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Monitoring geohazards and trigger level response on Deans Head in the Port Hills, Christchurch

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ABSTRACT

Following the recent Canterbury Earthquake, GNS Science have identified numerous mass movement areas in the Port Hills with a potential risk to nearby infrastructure and life lines. Deans Head, a Class I mass movement area near the Sumner suburb, comprises of an approximate modelled 46,000m^3 soil (loess) landslide on a steep sloping site. Different to other mass movements, the Deans Head landslide could be triggered by relatively frequent rainfall events. During the land clearance phase of works carried out by Land Information New Zealand (LINZ; formerly Christchurch Earthquake Recovery Authority, CERA), the Deans Head project has proven to be challenging including overcoming the multiple site constraints. These constraints include CERA Red Zoned structures, a key lifeline route below the site, cliff collapse and landslide hazards both susceptible to weather. During the land clearance phase, mass movement hazard monitoring has formed an integral part of the health and safety for personnel working on site. This paper will identify the numerous site hazards on Deans Head and provide an overview of the hazard monitoring techniques including ground movement, laser scan monitoring and groundwater monitoring used during LINZ's land clearance phase of works. An overview will be provided on the emergency management if trigger levels are exceeded and the importance of procedures and reporting during hazard monitoring throughout the project.

Keywords: monitoring, landslide, Deans Head, ground movement, ground water, laser scan.

1 INTRODUCTION

The Deans Head site area is located in the Christchurch suburb of Sumner and covers an area of approximately >8,300m^2. The site is located on a gentle to steep sloping hillside (averaging 20°-30°) above Main Road. Main Road forms a key lifeline route between the Lyttelton Port and Christchurch. The site comprises two main geohazards, cliff collapse (and retreat) along the northern fringes of the site (mainly Shag Rock Reserve) and a mass movement (landslide) area containing an estimated 46,000m^3 of soil material that could be triggered by potential rainfall events (Massey et al., 2014). From surface movement and slope displacements, landslide direction has been modelled in a northwest direction (in relation to the site). The site features and indicative landslide direction is outlined in Figure 1.

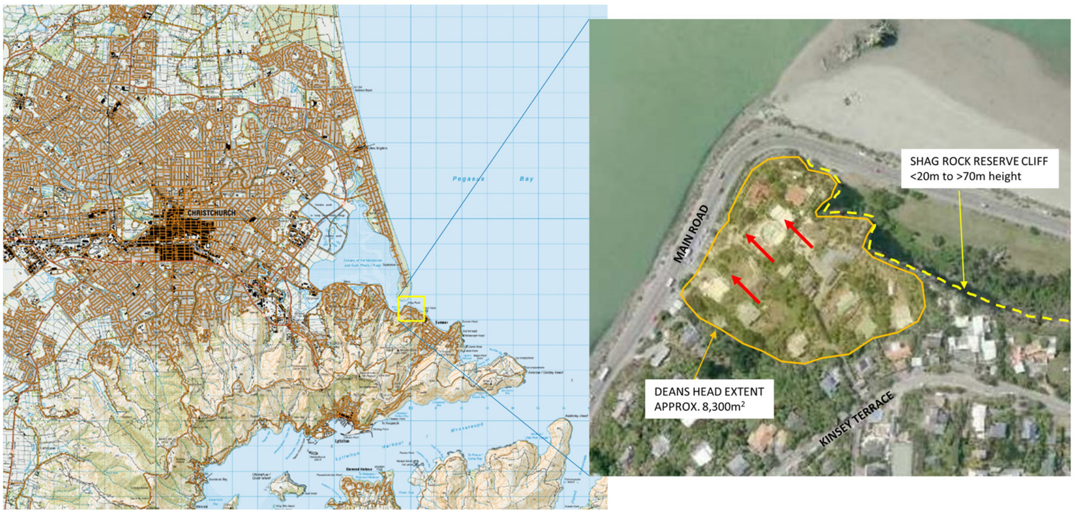

Figure 1. Deans Head site area, extent & indicative landslide direction (in red), LINZ and LiDAR, 2011

