Geotechnical Management at the Martha Pit

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Abstract

Subsidence issues associated with historic mine workings have highlighted the need for enhanced geotechnical management of the Martha pit over the remaining life. In conjunction with a detailed analysis of pit slope issues a comprehensive geotechnical management plan has been developed at Martha and is being used as the basis for development of similar plans in other Newmont operations.

This paper covers the geotechnical issues facing the Martha operation and the development and application of the management plan

Background

IGNS, (2002) report that the original Martha mine began as an underground operation in 1879 and by 1952, about 12 million tonnes of ore had been mined to yield 1,217 tonnes of gold-silver bullion. The historic mine extracted four main parallel lodes (the Martha, Welcome, Empire and Royal) together with numerous branch and cross lodes. All lodes dip steeply and are fillings of extensional faults and fractures. Early stoping employed the cut and fill method but this was phased out and largely replaced after 1914 by the shrink stoping method. Stopes were generally not backfilled after 1914 but left open. The workings reached a total depth of 600m from surface on sixteen levels. Man and supply access was by 7 known shafts and IGNS, (2002) report numerous other shafts were developed for ventilation and exploration purposes.

Exploration drilling between 1980 and 1984 identified large open pit reserves within the confines of the historic mining area. Following the granting of consents, the Licensed Pit commenced operation in 1988. The open pit was extended in 1997 to target deeper reserves and this final phase of open pit mining is scheduled to be completed in late 2006. The open pit extracts approximately 1.2 million tonnes of ore annually grading around 3.3 g/t gold and 33 g/t silver. Waste production is tailored to meet the ore supply and will drop significantly in late 2004 from the current stripping ratio of 3:1 to 0.7:1. At completion the pit will have a surface area of 24Ha. with dimensions 840m along strike, 575m in width and 250m deep.

All ore and waste from the open pit is crushed by either jaw crusher or stamler breakers located close to the Eastern wall of the pit and conveyed 3km to the Process Plant and Waste Disposal site respectively.

Bergin, (1993) discusses the geotechnical aspects of the design pit and states that design sectors for the pit slopes were delineated using geological criteria corresponding to domains of material with uniform geological conditions. Four primary divisions of the pit were delineated. These were:

- South of the lode complex
- North of the lode complex
- Post mineral sediments and ignimbrites
- Rock disturbed by mining.

Each of these sectors was further subdivided into oxidised, partly oxidised and fresh rock. The extended pit design in 1997 used similar boundaries for slope design as well as slope performance data from the Licensed Pit. This resulted in the pit slope parameters detailed in Table 1.

Sector	Subdivision	Batter Degrees	Bench (m)	Berm (m)	Overall degrees
North Wall	Oxidised	55-42.5	20	7	
	Partly Oxidised	65			43-46
	Fresh	75			
South Wall	Oxidised	30	20	7	
	Partly Oxidised	60-70			38-40
	Fresh	75			
Post Mineral	Ignimbrites	80	10	6	36
	Tuffs	40			
Disturbed Rock		60	20	7	43

Table 1 Design Pit Slopes at the Martha Open Pit

Many of the mined out lodes at Martha are located within the limits of the present open pit. However a few extend beyond the limits of the pit to beneath previously occupied areas of the town. During 1961, 1999 and 2001, chimney caving occurred from directly above the old workings (Royal Lode) subsiding to surface, which impacted outside of the Mining License area. Following an investigation into these events and the causes by IGNS between 1999 and 2002, the Hauraki District Council declared certain areas above the old workings within the Waihi Township to be hazardous and these areas were isolated and the residents relocated.

The historic Cornish Pumphouse classified as a Category 1 protected building is located close to the South wall of the Martha pit and bounded by the 1999 and 2001 subsidence events.

Geotechnical Issues

The geotechnical conditions at Waihi are significantly impacted by the presence of historic mine workings. In essence caving initiated during the historic mining has resulted in zones of poor quality rock mass within and outside of the pit slope limits. There has been ongoing large scale block movement over the last one hundred years and this large-scale block movement will continue into the caved zones in the future beyond the life of the open pit. Modelling suggests movements with displacements in the order of meters can be expected.

