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Emergency Response Planning for a Second Catastrophic Rock Slide at Turtle Mountain, Alberta

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Abstract: Since the original catastrophic slide at Turtle Mountain in 1903 that buried the Town of Frank, killing 70 people, government and public attention has shifted to the potential for a second large failure originating from the South Peak. In 2003, on the centennial of the initial slide, the design, installation and commissioning of a real time monitoring system for the South Peak was launched by the Government of Alberta to provide first and foremost the framework for a real time monitoring system to warn of the development of a second large failure. In addition, the monitoring system will also be an educational tool for the public. This paper briefly outlines the types of monitoring equipment deployed on the mountain and the rationale behind setting alarm thresholds to a network of sensors with various sensitivities and reactions to external effects. The main discussion of the paper will be on the database and computer interface utilized to view data and generate automated electronic call outs and the coordination of emergency response activities based on the types of alarms raised. The coordination of emergency response planning involves a large number of stakeholders, including the Municipality of Crowsnest Pass, various levels of provincial government and transportation companies, as well as law enforcement and fire rescue personnel.

1. Introduction

After the catastrophic 1903 rock slide at Turtle Mountain, known as the Frank Slide, that buried parts of the town of Frank and killed 70 people, studies of the remaining portions of the mountain highlighted a series of large cracks around the South Peak (Figure 1). Studies by Allan (1933) and BGC Engineering (2000) estimated that a failure of the mass at South Peak could potentially have a volume up to 5 million cubic meters of material and impact on municipal development and infrastructure below.

Although numerous studies have been undertaken since the early 1900's, there was not conclusive evidence of the overall movements of the peak and no way to provide a predictive warning should an acceleration of movements occur. In 2003, during a ceremony marking the centennial of the Frank Slide, the government of Alberta committed $ 1.1 million (CDN) to develop and deploy a real time monitoring system and develop a warning and response plan for the Municipality of Crowsnest Pass. This paper provides an overview of the sensor network, threshold determination, data management and an overview of the emergency response planning.

