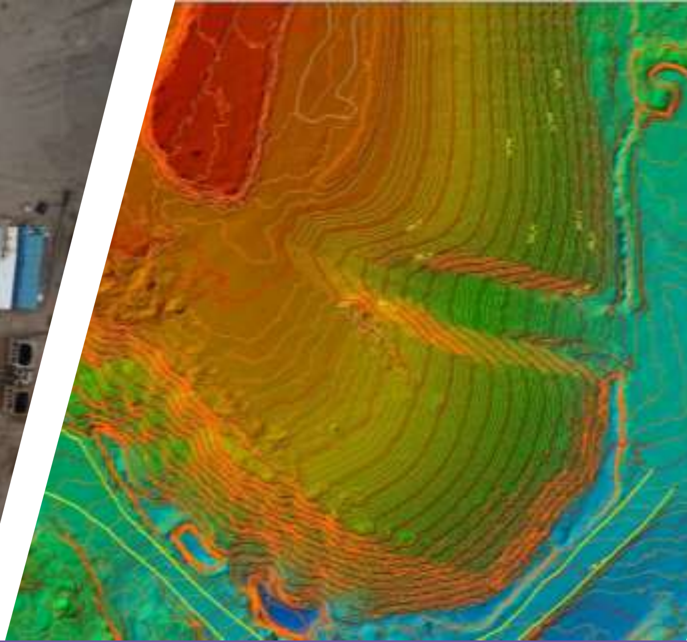




Exploring Mapping Capabilities of Small Commercial Drones

Christian Stallings R&D Manager and Certified Photogrammetrist

McKIM&CREED

locations

N. Carolina

Charlotte
Raleigh
Asheville
Wilmington

Virginia

Hampton Roads

Texas

Austin
Houston
Dallas
San Antonio

Florida

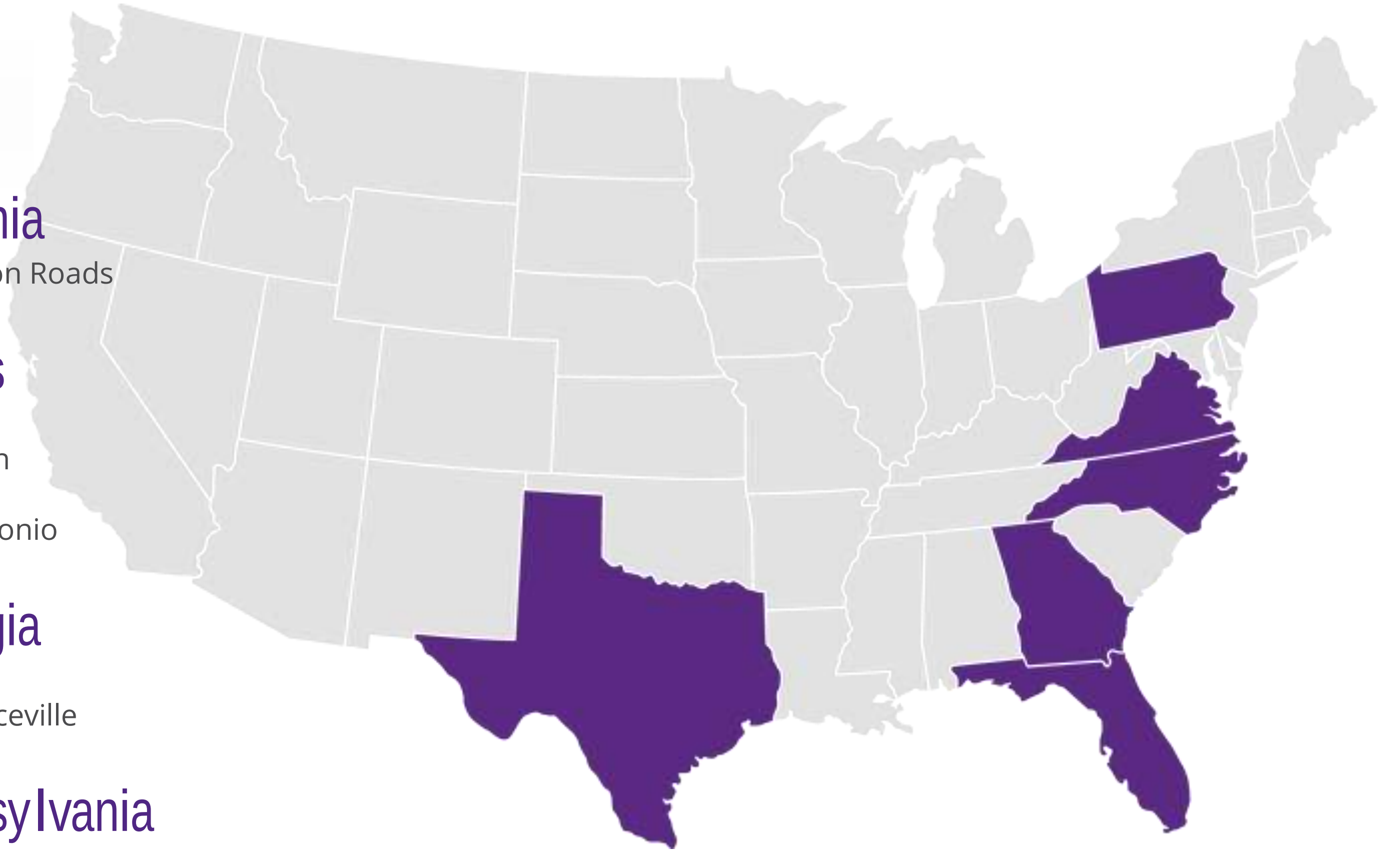
Clearwater
Gainesville
Tampa
Daytona Beach
Orlando
Deland
Fort Myers
Sarasota
Palm Coast

Georgia

Atlanta
Lawrenceville

Pennsylvania

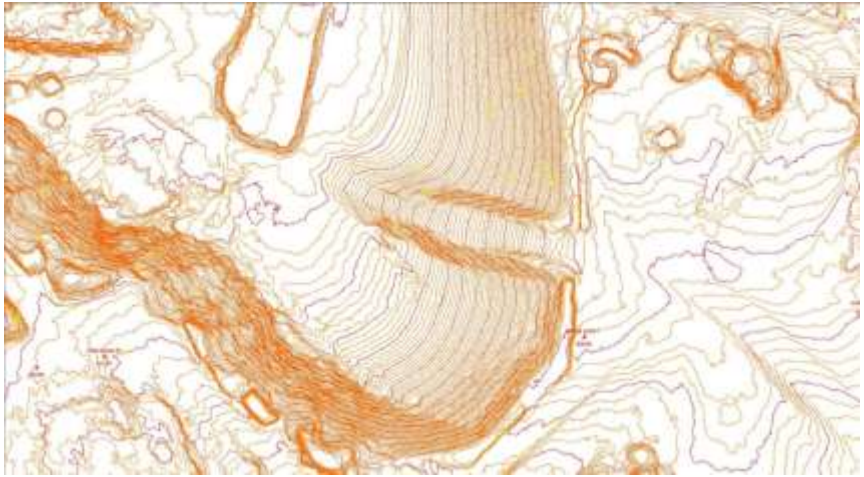
Pittsburgh



Completed projects in 38 States. Can deploy our assets nationally/internationally.

MCKIM & CREED'S UAS FOCUS

- Small drones, big sensors
- Empowering surveyors with drones (Another tool in the truck)
- Creating old products with new tools



What I have learned About Drone Mapping

- Accuracies, Quality, and Pricing needs to be similar or cheaper than established survey methods
- 100K drones to map 40 acres doesn't make financial sense
- Quality work however still requires qualified providers
- Drone mapping is a localized business (mob isn't cheap)

Wrightsville Beach - Proof of Concept

Site Scan
The Leading Aerial Analytics Platform

Wrightsville Beach - Proof of Concept

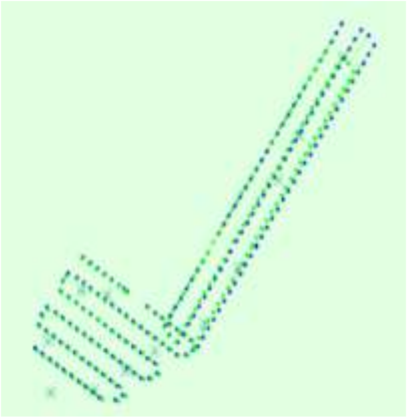
Total Area Processed

Oceanic Pier to
Masonboro Inlet
71.62 Acres

Ground Control Used

14 Points
Fully Surveyed

Photos Collected



Sony R10C
Total 195 / 1.25GB
Collection Time < 1hr / 2flts

Output Parameters

Horizontal GSD – 1.21 in
3D Points / Meter - 104

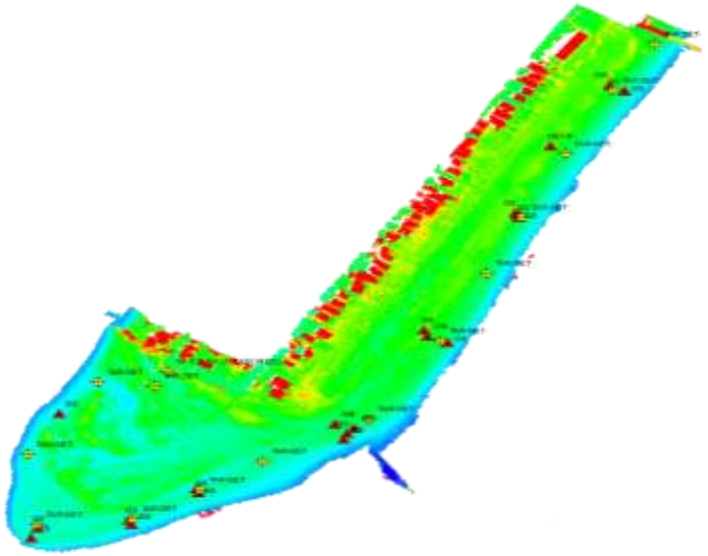
Processing Time: 4 hrs 32 mins
Products Produced: Orthos, DSM, Point Cloud, 3D Mesh
Overall Accuracy: Mean RMS 1.27 inches, or 3.23 cm

