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EVALUATION OF A LOW-COST DRONE FOR MONITORING RESTORATION OF WELL PADS

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Abstract: Oil and gas development activities disturb the land surface at well pads. These sites must be restored upon decommissioning, and this process takes several years to accomplish. Using drones to assess restoration of well pads can be more efficient and provide better data compared to manual inspection at the ground surface. Fieldwork was conducted in 2017 to evaluate the use of a small, low-cost drone for measuring and assessing reclamation at four well pads on crown land near Hudson's Hope, BC. These sites had an "abandoned" status for one year, were under the same operator, and had not yet received a Certificate of Restoration. This paper presents the results of the investigation and discusses the advantages and limitations of using drones for reclamation assessment purposes.

1 INTRODUCTION

Well pads used by the oil and gas industry must be restored to natural conditions when the sites are abandoned. This paper documents the evaluation of a small, low-cost drone for measuring and assessing the state of reclamation on well pads located on crown land near Hudson's Hope, British Columbia. A drone was flown over well pads to take a series of aerial images. The images were then used to evaluate the state of land disturbance and restoration activities under natural field conditions. The approach used in this research was to use the aerial images supplemented with field observations and photographs taken at the ground surface to characterize as many aspects of restoration as possible.

Four well pads were flown in July and again in September 2017. Three sites (well pads 1, 2, and 3) were clustered close to each other approximately 8 km west of Hudson's Hope. The fourth site (well pad 4) was located 7.4 km northwest of Hudson's Hope. These sites were accessible by road, with no gates. All sites are located in the BWBS biogeoclimatic zone (Boreal White and Black Spruce). Because of its location east of the Rocky Mountains, this region experiences a cold, humid continental climate similar to that of the Canadian Prairies.

2 DRONE AND FLIGHT PLANNING

A small, low-cost drone was used to acquire the aerial images. A DJI Phantom 4 Pro drone (Figure 1) was selected because it can be easily carried to the site and rapidly deployed. Furthermore, this drone model carries a relatively good camera with a mechanical shutter. At the time of its purchase in the summer of 2017, this drone cost $2100 plus taxes. An extra battery and larger capacity microSD card were also purchased for another $300 plus taxes. The selected drone has a practical flight time limit of 20 minutes. One well pad of a size limited to about 6 ha could be safely flown using a single fully charged drone battery.

Several factors affect battery usage, including flight length, average drone speed, temperature, flying in manual control versus automated flight paths, and wind speed and variability.

Figure 1: DJI Phantom 4 Pro drone (DJI 2017)

Different flight plans were used at the well pads. In most cases, the drone was pre-configured to fly a grid pattern under autonomous control. All flight paths specified a drone height of 50 m above ground. This height was selected as a compromise between battery life, number of acquired images, and ground pixel resolution. The images were taken with a 80% overlap. For these cases, PixCapture software was used to set up each flight plan. Details from the September flights are provided in Table 1. An example of a grid flight path flown over well pad 4 is shown in Figure 2.