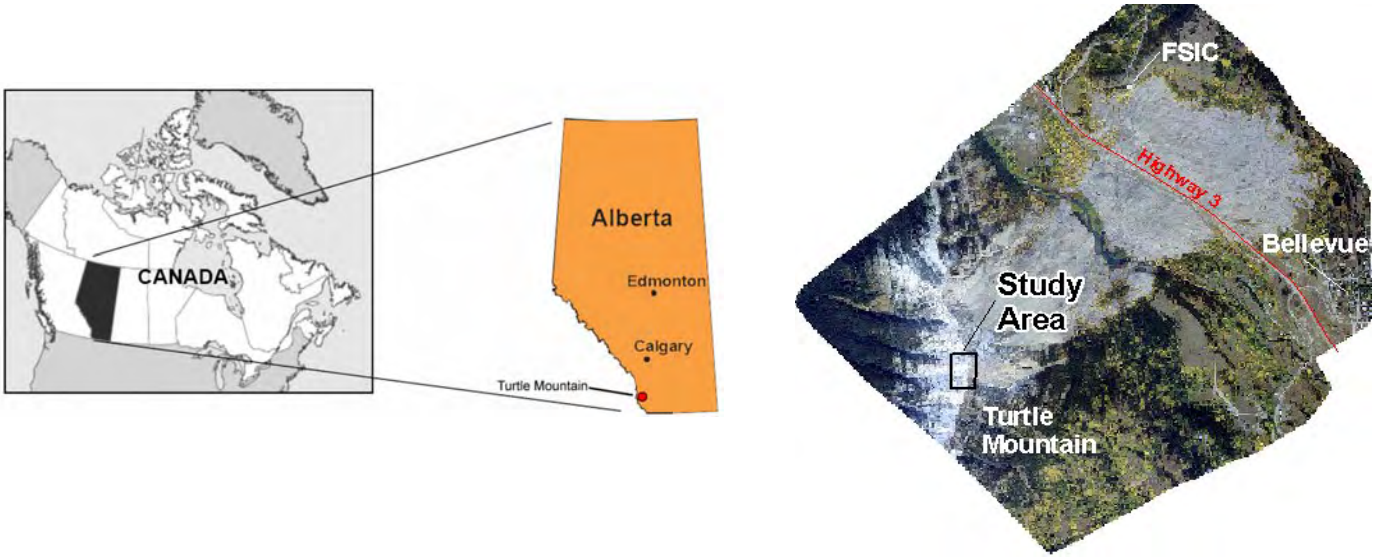

Figure 1. Location of Turtle Mountain and South Peak study area.

2. Background

The South Peak of Turtle Mountain is circumscribed by a series of long, deep cracks which are believed to have formed as a result of the 1903 Frank Slide. Detailed studies of the cracks and structure of the mountain lead John Allan, the founder of the Alberta Geological Survey, to estimate in 1933 that a second slide with a volume of approximately five million cubic metres could take place. Allan (1933) also used empirical relationships derived from the experience of the 1903 slide to estimate the potential runnout zone for a second slide, with the worst case scenarios crossing both the highway and the Canadian Pacfic Rail (CPR) mainline. As part of a study undertaken by BGC Engineering (2000), further refined Allan's zoning by using more modern rock fall and runnout relationships and computer modeling, but still found that a worst case runout scenario crossed both the highway and railway (Figure 2). As there have been no development restrictions placed on the areas outside the 1903 slide, there are numerous existing residential developments and a new sports and recreation facilitiy under construction in the zone that the large rock slide is projected to cover. As the eviction of the residents or halting of the construction of the sports complex is not currently under consideration, the development of an early warning system was proposed as a method to manage the risks to the residents, the highway and the railway.

3. Overview of Sensors

Between summer April 2003 and March 2005, a variety of sensors were installed around Turtle Mountain, with the large majority concentrated on South Peak. The initial aim of the instrumentation was to provide educational information to the public, to investigate the range of movements at the peak, and to provide an early warning for a second catastrophic landslide at Turtle Mountain.

The aim in designing the overall array was to both provide complementary types of instruments with varying sensitivities to movement and climatic influences and also have enough redundancy built into the system to be able to distinguish actual movements. In considering the types of sensors most suitable for providing early warning for impending slope movements, the sensors were grouped into the following categories:

