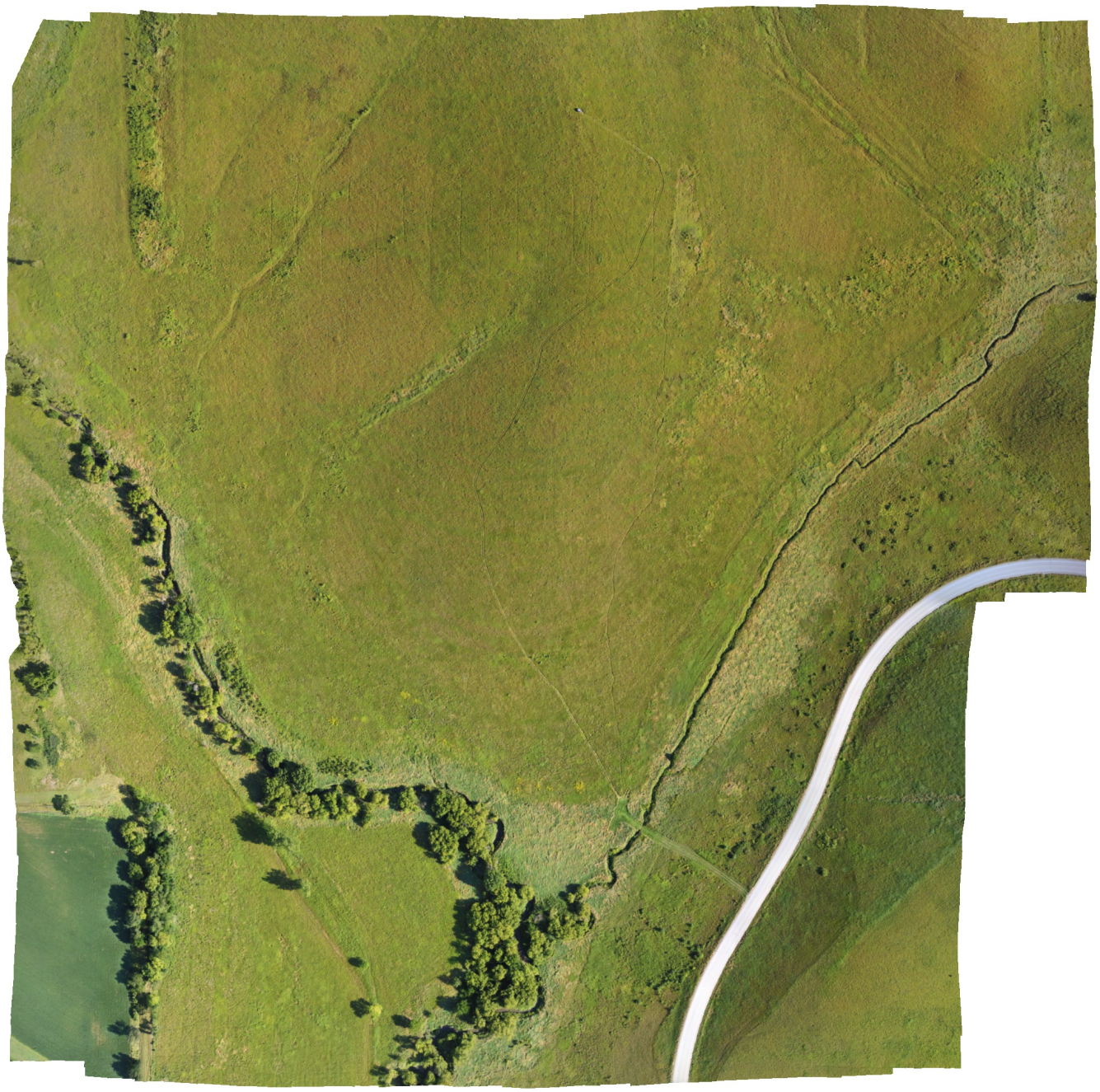
# Remote Sensing on Neal Smith NWR

**Images collected with a U.S. Fish and Wildlife Service unmanned aerial system (UAS) from August 20 to August 22, 2019.**