During their operation, the historic workings were well documented in terms of the spatial location and methods of stoping as well as descriptions of caved zones. The extents of the underground workings have been modelled in 3D using Minesight software. Figure 1 shows the extent of the underground workings in relation to the current open pit.

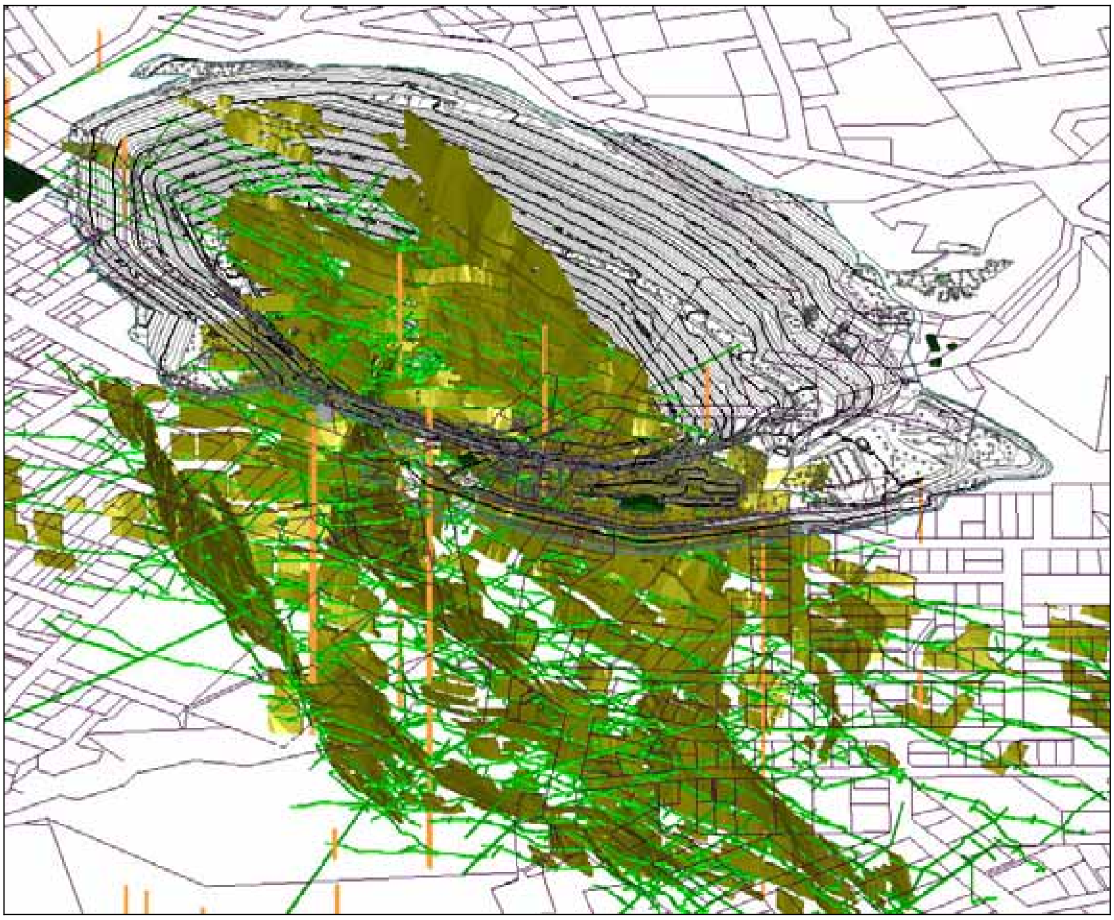


Figure 1 Model of Martha Open Pit and Historic Workings

The modelled pit slopes have factors of safety in terms of static slope stability greater than unity based on considered conservative parameters. This indicates the pit walls as designed can be expected to remain stable given the current rock mass conditions and static conditions. However the ongoing large scale block movement will mean that the pit walls will be undergoing movement during mining far greater than that which would be expected simply from excavation of the pit. This may result in local instability of slopes, if rock mass conditions deteriorate or are poorer in certain zones than modelled. Block movements can be rotational (tilting), downward or lateral. Movements are not expected to be continuous but of a stick-slip nature. For convenience, three states of deformation for the rock types have been delineated. These are:

- Caved zones, complete disaggregation of rock mass comprising rockfill of silt to coarse boulder size;
- Disturbed zones, disturbance due to large scale block sliding on shears, opening of joints and minor local caved zones
- Deformed zones, translational displacement on shears and stopes and minor block subsidence over large areas.

