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APPENDIX Q, PART 1

Geotechnical Study Martha Open Pit
Phase 4
(PSM)

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PROJECT MARTHA

GEOTECHNICAL STUDY MARTHA OPEN PIT PHASE 4

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PSM

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1 INTRODUCTION

This report presents the results of a geotechnical study of the planned Phase 4 Pit. The Phase 4 Pit entails a cutback of the eastern end of the north wall of the existing pit. In essence this represents a change to around one quarter of the existing pit and is essentially a cutback to remove the North Wall Failure. This cutback will allow access to the base of the pit to complete the East Layback Pit.

The extension to the open pit is being undertaken as part of Project Martha comprising:

- The Martha Pit Phase 4 (MP4) and
- The Martha Underground including the Rex orebody.

These project components are partly linked and interact with each other:

- MP4 and Martha Underground will operate largely in parallel,
- With waste material mined from MP4 used as backfill for the underground or alternatively placed at the RTSA (Rock and Tailings Storage Area);
- Additional access to the underground established from the open pit with portals on the south wall and or dedicated fill passes; and
- MP4 will operate from project years 3 to 10 and the Martha Underground from project years 1 to 11.

The exception to this is the Rex orebody, which is remote from the open pit and the Martha Underground.

Because a large portion of the existing Martha Pit slopes are completed and have already been the subject of geotechnical studies, this report will focus on the new cutback area. For the existing pit slope areas not affected by the cutback, this report:

- Lists the key reference documents,
- Includes key summary elements from those references;
- Mainly those elements related to pit stability;
- Assesses the long term monitoring data for these existing slopes; and
- Includes assessment of whether the stability will change as a result of MP4 and Martha Underground.

A separate modelling study and report on the interaction between the MP4 and Martha Underground has been undertaken, PSM125-283R.

2 AIMS OF RECENT PIT DEVELOPMENTS AT MARTHA

There have now been four pits excavated at Waihi; Licensed Pit, Extended Pit, South Stability Cutback (SSC), which was originally aimed at pit closure; and East Layback (Pit 66D).

Both the SSC and East Layback pits were designed to achieve more stable conditions by moving the new pit walls as far as practical outside the rock mass zone affected by the historical underground workings. This process has generally been successful as demonstrated by the performance and success of the SSC and the East Layback.

All failures to date in the Martha Pit, both large and small, have occurred in sections of the rock mass substantially affected by the historical underground workings. Analysis of the north wall failure, which occurred in April 2016, has also shown it is linked to the historical underground mining.

Hence the MP4 pit is a continuation of that stabilisation process, because the cutback removes the north wall failure, and moves the north wall further outside the rock mass zone affected by the historical underground mining. MP4 is a remedial cutback of a failure undertaken in order to re-establish the mine. This is a normal part of conventional mining activities and there is nothing unique or special in the planned cutback.

3 PLANNED MINING

3.1 MP4

MP4 will be mined in a single top down sequence. The planned cutback is shown in plan in Figure 1 and in a series of sections, Figures 5 to 8. In order to achieve the target depth and due to the limited size of the cutback, temporary ramps will be necessary. OceanaGold have divided the cutback into three:

- Cutback 1, the upper part of the cutback down to 1120 mRL, which is mined with small equipment and access via the east wall and Magazine Road, Figure 2;
- Cutback 2, the central portion including the establishment of the northern haul road to 1070 mRL and connection to the lower southern haul road with temporary ramps, Figure 3; and
- Cutback 3, the completion of the cutback to a depth of 275 m, 875 mRL, Figure 4.

The planned pit will take around eight years to mine. Ore and waste will be mined by conventional drill and blast methods. The controlled blasting practices used over the last two decades will be continued. The horizontal drain hole drilling will be continued as required in the cutback.

3.2 Martha Underground

The Project Martha project description states that some waste may be directed to the underground mine via portals established on the south wall or by dedicated fill passes. Figure 9 shows the planned intersection of the Martha Underground portals and/or passes with the existing pit. These are minor openings and will not impact on overall pit stability. Notwithstanding this care will need to be exercised in the breakthrough to the open pit. At least one of these openings already forms part of the Martha Drill Drive Project (MDDP) and the potential impacts on pit stability have already been evaluated, PSM125-278L and PSM125-279L.

Figures 10 and 11 are elevation views looking north and west, showing MP4, the planned underground drives and the location and type of the planned mining for Martha Underground.

The elements of the planned Martha Underground mining relevant to MP4 are:

1. Separate to the planned mining, 30% of the existing unfilled historical stopes will be stabilised by filling with rockfill. Approximately half of these stopes are located in the upper levels immediately below the MP4 Pit;
2. In addition, 30% of the planned mining will entail re-mining of historical stopes (remnant mining). The important factors about this mining are:
    a) The mining will be top down,
    b) A very large proportion of these stopes are located immediately below the MP4 Pit; and
    c) CAF will be used as dictated by site conditions, extensively in this mining.

These two factors will result in a significant improvement in overall rock mass conditions in the zone underlying the MP4 Pit. This will have two positive impacts on MP4 Pit, firstly by improving pit stability conditions both in the short and long term and secondly by reducing any impacts of the Martha Underground mining in general. This will also reduce the longer term potential for ongoing creep of the rock mass.

3.3 Rex Lode

The Rex Lode is a small, short life, narrow vein mine that is isolated from the historical and planned new underground mining. The mine is south of the MP4 Pit and underlies the rugby field and part of the township. The geometry of the planned mine and its geometric relationship to MP4 Pit is captured in the following points:

- The mine is around 250 m in strike length;
- The top of the mine is 80 m below ground surface;
- It extends from 1030 to 850 mRL;
- The lower RL is the level of the base of the MP4 Pit;
- In plan the top of the mine is located 180 m south of the MP4 Pit crest;
- However, measured horizontally the distances are much greater. The distances from the top and bottom of the underground mine to the MP4 Pit are 270 and 390 m respectively.

Access will be via the MDDP. Mining will utilise the Modified Avoca stoping method with stopes backfilled with waste rock and occasionally Cemented Aggregate Fill (CAF). Stoping will take place in years 2 and 3. No further dewatering is planned for this mine.

Based on these factors it is assessed the Rex Lode will have no impact on the MP4 Pit. The Rex Lode has not been included in the modelling of the MP4-Martha Underground interaction.

4 GENERAL DISCUSSION OF THE PHASE 4 PIT

4.1 General

The existing Martha Pit has been operating since 1987 and most of the pit walls are quite old. The cutback for MP4 only entails approximately the eastern half of the north wall and allows the lower part of the East Layback Pit to be completed at depth, Figure 1. Figures 2 to 4 show the main stages of cutback development.

Consequently the MP4 pit is in large part an existing structure that has already been constructed and its performance has been monitored over time. The existing pit stability condition is the starting point for MP4. The northeast pit wall will be a new cutback and is evaluated in accordance with the usual engineering standards.

The Rex Lode mining will not impact on the open pit as discussed above.

The main potential change to this existing system equilibrium is the Martha Underground, which will take place in parallel to the open pit mining. Evaluation of potential impacts comprises two main elements:

1. The first is a general consideration of the location and nature of the planned underground activities, as discussed in Section 3.2 above.
2. The second is whether the underground activities as a whole cause unacceptable global deformation and this is the subject of the underground open pit interaction modelling, report PSM125-083R.

4.2 Existing Pit Performance

Appendix J includes the monitoring data for the existing pit. Some of this monitoring has now been in place for almost two decades. The monitoring data has been reviewed many times over the years and does not show large scale or global pit wall instability movements. Consequently in engineering terms there has been a mine scale validation of the ultimate material properties used for the design of the pit walls.

However the scarp left by the north wall failure is a relatively new slope that has only been in existence for about two years. Additional monitoring was installed after the failure to monitor this new slope including:

- Prisms outside the failure scarp,
- Two inclinometers behind the north wall and
- Additional prisms on the remedial cutback.

Over the months following the failure there was some local movement and failures around the edges of the larger failure. This is a usual situation with large failures. However the monitoring shows that no global movement is occurring on or behind the failure scarp and this new slope is stable overall.

Notwithstanding the descriptions above, the monitoring data does show ongoing creep movements associated with the underground mining, principally the Milking Cow Zone.

The monitoring data for each pit domain is reviewed in more detail in Section 11.0.

4.3 MP4

The MP4 Pit is shown in plan in Figure 1. Included in Figure 1 are four section locations chosen to illustrate the relationship between the existing pit and MP4, Figures 5 to 8. In the cutback the new pit walls are relatively close to the failure scarp and therefore the geotechnical conditions and the stability of the scarp of the north wall failure itself assist with informing the assessment of the new Phase 4 Pit walls.

One focus for the Phase 4 studies has been to use the new drilling undertaken since the East Layback was designed in 2005. This new data shows the new pit is located in a better quality rock mass and where practicable, further removed from the historical mining influences.

There are a number of positives associated with the Phase 4 Pit, including:

- There is a long history and understanding from mining in the materials in the current Martha Pit;
- There is good drilling coverage in most areas,
- The planned cutback slope is relatively close to the existing pit wall,
- In the cutback area the MP4 pit will be further outside the potential disturbance envelope from the historical underground mining;
- The pit walls are largely depressurised; and
- The Martha Underground will stabilise many of the existing openings immediately below the open pit.

This stabilisation will make a significant difference to the long term post mining risk situation in Waihi.

There two other factors associated with the planned Project Martha that need to be addressed:

- The pit life will increase, and
- The groundwater level in Martha Underground will be lowered by an additional 200 m.

In regards to the second point there has also been no evidence that dewatering has had any negative impacts on pit stability, rather the opposite is the case and fully dewatered pit slopes have been a major benefit for pit stability.

In regards to the first point, one aim for previous pits was to limit the time between final mining of ore and pit flooding. The life of the MP4 pit is 10 years, which is a significant increase over previous planned mine lives. The implications of this relative to the performance of the current pit are assessed in more detail in Section 13.

5 MINING LICENCE CONDITIONS

The Mining Licence for the Martha Mine open pit was granted in 1987, subject to a number of conditions. A Land Use Consent and variation to the Mining Licence for an extension to the Martha Mine (known as the Extended Project) were granted by the Environment Court in 1999.

A number of conditions were imposed at the time of granting the Mining Licence in 1987, and also at the time of the variation to the Mining Licence in 1999. Condition 36 is particularly relevant and requires that:

> *"Mining processing and waste disposal operations shall be carried out in such a manner as to* ***ensure that the surface of the land suffers as little permanent damage as possible.*** *The licence area is to be left in a clean and tidy condition after mining operations have ceased including removing from public view any used derelict equipment and machinery and* ***the pit faces are to be left in a stable and safe condition****."*

Post extraction of the ore and waste materials from the open pit, the pit will be flooded with water to form a recreational lake. This together with the planned landform construction around the site is the completion of mining activities within the open pit and its immediate surrounds. The conditions state the pit is to be left in a safe and stable condition after all these activities are completed.

6 MAIN PREVIOUS STUDIES

Detailed geotechnical studies for the various Martha Pits have been ongoing at least since the time of granting the Mining Licence in 1987. There has been a great deal of information gathered about the geotechnical conditions, particularly around the historical underground mining and associated disturbances to the rock mass. The major legacy of the underground mining has also become increasingly apparent, with a number of significant subsidence events, collapses, areas of movement and deformations.

The existing pit and hence the majority of MP4 is already covered under a number of previous designs and design reports. It is not a new pit, with limited experience of slope behaviour and where the slope designs have not yet been tested.

The pit wall sectors and the relevant design documents are:

Northwest and west

Design Report Extended Pit
PSM125.R10
28th May 1997

South

Report on Pit Closure Studies
South Stability Cutback
PSM125.R34
4th April 2006

East and south east

East Layback, Pit 66D
PSM125.R39
11th January 2010

The area not covered by these design reports is the north wall failure and the remedial stabilisation cutback of the upper slopes of the failure. The relevant documents covering this area are:

Northeast

North All Stability Review
PSM125-235R
18th March 2015

North Wall Update
PSM125-237R
1st May 2015

Report on the North Wall Failure
PSM125-252R
19th October 2016

Interim Remediation North Wall
PSM125-253L
2nd December 2016

These documents include detailed stability calculations for all the pit walls, including analyses showing the changes in factors of safety away from the pit crest. All of these documents have all been presented to council and been peer reviewed.

7 SLOPE DESIGN CRITERIA

7.1 Introduction

The slope design criteria used for the design of the Extended, SSC and East Layback Pits are discussed in detail in reports PSM125.R10, PSM125.R34 and PSM125.R39.

Since that time, more up to date information is now available on earthquake design and the new recommended criteria, supplied by Dr T Matuschka (Engineering Geology Ltd.), comprises:

1. Ultimate limit state: a 500 year return period of shaking, Peak Ground Acceleration (pga) of 0.23 g.
2. Serviceability limit state: a 25 year return period of shaking; (pga not supplied, but estimated at 0.08 g according to NZS 1770.5:2004).
3. Amplification of 0 at the bottom of the pit, increasing linearly to 0.2 at the top of the pit.
4. The use of 1.0 as a pseudo-static factor (i.e., no reduction in peak ground acceleration for pseudo-static analysis, which is very conservative), but with a revised Acceptance Criteria for ultimate limit state:
    - FOS ≥1.0; or
    - FOS <1.0, and acceptable permanent deformation.

An acceptable permanent deformation criterion for the Martha Pit is considered to be 1% of slope height, which is around 2.0 m.

7.2 Discussion on Material Strengths and Design Criteria

In the Martha pit there is a mixture of soil, soil/rock and rock materials, some of which occurs in multiple layers. In soil/rock mixtures design is usually based on evaluation of the potential for local and overall slumping type failure. In hard rock conventional practice relies on consideration of rock structure and potential for rock structure controlled failure. However particular slopes, for example the southeast wall, have an upper Ignimbrite Zone layer underlain by Andesite. The reality is some parts of the slope have a FOS and some parts have a certain Probability of Failure (Pf) or Reliability. This is a function of the nature of the site materials.

In the Andesite, the inter-ramp and overall angles have been assessed using the geological structure data. It should be noted that for all the pit walls excavated at Waihi over the last 20 years in the Andesite rock, there has only been one significant failure related to structure, the North Wall Failure, for which the situation is complicated by the historical underground mining effects.

The stability criteria for the Martha Pit were developed as part of the studies for the SSC. Those criteria were reviewed and accepted by HDC and their independent reviewers. The criteria were developed initially for the Extended Pit and have then been expanded to allow for the impacts of the historical underground mining and the possibility of some ongoing creep of slopes.

In conventional engineering terms if a slope is moving it is often termed marginally stable and the FOS is thought to be close to 1.0. However in the Martha Pit one of the main causes for movement is the subsidence of the underground workings. A long term difficulty in the Martha Pit situation has been differentiating between creep movements due to subsidence and movements related to creep of the pit walls and or pre slope failure movements. These two movement causes could also form a continuum, with one ultimately leading to the other.

Assessment of historical survey data in 1989 shows Martha M Trig station had subsided 2 m over time, Appendix K. This Trig is located in the southeast pit area in the rock block between Martha, Empire, Edward and Royal Lodes, Figure 25.

Significant movement of rock materials causes a loss of strength. The slopes in the Licenced Pit were initially analysed using strength parameters derived from methodologies in common engineering usage. These strengths have continued to be revised downwards mainly based on back analysis of the various pits, assuming the observed movements indicate marginal stability and a FOS close to 1.0. This is a conservative assumption, but it means in some instances the final design strengths are probably understated. These uncertainties about the strengths means the resultant FOS are also probably understated. These factors need to be taken into account when evaluating the shear strengths used in stability analyses and the design FOS.

8 HISTORICAL UNDERGROUND MINING IMPACTS

8.1 History of Mining

Mining at Waihi started in 1878 and comprised two main phases:

- Underground mining, 1878 to 1952, and
- Open cut mining 1988 to present.

Detailed records are available for the period of open cut mining (approaching 30 years), but unfortunately only limited, poor quality records of the rock mass deformations and subsidence are available for the 70 year period of underground mining.

Historically subsidence events were of relatively minor importance for underground mining, they were just part of the day to day mining operations and hence detailed records are sparse. It was originally understood by the initial open cut mine owners and their successors that no surface collapses had occurred. However, it is now apparent from the records and mapping of the different pits that many chimney cave collapses developed throughout the period of underground mining. Between 1952 and 1988 there was no mining or monitoring of ground surface movements and the area was largely abandoned. However the information from Martha Trig Station is of relevance here, Appendix K. One other exception to this is the Royal Collapse in 1961 for which apart from the location no information is available.

8.2 Historical and Recent Events

The known major historical events and activities are summarised in Table 8.1.

TABLE 8.1
SUMMARY OF PRINCIPAL MINE RELATED EVENTS

DATE	EVENT
1907	Initial collapse above the Martha Lode.
1907-1952?	Ongoing subsidence and formation of the “Milking Cow”.
1907-1952?	Subsidence above the Albert, Empire and Princess Lodes
1952	Cessation of underground mining.
1952-?	Groundwater level recovers in underground workings.
1961	Collapse above the Royal Lode, after cessation of mining and recovery of the groundwater table.
1988	Start of open cut mining for Licensed Pit and dewatering.
1995	Movement on the upper south wall of the Licensed Pit. Originally thought to be slope instability but now understood to probably be an incipient subsidence/collapse over the Royal Lode.
1999	Second collapse above Royal Lode.
2000 (June)	Start of mining for the Extended Pit.
2001 (Dec)	Barry Road collapse over Royal Workings.
2002	East Wall Failure.
2002-2003	Cracking of South Wall.
2003	Eastern Stream cracking and water losses under Grey Street.
2007-2008	Re-occurrence of block subsidence and cracking on the south wall.
2009	Subsidence and failure of the east wall.
2016	North Wall failure
2017	Sinkhole collapse in Parklands north of rugby field

8.3 Geotechnical Investigations of Historical Mining and the Underground Model

In 2002-03, a comprehensive compilation was made of all the available information on historical underground mining and this work was updated in 2004 and for moving the Pumphouse. This information has continued to be analysed and integrated with the exposures in the pit and the pit wall performance. This is part of the ongoing development and refinement of the underground model. A further iteration of this model has been carried out as part of this study.

The main findings from the 2002-03 studies (Report PSM125.R28) include:

> *“…. over the past few years it has become increasingly apparent that the legacy resulting from historic underground mining at Waihi is very great. The main reasons for this are, firstly the full extent of the workings, both laterally and vertically is very large relative to the open pit, secondly the very long period of underground operations (70 years), thirdly because large underground openings were left unsupported and finally there were renewed mining activities superimposed over older workings and recommencement of mining even in areas*

that had failed earlier. Hence, because many large stopes were left unsupported and open at depth, failure processes, which started during historic mining have continued to various extents along the old workings ever since."

And

"….. during underground mining failure of the workings was common and the main types of instability recorded comprised; subsidence, caving and collapse."

And

"There is a complex history of mining for each lode, the upper levels were filled and many years later the pillars were robbed. As mining progressed the mining changed to open stope methods. At depth, caving was used."

And

"The main points arising from this research are:

- *The total area affected by historic subsidence is much greater than recorded previously and the eastern limit of the historic subsidence extended as far as Grey Street.*

- *Separate more local subsidence/collapses also occurred at depth elsewhere throughout the mining area and around many of the shafts."*

Hence from these extensive investigations it is now evident there has been widespread ongoing subsidence, movement and deformation occurring over a large area both inside and outside the open pit.

A comprehensive compilation of available information on historical and more recent underground mining related subsidence and collapse features is included in Report PSM125.34R.

The studies have all shown that the collapses and events over the last 23 years at Waihi comprise part of a long-term ongoing sequence of underground instability-related movements. These movements started early last century as extensive, large-scale block subsidence of the hanging and footwalls of the main lodes. The whole of the area of underground mining is effectively one system and while it appears events are separate, they are linked subsidence, movement and collapse mechanisms operating at scales ranging from the local to the widespread. These mechanisms started during underground mining and have probably continued.

8.4 Summary

In summary the historical and recent evidence shows the following approximate sequence of events or effects:

1. Large scale block subsidence and sliding on the hanging wall and footwall of the Martha Lode and the hanging wall of the Empire Lode occurred during mining around 90 years ago. This occurred on the more shallow cut and fill stopes, which were part clay filled.

1. Subsequent caving activities at depth resulted in:
   a) The cave effects developing right to the ground surface, as the Milking Cow and
   b) Partially to the ground surface west of the Milking Cow.
2. The caving was also facilitated by further sliding on the footwall of the Martha Lode, which formed the northern side of a large subsidence cone.
3. For both the 2001/02 and 2009 east wall failures, subsidence "faults" comprised the eastern edge of the failures. These faults had developed historically due to the caving subsidence up to about the level of the Welded Ignimbrite.
4. The precursor to the failure of the east walls was a small slump developed in the weaker Tuff and Alluvium along one of the "subsidence faults". This undermined the overlying and surrounding strata leading to the failure.
5. Long term creep and subsidence of the east wall area in and around the Milking Cow has continued throughout the period of open cut mining up to the present time.
6. This situation was exacerbated by the disturbance (weakening) to the strata due to the historical mining. The recent ravelling erosion failure in the southeast is in an area where the historical Empire hanging wall subsidence intersects the pit wall. The subsidence led to a downthrown step in the Ignimbrite Zone and local weakening of the strata.
7. The other contributing factor was that folding of the beds in the Ignimbrite Zone due to the Milking Cow led to steep dips towards the west out of the pit wall. Locally steep dips were intersected in the East Layback Pit as it was excavated because it lies east of and partially outside the Milking Cow.
8. In the south the Royal Lode workings were clay filled in the upper levels, forming in effect a "fault" and this has limited the spread of the majority of the subsidence to the north of this lode.
9. Based on the East Layback excavation there is now a well-defined eastern limit to the main cave affected subsidence effects on the east wall. This limit is also supported by the geometry and distribution of the stopes in the Martha Lode that show:
   a) The significant decrease in Martha stope widths to the east.
   b) The stopes plunge to the east.
   c) The stopes become more isolated and there are significant pillars.
   d) The stopes splay out in plan.
   e) Hence the reviews of borehole data shows disturbances due to the underground workings in this region are concentrated locally around stopes.

9 AVAILABLE INFORMATION

9.1 Drilling Coverage

Figure 12 shows the complete database of drill holes in and around the Martha Pit, with drill collars and drillhole traces. There are no gaps of any major size.

9.2 Exploration and Geotechnical Drilling

The status of new information available for this pit since the design of the South Stability Cutback and the East Layback comprises the following:

1. In 2016 approximately 31 exploration holes were drilled by Geology, series holes UW469 to UW500. These holes were drilled to explore the potential for the larger pit.
2. A model update was completed in May 2017.
3. Previously three long holes had been drilled to the north from inside Martha Pit, UW462 (in centre), UW463 (in east) and UW464 (in west),
4. In 2012/13 a series of holes were drilled for the MEP project, all along the north wall.
5. Two core inclinometer holes exist behind the north wall failure, Inclinometers 7 and 8. These holes have been logged by Geotechnics.

Figure 13 presents a plan of the new boreholes and the boreholes used for the rock mass model development. Figure 14 presents a breakdown of these holes showing their origins. Geotechnical logs for these holes have been produced and are presented in Appendix H.

It is evident from these two plans that there is good coverage of data for the whole pit.

A number of geotechnical sections have been prepared, for each of the new geotechnical holes and focussed particularly on the north wall cutback, Figures 15 to 20. Included on these sections is the latest rock mass model, the geology, the stopes and lodes.

9.3 Piezometers

Figure 21 shows the existing piezometers. The hydrographs are included in Appendix G.

9.4 Structural Data

9.4.1 Introduction

The available structural data comprises:

- Pit mapping,
- Oriented core,
- Sirovision mapping and

- Mapping of the interim cutback on the upper north wall.

All of this data in presented as stereonets in Appendix F.

9.4.2 Oriented Core Data

Figure 22 shows the collar location and drillhole traces for all the holes with oriented core. The stereonets for each hole are included in Appendix F.

9.4.3 Mapping

Figures 23 and 24 show the point source location of all faults, shears and joints mapped in the Martha Pit. These figures show large gaps in the east southeast, however this is a reflection of the occurrence of Andesite rock mass disturbed by the underground and the large thickness of the overlying Ignimbrite Zone.

9.4.4 Comparison of Data Sources

Figures 23 and 24 also present combined stereonets from the different sources and domains. There is a broad correlation between these sets of information.

10 SOUTH STABILITY CUTBACK

This section presents an Executive Summary of Report PSM125.R34. Reference should be made to the complete report for additional detail if required.

The South Stability Cutback (SSC) presents the results of studies undertaken for the planned closure of the Martha Pit at Waihi. The SSC was intended to be the final open pit excavation at Martha at that time. The SSC cut back the south and southeast pit walls in order to place the final south wall further from the historical underground influences. The monitoring and performance shows this was successful.

This report presents the updated geotechnical model and highlights this in relation to the Mining Licence Conditions. The report investigates the long-term stability; including seismic effects and the impacts of pit flooding and ongoing subsidence and collapse associated with the historical underground workings. Recommendations are provided on a strategy for pit rehabilitation that incorporates where practicable the intent of the Licence Conditions. The report also evaluates the benefits provided by a stabilising cutback of the south wall.

The major legacy of the underground mining had become increasingly apparent, with a number of very significant events, including the 1999 and 2001 Sinkhole Collapses outside the mine. A Technical Working Party was established in 1999 to investigate the sinkhole collapses near Seddon Street and the Barry Road Collapse in 2001. A report was prepared by IGNS to assess the causes of the collapses and it defined a series of hazard zones mainly outside the open pit. The IGNS Report was focussed principally on only one mechanism of deformation related to the old underground workings, namely the formation of sinkhole collapses. The IGNS report was done for the council, because the council in effect owns whatever legacy derives from these historical underground workings.

The Mining Licence referred to safe and stable conditions and post closure using the pit as a recreational facility. However since the mining approvals were given the various collapses and events, together with the subsequent IGNS Hazard Risk Zoning meant that some of the Mining Licence Conditions needed to be re-considered. What do these terms mean when long term subsidence due to the underground mining was continuing?

The problem was then how to provide an effective closure to the Martha Open Pit that honoured the intent of the Licence Conditions and the planned final end use, but at the same time recognised that the legacy of the underground mining is on a scale and an extent that it may not be appropriate to think only in conventional engineering terms.

The long term effect of the underground mining was causing significant movement of the south and east pit walls. It was assessed movements would continue even without the open pit mining. These were not pit design issues, but issues caused by the historical underground mining. In geotechnical engineering there are no precise definitions of “safe” and “stable” and it was difficult to demonstrate against a known standard the long term safety or stability of the slopes in the Martha Pit. Hence in terms of the Mining Licence Conditions what was the practical definition of these two terms and how could they apply in practice?

The report addresses these aspects using the available understanding and experience from the science of natural slopes, geomorphology. It was recognised that after Pit Closure and rehabilitation, the pit walls would be natural slopes. Therefore it was appropriate to consider the pit slopes initially in engineering and then subsequently in geomorphological terms. In geomorphology it is recognised that movement of slopes can still occur even though the FOS is >1 and the slope is thought of in layman’s terms as “stable”. In geomorphological terms, slopes with conventional engineering FOS (1.2 to 1.3) are termed “Conditionally Stable” in recognition of the fact that natural stable slopes may still undergo movement. This then led to the concept of Limiting Slope Angle. If a rock slope continues to move, but is not subject to catastrophic failure, then the result is a pile of rock fragments whose slope angle is dependent on the character of the rock. The angle at which a pile of rock remains stable is called the Limiting Slope Angle. This is the Angle of Repose, also termed the threshold or limiting angle of stability, which at Martha was about 40º.

In the context of the Martha Pit both creep and subsidence are relevant. Creep is described as the slow non-accelerating downslope movement and rates of 10 to 20mm per annum (up to 0.05 mm/day) have been quoted as occurring on “stable” slopes (Summerfield 1996). However others have recorded these creep zones to depths of several hundreds of metres with movement rates from 1 to 1000 mm per annum (0.003 to 2.7 mm/day) (Selby 1982).

The whole of the southern, south-eastern and eastern pit walls of the Martha Pit were affected by movement and subsidence due to underground mining and these movements were unlikely to completely stop in the future.

Relevant experience from the pit was collated in 2003 and showed that the upper bound angle for pit slopes in rock affected by underground mining was about 40º. Above this angle failures occurred but below 40º the slopes continued to move and deform while still maintaining their essential integrity, the Limiting Slope Angle.

The initial slopes in the Licenced Pit were analysed using strength parameters derived from methodologies in common engineering usage. These strengths were revised downwards a number of times using back analysis of moving slopes assuming the observed movements indicate marginal stability and a FOS close to 1.0, although this may not be absolutely correct. Hence there are uncertainties about the strength used and the resultant FOS. The situation was the slopes initially had a high FOS but are moving and are expected to continue to move.

The criteria adopted to satisfy the intent of the Mining Licence Conditions were:

1. Slopes not adversely affected by underground mining nor subject to major ongoing movement due to the underground mining – Minimum FOS = 1.5.
2. Controlled access in areas with a significant risk of subsidence collapse and major deformation.
3. Slopes affected by ongoing significant movement due to underground mining – maximum overall slope angle of 40º.

The studies undertaken for the SSC included:

1. A summary of geotechnical information gathered since 1999.
2. Delineation of zones potentially affected by underground workings and how these could impact on wall stability post closure.
3. Updating the geotechnical model, including rock mass strengths and the location of zones of disturbance due to underground mining.
4. Recalculation of the FOS for the pit walls in the same manner to Extended Pit, but for the new final pit depth, new slope geometry, water table conditions and rock mass properties.
5. Assessment of the stability of the pit, at closure (immediate), during flooding (medium-term) and the final lake level (long-term). This includes identifying critical pool levels during filling.
6. Estimation of likely consequences of worst case pit wall failure.
7. Evaluation of laying back batters above final lake level.
8. Examination of the potential for landslide waves including seismic events.

A comprehensive compilation of all the available information on historical underground mining was carried out in 2002-2003. This information was integrated with pit exposures, information from investigation drilling, geological mapping, pit wall performance and movements. The main movement and deformation mechanisms identified comprised:

- Large-scale subsidence over caved zones,
- Creep of large areas,
- Block subsidence or settlement;
- Local chimney development and
- Sinkhole collapse formation.

The classic model for deformations was recognised with three concentric zones:

1. **Caved Zone** - The central zone comprising a broken rock mass, with sizes ranging from very large blocks to silt size.
2. **Disturbed Zone** – A zone around the central zone comprising a disturbed rock mass with large block sliding on shears, opening of joints, infill and minor local caved zones.
3. **Deformed Zone** – An outer zone surrounding the inner two zones with displacement on shears/faults and any other underground workings, with movements and or subsidence over large areas.

These effects were identified in the whole area covered by the Edward Lode in the west, close to the footwall of the Martha Lode in the north, the approximate projection of the Royal Lode in the south and are somewhat open in the east southeast direction.

The new drilling was reviewed and rock mass zones defined. The existing cave zones were used initially as a guide. The geological strength index was then assessed using both visual and numerical means in order to provide a check on the results. This allowed the caving zones to be confirmed. Five separate caving zones were identified. The new strength model showed very extensive distribution of cave affected zones affecting the whole south wall and extending to great depth beneath it.

The old and updated parameters for each zone are included in Table 10.1. The parameters used for the stability analyses are included in Table 10.2.

TABLE 10.1
COMPARISON OF SSC ROCK MASS SHEAR STRENGTHS

CAVING ZONE	MATERIAL	PREVIOUS STRENGTH PARAMETERS			UPDATED STRENGTH PARAMETERS		
		C (kPa)	ϕ (deg)	E (GPa)	C (kPa)	ϕ (deg)	E (GPa)
1	Weathered and Disturbed	100	45°	2.5	90	25°	0.6
2	Disturbed	100	45°	2.5	160	46°	2.2
3	Caved	100	40°	1	135	40°	1.5
4	Deformed	250	53°	5	300	61°	5.8
5	Undisturbed	600	53°	7.5	400	65°	8.7

TABLE 10.2
MATERIAL STRENGTHS USED FOR SSC ANALYSES (PSM125.R34)

MATERIAL	EAST WALL (Section M)		SOUTHWEST WALL (Sections G + S)		WEST AND NORTH WALL	
	c (kPa)	Φ (deg)	c (kPa)	Φ (deg)	c (kPa)	Φ (deg)
Soil	20	35	20	35		
Alluvials	0	20	255	33		
Welded Ignimbrite	100	42.5	330	60		
Unwelded Sandy Ignimbrite	54	34	54	34		
Tuff	60	60	60	60		
Contact Andesite (Blue Shear)	55	26	55	26		
Andesite - weathered and disturbed	90	25	90	25	90	25
Andesite - disturbed	160	46	160	46	160	46
Andesite - caved	135	40	135	40	135	40
Andesite - deformed	300	61	300	61	300	61
Andesite - undisturbed	400	65	400	65	400	65

11 EAST LAYBACK

This section presents an Executive Summary of Report PSM125.R39. Reference should be made to the complete report for additional detail if required.

The East Layback is also termed Pit 66D. The design of the East Layback was optimised over a number of stages. Initial designs were not optimal for the geotechnical conditions and as a result the design was modified in order to:

- Better match the slopes to the geology,
- Reduce the risk of similar failures to those in the past,

- Thereby achieve a better final slope in terms of condition and performance; and
- Address the risk issues of concern to NWG and the independent reviewers.

The east wall of the then current pit (Pit 64) was formed in 2003 as an interim slope following 2001/02 collapse of the east wall of the Extended Pit. An interim slope was chosen at that time because of the large unknowns about the effects of the historical underground mining and the Milking Cow cave zone. The intention was to monitor the performance of this interim slope over time. This interim wall, after a long period of movement underwent a subsidence event and failed. The East Layback was a cutback of this failed slope. The East Layback design had been formulated to maintain the integrity of the slope during mining and by forming a pit slope in a new position, aimed at alleviating some of the historical underground mining influences so as to improve the long term slope stability.

A favourable feature of the East Layback is that it effectively places the majority of the historical underground cracking and collapses, associated with and around the Milking Cow, inside the pit crest and below the proposed lake level.

Pit wall performance at Waihi had been observed for over 20 years. The first and second pits excavated at Waihi, the Licenced and Extended Pits, were formed directly above the Milking Cow and within the main area of underground mining. The interim slope in the east was also similarly located. The east and south walls of these pits showed long term movements due to the underground mining influences. The SSC cut back the south and southeast pit walls in order to place the final south wall further from the historical underground influences. The monitoring and performance shows this was successful.

The geotechnical strategy adopted for the Pit 66D design was to alleviate, where practicable, the combined adverse impacts of the historical underground mining and the variable geotechnical conditions in the Ignimbrite Zone and Younger Andesite. This new design included remedial elements for long term pit closure and the formation of the pit lake and was considered closer to a closure design than a conventional cutback.

The proposal for the East Layback design was to honour the intent of the Licence Conditions, but at the same time recognise the practical reality of the situation created by the underground workings, utilise the IGNS Hazard Zoning and also incorporate the effects of pit flooding. The criteria also took account of the fact the mine is located within the Waihi Township.

The first eastern pit wall, the Licenced Pit, was formed on the western side of the Milking Cow and showed movement for about 4½ years but no failure. The east wall of the Extended Pit failed in 2002 after experiencing ongoing movement and cracking over a number of years. Analysis of the failure showed the cracking was related to the juxtaposition of the shrinkage stopes and caving at depth, beneath shallow cut and fill stoping on the Martha Lode. The cut and fill (which was clay fill) in effect formed a “geological fault” zone in the upper 150m to 200m along the Martha Lode.

The interim east wall had also shown ongoing movement for a period in excess of 4 years. An initial subsidence event occurred in August 2009 and this event appeared to be bounded by the same subsidence fault as the 2002 failure. Further significant failure occurred in October 2009. Both the 2002 and 2009 failures have been in the Ignimbrite Zone largely above the Younger Andesite.

Comparison of the historic underground information with the geology, the failure and cracking data and the monitoring shows both the 2002 and 2009 failures were on slopes located within historical cave and subsidence affected zones. The 2009 failure was also bounded in the east by a subsidence fault, which became evident as the failure developed.

Based on the available records there is now a well-defined eastern limit to the main cave affected zone on the east wall appears to be around the crest of the then current pit, Pit 64. This limit not only aligns with the historical records, but is also supported by the geometry, location, size and distribution of the underground stopes. Detailed review of historical drilling has provided further confirmation of this eastern limit to major underground disturbance to the rock mass.

The East Layback was located on the eastern margin of the Milking Cow and the upper half of the slope lies outside the Milking Cow Zone. However because of existing legal boundaries it was not possible to place this wall entirely outside the Milking Cow, which was the preferred situation. The overall conclusion from the assessment of the East Layback was that conditions overall and the long term stability would be considerably improved compared to the then current pit.

Stability analyses of the East Layback showed high Factors of Safety in accord with earlier pit designs at Waihi. Filling the pit with water post mining will further increase the Factors of Safety and improve stability. The East Layback Pit met all the slope design criteria adopted and accepted for the Southern Stability Cutback (SSC).

Probabilistic analysis showed the East Layback had a low Probability of Failure (PoF of 0%), and below generally accepted criteria. Stress displacement modelling had also been carried out as a check on the Limit Equilibrium analysis. This modelling showed largely elastic displacements but no indications of overall slope failure.

The SSC, which was in progress then was formulated to cutback the south wall to a flatter angle and move it further away from some of the very adverse historical underground effects. A substantial portion of the SSC had been completed and the monitoring results showed there was minimal movement. Hence this slope had achieved its design purpose.

The East Layback is in large part an extension of the SSC and together they form an overall arcuate shaped cutback of the majority of the south and east walls. This produces an overall pit shape that is more favourable from a stability perspective. Given the stability analysis results, the design modifications to improve stability and performance, and the planned remediation during mining, the East layback was designed to provide a long term safe and stable slope for the east wall of the pit.

The geotechnical strategy for the East Layback was formulated in conjunction with the mine's previous owner (Newmont) and comprised:

1. Steeper slopes in the higher strength layers and flatter slopes in the lower strength materials.

2. The new slope will incorporate the crusher at the top, at or just below lake level, 1101.5 mRL, which meant the new east wall was partially unloaded at the top compared to the current wall.
3. Over-excavation and buttressing of some of the weaker layers during mining with stronger rock, to control any potential for progressive deterioration, including local erosion, failure and sloughing.
4. Additional support, including shotcrete, mesh and bolting used as dictated by the conditions encountered during excavation.
5. Routine installation of horizontal drains in all layers from the Welded Ignimbrite down.
6. The overall effects of these measures on the stability and performance of the East Layback were:
    a) Moving the slope as far to the east as practicable,
    b) Hence the slope, at least in the lower strength materials, would for the large part lie outside the old "Milking Cow",
    c) Erosion of weaker units would be controlled,
    d) The new slope was lower at the top, because the crusher slot is incorporated within the pit shell increasing stability; and
    e) The East Layback would tie into the existing South Stability Cutback and remove the current external "noses" which protrude into the pit and have the potential to be less stable.
7. Where the risk of future subsidence/ collapse cannot be completely eliminated or controlled, then the risk is removed by design and or the controls associated with the Final Land Use Planning. Ensure the east wall including the East Layback is rehabilitated such that the area is below final lake level.

The Pit 66D design, which included many remedial elements for long term pit closure and the formation of the pit lake was closer to a closure slope design than a conventional cutback.

Notwithstanding the above, there are a number of areas of the East Layback where local adverse conditions could be encountered. Remediation of these areas during mining is required. The aim is to assist in maintaining the long term integrity of the East Layback.

12 GEOTECHNICAL AND HYDROGEOLOGICAL MODEL AND PARAMETERS

12.1 Geology

12.1.1 Lithology

The following description of the geology is taken in part from NWG *"Notes on the Geology of Martha Mine".* The descriptions are of a general nature and the lithologies may differ from those covered later in this report.

The Martha Hill Epithermal Deposit is located within the township of Waihi, in the south-eastern part of the Hauraki Goldfield, a 200km long metallogenic zone containing 50 separate epithermal deposits. Historical underground mining at Martha produced 5.5M oz Au and 30M oz Ag from 11M tonnes of ore between 1878 and 1952. The current open pit mining commenced in 1988 and was terminated in 2015.