In addition, properties within the Deans Head mass movement area were deemed high risk and have been CERA Red Zoned following the recent Canterbury Earthquakes. Through involvement on the Deans Head Project; how do you manage the geohazard risks when working on site, became the focus for establishing a monitoring network during site works on Deans Head. With multiple site features, removal of these properties has proven to be complex, requiring in depth monitoring and establishment of trigger level thresholds to undertake works safely. A brief outline of the main geohazard monitoring techniques used on the project and trigger thresholds are outlined below.

2 MONITORING

Several monitoring techniques have been implemented on Deans Head for ground movement, ground water, rainfall (weather), seismic and laser scan monitoring in Shag Rock Reserve. Addressing key site constraints and site features was important when selecting the most appropriate monitoring technique for Deans Head. These were identified and discussed in risk workshops with the project geotechnical team, survey team, project managers, client and key stakeholders so all hazards were covered and a robust monitoring network established. Some of the main constraints discussed during the Deans Head project included; the type of geohazards (and hazards) on site, mode of failure, likely triggers, access to the site (and reducing people in high risk areas), how often data is required, what cost effective equipment is available and proposed works on site. During the Deans Head project, each monitoring technique was run through a simple what are we trying to carry out (purpose), the aim of the technique and how would this be measured to identify if the main modes of failure and geohazard have been covered. An overview of the purpose, aim and how data was collected for each monitoring technique is outlined in Figure 2.

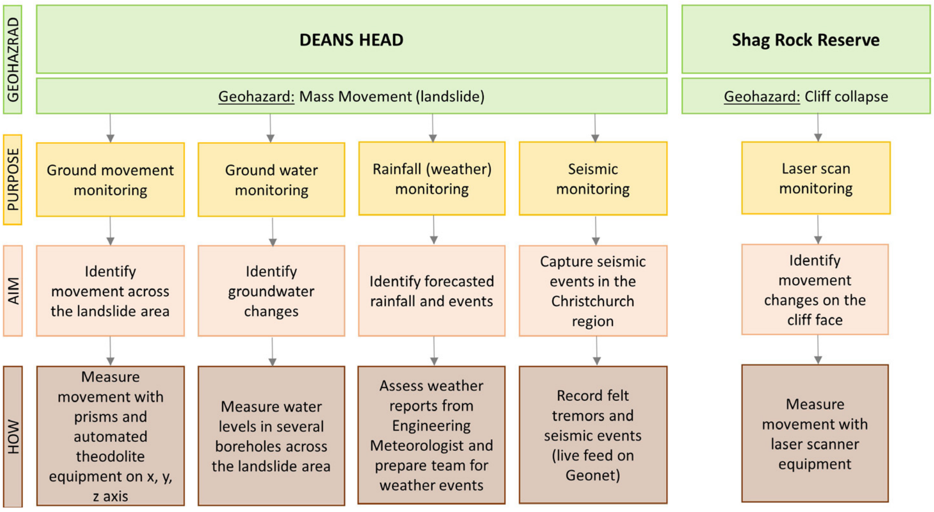

Figure 2. The main geohazards (mass movement and cliff collapse), monitoring technique (purpose), aim and how data was collected is outlined for Deans Head and Shag Rock Reserve.

Details on each monitoring technique including an overview of the setup is outlined below.

2.1 Ground movement monitoring

Ground movement monitoring was undertaken to identify the surface changes across the Deans Head mass movement area. A series of prisms and a theodolite total station was established on Reserve Spit (adjacent to the site) to remotely measure prism movement in the X, Y and Z axis, 24 hours a day, 7 days a week. Prior to survey establishment, several issues arose including limited suitable locations for equipment set up, security of equipment, powering the equipment, how will data be received and stabilising equipment (a low movement tolerance).

