STATE OF COLORADO

Simmons - DNR, Leigh <leigh.simmons@state.co.us>

REQ for Assist

Simmons - DNR, Leigh <leigh.simmons@state.co.us> Wed, Nov 6, 2019 at 11:13 AM
To: "Reilley - DNR, Robin" <robin.reilley@state.co.us>
Cc: Jason Musick - DNR <jason.musick@state.co.us>, "Ebert - DNR, Jared" <jared.ebert@state.co.us>, Susan Burgmaier - DNR <susan.burgmaier@state.co.us>

Apparently some of the pictures were lost during conversion from Word to PDF.
Here is another copy of the document with pictures included. When I tried to resize the pictures they were lost on conversion again, so the image of the orthomosaic in particular is fairly small.

Leigh Simmons
Environmental Protection Specialist

COLORADO
Division of Reclamation, Mining and Safety
Department of Natural Resources

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1313 Sherman Street, Room 215, Denver, CO 80203
leigh.simmons@state.co.us | http://mining.state.co.us/

On Wed, Nov 6, 2019 at 8:56 AM Simmons - DNR, Leigh <leigh.simmons@state.co.us> wrote:

> Robin,
>
> Although the drone was grounded by strong winds before the planned missions were complete, we were able to collect some potentially useful data.
>
> Attached is a report with links to data stored and shared via Google Drive.
>
> Leigh Simmons
> Environmental Protection Specialist
>
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>
> On Fri, Oct 4, 2019 at 10:10 AM Reilley - DNR, Robin <robin.reilley@state.co.us> wrote:
>
>> Good Morning,
>>
>> I'm requesting Leigh's assistance for a drone reconnaissance of the Williams Fork Facility area and drainage way from the portal to the facilities. WF is in the process of recontouring the facilities area for Phase I and reestablishing a drainage way. We plan to acquire the data on Thursday 17 October 2019.
>>
>> Thank you
>> Robin
>>
>> Robin Reilley, M.S. GISP
>> Environmental Protection Specialist II
>>
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>> Department of Natural Resources

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LDSMemo_WFTopographicSurvey.pdf
1161K

Interoffice Memorandum

November 6, 2019

From: Leigh Simmons
To: Robin Reilley

Subject: Williams Fork Mine (Permit No. C-1981-044)
Topographic Aerial Survey

As you requested, I accompanied you to the Williams Fork Mine on October 17, 2019, and completed an aerial survey using an Unmanned Aerial Vehicle (UAV, or "drone"). The intention of this memo is to provide you with a summary of the procedures I followed to collect and then process the imagery, and also to provide you with access to the data products.

Procedures for the use of UAVs have not yet been formalized by the Division, although some initial testing has been completed to provide a basis from which to proceed. For this project, imagery was collected using a DJI Phantom 4 Pro. The image collection missions were programmed using the Pix4D Capture app running on a Samsung Galaxy S9+. Images were written to a micro SD card. Following the inspection the images were downloaded from the card and shared using google drive (complete metadata is automatically appended to each image).

A total of 5 flights were planned to collect 2 sets of data, based on polygons you supplied.

1. The polygon covering the portal area was approximately 10 acres. It was flown in a single mission at approximately 100m above the highest point within the polygon. 382 images were collected
2. The polygon covering the facilities area was approximately 154 acres. It was planned to be flown in four overlapping missions at approximately 150m above the lowest point within the polygon. In the event the strong winds prevented us from flying the third and fourth missions over the southern end of the polygon. 940 images were collected

All of the images can be accessed at
https://drive.google.com/drive/folders/1vGziCZdK5p6UDi1Xho88qIdjh59i12BK?usp=sharing

All flight missions were flown as "double-grid" types with a camera angle of 70°. For the portal area the image overlap was 80%; for the facilities area the overlap was reduced to 70%. I suspect that these collection settings maybe overkill, and present an unnecessarily large processing burden, however they are recommended in the Pix4D Capture app, and ensure that coverage is adequate for topographic modelling. (I am continuing to refine data collection procedures in an attempt to strike a balance between "too much" and "not enough").