Pit wall mapping, reference to historic records and the 3D model have been used to determine the spatial extent of the caved zones, disturbed zones and deformed zones. These have been termed mining blocks. Pells Sullivan Meynink (2003) identified 10 Mining Blocks bounded by historic stoping on the Martha, Welcome, Empire, Edward, Royal, Letter and Albert veins. Nearly all these Mining Blocks show some ability to translate or rotate. Caved zones have been identified on the hangingwall of the Martha Empire and Edward lodes at 70-80 degrees to vertical and disturbed zones are interpreted to be sliding on pre-existing shears at 60-70 degrees towards the caved zones. Figure 2 shows the interaction of the various caved, disturbed and deformed zones.

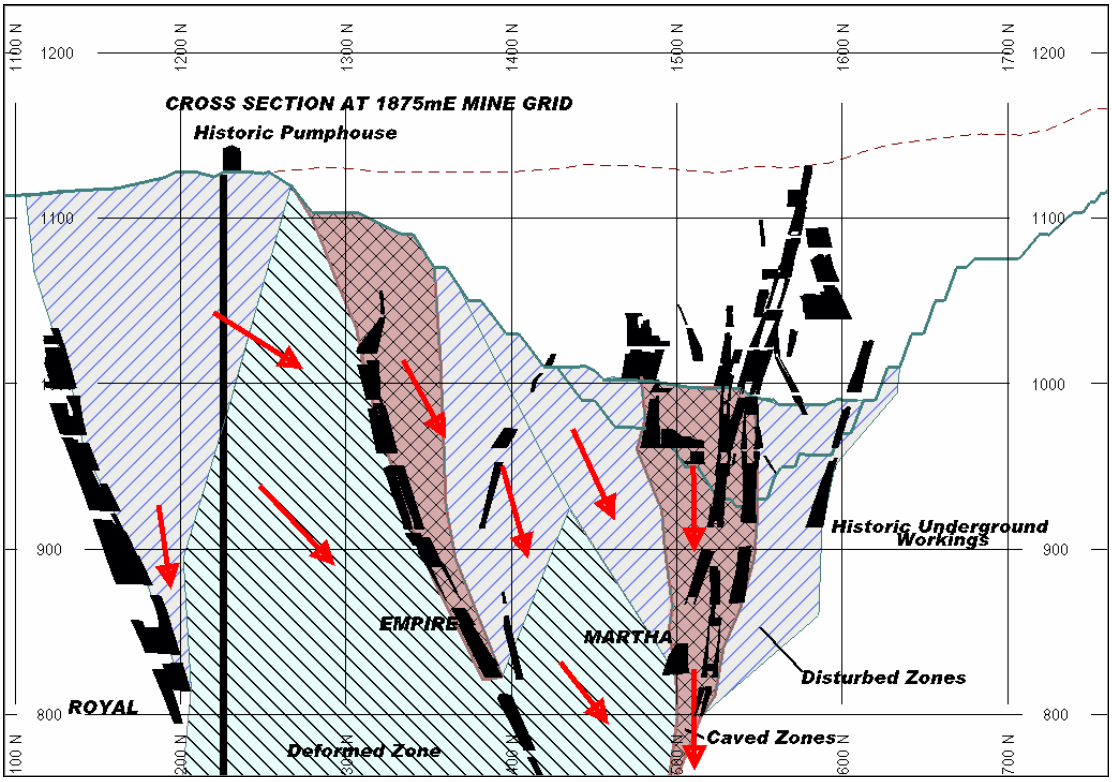


Figure 2 Schematic Caving Model

Understanding the mechanics of pit wall deformation requires an understanding of the underground caving and consequent block movements. Pit wall deformation as a result of the movement into the underground workings is expected to be reasonably constant over time but with some response to open pit excavation. Newmont Waihi Gold expects that rock mass conditions will deteriorate with deepening of the pit as the more extensively caved zones are intersected and has implemented a comprehensive geotechnical management system to address this.