Gold mineralisation is mainly contained in quartz veins within a low sulphidation epithermal vein system hosted by Miocene calc-alkaline volcanics of the Coromandel Volcanic Zone (Andesite).

The main east-north-east trending veins are (from north to south): Martha, Welcome, Empire and Royal. Note the Mine Grid North is 45° west of True North. The Martha dips steeply south while the other veins dip steeply north. The Albert and Edward Lodes trend north (True North). Numerous smaller veins and veinlets between the major lodes also contain gold. Ore grade mineralisation extends for 1600 metres along strike with a width of 500 metres and was mined to 600 metres below surface.

There are two main types of hydrothermal alteration; an outer zone of propylitic type calcite-chlorite alteration is overlapped by quartz-adularia-illite alteration adjacent to the veining.

After erosion of some hundreds of metres of the hydrothermal system, the andesitic pile formed a fossil hill with a thin layer of eluvial and alluvial deposits. Subsequently, the hill and its surrounds were covered with a sheet of ignimbrite to 50m thickness. In turn, it was eroded from the top of Martha Hill, leaving a window of andesite outcropping and containing the vein system, surrounded by ignimbrites on three sides.

A blanket of recent rhyolitic ash to 4m thickness covers another layer of eluvial quartz over ignimbrite.

In geotechnical terms, there are four main geological units in the pit:

Andesite

This is a variably jointed, high strength rock with a surficial layer of variable weathering/alteration and a zone of deep oxidation along the main lode. This unit contains the gold mineralisation. In local areas of the pit, the andesite is extensively clay-altered in which rock clasts are contained by and within a soft clay matrix, forming a low strength soil mass.

Younger (contact) Andesite also termed the Younger Andesite

This unit immediately overlies and is distinguishable from the main andesite (Unit H) as a low to high strength, blue grey coloured, variably sheared and variably clay altered rock.

Ignimbrite Zone forms the more recent overburden overlying the mineralised andesite host rocks

It is thickest in the east south-east but also extends into the west of the pit. The Ignimbrite Zone includes a range of material types including welded and un-welded ignimbrites, tuff, alluvium, and recent brown ash.

Welded ignimbrite

This is a high strength rock and is the main unit within the Ignimbrite Zone.

The geology of the MP4 pit is presented as a series of geotechnical cross sections, Figures 15 to 20.

12.1.2 Geological Structure

12.1.2.1 General Discussion of Data

The Martha Pit is intersected by a relatively minor number of geological faults, many of which exhibit parallel trends to the mineralisation zones and are steeply inclined. These faults have had minimal influence on pit stability over the last 30 years of open pit mining, with the exception of the North Wall Failure.

The Geological Survey Map of Waihi Goldfield (1923) shows an inferred northern fault, which appears to be the main regional bounding fault, located approximately 50 m north of the MP4 Pit crest. However this plan was sketch plan only with the fault projected as a dashed line. No actual mapping points were included. No major fault in the inferred location was intersected in the drilling.

Figures 23 and 24 present the available joint and fault/shear orientation data available for the Martha Open Pit subdivided by data source. To highlight the relevant structural populations and to illustrate the structural bias in the data, Figure 24 presents seven stereoplots:

- Mapping - North Wall,
- Mapping - South Wall,
- Sirovision - North Wall,
- Orientated Core - North Orientated Boreholes (excl. WDH168 & WDH165);
- Orientated Core - East/South Orientated Boreholes (excl. WDH168 & WDH165);
- WDH168 and
- WDH165.

Boreholes WDH168 and WDH165 have been presented exclusively because of the large population of data collected from each.

The jointing is quite dispersed without well-defined defect sets. This is in accord with the pit exposures that all show somewhat random jointing all of discrete lengths and mostly less than 5m long. This pattern is generally repeated across each data source, Figure 23.

12.1.2.2 Design Data – Existing Pit

The mapping data of faults and shears is considered to be the best representation of structure at Martha for assessments of the potential impact on slope design. The mapping of the north and south walls indicates four structural sets, Table 12.1 and Figure 24. Defects in all these orientations are evident around the Martha Pit, but generally the individual sets are not well developed in any one location.

TABLE 12.1
MAIN DEFECT SETS FOR KINEMATIC ASSESSMENT

DEFECT SET	DATA SET	MEAN DIP (°)	MEAN DIP DIRECTION (°)
Set 1	Mapping	75	195
Set 2	Mapping	85	340
Set 3	Mapping	60	300
Set 4	Mapping	70	125

12.1.2.3 North Wall Cutback

Figure 24 also includes mapping data from the remedial cutback of the north wall failure. It is clearly evident from this data that:

- The structural pattern is very different from both the north and south wall data sets; and
- None of the major planes associated with the north wall failure and surrounding areas is represented in the north and south wall mapping data.

12.2 Groundwater

A review of all historical and current operational piezometers has been carried out. While most of the piezometers located within the East Layback have been decommissioned due to pit development, the surrounding operational piezometers indicate that the groundwater regime has not changed dramatically in the last few years. Appendix G contains the groundwater hydrographs for the current piezometers. The piezometer location plan is presented in Figure 21.

The data shows underdrainage by the Andesite is a universal condition throughout the region. To the south, east and south west groundwater levels in the Andesite have continued to fall and follow the pit dewatering. There are no indications of seepage on these walls. In the north there are limited underground workings, the groundwater levels in Andesite have stabilised, also show underdrainage and are well behind the pit face.

In 2014 a comprehensive review and comparison of design versus actual pore pressures in the Ignimbrite Zone for the East layback was carried out, PSM125-227L. Pore pressures within the ignimbrite zone were modelled using piezometer data from piezometer P20 (since mined out). The condition modelled was for substantial underdrainage and assuming zero pore pressure at the immediate pit face. Three multipoint piezometers were installed and these confirmed the general design pore pressure assumptions. Notwithstanding this horizontal drains in the lower East Layback

(1010 mRL), did intersect flows, but mainly in the centre of the wall and the centre of the folding associated with Milking Cow.

Experience with all slopes in the east wall to date emphasises the need for horizontal drains to control both existing groundwater and transient groundwater stresses due to rainfall / runoff.

Observations indicate shallow groundwater tables, also under drained, occur in the upper south and north walls. The MP4 pit will require some shallow piezometers in the cutback area outside the planned pit crest and horizontal drains in the upper levels.

12.3 Underground Mining Cave Model

12.3.1 Introduction

The classic model for deformations of the rock mass around a planned underground caving operation entails three concentric zones. The geotechnical investigations and exposures associated with the four pits excavated at Martha confirm this general model, with:

Zone 1 - Caved Zone

The central zone comprising a completely broken rock mass, with particle sizes ranging from very large blocks to silt size. This zone surrounds the main lodes to some extent and forms the historical cave zone, the Milking Cow.

Zone 2 - Disturbed Zone

A zone around the central zone comprising a disturbed rock mass, possibly with block sliding on shears, opening and weathering of joints, noticeably increased fracturing and minor local caved zones. In places the intact rock appears altered or weathered. This zone also includes some large rafted blocks with lesser disturbance.

Zone 3 - Deformed Zone

An outer zone surrounding the inner two zones within which there have been smaller displacements. The rock appears intact, but there is noticeable staining of rock substance and defects; together with an increase in fracturing compared to fresh intact rock at depth.

There is a continuum of rock mass conditions across the three zones, with the boundaries sometimes difficult to define. There are also rafted blocks of more intact rock mass located within zones of greater deformation. The following sections describe the cave model development and model updates.

In simple terms, the overall underground system at Waihi can be conceptualised in terms of this classic model, with the exceptions that because of geometry and layout of the underground workings the zones are skewed towards the south, southeast and east. A compilation of photographs illustrating the degree and character of deformation in these zones is included in Appendix B.

Zones 2 and 3 (the Disturbed and Deformed zones) were thought to be poorly developed in the north. However the North Wall Failure has now shown this is not the case and the northeast area did lie partially within a Disturbed Zone, albeit at depth. There is no evidence of any of these Zones in the west and northwest of the pit. Further to the east where the more recent volcanic layers (Ignimbrite Zone) overlies the Andesite the more shallow expression of these zones are masked.

In summary the underground deformation model as it is currently understood comprises the following elements:

1. Widespread subsidence over caved zones.
1. Creep movement of large blocks of deformed and disturbed rock masses.
2. Block subsidence or settlement, with some block rotation.
3. Local chimney development.
4. Leading to some local sinkhole collapses at the surface.

12.3.2 Initial Cave Model Development

The concept of the current caving model was first documented in PSM125-R28. A series of north south sections were developed, showing the inferred and mapped boundaries of the three caving zones. All the available andesite core was visually classified (from core photographs) into rock mass zones based on the caving classification system above in 2002/2003. The model was then used for earlier studies, PSM125.R28 and modified for PSM125.R34.

These models were calibrated using undisturbed (high strength fresh intact) Andesite and exposures of caved rock in the hanging wall of Martha Lode in the known underground caving areas. All other zones were visually calibrated relative to the undisturbed and completely caved material.

Since PSM125.R28, localised revisions to the model have been made, comprising:

- Report on Pit Closure studies, PSM125.R34, 4 April 2006;
  - Revision of caving model along five borehole sections on the south wall;
- East Layback, Pit 66D, PSM125.R39, 11 January 2010;
  - Revision of Martha Caved Zone on the East Wall; and
- Site Visit Report December 2013, PSM125-226L, 30 January 2014;
  - Revision of Martha Caved Zone, termed ‘Ezra 2013’.

These models have proven to be quite robust over time as additional exploration drilling was carried out and additional pit walls excavated.

12.3.3 Cave Model Update - 2018

12.3.3.1 Data and model development

This current study presents a further evolution of the cave model. The update has been carried out along the original 16 of the sections, PSM125.R28, Figure 27. The data used to update the model has mainly comprised:

- The original interpretation model, PSM125.R28;
- Observations and mapping from the pit,
- A compilation of the cave photographs from the pits, Appendix B;
- A compilation of historical surface subsidence effects and recorded events;
- Previous revisions to the caving model,
- Surface subsidence, Figure 25,
- Classification of the extensive exploration drilling since 2005, Figures 13 and 14;
- The geotechnical drilling, Figure 14;
- The cover drill holes for the MDDP, Figure 14;
- In-pit mapping of caved and disturbed zones; and
- The geometry of the lodes and stopes.

Initially all the new boreholes were classified according to the cave model classification system, Figure 26. The interpretation for each borehole is included in Appendix C. The interpretation to develop the 3-d cave model was then carried out using the same historical mine sections as used in previous model developments, Figures 27 to 42. The updated sections including both the old and new interpretations and illustrate that there has been an evolution of the model, not major revisions.

Figure 46 shows the intersection of the cave zones with the MP4 pit.

12.3.3.2 Variability in Rock Mass

The rock mass conditions within each zone (i.e. caved, disturbed or distinct) are expected to be variable. There is insufficient borehole data to define the full extent of the variability, and so each zone is considered as a broad envelope. A conservative approach to modelling was done, where the more extensive, poorer rock mass has been adopted throughout the entire zone. Specific examples with type sections are provided below.

Figure 32 - Section 1784.5 mE

The hanging wall of the Royal lode is broadly defined as disturbed. The zone correlates well with surface deformation (cracking and sink holes), and historical information describes this zone as poorer rock mass condition compared to the Martha lode. The majority of boreholes indicate disturbed rock mass, although some sections (Section 1784 mE) show boreholes with primarily deformed rock mass.

Figure 34 - Section 1875.9 mE

There are several areas with limited or no drilling to confirm the actual rock mass conditions. Available information from location and extent of historical workings correlates well with surface subsidence and provides reasonable control on the boundaries; for example the northern boundary of intact-deformed rock on section 1875.9 mE.

Figure 42 - Section 2110 mE

Localised caved zones associated with stopes as well as discreetly in the rock mass are expected in the disturbed and deformed rock masses.

To the east of 2160 mE the deformed zone is expected to be a mix of deformed and intact rock, based on borehole logging. Due to minimal surface deformation and the presence of intact rock zones, this area of deformed rock is interpreted up to the base of the young Volcanics rather than to the ground surface.

12.3.3.3 Poor rock mass zones

In an environment where rock mass quality is controlled by both geological processes and underground mining, differentiating between the two can be difficult. There are two areas of note which appear to be of poor rock mass due to geological processes rather than mining. This inference is supported by the locations in regards to the underground workings and site observations.

Figure 30 - Section 1723.5 mE

The upper slopes of the south wall, typically west of ~1750 mE have poorer rock mass conditions compared to the rest of the pit. Borehole classification in this area suggests large zones of caving. The pit exposures suggest a rock mass, which is altered and disturbed but does not show signs of caving. The distribution of stopes in this area suggests caving is unlikely. As such, this area of poor rock mass is likely a function of the rock mass rather than underground workings.

Figure 36 - Section 1930 mE

The area of the north wall failure is coincidental with borehole classifications of deformed rock in the upper andesite profile. However, due to the geometry of the underground workings, this zone is considered too far from the stopes for mining induced rock mass deterioration. The apparent deformed nature is considered a function of lithology and or alteration of the rock mass. However the interpretation of the North Wall failure does show a deformed to disturbed rock mass in the lower part of the slope.

12.4 Parameters

12.4.1 Soil and Rock Mass Strengths

The strengths of the various lithological units have continued to be refined over the last 2030 years, in order to match the observed performance and as additional investigation information becomes available. The derived strengths are also take account of the various instabilities and movements and reflect the disturbance due to the historical underground workings.

For the SSC, the strengths used for the Welded Ignimbrite and Alluvium in the Ignimbrite Zone for the current east and southeast pit walls were different. These differences resulted from the back analyses of failures and pit movements; and also reflected the increased disturbance of the east wall due to caving associated with the "Milking Cow" zone. Hence lower strengths were used for the analysis of the east wall because there was more underground disturbance.

The derivation of the strength used for general analysis and design comprises:

1. Unit A – Sediments – Triaxial plus CPT and SPT insitu testing.
2. Unit B – Welded Ignimbrite – Rock Mass Rating (RMR) and Geological Strength Index (GSI).
3. Unit C – Unwelded Ignimbrite– Triaxial.
4. Unit D – Tuff – Triaxial and Direct Shear.
5. Unit E – Alluvium – Triaxial and Direct Shear.
6. Unit G – Younger Andesite – Triaxial.
7. Unit H – Andesite – RMR and GSI.

The laboratory testings were undertaken by Barrett, Askew, Fuller and Partners; Ministry of Works, Geotechnics and Engineering Geology Limited in 1982, 1989, 1995, 1996, 1998 and 2003. This data was reviewed and collated in 2003. A compilation of all strengths and their origins over the years is presented in Appendix A. In each case as new test information became available all the testing was collated and re-evaluated to establish the data envelopes and the design strengths.

12.4.2 Short to Medium Term Strengths

Table 12.2 summarises the soil and rock mass strengths used previously for the east wall. These strengths have been adopted for limit equilibrium analysis of the East Layback.

All parameters from all sources have been calibrated, where possible, by back analysis of failures and slope movements, which themselves are influenced by location relative to underground disturbance.

In regards to the Tuff strengths the cohesion of 60 kPa and Angle of Friction of 60° may seem unusual. However initial testing up to 1997 gave cohesion of 154 kPa and angle friction of 49°. Additional testing in 1998 produced a well-defined envelope and when higher strength materials that had been excluded prior to 1998 were included, a much stronger strength envelope resulted. At this stage because the individual tests have been reviewed a number of times and then carefully collected there is no basis for not accepting the information as real data. Any uncertainty with the strength of the Tuff has been incorporated by using much lower fully softened strengths.

12.4.3 Fully Softened Strengths

The fully softened strengths have been derived from back analysis of the two east wall failures and then checked against residual strengths from multi-stage shear box testing of intact material. Back Analysis of the 2001/2002 failure gave the following:

1. Subsidence Fault; cohesion = 0, and Angle of friction = 35° or 40°.
2. Alluvium; cohesion = 0 and, Angle of friction = 20°.

Table 12.3 compares the back analysed strengths with the fully softened strengths and the residual strengths from laboratory testing where available. The parameters are in very good agreement, which gives confidence for the design.

TABLE 12.2
SOIL AND ROCK MASS STRENGTHS

GEOTECHNICAL UNIT	CURRENT PARAMETERS		SOFTENED PARAMETERS		DISTURBED[2] PARAMETERS		OTHER PARAMETERS	
	c (kPa)	ϕ (degrees)	c (kPa)	ϕ (degrees)	c (kPa)	ϕ (degrees)	E MPa	γ kN/m^3
Sediments (Unit A)	20	35°	15	30°	15	32°	30	18
Welded Ignimbrite (Unit B)	900 [1]	67° [1]	330	60°	600	63°	8000	25
Unwelded Sandy Ignimbrite (Unit C)	54	34°	35	30°	45	32°	1000	21
Tuff (Unit D)	60	60°	20	40°	40	50°	1000	17
Alluvium (Unit E)	255	33°	20	35°	140	35°	500	17
Hydrothermal Clay	13	6°	NA	NA			500	17
Younger Andesite (Unit G)	55	26°	40	25°	48	26°	700	20
Andesite (Unit H - disturbed) (Domain 2)	160	46°	50	40°			2200	26
Andesite (Unit H - caved) (Domain 1A - Martha Cave)	5 [1]	35° [1]	5 [1]	35° [1]			600	22
Andesite (Unit H - deformed) (Domain 4)	300	61°	70	40°			5800	626
Andesite (Unit H - undisturbed) (Domain 5)	400	65°	400	65°			8700	27

Notes: Parameters taken from PSM125.R34 Table 9.4 unless otherwise noted
[1] Taken from Reference 2 (PSM125.R28, 2003)
[2] These are strengths down rated to take account of underground disturbance

TABLE 12.3
SOIL AND ROCK MASS STRENGTHS

UNIT		BACK ANALYSED		FULLY SOFTENED		RESIDUAL FROM TESTING	
		c (kPa)	ϕ (degrees)	c (kPa)	ϕ (degrees)	c (kPa)	ϕ (degrees)
A	Sediments	NA	NA	15	30		
B	Welded Ignimbrite	90	67	330	60		
C	Unwelded Ignimbrite	5.4	34	35	30	54	34
D	Tuff	0[1]	20[1]	20	40	2	38
		10[2]	40[2]			40.5	31
E	Alluvium	25	33	20	35	18	34.5
G	Younger Andesite	NA	NA	40	25		
H	Andesite	NA	NA	400	65		

[1] 2001/2002 Failure
[2] 2009 Failure

13 PERFORMANCE OF MARTHA PIT

13.1 Monitoring Data Existing Slopes

13.1.1 Introduction

The monitoring data has been assessed based on the geotechnical domains shown in Figures 25 and 26. The monitoring data and a prism plan are included in Appendix J. There are two base stations used for the prism monitoring; one on the pit edge in the middle of the south wall and the other (P1120_6R) on an upper bench in the northwest (TP4(2016)S). Up until the north wall failure in April 2016 the TP4 base station was located at the top of the north wall within the failure area.

The data shows long term creep movements have impacted on base station P1120_6R on the upper south wall and also TP4 on the north wall prior to the North Wall Failure. This needs to be taken into account when assessing the prisms monitored from this station.

13.1.2 West

This area is actually the western end of the pit, extending from the Edward Lode in the southwest around to include the western end of the north wall. The current base station TP4 is located within this domain. This domain comprises high strength Andesite rock mass with minimal underground workings. The rock mass is intact and shows no visible signs of disturbance from any historical mining.

Long term monitoring data, since 2004, shows minimal movements, less than 100 mm over the 14 year period or less than 0.02 mm/day. However all long term prisms show the same movement and hence this is creep movement of the monitoring base station itself not the prisms or the pit wall.

13.1.3 South

This domain comprises the area of the SSC along the south wall. In the west it is the extent of the SSC cutback and in the east the boundary is coincident with the small south wall erosion/failure. The majority of the wall is formed within rock that has been affected by historical underground mining, mainly disturbed and deformed rock mass. There is a small outcrop of the Empire Cave in the area of the erosion/failure.

Long term monitoring for some prisms has been in place since 2004. Other prisms lower on the wall were installed as mining progressed and comprises about six years of monitoring. The data shows:

1. No movement in the lower half to two thirds of the slope.
2. No movement of the slope at the western end of the domain.
3. Very minor creep movements of a region in the upper central portion of the domain, which is a zone in the hanging wall of the Royal Lode.

The zone of creep movement has the following characteristics:

- The movement was greatest soon after excavation (about five or six years) but has then reduced progressively in rate over the years;
- The movement pattern is either linear or reducing with time;
- The movement is northwards and downwards at the same rates and magnitudes;
- The movement rates are very low, about 0.02 mm/day or less than 10 mm/annum;
- This is at the lower limit of monitoring for pit slopes in world wide experience; and
- The region is co-incident with the zone of historical cracking on the upper south wall associated with historical sinkhole collapse events, Figure 19.

Overall the south wall is stable with a zone of very minor creep associated with historical underground mining.

13.1.4 Northeast

When the base station movement is accounted for there is generally no movement on or behind the northeast pit wall. The exceptions are isolated prisms immediately adjacent to the failure scarp and some prisms below the upper haul road east of the failure.

13.1.5 Local Exceptions

The exceptions to the patterns described above are both local, comprising:

1. Movement in the lower southwest around the intersection of the Edward Stopes.
2. In the south east where local erosion is occurring associated with the sub-crop of the Edward Cave.

13.1.6 East Wall

13.1.6.1 Movement Rates

This domain extends from the erosion failure in the southeast around to the junction with the north wall. It entails the east wall section of the East Layback. The Martha Lode stopes are along the northern boundary of this domain and the Milking Cow cave zone lies south of the Martha Lode approximately in the middle of the slope.

Long term monitoring data is available from the start of mining of the East Layback in 2010. Other prisms lower on the wall were installed as mining progressed and comprise up to seven years of monitoring, 2011 to 2018. More recently some additional prisms were installed on the lower east wall, but their usefulness is limited because of the short monitoring timeframe.

This domain has a very complex pattern of historical mining both outcropping on the slope and underlying it. In addition this domain has a considerable thickness of the multi-layered Ignimbrite Zone, which has also had some impacts from the historical underground mining. Notwithstanding this overall situation on a broader scale some reasonably well defined patterns are evident. These patterns become evident when the three components of potential movement are assessed and then overlain onto the known historical mining effects.

There was initially small modulus reaction to the excavation of the East Layback and the following description only covers that period after this initial response subsided. In summary the main effects evident are:

1. The vertical movement pattern shows, Figure 43:
   a) A zone of downwards movement on the lower slope centred over the old Milking Cow;
   b) A small zone of upwards movement centred on the upper Martha Lode and its immediate hanging wall; and
   c) To the east and south of these two zones there is no vertical component of movement.
2. Except for two zones the prisms are not showing a north-south component of movement. The exceptions are, Figure 44:
   a) Prisms around the old Milking Cow which show a northerly component of movement; and
   b) Prisms along the upper Martha Lode which show a southerly component of movement.
3. All prisms show a component of westerly movement, which is continuing in a linear pattern. However the movement rates are quite variable and again display a geographic distribution, Figure 45:

a) Two zones of higher movement rates, along the lower Martha Lode and in the southeast in the hanging wall of Empire Lode;

b) Rates tend to decrease somewhat linearly away from these zones;

c) The crest and toe of the slope have rates around 0.02 mm/day, which is at the very lowest end of the measureable range; and

d) Behind the crest there appears to be no westward movement.

In combination these patterns of movement are interpreted as being a result of:

- Continued subsidence of the Milking Cow,
- Which tends to drag prisms around this horizontally towards the subsidence;
- Movement along the Martha Lode towards the south southwest,
- Linear movement patterns, and
- All movement patterns are consistent with the continued subsidence over the old underground workings.

These patterns are consistent with excavation of a pit slope that lies partially within an old caving subsidence zone.

13.1.6.2 Comparison with Historical Data

Table 13.1 is a summary of the monitoring data for the four pit walls excavated to date. In order to understand the significance of these results it is important to firstly establish the geotechnical setting for each of these pit walls:

- The Licenced Pit was west of the Milking Cow but within the associated large surface subsidence bowl;
- The Extended Pit (the second wall) was centred directly over the Milking Cow and within the large subsidence bowl;
- Pit 64 was situated further east but still right on the eastern edge of the Milking Cow and the large subsidence bowl; and
- The East Layback was moved as far east as allowed at that time, the Milking Cow is a much smaller structure, occurs in the lower part of the pit wall and importantly because of the funnel shape of the subsidence bowl more of the rocks are outside the large subsidence bowl.

The Extended Pit failed in the shortest period, after one to one and half years. This wall also had the most adverse geology in the Ignimbrite Zone with the steep westerly dips of the large subsidence bowl dipping directly into the pit. The first and the third pit walls were furthest from the centre of the Milking Cow and showed about 4 to 5 years of movement before collapse.

The movement and deformation patterns for the first three pit walls were very similar with an initial elastic movement, early development of tension cracking, movements occurred both inside and outside the pit; followed by a long period of creep, which then accelerated to failure. These pit walls all showed typical failure patterns, with movements in a westerly and downwards direction.

As shown in Table 13.1, the current movement rates for the East Layback are lower than for the other walls. Also as discussed above (Section 13.1.5.1) rather than global movements of the whole slope, which occurred with all the previous walls there are complex local patterns directly related to the geotechnical setting. The main differences with the East Layback are that the higher movement rate zone is:

- Concentrated only in the lower slope around the Milking Cow;
- The majority of the slope shows very little or no vertical movement; and
- There does not appear to be movement outside the pit.

Although definite conclusions about the long term future of the east wall of the East Layback are difficult, based on this data the wall is largely performing in keeping with the original design intent, Section 11.

TABLE 13.1
SUMMARY EAST WALL CREEP MOVEMENTS

COMPONENT OF MOVEMENT		**LICENCED PIT**	**EXTENDED PIT**	**PIT 64**	**EAST LAYBACK**
Total * Movement (mm)	**Vertical**	> 40 - 240	50 - 120	50 - 100	0 – 50*
	Horizontal	> 120 - 240	40 - 140	120 - 200	15 – 195*
Rates (mm/day)	**Vertical**	0.02 – 0.15	0.14 – 0.32	0.03 – 0.07	0 – 0.08
	Horizontal	0.07 – 0.15	0.11 – 0.38	0.08 – 0.14	0.02 – 0.25
Period prior to onset of failure (years)		> 4 ½	1	> 4	Period elapsed so far post initial response 2 to 3 years

*Discussed further in text

13.2 Stable Angles in Deformed Rock Masses

The southern, south-eastern and eastern pit walls of the Martha Pit are affected by movement and subsidence due to underground mining, refer to Section 4, Figure 46. Those movements were initiated during the period of underground mining and have probably continued ever since. It is possible the movements were somewhat slower during the period of no mining and will probably stabilise when pit flooding is completed.

There is now long experience with slopes in the Martha Pit. These slopes were designed with conventional and conservative FOS and analyses still show high FOS in some areas. However some slopes are moving and may continue moving. Relevant experience from the pit was collated in 2003 and shows that the limiting angle for slopes in rock affected by underground mining at Waihi is about 40º. Above this angle failures occur but below 40º the data indicates the slopes can continue to move and deform while still maintaining their essential integrity. This is in the Deformed and Disturbed Rock Mass Zones. It is noted that this is also in accord with the published experience with natural slopes in geomorphology studies, the Limiting Slope Angle as discussed in Section 10. This design angle has now been confirmed by the performance of the SSC.

14 MP4 CUTBACK

14.1 North Wall Investigation

14.1.1 Introduction

The north wall failure occurred in April 2016, and is located on the northern wall of the East Layback Pit. The failure is shown in plan and on an aerial photo on Figures 2 and 21. The failure occurred partially along one major and several minor structures, with an element of rock mass failure at the toe. The major failure plane in the upper central part of the failure scarp is the focus of this assessment. The location and extent of the exposed failure plane is shown in Figure 27. In summary this failure had two main elements:

- The main failure plane in the mid-upper part of the slope and
- Rock mass failure at the toe, considered to be principally through remnant pillars around the Martha Lode.

In regards to the latter element it is recommended that locally some of the open stopes in the Martha Lode for a distance of approximately 30 m below the toe of MP4 are filled where practicable as the mining progresses. Refer to Section 14.2.4. It is acknowledged that there are practical difficulties with this endeavour and this may govern possible success. The stability analyses do not indicate this remediation must be carried out, rather it is recommended as a sound measure given the history of the old north wall. It is recommended the final decision on this remediation is made as mining of the cutback progresses.

Although MP4 is a cutback of a failed slope, there is the potential for another structure of similar orientation, behind the cutback. This section describes the study undertaken to evaluate this potential. Because the north wall failure plane was not part of the overall structural pattern in the Martha Pit, it was assumed that any repeat structure would have been formed in the same geological setting and could have similar characteristics to the north wall failure plane. By similar characteristics the assumption is similar surface characteristics and similar general orientation.

The assessment has comprised:

- Characterisation of the basal failure plane,
- Investigation of near-by boreholes to identify any similar structures;
- Correlation of any structures between holes and
- Modelling in three-dimensions.

14.1.2 Available data and methodology

The available data comprises:

1. 3D survey surfaces of the pit before (March, 2015) and after (31 August 2017) the failure. The exposed portion of the failure plane was taken from these surfaces.
2. Ten fully core drillholes in proximity to the failure (six before and two after failure) with core photos and geotechnical logs.
3. Four inclinometers.
4. Oriented core data for three boreholes, Figure 22.

Borehole locations relative to the basal failure plane surface are shown in Figure 47.

The process undertaken to characterise the fault and identify similar structures comprised:

1. Characterisation of the basal fault from intersections in pre-failure drillholes using core photographs and geotechnical logs.
2. Investigation of the other drillholes to assess whether there were similar structures present.
3. Correlation and 3-d modelling to try and extrapolate any intersections across to other drillholes in the region.

14.1.3 North Wall Failure Plane Characterisation

Two boreholes with core photos intersected the main failure plane; INCLO_003 and INCLO_004, Figure 47. The intersection depths and characteristics of the north wall failure plane are presented in Table 14.1. The core photos of the fault intervals are shown in Plates 1 and 2 for each borehole, respectively.

In summary the north wall failure plane is classified as:

- A zone up to 1.5 m thick,
- Dark grey in colour,
- With clay gouge and very low strength rock in the interval; and
- Comprising a number of planes with closely spaced (<200mm) gouge filled defects and some clay filled (<10mm thick) defects.

There was no evidence of any weathering on the plane.

TABLE 14.1
CHARACTERISTICS OF FAILURE PLANE

DRILL HOLE	DEPTH FROM FAILURE PLANE SURVEY (m)	DOWNHOLE DEPTH IN DRILL HOLE (m)	CHARACTER (from photos)	CHARACTER (from geotechnical log)
INCLO_003	29.3m	29.4 – 30.8 1.4m true thickness	0.5m out of 1.4m recovered (36%) Dark grey fault gouge dominated by clay matrix with andesite clasts	Strength = R0 – R4 RQD = 20% Dominant defect type Shears
INCLO_004	>35.3m(1)	38 – 40 <2m thick (2)	1.8m out of 2m recovered (90%) Dark grey, extremely low strength rock. Fracture zone with angular rock fragments typically <50mm size	Strength = R0 (minor R3) RQD = 65% Dominant defect type Shears

Notes

1. Borehole intersects 31 August pit surface within the failed debris (10m below the surface expression of the failure plane). As such, the failure plane is anticipated to be below the failure debris.
2. Borehole drilled oblique to structure so drilled thickness over estimates true thickness

PLATE 1 **Core photo of fault in INCLO_003, highlighted in red. Note 0.9m of core loss over interval**

PLATE 2 **Core photo of fault in INCLO_004, highlighted in red. Note 0.2m of core loss over interval**

14.1.4 Groundwater

An extensive series of horizontal drains were drilled into the north wall prior to the failure. The flows were highly variable and none of these holes encountered high flows. This is in keeping with the character of the rock mass as described above.

Some flows from the rock mass also occurred after the failure in different locations. This was to be expected and part of the usual response when a slope has been moving for more than a year in the rainfall conditions applying at Waihi. These flows were simply rainfall runoff water released from storage after the failure.

There have been no long term major groundwater flows from around the north wall area after the failure.

14.1.5 Investigation of similar structures

There are ten cored drillholes in proximity to the north wall failure and these were all assessed for structures similar to the basal failure plane.

Potentially similar structures were only identified in three drillholes:

- P104 at 4m depth,
- P105 at 23.4m depth and
- GT021 at 223m depth.

The intersections in P104 and P105 are too shallow and above the north wall failure plane. Figure 47 shows the intersection in GT021.

The orientation of the north wall failure plane was 36° towards 180°, PSM125-252R.
This orientation was used to extrapolate for the intersection in GT021 out to the other drillholes using a wide possible intersection cone. No other structures were identified in the other drillholes within this potential intersection cone.

The final independent check on this interpretation is the inclinometers. These are very sensitive geotechnical instruments used to evaluate potential sliding on structures. If similar structures to the north wall failure plane were present then dislocations would have been evident in the inclinometers. The inclinometers have not shown the presence of any planes below the north wall failure plane.

14.1.6 Summary

There have been detailed drilling investigations undertaken behind the north wall failure. This has been supplemented with monitoring over the last two years. The data has been assessed in detail and no additional large continuous structures have been identified behind the north wall failure plane.

14.2 Stability Analyses

14.2.1 Introduction

The MP4 Pit entails a cutback of the north wall failure and completion of the East Layback at depth.

The area around and behind the cutback has been investigated and this has shown the rock mass is generally in accord with the rock mass exposed in the north wall of the East Layback, but without the major continuous structure.

Comparison of the overall and inter-ramp angles for the East Layback north wall and MP4 shows:

1. East Layback:
   a) Upper slope 30° for 85 m and
   b) Lower slope 50° for 160 m.

2. MP4:
   a) Upper slope 30° for 160 m and
   b) Lower slope 50° for 85 m.

The MP4 pit is much flatter overall and this is necessitated by the operational need to incorporate additional haul roads and wide benches, Figures 1 to 7.

MP4 uses the same general bench and berm configuration as that used successfully for the north wall of the East Layback and before that for the Extended Pit north walls. Because of the above factors, the similarity of geotechnical conditions and the fact that considerably flatter and smaller slope heights are used for MP4 the stability analyses have comprised a check on the overall stability for rock mass failure. Figure 46 shows the intersection of the rock mass model with MP4. Also shown are the sections chosen for check analyses of stability.

In addition the impact of deepening the East Layback to the original planned depth has also been checked.

14.2.2 Limit Equilibrium Analyses

Limit Equilibrium (LE) analyses were undertaken to check the potential for overall, inter-ramp and bench scale failure of the MP4 pit using the Morgenstern Price method. The target Factor of Safety (FoS) for design was taken as ≥ 1.2 for current parameters. However the analyses also include softened parameters which are assumed to provide a lower bound check. The stability models use the rock mass parameters and groundwater regime defined in Section 12. The stability model outputs are summarised in Table 14.2 and presented in Appendix I.

Four sections were chosen for the analyses to cover the range of north wall geotechnical conditions, comprising, Figure 46:

- The slopes with the steepest angle,
- Greatest height,
- Most adverse location of underground workings; and
- The areas with the greatest thickness of the young volcanics and caved rock masses.

In summary the key geotechnical factors for each section are:

1. Section 2 – General conditions of intact Andesite rock mass with minor caved/deformed rock mass at the toe.
2. Section 3 – General conditions of intact Andesite rock mass with caved/deformed rock mass at the toe.
3. Section 5 – Thick Young Volcanics (upper slopes) with caved, disturbed and deformed Andesite rock masses in the lower slopes.
4. Section 6 – Potentially adverse location of underground workings on lower inter-ramp slope of the north wall.

14.2.3 Modelling Approach

The modelling was undertaken in a number of stages and the main variables assessed were the mass shear strengths (current and softened), the rock mass model, groundwater position and the impacts of underground mining. The conditions modelled in each stage are summarised in Table 14.2.

The slopes were analysed assuming the following general groundwater conditions:

1. Section 2, 3, and 6 - A water table at the pit surface above ~ 1030mRL in the Andesite on the north wall.
2. Section 5 - A water table to the base of the young Volcanics on the east wall. All slopes below 1030mRL (in the Andesite) were modelled dry.
3. Based on piezometer data and proximity to underground workings, depressurisation of 50% was assumed.

These groundwater conditions are considered conservative, based on the data and observations. The modelling results are summarised in Tables 14.3 to 14.6 with model outputs included in Appendix I. Cases where FoS < 1.2 are highlighted in red in the table.

TABLE 14.2
SUMMARY OF MODELLED CONDITIONS

SECTION	SLOPE	PIT	STRENGTH	ROCK MASS MODEL	FAILURE MODE	RESULTS
2	Lower inter-ramp and overall	Phase 4 final	Current and Softened	Figure 46	Circular	Table 14.3 Figure 48
3	Lower inter-ramp and overall	Phase 4 final	Current and Softened	Figure 46	Circular	Table 14.3 Figure 48
5	Lower inter-ramp, Upper inter-ramp and overall	Current pit [(1)] Phase 4 final	Current and Softened	Figure 46 and Sensitivity for increased disturbance	Circular	Table 14.3 Figures 48 to 50
6	Lower inter-ramp and bench	Phase 4 final	Softened	Figure 46	Circular and non-circular	Table 14.3 Figure 50

(1) March 2015 pit, showing slopes prior to North wall failure

14.2.4 North Wall

The north wall overall and inter-ramp slopes have high FoS for all cases, except the lower inter-ramp slope using softened parameters, Figure 48 and Table 14.3. This is in keeping with the monitoring and the observations of performance. The exception, the lower inter-ramp slope on Section 3 has a FoS = 1.19 for the fully softened parameters. The location of this potential failure path is in the lower disturbed rock mass around the stopes. Based on this result and the history with the north wall failure the potential for impacts on the lower slope due to ongoing creep of the underground workings is assessed in more detail using Section 6.

TABLE 14.3
NORTH WALL STABILITY ANALYSIS RESULTS

SLOPE SEGMENT	STABILITY SECTION	FACTOR OF SAFETY STRENGTH TYPE	
		CURRENT	SOFTENED
Overall	2	4.52	4.52
	3	4.11	4.01
Lower Inter-ramp	2	3.80	3.54
	3	3.40	1.19

14.2.5 Impact of Old Workings on lower North Wall

The effect of existing stopes on rock mass stability at the toe of the north wall was assessed using Section 6. This section has a number of old workings behind the face and these could link up to produce a failure plane. Figure 50 and Table 14.4 present the stability results with unfilled stopes at the toe, for bench and inter-ramp failure. The effect of filling stopes with cemented rock fill (CAF) was also evaluated. In this case there was only a marginal improvement in FoS.

The results show for current and softened parameters:

- FoS is very high and greater than 1.2 for all cases,
- There is a 36% increase in FoS for circular bench scale failure with the addition of CAF in the unfilled stopes; and
- There is a 1% increase in FoS for a non-circular failure path extending to the stopes behind the current pit face with the addition of CAF in the unfilled stopes.

TABLE 14.4
LOWER NORTH WALL STABILITY ANALYSIS RESULTS – SECTION 6 - FAILURE THROUGH STOPES

SLOPE SEGMENT	FAILURE TYPE ASSESSED	STRENGTH TYPE	FACTOR OF SAFETY	
			EXISTING STOPE CONDITION	STOPES FILLED WITH CAF
Lower Inter-ramp	Non-circular failure along existing stopes behind slope	Softened	3.13	3.16
Bench	Circular failure along existing stopes at pit face	Softened	2.10	2.86

14.2.6 East Wall

Section 5 has the greatest thickness of the Young Volcanics and caved/disturbed rock mass. There will also be some groundwater present in the Young Volcanics. In addition the lower east wall of the East Layback lies in part within the Milking Cow and has a marginal FoS if caved parameters are assumed. However only small increases in the material properties results in acceptable FoS. The photographs of the caved zone in the pit, Appendix B, shows significantly higher strength properties than assumed for the caved material, which is assumed similar to an unconsolidated rockfill with cohesion 5 kPa and angle of friction of 35°. Hence the caved rock mass properties are a lower bound strength and conservative. This understanding needs to be taken account of when assessing the stability analysis results below.