A set of 10 Propeller Aeropoints were distributed around the survey area to act as ground control points (GCPs). Aeropoint data was processed using the Propeller Correction Network, and was projected in:

- Coordinate System: **EPSG 6342 - NAD83(2011)/UTM zone 13N**
- Vertical Datum: **NAD83(2011) (Ellipsoid height)**
- Measurement Unit: **Meters**

The GCP data was exported from the Propeller portal as a .csv file.

Images were processed on a 64-bit Lenovo desktop PC, with an Intel Core i7-7700 CPU and 32GB of installed RAM, using Pix4D Mapper.

Folders containing the complete processing reports and all data products are shared at https://drive.google.com/drive/folders/14QN3Ii5B0YwX7GUMHyla1b8TTvQToX9A?usp=sharing (portal) and https://drive.google.com/drive/folders/1gPNx7sL_TClUp-Am86R5fE-6Qsaa4I9E?usp=sharing (facilities).

The processing workflow was similar for both sets of data, and is summarized as follows:

1. Create a new project in Pix4D, import images using exif data to automatically set input coordinate system.
2. Define the output coordinate system to match that of the GCPs:
   - Unit: **m**
   - Coordinate System From EPSG 6342: **NAD83(2011)/UTM zone 13N**
   - Vertical Coordinate System: **Geoid Height Above GRS 1980 Ellipsoid [m] = 0**
3. Use the “Rapid/Low Res” template for initial processing to generate a Ray Cloud and an Orthomosaic preview
4. Import GCP data and mark those points using the Ray Cloud editor
5. Reoptimize the Ray Cloud to take account of the GCPs
6. Complete the second processing step to generate a point cloud using the following settings:
   - Quarter image size
   - Low point density
   - Automatic point classification
7. Check and manually correct point classification*
8. Complete the third processing step to generate a Digital Surface Model (DSM), an Orthomosaic, and a Digital Terrain Model (DTM). The DSM generation algorithm has a filter to remove noise but includes points of all classes, whereas the DTM generation algorithm uses only points classified as “ground” or “road surface” and includes a smoothing function – it represents a bare ground topographic model and is useful for generating surface contours.

*Pix4D classifies points as “ground”, “road surface”, “high vegetation”, “building” or “human made object”. The automatic classification algorithm results in many errors, which is not surprising given that the point cloud is derived from imagery rather than directly measured. When correcting errors my focus was on achieving adequate coverage of “ground” and “road surface” points, so as to optimize the DTM; if, for example, vegetation was incorrectly classified as “human made object” I did not necessarily attempt to correct the error

The quality report for each data set shows good coverage of the surveyed area and good image overlap. Data quality indicators are quoted to a high degree of precision in the quality report, but they should be considered as approximations since each value is derived in part from the ground sampling distance (GSD) which is itself an approximation since the drone flew at a constant elevation while the elevation of the ground surface varied.

Table 1: Summary of data quality indicators

	Portal	Facilities
Ground Sampling Distance	3.7 cm/pixel	4.16 cm/pixel
Average Point Density	11.89 points/m^3	7.1 points/m^3
DSM/Orthomosaic Resolution	4 x GSD (≈15cm/pixel)	4 x GSD (≈16.6 cm/pixel)
DTM Resolution	5 x GSD (≈18.5cm/pixel)	5 x GSD (≈20.8 cm/pixel)

The DSM, Orthomosaic and DTM are GeoTIF files. They can be imported into any GIS program for further analysis, and reprojected, clipped, smoothed, etc. as necessary. Thumbnail images of the data, captured in Global Mapper are presented below.

Based on my experiences from this project I will investigate mission parameters that satisfy the coverage and overlap requirements but require shorter flights and record fewer images. (Since shorter flights would have given us a greater chance of covering the whole of the Area of Interest in our short window of opportunity, and fewer images would reduce redundancy and speed up data processing). I also intend to collect some redundant GCPs that can be used to validate the final data products.