**30 August 2019**



# Survey Data

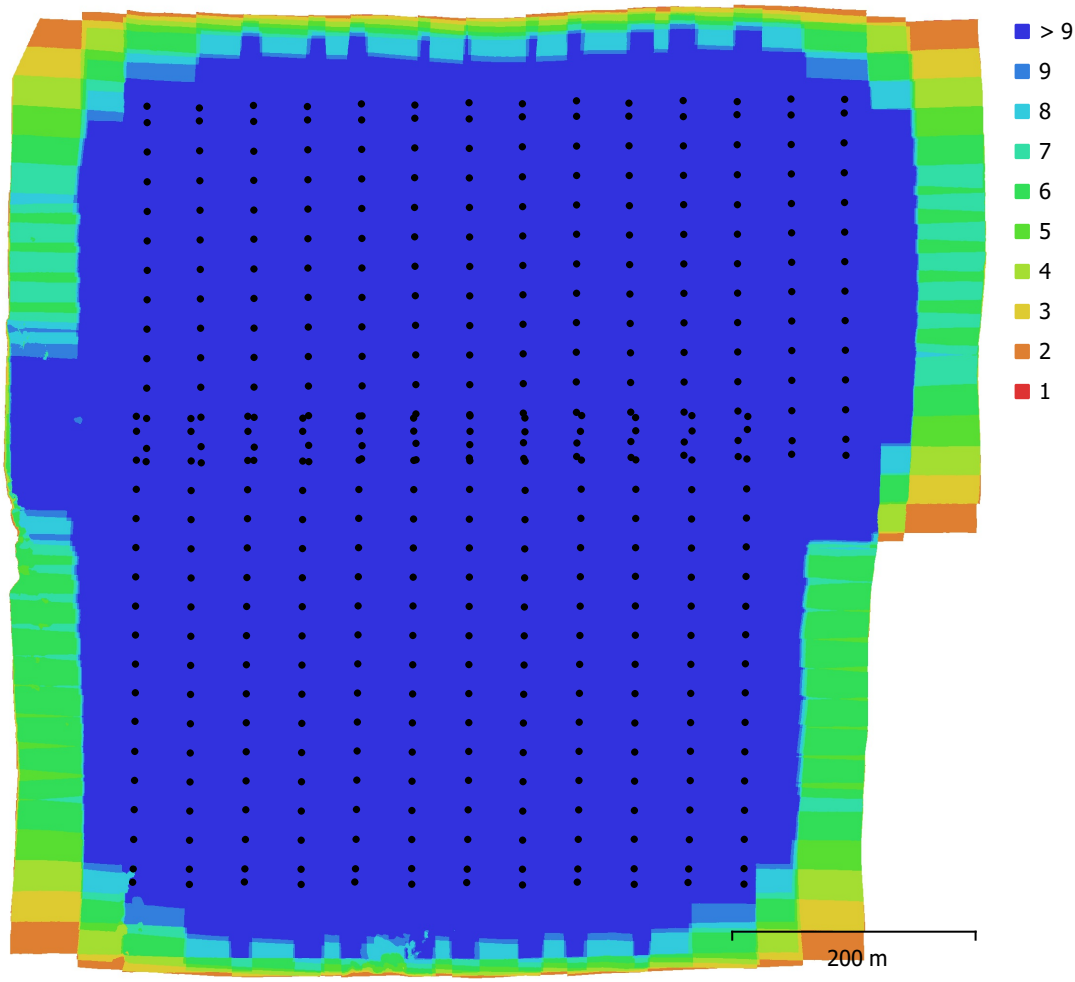



Fig. 1. Camera locations and image overlap.

| | | | |
|---|---|---|---|
| Number of images: | 412 | Camera stations: | 412 |
| Flying altitude: | 147 m | Tie points: | 228,503 |
| Ground resolution: | 4.36 cm/pix | Projections: | 1,599,889 |
| Coverage area: | 0.593 km² | Reprojection error: | 0.815 pix |

| Camera Model | Resolution | Focal Length | Pixel Size | Precalibrated |
|---|---|---|---|---|
| Anafi (4mm) | 4608 x 3456 | 4 mm | 1.34 x 1.34 µm | No |
| Anafi (4mm) | 4608 x 3456 | 4 mm | 1.34 x 1.34 µm | No |
| unknown | 4608 x 3456 | unknown | unknown | No |

Table 1. Cameras.

