics			
Parameter	X residual	Y residual	Z residual
Number of Points			8
Maximum (ft.)			0.105
Minimum (ft.)			-0.311
Mean (ft.)			-0.133
Standard Deviation (ft.)			0.127
RMSE (ft.)			0.178
95% Accuracy (ft)			0.349
99.74% Accuracy (ft)			0.535

35,459,071 points for 19.18 acres

Classified Point Cloud Boundary
from 03-18-20 UAS Flight

Point Cloud Generation Process is fully automated so whatever is shown in imagery is captured

1-Foot DEM Accuracy Results

Vertical RMS Summary Statistics for Check Points using 1-foot DEM

The following table provides a summary of the vertical RMS statistics for all Check point measurements taken from the 1-foot DEM data.

Check Point RMS Statistics			
Parameter	X residual	Y residual	Z residual
Number of Points			8
Maximum (ft.)			0.115
Minimum (ft.)			-0.286
Mean (ft.)			-0.128
Standard Deviation (ft.)			0.128
RMSE (ft.)			0.176
95% Accuracy (ft)			0.344
99.74% Accuracy (ft)			0.527

835,547 points for 19.18 acres

Classified Point Cloud Boundary
from 03-18-20 UAS Flight

Point Cloud Generation Process is fully automated so
whatever is shown in imagery is captured

2.5-Foot DEM Accuracy Results

Vertical RMS Summary Statistics for Check Points using 2.5-foot DEM

The following table provides a summary of the vertical RMS statistics for all Check point measurements taken from the 2.5-foot DEM data.

Check Point RMS Statistics			
Parameter	X residual	Y residual	Z residual
Number of Points			8
Maximum (ft.)			0.132
Minimum (ft.)			-0.304
Mean (ft.)			-0.112
Standard Deviation (ft.)			0.133
RMSE (ft.)			0.167
95% Accuracy (ft)			0.328
99.74% Accuracy (ft)			0.501

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133,679 points for 19.18 acres
 Classified Point Cloud Boundary
 from 03-18-20 UAS Flight

Point Cloud Generation Process is fully automated so whatever is shown in imagery is captured

Vertical RMS Summary Statistics for Control & Check Points using UASMaster Stereo View at a Base to Height Ratio Near 0.15

The following table provides a summary of the vertical RMS statistics for all check point stereoscopic measurements using a base to height ratio of 0.15 or less for UAV stereo pairs with an 80% overlap (sensor dependent). A small base to height ratio demonstrates weakness in stereo measured vertical accuracies.

Check Point RMS Statistics			
Parameter	X residual	Y residual	Z residual
Number of Points			12
Maximum (ft.)			-0.420
Minimum (ft.)			0.301
Mean (ft.)			0.088
Standard Deviation (ft.)			0.196
RMSE (ft.)			0.207
95% Accuracy (ft)			0.406
99.74% Accuracy (ft)			0.621

Vertical RMS Summary Statistics for Control & Check Points using UASMaster Stereo View at a Base to Height Ratio Near 0.60

The following table provides a summary of the vertical RMS statistics for all check point stereoscopic measurements using a base to height ratio of, or very near 0.60 for UAV stereo pairs with an 20% overlap (sensor dependent), may include cross strip stereo pairs. A large base to height ratio demonstrates greater stereo measured vertical accuracies.

Check Point RMS Statistics			
Parameter	X residual	Y residual	Z residual
Number of Points			12
Maximum (ft.)			-0.207
Minimum (ft.)			-0.031
Mean (ft.)			-0.112
Standard Deviation (ft.)			0.065
RMSE (ft.)			0.128
95% Accuracy (ft)			0.252
99.74% Accuracy (ft)			0.385

Summary of Earthwork Quantities

(Classified Ground Boundary from 03-18-20 UAS Flight)

R-2582A Fitzhugh Pit Cut Quantities for 19.18 Acre Terrain Data Boundary

(as Compared to Original DTM collected from Manned Aircraft Mission)

Comparison DTM	Mission Date	Point Spacing (ft)	Voided Areas Excluded	Cut (cubic yards)
UAS Mission UCS-744FP	03/18/2020	2.5	No Void Areas	733.295
UAS Mission UCS-744FP	03/18/2020	1	No Void Areas	692.192



Manned Flight DTM Accuracy Results

Vertical RMS Summary Statistics for Check Points using Manned Flight DTM

The following table provides a summary of the vertical RMS statistics for all Check point measurements taken from the Manned Flight DTM data.

