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

Interoffice Memorandum

June 21, 2019

From: Leigh Simmons
To: Zach Trujillo

Subject: **Colowyo Mine (Permit No. C-1981-019)**
SL-15 Aerial Survey

As you requested, I accompanied you on the SL-15 partial phase I bond release inspection at the Colowyo Mine on June 12, 2019, and completed an aerial survey of the areas where bond release had been requested 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 present some analysis of 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 6th generation Apple iPad. Images were written to a micro SD card. Following the inspection the images were downloaded from the card and shared with the operator using google drive (complete metadata is automatically appended to each image). Anyone may view the files using the following link:
https://drive.google.com/open?id=1hEJ7FGHdKZpIpWZywzE4oyda4pVVKzVA&authuser=leigh.simmons@state.co.us&usp=drive_fs

A total of 6 flights were required to collect 3 sets of data:

- Colowyo1, covers the 4 parcels to the west, including the A-A' cross section. It comprises 193 images, recorded using 2 flights. A set of Propeller Aeropoints were distributed around the area to act as easily identifiable locations whose position is known to a relatively high degree of accuracy (Ground Control Points, or GCPs). The Aeropoint data was processed using the Propeller Correction Network; the corrected point locations were reported by Propeller to ~1cm accuracy in the X, Y and Z dimensions. These GCPs can be used during image processing to constrain the model produced and to accurately locate it on the Earth.
- Colowyo2 covers the 13.9 acre parcel, including the B-B' cross section. It comprises 68 images recorded in a single flight. No GCPs were used.
- Colowyo3 covers the Gulch A Ditch. It comprises 222 images, recorded using 3 flights. No GCPs were used.

All flight missions were flown as "double grid" types (which is recommended when collecting data to be used for 3D modelling). Similar collection settings were used for each mission:

- Altitude = 190m above approximate mid-point ground surface elevation of surveyed area
- Camera Angle = 70°
- Image Overlap = 70%

Images were processed on a 64-bit Lenovo desktop PC, with an Intel Core i7-7700 CPU and 32GB of installed RAM, using Global Mapper v20.1 (specifically the Pixels to Points tool, which is part of the LiDAR module).

The processing tool was configured to generate a point cloud, a 2D orthoimage, and a 3D mesh.
A standard 3x3 resampling filter was applied to the orthoimage to remove noise.
Image sizes in Colowyo2 and Colowyo3 were reduced by a factor of 2, and images sizes in Colowyo 1 were reduced by a factor of 4 – this was to enable faster processing and mitigate issues with memory requirements.
An incremental analysis method was employed, which treats each image in sequence and is recommended as the default option.

There were complications using the GCP data with the Colowyo1 data set, caused by a memory issue which prevented acceptable model convergence (I think the root cause was a conflict between coordinate systems). I will continue to investigate this issue, but the data presented here **does not** use the GCPs.

Processing used ~100% of the CPU, and took between 20 minutes and 1 hour 40 minutes for these data sets. Mean fit errors based on the position recorded by the drone GPS sensor were between 4 and 6 meters, which is acceptable. All figures are exported directly from Global Mapper, with the data projected in UTM Zone 13N, using the NAD83 datum

Figure 1 shows the 2D orthoimage of all 3 data sets combined, with polygons representing the approximate locations of the bond release parcels overlain.

Figure 2 shows projected contour lines at 25 ft intervals, with imagery removed for clarity. The contour intervals are the same as those used by Colowyo Coal Company (CCC) on the map that came in the SL15 application packet, which allows visual comparison, but it is important to note that the absolute elevation values are not directly comparable since no attempt was made to use a common datum or coordinate system.

Figure 3 shows the point cloud generated from the Colowyo1 data set, with a path profile projected at the approximate location of the A-A' transect shown on the CCC map.

Figure 4 shows the point cloud generated from the Colowyo2 data set, with a path profile projected at the approximate location of the B-B' transect shown on the CCC map.

Figure 5 shows the point cloud generated from the Colowyo3 data set, with a path profile projected along the Gulch A Ditch channel.

There are a myriad of tools available to us to (i) improve the quality of our data (for example, through using ground control points to improve precision, or filtering the point cloud to remove noise), (ii) analyze the data, (iii) visualize the data products we have produced. I would appreciate any feedback or comments you have on this project, and would be happy to work with you further to improve the project.