Overview of Newmont Waihi Geotechnical Management System

The purpose of the Geotechnical Management System is to assist in providing a safe working environment for the open pit mining operation by managing the geotechnical risk. The Geotechnical Management System does this through:

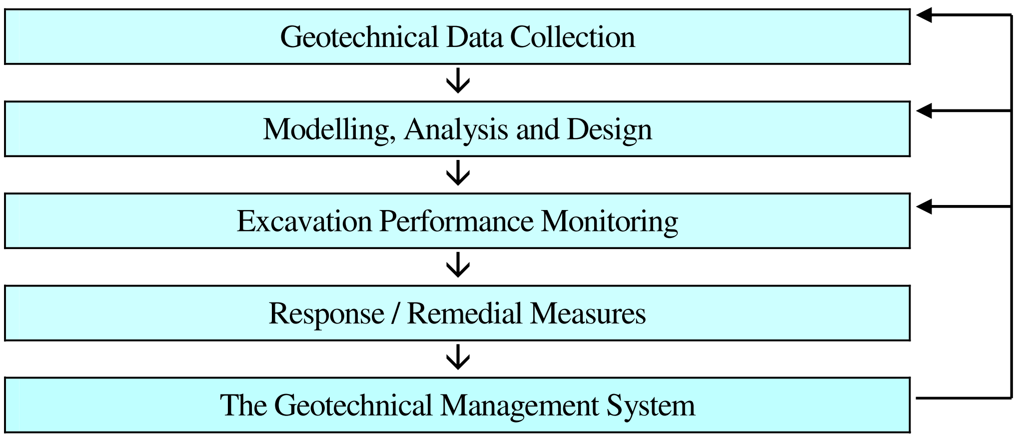
a) Hazard identification involving a range of geotechnical monitoring comprising instrumentation, survey and visual inspection by qualified persons. Trigger levels will be used to define potentially hazardous situations.
b) Exposure assessment involving comparisons with historic trends from monitoring and comparisons with predicted performance modelling from the geotechnical model.

c) Consequence assessment in terms of safety to personnel in the open pit, determined with reference to the risk from the identified hazard(s), the location of personnel and /or structures and status of open pit excavation.
d) Response assessment governed by trigger levels.
e) Mitigation which may involve a range of options such as evacuation, buttressing, changes to berm widths, changes to pit batters, mine extraction sequencing, installation of ground support as well as installation of additional remote sensing devices.

In addition the Geotechnical Management System also:

- Provides a comprehensive record management system related to geotechnical matters.
- Standardises procedures including collecting data, monitoring frequency, excavation practices, working around historic openings, implementing design changes etc.

The Geotechnical Management System is dynamic (meaning that it is updated continually) and comprises the following general activities:



The Geotechnical Management System processes are described in the Geotechnical Management System Manual which is available on the Martha intranet and is grouped into five sections, A to E, for convenience. These sections are:

SECTION A. Overview of the Geotechnical Management System, the roles and responsibilities of key personnel involved in the Geotechnical Management System, location of where information and data can be accessed as well as personnel trained to access the information.

SECTION B. Describes the geotechnical hazard monitoring and response systems particular to open pit geotechnical issues, covering slope failures, subsidence and earthquake, the description of trigger levels. This section is continually updated as trigger levels change; response measures amended or as key personnel change.

SECTION C. Is a reference section which contains the most up to date information from survey, monitoring, remote sensing, instrumentation, pumping records, visual inspection records and pit development status reports.

SECTION D. Is a reference section summarising the geotechnical caving model, the geologic units, and the expected response to mining of the geotechnical blocks.

