UNMANNED AERIAL SYSTEMS FOR RESOURCE MANAGEMENT
Highwood River Cliff Site - 2019

Introduction

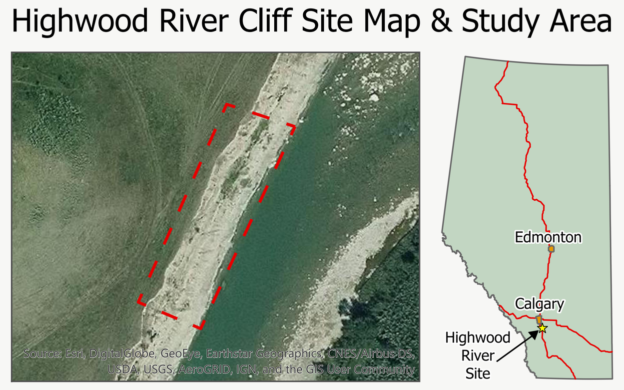
This project was assigned to us by the Centre for Innovation and Research into Unmanned Systems (CIRUS) at SAIT. The aim was to create a professional stratigraphic assessment product with repeatable workflows and end to end processes, which could help geologists correctly and accurately classify stratigraphic geologic formations for workers out in the field.

We utilized UAS technology for data aquisiton. Three flight missions were undertaken so as to test the reconstruction accuracy that would produce the best visual output for stratigraphic classification and geological formation analysis.

The data was processed with PIX4D mapper and then integrated into ESRI based formats. From there the UAS output data was converted into a format that doesn't require any specialized geospatial software knowledge by the end user. For that purpose, we created a user friendly web mapping application in ArcGIS Online.

To this end, we created a 3D model of the cliff face at a site along the Highwood River southeast of Calgary that would serve as a proof of concept that could be applied to other sites that needed stratigraphic classification in the future.

Highwood River Cliff Site Map & Study Area



Goals and Objectives

Goals

- Integrate repeatable UAS data gathering and data analysis processes
- Improve cost and time efficiency of mining assessments
- Empower geologists to make decisions
- Quickly get the results to the site operational extraction team

Objectives

- UAS Data Capture
  - UAS Flight Plan
  - Collector Form
- PIX4D Data Transformation
  - Orthophoto Raster
  - DTM, DEM, DSM Raster
  - 3D Point Cloud LAS file
- Studies & Analysis
  - Stratigraphic Classification
- Output
  - ArcGIS Online and Web Mapping Application

Methods

Data Capture Stage

Flight Planning & Collector App

Data Processing & Analysis Stage

Process Collected Data

ESRI Stage

Import into ESRI

Web Stage

Release App

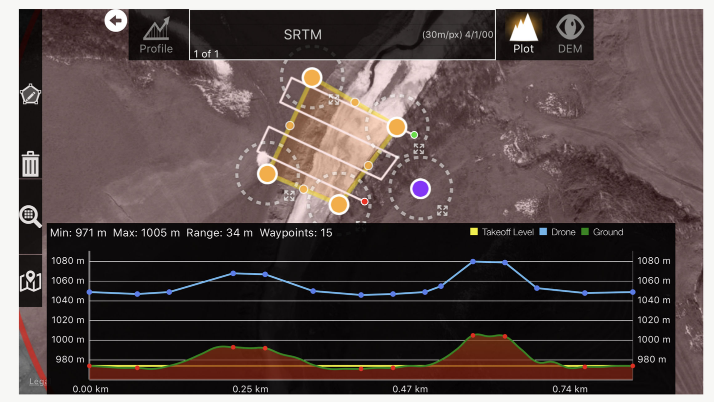
Date: August 1, 2019
Projection: Transverse Mercator
Cartography: Martinus McEachern
Source: CIRUS Labs & ESRI Basemaps
Danny Wong, Oladipupo Olatunbosun, & Martinus McEachern

Data Capture

Applied Research

- Nadir flight captures overhead view
- Oblique view helps with changes in elevation and produces the most accurate 3D model
- A combination of these drone techniques help with the edge definition on cliff faces
- We propose three drone flights be undertaken using Map Pilot to plan out the mission and Arc Collector to highlight any hazards around the site

Map Pilot Flight Plan



Conduct Three Drone Flights

- Flight #2 had a Nadir View and is most appropriate for the Orthomosaic, DSM, and DTM computation
- Flight #3 had an Oblique View and was used to highlight the elevation of the hill and the texture of the surface
- Flight #4 had an Oblique View and was used to highlight the detailed texture of the cliff surface

Flight Line with Geotagged Images

Data Processing & Analysis

PIX4D Processing Steps

Step One — Automatic Tie Points Generation → **Step Two** — Manual Tie Points Generation → **Step Three** — Point Cloud Data Generation → **Step Four** — 3D Textured Mesh Generation

Keypoints were computed and used to determine Matching Points between images. The Matching Points in conjunction with the Automatic Aerial Triangulation and Bundle Block Adjustment were used to produce the Automatic Tie Points.