Wrightsville Beach - Proof of Concept

Wrightsville Beach Flight

- McKim & Creed placed 14 survey targets on the beach
- 22 Blind check shots were collected randomly
- 2 Flights were flown with the Solo / R10C setup (400 Ft. AGL 1.21 Inch GSD)
- 1 Flight was flown using the Solo / GoPro setup (400 Ft. AGL 2.44 Inch GSD)
- 1 Flight was flown with a Phantom 4 (200 Ft. AGL 1.01 Inch GSD)

Wrightsville Beach - Proof of Concept



Accuracy Reporting

- After Dense Image Matching (DIM), the Point clouds were compared to the blind checkpoints to verify accuracy.

- A TIN model was created in the ArcGIS extension LP360 to calculate the DeltaZ of each point. This is the same method used for verifying LiDAR point clouds.

Wrightsville Beach - Proof of Concept

Results

DJI Results

```
---------- Report Summary ----------

X Error Mean:                    0.000
X Error Range:                   [0.000,0.000]
X Skew:                          0.000
X RMSE:                        0.000
X NMAS/VMAS Accuracy (90% CI):      ±0.000
X ASPRS/NSSDA Accuracy (95% CI):      ±0.000
X Accuracy Class:     ------

Y Error Mean:                    0.000
Y Error Range:                   [0.000,0.000]
Y Skew:                          0.000
Y RMSE:                        0.000
Y NMAS/VMAS Accuracy (90% CI):      ±0.000
Y ASPRS/NSSDA Accuracy (95% CI):      ±0.000
Y Accuracy Class:     ------

Planimetric Error Mean:                    0.000
Planimetric Error Range:                   [0.000,0.000]
Planimetric Skew:                          0.000
Planimetric RMSE:                        0.000
Planimetric NMAS/VMAS Accuracy (90% CI):      ±0.000
Planimetric ASPRS/NSSDA Accuracy (95% CI):      ±0.000
Planimetric Accuracy Class:     ------

Vertical Error Mean:                       -0.000
Vertical Error Range:                      [-0.839,1.481]
Vertical Skew **:                             1.173
Vertical RMSE:                          0.527
Vertical NMAS/VMAS Accuracy (90% CI):      ±0.867
Vertical ASPRS/NSSDA Accuracy (95% CI):      ±1.034
Vertical Accuracy Class:    0.53
Vertical Min contour Interval:    1.59
```

GoPro Results

```
---------- Report Summary ----------

X Error Mean:                    0.000
X Error Range:                   [0.000,0.000]
X Skew:                          0.000
X RMSE:                        0.000
X NMAS/VMAS Accuracy (90% CI):      ±0.000
X ASPRS/NSSDA Accuracy (95% CI):      ±0.000
X Accuracy Class:     ------

Y Error Mean:                    0.000
Y Error Range:                   [0.000,0.000]
Y Skew:                          0.000
Y RMSE:                        0.000
Y NMAS/VMAS Accuracy (90% CI):      ±0.000
Y ASPRS/NSSDA Accuracy (95% CI):      ±0.000
Y Accuracy Class:     ------

Planimetric Error Mean:                    0.000
Planimetric Error Range:                   [0.000,0.000]
Planimetric Skew:                          0.000
Planimetric RMSE:                        0.000
Planimetric NMAS/VMAS Accuracy (90% CI):      ±0.000
Planimetric ASPRS/NSSDA Accuracy (95% CI):      ±0.000
Planimetric Accuracy Class:     ------

Vertical Error Mean *:                      -0.221
Vertical Error Range:                      [-0.535,0.171]
Vertical Skew:                             0.037
Vertical RMSE:                          0.310
Vertical NMAS/VMAS Accuracy (90% CI):      ±0.510
Vertical ASPRS/NSSDA Accuracy (95% CI):      ±0.608
Vertical Accuracy Class:    0.32
Vertical Min Contour Interval:    0.96
```

R10C Results

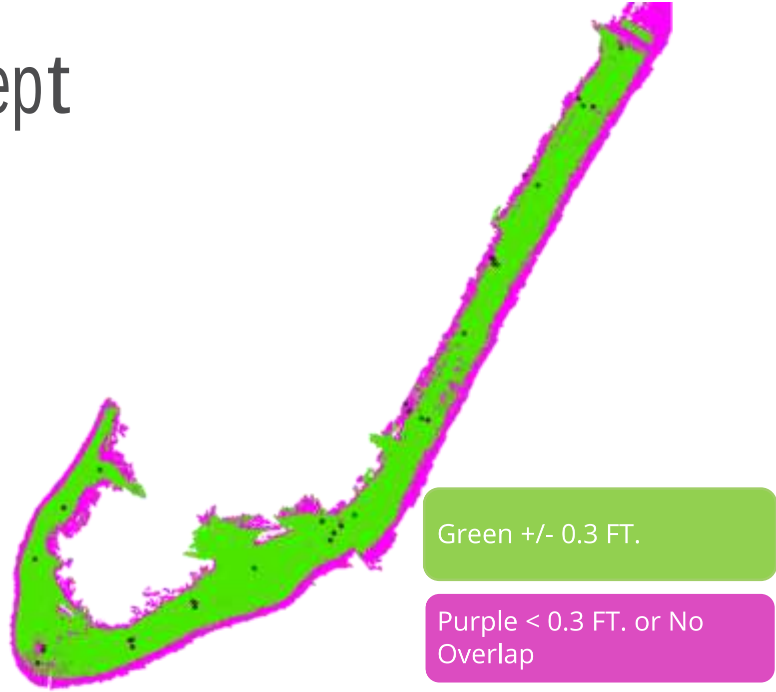
```
---------- Report Summary ----------

X Error Mean:                    0.000
X Error Range:                   [0.000,0.000]
X Skew:                          0.000
X RMSE:                        0.000
X NMAS/VMAS Accuracy (90% CI):      ±0.000
X ASPRS/NSSDA Accuracy (95% CI):      ±0.000
X Accuracy Class:     ------

Y Error Mean:                    0.000
Y Error Range:                   [0.000,0.000]
Y Skew:                          0.000
Y RMSE:                        0.000
Y NMAS/VMAS Accuracy (90% CI):      ±0.000
Y ASPRS/NSSDA Accuracy (95% CI):      ±0.000
Y Accuracy Class:     ------

Planimetric Error Mean:                    0.000
Planimetric Error Range:                   [0.000,0.000]
Planimetric Skew:                          0.000
Planimetric RMSE:                        0.000
Planimetric NMAS/VMAS Accuracy (90% CI):      ±0.000
Planimetric ASPRS/NSSDA Accuracy (95% CI):      ±0.000
Planimetric Accuracy Class:     ------

Vertical Error Mean *:                      -0.062
Vertical Error Range:                      [-0.258,0.190]
Vertical Skew:                             0.098
Vertical RMSE:                          0.137
Vertical NMAS/VMAS Accuracy (90% CI):      ±0.225
Vertical ASPRS/NSSDA Accuracy (95% CI):      ±0.268
Vertical Accuracy Class:    0.14
Vertical Min contour Interval:    0.42
```

0.137 ft = 4.17 cm = 1.64 in

Wrightsville Beach - Proof of Concept

Terrestrial LiDAR Analysis

- Terrestrial LiDAR was collected the same day by the Charleston USACE district
- The Terrestrial LiDAR was off by almost the same amount as the R10C data from the blind checkpoints.
- The error however was in the opposite direction creating an offset between the two datasets by 3 – 5 tenths
- By normalizing the terrestrial LiDAR surface to the UAS surface we were able to compare the overall fit of the two surfaces relative to each other
- The two surfaces matched well in most areas. The terrestrial data extended further out than the UAS data due to time of collection