Based on the observed slope performance the existing pit slope as at March 2015, Section 5, was back analysed also as a check on the strength parameters. The analysis results, Table 14.5 show FoS for current and softened strengths of 1.28 and 1.16 respectively for overall and inter-ramp slopes. Using the current parameters the FoS was high. Analysis of the MP4 pit gives acceptable FoS for all but the lower inter-ramp and softened parameters.

However there is also a question about the exact extent of the caved material along Section 5. Consequently, sensitivity analyses were run, modifying the caved zone to disturbed parameters, Figures 46, 49 and Table 14.6. This was done for the disturbed current and softened strengths; and for both the lower inter-ramp and overall slopes. This shows adequate FoS using current strengths. However using the softened strengths and a range of groundwater assumptions the FoS ranges from 1.11 to 1.16.

The lowest part of the slope is in the Milking Cow and has a FoS of 1.08. However with modified properties in the caved zone the FoS if greater than 1.2 for current and softened parameters.

Given the fact this is caved and disturbed material using a groundwater table at the pit surface is conservative and unlikely. As such, Figure 50 presents the results of a sensitivity analysis of groundwater distance behind the face assuming setbacks of the groundwater from the slope face of 10 m and 20 m. Groundwater 20 m behind the pit face increases the FoS by 5%, up to 1.16.

TABLE 14.5
EAST WALL STABILITY ANALYSIS RESULTS – SECTION 5 - CURRENT MODEL

SLOPE SEGMENT	FACTOR OF SAFETY			
	MARCH 2015 PIT		MP4 PIT	
	Current Strengths	Softened Strengths	Current Strengths	Softened Strengths
Overall	1.57	1.28	1.33	1.18
Upper Inter-ramp	1.4	1.16	1.41	1.16
Lower Inter-ramp	-	-	1.08	0.96

TABLE 14.6
EAST WALL STABILITY RESULTS – SECTION 5 – SENSITIVITY ANALYSES

SLOPE SEGMENT	FACTOR OF SAFETY			
	DISTURBED PARAMETERS IN THE CAVE ZONE			
	Groundwater			
	Base Case		10m Behind Pit Face	20m Behind Pit Face
	Current Strengths	Softened Strengths	Softened Strengths	Softened Strengths
Overall	1.4	-	-	-
Upper Inter-ramp	1.27	1.11	1.13	1.16
Lower Inter-ramp	1.75	1.19	1.19	1.2

14.2.7 Summary

This analysis has shown that the MP4 cutback will be stable. The analysis of the lower slope of the cutback in the zone shows marginal stability depending on the section location and the parameters assumed for the cutback.

15 SUMMARY AND CONCLUSIONS

The Phase 4 Pit entails a cutback of the eastern end of the north wall of the existing pit. In essence this represents a change to around one quarter of the existing pit and is essentially a cutback to remove the North Wall Failure. The existing pit is a combination of the Extended, South Stability Cutback and East Layback pits.

The MP4 pit is much flatter overall than the north wall of the East Layback and this is necessitated by the operational need to incorporate additional haul roads and wide benches.

Both the SSC and East Layback pits were designed to achieve more stable conditions by moving the new pit walls and important historical infrastructure as far as practical outside the rock mass zone affected by the historical underground workings. This process has generally been successful as demonstrated by the performance and success of the SSC, the East Layback and the moving of the Pumphouse.

Hence the MP4 pit is a continuation of that stabilisation process. MP4 is a remedial cutback of a failure undertaken in order to re-establish the mine, which is a normal part of conventional mining activities and there is nothing unique or special in the planned cutback.

The Martha Underground will run in parallel with MP4 and has a number of major benefits:

1. 30% of the existing unfilled historical stopes will be stabilised by filling with rockfill and half of these lie in the upper levels immediately below the MP4 Pit.
2. 30% of the total planned mining is re-mining of historical stopes, it will be mining from the top down, a very large proportion of these lie immediately below the MP4 Pit; and CAF will be used extensively in this mining.
3. These two factors will result in a significant improvement in overall rock mass conditions; firstly by improving pit stability conditions both in the short and long term, secondly by reducing any impacts of the Martha Underground mining and thirdly by reducing the longer term creep of the rock mass around the historical underground.

The MP4 pit is in large part an existing structure that has already been constructed and its performance has been monitored over time. The existing pit stability condition is the starting point for MP4. Monitoring has now been in place for up to two decades and does not show large scale pit wall instability movements. Consequently in engineering terms there has been a mine scale validation of the ultimate material properties used for the design of the pit walls.

The model showing the distribution of the zones affected by the historical underground mining has been updated using the new drilling undertaken by OceanaGold since 2005. This cave model has proven to be quite robust over time with only relatively small changes. The model shows a large area in the south and the lower east of the pit that progresses outwards from caved to disturbed to deformed materials. This area is approximately bounded by the Martha Lode in the north, the Edward Lode in the west and extends south to the surface projection of the Royal Lode. In the east the effects are masked in part by the thickening unit of younger volcanics.

The monitoring data reflects this cave model with:

1. No movement in the north and west.
2. Small creep movements in the upper south, which is the hanging wall of the Royal Lode.
3. In the east wall low rates of creep movement are occurring in parts. However this area has a very complex pattern of historical underground mining both outcropping on the slope and underlying it. It appears that subsidence of the Milking Cow is continuing. There are also some local movement of the filled Martha Stopes.
4. These overall patterns of movement were expected and were known to probably be the result when both the South Stability Cutback and the East Layback were designed.

An investigation has been carried out to evaluate the potential for other structural planes to that which contributed to the north wall failure. This study has not identified any related structures.

The stability has been checked and overall the FoS are high for the MP4 pit. The lower slope is potentially affected by underground stopes and disturbed rock mass. It is recommended that consideration be given to backfilling the Martha stopes in the upper 30 m below the pit during mining. The details of this remediation and the need for it should be determined based on the performance and exposures during mining.

The lower east wall appears to have marginal stability mainly in and around the Milking Cow. This was known and was part of the original understanding for the East Layback Pit. This is the region currently affected by the creep movements. However the strength parameters are known to be conservative based on the actual pit exposures. Hence depending on the assumed strength parameters higher FoS in keeping with generally accepted standards apply.

16 RECOMMENDATIONS

This study has shown that one of the current base stations is located within a zone of rock mass affected by creep movements. The base station monitoring network needs to be reviewed such that either more suitable locations are found or remote secondary stations are installed to allow correction of any base station movements as required.

Before mining of the cutback commences a new prism monitoring network should be implemented and include prisms located behind the planned pit crest. Additional prisms should be installed on the benches as excavation advances.

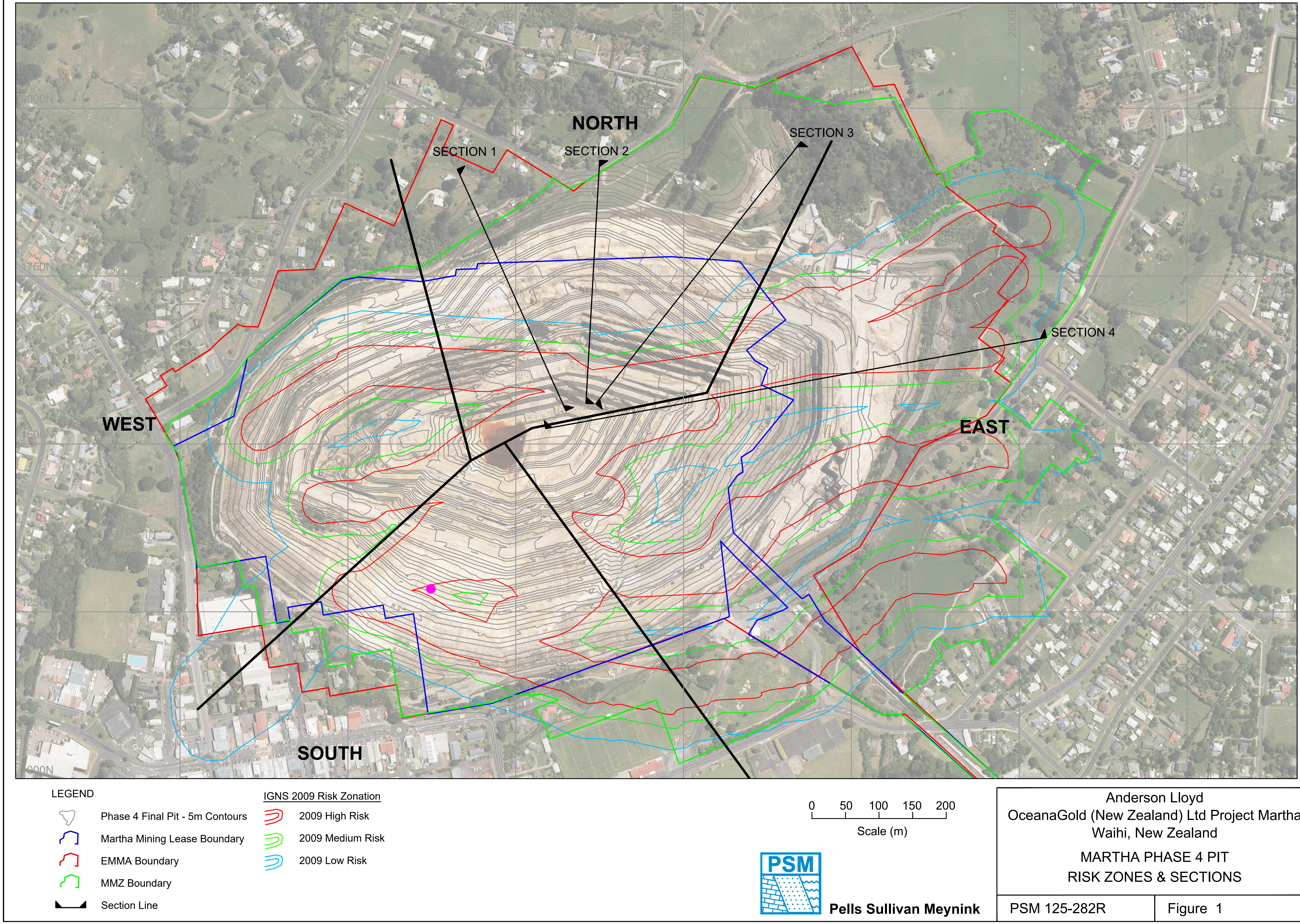
For and on behalf of
PELLS SULLIVAN MEYNINK

TIM SULLIVAN
Principal

REFERENCES

1. Pells Sullivan Meynink Pty Ltd., 2006: Report on Pit Closure Studies. Unpublished consultants report for Newmont Waihi Operations, report reference PSM125.R34, dated April 2006.
2. Pells Sullivan Meynink Pty Ltd., 2003: 2002 – 2003 Geotechnical Investigations Waihi Vol. 1 Text, Plates & Figures. Unpublished consultants report for Newmont Waihi Operations, report reference PSM125.R28, dated July 2003.
3. Pells Sullivan Meynink Pty Ltd., 2005. Risk Assessment Pumphouse. Unpublished consultants report for Newmont Waihi Operations, report reference PSM125.R33, dated April 2005.
4. Bieniawski, (1993) "Classification of rock masses for engineering: the RMR system and future trends", Comprehensive Rock Engineering, Ed. Hudson, Vol 3 p553-574, 1993, Pergamon.
5. Hoek, E, Carranza-Torres, C. and Corkum, B. "Hoek Brown Failure Criterion – 2002 Edition". Proceedings North American Rock Mechanics Society & Tunnelling Association of Canada, Toronto, July 2002.
6. Hoek, E. & Brown, E.T., "Practical Estimates of Rock Mass Strength", International Journal of Rock Mechanics and Mining Sciences, Vol 34, No 8, pp1165-1186, 1997.
7. Douglas, K., 2002: The shear strength of rock masses. Thesis submitted in partial fulfilment of the requirements for a Doctoral of Philosophy, University of New South Wales, Australia.
8. McVerry, G., 2007: Unpublished Institute of Geological & Nuclear Sciences Ltd. Letter for report prepared for Engineering Geology Ltd., dated 26 June 2007, reference No. 200178LR, Project No. 430W1272.
9. Pacific Geotech Ltd., 2008: Unpublished consultants memorandum prepared for Pells Sullivan Meynink Pty Ltd., undated and unreferenced.
10. NZS 1170.5, 2004: Structural Design Actions, Part 5 Earthquake Actions – New Zealand.
11. Pells Sullivan Meynink Pty Ltd., 2009: Site Visit Report February 2009. Unpublished consultants report for Newmont Waihi Operations, report reference PSM125.L105, dated February 2009.
12. Pells Sullivan Meynink Pty Ltd., 2009b: South Stability Cutback – Stability Update No. 2. Unpublished consultants report for Newmont Waihi Operations, report reference PSM125.L106, dated March 2009.
13. Makdisi, F.I., Seed, H.B., 1978, "Simplified Procedure for Estimating Dam and Embankment Earthquake-Induced Deformations". Journal of Geotechnical Engineering, Vol 104, No. GT7, pp. 849-867.
14. Ambraseys, N., Menu, J., 1988, "Earthquake-Induced Ground Displacements". Earthquake Engineering and Structural Dynamics, Vol 16, pp. 985-1006.

15. Romeo, R., 2000, “Seismically induced landslide displacements: a predictive model”. Engineering Geology, Vol. 58, pp. 337-351.
16. Pells Sullivan Meynink Pty Ltd. 2005: Geotechnical Review and Update 2004. Unpublished Consultants report for Newmont Waihi Operations. Report Reference PSM125.R31, 12th January 2005.



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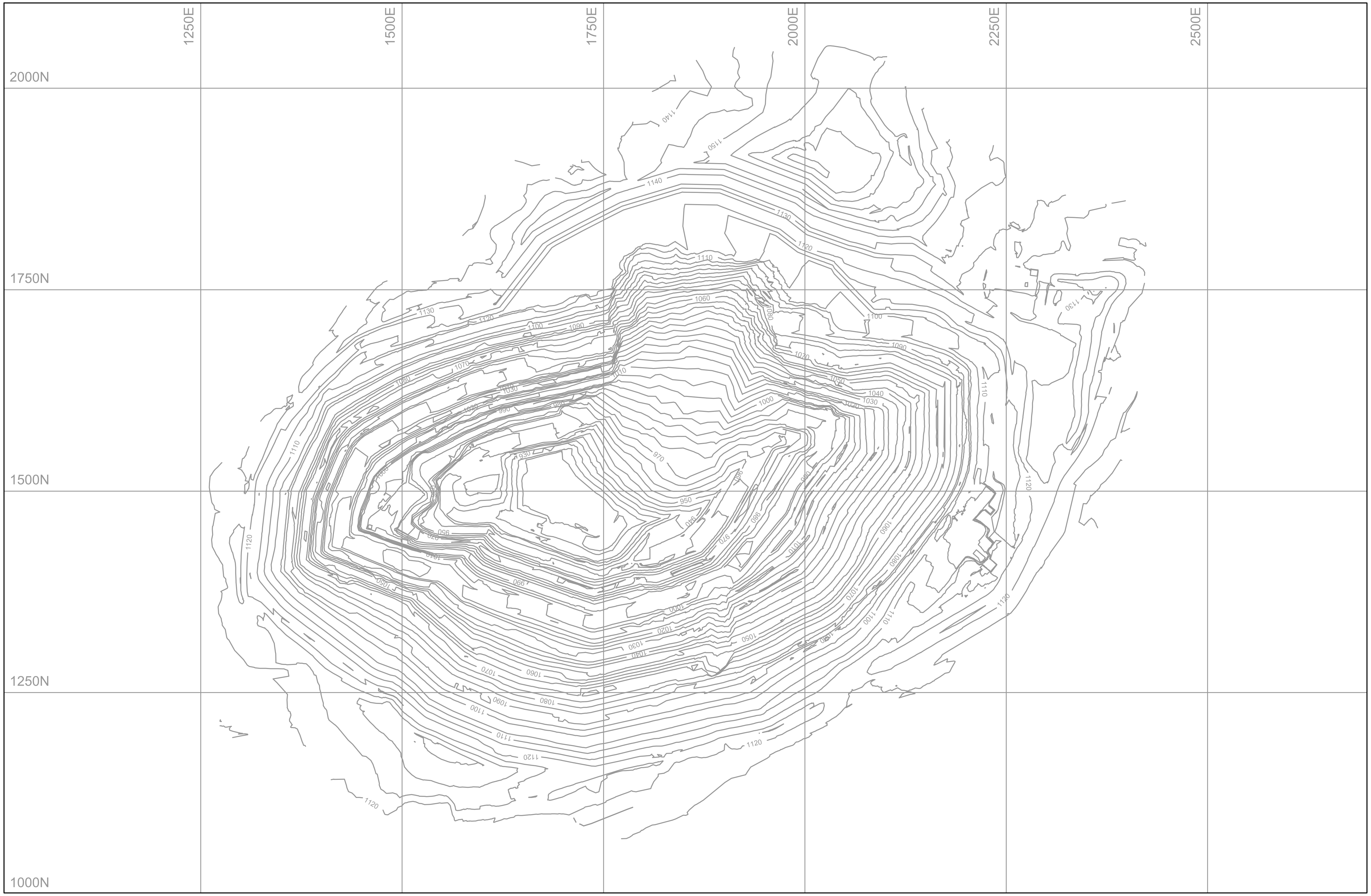
MARTHA PHASE 4 PIT
RISK ZONES & SECTIONS

PSM 125-282R | Figure 1



0 50 100 150 200

Scale (m)

PSM

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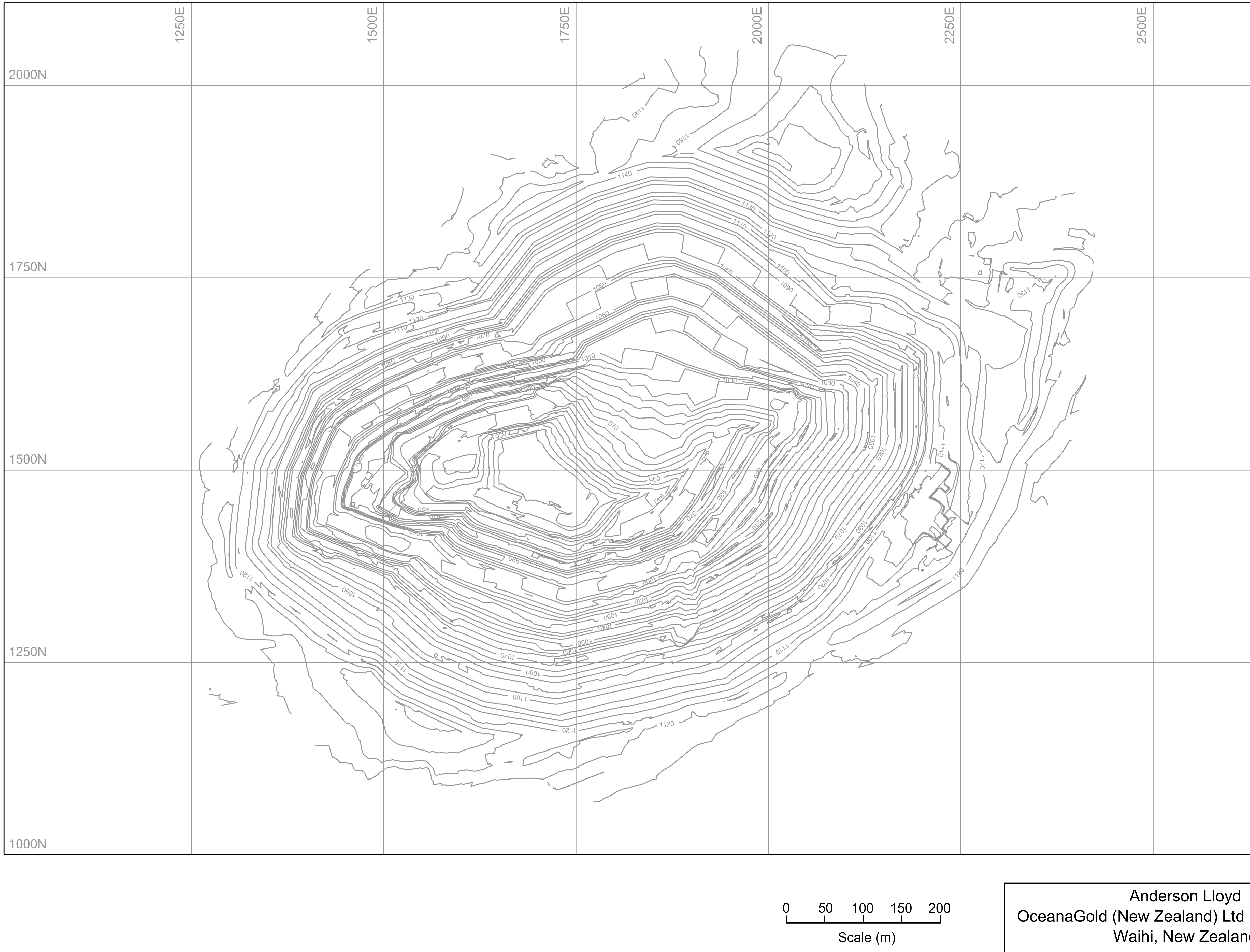
PHASE 4 INTERIM PIT 1 UPPER
5m CONTOURS

PSM 125-282R	Figure 2



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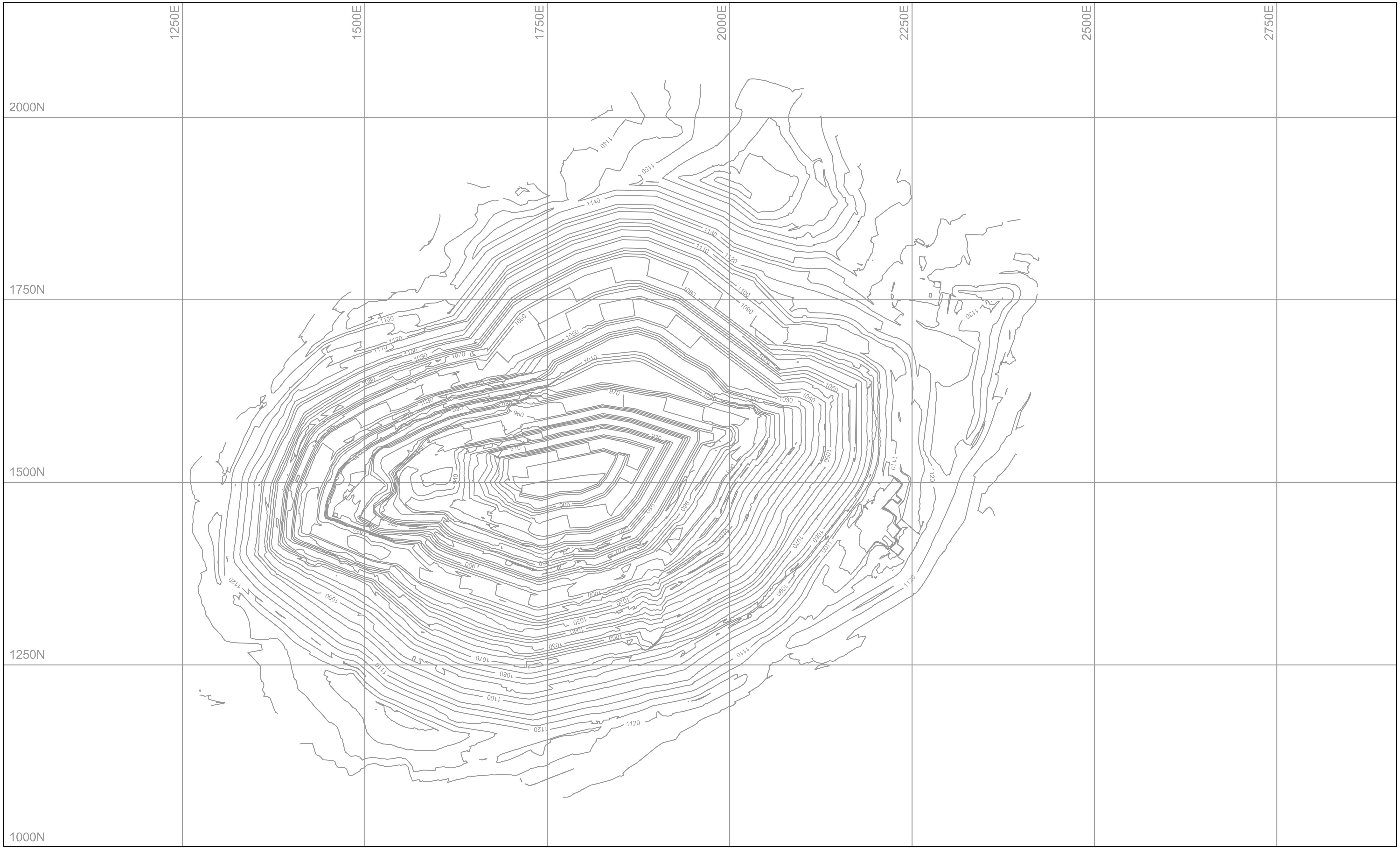
PHASE 4 INTERIM PIT 2
5m CONTOURS

PSM 125-282R	Figure 3



0 50 100 150 200

Scale (m)

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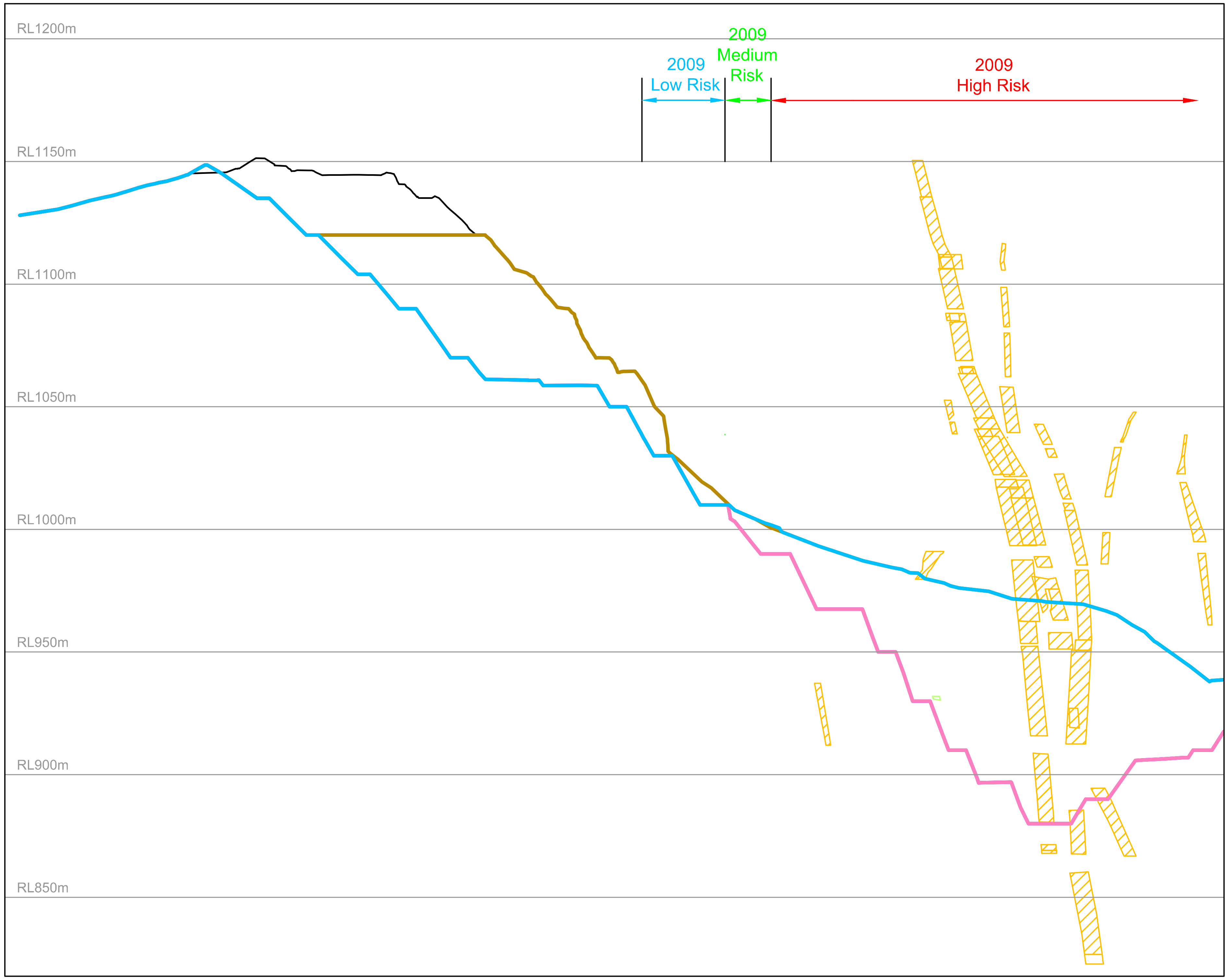
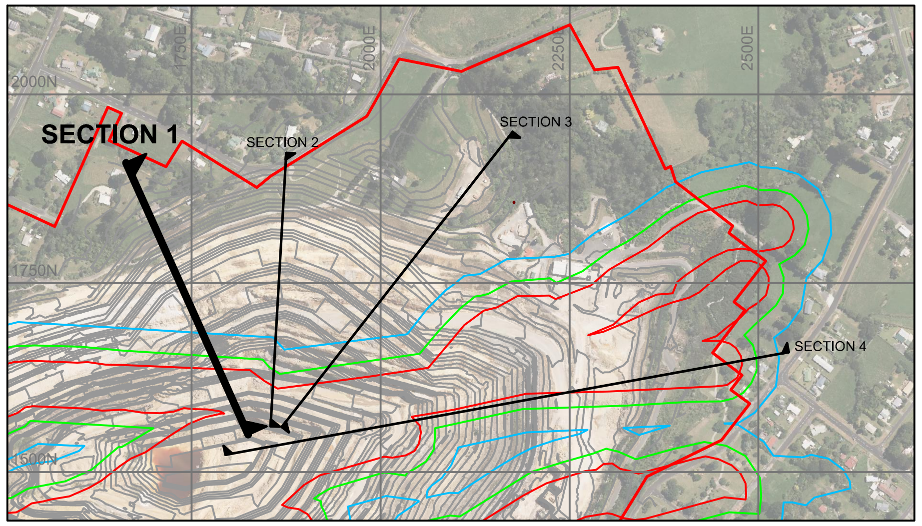
PHASE 4 FINAL PIT
5m CONTOURS

PSM 125-282R	Figure 4





LEGEND

- Phase 4 Final Pit
- Phase 4 Cutback 2 Pit
- Phase 4 Cutback 1 Pit
- Martha Surface Pit 31 August 2017
- Stope Filled
- Stope Unfilled

0 50 100

Scale (m)

PSM

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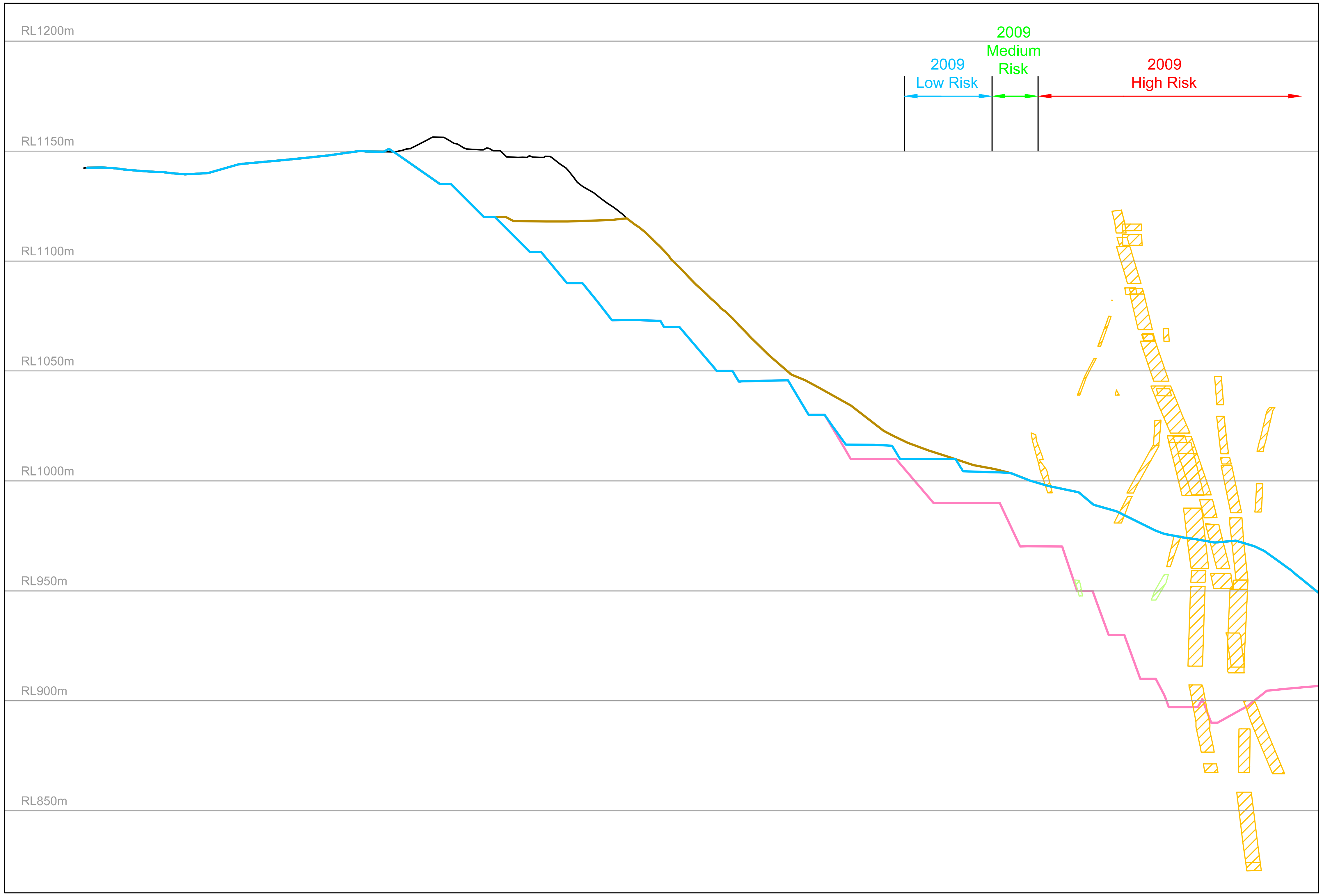
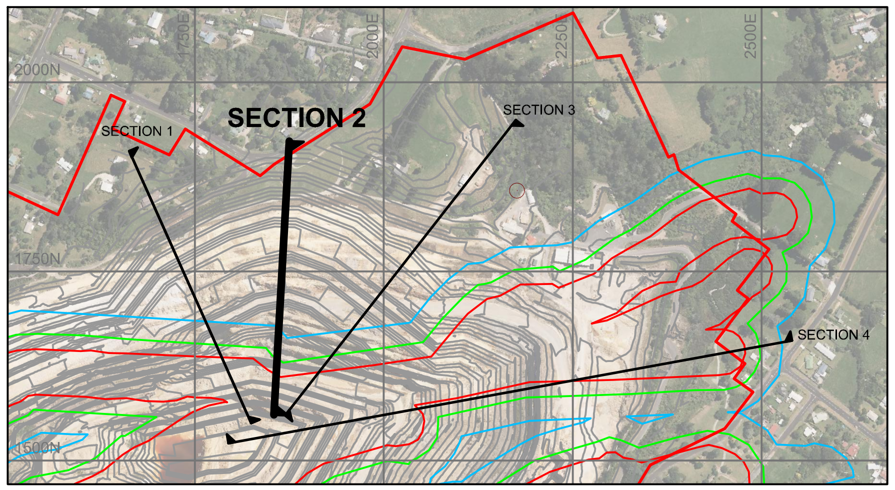
MARTHA PIT
PHASE 4 PIT STAGE SECTION 1

PSM 125-282R	Figure 5





LEGEND

- Phase 4 Final Pit
- Phase 4 Cutback 2 Pit
- Phase 4 Cutback 1 Pit
- Martha Surface Pit 31 August 2017
- Stope Filled
- Stope Unfilled

0 50 100

Scale (m)

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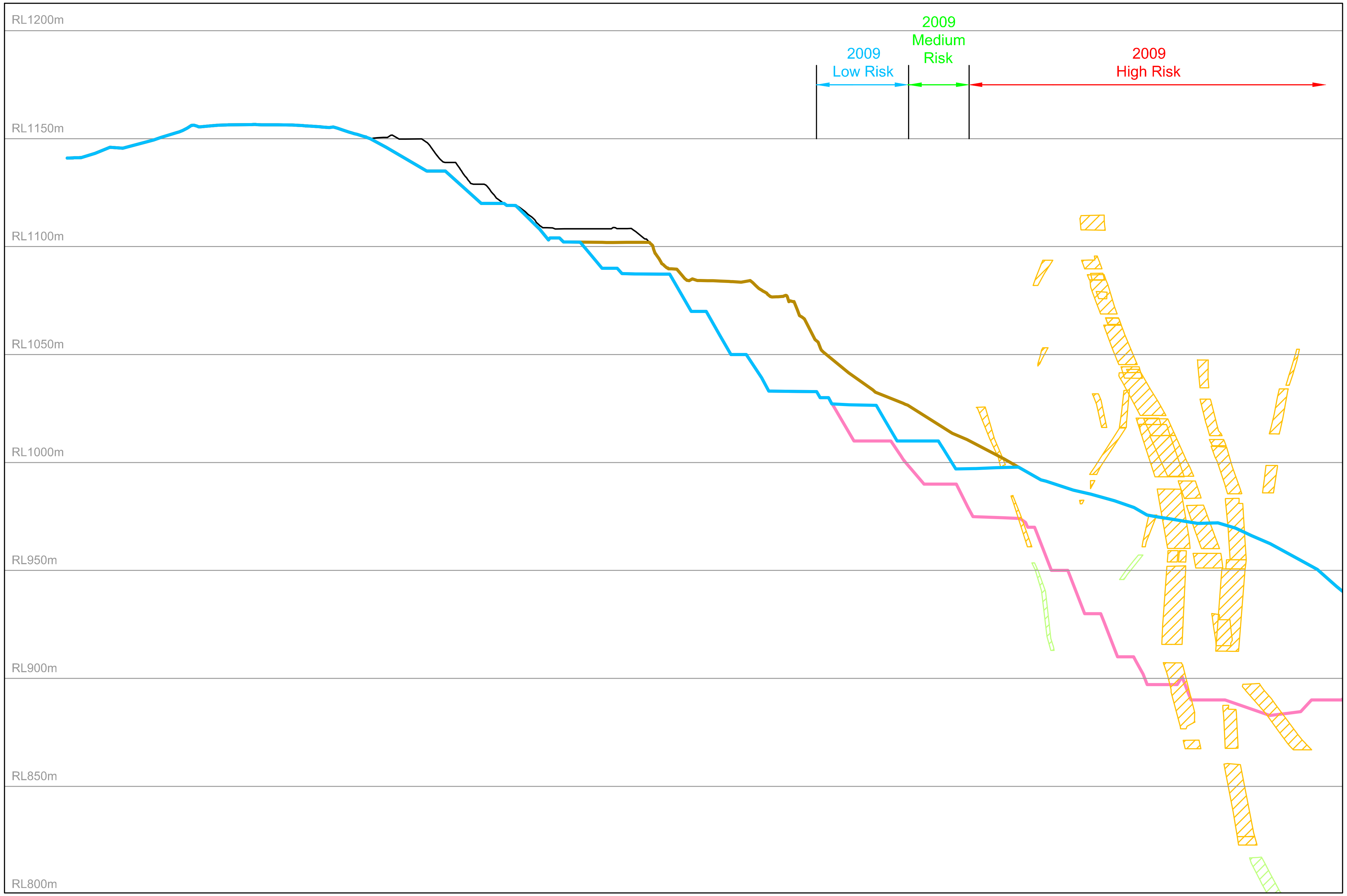
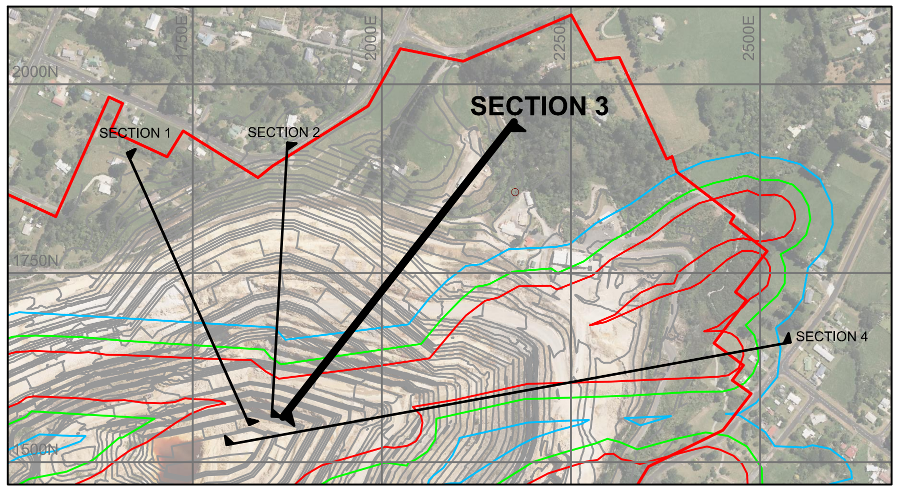
MARTHA PIT
PHASE 4 PIT STAGE SECTION 2