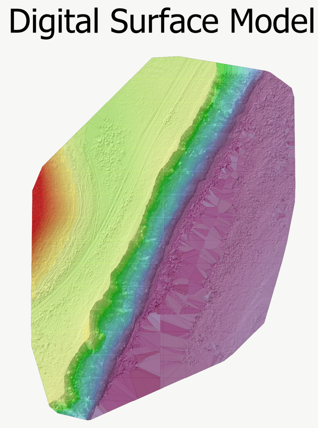
Manual Tie Points represent 3D points corresponding to keypoints that were created on the images and were used to improve the reconstruction accuracy of the model. For our project we used three manual tie points to combine the different flights missions and calibrate the images before optimization.

The densified point cloud was computed based on the automatic tie points of the intial step. The densified point cloud is a representation of 3D points that reconstructs the model and contains X, Y, & Z position and colour information for each point. It also serves as a background for surface measurement and volumetric analysis.

The 3D textured mesh was created and is a representation of the shape of the model, which consists of vertices, edges, faces, and the texture from the images that were projected on it. The point cloud was used to generate the 3D textured mesh, which is a surface composed by triangles.

Data Outputs

Digital Surface Model

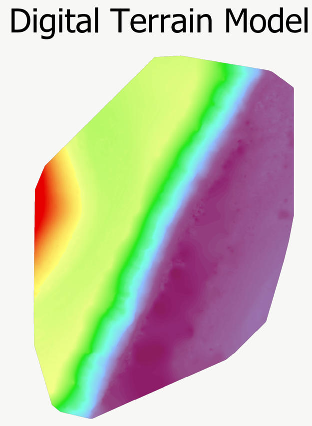


For every X and Y position, the DSM has only one Z value, which is the highest altitude of each point in the point cloud. This Z value makes the DSM a 2.5D model. It enables the computation of volumes, the orthomosaic, and the reflectance map.

Combined Orthomosaic

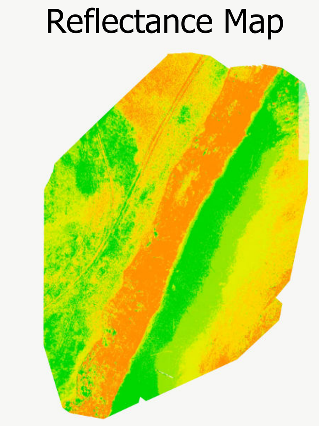
The orthomosaic was generated based on orthorectification and used the DSM to remove perspective distortions from the images. Distances are preserved within the model thereby making it reliable for measurement.

Digital Terrain Model



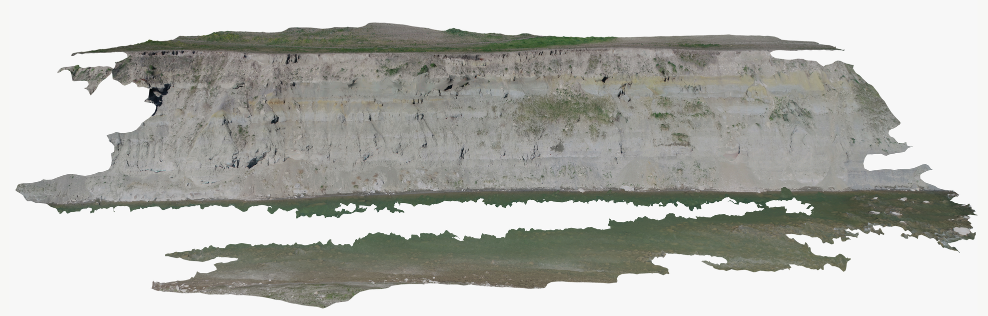
The DTM only considers the points and altitude that correspond to the terrain and ground. It was generated based on the DSM and only considers the terrain/ground altitude. The DTM serves as a basis for stockpiling and volumetric measurements.

