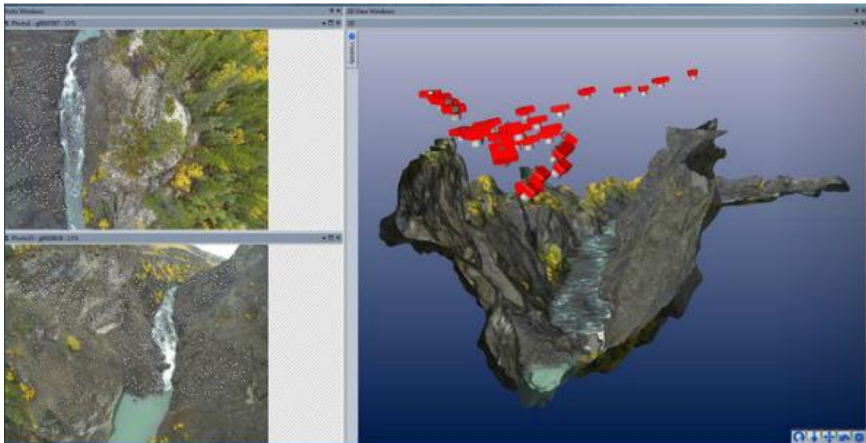

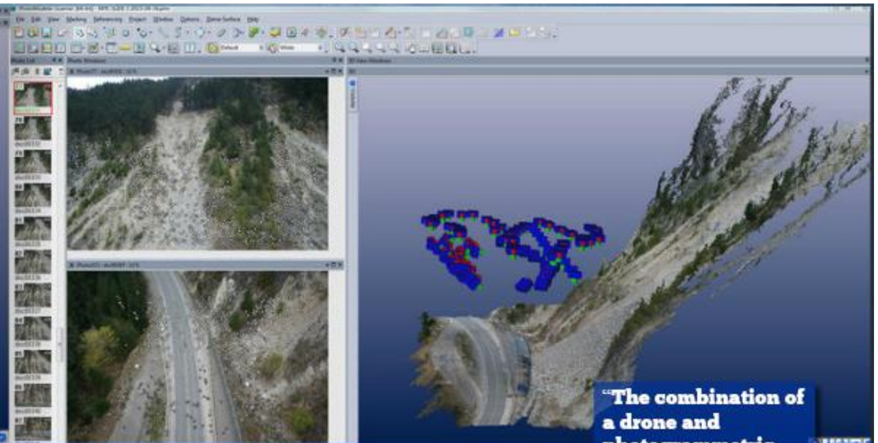

UAS + Photogrammetry Reduces Cost and Risk of Surveys

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> "The combination of a drone and photogrammetric software made it possible to complete all of these projects with much higher levels of safety, cost efficiency and accuracy than could have been achieved with conventional techniques"

There are many civil engineering and environmental remediation applications that require survey data in hazardous areas where conventional survey methods aren't effective. "Photogrammetry helps us win more jobs by providing more competitive pricing," said Paul Lepine, Senior Geotechnical Technician for **exp** Services Inc., Burnaby, British Columbia. Using a drone UAS (Unmanned Aerial System) to acquire photos that can be used as the basis for accurate surveys is rapidly gaining traction as a preferred technique. Matt Sakals, Research Geomorphologist for British Columbia's Ministry of Forests, Lands and Natural Resource Operations (FLNRO) added that "Combining a UAS with photogrammetric software makes it possible for us to efficiently complete difficult surveys in remote and rugged areas."

Rock slope surveys

exp specializes in performing rock slope surveys that are required when rock slope remediation systems are built alongside highways. The company surveys the rock slopes and calculates the amount of mesh required to cover the slope and also proposed locations for metal stanchions used to secure the mesh. The company also estimates the required rock scaling -- the removal of loose rock from slopes – and shotcrete – concrete that is sprayed onto the rock slopes. One of the critical areas in the survey is at the joint planes formed by breaks of natural origin in the continuity of either a layer or body of rock. Water often invades cracks at the joint line or fracture. Later as the temperature drops and freezes the water, its volume expands. This expansion pushes the rocks on either side of the joint apart, breaking off pieces of rock that may fall onto the road.

In the past, **exp** surveyors used a total station to survey a few thousand points on a typical 100 meter long rock slope. This process normally took three days. One of their challenges was that the two-lane highways are typically only 15 meters wide and the rock slope cuts are commonly 30 to 50 meters high and sometimes up to 100 meters. "It is very difficult to take measurements that high and to find safe and appropriate total station setups while surveying by the highway," Lepine said.

Several years ago, **exp** began using PhotoModeler photogrammetry software from Eos Systems. **exp** originally used a different software package but switched to PhotoModeler when it was discovered that PhotoModeler could be purchased for the amount that it cost to rent the other software for one month. When Lepine first began using photogrammetry, he placed photo control targets on the rock and surveyed the 3D coordinates for those points in order to provide the proper scale rotation and translation for the photographs. He then walked along the rock slope and took pictures with a digital camera, taking care to obtain at least a 60% overlap between adjacent pictures. This process took only one day for a 100 meter long rock slope.