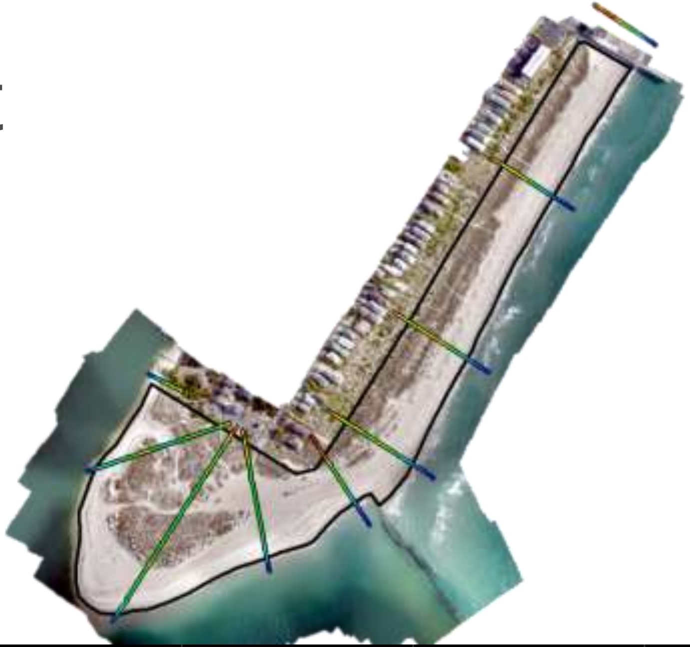


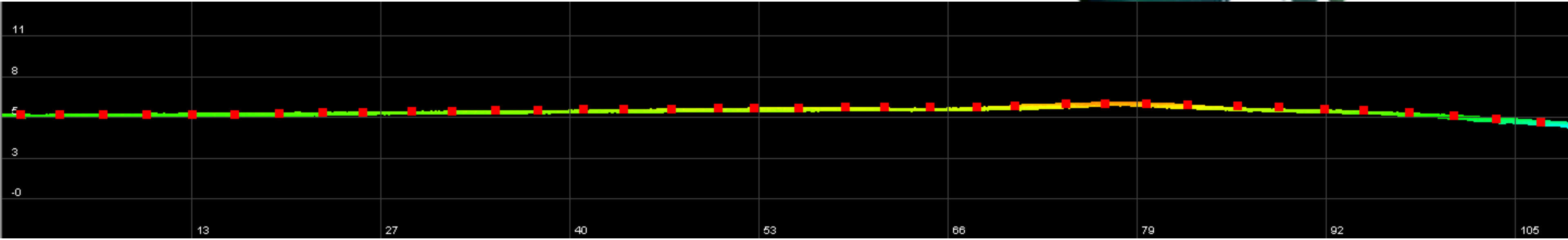

```
Vertical Error Mean *:                0.118
Vertical Error Range:              [0.023,0.200]
Vertical Skew:                     -0.333
Vertical RMSE:                  0.130
Vertical NMAS/VMAS Accuracy (90% CI):   ±0.214
Vertical ASPRS/NSSDA Accuracy (95% CI):   ±0.255
Vertical Accuracy Class:   0.14
Vertical Min Contour Interval:   0.42
```

Wrightsville Beach - Proof of Concept

Beach Profiles

- Transects were collected of the beach earlier in the year.
- Beach profiles are spaced at 1,000 ft. To each other and 3 ft. downline.
- Both profiles and UAS data match well.





Wrightsville Beach - Proof of Concept

Final business comparison: UAV vs. traditional methods

	Traditional surveying	Terrestrial LiDAR	Aerial LiDAR
Accuracy	Higher accuracy (0.07 ft / 2 cm)	Similar to Site Scan (0.13 ft / 4 cm)	Similar to Site Scan (0.13 ft / 4 cm)
Cost savings using Site Scan	~30%	~15%	~60%
Time	UAV captures greater details in less time	UAV much faster collection & processing. Similar mobilization & coverage	UAV much faster mobilization, collection & processing. Similar coverage.

Eagle island disposal site – Proof of Concept

Goals:

- Measure the volume of material dredged by the river twice a year (before and after the dredging)
- Evaluate the ability to achieve the same accuracy as traditional surveying without putting people into harm's way
- Assess the viability of volumetric collection with UAVs

Eagle island disposal site – Proof of Concept

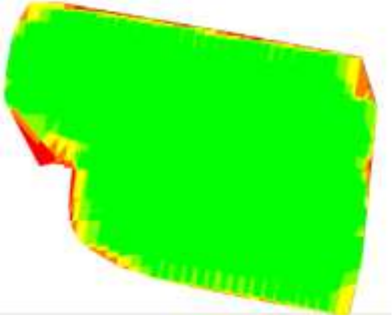
Total Area Processed

Partial Cells 1 & 2
106 Acres

Ground Control Used

7 Points
Fully Surveyed

Photos Collected



Sony R10C
Total 214 / 1.34GB

Output Parameters

Horizontal GSD – 1.32 in
3D Points / Meter - 104

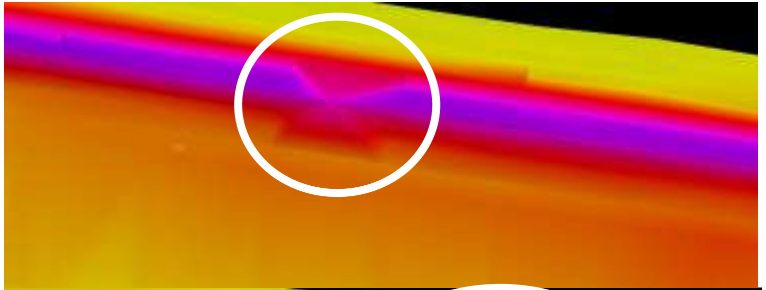
Processing Time: 5 hrs 7 mins
Products Produced: Orthos, DSM, Point Cloud, 3D Mesh
Overall Accuracy: Mean RMS 2.64 inches

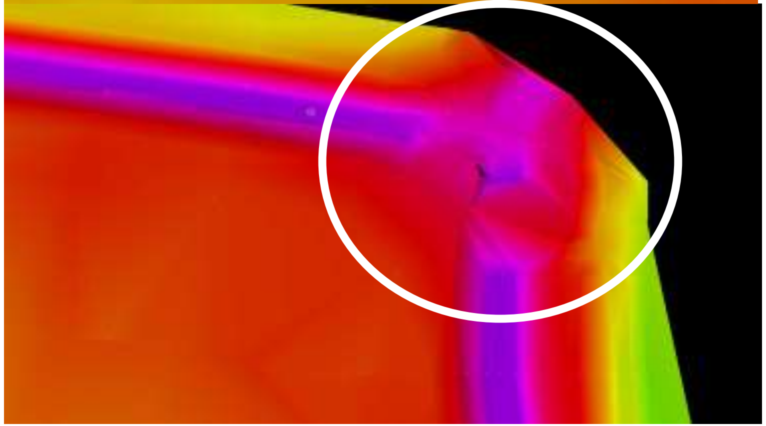
Eagle island disposal site – Proof of Concept

Eagle island disposal site – Proof of Concept

Traditional Survey Data

- Cell 1 (280 Acres approx.) was previously surveyed using conventional.
- 3642 individual survey shots were collected (2 weeks of work approx.)
- Irregularities in the surface model existed due to either bad elevations or incorrect triangulation