SECTION E. Contains all relevant standard operating procedures (SOP's) covering probing, monitoring, geotechnical survey, methods of working and. presentation of data. This is updated only as procedures are revised.

Geotechnical Hazard Identification

The Geotechnical Management System is a four level system; green, yellow, red and the Emergency Management Plan in increasing severity of risk assessment.

Under normal conditions (Condition Green) the hazard identification process includes:

- Borehole extensometer data loggers alarmed with triggers set at levels above the current readings and if triggered will transmit a text message to cell phones of supervisory personnel. Data is downloaded and reviewed on a daily basis.
- Inclinometer measurements using time displacement plots and cumulative displacement plots. Results of inclinometer monitoring are communicated by email on a weekly basis as soon as the data has been processed.
- Wall prism monitoring on a weekly basis by total station. Individual or groups of prisms may be monitored at greater or lesser intervals as may be notified from time to time.
- Crusher personnel inspect the crusher slot area on a daily basis to visually assess the cracks in the shotcrete lining. Any changes in existing cracks or new cracking reported to supervisory staff.
- Crusher personnel inspect the tunnel laser on a daily basis. The crusher operator will check the laser offset from target and report any change / deviation from target to the mine survey.
- Geotechnical personnel walk over accessible parts of the pit, surface facilities area and crusher area on a weekly basis noting cracks, subsidence features, blast damage or other signs of instability.

Other forms of monitoring in use from time to time include levelling, crack monitors, wire line extensometers.

Trigger Levels

Based on Martha site experience and a peer review process, trigger levels to trigger the operating conditions have been defined. Trigger levels are described fully in the Geotechnical Management System Manual and relate mainly to magnitudes of displacements or differential displacement for extensometers, inclinometers and prisms above the instrument accuracy level, identification of new cracking, rockfalls, probe hole intersecting cavities and loss of water.

Response On Trigger Levels Being Reached

Figure 3 is a flowchart showing the response mechanism. On one or more of the trigger conditions being exceeded, management are notified by geotechnical personnel. Responses at the Yellow Condition include:

- inspecting the data and the areas affected,
- notifying the Geotechnical Consultant,
- increasing the level of monitoring.
- convene formal meetings and assess risk.

- if excavation is being undertaken in close proximity to the area where the trigger level has been exceeded, then the area shall be considered unstable and Procedures defined for working below unstable walls implemented.

For Condition Red trigger levels, senior management and pit operations supervisory personnel are immediately notified. A decision is made as to whether to invoke the Emergency Management Plan, based on any safety threat which may be present and to evacuate the open pit area in accordance with standard operating procedures.

Extensometer, prism, inclinometer data is analysed by the Geotechnical Consultant and in terms of the open pit prism data, the following procedures are implemented:

- The area of the moving prism(s) is inspected and if the cause of the movement cannot be determined, then mining activity in the area should be reduced or suspended.
- Continued acceleration of the movement should require closure of the pit floor below the moving area until the situation has been fully investigated.
- In the event that an increase in movement greater than four times the survey error is recorded for any reading when there has been no previous accelerations noted on a prism, operations supervisory personnel are to be informed immediately and the area below cleared until the point has been resurveyed.

The Geotechnical Consultant reviews data against geotechnical model predictions and provide recommendation which may include mining sequence, buttressing, additional support to stope backfill, modifying batters / berms or additional instrumentation.