# Camera Calibration

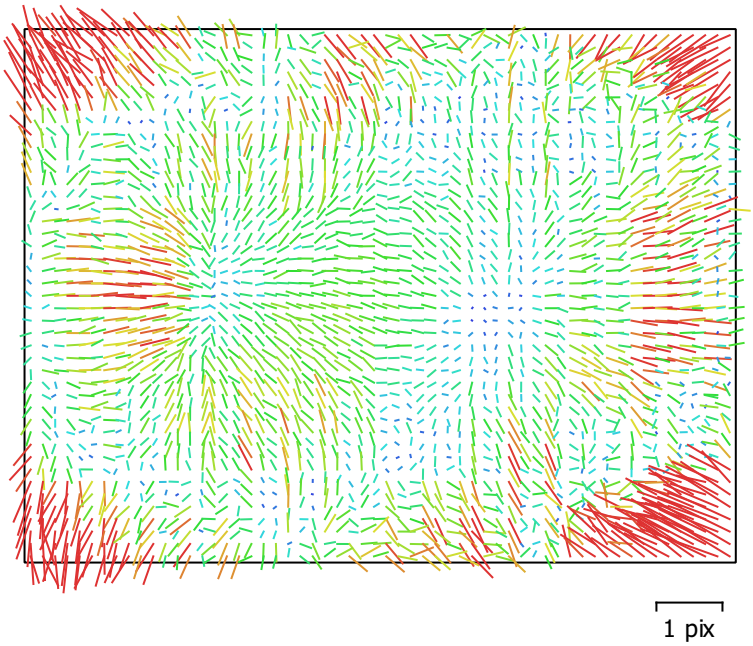



Fig. 2. Image residuals for Anafi (4mm).

**Anafi (4mm)**

210 images

| Type | Resolution | Focal Length | Pixel Size |
|---|---|---|---|
| **Frame** | **4608 x 3456** | **4 mm** | **1.34 x 1.34 µm** |

| | Value | Error | F | Cx | Cy | B1 | B2 | K1 | K2 | K3 | P1 | P2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **F** | **3046.87** | 1.3 | 1.00 | -0.64 | -0.61 | -0.00 | 0.05 | -0.04 | 0.12 | -0.23 | 0.62 | 0.17 |
| **Cx** | **28.0612** | 0.088 | | 1.00 | 0.38 | -0.01 | -0.09 | 0.03 | -0.08 | 0.15 | -0.24 | -0.13 |
| **Cy** | **-6.4456** | 0.077 | | | 1.00 | 0.03 | -0.03 | 0.03 | -0.07 | 0.14 | -0.40 | 0.11 |
| **B1** | **-0.587481** | 0.14 | | | | 1.00 | 0.00 | 0.00 | -0.00 | -0.01 | -0.04 | 0.03 |
| **B2** | **20.0362** | 0.14 | | | | | 1.00 | -0.00 | 0.01 | -0.02 | 0.02 | -0.04 |
| **K1** | **-0.000720366** | 4.4e-005 | | | | | | 1.00 | -0.62 | 0.57 | -0.19 | -0.27 |
| **K2** | **0.00495588** | 7.6e-005 | | | | | | | 1.00 | -0.98 | 0.06 | 0.02 |
| **K3** | **-0.00533369** | 6.3e-005 | | | | | | | | 1.00 | -0.12 | -0.03 |
| **P1** | **0.0036844** | 2.7e-006 | | | | | | | | | 1.00 | 0.14 |
| **P2** | **0.00065329** | 1.9e-006 | | | | | | | | | | 1.00 |

Table 2. Calibration coefficients and correlation matrix.