PSM 125-282R	Figure 6





LEGEND

- Phase 4 Final Pit
- Phase 4 Cutback 2 Pit
- Phase 4 Cutback 1 Pit
- Martha Surface Pit 31 August 2017
- Stope Filled
- Stope Unfilled

0 50 100

Scale (m)

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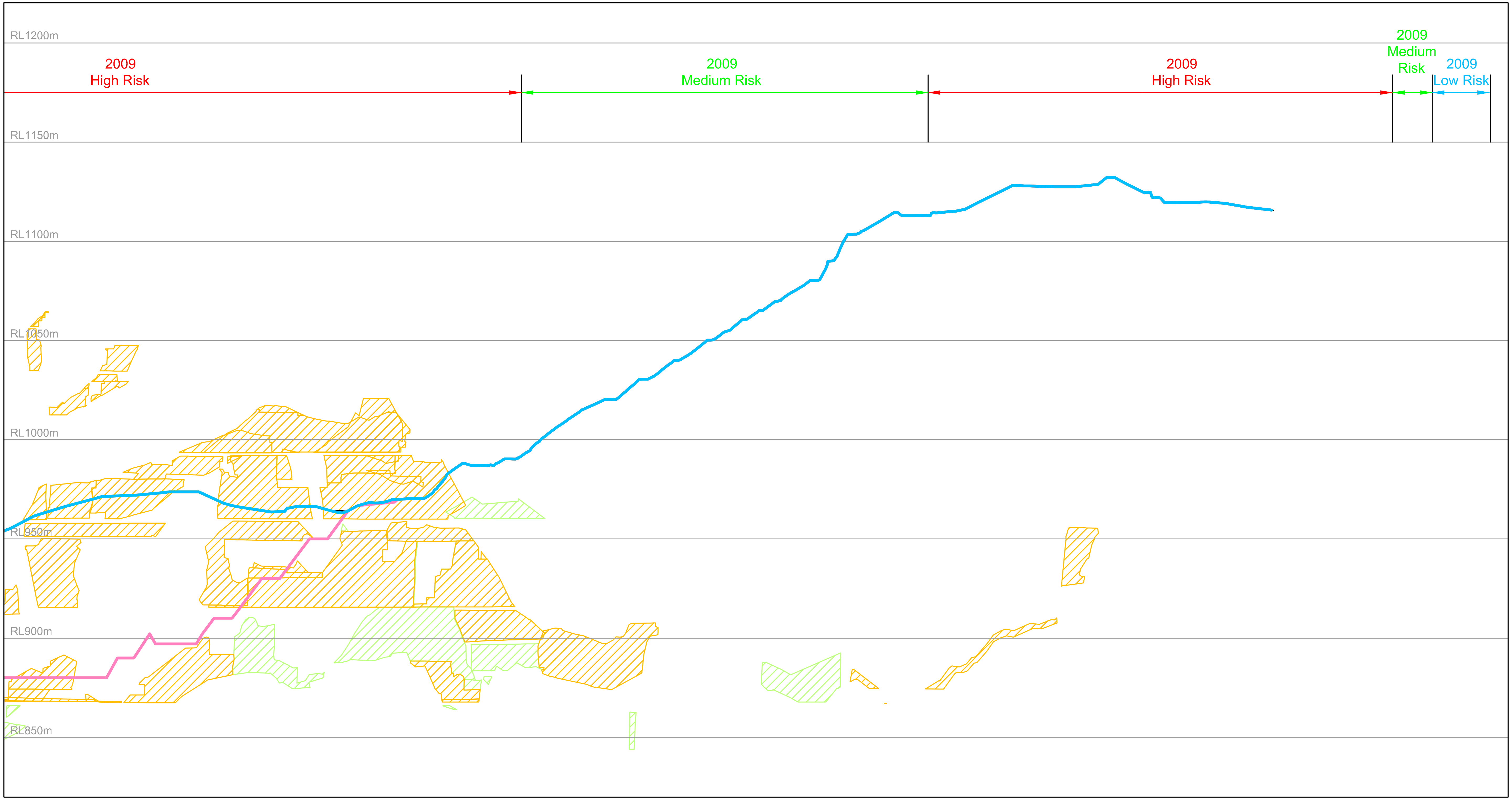
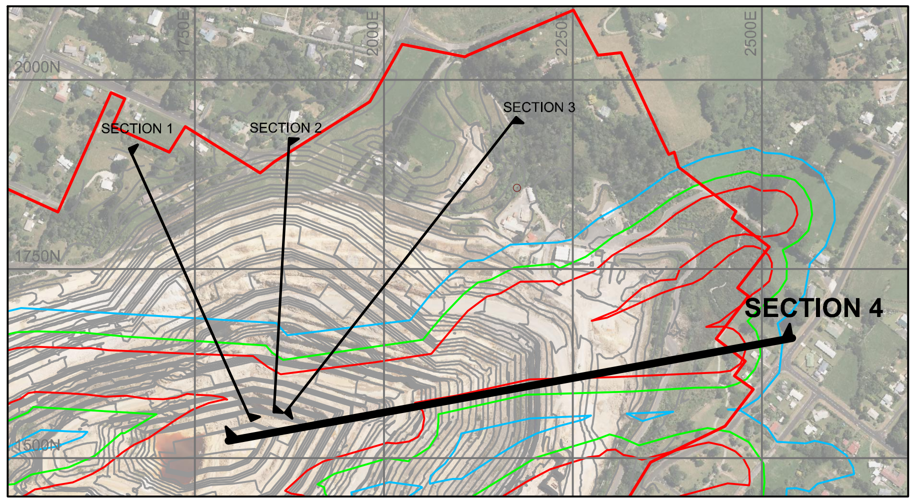
MARTHA PIT
PHASE 4 PIT STAGE SECTION 3

PSM 125-282R	Figure 7





LEGEND

- Phase 4 Final Pit
- Phase 4 Cutback 2 Pit
- Phase 4 Cutback 1 Pit
- Martha Surface Pit 31 August 2017
- Stope Filled
- Stope Unfilled

0 50 100
Scale (m)

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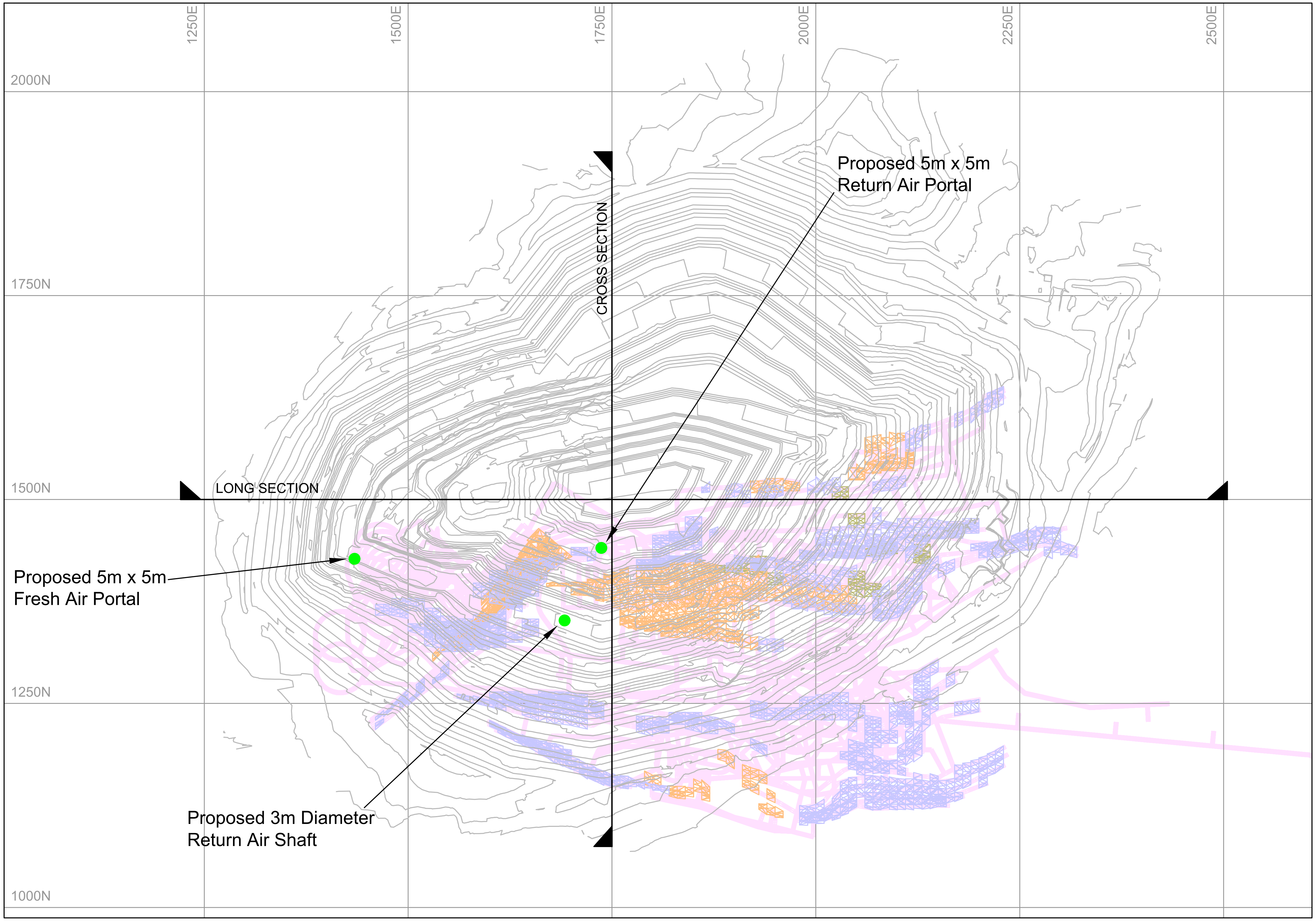
MARTHA PIT
PHASE 4 PIT STAGE SECTION 4

PSM 125-282R	Figure 8



LEGEND

- Phase 4 Final Pit - 5m Contours
- Proposed Underground Drives
- Avoca Stopes
- Backfilled Remnant Stopes
- Remnant Stopes
- Proposed Underground Portals

0 50 100 150 200

Scale (m)

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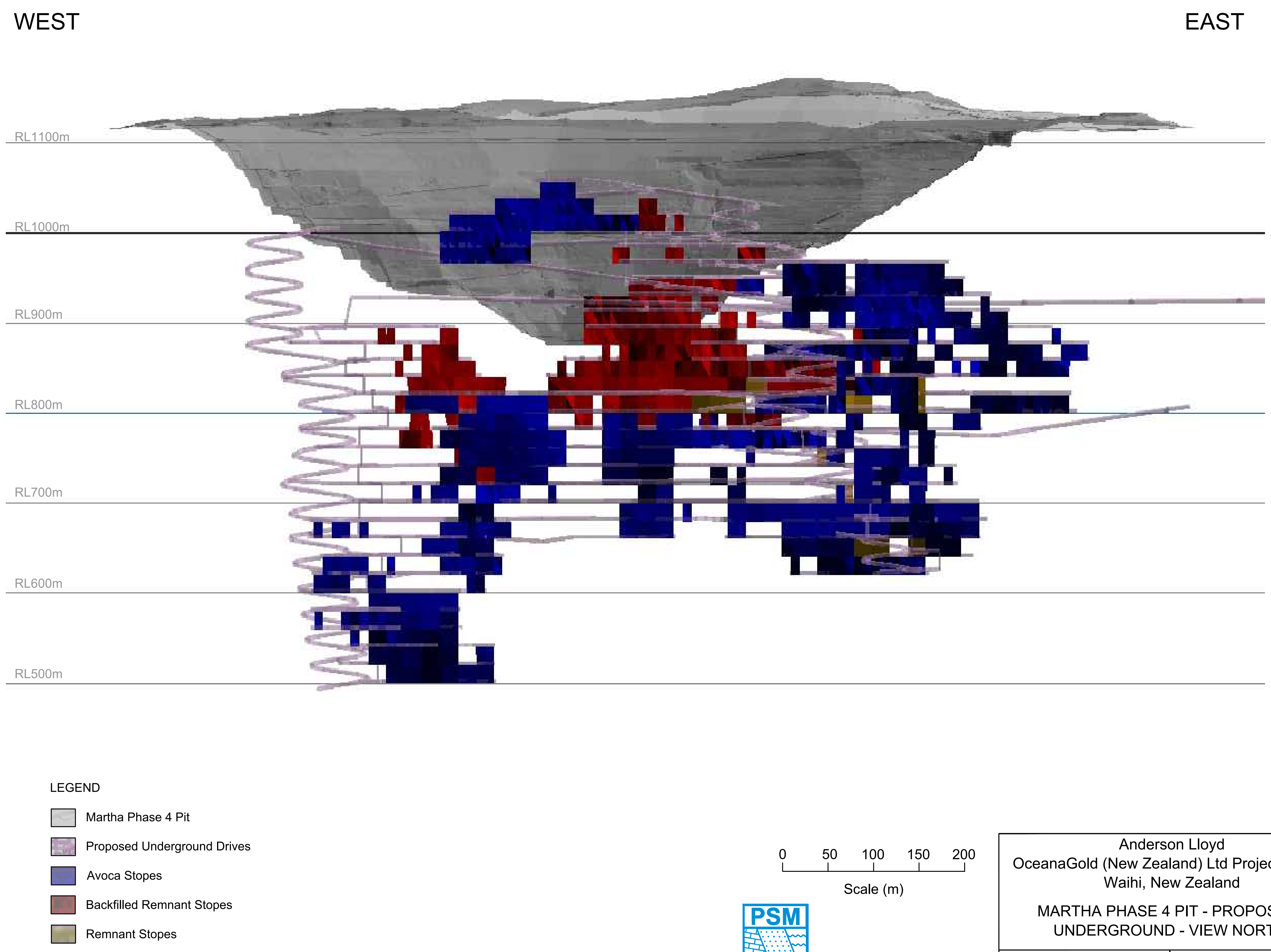
MARTHA PHASE 4 PIT
PROPOSED UNDERGROUND WORKINGS

PSM 125-282R	Figure 9



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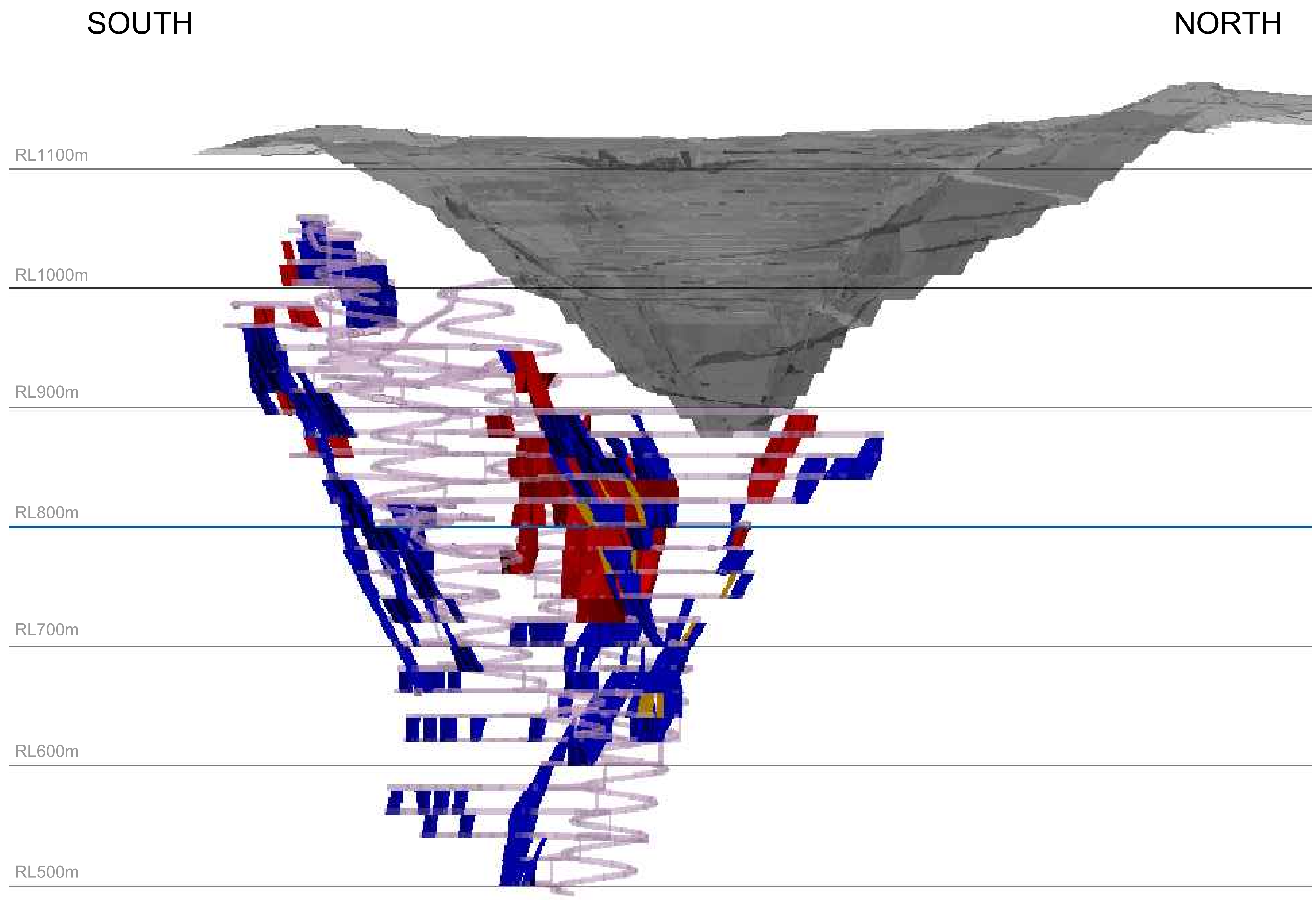
MARTHA PHASE 4 PIT - PROPOSED UNDERGROUND - VIEW NORTH

PSM125-282R	Figure 10



LEGEND

- Martha Phase 4 Pit
- Proposed Underground Drives
- Avoca Stopes
- Backfilled Remnant Stopes
- Remnant Stopes

0 50 100 150 200

Scale (m)

PSM

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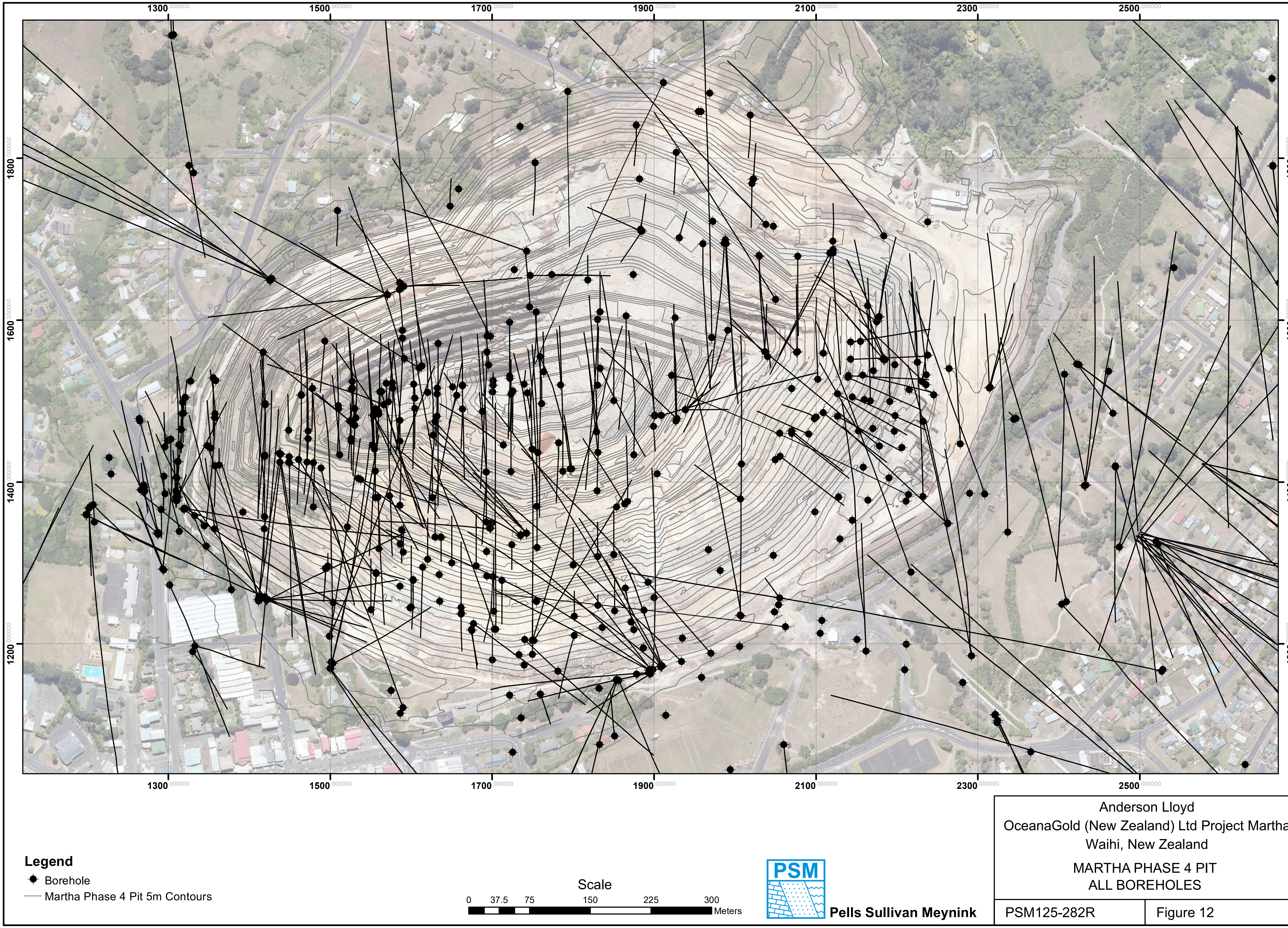
MARTHA PHASE 4 PIT - PROPOSED UNDERGROUND - VIEW WEST

PSM125-282R	Figure 11



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MARTHA PHASE 4 PIT
ALL BOREHOLES

PSM
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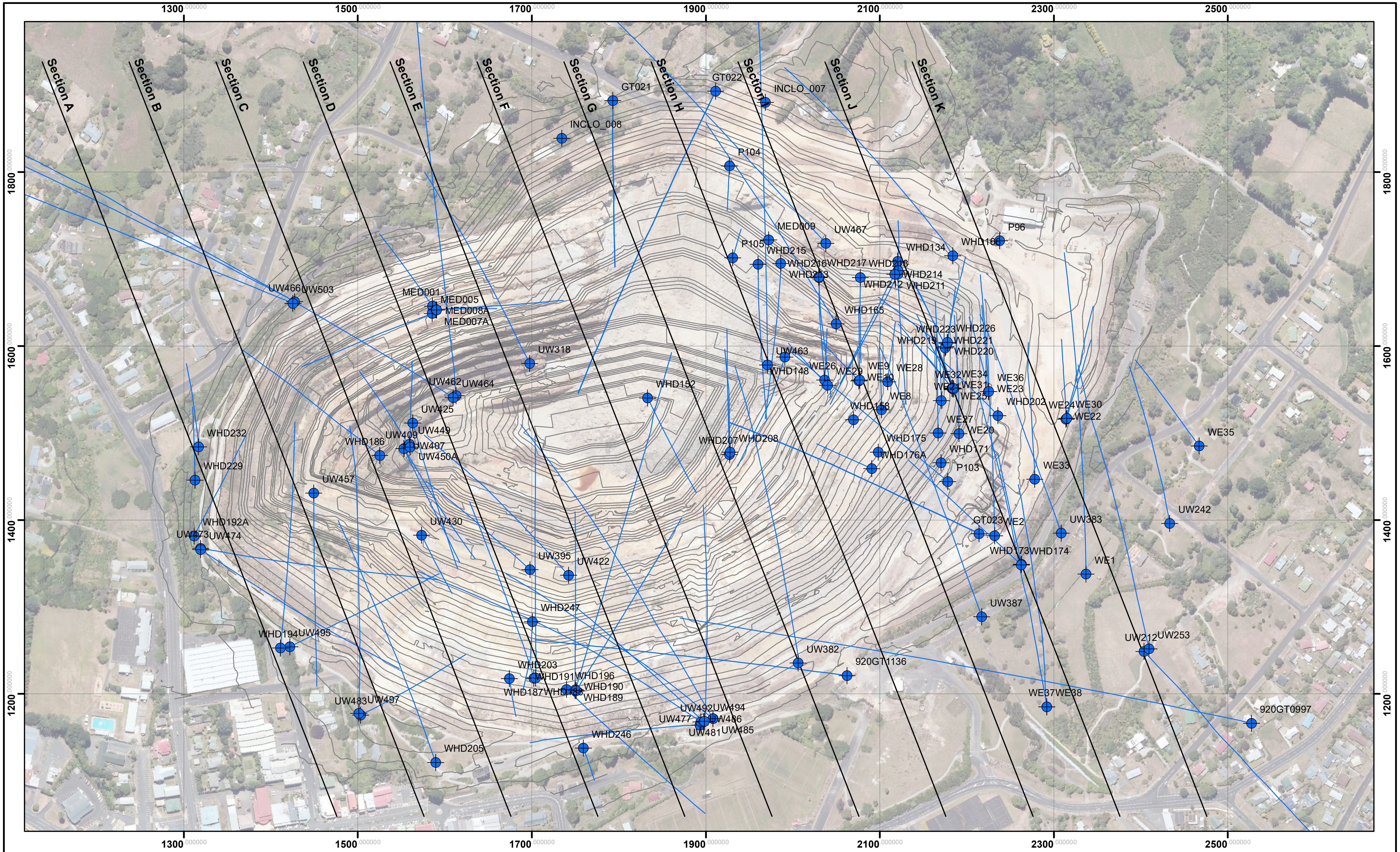
PSM125-282R | Figure 12



Legend

- Boreholes Used for Rock Mass Assessment
- Section Lines
- Martha Phase 4 Pit 5m Contours

Scale

0 37.5 75 150 225 300 Meters

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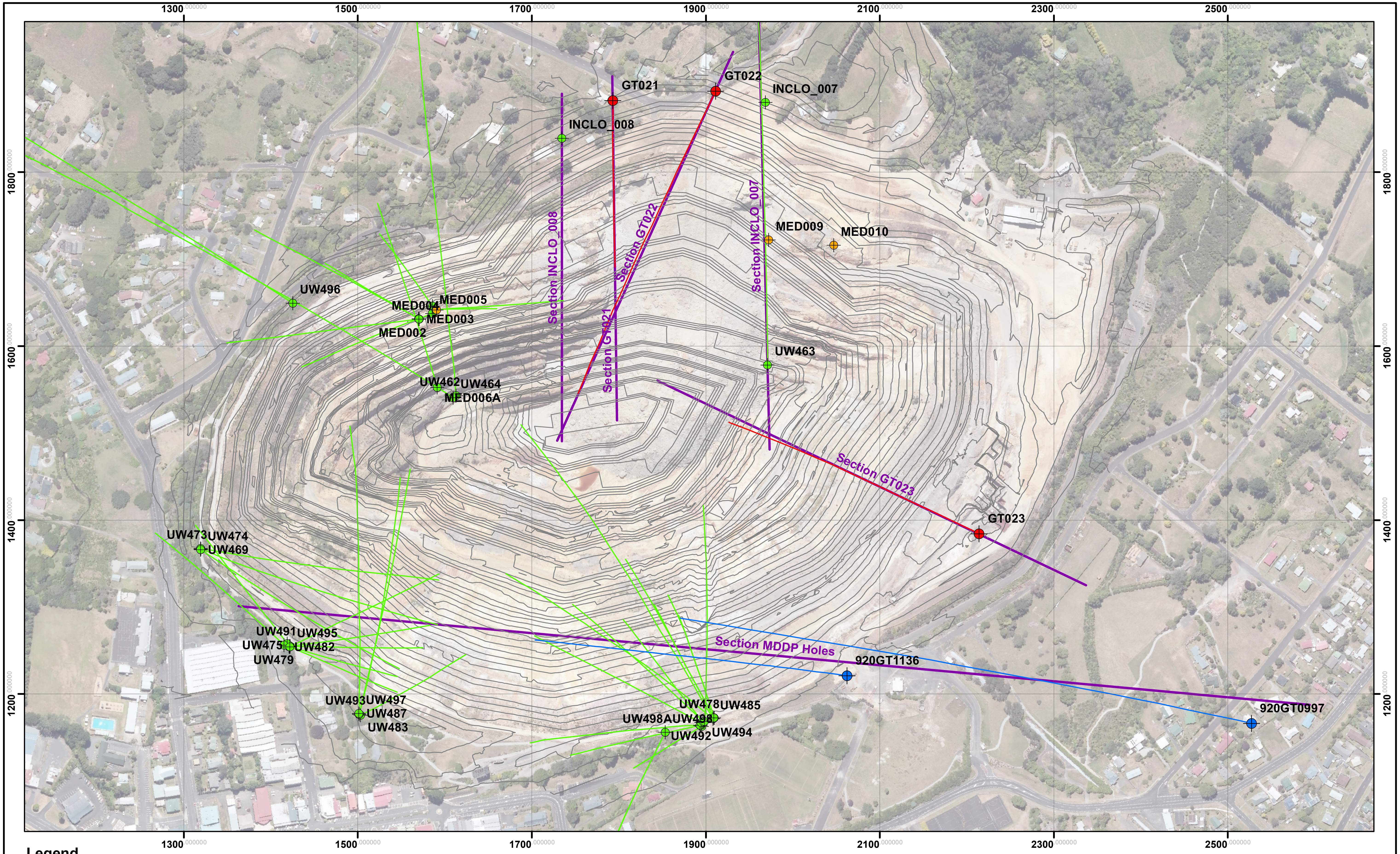
MARTHA PHASE 4 PIT - BOREHOLES USED FOR ROCK MASS ASSESSMENT

PSM125-282R	Figure 13



Legend

- Geotechnical Borehole
- Underground Borehole
- Recent Borehole - Excel Logs
- Recent Borehole - PDF Logs
- Martha Phase 4 Pit 5m Contours
- Martha Phase 4 Geotechnical Sections

Scale

0 37.5 75 150 225 300 Meters

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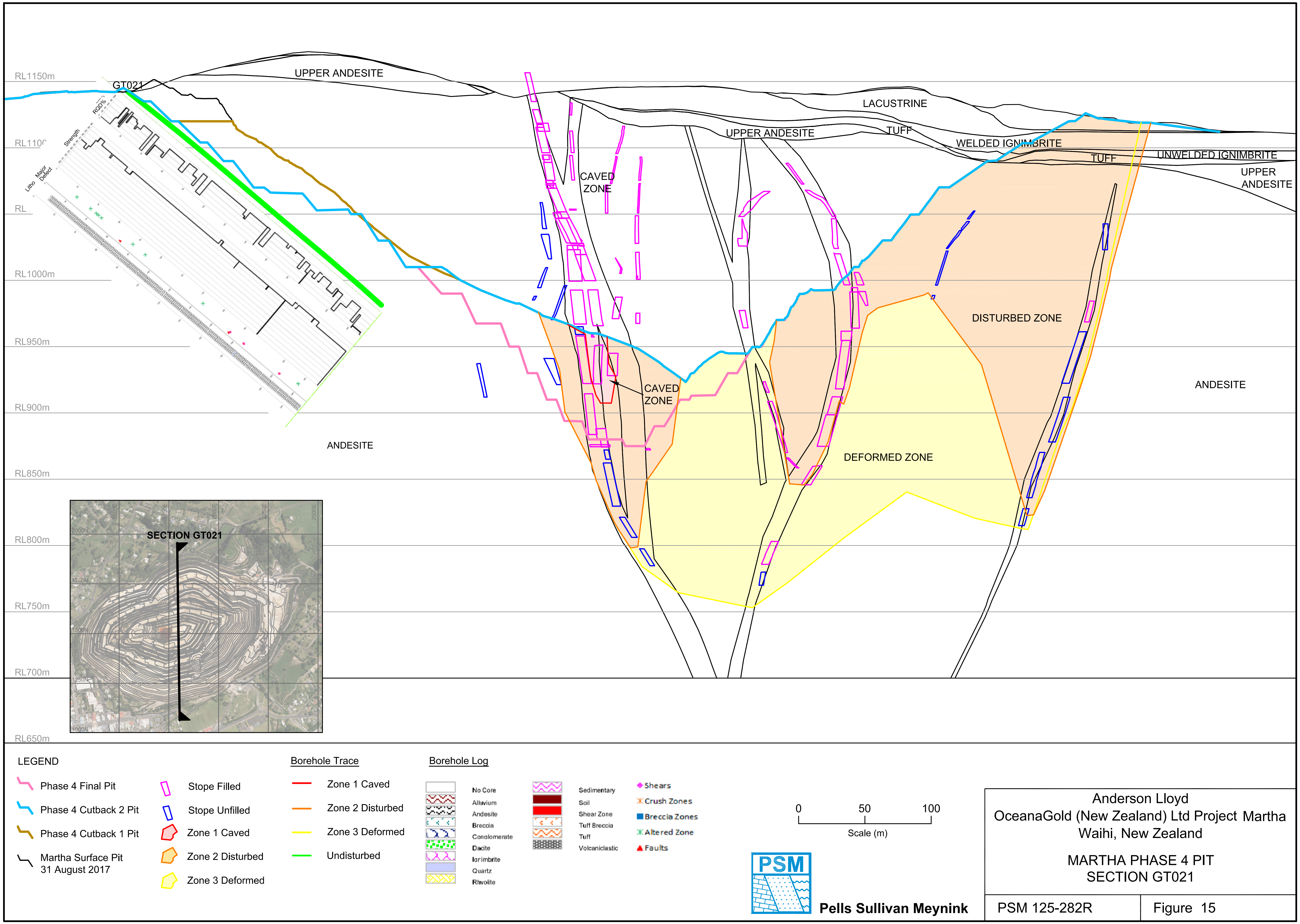
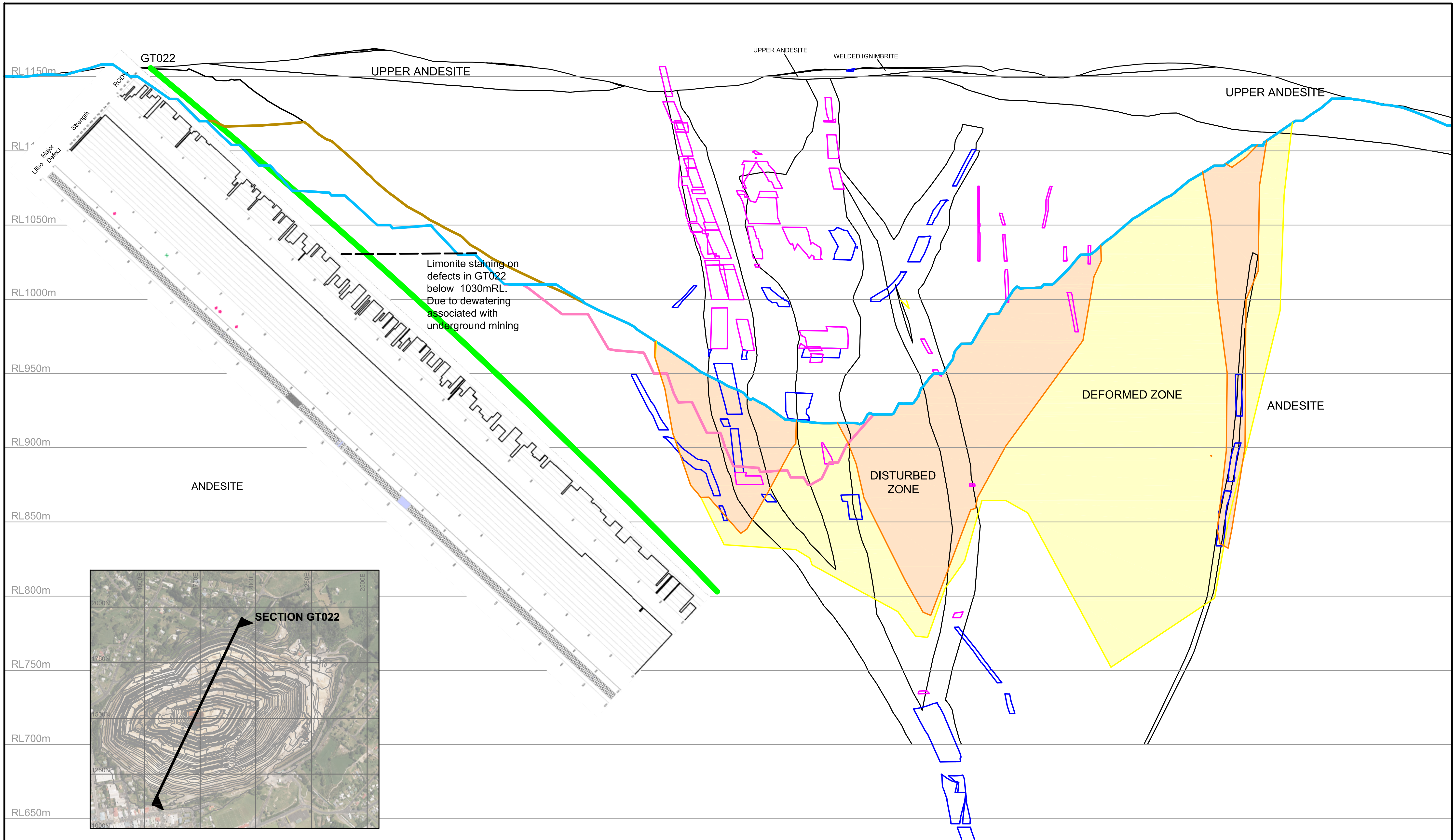
MARTHA PHASE 4 PIT - RECENT BOREHOLES
GEOTECHNICAL SECTIONS

PSM125-282R	Figure 14



RL1150m
RL1100
RL
RL1000m
RL950m
RL900m
RL850m
RL800m
RL750m
RL700m
RL650m
GT021
ROD%
Strength
Major Defect
Litho
UPPER ANDESITE
LACUSTRINE
UPPER ANDESITE
TUFF
WELDED IGNIMBRITE
TUFF
UNWELDED IGNIMBRITE
UPPER ANDESITE
CAVED ZONE
CAVED ZONE
DISTURBED ZONE
DEFORMED ZONE
ANDESITE
ANDESITE
SECTION GT021
LEGEND
Phase 4 Final Pit
Phase 4 Cutback 2 Pit
Phase 4 Cutback 1 Pit
Martha Surface Pit 31 August 2017
Stope Filled
Stope Unfilled
Zone 1 Caved
Zone 2 Disturbed
Zone 3 Deformed
Borehole Trace
Zone 1 Caved
Zone 2 Disturbed
Zone 3 Deformed
Undisturbed
Borehole Log
No Core
Alluvium
Andesite
Breccia
Conglomerate
Dacite
Ignimbrite
Quartz
Rhyolite
Sedimentary
Soil
Shear Zone
Tuff Breccia
Tuff
Volcaniclastic
Shears
Crush Zones
Breccia Zones
Altered Zone
Faults
0
50
100
Scale (m)
PSM
Pells Sullivan Meynink
Anderson Lloyd
OceanaGold (New Zealand) Ltd Project Martha
Waihi, New Zealand
MARTHA PHASE 4 PIT
SECTION GT021
PSM 125-282R
Figure 15