Assessing Geotechnical Hazard

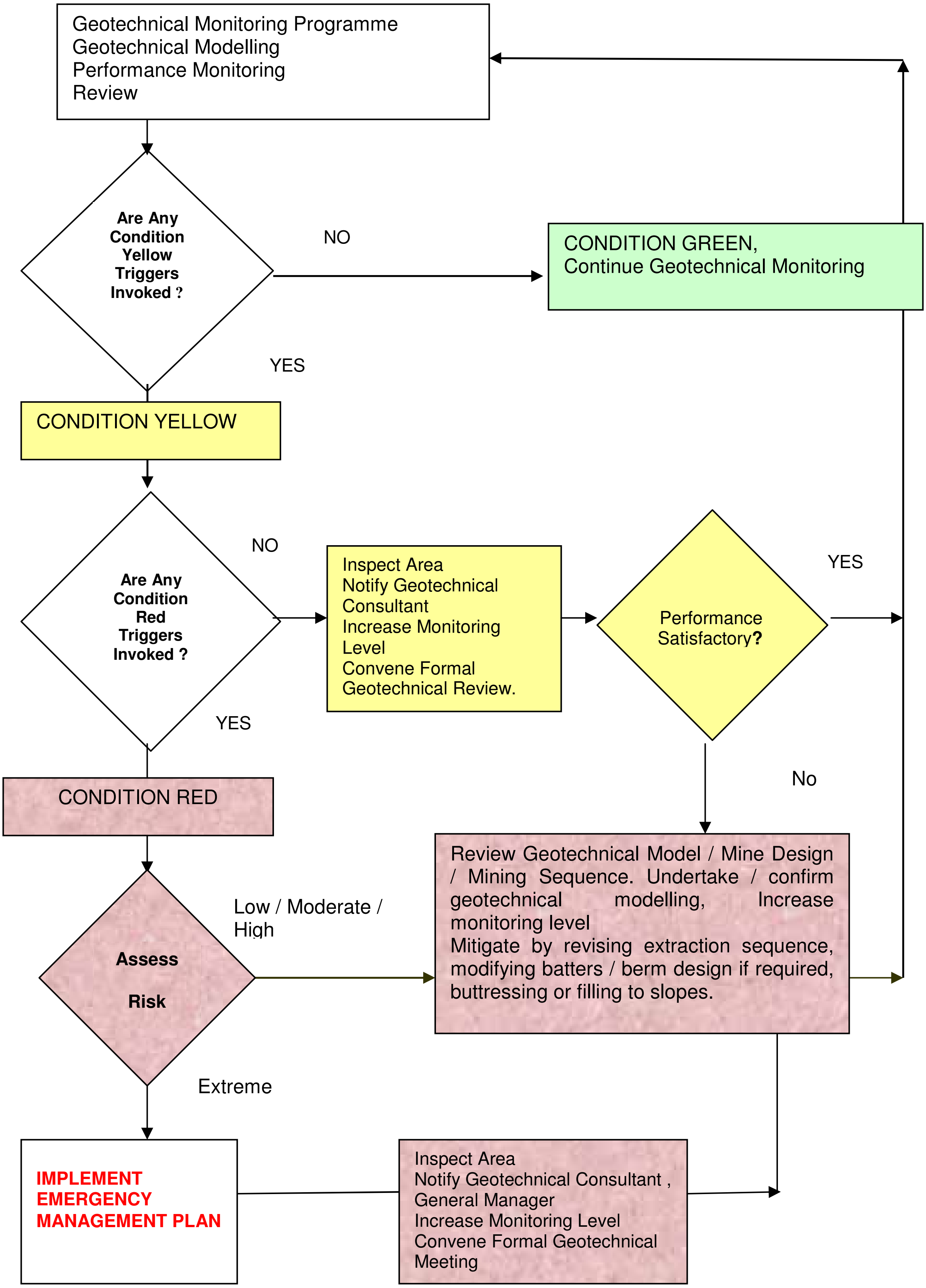
Guidelines are used for assessing the extent of the geotechnical hazard risk posed by the trigger levels previously described. Consideration is given to consequence and the likelihood of the event occurring. Consequence parameters include:

- management factors, ranging from events which can be absorbed through normal activity to events that have the potential to lead to collapse of the business,
- economic cost factors ranging from damage to equipment to large scale wall failure or loss of major haul road.
- safety factors ranging up to potential fatalities.

Further Work

The Geotechnical Management System has been through a rigorous Peer Review process and in place since mid 2003. The system will be formally reviewed, following the first red condition incident. The Geotechnical Management System developed at Martha is being used as the basis for developing systems at other Newmont sites.

Figure 3 Flowchart -Geotechnical Hazard Monitoring & Response



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