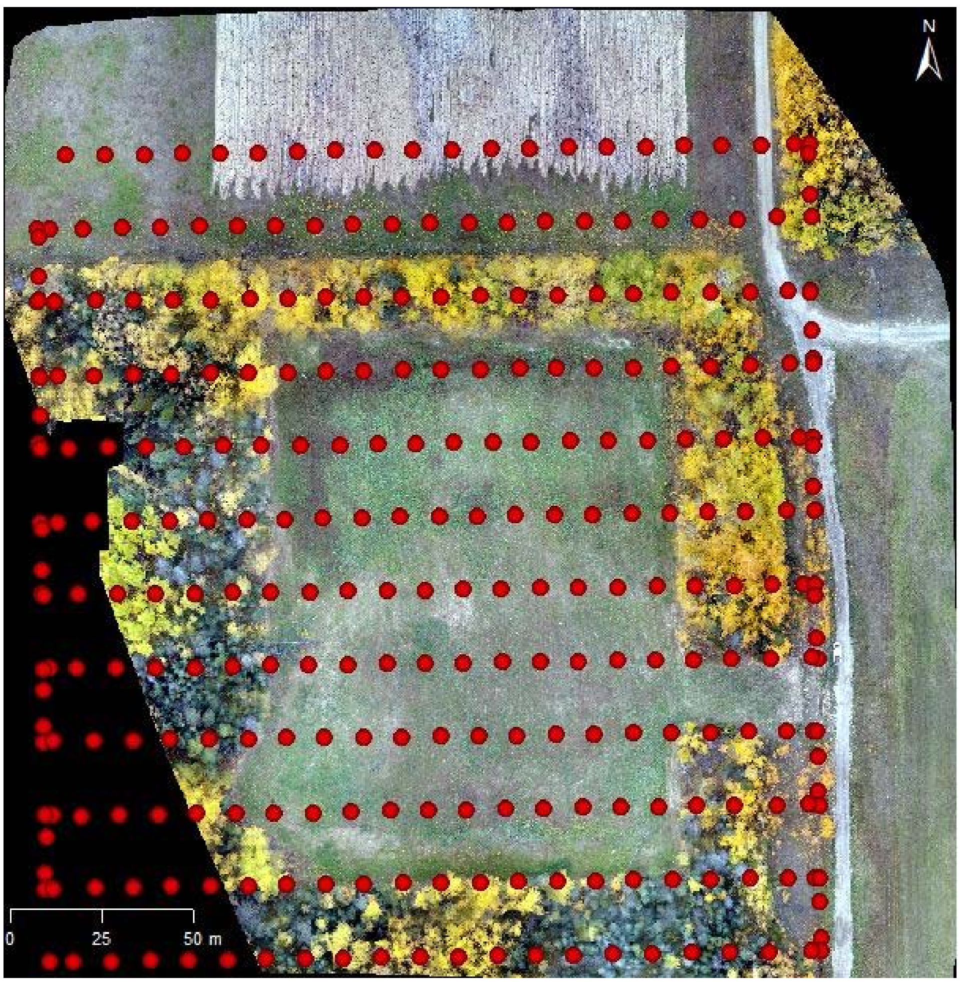

Figure 2: Flight path showing camera location for each photo taken in a grid configuration over well pad 4

Table 1: September flight details

Well Pad	Area Covered (ha)	Average Speed (m/s)	Flight Duration (mm:ss)	Images Taken	Processing Time (h:mm:ss)	Points in Point Cloud (millions)
1	3.26	2.87	13:10	250	4:11:02	25.4
2	3.07	2.92	04:02* 06:19* 01:33*	204	2:04:40	14.5
3	3.83	2.98	09:50	183	1:54:39	13.2
4	5.91	2.43	15:44	296	2:49:25	26.3

*Well pad 2 was flown in 3 separate flights

3 STRUCTURE-FROM-MOTION PHOTOGRAPHIC ANALYSIS

The images from each flight were loaded into Pix4D version 4 (Pix4D 2017) structure-from-motion software for processing to create large point clouds and generate orthomosaics, contour maps, digital surface models, and other outputs. The points were georeferenced using the drone’s built-in GPS; no ground control points were used. While the UTM Northing and Easting coordinates are likely within a few metres of accuracy, the elevation values associated with the point cloud could be off by 10s of metres. However, the relative coordinates of the points within the generated point cloud provide a more reliable and useful measure with accuracies estimated to be within a range of 0.1 m.

Depending on what outputs are generated and which settings are selected, processing of the acquired images for one well pad in the structure-from-motion software can take many computer hours. These times were obtained when the computer was dedicated to running only one model. The image processing was performed on a desktop computer with an Intel Xeon® ES 1607 V3, 3.7 GHz quad-core processor with 64GB RAM and Nvidia® Quadro K2200 GPU.

The photographs were taken at an ISO setting of 100. The camera has a 1” CMOS sensor, and the image sizes are 5472x3648 pixels. Each model was run with an image scale of one half (default), and points were set to have a minimum of 3 image matches. The contours were generated at 10 cm resolution and 25 cm intervals. To generate the digital surface model (DSM) and the orthophotographs, the pixel size was set to the default setting of 1xGSD, where the GSD is the average ground sampling distance, which was 1.3 cm for these models.

4 CERTIFICATE OF RESTORATION REQUIREMENTS

Version 1.2 of the BCOGC Certificate of Restoration Application Manual (BCOGC 2016) lists the site reclamation objectives for well pads. To assess the capabilities and limitations of the drone for evaluating reclamation, the objectives were summarized into the following five criteria that were used to analyze reclamation at each of the well pads.

4.1 Geotechnical Stability

There should be no visible slope movement, slumping, subsidence, or tension cracks on the well pad surface. On-site cut and fill slopes should be stabilized.