Check Point RMS Statistics			
Parameter	X residual	Y residual	Z residual
Number of Points			8
Maximum (ft.)			0.290
Minimum (ft.)			-0.124
Mean (ft.)			0.117
Standard Deviation (ft.)			0.152
RMSE (ft.)			0.185
95% Accuracy (ft)			0.362
99.74% Accuracy (ft)			0.554

Manned flight DTM has break lines and a 10' grid spacing for points

Vertical RMS Summary Statistics for Check Points using ISDM Stereo View at 60 Degrees

The following table provides a summary of the vertical RMS statistics for all check point stereoscopic measurements using a base to height ratio near 0.30 for manned flight stereo pairs with a 60% overlap.

Check Point RMS Statistics			
Parameter	X residual	Y residual	Z residual
Number of Points			8
Maximum (ft.)			0.009
Minimum (ft.)			-0.190
Mean (ft.)			-0.023
Standard Deviation (ft.)			0.056
RMSE (ft.)			0.060
95% Accuracy (ft)			0.117
99.74% Accuracy (ft)			0.180

Summary Table of RMSE & 95% FVA

Platform	Camera Size & Type	No. of Images	Date of Photography	Product	No. of Independent Check Points	RMSE Z (ft)	FVA (ft)
UAS	20 Mpixel non-metric	160	2/4/2020	AT (GCP only)	8	0.139	0.271
				AT (GCP+ GNSS)	8	0.076	0.149
UAS	20 Mpixel non-metric	160	2/4/2020	2 Image Stereo Measurement (80% FOL)	8	0.207	0.406
				2 Image Stereo Measurement (20% FOL)	8	0.128	0.252
Manned Aircraft	450 Mpixel metric	4	1/28/2020	2 Image Stereo Measurement (60% FOL)	8	0.060	0.117
UAS	20 Mpixel non-metric	160	2/4/2020	Dense Point Cloud	8	0.178	0.349
				1 foot DEM*	8	0.176	0.344
				2.5 foot DEM*	8	0.167	0.328
Manned Aircraft	450 Mpixel metric	4	1/28/2020	DTM* (breaklines & 10 foot spaced points)	8	0.185	0.362

*Standard delivery products (note 2.5 foot DEM may exceed CADD software limits due to number of points)

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Conclusions

- Target RMSE accuracy values are an X and Y (Easting & Northing) of 0.12 ft and Z (Elevation) of 0.18 ft. The image alignment (aerotriangulation) results using 4 ground control points and GNSS PPK camera station positions yielded RMSE values of 0.067 ft in X, 0.078 ft in Y, and 0.076 ft in Z, all well below the target accuracy values.
- On this project, the 2 image stereo measurements at 60% forward overlap taken on the Manned flight imagery indicate better RMSE Z and FVA values than both the 80% and 20% forward overlap image stereo measurements taken on the UAS imagery. Testing on other UAS project imagery also indicates 2 UAS image stereo measurements are not reliably accurate for earthwork determination.
- The 1 ft DEM contains 625% more points than the 2.5 ft DEM, thus making the 2.5 ft DEM file size much smaller and more manageable. With a cut difference of only 41.10 cubic yards between the 1 ft DEM and 2.5 ft DEM over 19.2 acres one can conclude that the 2.5 ft DEM is dense enough data to provide for accurate volumetric calculations and comparisons and the 1 ft DEM is not necessary.
- The 2.5 ft UAS DEM has a lower RMSE Z and FVA than the DTM collected from the Manned flight. The denser 2.5 ft DEM point interval captures the overall terrain better than the break lines and 10 ft point interval of the DTM.
- Since there is a limit to the amount of data that can be input into our CADD software, UAS imagery projects are not ideal for larger mapping areas.
- Projects best suited for utilizing UAS imagery should have cleared ground with little to no vegetation.