Reflectance Map



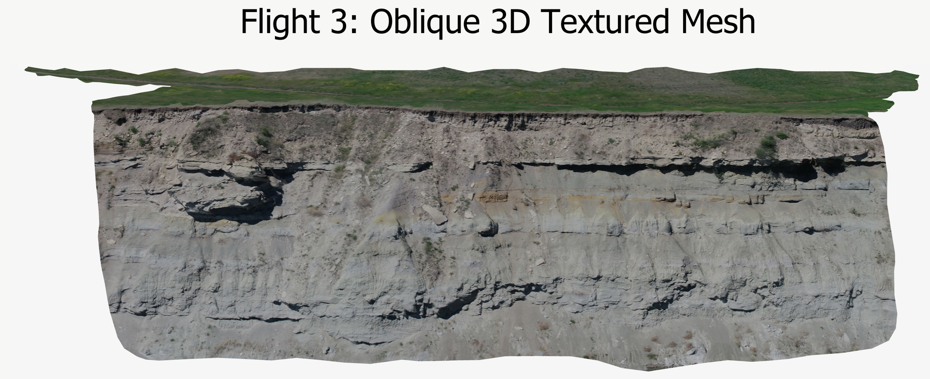
The reflectance map contains the values of each pixel and is measured in wavelengths. The goal is to produce a map where each pixel value faithfully indicates the reflectance of features.

Flight 2: Nadir 3D Textured Mesh



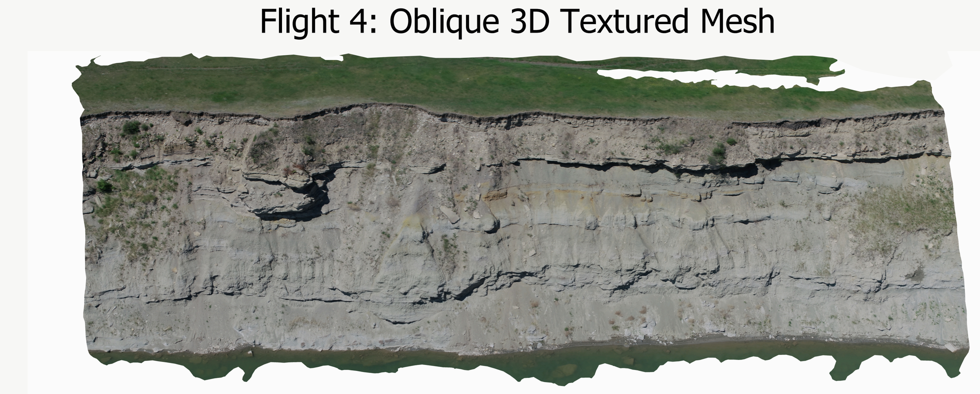
A 3D model based on flight 2. It shows some generalization of the cliff surface thereby indicating a less accurate 3D model. The elevation of the hill was also not taken into consideration in this model.

Flight 3: Oblique 3D Textured Mesh



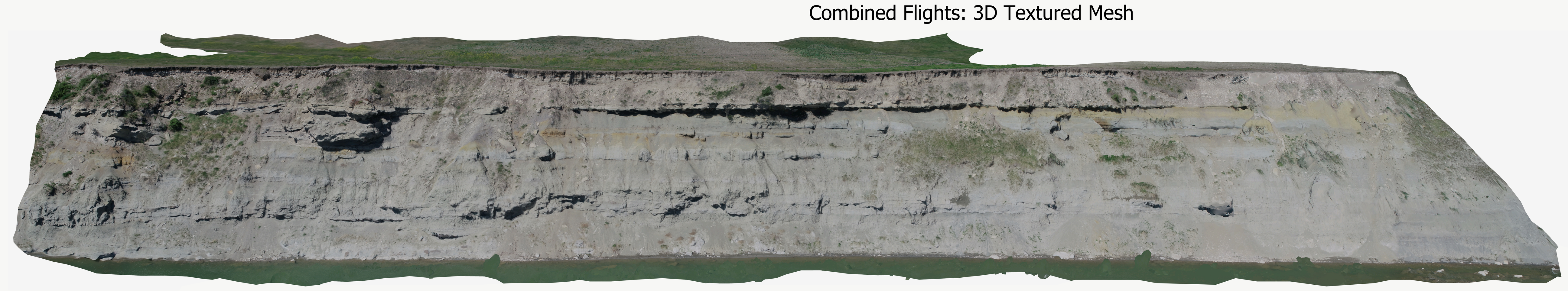
A 3D model based on flight 3. It takes into consideration the elevation of the hill and the cliff surface was accurately detailed. It gives the best and most accurate reconstruction of the Highwood River Cliff Site.

Flight 4: Oblique 3D Textured Mesh



A 3D model based on flight 4. It intentionally disregarded the hill to focus solely on the cliff surface. It therefore produces the most detailed representation of the cliff surface.