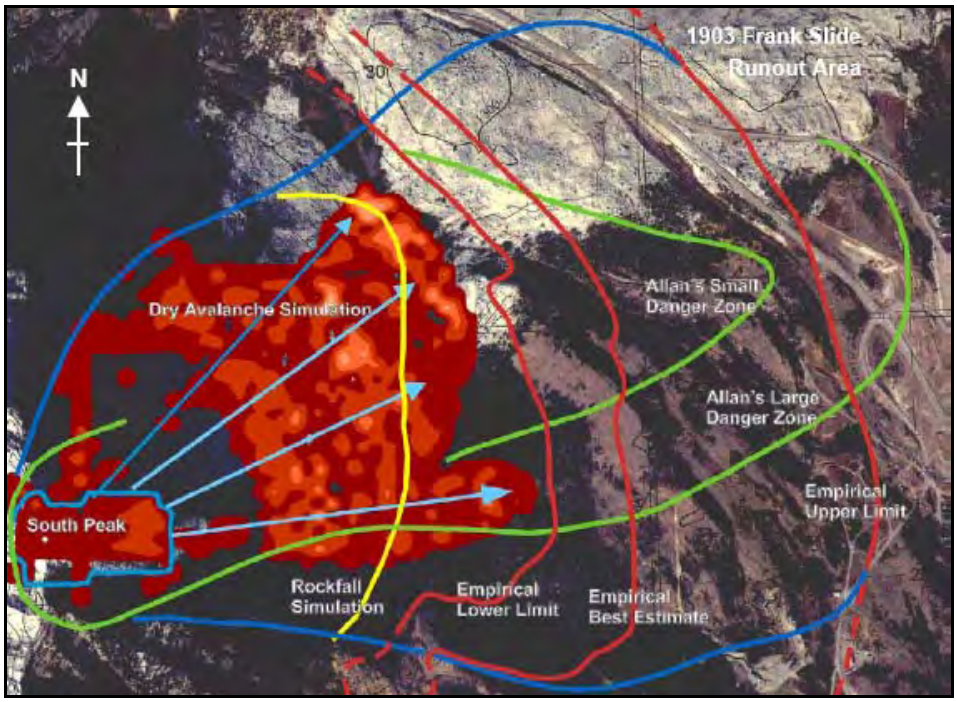

Figure 2. Locations of empirical and modeled runout estimates for a failure of South Peak (BGC, 2000)

Primary Sensors: The primary sensors are those which provide a reliable data stream on a year round basis and which measure easily interpretable parameters of the rock mass such as length changes or rotation. The primary sensors include ten tiltmeters, four surface wire extensometers and twenty-two crack gauges. The surface wire extensometers and crack gauges provide absolute deformations with submillimeter level precision while the tiltmeters provide values of rotation in arcdegrees.

Secondary Sensors : Secondary sensors are those that measure quantifiable parameters, but which may be subject to more variation due to environmental effects and other reasons. The secondary sensor network consists of ten prisms with distance measurements shot from a robotic total station located at the Frank Slide Interpretive Centre and six single frequency GPS receivers. At this time it is projected that these systems will be operational near the end of the summer of 2006.

Tertiary Sensors: Tertiary sensors provide background data that is useful in the interpretation of the results from the Primary and Secondary sensors. The tertiary sensor network consists of a meterological station (rain, wind, temperature, barometric pressure), an outflow weir (at the base of the mountain), two subsurface microseismic sensors and six surface passive microseismic stations. A tertiary sensor which has the potential to become a secondary, or possibly a primary sensor, is the microseismic system which, once it is calibrated, may become capable of detecting and locating the source of deformations within the subsurface of the mountain.

The layout of the above instruments is provided on Figure 3 A more detailed overview of the sensor network is provided by Read et al (2005) and RSRC (2005).