LEGEND

- Phase 4 Final Pit
- Phase 4 Cutback 2 Pit
- Phase 4 Cutback 1 Pit
- Martha Surface Pit 31 August 2017
- Stope Filled
- Stope Unfilled
- Zone 1 Caved
- Zone 2 Disturbed
- Zone 3 Deformed

Borehole Trace

- Zone 1 Caved
- Zone 2 Disturbed
- Zone 3 Deformed
- Undisturbed

Borehole Log

- No Core
- Alluvium
- Andesite
- Breccia
- Conglomerate
- Dacite
- Icnimbrite
- Quartz
- Rhyolite
- Sedimentary
- Soil
- Shear Zone
- Tuff Breccia
- Tuff
- Volcaniclastic
- Shears
- Crush Zones
- Breccia Zones
- Altered Zone
- Faults

0 50 100
Scale (m)

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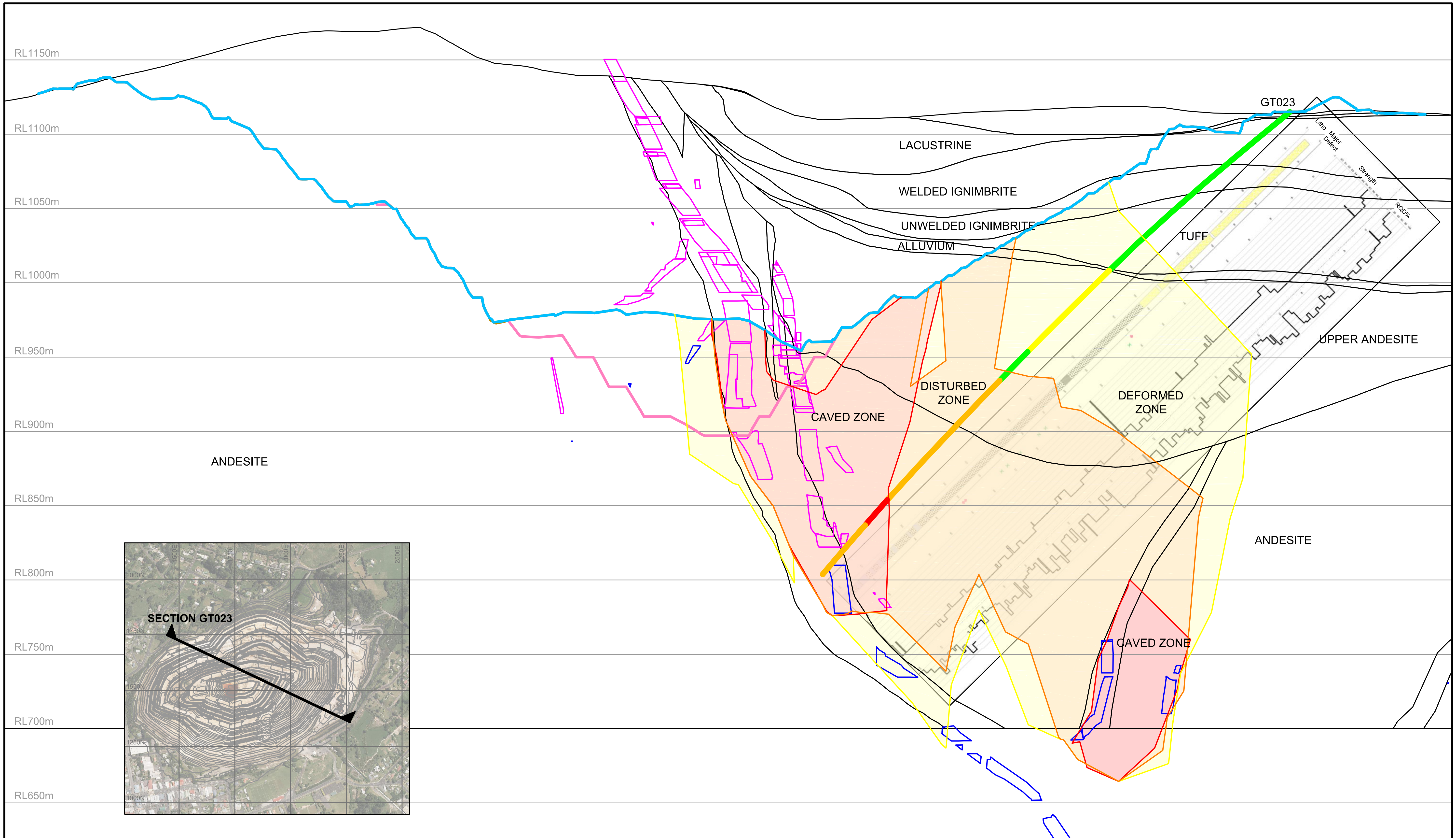
MARTHA PHASE 4 PIT
SECTION GT022

PSM 125-282R | Figure 16



LEGEND

- Phase 4 Final Pit
- Phase 4 Cutback 2 Pit
- Phase 4 Cutback 1 Pit
- Martha Surface Pit 31 August 2017
- Stope Filled
- Stope Unfilled
- Zone 1 Caved
- Zone 2 Disturbed
- Zone 3 Deformed

Borehole Trace

- Zone 1 Caved
- Zone 2 Disturbed
- Zone 3 Deformed
- Undisturbed

Borehole Log

- No Core
- Alluvium
- Andesite
- Breccia
- Conglomerate
- Dacite
- Ignimbrite
- Quartz
- Rhyolite
- Sedimentary
- Soil
- Shear Zone
- Tuff Breccia
- Tuff
- Volcaniclastic
- Shears
- Crush Zones
- Breccia Zones
- Altered Zone
- Faults

0 50 100
Scale (m)

PSM
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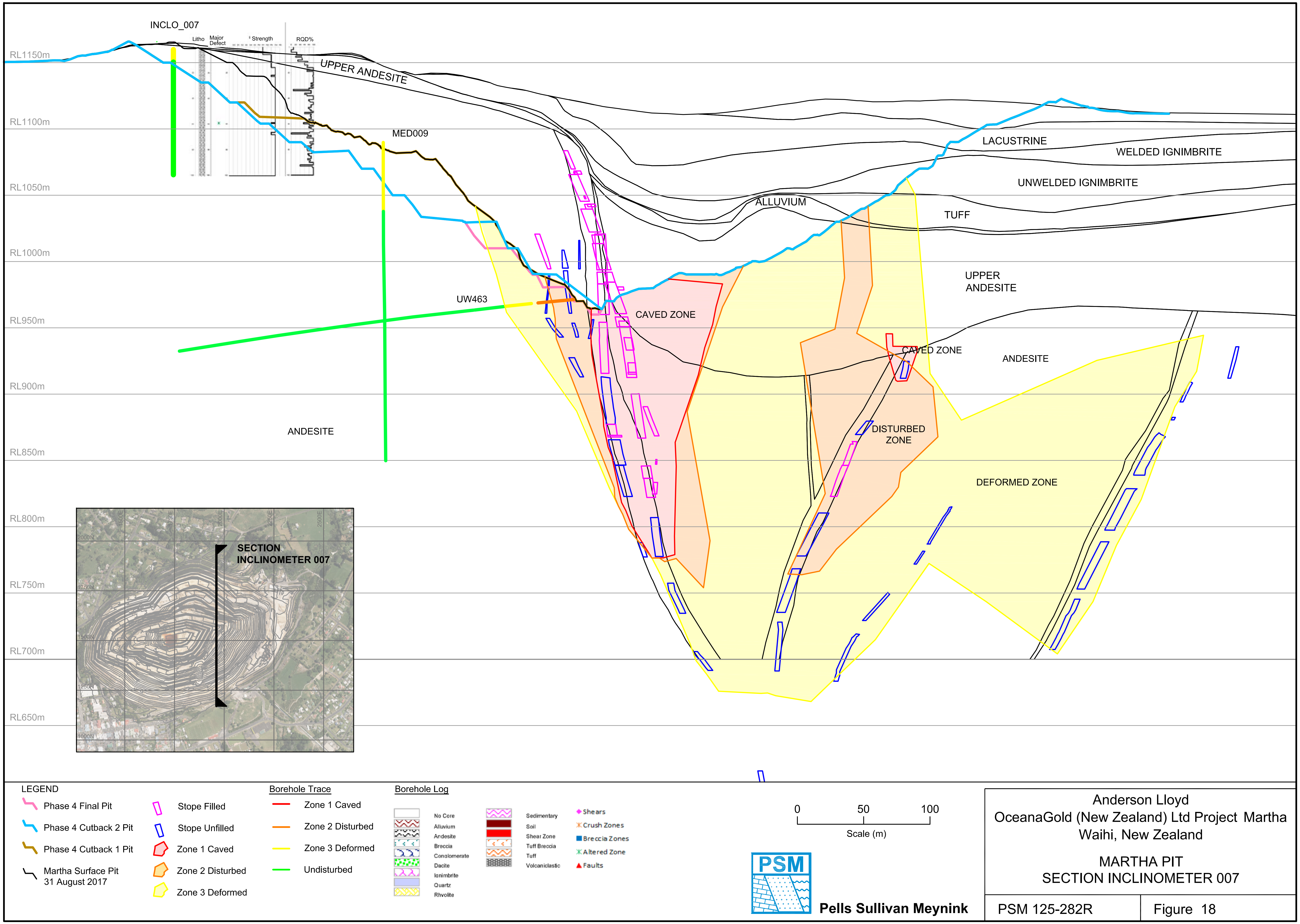
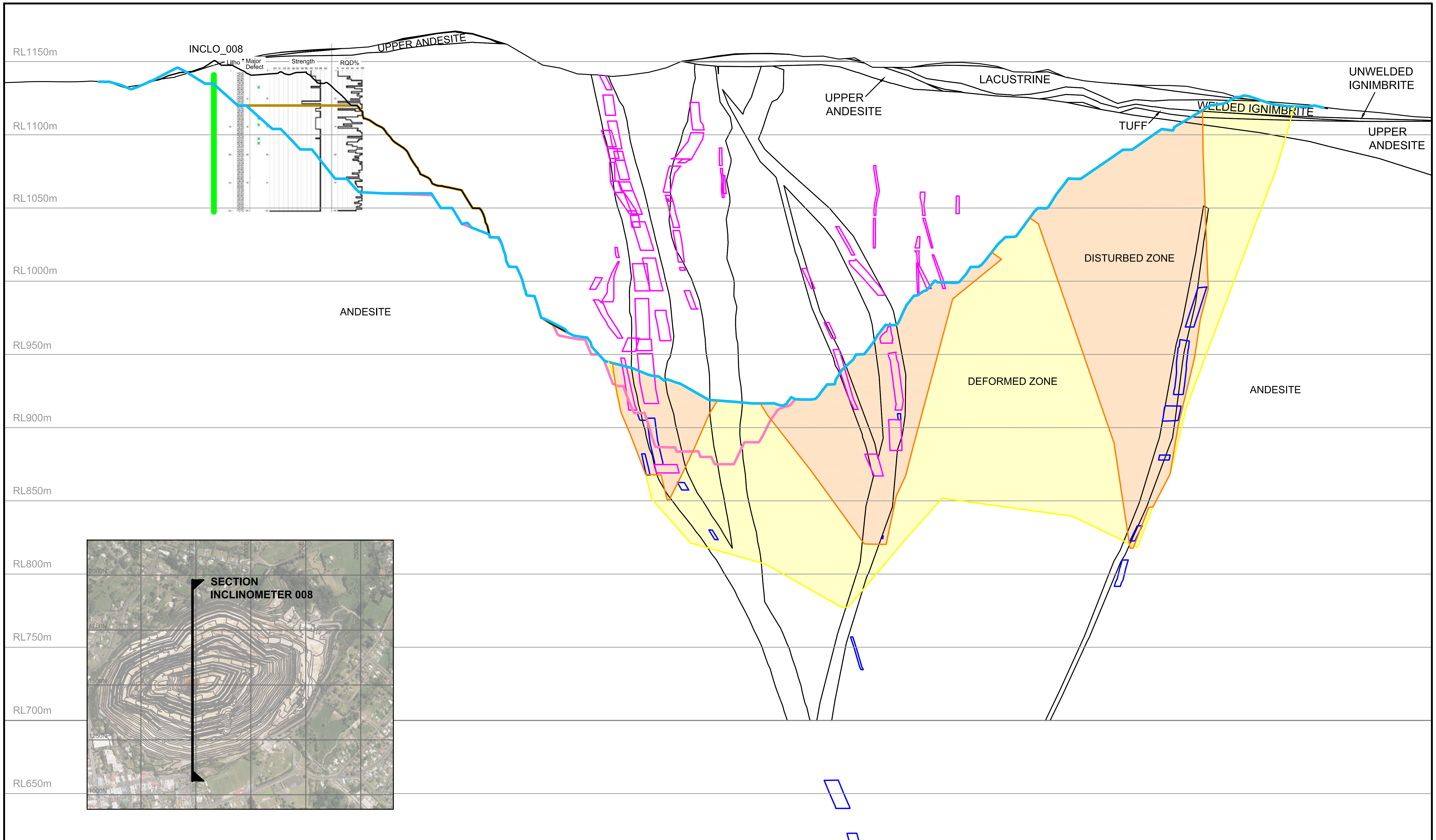
MARTHA PHASE 4 PIT
SECTION GT023

PSM 125-282R | Figure 17



INCLO_007
Litho
Major Defect
Strength
RQD%
RL1150m
RL1100m
RL1050m
RL1000m
RL950m
RL900m
RL850m
RL800m
RL750m
RL700m
RL650m
UPPER ANDESITE
MED009
UW463
LACUSTRINE
WELDED IGNIMBRITE
UNWELDED IGNIMBRITE
ALLUVIUM
TUFF
UPPER ANDESITE
CAVED ZONE
CAVED ZONE
ANDESITE
ANDESITE
DISTURBED ZONE
DEFORMED ZONE
SECTION INCLINOMETER 007
LEGEND
Phase 4 Final Pit
Phase 4 Cutback 2 Pit
Phase 4 Cutback 1 Pit
Martha Surface Pit 31 August 2017
Stope Filled
Stope Unfilled
Zone 1 Caved
Zone 2 Disturbed
Zone 3 Deformed
Borehole Trace
Zone 1 Caved
Zone 2 Disturbed
Zone 3 Deformed
Undisturbed
Borehole Log
No Core
Alluvium
Andesite
Breccia
Conglomerate
Dacite
Ignimbrite
Quartz
Rhyolite
Sedimentary
Soil
Shear Zone
Tuff Breccia
Tuff
Volcaniclastic
Shears
Crush Zones
Breccia Zones
Altered Zone
Faults
0
50
100
Scale (m)
PSM
Pells Sullivan Meynink
Anderson Lloyd
OceanaGold (New Zealand) Ltd Project Martha
Waihi, New Zealand
MARTHA PIT
SECTION INCLINOMETER 007
PSM 125-282R
Figure 18



LEGEND

Phase 4 Final Pit	Stope Filled	**Borehole Trace**	**Borehole Log**
Phase 4 Cutback 2 Pit	Stope Unfilled	Zone 1 Caved	No Core, Alluvium, Andesite, Breccia, Conglomerate, Dacite, Ignimbrite, Quartz, Rhyolite
Phase 4 Cutback 1 Pit	Zone 1 Caved	Zone 2 Disturbed	Sedimentary, Soil, Shear Zone, Tuff Breccia, Tuff, Volcaniclastic
Martha Surface Pit 31 August 2017	Zone 2 Disturbed	Zone 3 Deformed	Shears, Crush Zones, Breccia Zones, Altered Zone, Faults
	Zone 3 Deformed	Undisturbed	

0 50 100
Scale (m)

PSM
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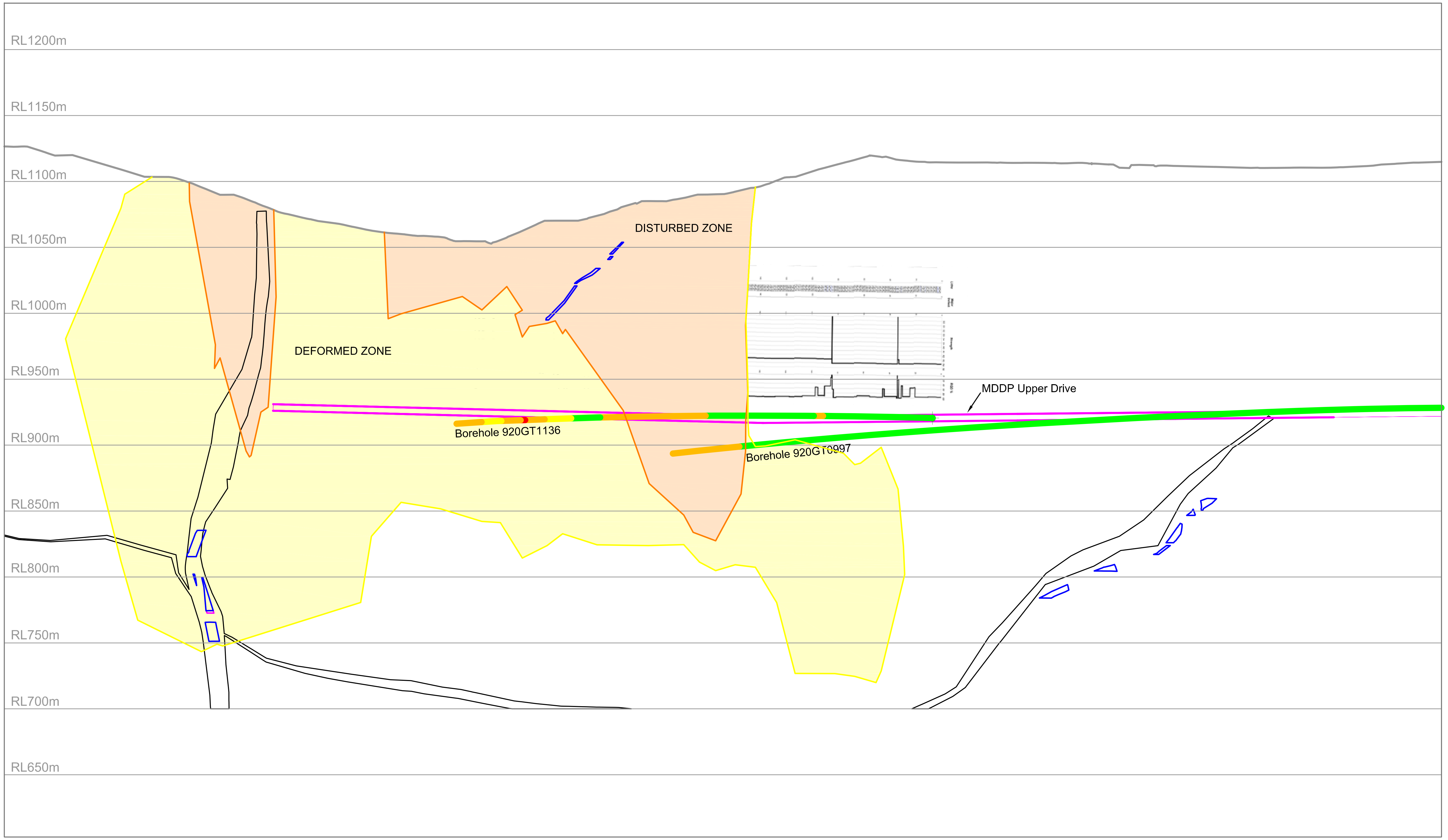
Waihi, New Zealand

MARTHA PIT
SECTION INCLINOMETER 008

PSM 125-282R | Figure 19



LEGEND

- May 2017 Pit Shell
- MDDP Drives
- Lodes
- Stopes Filled
- Stopes Unfilled
- Zone 1 Caved
- Zone 2 Disturbed
- Zone 3 Deformed

Borehole Trace

- Zone 1 Caved
- Zone 2 Disturbed
- Zone 3 Deformed
- Undisturbed

Borehole Log

- No Core
- Alluvium
- Andesite
- Breccia
- Conglomerate
- Dacite
- Ignimbrite
- Quartz
- Rhyolite
- Sedimentary
- Soil
- Shear Zone
- Tuff Breccia
- Tuff
- Volcaniclastic
- Shears
- Crush Zones
- Breccia Zones
- Altered Zone
- Faults

0 50 100
Scale (m)

Pells Sullivan Meynink

Anderson Lloyd
OceanaGold (New Zealand) Ltd Project Martha
Waihi, New Zealand

MDDP
LONG SECTION

PSM125-282R	Figure 20

Legend

Well Locations

- Data
- No Data

Scale

0 50 100 200 300 400 Meters

Grid: Magnetic North

PSM

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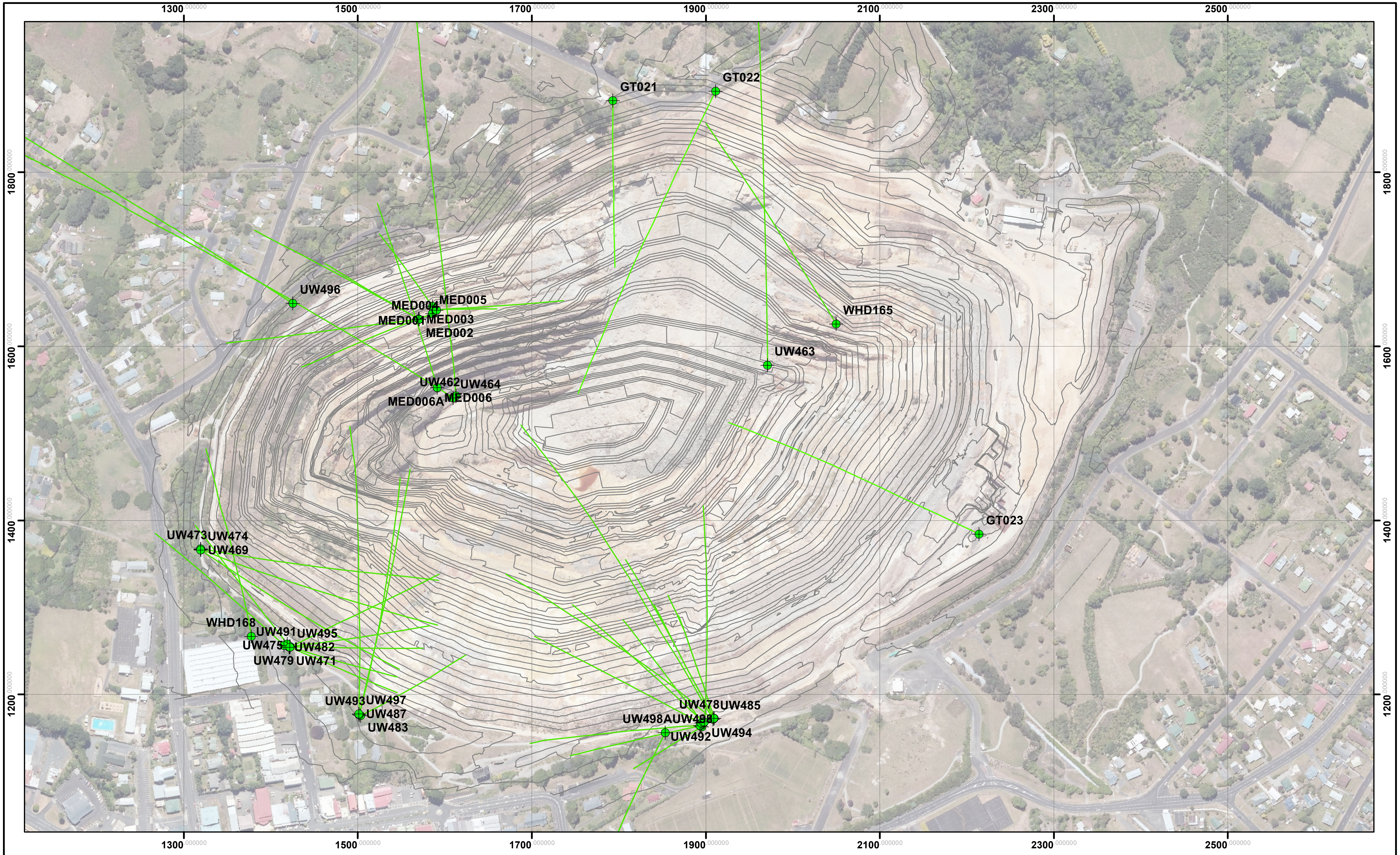
Anderson Lloyd OceanaGold (New Zealand) Ltd Project Martha Waihi, New Zealand MARTHA PIT PHASE 4 PIEZOMETER LOCATIONS	
PSM125-282R	Figure 21



Legend

- Oriented Core Boreholes
- Martha Phase 4 Pit 5m Contours

Scale

0 37.5 75 150 225 300 Meters

PSM

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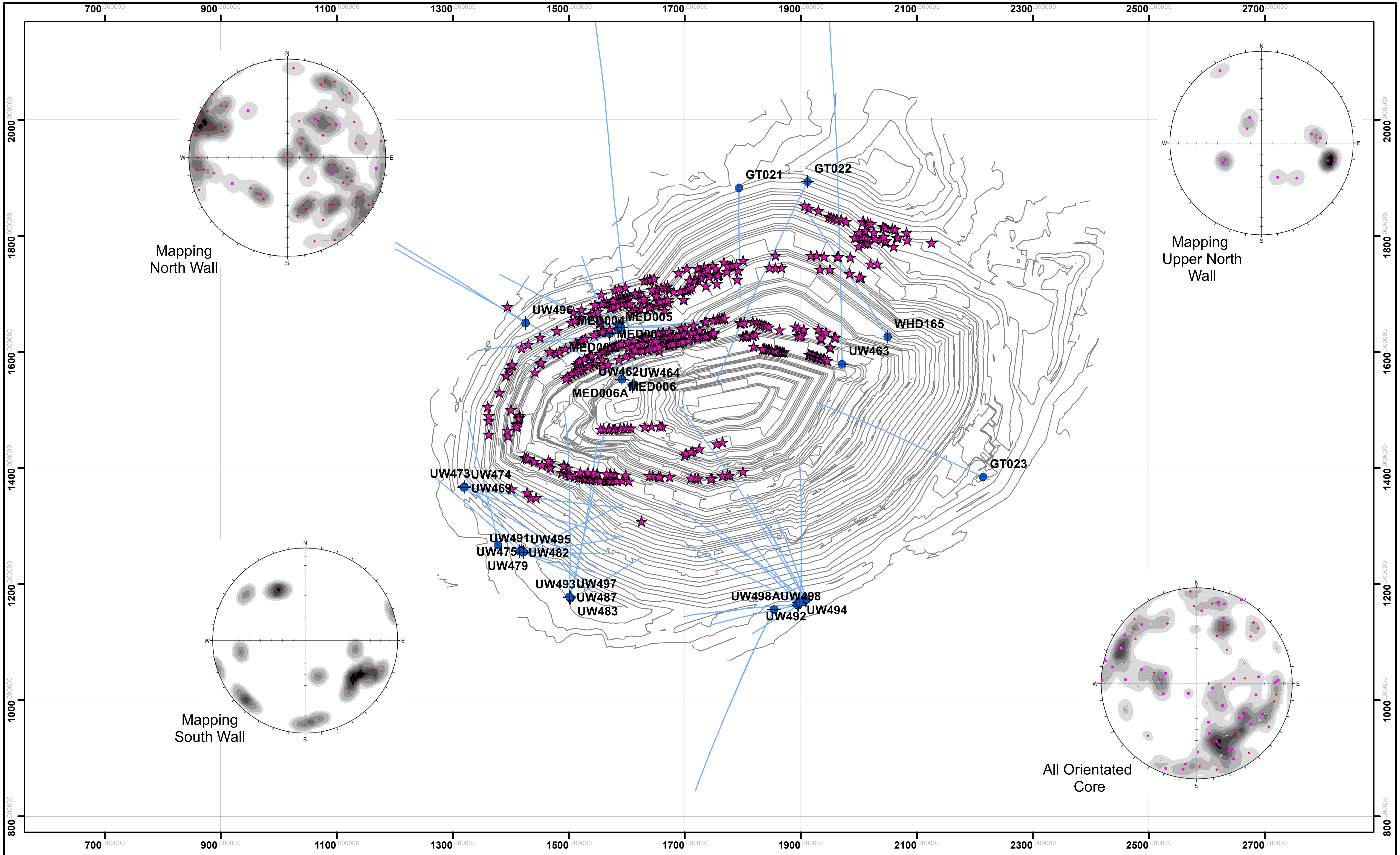
MARTHA PHASE 4 PIT
ORIENTED CORE BOREHOLES

PSM125-282R | Figure 22



Legend

- Martha Mapping
- Oriented Core Boreholes
- Oriented Core Borehole Strings
- Martha Phase 4 Pit 5m Contours

Scale

0 50 100 200 300 400 Meters

PSM

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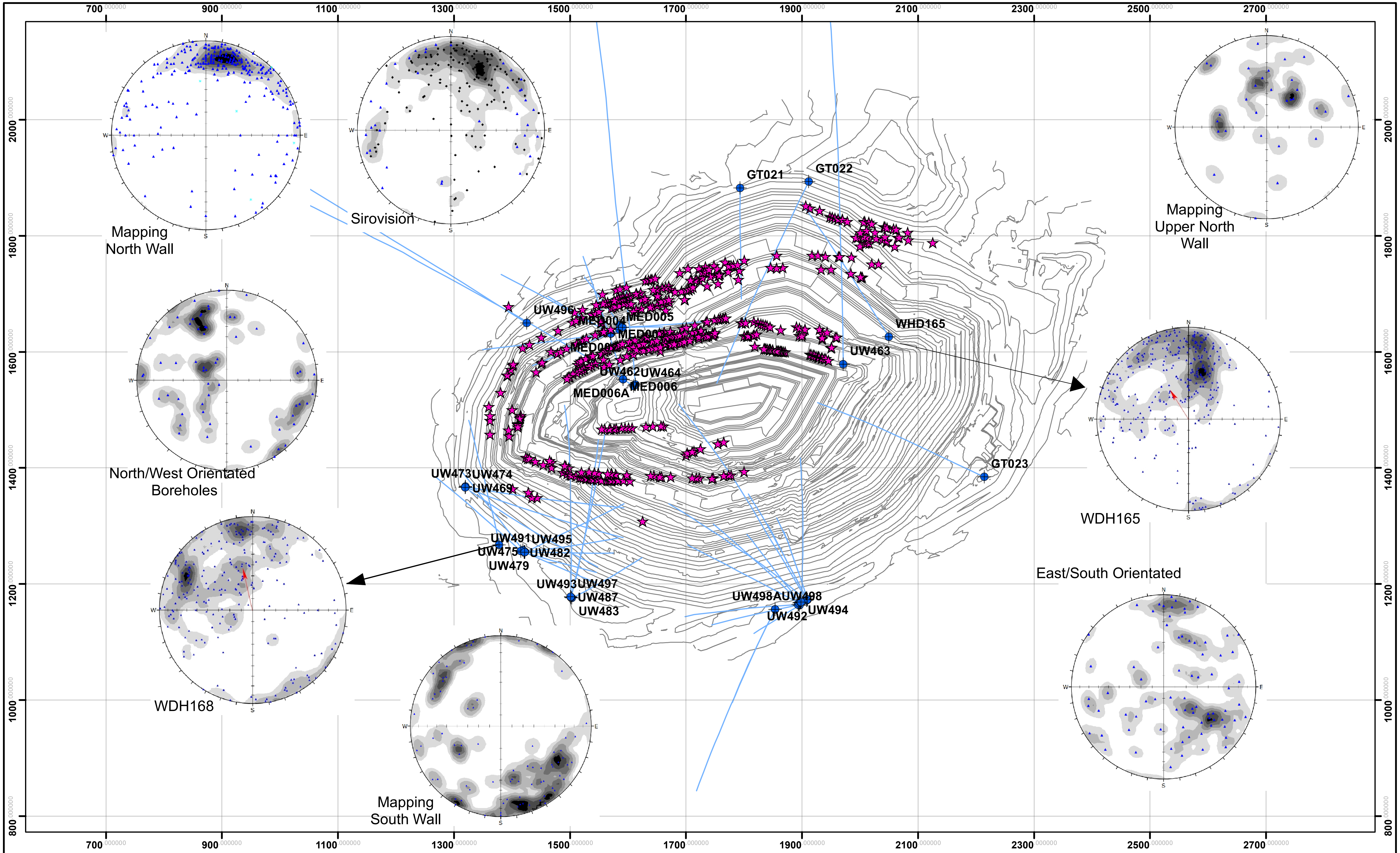
Waihi, New Zealand

MARTHA PHASE 4 PIT
STRUCTURAL MODEL - FAULTS/SHEARS

PSM125-282R	Figure 23



Legend

- Martha Mapping
- Oriented Core Boreholes
- Oriented Core Borehole Strings
- Martha Phase 4 Pit 5m Contours

Scale

0 50 100 200 300 400 Meters

PSM

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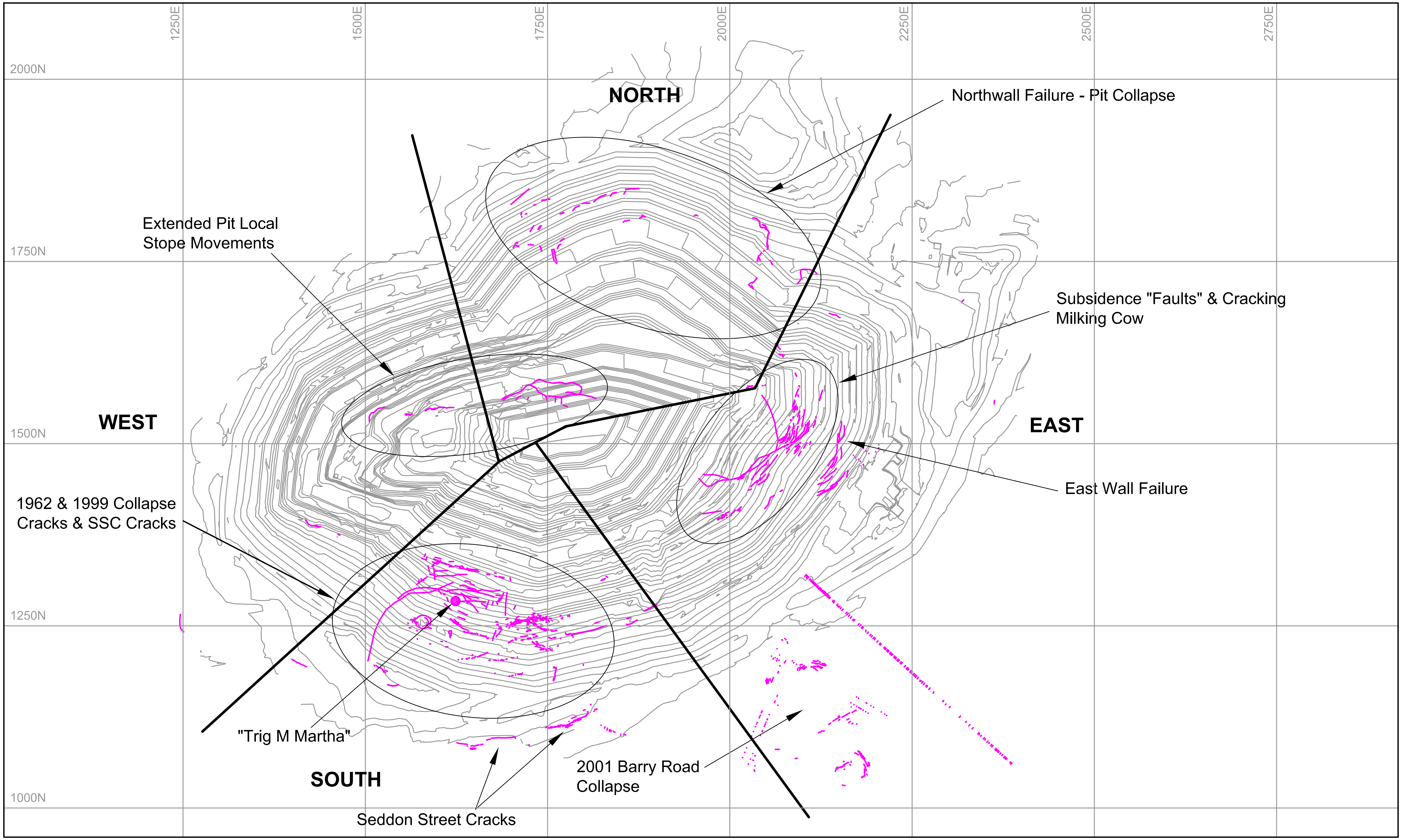
MARTHA PHASE 4 PIT
STRUCTURAL MODEL - JOINTS

PSM125-282R	Figure 24



LEGEND

Phase 4 Final Pit - 5m Contours

Cracks

Geotechnical Domains

0 50 100 150 200

Scale (m)