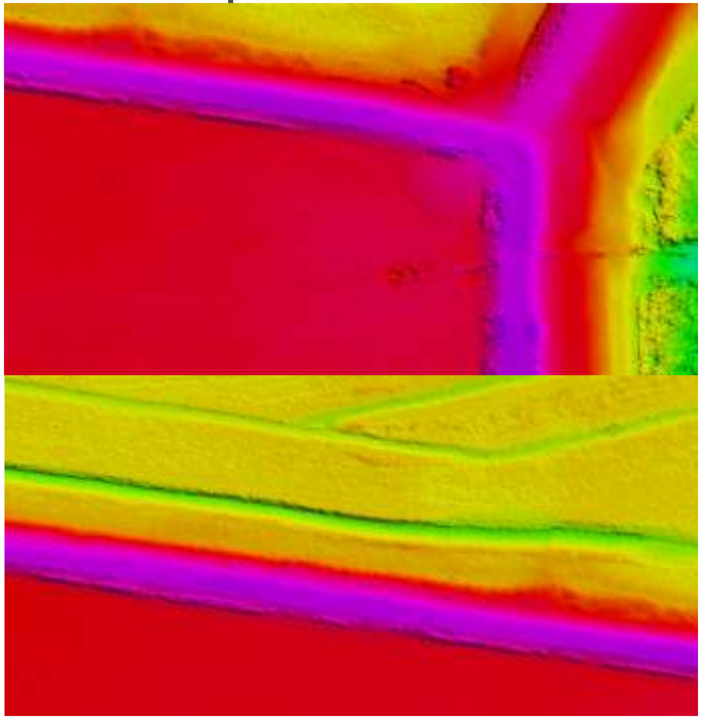




Eagle island disposal site – Proof of Concept

UAS Survey Data

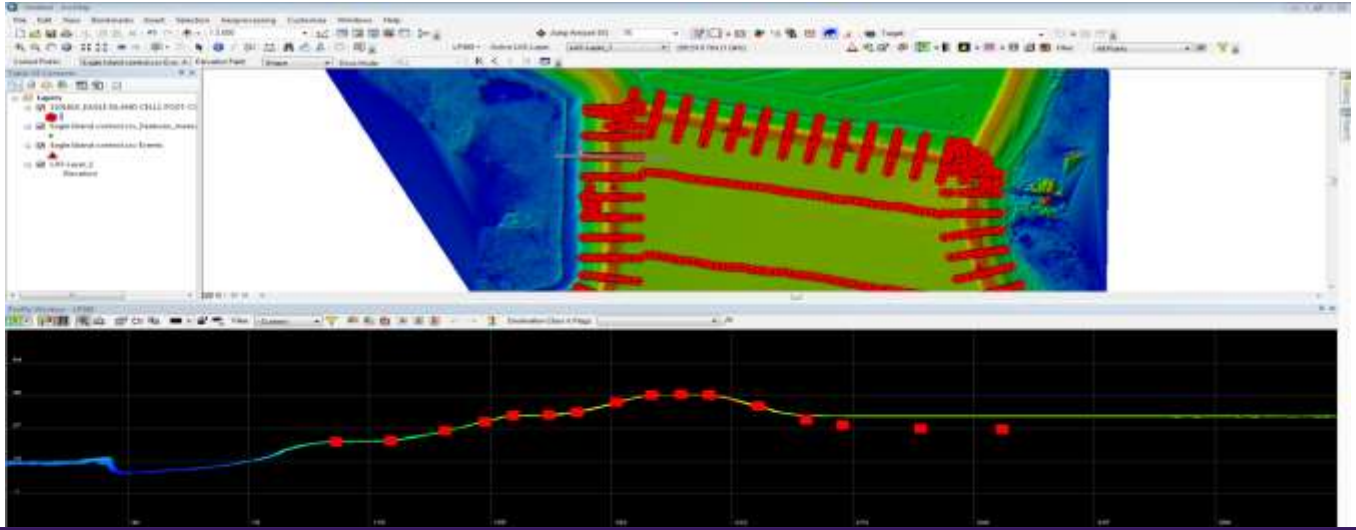
- Portions of Cell 1 and Cell 2 were collected in two 15 minute flights.
- 5 flights would be required to collect all of Cell 1 (half a day of flight and target survey approx.)
- 104 points per square meter vs. 0.07 (averaged from survey)



Eagle island disposal site – Proof of Concept

Accuracy Reporting

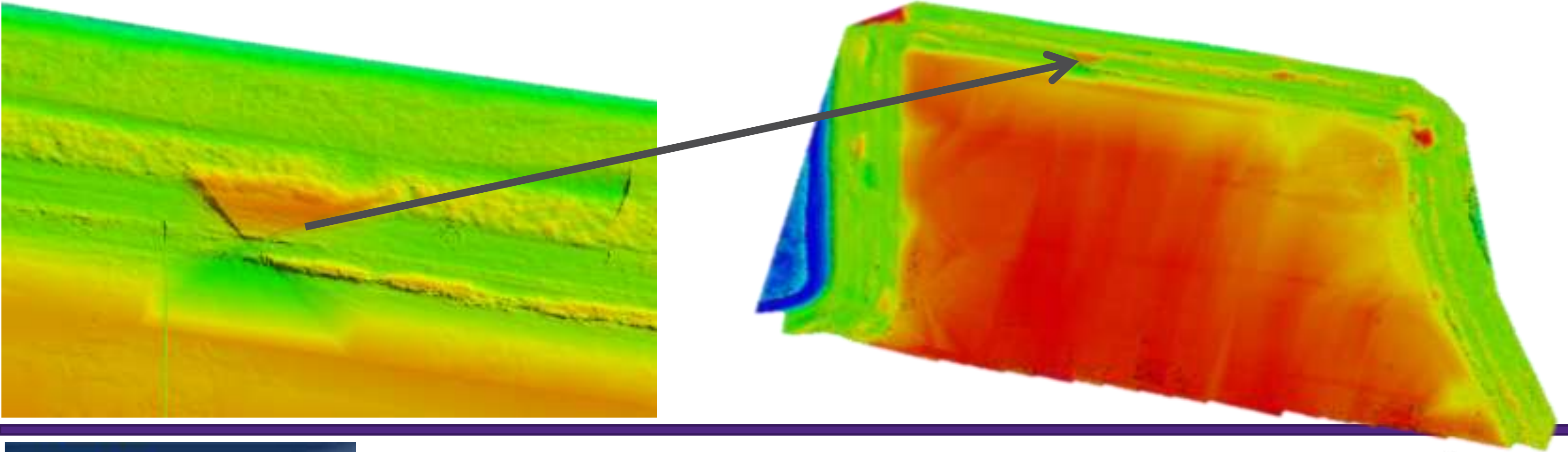
- No blind checkpoints were collected only control points.
- UAS and survey lined up very well on the dikes. The volume inside had changed however since the survey.



Eagle island disposal site – Proof of Concept

Surface Comparison

- The difference between data collections were normalized to visualize differences between datasets
- Most locations on the dike were less than 0.1 ft. up to 0.02 ft. difference between surfaces.
- In Places where the survey did not triangulate well, the differences were greater.



Eagle island disposal site – Proof of Concept

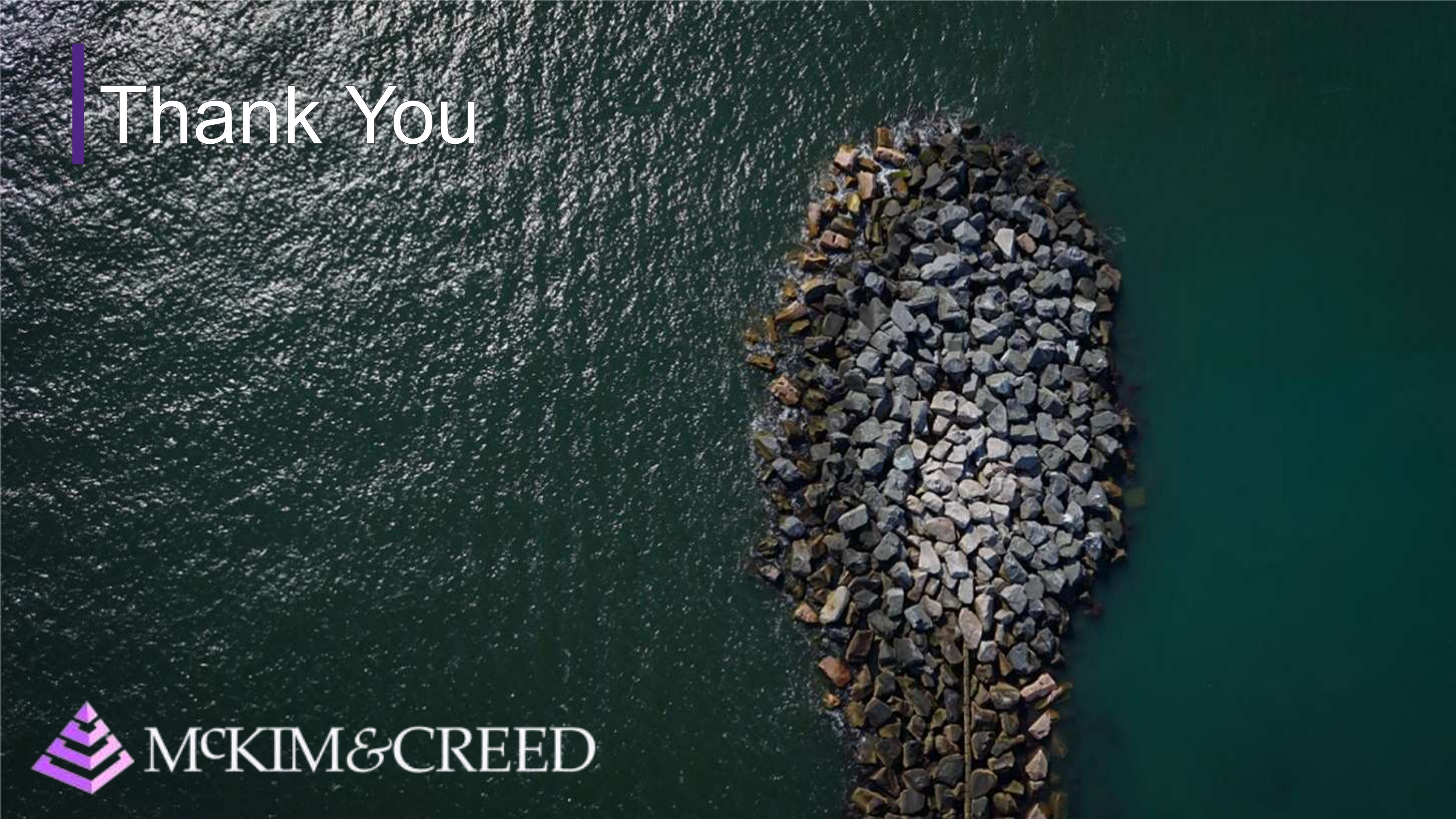
Final business comparison: UAV vs. traditional methods

	Traditional surveying	Terrestrial LiDAR	Aerial LiDAR
Accuracy	Higher accuracy (0.07 ft / 2 cm)	Inadequate ground stability	Similar to Site Scan (0.13 ft / 4 cm)
Cost savings using Site Scan	~80%	/	~50%
Time	UAS captures greater detail in less time and is safer!	/	UAV much faster mobilization, collection & processing. Similar coverage.