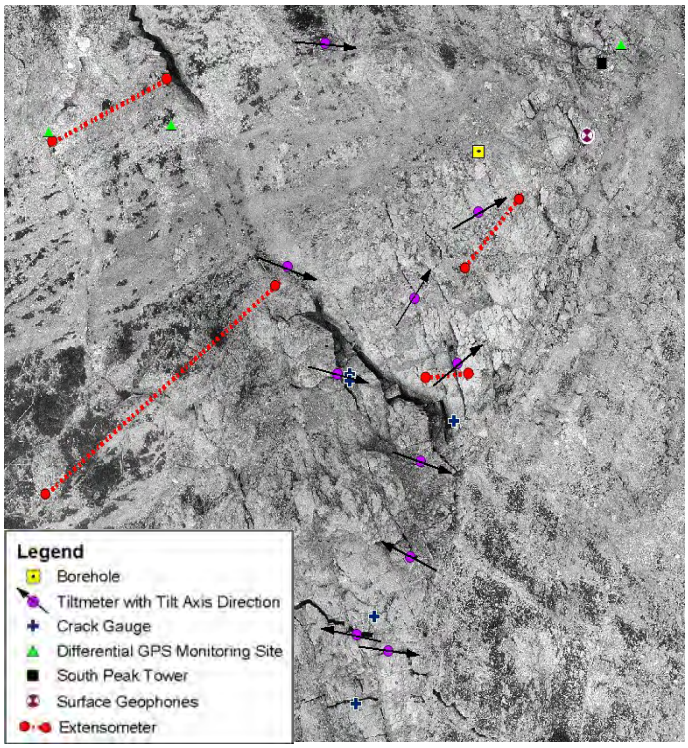

Figure 3. Plan showing the location of instrumentation on South Peak

4. Data Management and Alarm Delivery

Data from all of the deformation-type sensors is collected on the west side of South Peak using Campbell Scientific data loggers and sent via a wireless radio link to the provincial building in Blairmore, Alberat (via a 900 Hz digital wireless link) then relayed to the Frank Slide Interpretive Centre (FSIC) by a 5.3 GHz digital wireless link. The continuous data stream from the surface seismic network is relayed via a 5.8 GHz digital wireless link directly to the FSIC (Figure 4). The deformation based data is then stored on a MySQL server called Snapping, where it can be accessed via the internet through a cable connection at the provincial building.

There are two applications that are currently in use for viewing of data captured at the FSIC. At regularly scheduled intervals, Alberta Geological Survey/Energy and Utilities Board (AGS/EUB) geotechnical personnel access the data at the FSIC via an application called TMClient, which pulls any data not previously downloaded to an Access database on a computer at the AGS/EUB in Edmonton. This data is then pulled into an Excel spreadsheet for viewing and graphing of data. Excel is the primary application utilized in reporting data and evaluating data trends.

The second application utilized to view data is a commercially available application called ARGUS (2005). The AGS/EUB is currently utilizing the web-based version of ARGUS where the data stream from the loggers on the west side of the mountain are accessed directly via the internet and radio links from Blairmore and data is recorded on a database housed by the company that provides the ARGUS monitoring service. Within the ARGUS web-based software, all of the instruments are displayed in a user friendly manner on a photo of the mountain, with color status buttons for each sensor. For each sensor operating within it's predefined threshold a green box will appear. If any of the absolute or velocity based deformation thresholds (see below) are violated then either a yellow or red box will appear. The user can then click on the box to view the graph of the data (Figure 5).

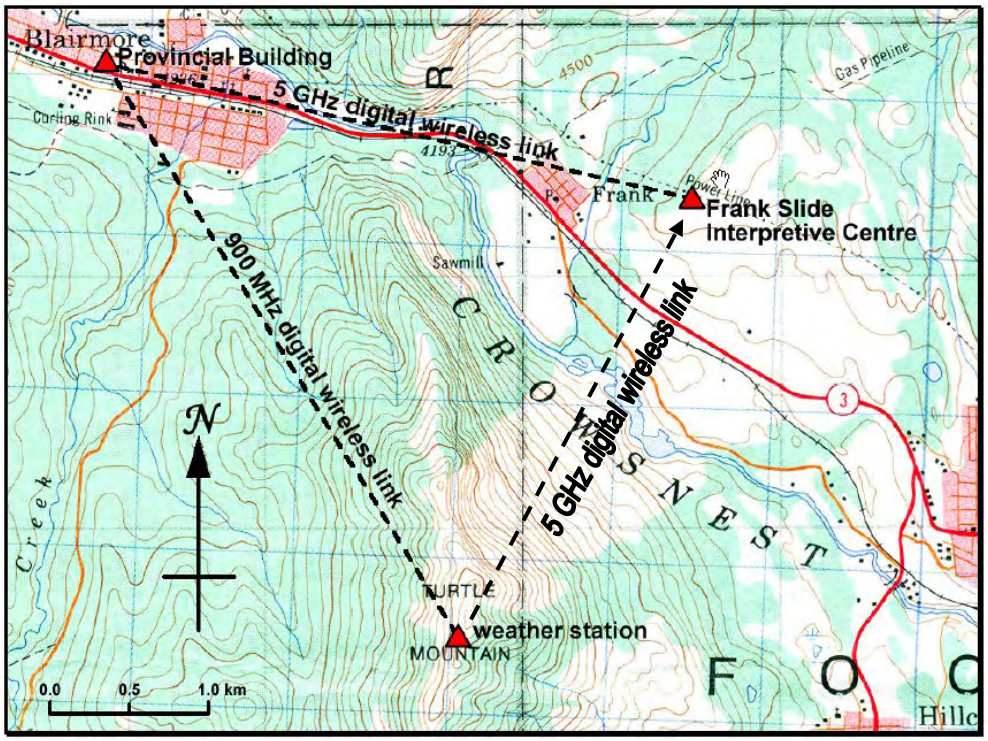

Figure 4. Schematic showing the flow of data from both the west and east sides of South Peak