PSM

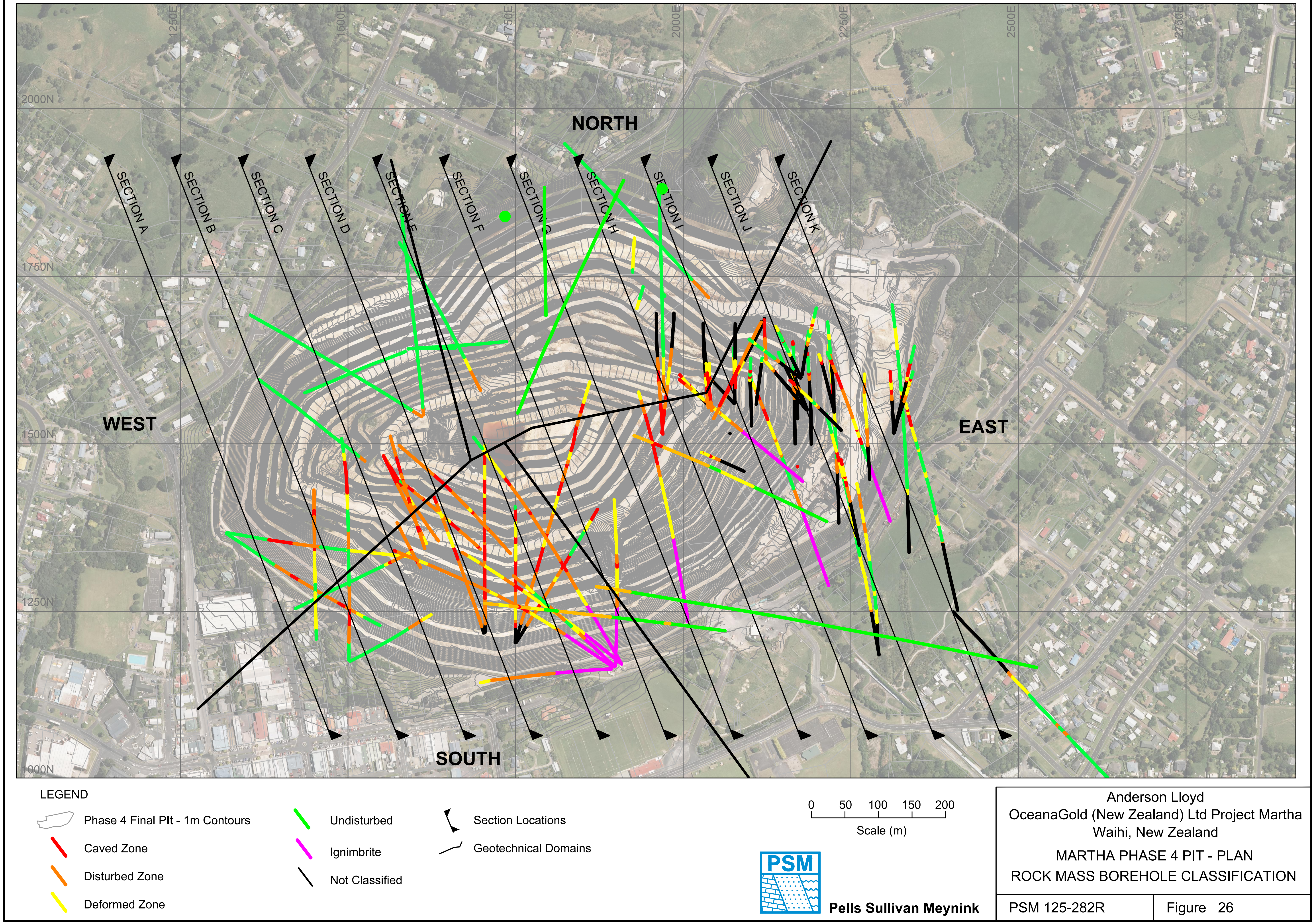
Pells Sullivan Meynink

Anderson Lloyd
OceanaGold (New Zealand) Ltd Project Martha
Waihi, New Zealand

MARTHA PHASE 4 FINAL PIT
ALL CRACKS MAPPED 2001 TO PRESENT

PSM 125-282R

Figure 25



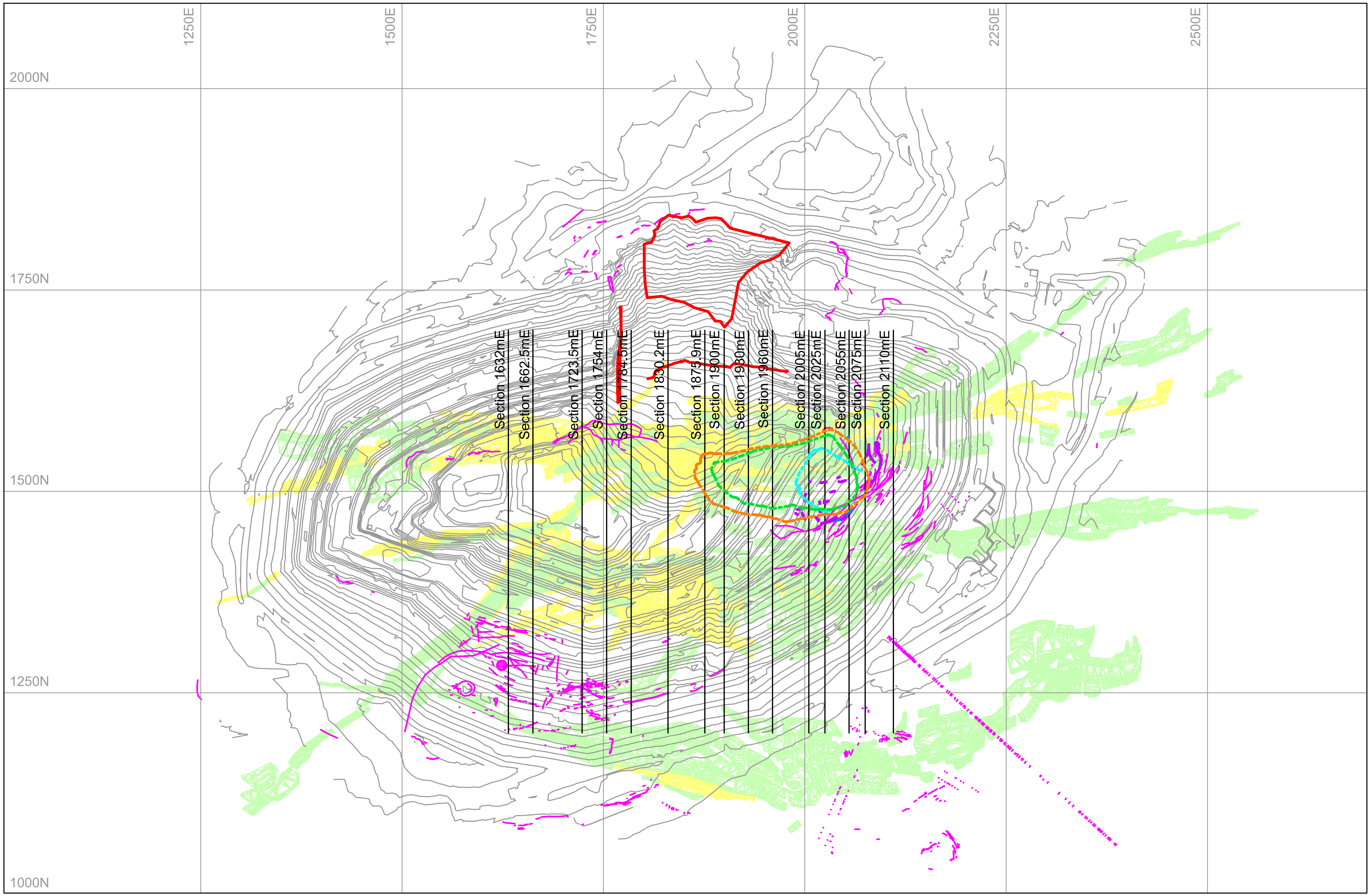
PSM

Pells Sullivan Meynink

Anderson Lloyd
OceanaGold (New Zealand) Ltd Project Martha
Waihi, New Zealand

MARTHA PHASE 4 PIT - PLAN
ROCK MASS BOREHOLE CLASSIFICATION

PSM 125-282R	Figure 26



LEGEND

- 31 August 2017 Pit Contours - 5m
- Martha Cave Model (Ezra,2013)
- Martha Cave Model Original (PSM125-226L)
- Martha Cave Model (Coyle,2013)
- Stopes - Filled
- Stopes - Unfilled
- Mapped Faults
- Cracks
- Milking Cow Cracks
- Milking Cow Caved Zone Survey
- Caving Section Lines

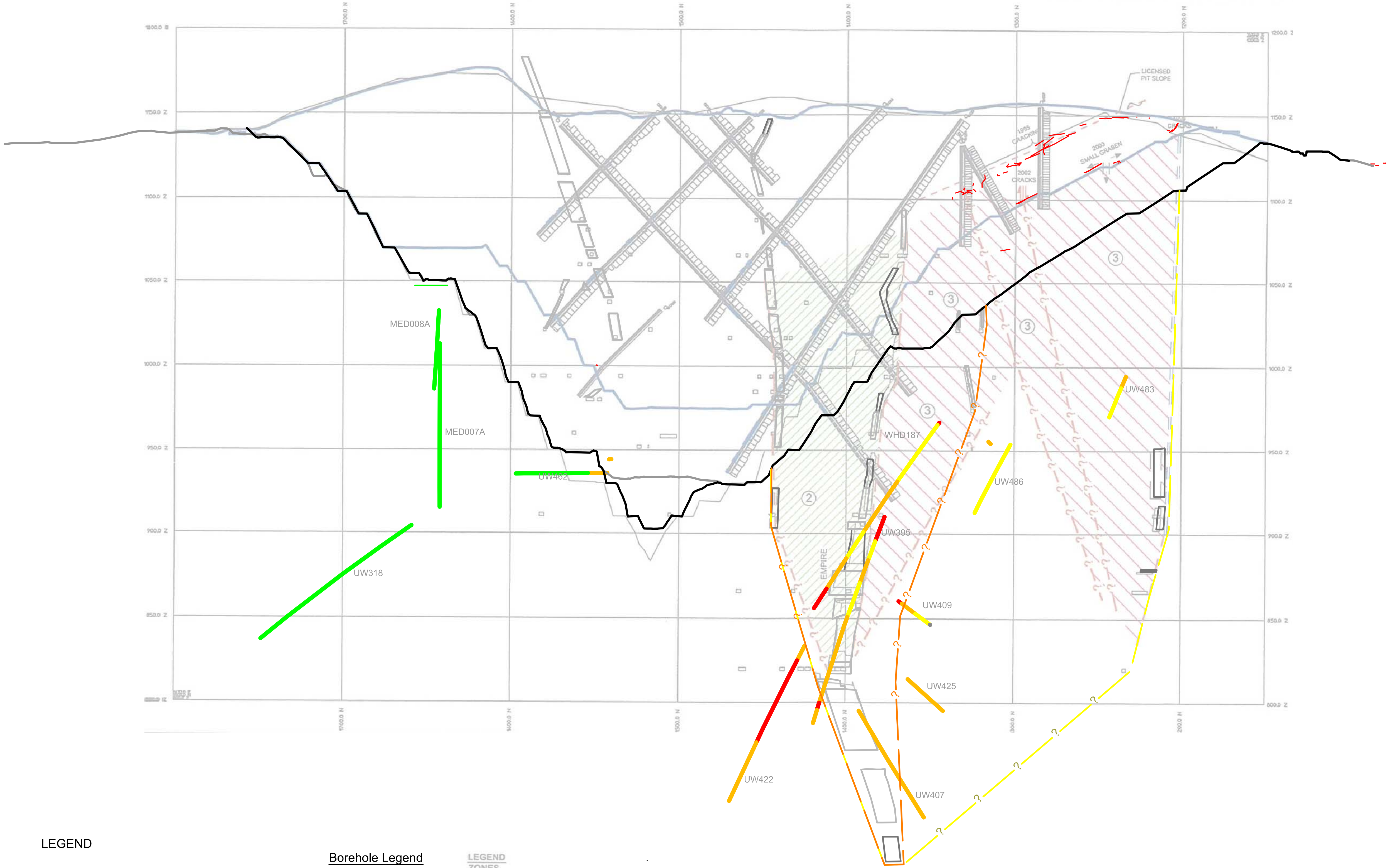
0 50 100 150 200
Scale (m)

PSM
Pells Sullivan Meynink

Anderson Lloyd
OceanaGold (New Zealand) Ltd Project Martha
Waihi, New Zealand

CAVING MODEL UPDATE
AVAILABLE DATA

PSM 125-282R	Figure 27



LEGEND

- 31 August 2017 Pit
- March 2015 Pit
- Stopes - Filled
- Stopes - Unfilled
- Caved Zone
- Disturbed Zone
- Deformed Zone
- Cracks
- Milking Cow (Ezra,2013)
- Milking Cow Survey Points
- Mapped Faults

Borehole Legend

- Ignimbrite
- Caved
- Disturbed
- Deformed
- Intact
- Not Logged

Note: Clipping of ±25m for boreholes & cracks

0 50 100
Scale (m)

PSM
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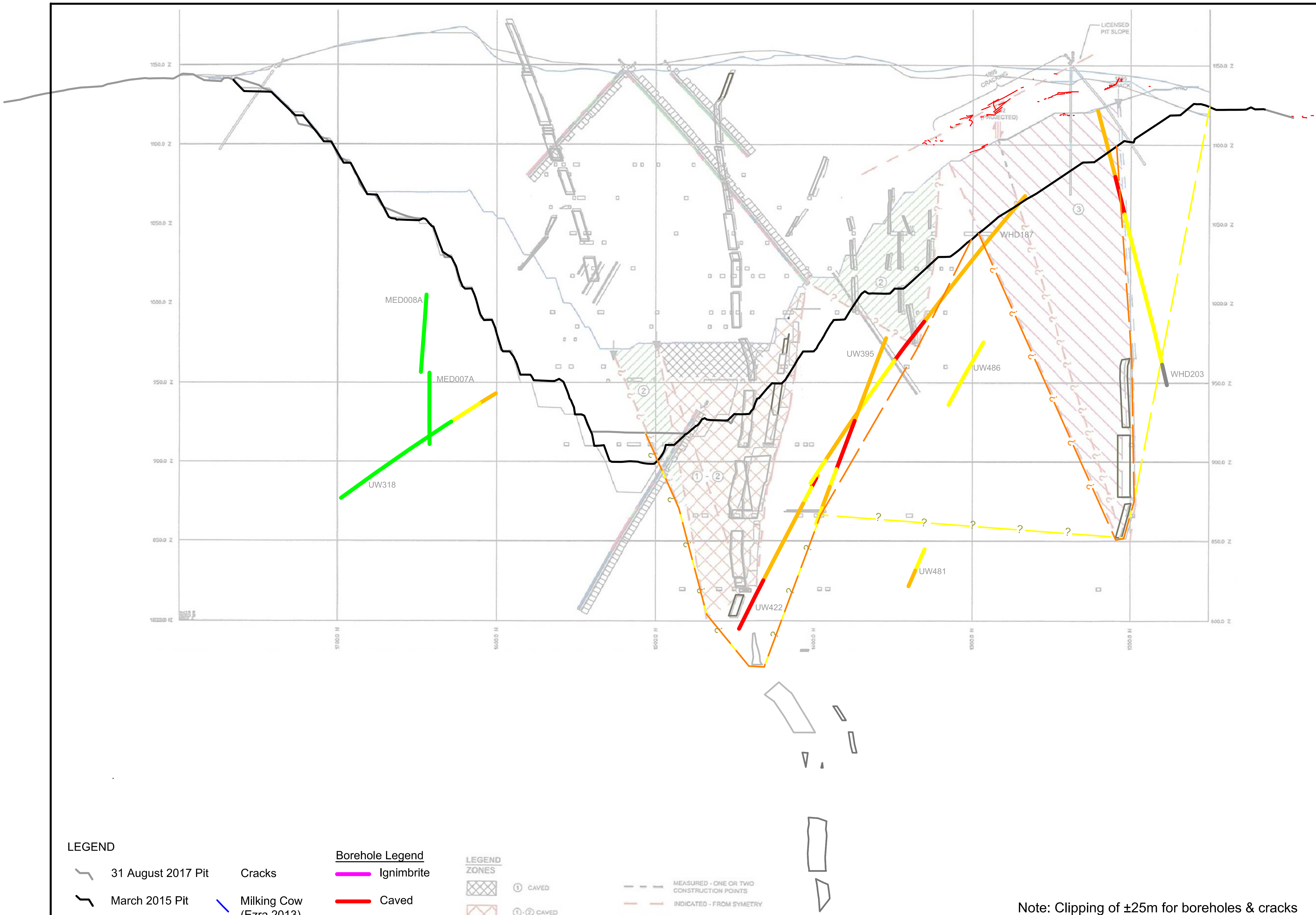
Anderson Lloyd
OceanaGold (New Zealand) Ltd Project Martha
Waihi, New Zealand

CAVE MODEL UPDATE
SECTION 1632mE

PSM125-282R	Figure 28



LEGEND

31 August 2017 Pit	Cracks	**Borehole Legend**
March 2015 Pit	Milking Cow (Ezra,2013)	Ignimbrite
Stopes - Filled	Milking Cow Survey Points	Caved
Stopes - Unfilled	Mapped Faults	Disturbed
Caved Zone		Deformed
Disturbed Zone		Intact
Deformed Zone		Not Logged

LEGEND
ZONES

① CAVED	MEASURED - ONE OR TWO CONSTRUCTION POINTS
①-② CAVED	INDICATED - FROM SYMETRY
② DISTURBED	INFERRED
②-③ DISTURBED	ALTERNATE ZONE BOUNDARIES
③ DEFORMED	CRACK
SLOPE FAILURE	CRACK - WITH SENSE OF MOVEMENT SHOWN
DEFORMATION IN SHAFT	FAULT
	SHEAR WITH DISPLACEMENT INDICATED

Note: Clipping of ±25m for boreholes & cracks

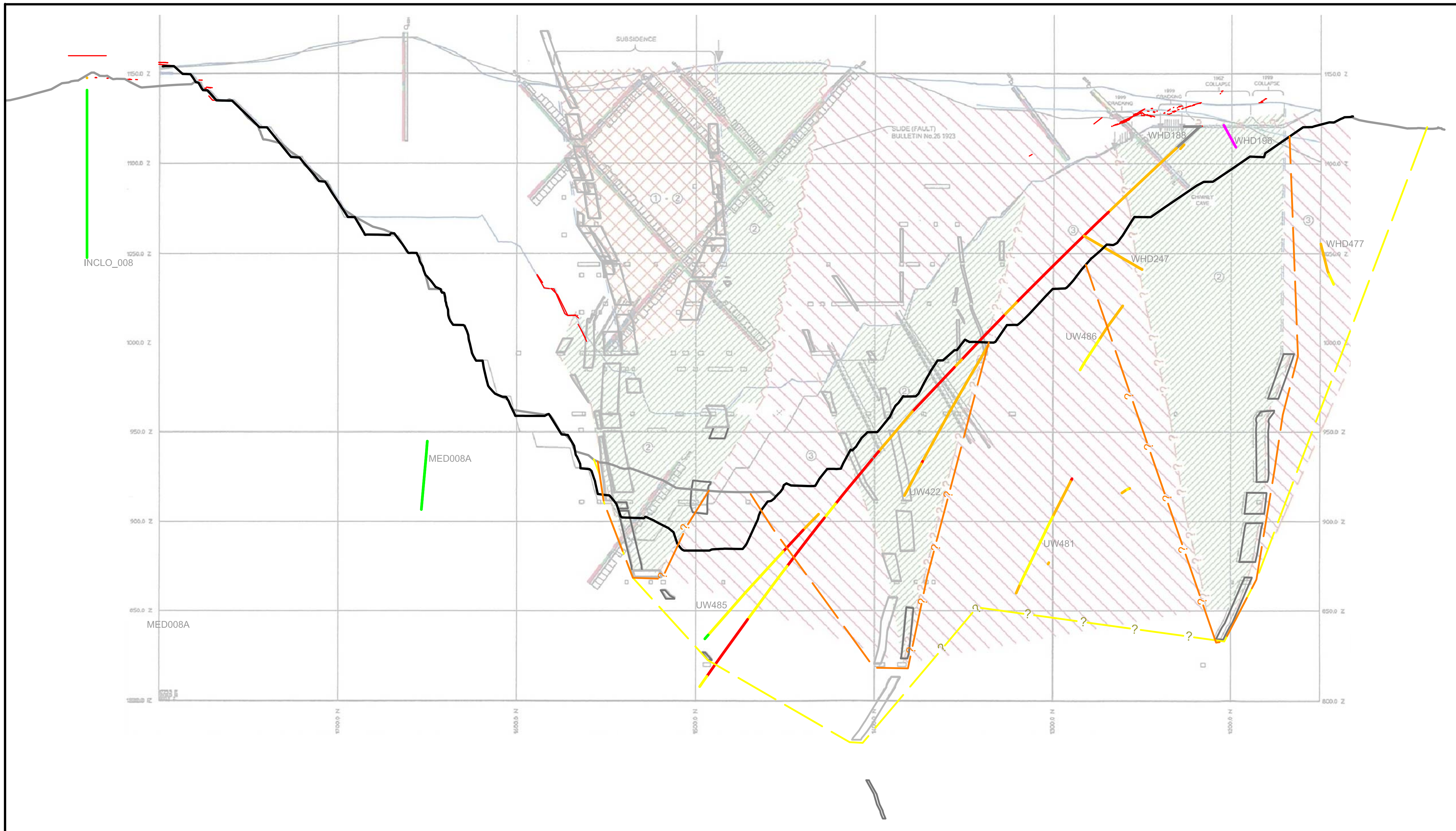
0 50 100
Scale (m)

PSM
Pells Sullivan Meynink

Anderson Lloyd
OceanaGold (New Zealand) Ltd Project Martha
Waihi, New Zealand

CAVE MODEL UPDATE
SECTION 1662.5mE

PSM125-282R | Figure 29



LEGEND

- 31 August 2017 Pit
- March 2015 Pit
- Stopes - Filled
- Stopes - Unfilled
- Caved Zone
- Disturbed Zone
- Deformed Zone
- Cracks
- Milking Cow (Ezra,2013)
- Milking Cow Survey Points
- Mapped Faults

Borehole Legend

- Ignimbrite
- Caved
- Disturbed
- Deformed
- Intact
- Not Logged

Note: Clipping of ±25m for boreholes & cracks

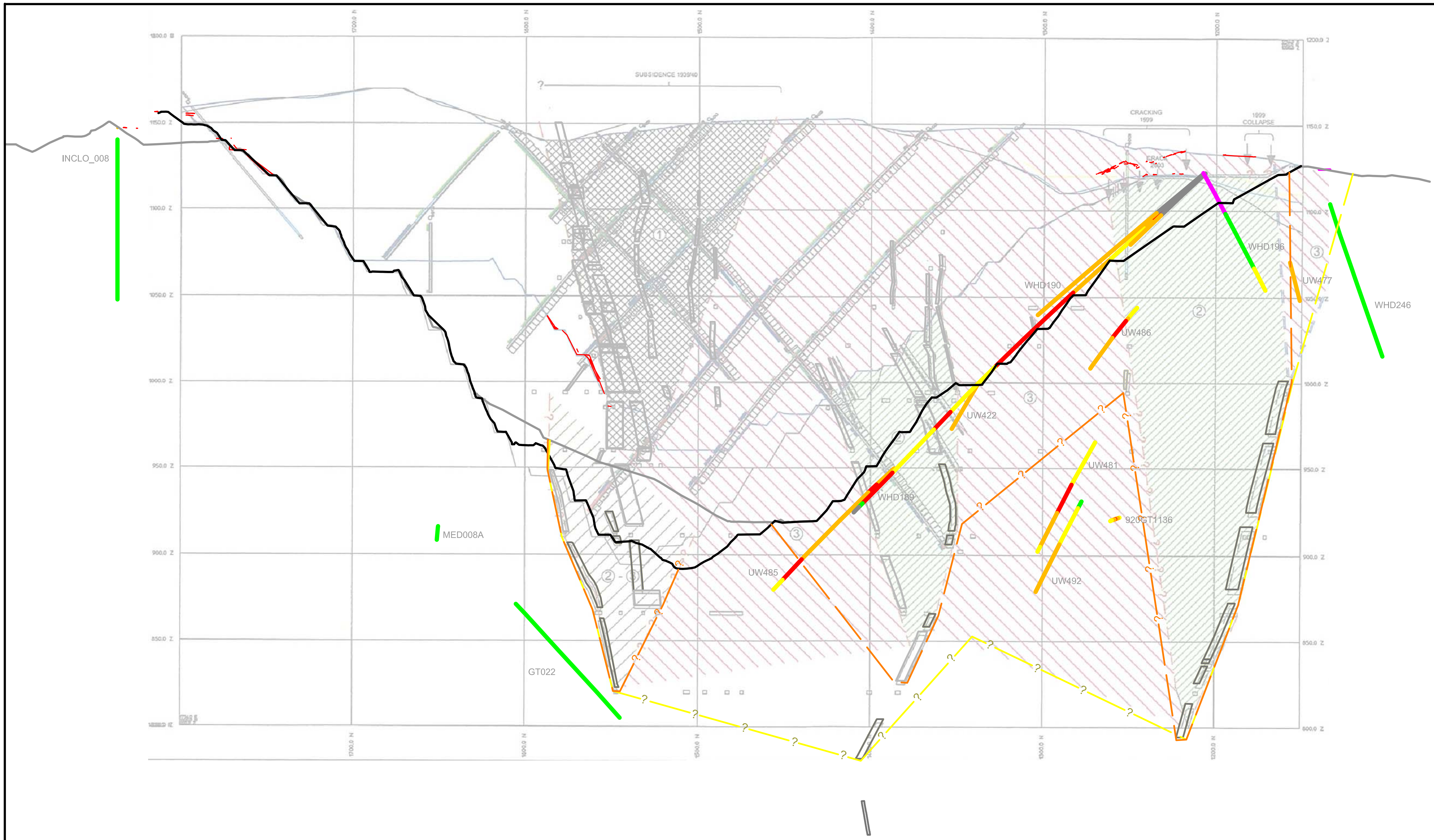
0 50 100
Scale (m)

PSM
Pells Sullivan Meynink

Anderson Lloyd
OceanaGold (New Zealand) Ltd Project Martha
Waihi, New Zealand

CAVE MODEL UPDATE
SECTION 1723.5mE

PSM125-282R	Figure 30



LEGEND

- 31 August 2017 Pit
- March 2015 Pit
- Stopes - Filled
- Stopes - Unfilled
- Caved Zone
- Disturbed Zone
- Deformed Zone
- Cracks
- Milking Cow (Ezra,2013)
- Milking Cow Survey Points
- Mapped Faults

Borehole Legend

- Ignimbrite
- Caved
- Disturbed
- Deformed
- Intact
- Not Logged

LEGEND ZONES

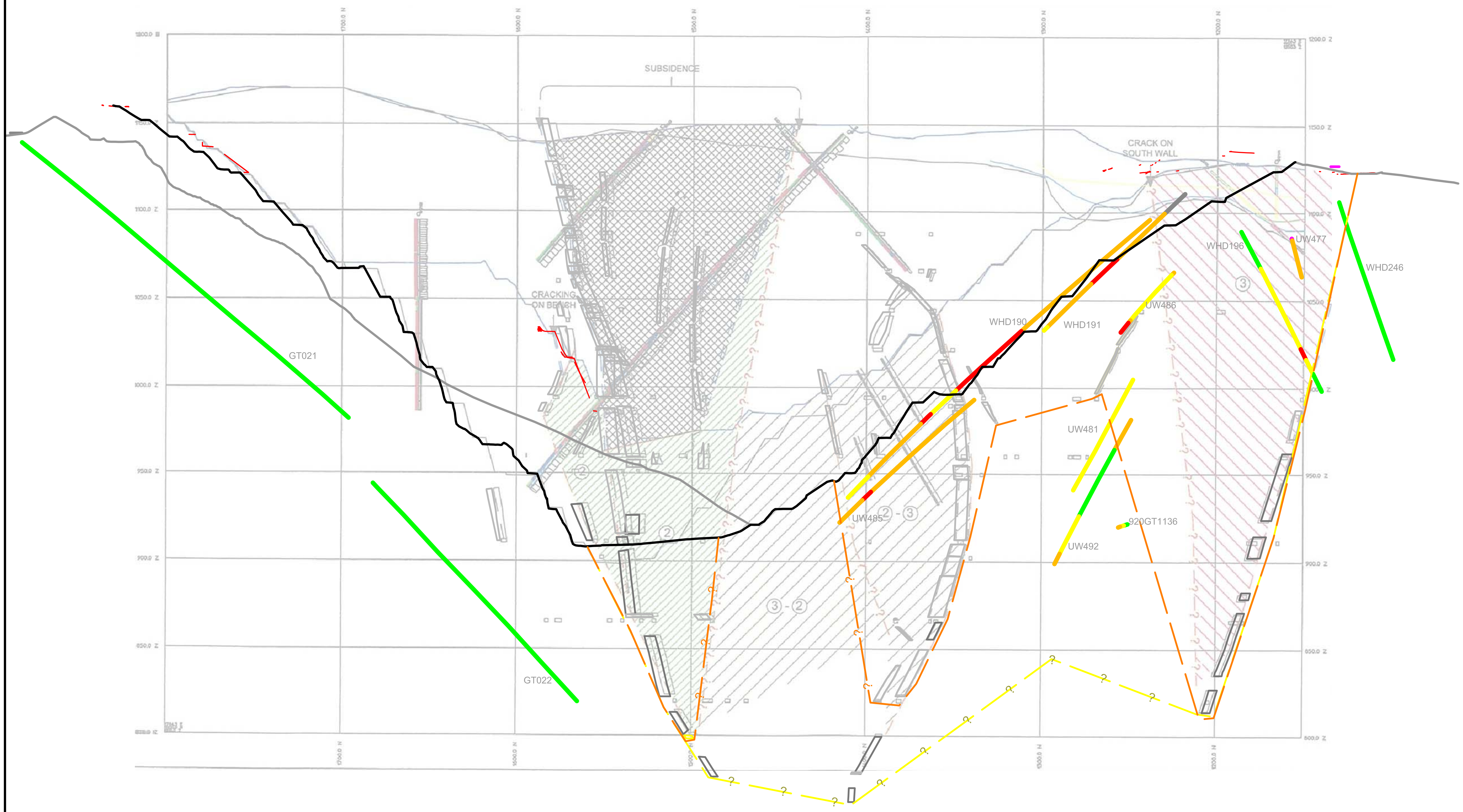
- ① CAVED
- ①-② CAVED
- ② DISTURBED
- ②-③ DISTURBED
- ③ DEFORMED
- SLOPE FAILURE
- DEFORMATION IN SHAFT
- MEASURED - ONE OR TWO CONSTRUCTION POINTS
- INDICATED - FROM SYMETRY
- INFERRED
- ALTERNATE ZONE BOUNDARIES
- CRACK
- CRACK - WITH SENSE OF MOVEMENT SHOWN
- FAULT
- SHEAR WITH DISPLACEMENT INDICATED

Note: Clipping of ±25m for boreholes & cracks

0 50 100
Scale (m)

PSM
Pells Sullivan Meynink

Anderson Lloyd OceanaGold (New Zealand) Ltd Project Martha Waihi, New Zealand CAVE MODEL UPDATE SECTION 1754mE	
PSM125-282R	Figure 31



LEGEND

- 31 August 2017 Pit
- March 2015 Pit
- Stopes - Filled
- Stopes - Unfilled
- Caved Zone
- Disturbed Zone
- Deformed Zone
- Cracks
- Milking Cow (Ezra,2013)
- Milking Cow Survey Points
- Mapped Faults

Borehole Legend

- Ignimbrite
- Caved
- Disturbed
- Deformed
- Intact
- Not Logged

LEGEND ZONES

- ① CAVED
- ①-② CAVED
- ② DISTURBED
- ②-③ DISTURBED
- ③ DEFORMED
- SLOPE FAILURE
- DEFORMATION IN SHAFT
- MEASURED - ONE OR TWO CONSTRUCTION POINTS
- INDICATED - FROM SYMETRY
- INFERRED
- ALTERNATE ZONE BOUNDARIES
- CRACK
- CRACK - WITH SENSE OF MOVEMENT SHOWN
- FAULT
- SHEAR WITH DISPLACEMENT INDICATED

Note: Clipping of ±25m for boreholes & cracks

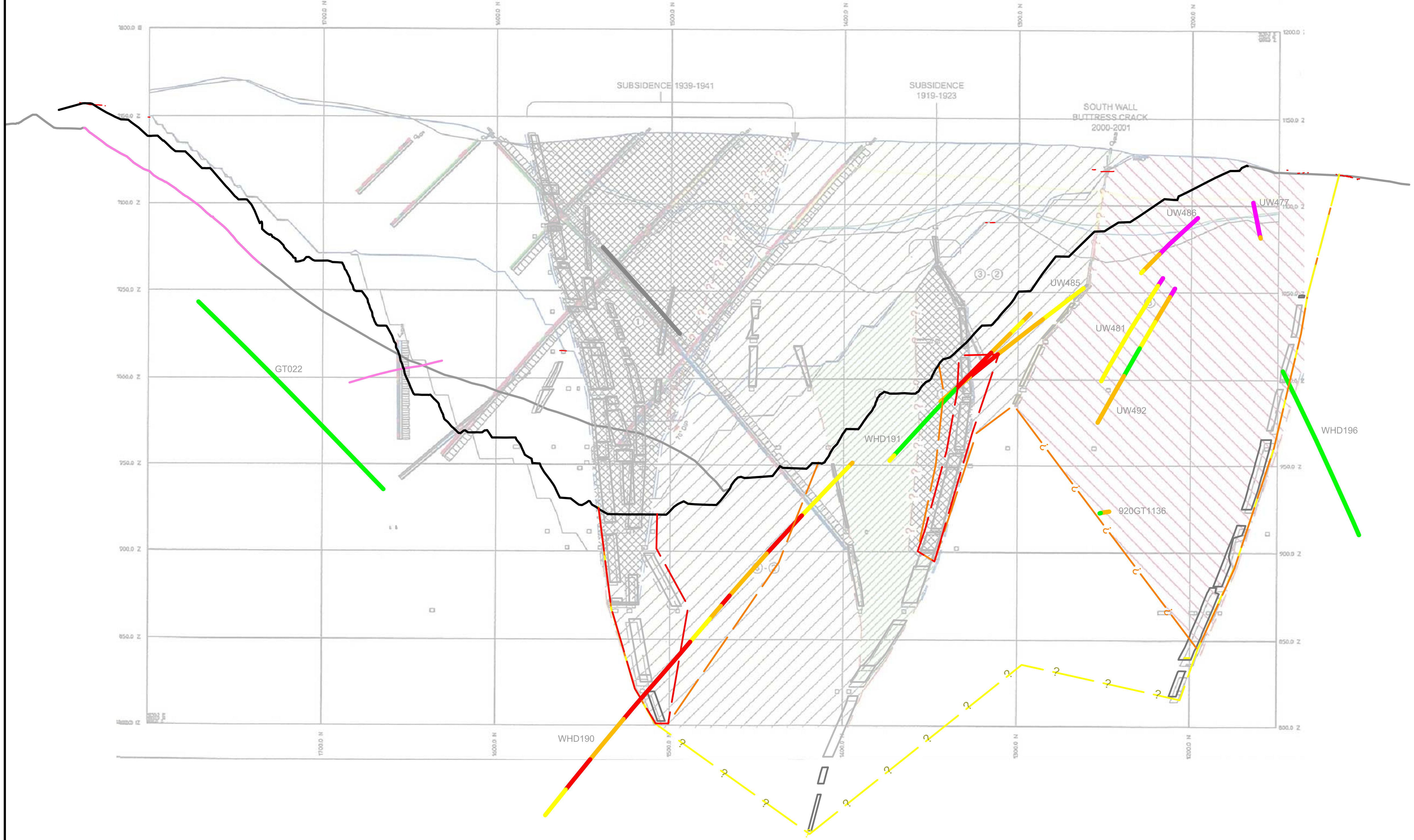
0 50 100
Scale (m)

PSM
Pells Sullivan Meynink

Anderson Lloyd
OceanaGold (New Zealand) Ltd Project Martha
Waihi, New Zealand

CAVE MODEL UPDATE
SECTION 1784.5mE

PSM125-282R	Figure 32



LEGEND

31 August 2017 Pit	Cracks
March 2015 Pit	Milking Cow (Ezra,2013)
Stopes - Filled	Milking Cow Survey Points
Stopes - Unfilled	Mapped Faults
Caved Zone	
Disturbed Zone	
Deformed Zone	

Borehole Legend

- Ignimbrite
- Caved
- Disturbed
- Deformed
- Intact
- Not Logged

LEGEND
ZONES

- ① CAVED
- ①-② CAVED
- ② DISTURBED
- ②-③ DISTURBED
- ③ DEFORMED
- SLOPE FAILURE
- DEFORMATION IN SHAFT
- MEASURED - ONE OR TWO CONSTRUCTION POINTS
- INDICATED - FROM SYMETRY
- INFERRED
- ALTERNATE ZONE BOUNDARIES
- CRACK
- CRACK - WITH SENSE OF MOVEMENT SHOWN
- FAULT
- SHEAR WITH DISPLACEMENT INDICATED

Note: Clipping of ±25m for boreholes & cracks

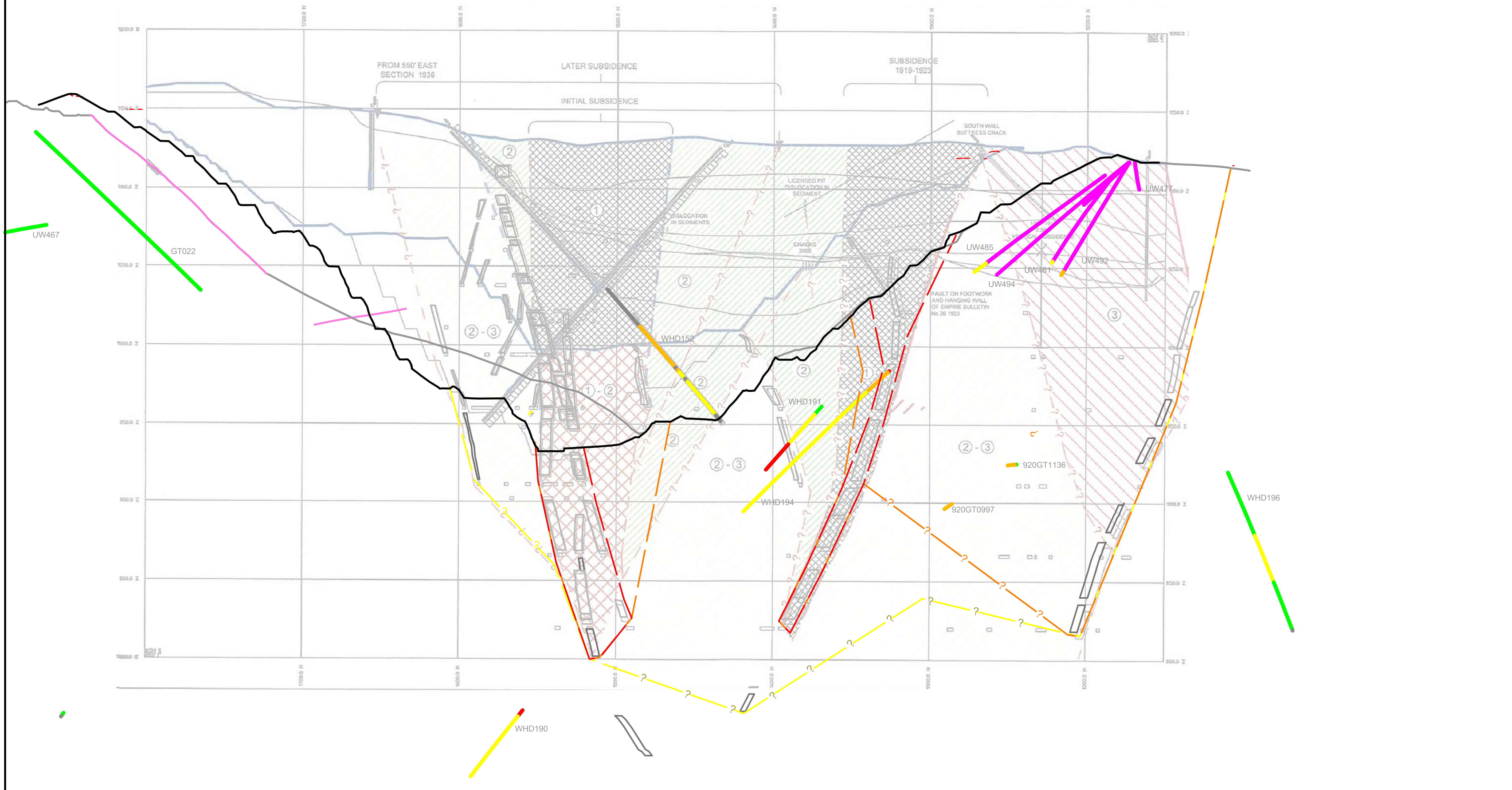
0 50 100
Scale (m)

PSM
Pells Sullivan Meynink

Anderson Lloyd
OceanaGold (New Zealand) Ltd Project Martha
Waihi, New Zealand

CAVE MODEL UPDATE
SECTION 1830.2mE

PSM125-282R	Figure 33



LEGEND

- 31 August 2017 Pit
- March 2015 Pit
- Stopes - Filled
- Stopes - Unfilled
- Caved Zone
- Disturbed Zone
- Deformed Zone
- Cracks
- Milking Cow (Ezra,2013)
- Milking Cow Survey Points
- Mapped Faults