Community Effort

USACE Wilmington, City of Wrightsville Beach, UNC-W, NC Coastal Land Trust, Cape Fear Audubon

Thank You



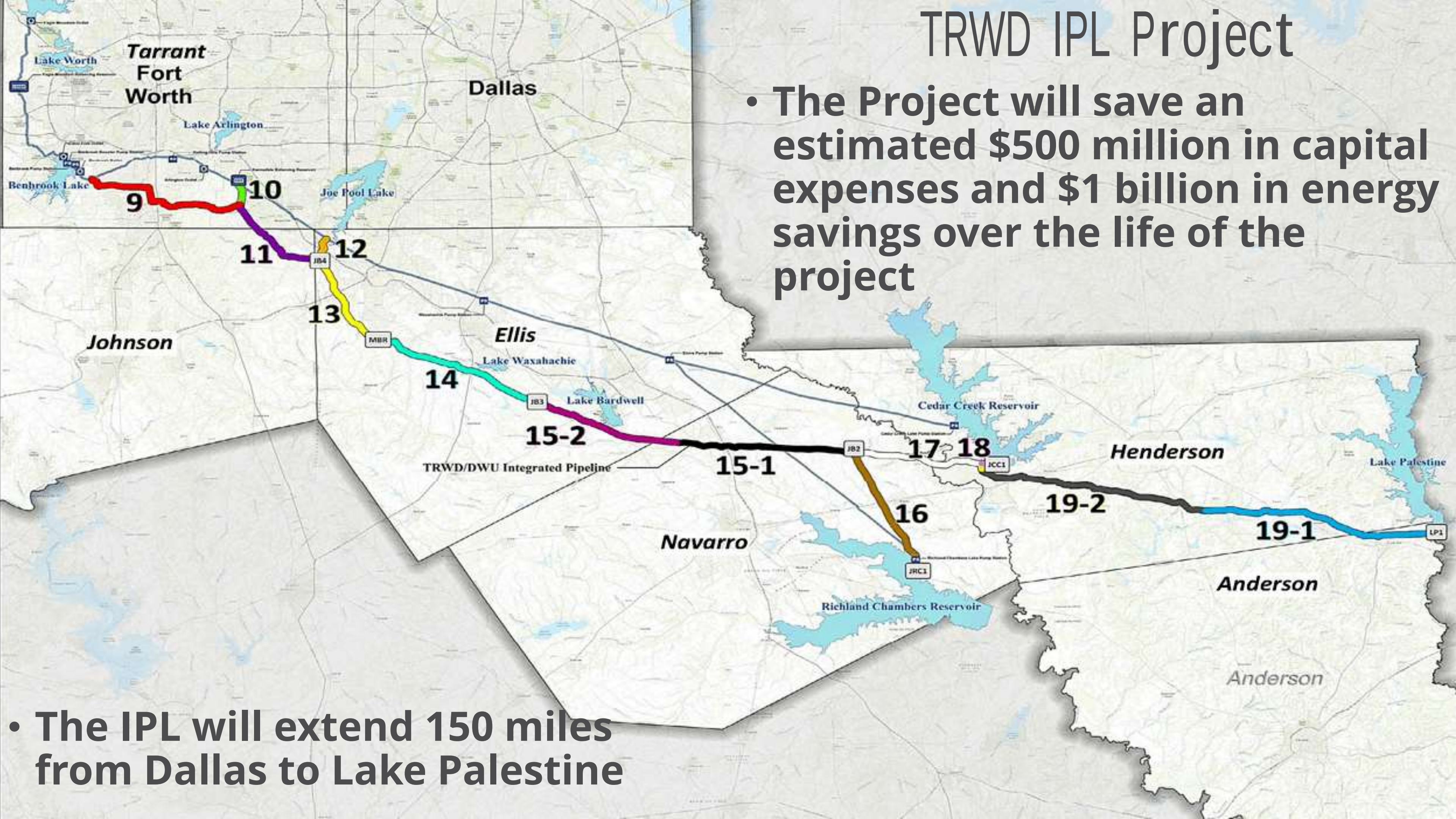
McKIM&CREED

TWRD

Integrated Pipeline Drone Mapping

TRWD IPL Project

- **The Project will save an estimated $500 million in capital expenses and $1 billion in energy savings over the life of the project**



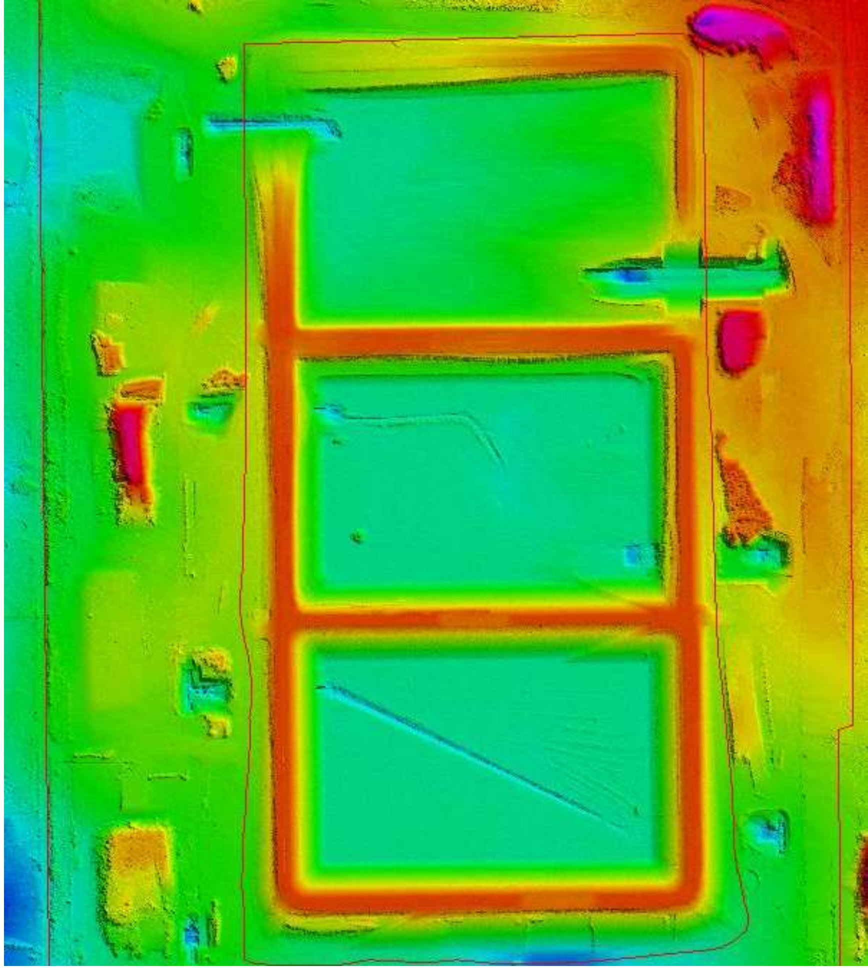
- **The IPL will extend 150 miles from Dallas to Lake Palestine**

Midlothian Balancing Reservoir (MBR)

- The MBR will hold 400 million gallons of water when completed
- Construction ongoing since 2015 on this site
- During construction the dirt contractor submitted invoices that were in excess of the truck count numbers
- 2 drone operators previously hired
- Results submitted were highly inaccurate than those reported by contractor
- We provided verification of the volumes reported

Midlothian Balancing Reservoir.