# Camera Calibration

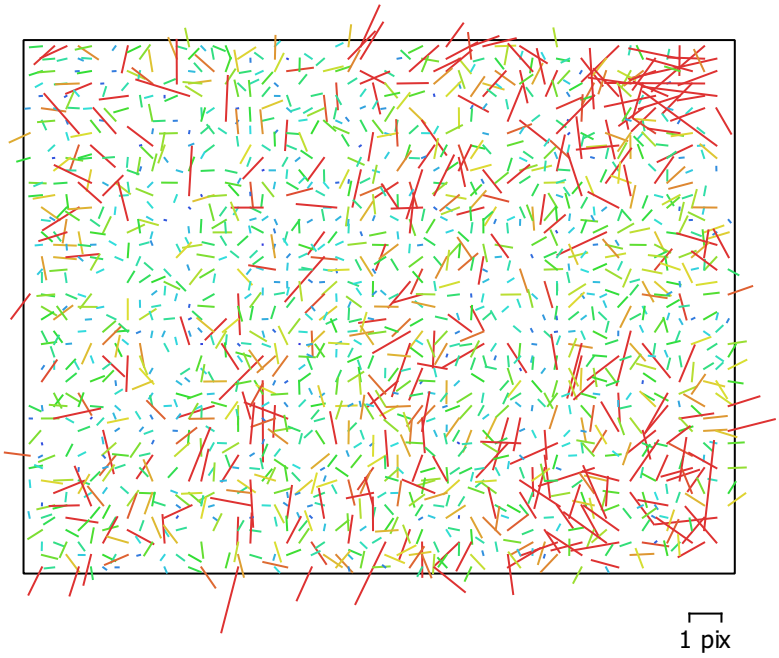



Fig. 3. Image residuals for Anafi (4mm).

**Anafi (4mm)**

1 images

| Type | Resolution | Focal Length | Pixel Size |
|---|---|---|---|
| **Frame** | **4608 x 3456** | **4 mm** | **1.34 x 1.34 µm** |

| | Value | Error | B1 | B2 | P1 | P2 |
|---|---|---|---|---|---|---|
| **F** | **2975.66** | | | | | |
| **B1** | **-0.949389** | 0.14 | 1.00 | 0.01 | 0.09 | -0.02 |
| **B2** | **19.8826** | 0.14 | | 1.00 | 0.06 | 0.05 |
| **P1** | **0.0035623** | 2.6e-005 | | | 1.00 | -0.03 |
| **P2** | **0.000641059** | 2.1e-005 | | | | 1.00 |

Table 3. Calibration coefficients and correlation matrix.

# Camera Calibration

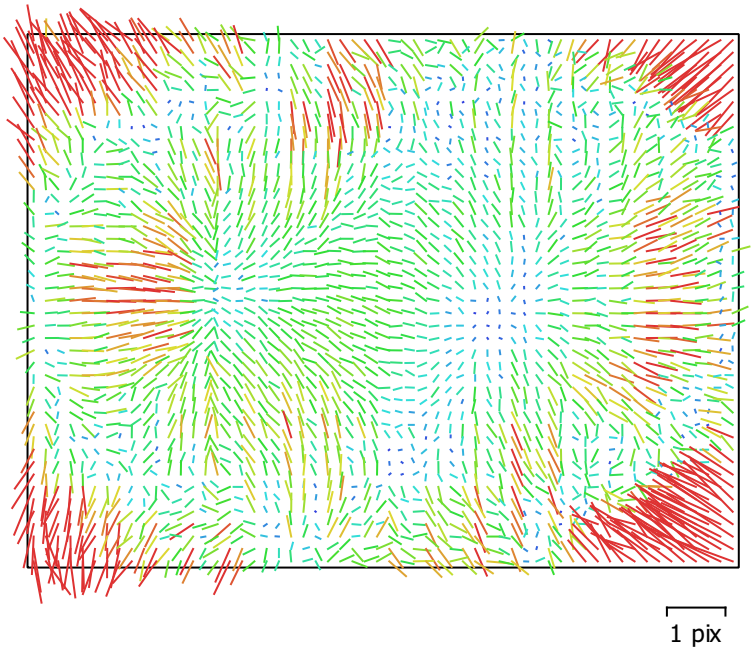



Fig. 4. Image residuals for unknown.