There are two main types of instrumentation thresholds that were recommended for the system sensors (AMEC, 2005). Exceedence of these thresholds would result in an alarm condition and/or change in alert level:

Absolute Thresholds: These are specific values that are set typically based on two to three standard deviations above the instrument noise and/or known seasonal thermal fluctuations of the sensors and rock mass. As ongoing movement occurs, it may be necessary to reset the absolute threshold.

Velocity Based Thresholds: Velocity based thresholds consider the rate of movement or rate of change of the rock mass/reading. These types of thresholds are often expressed in millimeters per day or week and are based on the experience based judgment of a rock slope engineering specialist.

Both types of threshold levels are provided for the instruments on South Peak. The threshold values are used in the data acquisition and interpretation process to identify Alert Levels (Section 5) and to provide automatic call-out notification from the system.

Although ARGUS can be used as a general viewing tool that does not require anything more than an internet connection, it's main purpose is to generate call-outs should an alarm threshold be exceeded. ARGUS has been programmed to send out emails to project staff in the event of the exceedence of a preset threshold on each individual sensor. If multiple sensors thresholds are triggered, then a message is also sent to a 24/7 security desk for verbal acknowledgment that the project engineers have received and are addressing the callout.

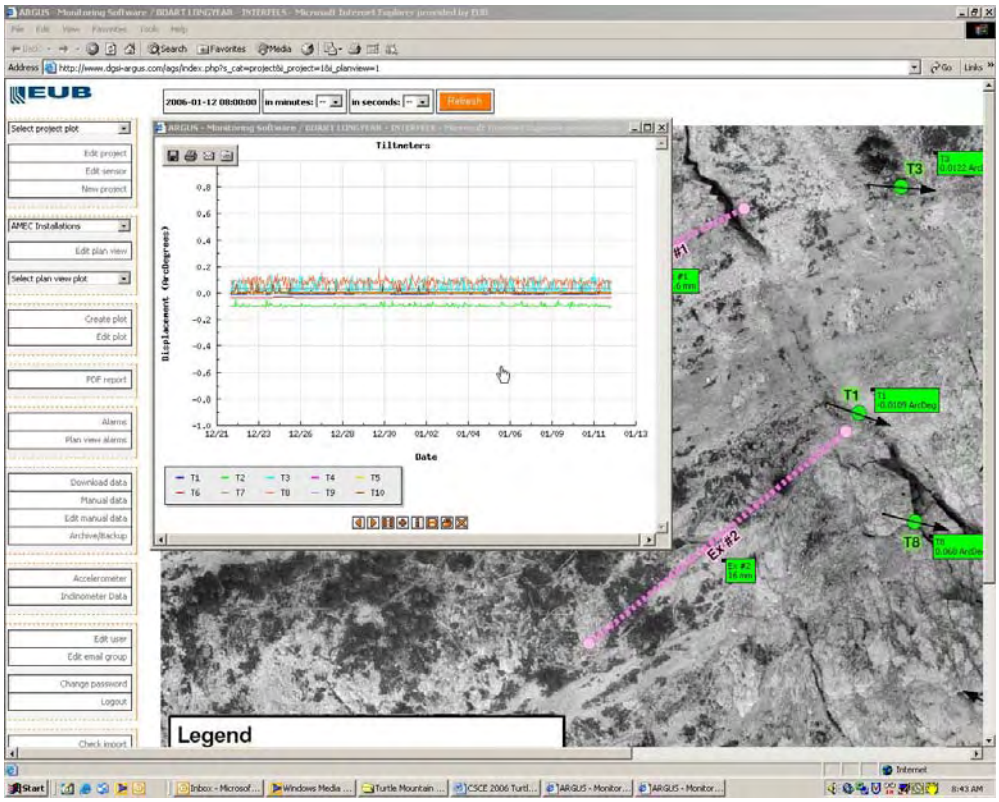

Figure 5. Screen shot showing ARGUS plan view and sensor specific plots for South Peak