I would appreciate any feedback or comments you have.

Figure 1: Orthomosaic, showing extent of data coverage

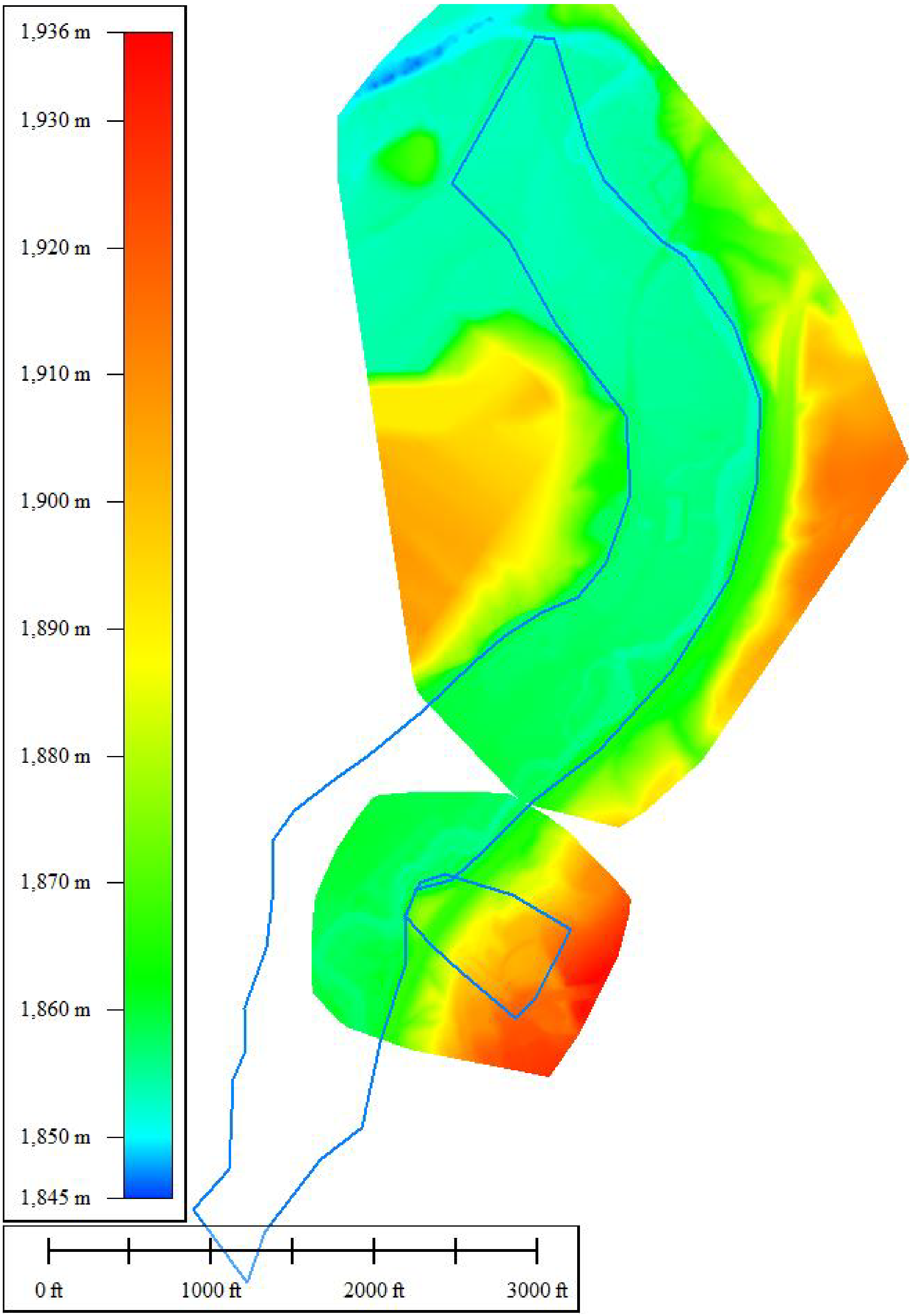