**unknown**

201 images

| Type | Resolution | Focal Length | Pixel Size |
|---|---|---|---|
| **Frame** | **4608 x 3456** | **unknown** | **unknown** |

| | Value | Error | F | Cx | Cy | B1 | B2 | K1 | K2 | K3 | P1 | P2 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **F** | **3051.26** | 1.3 | 1.00 | -0.63 | -0.63 | 0.00 | 0.06 | -0.05 | 0.14 | -0.27 | 0.63 | 0.17 |
| **Cx** | **27.7941** | 0.068 | | 1.00 | 0.40 | -0.01 | -0.12 | 0.03 | -0.09 | 0.17 | -0.25 | -0.13 |
| **Cy** | **-4.53571** | 0.063 | | | 1.00 | 0.05 | -0.03 | 0.03 | -0.08 | 0.16 | -0.40 | 0.07 |
| **B1** | **-1.25076** | 0.14 | | | | 1.00 | 0.01 | 0.00 | 0.00 | -0.01 | -0.00 | 0.04 |
| **B2** | **20.1303** | 0.14 | | | | | 1.00 | -0.00 | 0.01 | -0.02 | 0.00 | -0.02 |
| **K1** | **-0.000896736** | 4.4e-005 | | | | | | 1.00 | -0.62 | 0.57 | -0.16 | -0.22 |
| **K2** | **0.00556686** | 7.7e-005 | | | | | | | 1.00 | -0.97 | 0.07 | 0.02 |
| **K3** | **-0.00625605** | 6.4e-005 | | | | | | | | 1.00 | -0.15 | -0.04 |
| **P1** | **0.00362367** | 2.7e-006 | | | | | | | | | 1.00 | 0.12 |
| **P2** | **0.00069051** | 1.7e-006 | | | | | | | | | | 1.00 |

Table 4. Calibration coefficients and correlation matrix.