- Due to construction 6 days a week, traditional ground survey would have been difficult, dangerous, and impacted work
- Traditional aerial LiDAR would have been too expensive for such a small site (180 acres)
- sUAS was determined to be the best approach despite the clients reluctance from previous experience



June 6th 2016

July 10th 2016

August 7th 2016

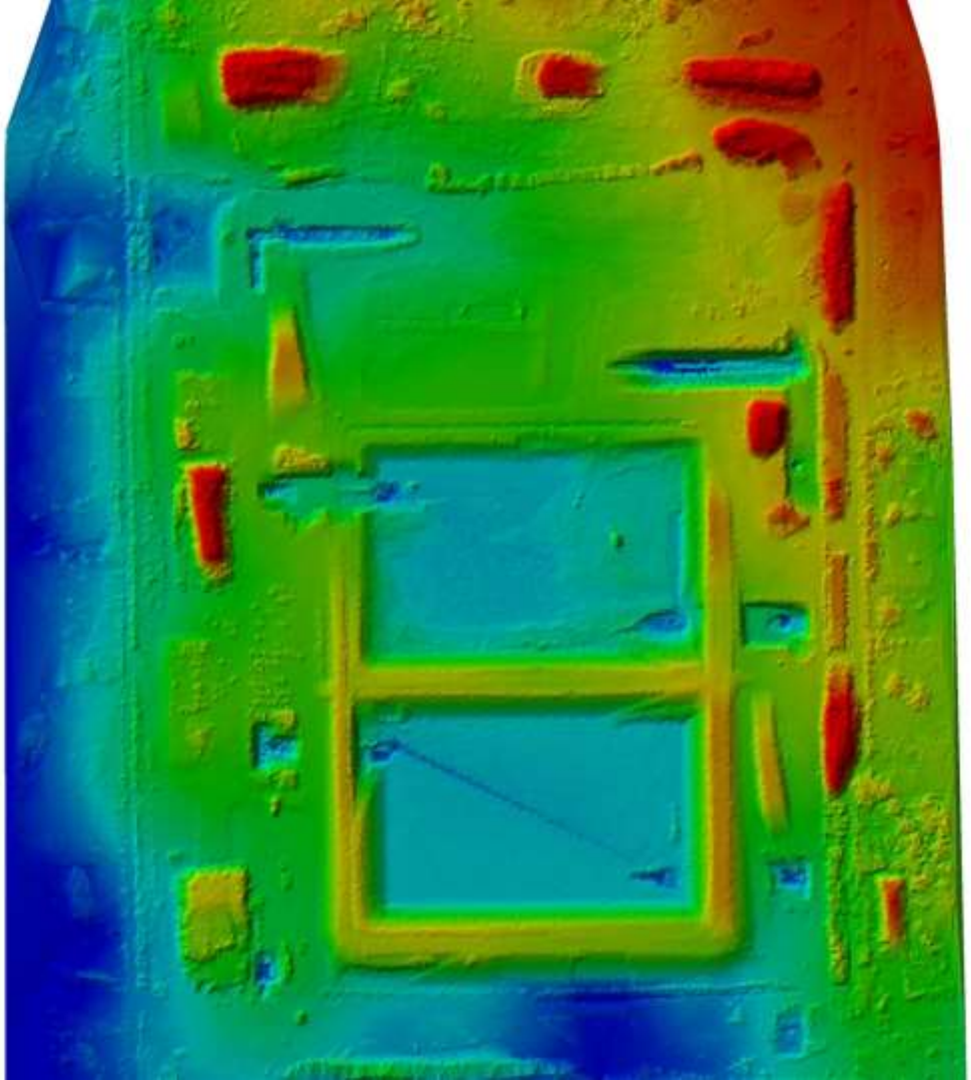
Sept. 11th 2016