Borehole Legend

- Ignimbrite
- Caved
- Disturbed
- Deformed
- Intact
- Not Logged

LEGEND ZONES

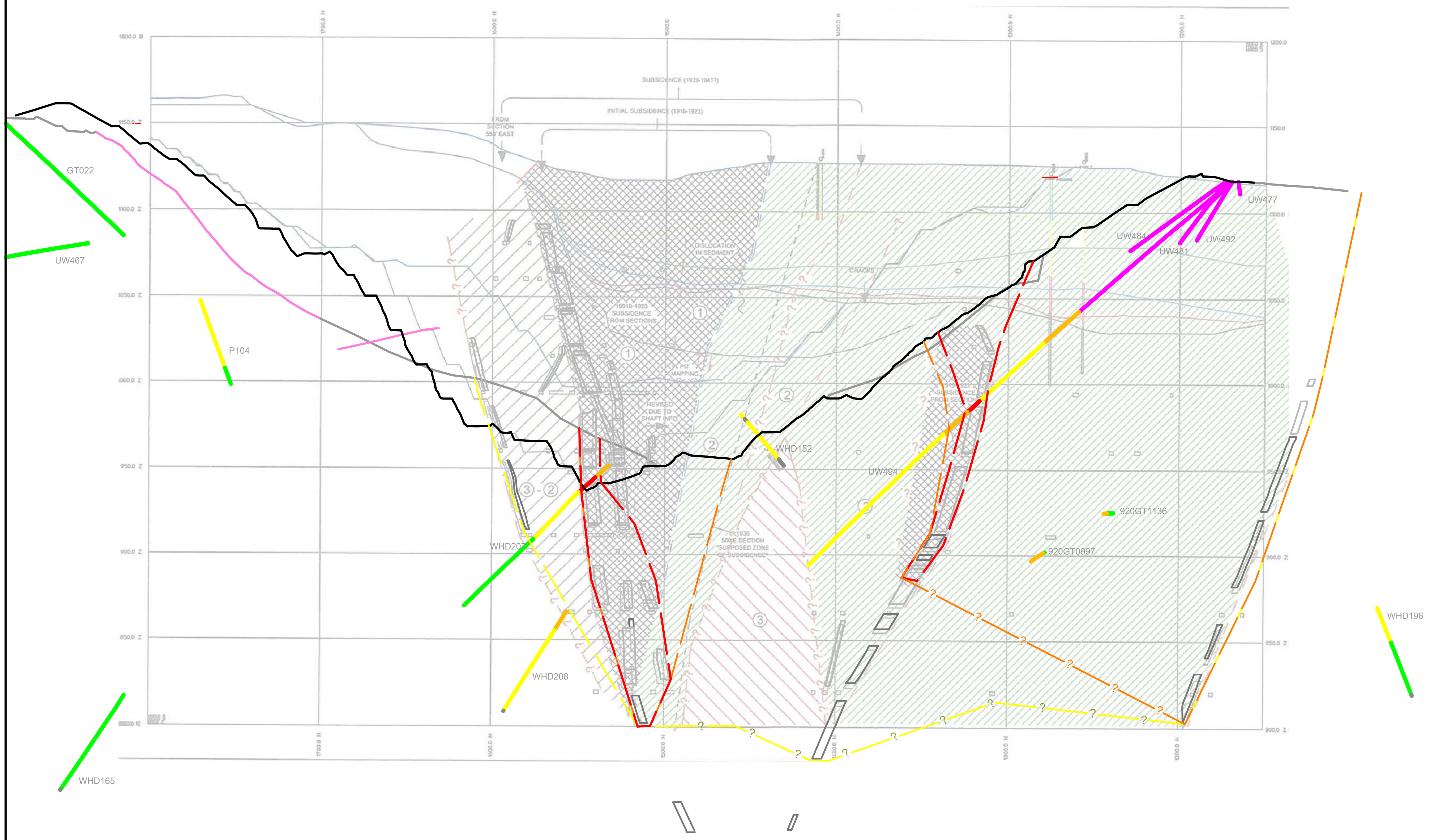
- ① CAVED
- ①-② CAVED
- ② DISTURBED
- ②-③ DISTURBED
- ③ DEFORMED
- SLOPE FAILURE
- DEFORMATION IN SHAFT
- MEASURED - ONE OR TWO CONSTRUCTION POINTS
- INDICATED - FROM SYMETRY
- INFERRED
- ALTERNATE ZONE BOUNDARIES
- CRACK
- CRACK - WITH SENSE OF MOVEMENT SHOWN
- FAULT
- SHEAR WITH DISPLACEMENT INDICATED

Note: Clipping of ±25m for boreholes & cracks

0 50 100
Scale (m)

PSM
Pells Sullivan Meynink

Anderson Lloyd OceanaGold (New Zealand) Ltd Project Martha Waihi, New Zealand CAVE MODEL UPDATE SECTION 1875.9mE	
PSM125-282R	Figure 34



LEGEND

- 31 August 2017 Pit
- March 2015 Pit
- Stopes - Filled
- Stopes - Unfilled
- Caved Zone
- Disturbed Zone
- Deformed Zone
- Cracks
- Milking Cow (Ezra,2013)
- Milking Cow Survey Points
- Mapped Faults

Borehole Legend

- Ignimbrite
- Caved
- Disturbed
- Deformed
- Intact
- Not Logged

Note: Clipping of ±25m for boreholes & cracks

0 50 100
Scale (m)

PSM
Pells Sullivan Meynink

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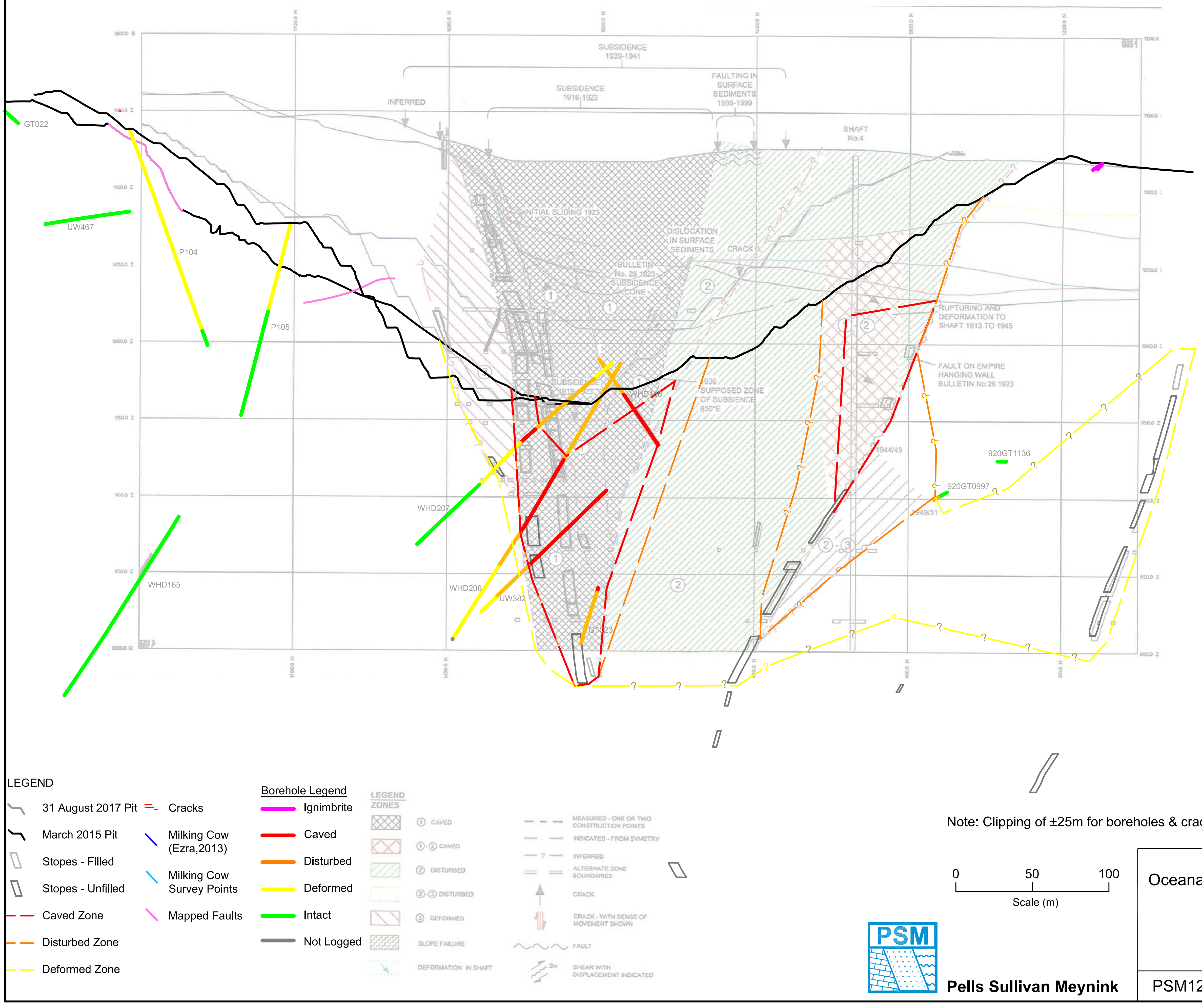
OceanaGold (New Zealand) Ltd Project Martha
Waihi, New Zealand

CAVE MODEL UPDATE
SECTION 1900mE

PSM125-282R | Figure 35



Note: Clipping of ±25m for boreholes & cracks

0 50 100
Scale (m)

PSM
Pells Sullivan Meynink

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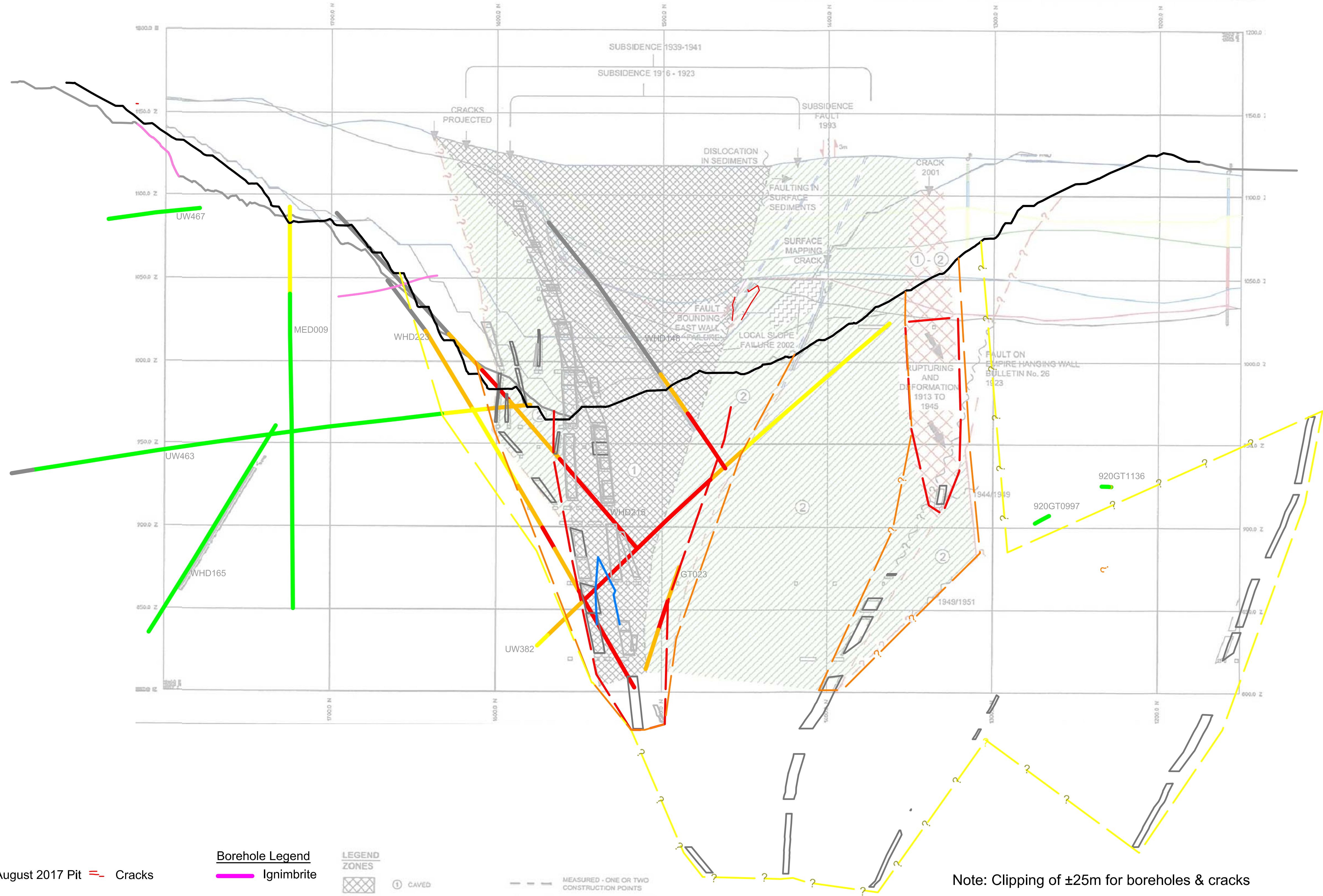
Waihi, New Zealand

CAVE MODEL UPDATE
SECTION 1930mE

PSM125-282R	Figure 36



LEGEND

- 31 August 2017 Pit
- March 2015 Pit
- Stopes - Filled
- Stopes - Unfilled
- Caved Zone
- Disturbed Zone
- Deformed Zone
- Cracks
- Milking Cow (Ezra,2013)
- Milking Cow Survey Points
- Mapped Faults

Borehole Legend

- Ignimbrite
- Caved
- Disturbed
- Deformed
- Intact
- Not Logged

LEGEND ZONES

- ① CAVED
- ①-② CAVED
- ② DISTURBED
- ②-③ DISTURBED
- ③ DEFORMED
- SLOPE FAILURE
- DEFORMATION IN SHAFT
- MEASURED - ONE OR TWO CONSTRUCTION POINTS
- INDICATED - FROM SYMETRY
- INFERRED
- ALTERNATE ZONE BOUNDARIES
- CRACK
- CRACK - WITH SENSE OF MOVEMENT SHOWN
- FAULT
- SHEAR WITH DISPLACEMENT INDICATED

Note: Clipping of ±25m for boreholes & cracks

0 50 100
Scale (m)

PSM
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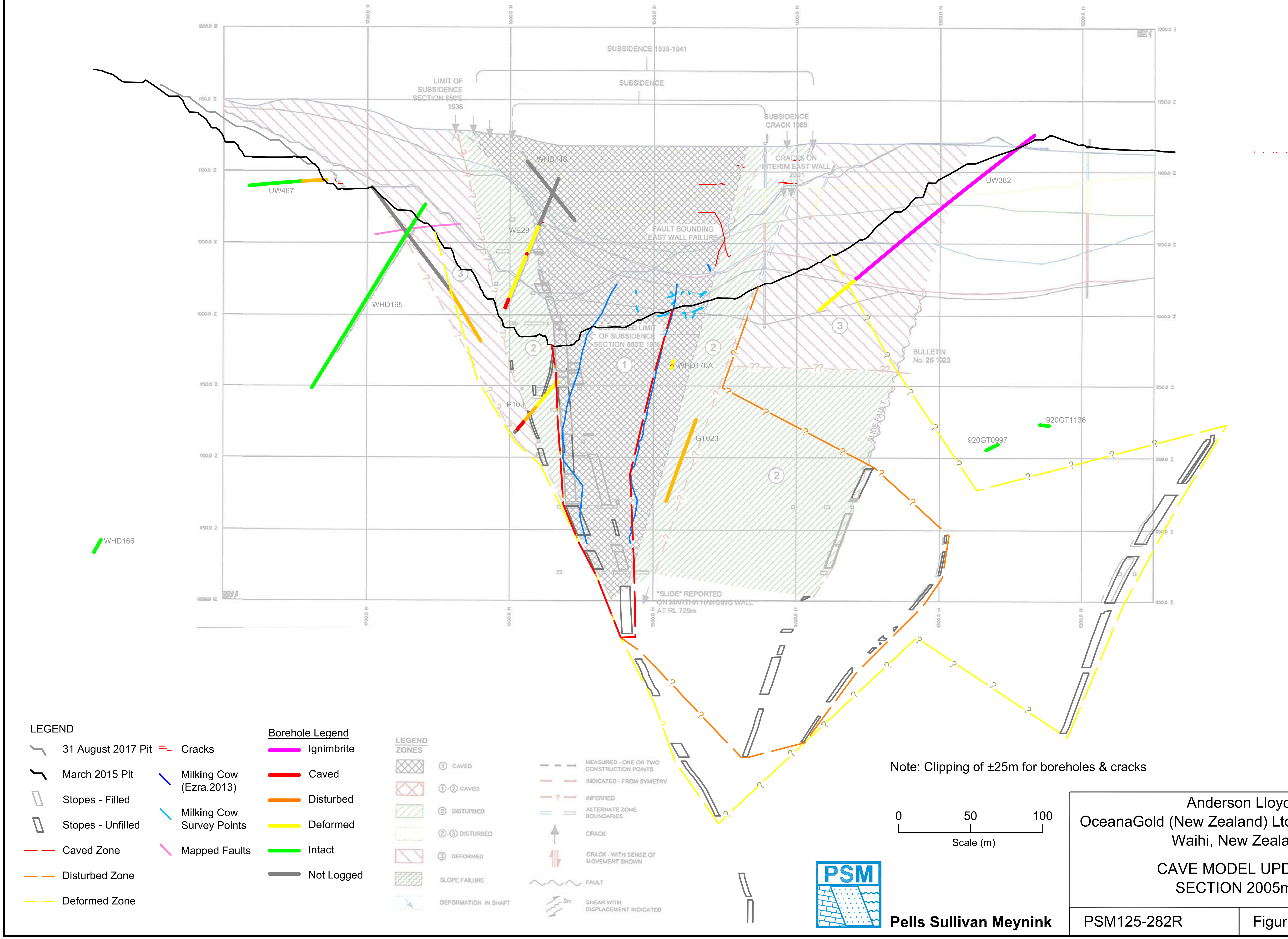
Waihi, New Zealand

CAVE MODEL UPDATE
SECTION 1960mE

PSM125-282R | Figure 37

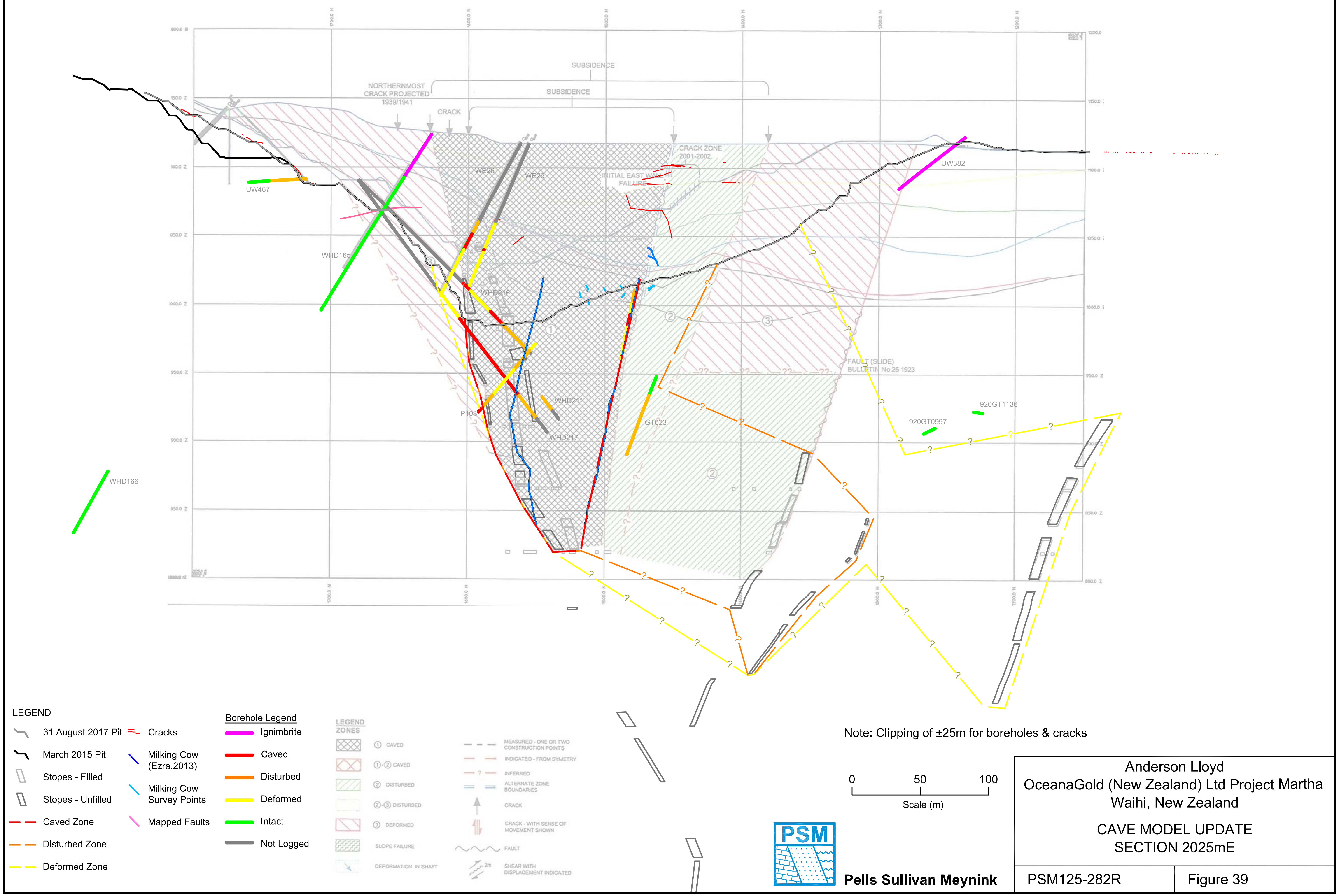


PSM Pells Sullivan Meynink

Anderson Lloyd
OceanaGold (New Zealand) Ltd Project Martha
Waihi, New Zealand

CAVE MODEL UPDATE
SECTION 2005mE

PSM125-282R | Figure 38



Note: Clipping of ±25m for boreholes & cracks

PSM

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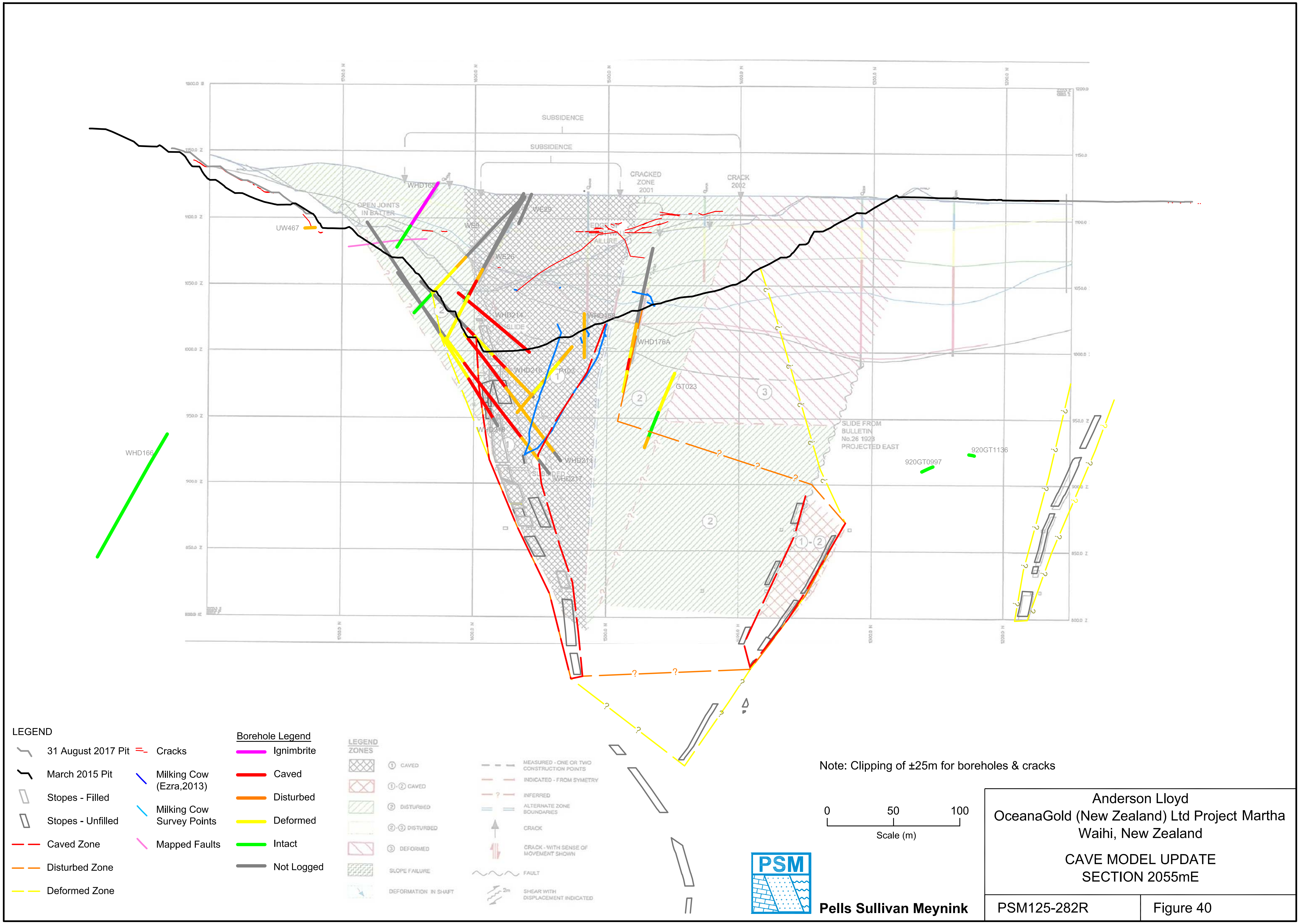
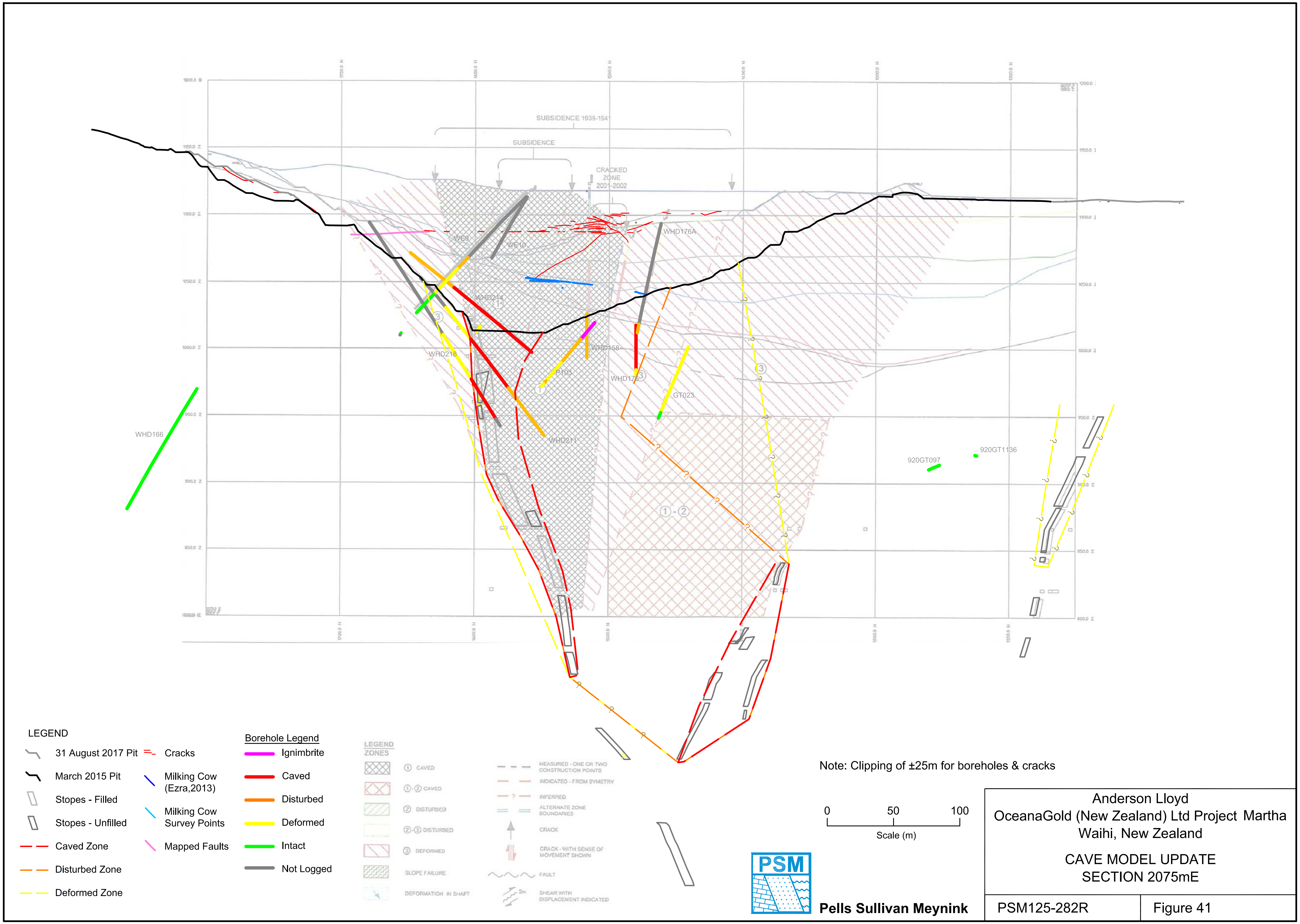
Waihi, New Zealand

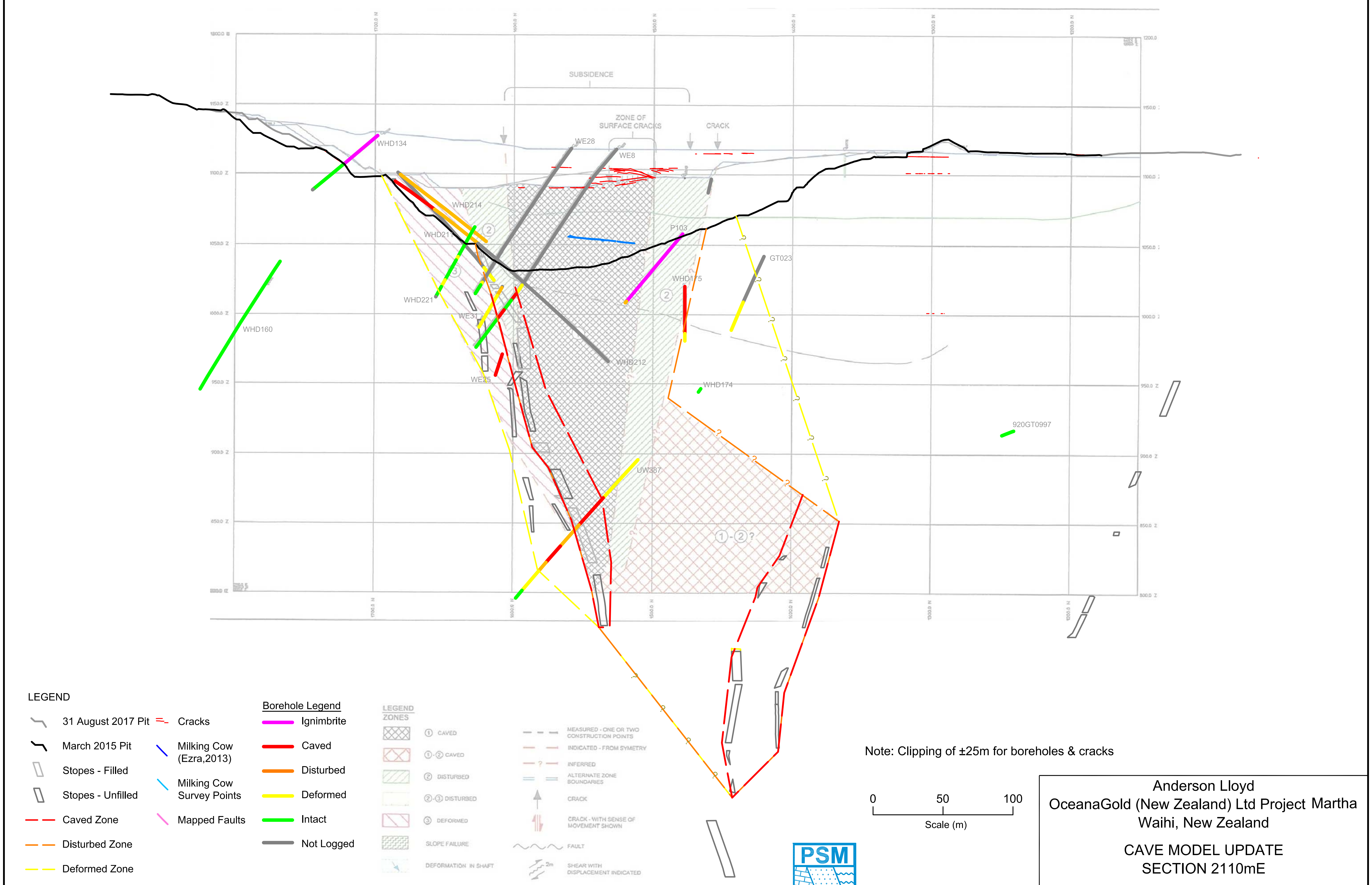
CAVE MODEL UPDATE
SECTION 2025mE

PSM125-282R	Figure 39



SUBSIDENCE
SUBSIDENCE
CRACKED ZONE 2001
CRACK 2002
OPEN JOINTS IN BATTER
UW467
WHD166
WHD214
WHD216
WHD176A
GT023
WHD211
WHD217
P103
SLIDE FROM BULLETIN No.26 1928 PROJECTED EAST
920GT0997
920GT1136
LEGEND
31 August 2017 Pit
March 2015 Pit
Stopes - Filled
Stopes - Unfilled
Caved Zone
Disturbed Zone
Deformed Zone
Cracks
Milking Cow (Ezra,2013)
Milking Cow Survey Points
Mapped Faults
Borehole Legend
Ignimbrite
Caved
Disturbed
Deformed
Intact
Not Logged
LEGEND ZONES
Note: Clipping of ±25m for boreholes & cracks
0
50
100
Scale (m)
PSM
Pells Sullivan Meynink
Anderson Lloyd
OceanaGold (New Zealand) Ltd Project Martha
Waihi, New Zealand
CAVE MODEL UPDATE
SECTION 2055mE
PSM125-282R
Figure 40


SUBSIDENCE 1939-1941
SUBSIDENCE
CRACKED ZONE 2001-2002
WE9
WE10
WHD176A
WHD214
WHD218
WHD158
P103
WHD176
GT023
WHD211
WHD166
920GT097
920GT1136
LEGEND
31 August 2017 Pit
March 2015 Pit
Stopes - Filled
Stopes - Unfilled
Caved Zone
Disturbed Zone
Deformed Zone
Cracks
Milking Cow (Ezra,2013)
Milking Cow Survey Points
Mapped Faults
Borehole Legend
Ignimbrite
Caved
Disturbed
Deformed
Intact
Not Logged
Note: Clipping of ±25m for boreholes & cracks
0
50
100
Scale (m)
PSM
Pells Sullivan Meynink
Anderson Lloyd
OceanaGold (New Zealand) Ltd Project Martha
Waihi, New Zealand
CAVE MODEL UPDATE
SECTION 2075mE
PSM125-282R
Figure 41



PSM

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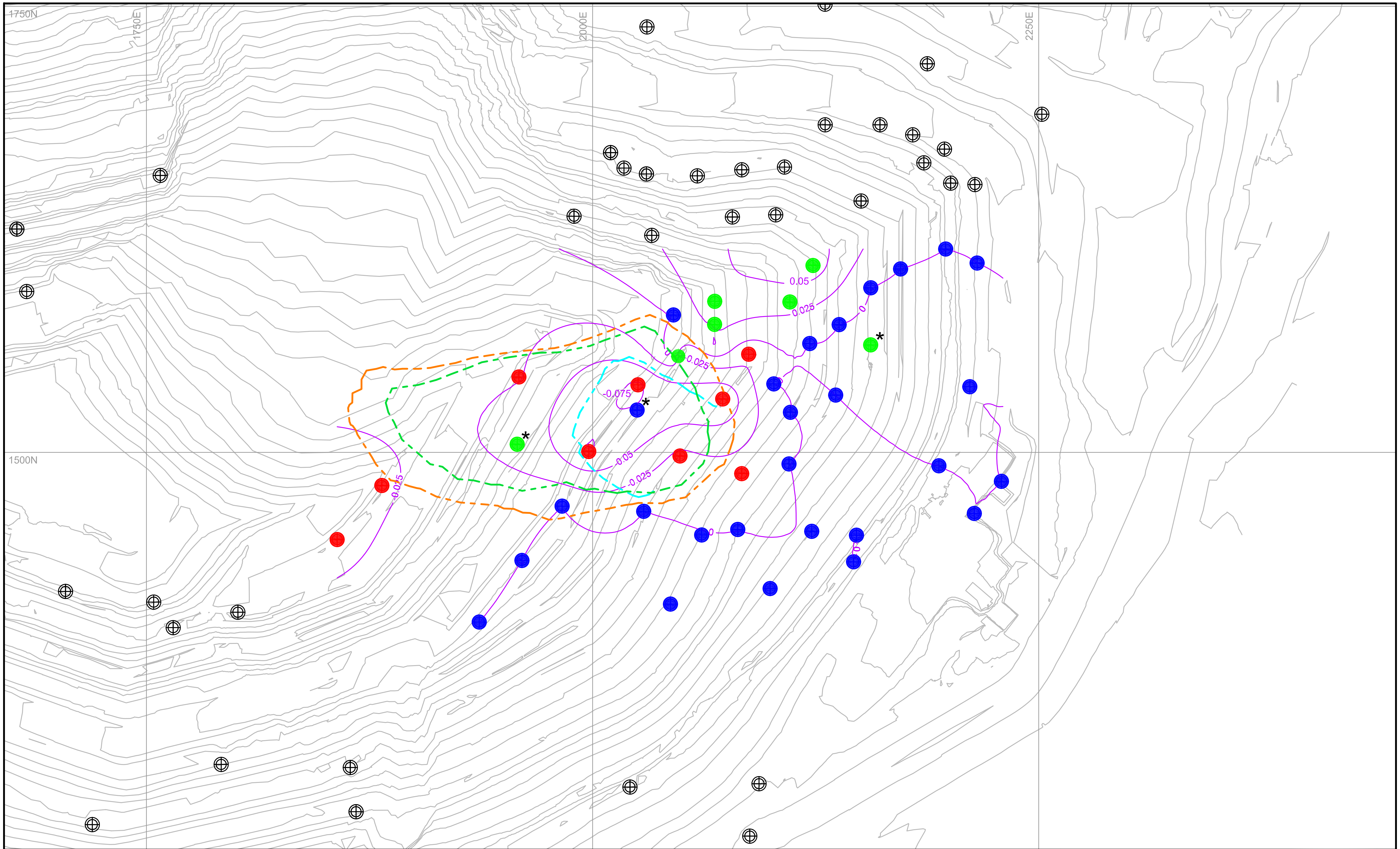
Anderson Lloyd
OceanaGold (New Zealand) Ltd Project Martha
Waihi, New Zealand

CAVE MODEL UPDATE
SECTION 2110mE

PSM125-282R	Figure 42



LEGEND

- 31 AUGUST 2017 PIT
- PRISM ELEVATION MOVEMENT - DOWN
- PRISM ELEVATION MOVEMENT - UP
- PRISM ELEVATION MOVEMENT - NONE
- PRISM - NOT ASSESSED
- * PRISM CONSIDERED ANOMALOUS AND EXCLUDED FROM CONTOURS
- MARTHA CAVE MODEL (EZRA, 2013)
- MARTHA CAVE MODEL ORIGINAL (PSM125-266L)
- MARTHA CAVE MODEL (COYLE, 2013)
- PRISM BASE STATION
- 0.025 PRISM MOVEMENT CONTOURS - 0.025mm/DAY
  POSITIVE = MOVEMENT UP
  NEGATIVE = MOVEMENT DOWN

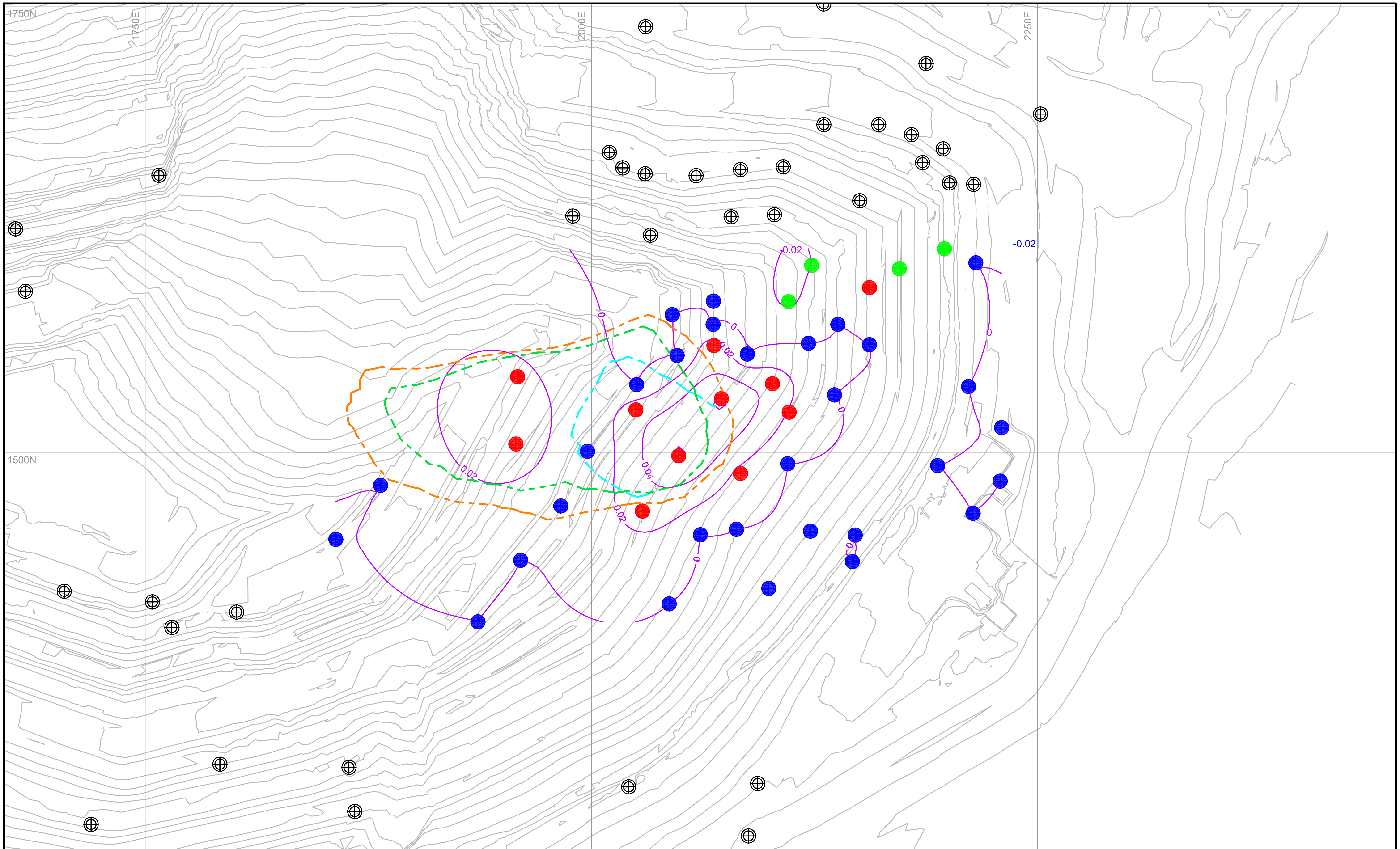
0 50 100 150 200
Scale (m)