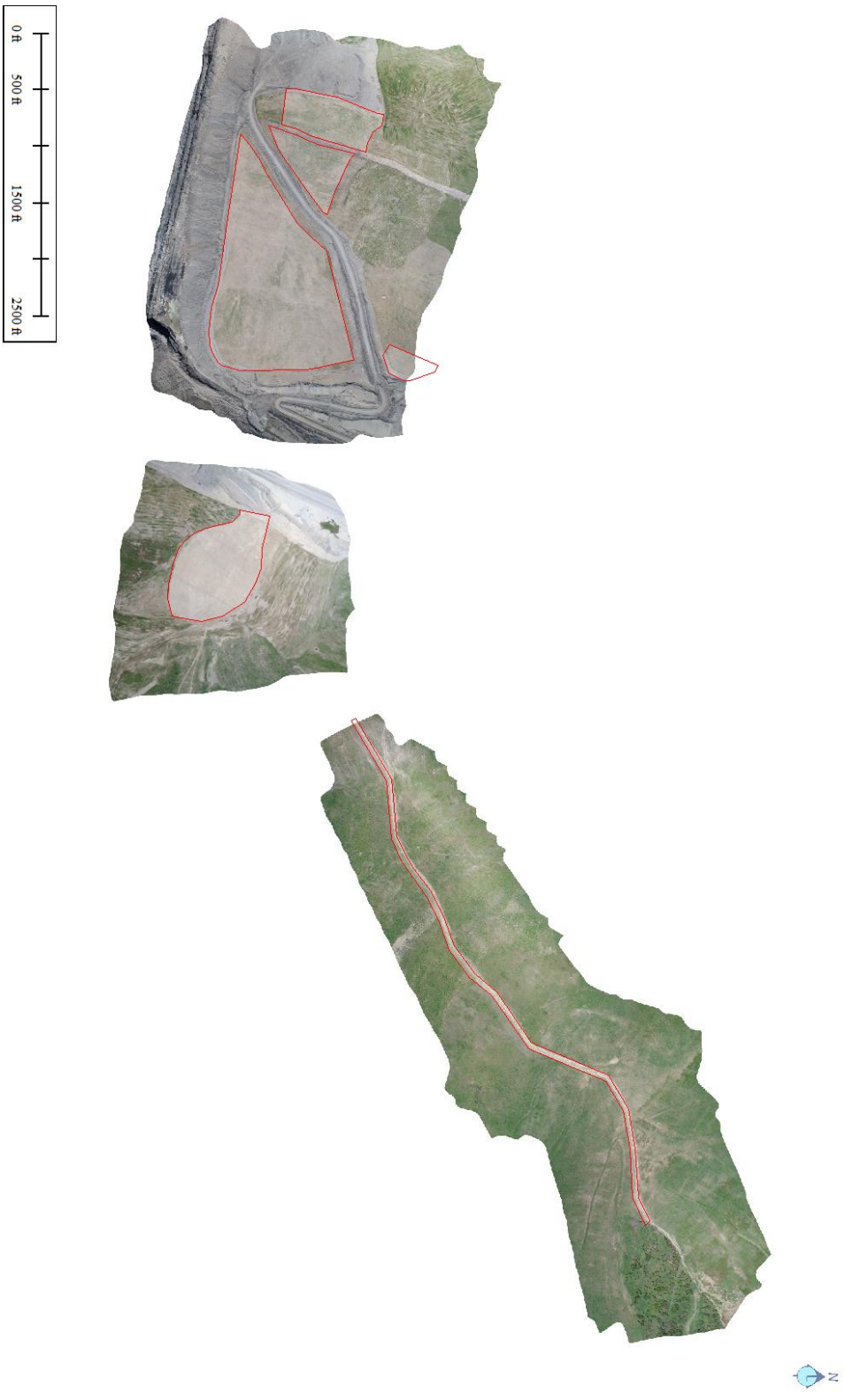

Figure 1: Orthoimage with approximate SL15 parcels

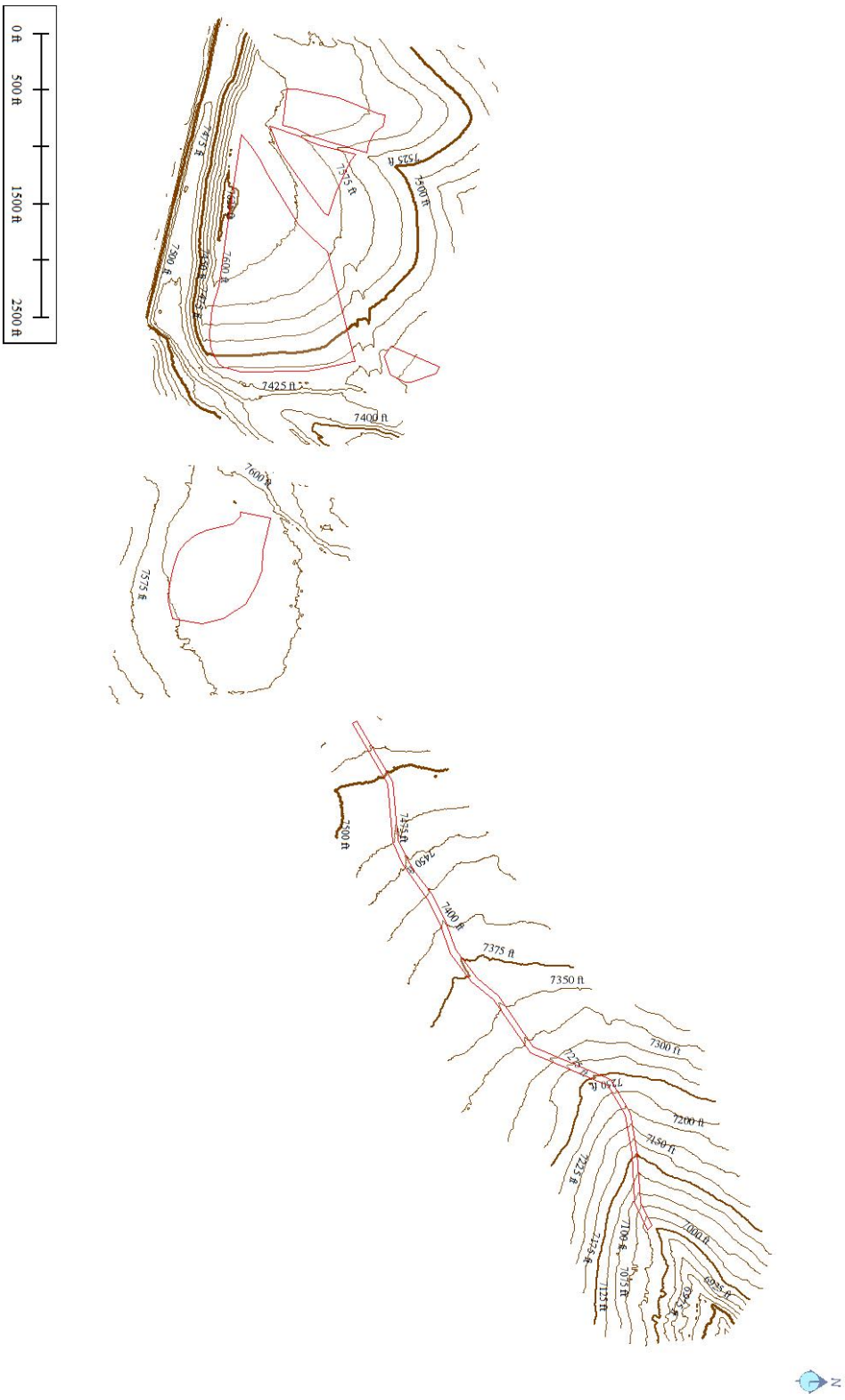