4.2 Land Use and Facilities

Any facilities remaining from oil and gas development activities should not affect the natural drainage or slope of the area. There should be no gravel or rock piles or windrows. There should be no industrial debris or woody debris interfering with reclamation efforts.

4.3 Vegetation

There should be no prohibited nuisance weeds and no infestation of any particular species on the well pad. There should be an even distribution of vegetation density with no bare areas, and a sustainable, intentional plant community growing such that at least 80% of the well pad surface area is covered with vegetation, as outlined in Schedule B, BCOGC Site Reclamation Requirements (BCOGC 2013).

4.4 Slope and Drainage

There should be no areas with water ponding or erosion resulting from the ground topography that would affect land reclamation. The land should be restored to the original slope of the site, or to a condition that is compatible with the surrounding landscape. Ditches should be refilled along the edges of the well pad and access routes.

4.5 Soil Replacement

Any salvaged soil that was piled on the well pad should be spread over the site. Soils that were compacted from oil and gas development activities must de-compacted to assist with plant growth. There should be no evidence of impact from adjacent land use.

5 RESULTS

The well pads considered in this study were each evaluated against the five criteria outlined in Section 4. This section focuses on the use of drone-acquired aerial images and the resulting digital outputs generated with the images to evaluate these criteria.

5.1 Geotechnical Stability

There is no visible slope movement, slumping, subsidence, or tension cracks on or around any of the well pads that were examined, and there are no remaining cut and fill slopes. These features could be easily detected from aerial images taken using the drone if they were present.

5.2 Land Use and Facilities

Approximately 40 m northwest of the well pad 2 there is a large gravel quarry. This quarry is not shown in GoogleEarth where a 2012 image was obtained, but it was detected in the aerial images taken while flying the drone over the well pad. The northwest edge of the well pad and the southeast edge of the gravel quarry are both captured in the aerial image shown in Figure 3. Some fallen trees can also be seen.

Figure 3: Aerial photograph showing edge of a gravel quarry 40 m northwest of well pad 2

Because of the trees between the well pad and the gravel quarry, this quarry is not easily seen at the ground level, and it is not shown in GoogleEarth. The quarry does not seem to affect the drainage of the well pad area. However, it is worth noting the close proximity of the quarry to the well pad. The presence of the open quarry might have contributed to blow-down of trees on the northwest side of the well pad.

Adjacent land use activities can be seen in aerial images taken by the drone over well pad 4. Approximately 25 m north of the well pad, the land is being used for farming as shown in Figure 4. The well pad is separated from the farming field by a strip of trees.

Figure 4: Strip of trees and agricultural land north of well pad 4 captured by the drone

5.3 Vegetation

Well pad 4 had an approximate surface area of 1.8 hectares in July 2017. The area of this well pad was significantly smaller in 2012 as seen in a comparison between images taken 2012 (Google Earth) and 2017 as shown in Figure 5. This well pad was expanded, likely because additional wells were drilled from the same pad.

The contrast in vegetation coverage on this well pad was significant over a two-month period. The aerial images from July and September in Figure 5 show that large areas that were sparsely vegetated in mid-summer had become better vegetated by the fall. Note that 2017 was the first summer after the well pad had been seeded.

Figure 5: Restoration progress of well pad 4: 2012 (Google Earth), July 2017, and September 2017

While plant species growing on well pads are difficult to discern from aerial images taken by a drone, it is easy to spot areas where vegetation is density or height differs. Some vegetation differences in aerial images taken over well pads 3 and 4 are shown in Figure 6. The aerial images taken by the drone over some of the well pads clearly showed evidence of fallen trees and woody debris.

Figure 6: Vegetation differences shown in aerial images over well pads 3 (left) and 4 (right)

5.4 Slope and Drainage

It is easily confirmed with aerial images taken by the drone whether drainage ditches remain at the well pads or whether they have been removed, as required in the Certificate of Restoration criteria. Drainage ditches were not present at any of the well pads examined.

The 2D digital surface model generated using point cloud data from well pad 2 shows that water could pond in a slight depression near the centre of the well pad. The area of potential ponding corresponds to an area with slightly impeded vegetation growth as seen in Figure 7. Lack of drainage from the low area may be affecting the vegetation since there is no apparent link to heavily compacted soil or any other cause. A similar trend can be found in the southwest corner of well pad 4, as shown in Figure 8.