Combined Flights: 3D Textured Mesh



A 3D model based on Fight 2, 3, and 4. It is an accurate representation of the cliff surface and the hill behind the cliff. It also shows in detail the texture of the cliff surface and the changes in terrain and elevation. This 3D model provides the most accurate reconstruction, which the geologists can use to accurately carry out geological formation analysis including stratographic classification, sedimentation determination, elevation profiling, and break line insertion.

Validation Techniques

Validation techniques used in our project include developing an in-depth understanding of the files included in a PIX4D output. Since PIX4D creates the same series of folders when an output is run, understanding these folders helps us understand the entire process. Understanding the content of each folder and its structure, we can see if we are missing data or require further analysis. Also, PIX4D provides a report that goes through the analyzed images, highlighting quality checks and calibration details. It can help us see if all the images are properly geolocated and the level of uncertainty for each ground control point.

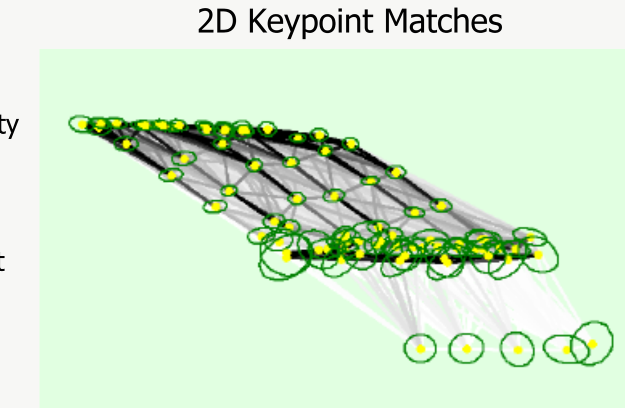
2D Keypoint Matches Image

The 2D Keypoint Matches image shown on the right links between matched images. Therefore if we see darker links between the keypoints we can validate that our data is accurate.

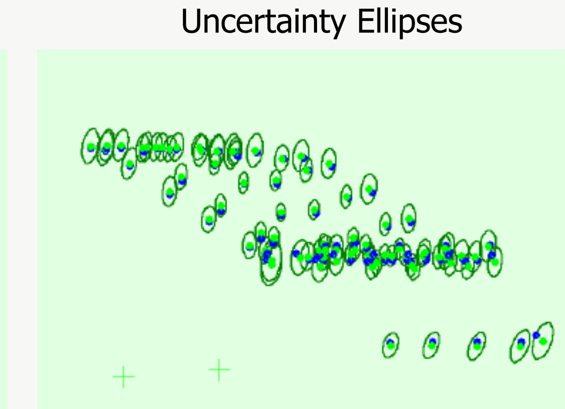
Uncertainty Ellipses Image

With the Uncertainty Ellipses image shown on the far right, we see the offset between the intial (blue) and computed (green) image positions. If the ellipses between the two are small, denoting the blue and green dots are close together, we can validate that our 3D reconstruction will be accurate.

2D Keypoint Matches



Uncertainty Ellipses



ESRI Stage

Importing into ArcGIS Pro

A python script was used to automate the creation of the geodatabase and the importing of files into it. Three raster datasets were created and then the DSM, DTM, and Orthomosaic were imported into them. A LAS dataset was created and populated with the point cloud data. This was then converted into a Scene Layer Package (.slpk) format. A Layer of Display (LOD) Scene Layer Package integrated 3D mesh was created to support the 3D mesh outputs in the ArcGIS Pro Scene environment.