With Main Road and the Avon Heathcote Estuary below, suitable site locations were limited. A raised sandy beach area was selected across from the site, accessed via a 4WD track. Equipment was housed in a purpose built container for security and protection from the elements. A viewing window and series of backsight windows were fabricated on the front of the container and around the side to measure monitoring and control prisms. A concrete plinth and footing was fabricated for equipment mounting. The footing was buried in the underlying sand prior to container placement. The container was mounted over the plinth so the container and plinth could move independently. Two control prisms were installed on Reserve Spit in a similar manor except control prisms did not require container housing. The total station was linked to solar power and battery units to power the equipment continuously. The theodolite and monitoring computer in the project office was linked by radio communication via a radio repeater located on an adjacent site. Photographs of the ground movement monitoring set up and view from the container towards Deans Head are shown in Figure 3.

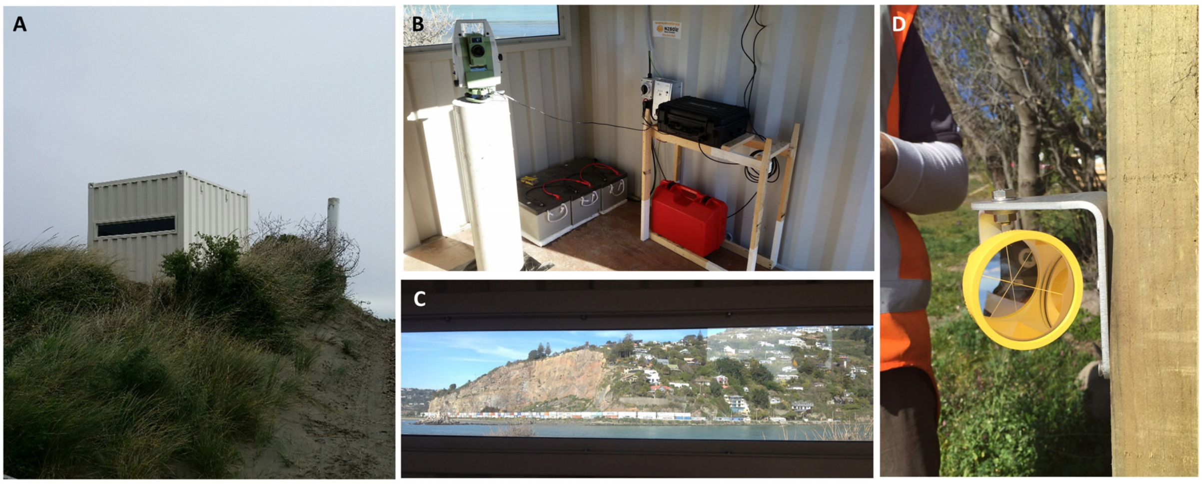

Figure 3. Ground movement monitoring set up; A, monitoring container on Reserve Spit, Southshore; B, equipment set up in the container; C, view from monitoring container looking towards Deans Head area; D, monitoring prism installed on Deans Head. Photographs taken 20.7.2015.

Across from the container on Deans Head, a series of prisms (up to 50) were installed on structures, retaining walls and permanent posts in the ground. Throughout the project, prisms could be relocated depending on the project phase of works. Data is collated using Geomos software to capture and track prism movements. Displacement movement relative to the total station is measured on three axis, that is transverse (left and right), longitudinal (in and out) and height (up and down). Aerial imagery and graphs could then be created to model and present prism changes. Prism data could be accessed remotely on smart phones and laptop devices in the field using TeamViewer software. Prism data for each axis was displayed for the week, month, cumulative and issued to the project team in the Deans Head Weekly monitoring update. Following baseline studies, a series of trigger level thresholds were loaded into the software program to send text alerts to a designated list of people on the project.