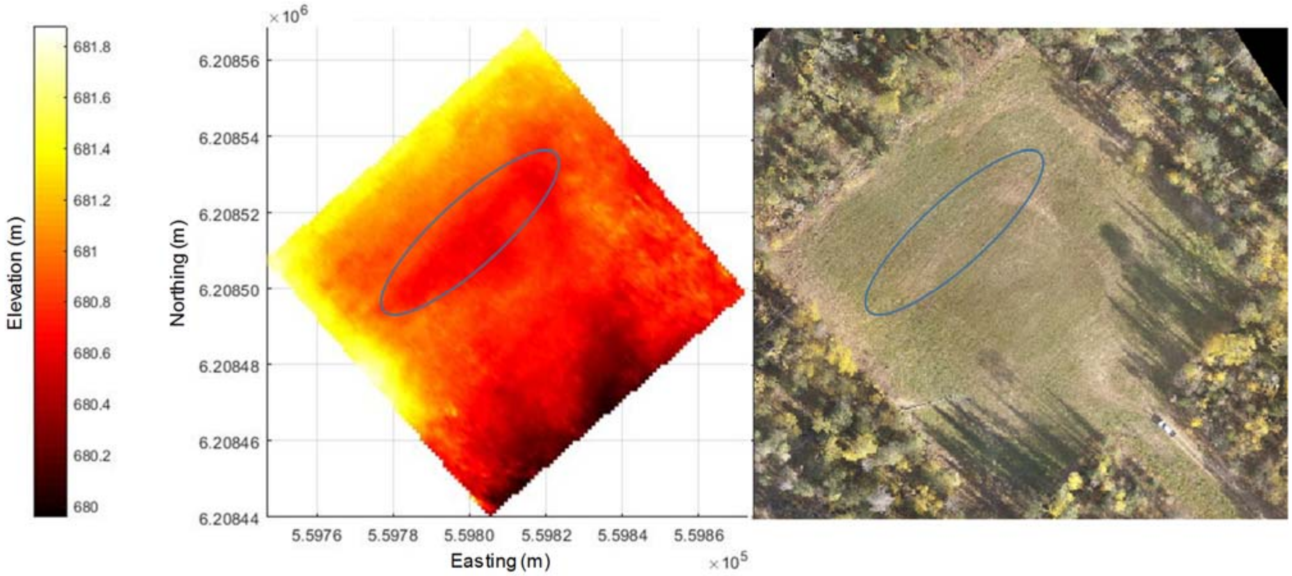

Figure 7: Slight depression and impeded vegetation growth near the centre of well pad 2

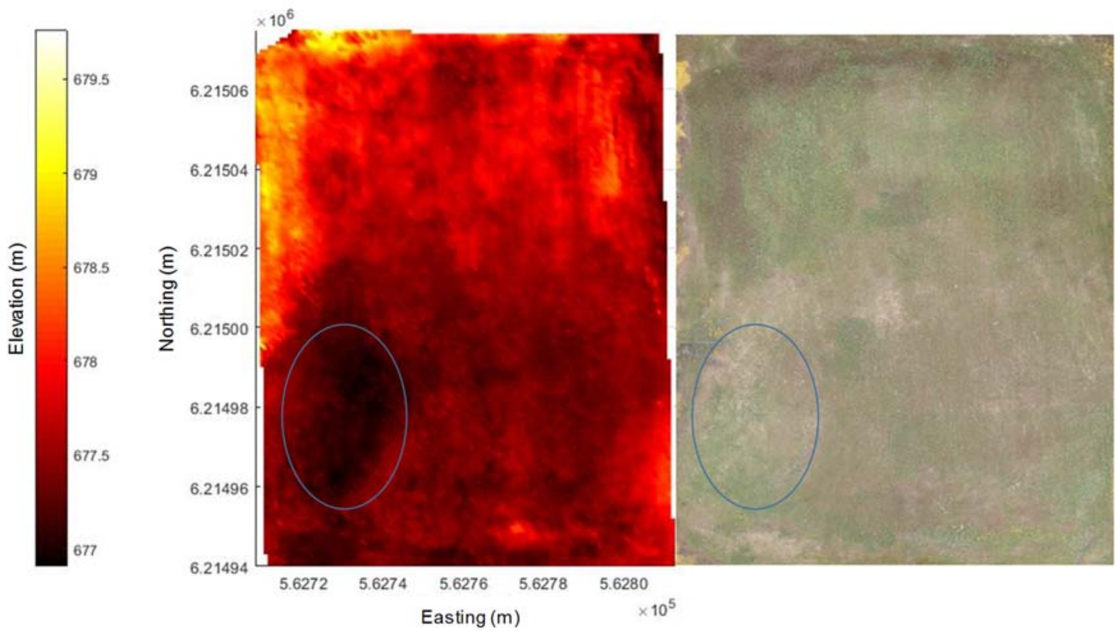

Figure 8: Potential ponding may impede growth on well pad 4

The Certificate of Restoration criteria state that drainage should be restored to the conditions present prior to oil and gas development activities taking place, or to a state that is consistent with the surrounding drainage conditions. The slopes of the examined well pads are relatively flat; they were all less than 5%.