5. Alert Levels

Based on the rates of movement, the sensors involved and an assessment of the data by the AGS/EUB geotechnical personnel, different alert conditions will be determined. Each Alert Level is associated with an appropriate level of action. The alert framework may require adjustment based on experience. In addition, individual circumstances may require deviations from the actions suggested below. The sections below provide specific details on the responses for the various alert levels (Froese et al, 2005).

Condition Green (Normal Operations) : A green condition is the alert designation for normal operations including regularly scheduled data review and field checks where the following conditions are true:

1. There are no deformations above specified thresholds and the system is functioning properly; and/or
2. A threshold exceedence is detected on a single sensor and it is determined by AGS/EUB geotechnical personnel that this is indicative of instrument error, vandalism or climatic influence and/or the exceedence is due to a local condition that is not considered to be a problem with respect to overall rock mass movement conditions;and/or
3. Trends are observed on a number of instruments that are deemed by the AGS/EUB to be within acceptable limits not requiring notifications would to Emergency Management Alberta (EMA) and not requiring changes in alert levels.

During the green alert level, regular data summary reporting would be completed and no additional notifications would be necessary.

Condition Yellow (Watch) : Should a trend of systematic deformations be observed on a number of sensors and the AGS/EUB identifies that these are likely indicative of slope deformation and not due to climatic or other non-slope effects, then a watch (Condition Yellow) would be triggered. Under a watch, the AGS/EUB geotechnical personnel would phone the EMA Duty Manager, indicating that movements are developing in a controlled manner and there is no need to raise an alarm and that these agencies would be provided updates on a daily/weekly basis until either the alert level is lowered or raised. The EMA Duty Manager would then notify the Municipality of Crowsnest Pass (MCNP) and the EMA District Officer of the Alert Condition change but no other specific action would be required.

Under a watch, the recommendations by the AGS/EUB may include, but are not limited to the following actions:

1. Increasing the frequency of reviewing monitoring data;
2. Increasing the frequency of data acquisition;
3. Site reconnaissance/investigation;
4. Further analysis (perhaps with supplemental information from other sources, e.g. InSAR); and
5. Lower, maintain or raise current alert level.

From these recommendations, AGS/EUB will make a decision to lower, maintain or raise the alert level and initiate the necessary actions. If an alert level is raised to a warning (Condition Orange) or greater, there must be follow-up of the recommended action items to ensure that the integrity of the system is not compromised. Any change in alert condition would be relayed via telephone to the EMA Duty Manager. Until threshold values are established, there will need to be frequent and open discussion between the geotechnical specialist and the internal government resource carrying out the regular data review.

Condition Orange (Warning) : In the event that the systematic deformations accelerate and visual observations of the progression of slope movement are made, then the AGS/EUB geotechnical engineer would raise the alert level to a WARNING (Condition Orange). Under an Orange warning condition, deformations on the on South Peak would be accelerating, leading to concern of a possible future failure of significant portions of the peak or of the entire peak.

Under this Alert condition, the EMA Duty Manager would be notified by telephone that they should begin notifying the public (both recreational users and residents) in the vicinity of South Peak that a failure on South Peak may occur. Other appropriate actions such as public advice notices and evacuation preparation may be required as outlined under the municipal emergency plan.

Due to the very serious nature of this condition and the fact that the public will be notified, it is imperative that the determination of the warning is to be made with input by the AGS/EUB geotechnical engineer based on the instrumentation results, visual observations and judgment based on specific experience with rock slope failures and interpretation of data on other projects. The misdiagnosis of warning could both lead to either a catastrophic collapse not being detected in time or the public believing that the system is unreliable resulting in a loss of confidence.