2.2 Cliff face monitoring

Cliff face monitoring was undertaken to identify cliff face changes below the site in Shag Rock Reserve. A laser scan MS50 laser scanner was established adjacent to Main Road to remotely measure cliff face changes using a mesh comparison model full time. Similar to the set up of the ground movement monitoring system as outlined in Section 2.1 above, several issues arose prior to equipment establishment, including limited suitable locations for equipment set up, security of equipment, powering the equipment, how will data be received and stabilising equipment (a low movement tolerance).

With Main Road and the Shag Rock beach area below, suitable site locations were limited. Equipment was housed in a purpose built container along Main Road and in alignment with other temporary containers protecting the road against potential rockfall. Equipment was secured on a thick steel pole that was welded to the top of a container. The internal area of the container was reinforced below the steel pole to reduce warping of the container and equipment movement. One of the control prisms on reserve Spit (from the ground movement monitoring) were referenced as a control prism and an additional prism was mounted in Shag Rock Reserve. The laser scanner was linked to solar power and battery units to power equipment continuously. Data was relayed to the project office via the same radio communication system used for ground movement monitoring. Photographs of the laser scan monitoring set up and aerial of the Shag Rock Reserve cliff face area are shown in Figure 4 (overleaf).

Laser scan data is processed to create a mesh that can be overlayed and compared to daily scan and baseline data. For presenting and reporting the cliff face was divided into quadrants and scans could be undertaken for each quadrant. Laser scan data could be accessed remotely on smart phones and laptop devices in the field. Laser scan data was displayed for the day and month (baseline comparison model) and was issued to the project team in the Deans Head Weekly monitoring update.

Figure 4. Laser scan monitoring Shag Rock Reserve, Sumner; A, aerial of Shag Rock Reserve cliff face and reserve area, the monitoring container location is shown with the red arrow; B, laser scan unit in monitoring box mounted in the monitoring container (as indicated by red arrow in photograph A).

2.3 Piezometer (ground water) monitoring

A series piezometers were installed across the Deans Head including four vibrating wire piezometers and a levelogger. Piezometer locations were based on an even spread across the mapped mass movement area and included parts of the lower, middle and upper areas of the slope. When selecting suitable piezometer locations on Deans Head, drainage paths and features, site access and known areas of localised instability were given consideration. Although modelling has indicated the likely slip surface to be between the loess colluvium and underlying volcanic bedrock. A response zone from bedrock to ground level was installed in all piezometers as modelling indicated complete ground saturation could cause instability.

Given the site is susceptible to water level changes, retrieving ground water data was important during periods of heavy rainfall. Where practical, piezometers were linked to a vibrating wire logger and mobile network so data could be remotely accessed from the project office. This reduced the time people were on site, in particular during periods of heavy rainfall when the site was most at risk. Cumulative rainfall and ground water level responses were graphed and issued to the project team in the Deans Head Weekly monitoring update.

2.4 Rainfall monitoring

Understanding weather patterns and forecasted rainfall events were used to manage site access, schedule site visits and walkovers. Rainfall forecasts were a key component in ground water monitoring and allowed the project team to identify early, be alert and prepare in case of an emergency event. Rainfall and ground water monitoring were closely linked during trigger level monitoring on the Deans Head project.

Weather forecasting was undertaken by an Engineering Meteorologist, providing information on weather forecast and patterns to the wider team throughout the project. Weather events such El Nino often lead to periods of dry weather and adverse or abnormal rainfall events. Although uncommon for such events to occur, they have been noted in areas of the Port Hills such as the 1 in 100 year rainfall event that occurred during August 2014. Rainfall measurements were collected locally in a rain gauge during works on site.

2.5 Seismic monitoring

With the recent Canterbury earthquakes, regional seismic activity in Christchurch was monitored on Geonet (refer www.geonet.org.nz). Seismic monitoring is the most passive of all the monitoring techniques used on Deans Head as you cannot predict (day to day) a seismic event happening and it is assumed an aftershock may occur at any time. Throughout the Deans Head project, seismic activity was monitored on Geonet (via local seismometers) and reported during the Deans Head weekly monitoring updates. During the Deans Head project, the most notable earthquake was the Valentines earthquake (Ma5.7 on the 14.2.2016). Following the earthquake, site works were put on hold for a few days while assessments, data analysis and walkovers were undertaken across the site area before works recommenced. Earthquake trends in the Christchurch area can be viewed on the GNS website (refer to 'recent aftershock map', refer www.GNS.cri.nz).