5.5 Soil Replacement

Compaction of the soil beneath a salvaged soil stockpile that once sat on well pad 4 may be a possible explanation for the reduced vegetation along the southeast side of the well pad as seen in Figure 9. The soil pile is no longer present as it was likely redistributed across the well pad as required.

Figure 9: Reduced vegetation density where salvaged soil pile was located on well pad 1

Tire tracks were noted where vehicles have driven over the well pads after the ground surface had been prepared and seeded. There is noticeably less dense vegetation growth in these tire tracks. Soil compaction under the vehicle tires and direct damage to the vegetation is likely reducing the vegetation growth in these tracks. This is shown over well pad 1 in Figure 10. The well pads have nothing around them to restrict vehicle entry, and the access road had not been decommissioned.

Figure 10: Reduced vegetation on soil compacted by vehicle traffic on well pad 1

6 DISCUSSION

Obtaining aerial images of the heavily forested areas surrounding the well pads using the drone enables detection of surrounding land uses that are difficult to see through the trees from ground level. The gravel quarry northwest of the well pad 2 and the agricultural lands north of well pad 4 were noted in the aerial photos. The ability to see adjacent land uses and their location relative to the well pad can give insight as to whether these land uses are impacting reclamation practices.

There does not seem to be a direct correlation between where various equipment or the wells were located on the well pad and vegetation growth. However, vegetation growth does appear to be affected where salvaged soil was piled on the well pad. It can be inferred that the salvaged soil was redistributed over the well pads as soil piles are no longer present. However, the soil compacted from being beneath the piles of salvaged soil may not have been fully de-compacted, and soil compaction does impede vegetation growth.

For the four well pads flown in both July and September of 2017, the contrast in vegetation coverage over this two-month period is significant. In September, the well pads had fewer bare areas and more uniform vegetation as emphasized in the orthophotographs. Photographs taken at ground level can supplement the aerial images regarding what specific plant species are present. Knowing the composition of the seed mixtures planted on these well pads for reclamation purposes would be useful in determining whether the intended plant community is growing and if undesirable plant species are present.

When the structure-from-motion software generates a dense point cloud, the 3D coordinates include all features captured in the aerial images. Therefore the contour plots and surface models may not be representative of bare-earth topography and can be affected by variance in the vegetation height. To create detailed topographic maps, well pads should be flown once reclamation activities have been completed, and before vegetation begins to grow. Later flights could then assess the vegetation growth on the well pad. The point cloud data appropriately captures the surface topography when there is bare earth and in early stages of vegetation growth. However, once shrubs and trees begin to grow on the well pad and the vegetation density and height varies across the well pad it becomes more difficult to generate a DSM that represents the bare earth conditions for analysis of drainage and slope. At these later stages of reclamation the orthomosaics alone may be a more reliable indicator stage of restoration.

7 CONCLUSIONS

For the four well pads included in this study, the drone was flown at a 50 m height above ground using preset autonomous grid patterns. The aerial images captured by the drone were used to assess the requirements for a Certificate of Restoration for the well pads, including geotechnical stability, land use and facilities, vegetation, slope and drainage, and soil replacement. With photogrammetry software and post-processing of the point cloud data, the imagery can be used to identify several quantifiable features, including the health and uniformity of vegetation coverage and occurrence of bare areas, the magnitude and direction of the slope and areas of potential ponding, whether salvaged soil has been redistributed across the well pad, appearance of debris or fallen trees, adjacent or nearby land uses and whether oil and gas facilities have been removed, and other disturbances including tire tracks that compact soil and prevent vegetation growth.

The results of the study suggest that drones can be a valuable tool to evaluate reclamation progress of well pads. In many cases, the data that can be produced from the drone imagery can be used to assess multiple requirements needed for a Certificate of Restoration.

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