When Lepine returns to the office, he uploads the photos into the photogrammetry software and uses a feature called SmartMatch to automatically detect and match features across multiple overlapping photos. The software then computes the position of each point in the images in 3D space. "SmartMatch saves a considerable amount of time compared to the previous process of manually matching common features between the photos," Lepine said. "The time required to orient the photos is reduced from a few days to a few hours. The result is a dense point cloud consisting of millions of points that defines the topography of the rock slope to a much higher level of accuracy than was possible in the past." Accurately depicting the 3D geometry of the rock slope is critical because contractors prepare their bids for the remediation work based on this geometry.

More recently, **exp** has further improved the survey process by using a DJI S900 Hexacopter UAS with a calibrated Sony NX5T camera to take the photos. Lepine commands the UAS to hover and moves the gimbal into position for the shot of the rock slope.

This method allows for better survey coverage of the rock slope than photos previously taken along the highway by hand. As with the manual photos, he overlaps each photo with the preceding shot.

Exp's governmental customers typically markup photos of the rock slope with lines drawn to indicate the outline of where they want the mesh. Lepine then makes a 3D model of the mesh using the surface drawing tools in PhotoModeler. At this point, the model is exported to AutoCAD Civil 3D where Lepine calculates the area of each section of mesh, creates annotations and generates separate surface models of each mesh. These deliverables are then provided to **exp**'s client.

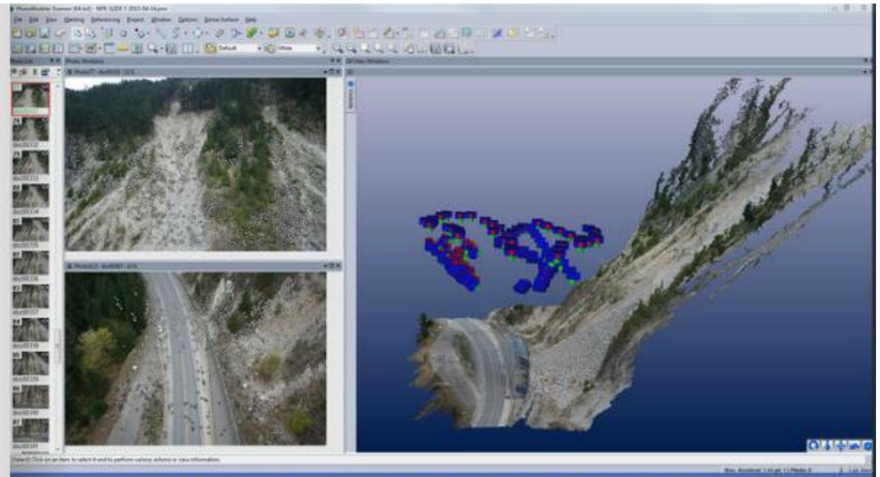
Sometimes the client requests modifications and when the client is satisfied Lepine produces a final drawing that is included in the package provided to the contractors for bidding. Often, when the construction is being performed, contractors may propose changes, such as extending the mesh to cover additional areas of the rock slope. In this situation, exp returns to the site after the construction is completed and performs an as-built survey using PhotoModeler that is used to determine the contractor's payment.

Environmental monitoring and research

Matt Sakals' work for FLNRO involves environmental research and monitoring in support of ecosystems that may be impacted by natural or human-related events and structures such as landslides, dams, and mining sites. In one case a rockslide in a remote canyon created an obstruction in a river with a large salmon run. The smaller salmon could get through the obstruction but the larger fish had to be netted and flown by helicopter past the blockage as a temporary measure. "Photos of the obstruction and surrounding area had been taken from a helicopter but they did not provide the complete understanding that was needed to plan remediation operations," according to Sakals. "Our capability for acquiring survey data via photogrammetry in rugged areas with limited accessibility provided a solution."

Working from the top of the canyon, Sakals flew his UAS at eye level up and down the canyon. The photographs taken by the UAS were to support the investigation into a possible plan, which was to wait until the river froze, then drive an excavator over the ice to clear the obstruction. The photographs showed the gravel bars where the river is shallow. Knowing the location of these bars was important because the planners wanted to drive the excavator over these spots for as much of the route as possible to provide safety for the operator in case the machine broke through the ice.

Aerial view of a debris slide catchment area. This photo shows the catchment area before the contractor has removed the debris and is one of many that will be imported into PhotoModeler to calculate the total debris volume of the slide.



3D point cloud (right) of the debris slide seen in previous image. This point cloud, used to determine the total volume of the debris, was created in PhotoModeler from about 90 individual photos of the slide. SmartMatch points can be seen dotting the actual site images on the left.