Figure 2: Projected contour lines, 25ft intervals

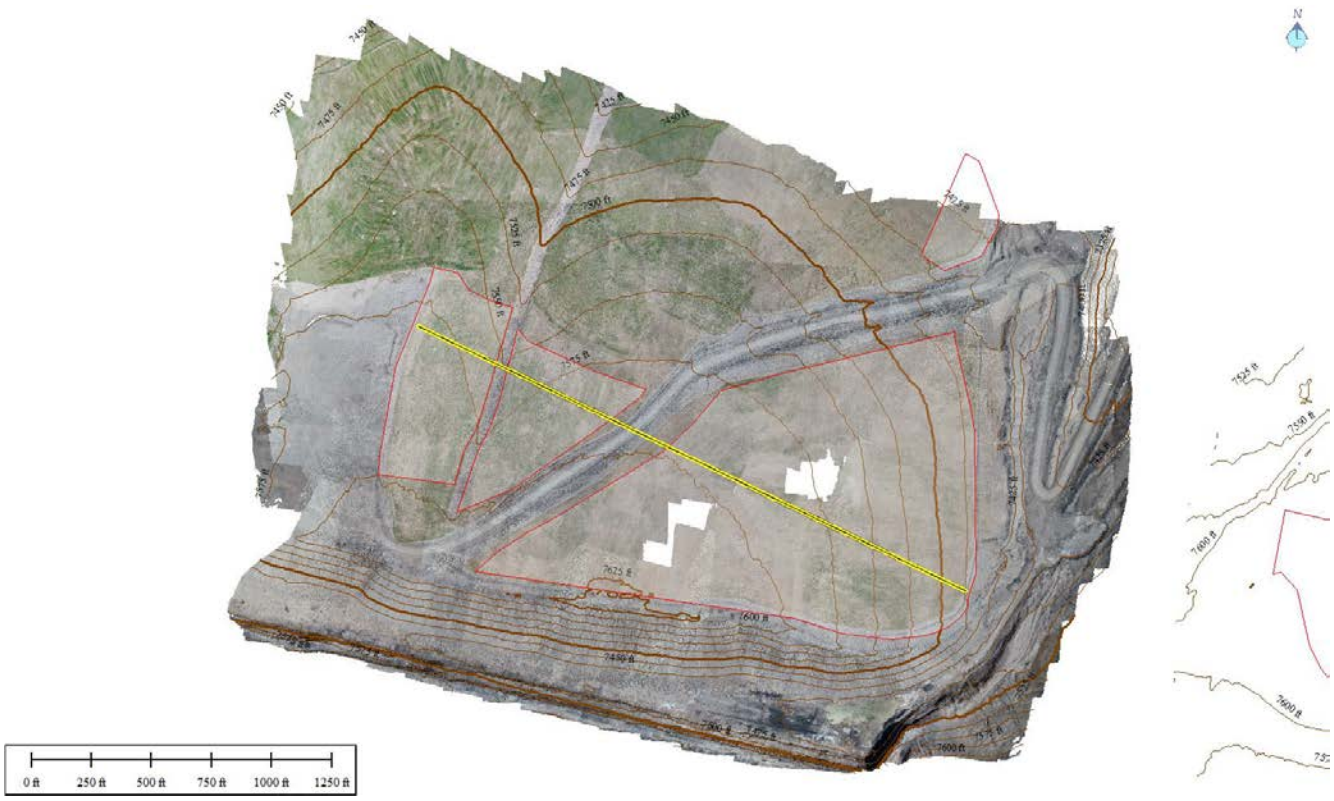

Figure 3: Path profile in approximate location of A-A'