# Camera Locations

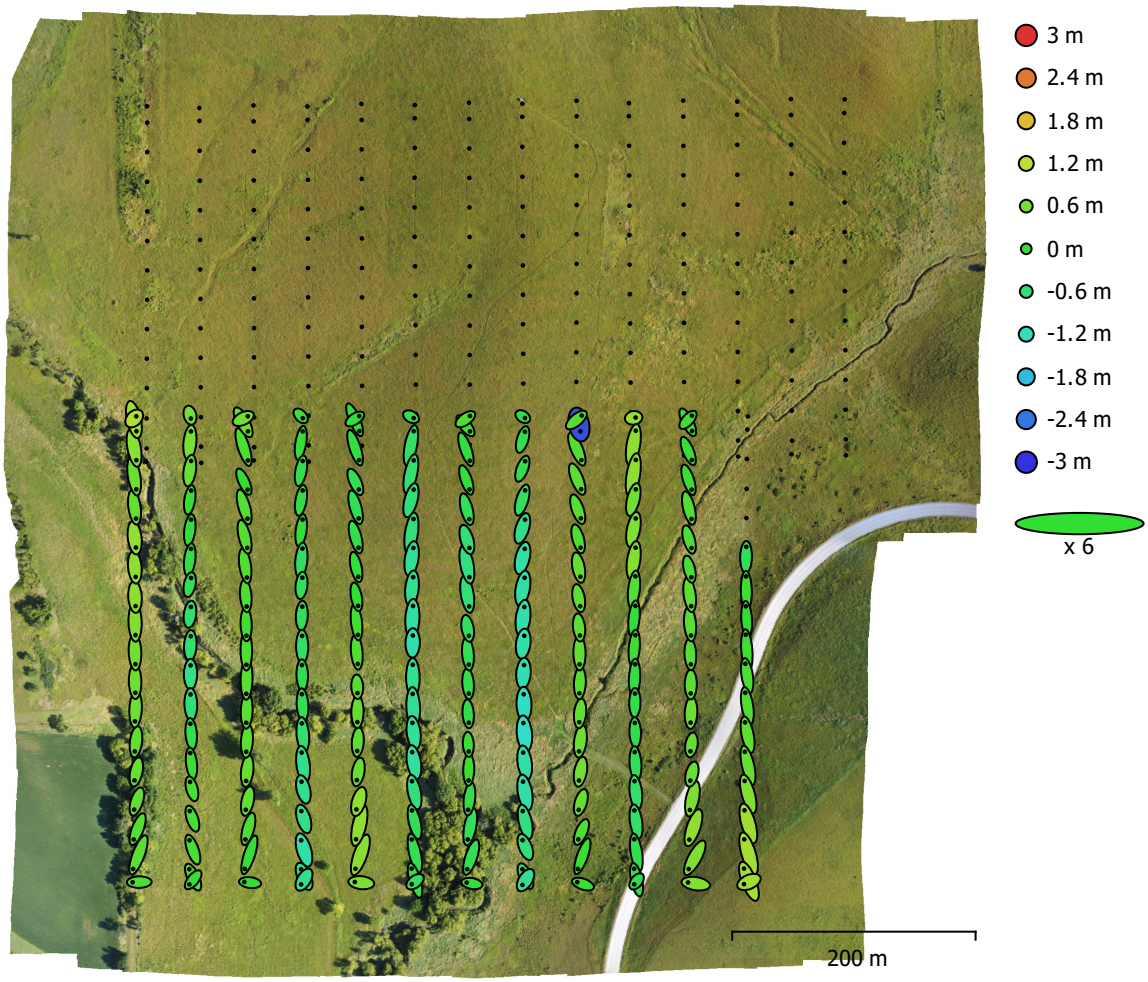



Fig. 5. Camera locations and error estimates.
Z error is represented by ellipse color. X,Y errors are represented by ellipse shape.
Estimated camera locations are marked with a black dot.

| X error (m) | Y error (m) | Z error (m) | XY error (m) | Total error (m) |
|---|---|---|---|---|
| 0.720843 | 2.78025 | 0.555439 | 2.87217 | 2.92539 |

Table 5. Average camera location error.
X - Longitude, Y - Latitude, Z - Altitude.