PSM
Pells Sullivan Meynink

Anderson Lloyd
OceanaGold (New Zealand) Ltd Project Martha
Waihi, New Zealand

ACTIVE PRISMS - EAST WALL
MOVEMENT - UP-DOWN

PSM 125-282R	Figure 43



LEGEND

- 31 AUGUST 2017 PIT
- PRISM MOVEMENT NORTH
- PRISM MOVEMENT SOUTH
- PRISM MOVEMENT - NONE (NORTH OR SOUTH)
- PRISM - NOT ASSESSED
- MARTHA CAVE MODEL (EZRA, 2013)
- MARTHA CAVE MODEL ORIGINAL (PSM125-266L)
- MARTHA CAVE MODEL (COYLE, 2013)
- PRISM BASE STATION
- PRISM MOVEMENT CONTOURS - 0.02mm/DAY
  POSITIVE = MOVEMENT NORTH
  NEGATIVE = MOVEMENT SOUTH

0 50 100 150 200

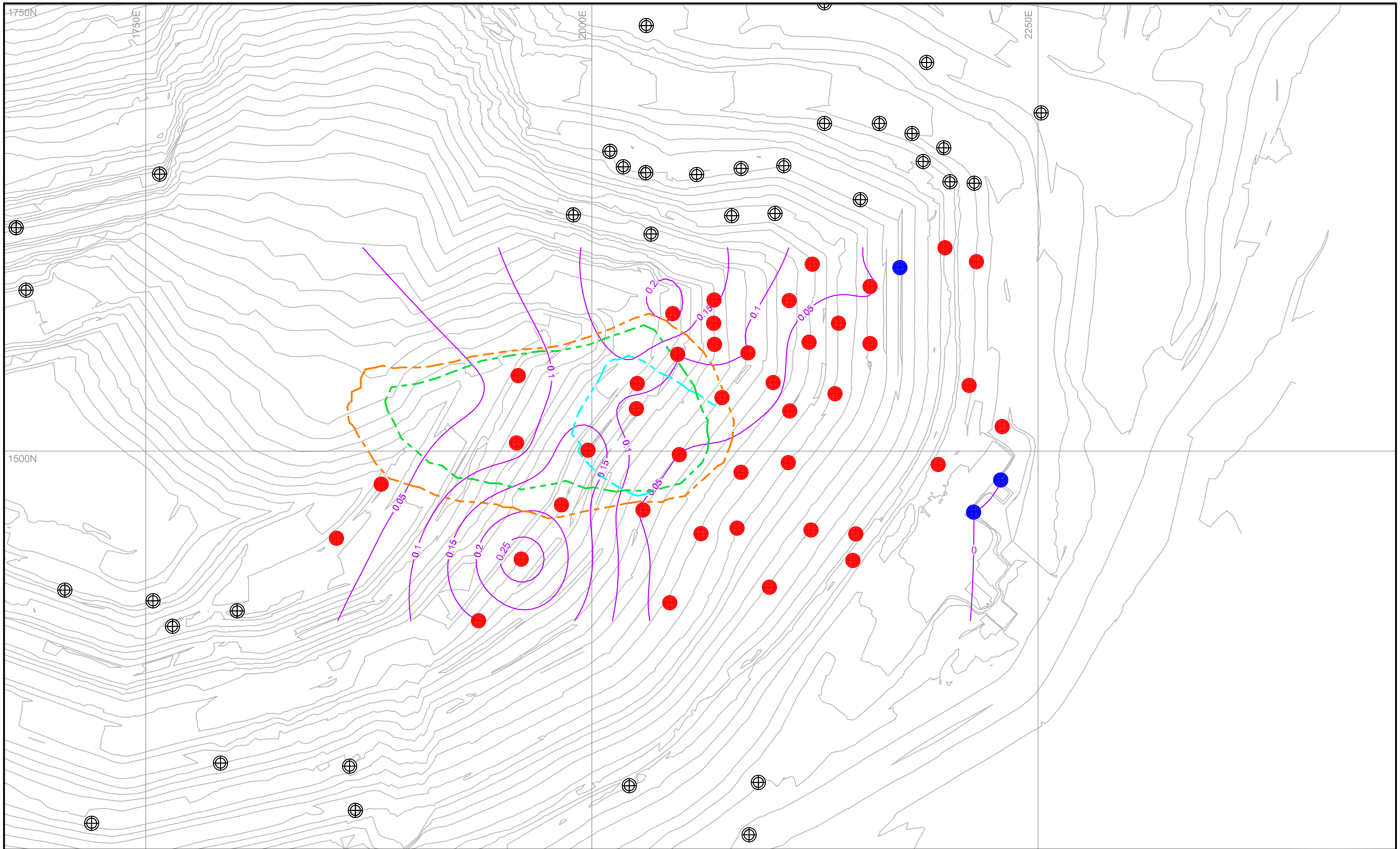
Scale (m)

Pells Sullivan Meynink

Anderson Lloyd
OceanaGold (New Zealand) Ltd Project Martha
Waihi, New Zealand

ACTIVE PRISMS - EAST WALL
MOVEMENT NORTH-SOUTH

PSM 125-282R	Figure 44



LEGEND

- 31 AUGUST 2017 PIT
- PRISM MOVEMENT WEST
- PRISM MOVEMENT - NONE (WEST OR EAST)
- PRISM - NOT ASSESSED
- PRISM BASE STATION
- MARTHA CAVE MODEL (EZRA, 2013)
- MARTHA CAVE MODEL ORIGINAL (PSM125-266L)
- MARTHA CAVE MODEL (COYLE, 2013)
- 0.025 PRISM MOVEMENT CONTOUR - 0.05mm/DAY
  POSITIVE = MOVEMENT WEST
  NEGATIVE = MOVEMENT EAST

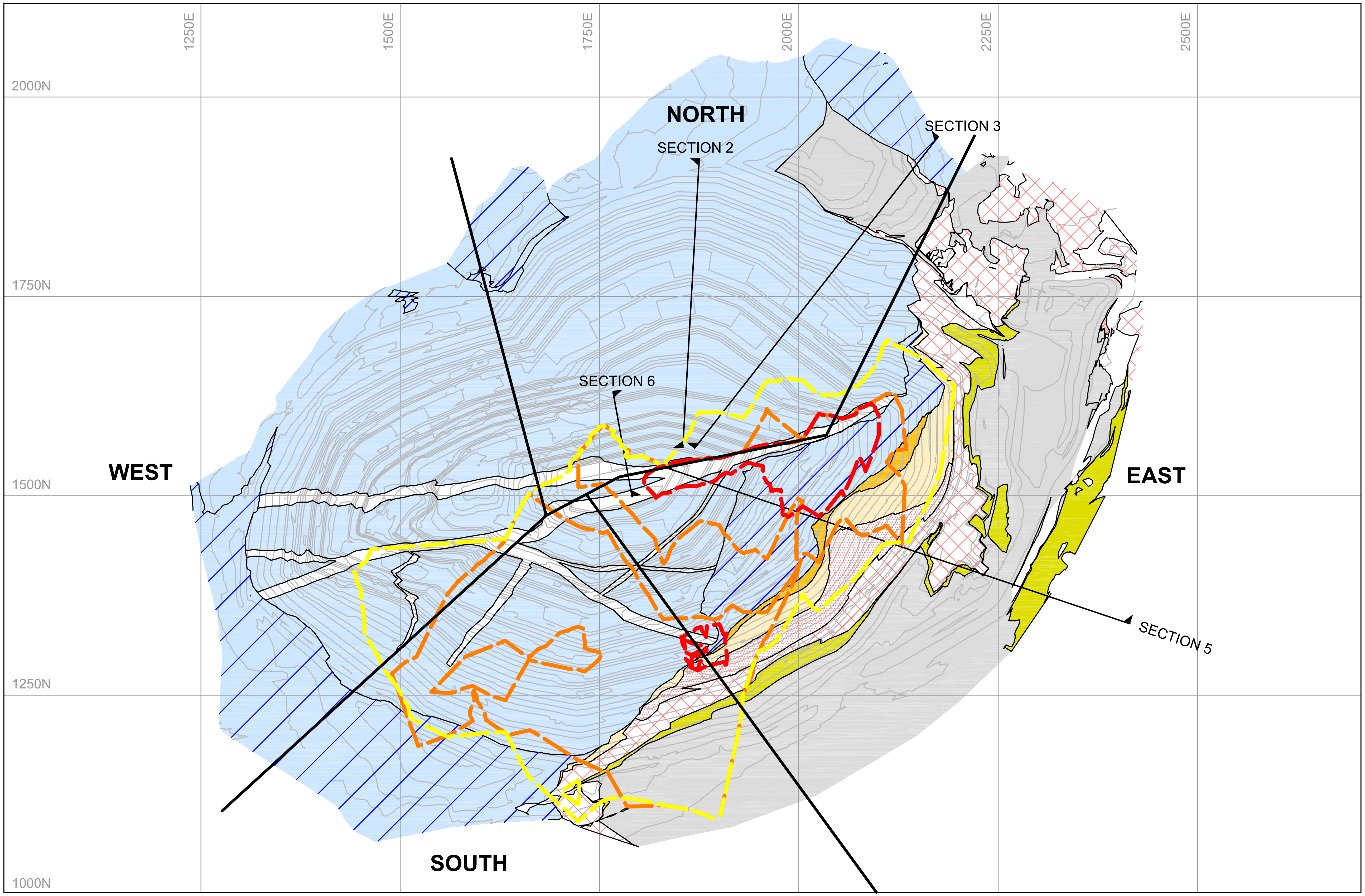
0 50 100 150 200
Scale (m)

PSM
Pells Sullivan Meynink

Anderson Lloyd
OceanaGold (New Zealand) Ltd Project Martha
Waihi, New Zealand

ACTIVE PRISMS - EAST WALL
MOVEMENT EAST-WEST

PSM 125-282R | Figure 45



LEGEND

Pit Final Phase 4 5m Contours	Intersect PH4 Caved	Lacustrine
Analysis Section Location	Intersect PH4 Disturbed	Welded Ignimbrite
Geotechnical Domains	Intersect PH4 Deformed	Unwelded Ignimbrite
		Tuff
Alluvium	Upper Andesite	Andesite
Unknown		

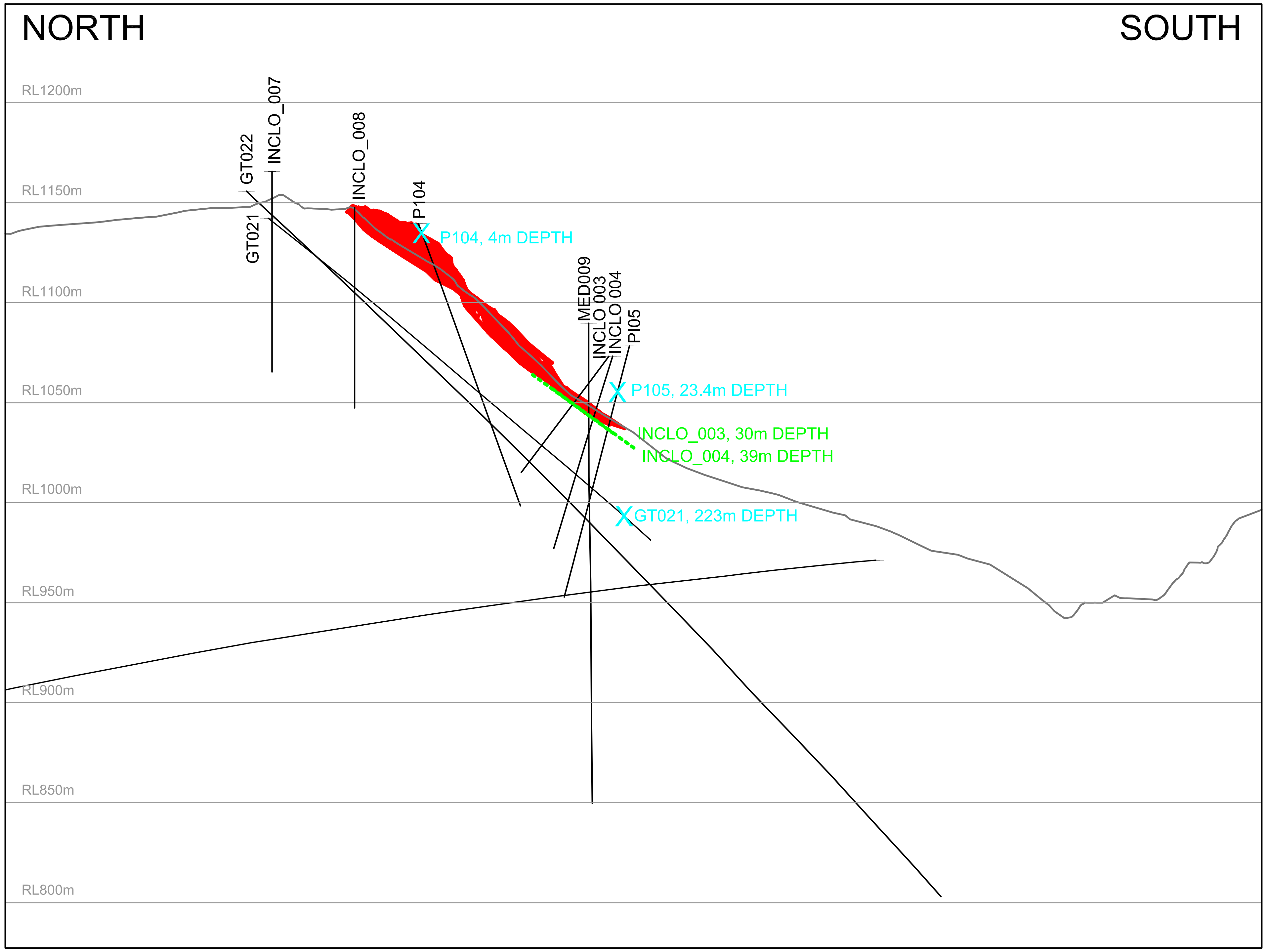
0 50 100 150 200
Scale (m)

PSM
Pells Sullivan Meynink

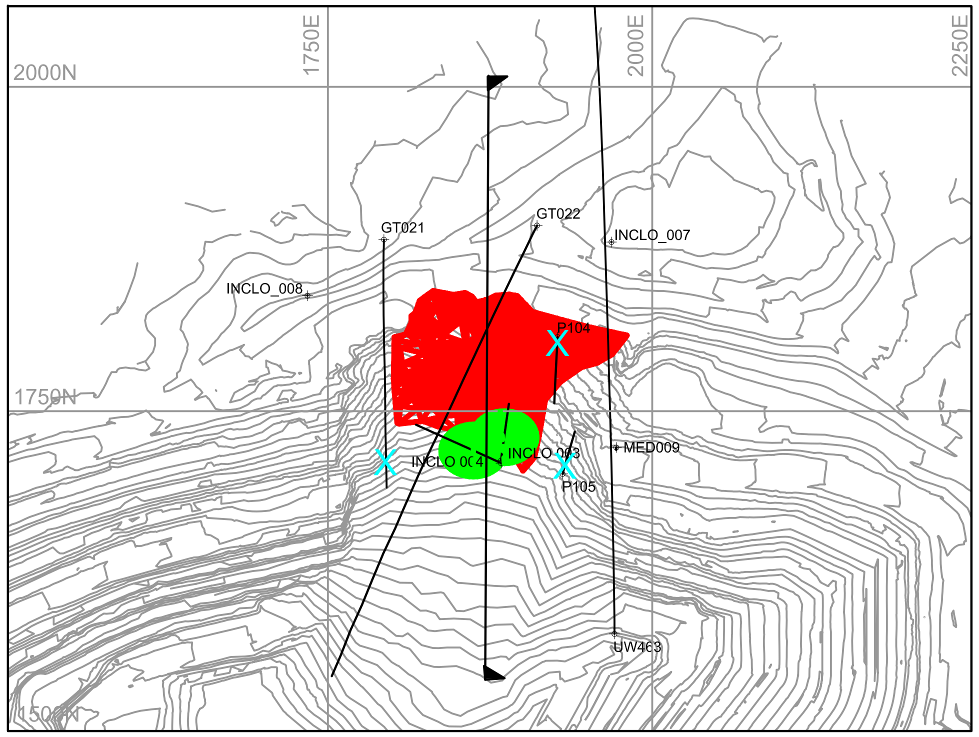
Anderson Lloyd
OceanaGold (New Zealand) Ltd Project Martha
Waihi, New Zealand

LITHOLOGY AND CAVED ZONE INTERSECTIONS WITH PHASE 4 FINAL PIT

PSM 125-282R | Figure 46



ELEVATION VIEW LOOKING EAST



LEGEND

- 31 August 2017 pit surface
- Borehole assessed for structure
- Failure plane from pit surface
- Fault interpreted in borehole as part of failure plane
- Fault interpreted as similar structure in borehole away from failure plane

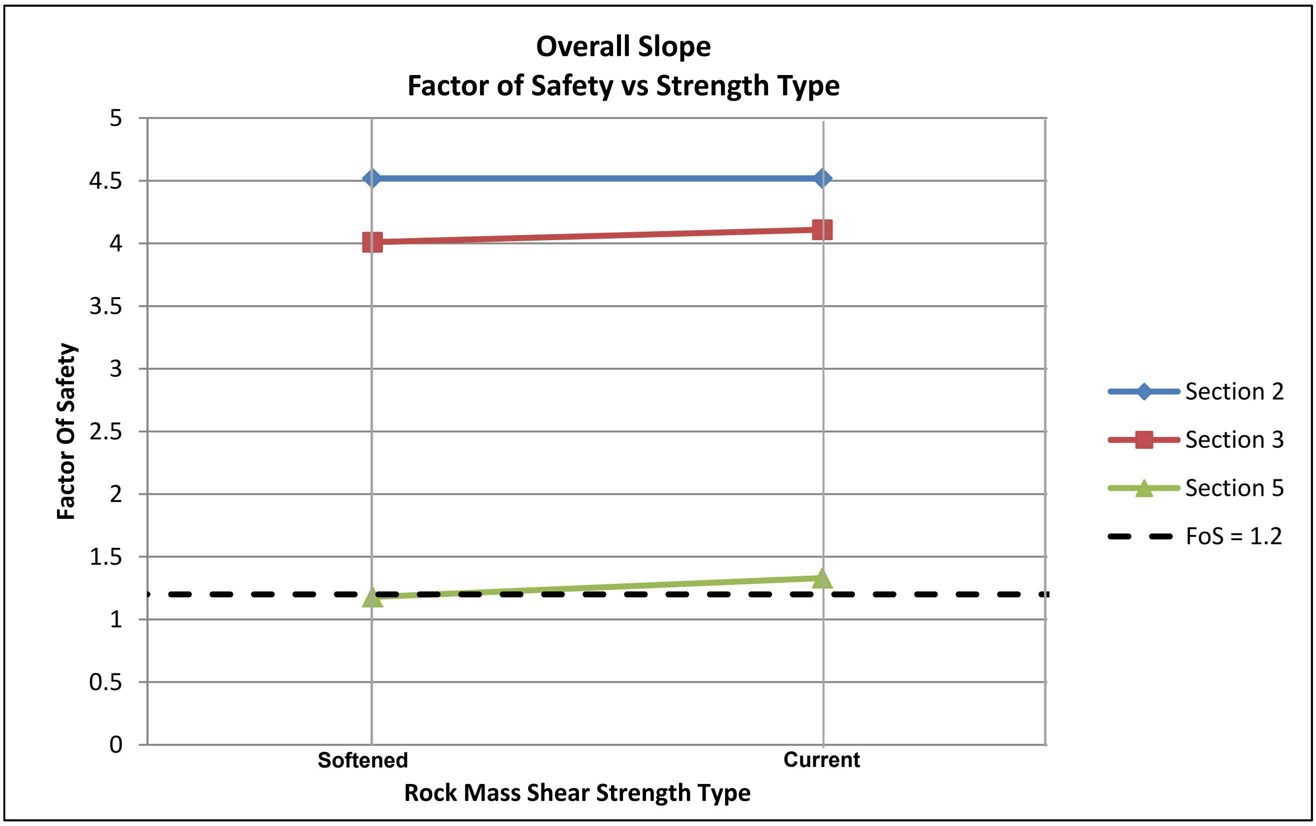
0 50 100
Scale (m)

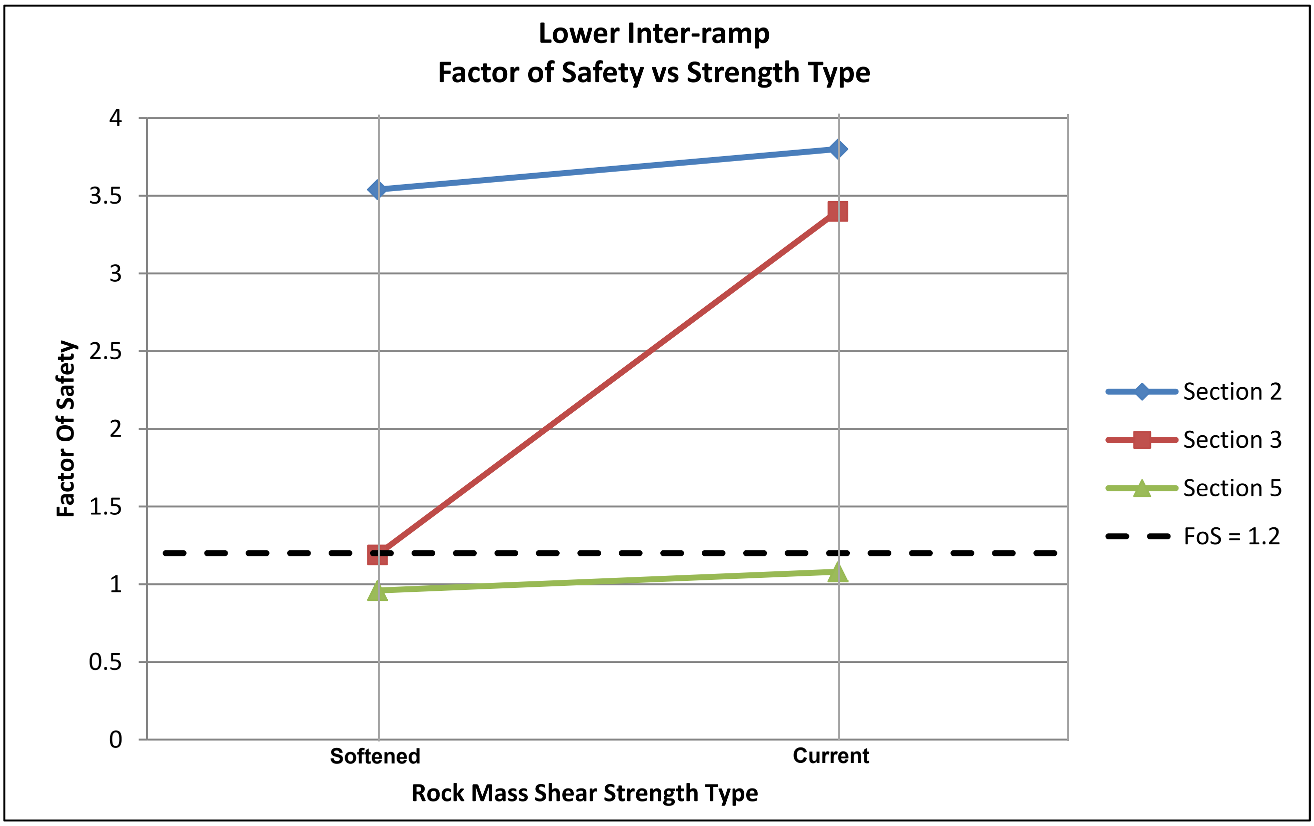
PSM
Pells Sullivan Meynink

Anderson Lloyd
OceanaGold (New Zealand) Ltd Project Martha
Waihi, New Zealand

MARTHA PHASE 4 PIT
NORTH WALL STRUCTURE ASSESSMENT

PSM 125-282R	Figure 47

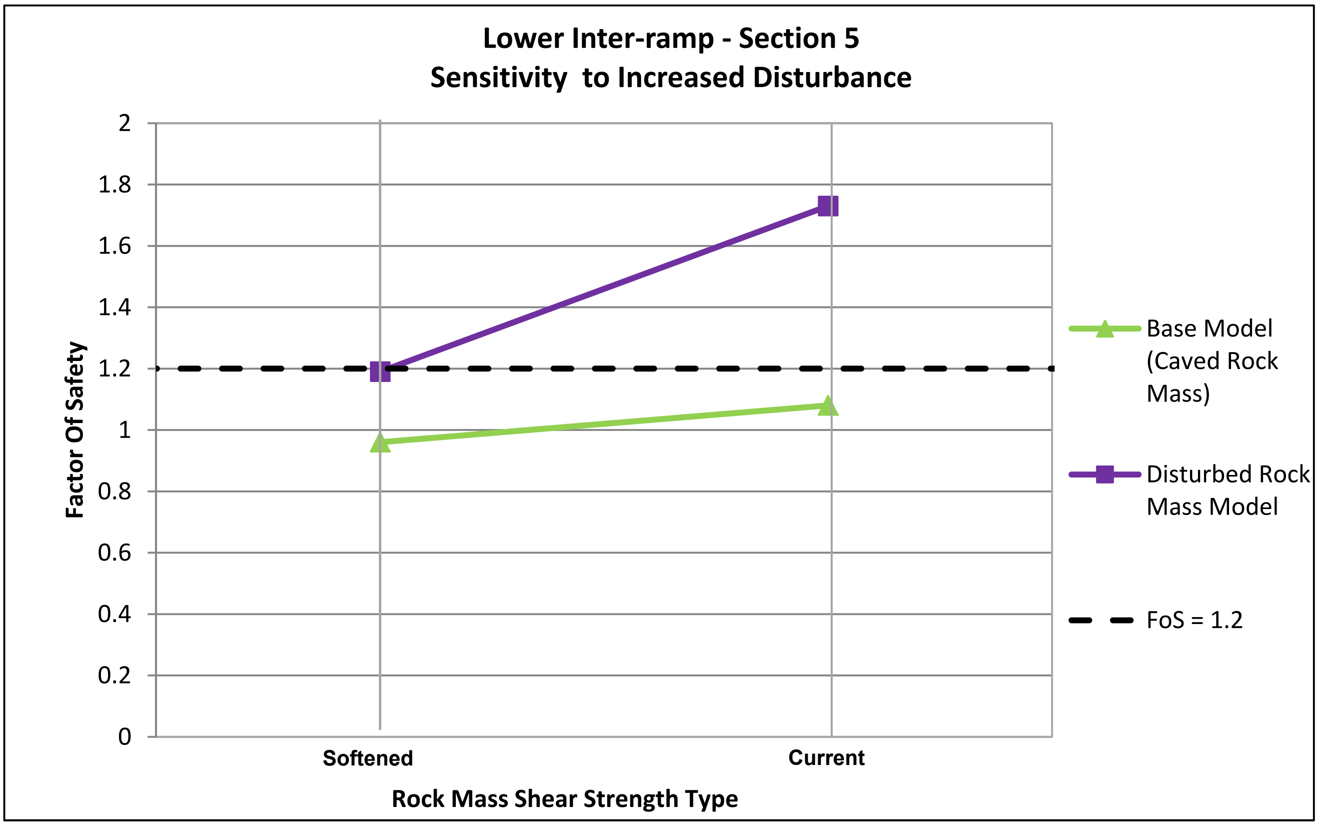


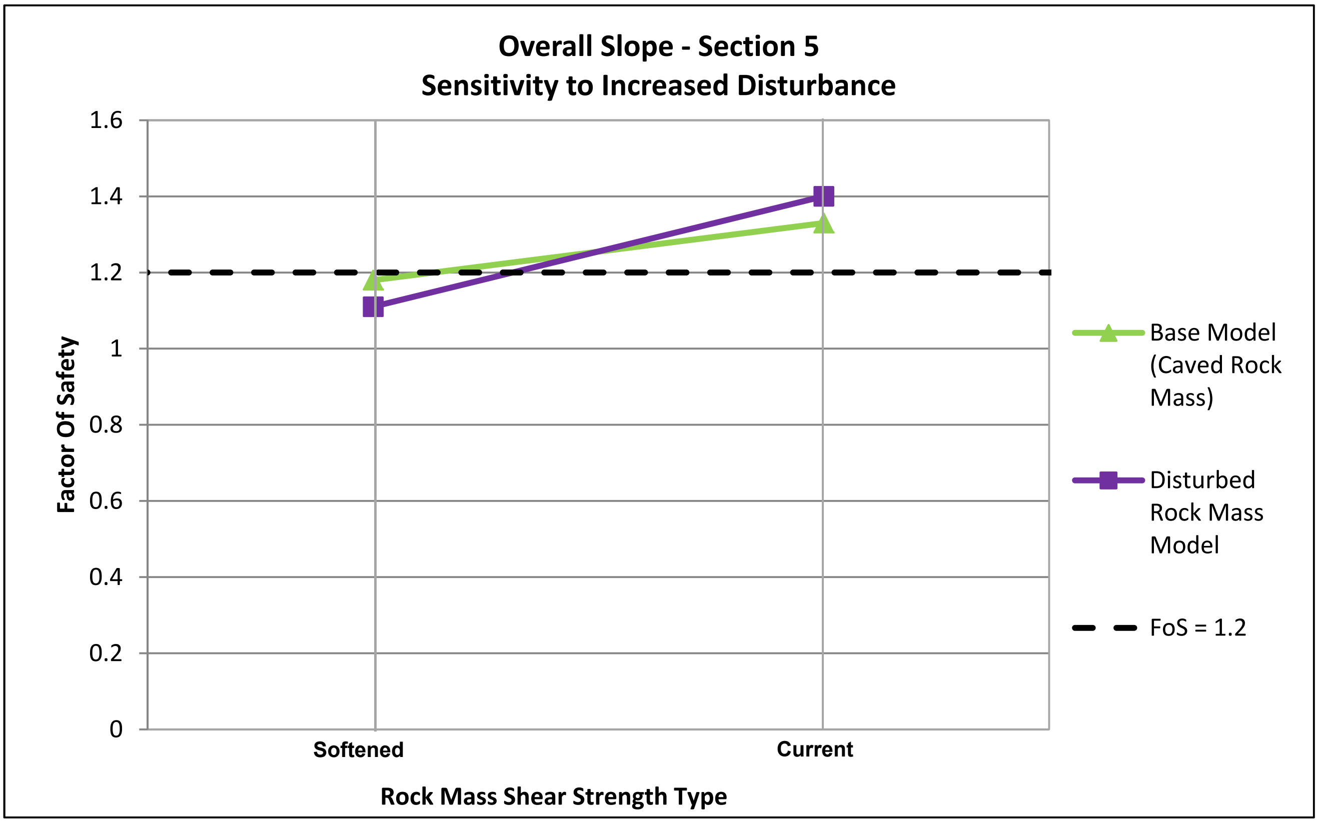


Pells Sullivan Meynink

Anderson Lloyd
OceanaGold (New Zealand) Ltd Project Martha
Waihi, New Zealand
MARTHA PHASE 4 PIT FINAL
INITIAL STABILITY ANALYSIS RESULTS

PSM125-282R	Figure 48





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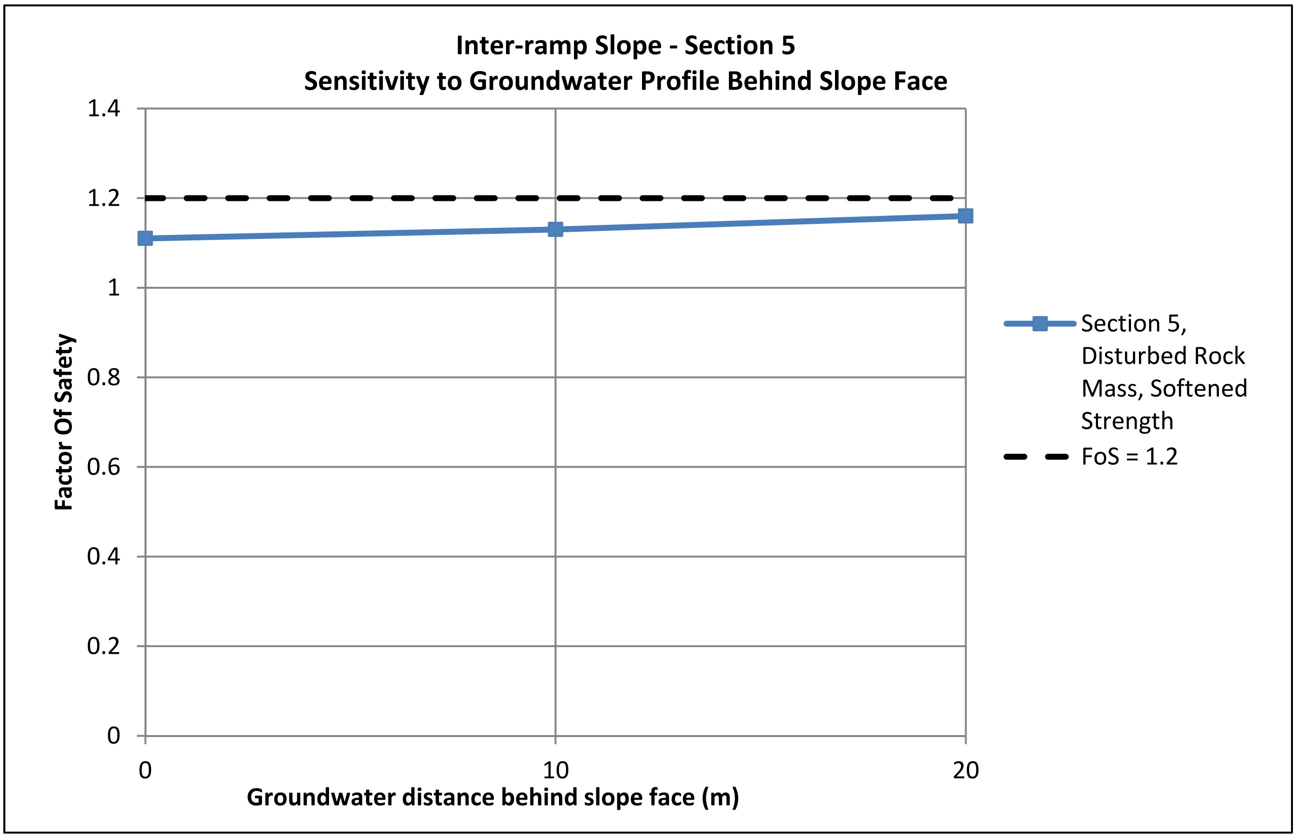
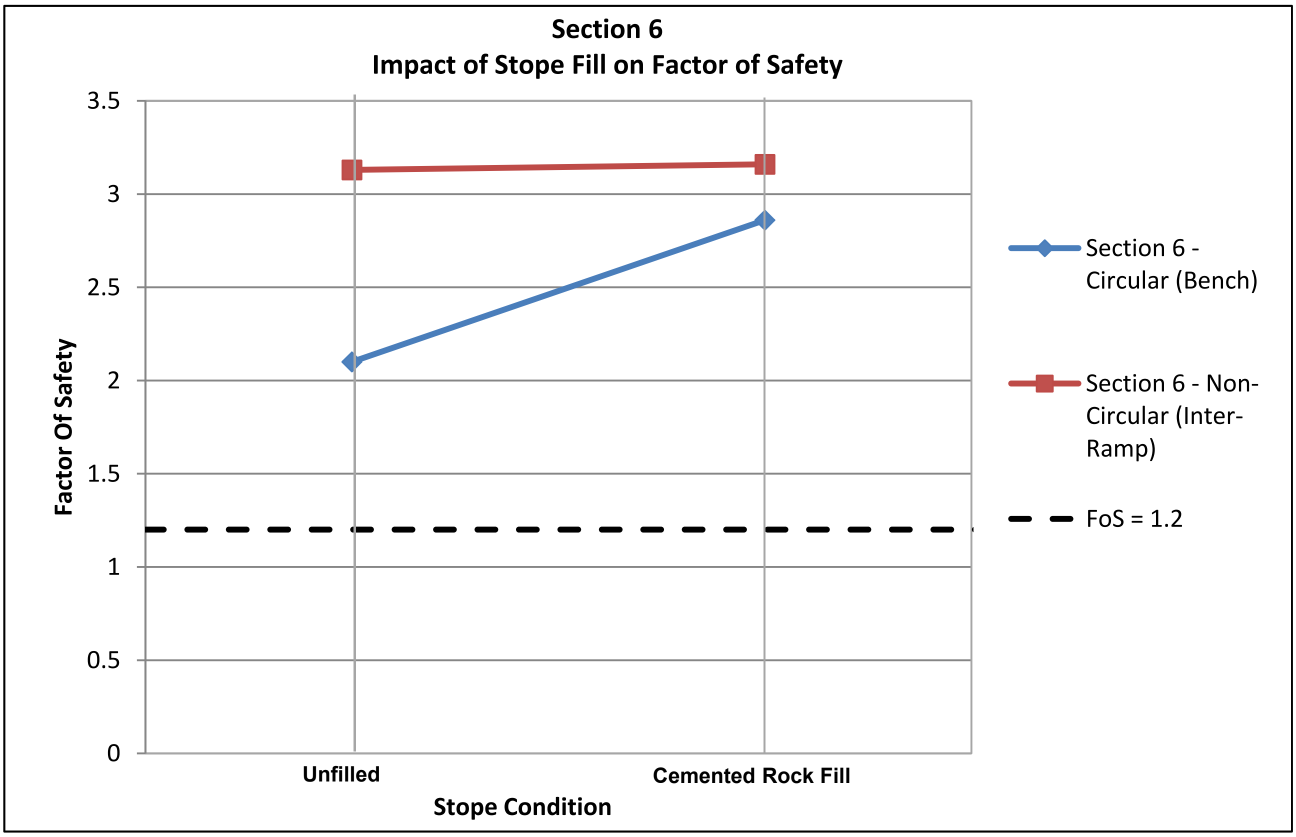
Anderson Lloyd OceanaGold (New Zealand) Ltd Project Martha Waihi, New Zealand MARTHA PHASE 4 PIT FINAL SENSITIVITY TO INCREASED DISTURBANCE	
PSM125-282R	Figure 49





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OceanaGold (New Zealand) Ltd Project Martha

Waihi, New Zealand

MARTHA PHASE 4 PIT FINAL

GROUNDWATER AND STOPE SENSITIVITY ANALYSES

PSM125-282R	**Figure 50**

PSM

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