October 6th 2016

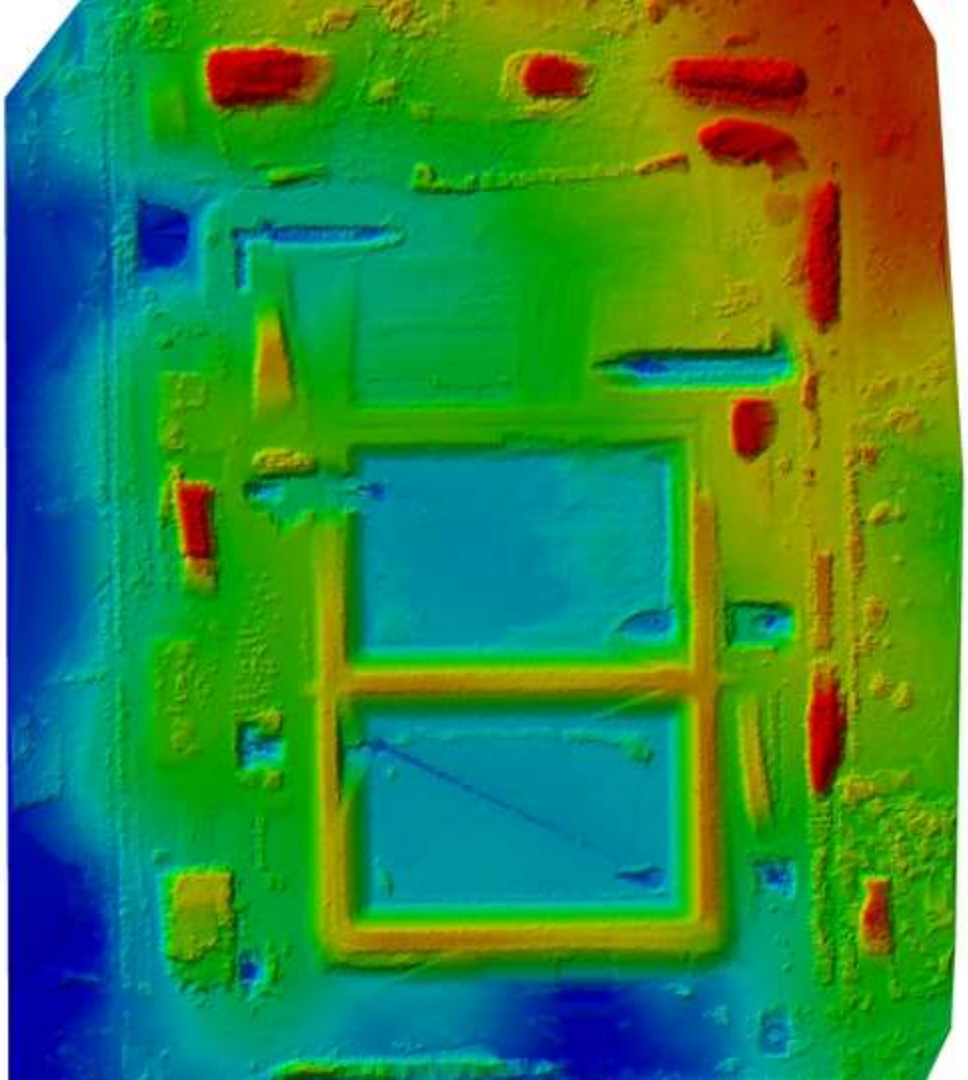
Nov. 6th 2016

Dec. 18th 2016

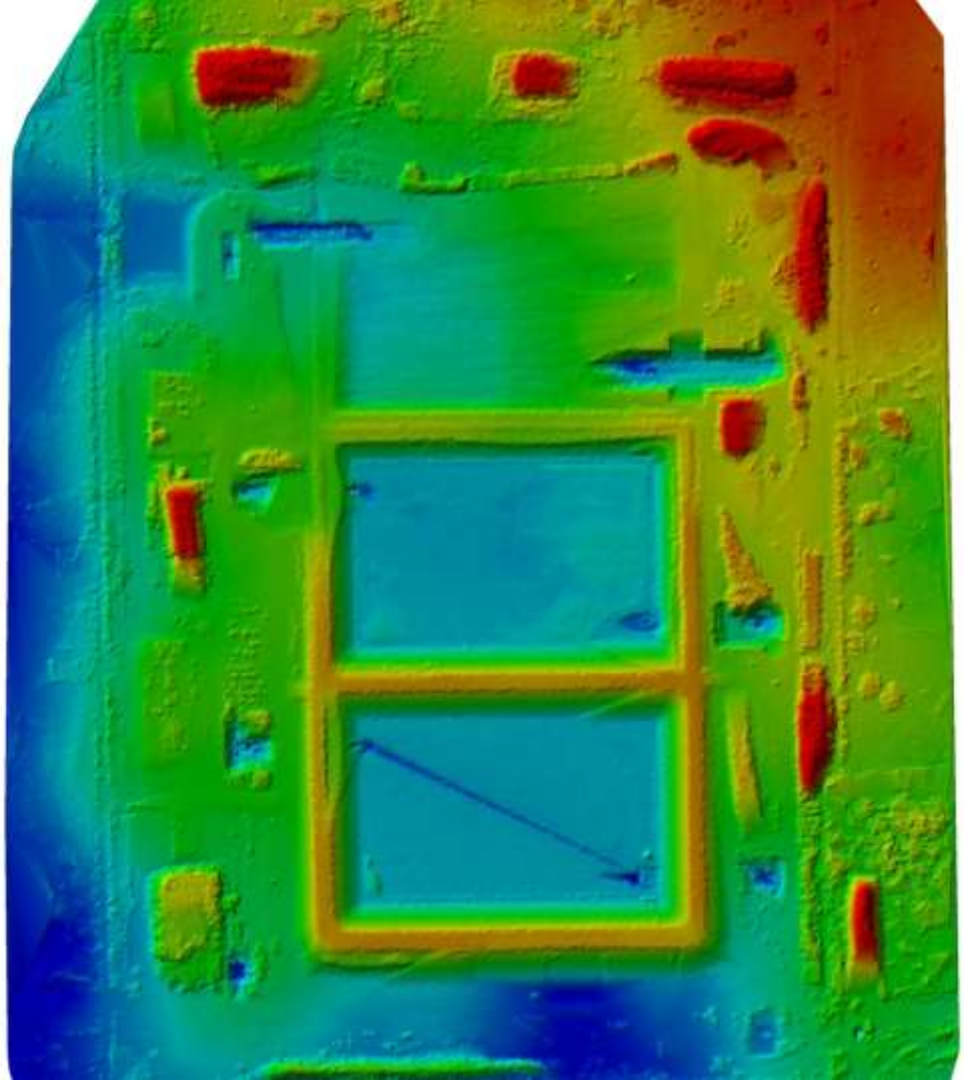
January 29th 2017



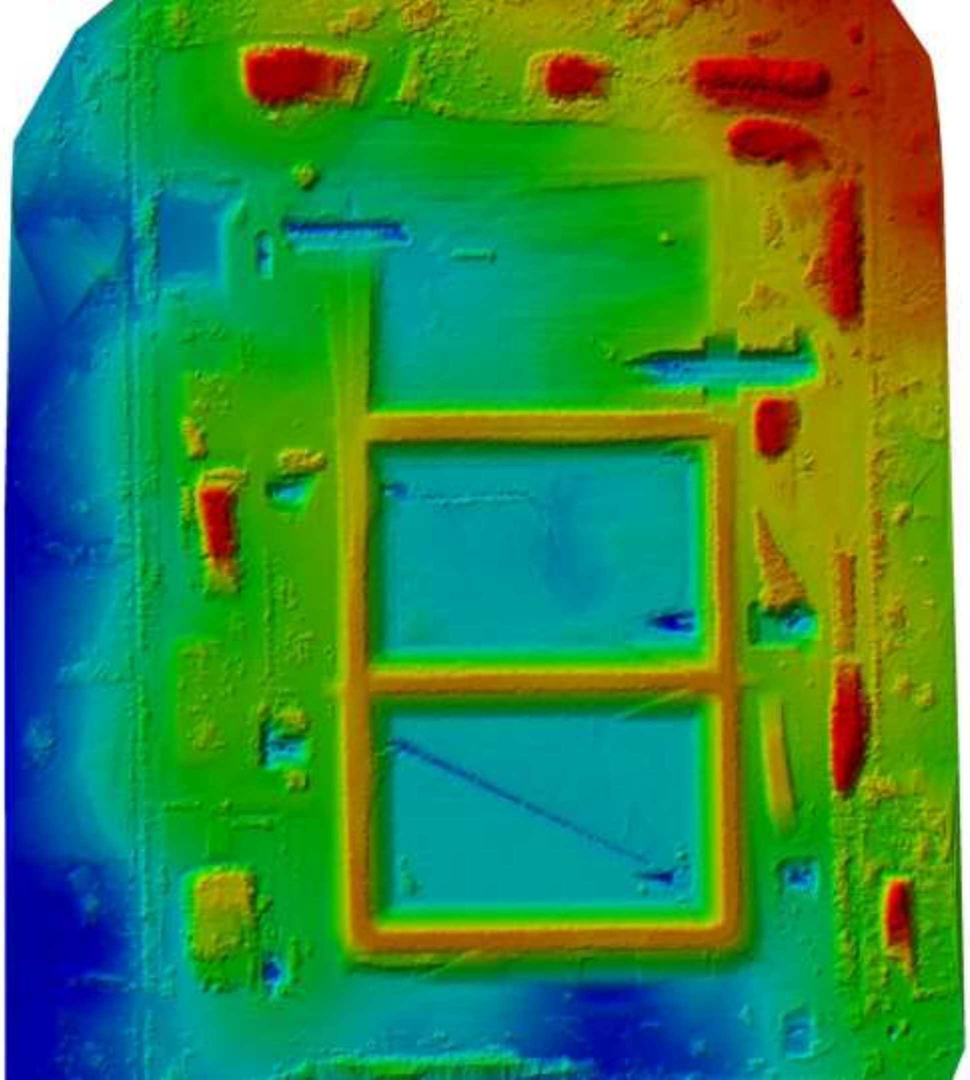
June 6th 2016



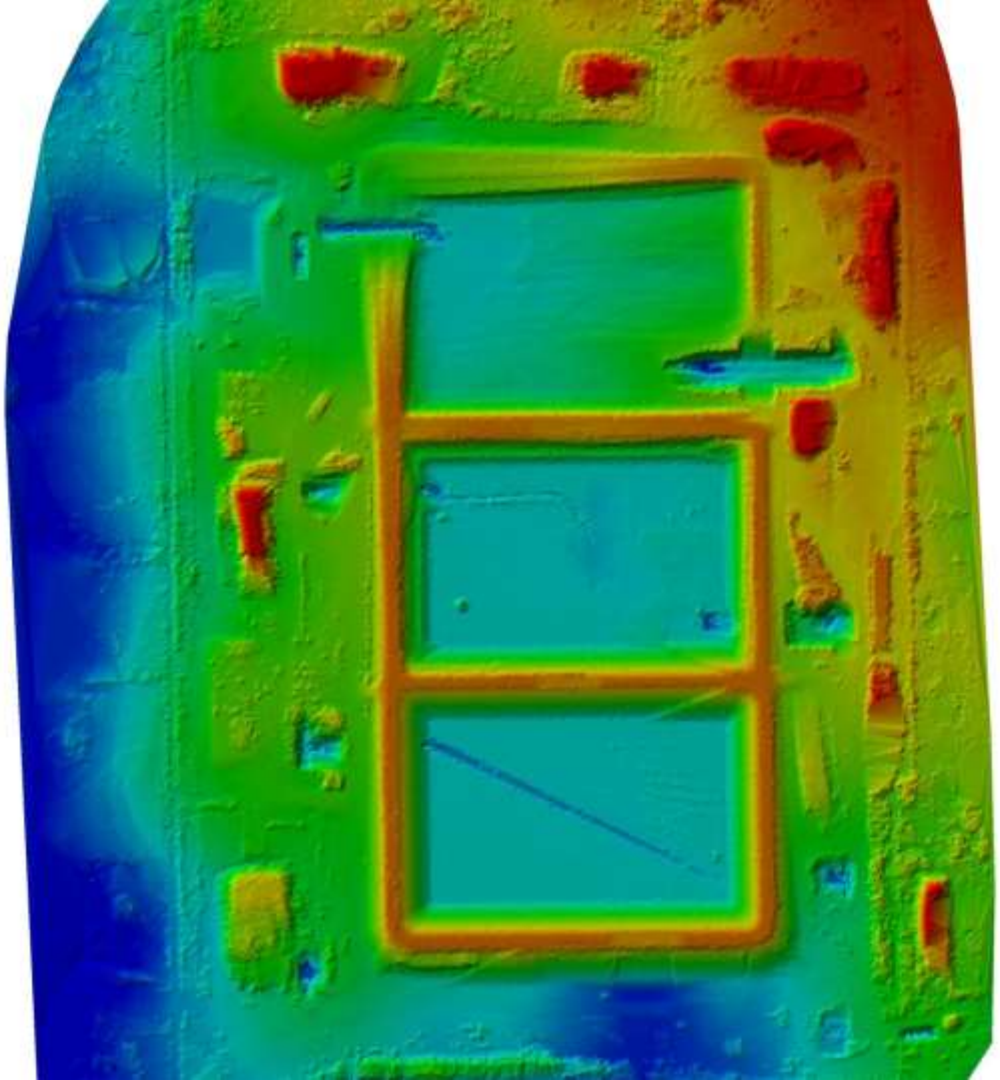
July 10th 2016



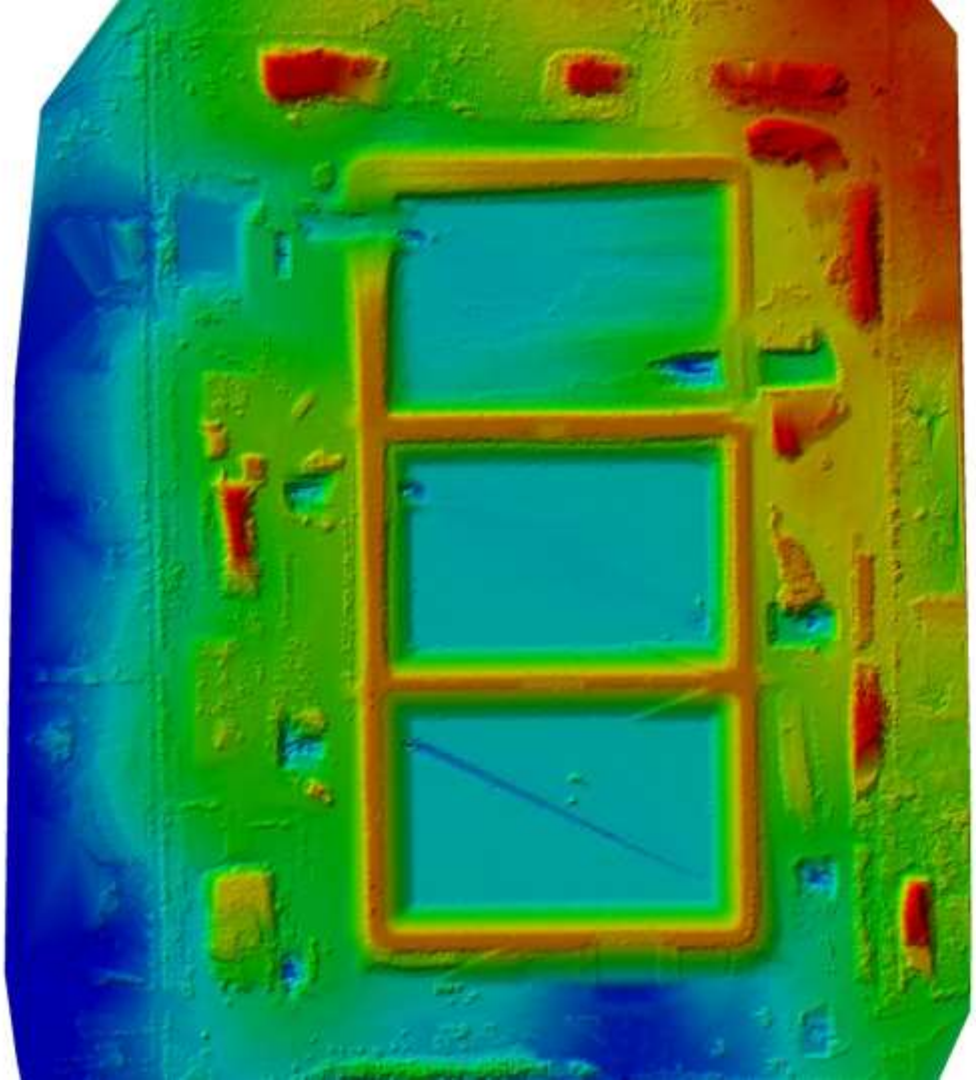
August 7th 2016



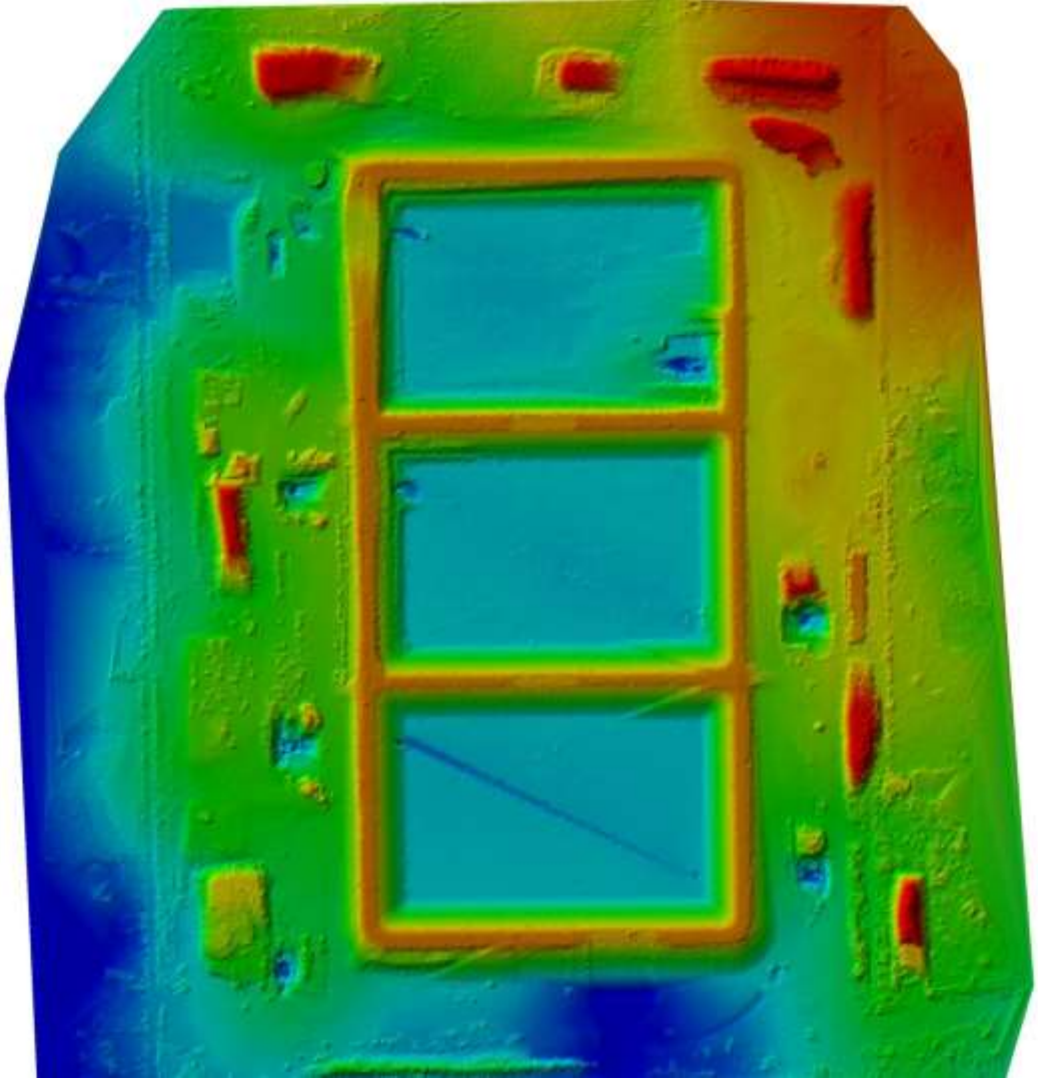
Sept 11th 2016