# Digital Elevation Model

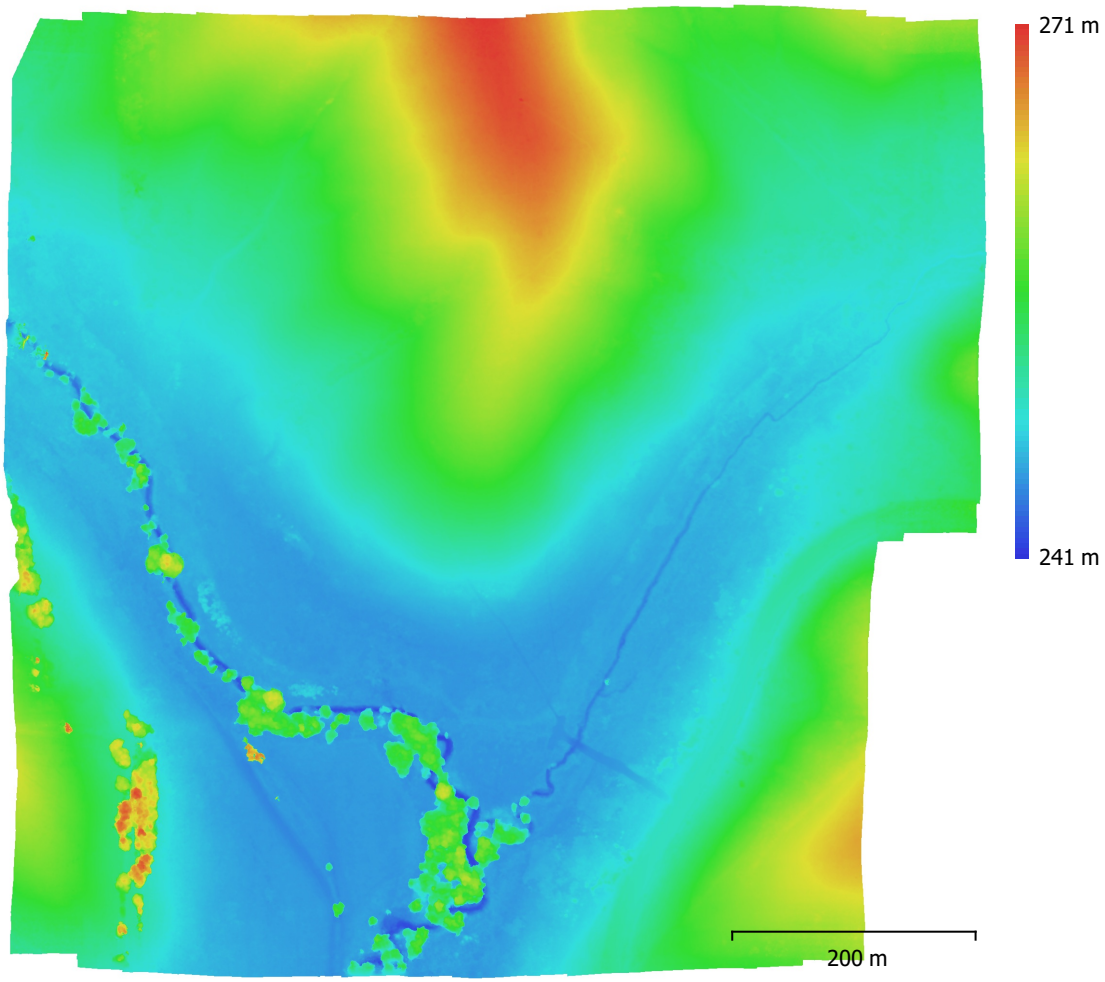



Fig. 6. Reconstructed digital elevation model.

| | |
|---|---|
| Resolution: | 17.4 cm/pix |
| Point density: | 32.9 points/m² |

# Processing Parameters

| | |
|---|---|
| **General** | |
| Cameras | 412 |
| Aligned cameras | 412 |
| Coordinate system | WGS 84 (EPSG::4326) |
| Rotation angles | Yaw, Pitch, Roll |
| **Point Cloud** | |
| Points | 228,503 of 245,438 |
| RMS reprojection error | 0.267943 (0.815037 pix) |
| Max reprojection error | 0.901623 (27.9864 pix) |
| Mean key point size | 3.04744 pix |
| Point colors | 3 bands, uint8 |
| Key points | No |
| Average tie point multiplicity | 7.4833 |
| **Alignment parameters** | |
| Accuracy | High |
| Generic preselection | Yes |
| Reference preselection | Yes |
| Key point limit | 40,000 |
| Tie point limit | 4,000 |
| Adaptive camera model fitting | Yes |
| Matching time | 15 minutes 33 seconds |
| Alignment time | 6 minutes 26 seconds |
| **Optimization parameters** | |
| Parameters | f, b1, b2, cx, cy, k1-k3, p1, p2 |
| Adaptive camera model fitting | Yes |
| Optimization time | 25 seconds |
| Software version | 1.5.2.7838 |
| **Depth Maps** | |
| Count | 412 |
| **Depth maps generation parameters** | |
| Quality | Medium |
| Filtering mode | Aggressive |
| Processing time | 1 hours 40 minutes |
| Software version | 1.5.2.7838 |
| **Dense Point Cloud** | |
| Points | 21,096,612 |
| Point colors | 3 bands, uint8 |
| **Depth maps generation parameters** | |
| Quality | Medium |
| Filtering mode | Aggressive |
| Processing time | 1 hours 40 minutes |
| **Dense cloud generation parameters** | |
| Processing time | 28 minutes 49 seconds |
| Software version | 1.5.2.7838 |
| **DEM** | |
| Size | 7,652 x 8,022 |
| Coordinate system | WGS 84 / UTM zone 15N (EPSG::32615) |
| **Reconstruction parameters** | |
| Source data | Dense cloud |
| Interpolation | Enabled |

| | |
|---|---|
| **General** | |
| Processing time | 1 minutes 2 seconds |
| Software version | 1.5.2.7838 |
| **Orthomosaic** | |
| Size | 18,559 x 18,343 |
| Coordinate system | WGS 84 / UTM zone 15N (EPSG::32615) |
| Colors | 3 bands, uint8 |
| **Reconstruction parameters** | |
| Blending mode | Mosaic |
| Surface | DEM |
| Enable hole filling | Yes |
| Processing time | 9 minutes 6 seconds |
| Software version | 1.5.2.7838 |
| **Software** | |
| Version | 1.5.2 build 7838 |
| Platform | Windows 64 |