At this stage, the message to be relayed to the EMA Duty Manager is that there is a concerning acceleration of slope movements on the South Peak and that notification of the public in the affected areas be notified with recommendations for voluntary evacuations. It is most likely that a Orange condition would be reached after ongoing deformation of the peak. However, if the deformations occur in the evening or under snow or poor visibility conditions, visual assessment, may be impaired and consideration of whether a mandatory evacuation order should be issued until a detailed assessment could be undertaken. As the worst case empirical estimate for a rock slide runnout incorporates the highway and railway, it may also be prudent for EMA to notify Alberta Infrastructure and Transportation (AIT) and Canadian Pacific Railway (CPR).

During the Condition Orange, the AGS/EUB geotechnical engineer would be available to act as the Subject Matter Expert (SME) to provide briefings to EMA and the MCNP as to the technical details of the assessment and relay any changes directly to these parties during the event.

Condition Red (Failure) : Under this stage, it has been confirmed based on the instruments and detailed visual assessment (may require a safe vantage point such as a helicopter) that a catastrophic collapse of the South Peak appears to be imminent (within one to three days). At this stage the alert level would be raised to red and the message delivered from the AGS/EUB to the EMA Duty Manager would be that a catastrophic failure of all/a portion of South Peak is underway and that the potential affected area should be evacuated, highway and rail traffic completely restricted and emergency response personnel should be mobilized to control access and remain a safe distance from the potential runnout areas. The information flow during this stage from the AGS/EUB to EMA would remain as in Condition Orange with the external specialist on site and providing liaison with EMA and the municipality as the SME.

6. Emergency Response Planning

At the conclusion of the sensor network implementation, an emergency response protocol (ERP) and warning system was developed by Alberta Municipal Affairs (2005) to ensure a coordinated series of actions between various orders of government and the private sector. This protocol provides that coordination between Alberta Municipal Affairs (AMA), through EMA, AGS/EUB, AB Infrastructure and Transportation, the Ministry of the Solicitor General and Public Security and K Division Royal Canadian Mounted Police (RCMP), the CPR, the Municipality of Crowsnest Pass (MCNP) and other possible participants at the provincial and federal order of government. While the MCNP has it's own Municipal Emergency Plan (MEP) that includes evacuation protocols and tasks for municipal officials, first responders etc, this protocol is designed to ensure the relevant organizations are notified and that appropriate coordination follows to ensure the MCNP received the assistance and information they require to respond to and recover from a slide emanating from the south Peak of Turtle Mountain.

The ERP is based on Alberta's emergency management framework, which specifies that the coordination of emergency management response and recovery begin at the municipal order of government and escalated as required. The MCNP will take the required action in accordance with its MEP. In accordance with the ERP call tree, EMA will make the necessary calls to relevant GOA ministries and private sector companies that will be directly affected by a slide (e.g. RCMP, CPR etc). This call down will begin at level Orange, though individual organisations may be warned depending on input from the AGS/EUB technical expert. The EMA District Officer will move to the MCNP EOC to provide assistance and advice as required, as well as performing his standard liaison function with the EMAOC in Edmonton. This liaison function will include informing the EMAOC of any additional resources and assistance required by the MCNP that cannot be acquired through normal channels or via mutual aid agreements. Figure 6 provides a schematic of the function and communication flow that would apply for Alert Conditions Orange and Red, as per the ERP.

7. Summary

In order to reduce the risks to the Municipality of Crowsnest Pass, Highway 3 and the CPR mainline with respect to a large rock slide from the South Peak of Turtle Mountain, a near real time warning system was installed between 2003 and 2005. Based on this system alarm thresholds were set for the various sensors and a detailed protocol outlining the monitoring procedure, communications and emergency response was developed.

8. Acknowledgments

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Figure 6. Sequence of functions and communications flow for Conditions Orange and Red

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