Figure 2: DSM/DTM, shaded by elevation

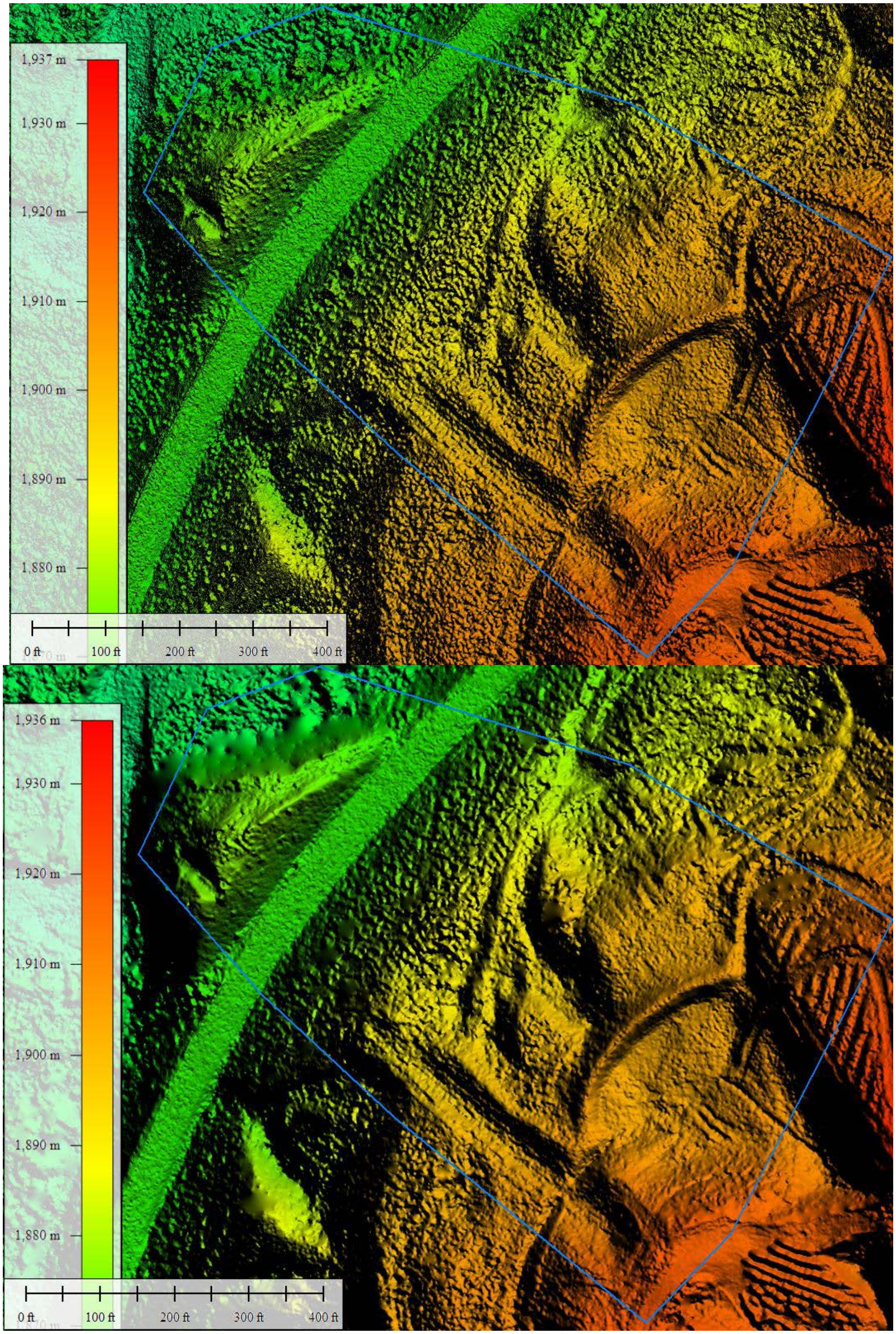

Figure 3: DSM (above) and DTM (below) zoomed on portal area, with hillshade