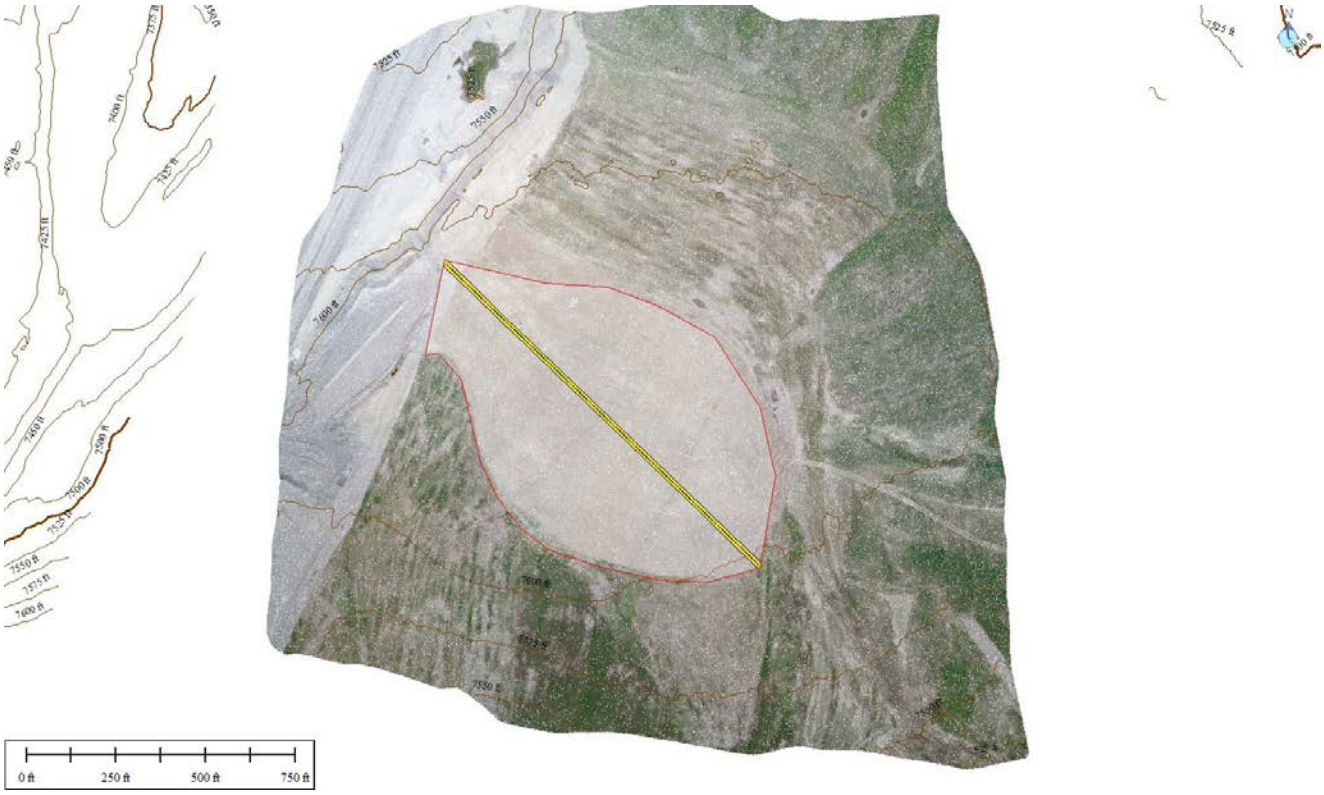

Figure 4: Path profile at approximate location of B-B'