Sakals used PhotoModeler to build a 3D model of the canyon and obstruction from the still photos collected with FLNRO's UAS. He then used PhotoModeler to create an orthophoto, which is an aerial photograph that has been geometrically corrected so that every section of the photo looks as though it's a birds eye view from directly above, without the distortion inherent with a photo from a single camera position. The orthophoto gave their machine operator an accurate map to plot his driving route to maximize time over the safer sections of ice. "The 3D model enabled us to understand the exact extent of the obstruction and helped to evaluate alternative removal methods," Sakals said. "The model also helped predict the potential for further landslides and the risk these might pose to workers involved in clearing the obstruction."

In another project, Sakals investigated the downstream effects of a recently constructed dam. Dams commonly trap larger debris such as tree trunks, which can create scour pools that become significant fish habitats and also affect the distribution of finer sediment in the stream. In this

View of catchment area of slide after contractor's removal of the debris.

project, Sakals used the UAS to photograph the stream channel downstream from the dam. He used Mission Planner software to create the flight plan by defining the area that he wanted to cover, the elevation and the degree of overlap and sidelap for the pictures, which in this case was 75%. PhotoModeler provided Sakals with the capability to assemble the photos into a single 3D model and resulting orthophoto that provided a coherent visualization of the stream. Sakals saved the flight path and plans so that he can fly the drone over the stream again in the future to facilitate comparisons over time. The data from PhotoModeler can be exported to various other software packages that calculate the differences between models to easily and quickly determine what changes have occurred in the stream since his last model was created. Results over time will be evaluated to determine if changes to further developments are required.

Placer mines that excavate stream bed deposits for minerals are also sometimes a subject for Sakals to survey. In certain areas, limits are placed on the amount of disturbed ground allowed. Sakals uses PhotoModeler and UAS photography to create georectified orthophotos to quantify the disturbed area. Other staff in FLNRO's Resource Management Division can then view the orthophotos in GIS software to assess the level of ecosystem rehabilitation and determine whether the survey area is once again a habitat for wildlife and allow the miners to continue working elsewhere.

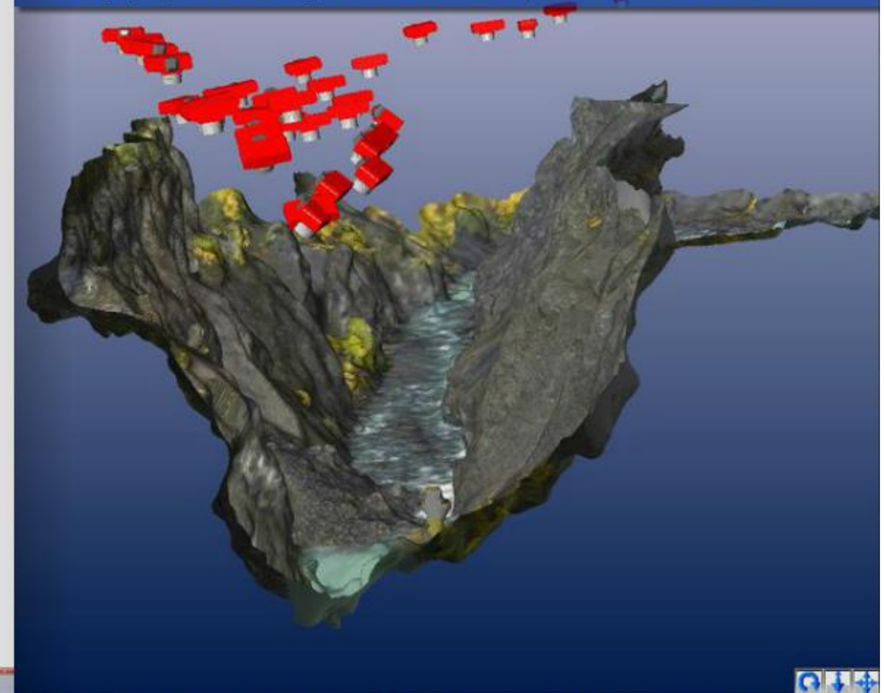
"The combination of a drone and photogrammetric software made it possible to complete all of these projects with much higher levels of safety, cost efficiency and accuracy than could have been achieved with conventional techniques," Sakals concluded.

For more information about PhotoModeler, contact Eos Systems Inc., 210 - 1847 West Broadway, Vancouver BC V6J 1Y6, Canada. Ph: 1.604.732.6658 or email **sales@photomodeler.com**

Photo of a bluff requiring rock slope remediation. Part of a government remediation project, this photo will be one of many used to calculate the mesh area and other

Below: **Rendered 3D surface model (right) of the bluff in previous image. The individual photos taken at the site are shown in the two images on the left. PhotoModeler surface drawing tools were used to outline the area of proposed slope mesh (green lines on surface model). The surface model with 3D lines outlining proposed slope mesh areas are imported into AutoCAD Civil 3D to calculate mesh surface areas and produce final drawings.**

Oblique perspective of the canyon and the fish-obstructing rockslide created in PhotoModeler.



Two of the photographs taken from a UAV of the canyon and rockslide that were used to build the surface model and orthophoto.