Importing into ArcGIS Online

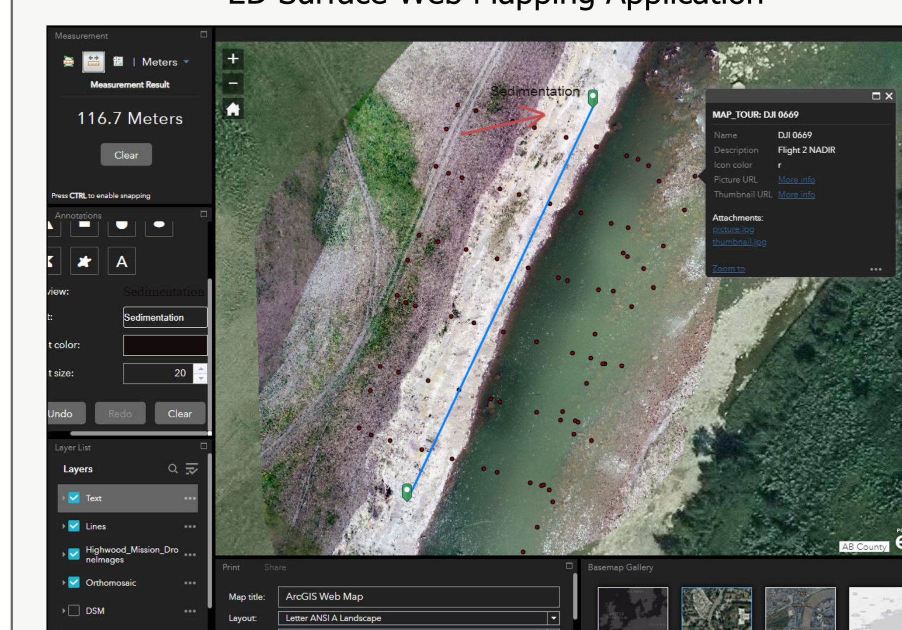
The 2D raster surfaces were converted to KML using the Layer to KML tool. Thereafter, they were registered in ArcGIS Online as hosted feature layers that were then viewable in the web viewer. The 3D meshes were already in .slpk format which is recognized by ArcGIS Online. These were hosted as a web scene layer and then they were viewable in the web scene environment.

Importing into ArcGIS Enterprise

The contents of our geodatabase was imported into our predefined SDE on the server. The files still retained the structure of the GDB, but are now hosted on the server. From there they could be accessed by online applications instead of hosted by ArcGIS Online.

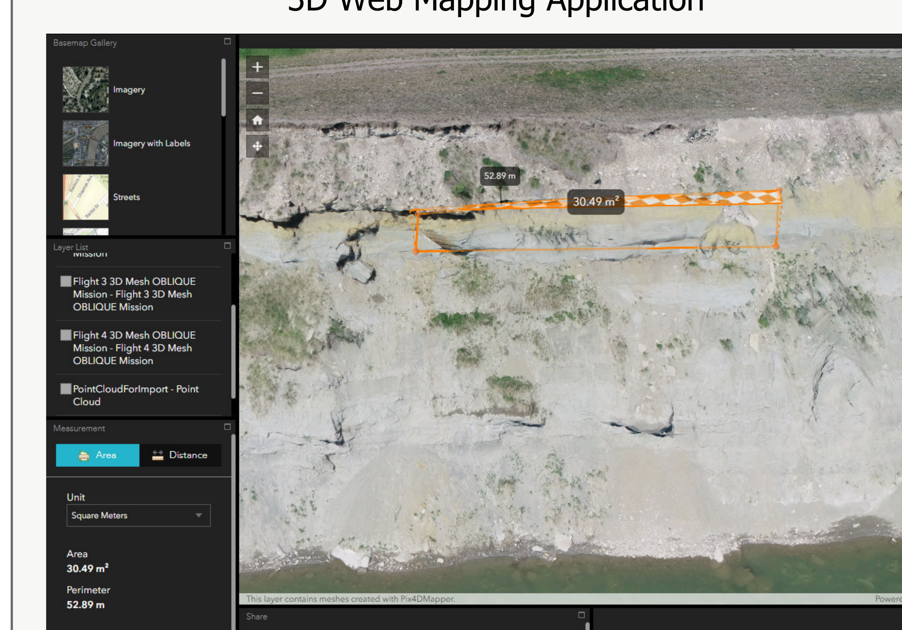
Web Applications

2D Surface Web Mapping Application



In the 2D surface web application seen above, we incorporated the measurement, annotations, layer list, print, share, and base map gallery widgets. The annotations were necessary to enable geologists to make notes on the imageries and share those same notes with other employees.

3D Web Mapping Application



For the 3D web mapping application seen above, we included the measurement, layer list, print, share, and base map gallery widgets. We could not include an annotation widget, which hinders the usefulness of the app to geologists using it for stratigraphic assessment as they could not annotate the layers for the field staff to read.

Conclusion

At the end of the project we had satisfied our client's needs of creating a repeatable workflow with processes that can be replicated on other sites. Our final outputs were easy to use web mapping applications that allow for stratigraphic assessment of cliff faces and can be used by geologists to better communicate their plans to workers in the field.

Some constraints we ran into included the limitations with ArcGIS Online 3D web mapping applications as stated above. As well, our initial plan to integrate our 2D and 3D web applications into a single web mapping application was unacheiveable in ArcGIS Online.

For future study we believe it would be beneficial to develop repeatable workflow and processes to streamline volumetric data assessments. As well, we would be interested in importing this data into a 3D mining centric modelling application for further analysis and study.