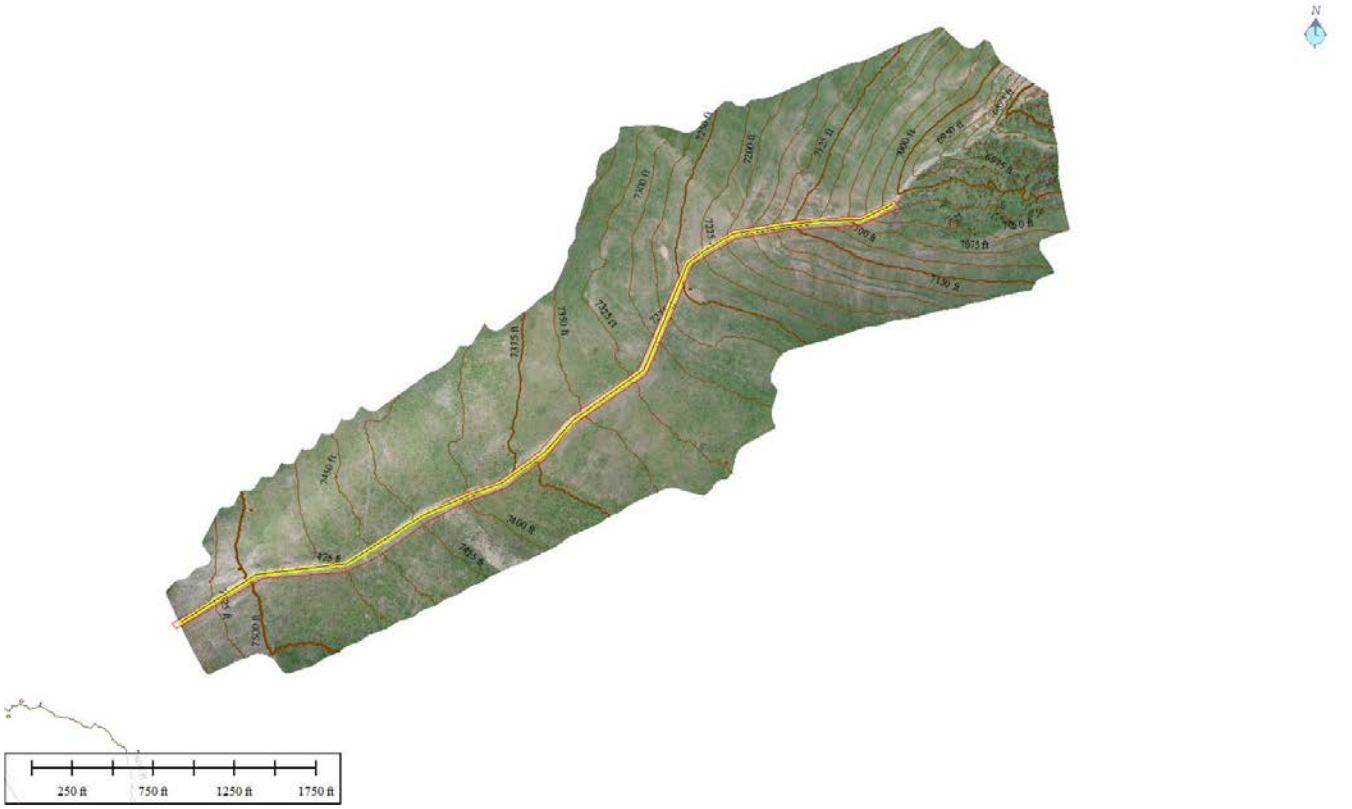

Figure 5: Path profile along Gulch A Ditch channel