3 MONITORING TRIGGER LEVELS

A series of trigger levels were developed for each monitoring aspect to identify if thresholds had been exceeded or if there is a heightened risk of failure. This section provides an outline of the trigger level system developed on the Deans Head project and does not go into detail on the individual trigger level thresholds for each monitoring technique.

Thresholds were implemented for ground movement, ground water, seismic, weather and laser scan monitoring to advise the project team if trigger level thresholds have been exceeded or are likely to be exceeded. Depending on the monitoring technique, data was reviewed at different intervals during the day. Deciding when to review data was important throughout the project as data may need to be reviewed prior to works or specific tasks.

During ground movement monitoring, an automated text alert system was implemented so alerts could be sent if pre-recorded trigger level thresholds were reached or exceeded. This reduced human error however it was important to understand if a text alert was received, why changes have occurred as the text is computer generated. Three trigger thresholds were developed for ground movement monitoring (low, moderate, high) following baseline assessments. A text alert stated which threshold had been exceeded and to contact the project engineer. Although the project did not have an on-call roster, an overlap type system was developed so multiple personnel were on the text list at any given time. As the site was more susceptible to failure during periods of heavy rainfall, an on-call system could be implemented if deemed appropriate by the project engineer. System checks were carried out randomly including manually covering up prisms to confirm the automated system was operating correctly and the proper lines of reporting were followed by the monitoring team.

A monitoring status system was established on the project and was issued following review of the monitoring data each working day. A simple 'green' and 'amber' light system was created and issued in email format to notify the project team, client, key stakeholders and contractor(s) of the daily status update. It was important to undertake briefings on these systems to communicate a clear understanding to the wider team. The monitoring status system formed a key component of the contractor's methodology and for the health and safety of personnel working on a high risk geohazard site. Geohazard monitoring and systems in place were discussed during project meetings, site prestarts and site toolbox talks.

Another key component of monitoring was the stipulation of when monitoring will be undertaken, will monitoring be undertaken on non-work days, weekends, public holidays. This became important in managing project expectations and keeping a clear communication about when data was monitored. Data may be collected outside work times but may not be reviewed till the following day. A hierarchy of who to contact was developed as part of the monitoring management. Texts alerts were issued to a list of people from the project geotechnical and survey team. From a technical aspect, understanding why texts have been generated was important as often data can be miss leading and false alarms can be generated. This was highlighted when a prism was being measured through an earthquake event causing an inaccurate measurement to be recorded and a false alarm text alert issued. Managing who is on the text alert system is important, so they are clear on what they need to do, who they need to contact or report to and what happens next. Not having a clear line of communication and instructions could lead to a chaotic response. A clear communication line proved fundamental in managing, prioritising, assessing and reporting following the recent Valentines earthquake in Christchurch.

4 CONCLUSION

The main geohazards on Deans Head include a Class I Mass Movement area (landslide) and cliff collapse. Several monitoring techniques have been implemented on the Deans Head project, including for ground movement, ground water, rainfall (weather), seismic and laser scan monitoring in Shag Rock Reserve. These techniques have been adapted around the many site constraints and site features on Deans Head. During the Deans Head project, each monitoring technique was run through a simple what is the purpose of the technique, the aim of the technique and how would this be measured to identify if the main modes of failure and geohazards have been addressed.

Monitoring trigger level thresholds were implemented on the project including a text alert system for ground movement (prism) monitoring. When establishing an emergency management system, clear communication between the team is fundamental in creating a robust system. Who is on the text alert system is important as miss interpreting data and receiving false alarm texts may lead to a chaotic response.

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