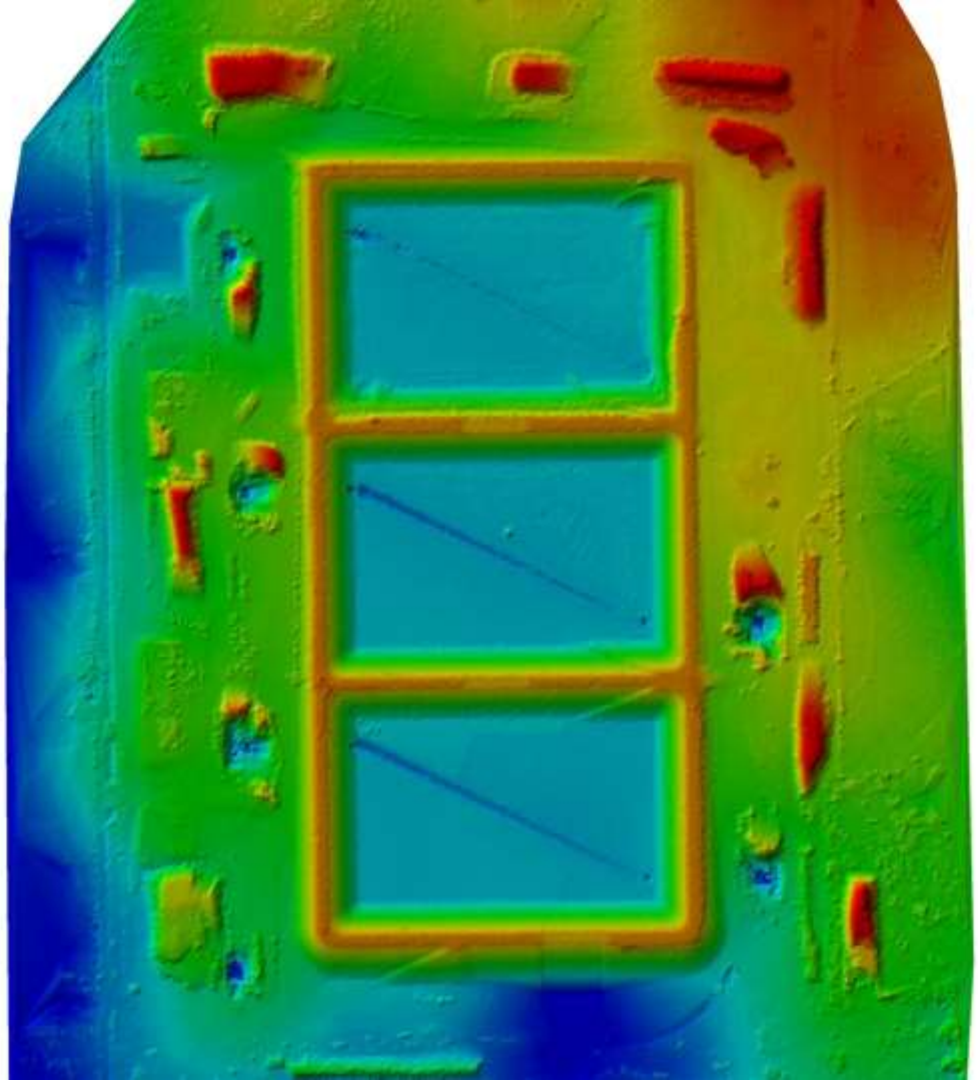
Oct. 6th 2016



Nov. 6th 2016



Dec. 18th 2016



January 29th 2017

Benefits of Drone Flights

- The Contractor has now been held accountable for their volumes
- Tax payers are saving money that was erroneously being paid to the contractor
- Drone Flights have not disrupted construction
- As a byproduct, TRWD now has a high accuracy cost effective record of the entire construction process