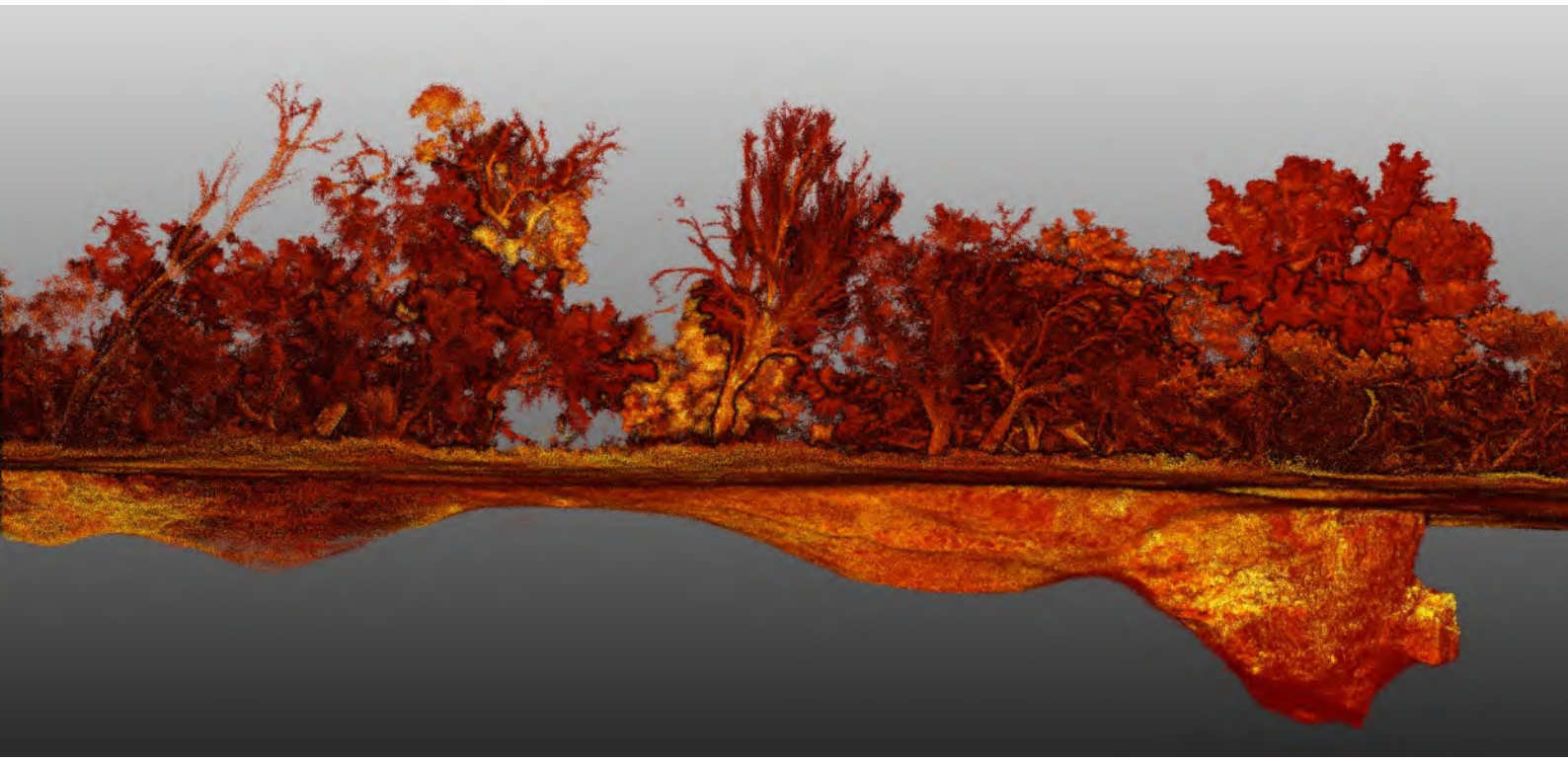

Department of Mines, Industry Regulation and Safety

Wheal Ellen Mine Shafts and Open Pits Geotechnical Assessment and Remediation Methodology (DMIRS750620)

Geotechnical Report

September 2020

Table of contents

Table index

Image index

Figure index

Appendices

1. Introduction

This report presents a geotechnical assessment of the abandoned Wheal Ellen lead mine located approximately 2 km south west of Northampton, a small town 465 km north of Perth, Western Australia.

The purpose of the report is to document existing features associated with mine shafts, pits and subsidence and to comment on other identified features and potential for future subsidence. Attention is given to the mining history, geological setting and processes occurring in order to inform the design of mitigation treatments. These treatments are documented in a separate "Remediation Report" by GHD. Details of a fauna night survey undertaken by GHD are also presented in the Remediation Report.

The work was commissioned by the Department of Mines, Industry Regulation and Safety (DMIRS) as part of their Abandoned Mines Program (AMP). With respect to Wheal Ellen, the DMIRS stated project objectives are to:

- Provide a long-term solution to mitigate safety risks, to a standard where the site could be opened to the public.
- Minimise risk to personnel during construction.
- Be technically feasible and cost-effective.
- Minimise disturbance to the surrounding area.
- Require minimal ongoing monitoring or maintenance for the first 10 years, require no ongoing monitoring or maintenance post 10 years.

In addition to the above, there are more immediate safety concerns regarding the access road which is planned to be used from October 2020 for transport of contaminated soil to a containment cell in the southern portion of the site as part of the Northampton Lead Tailings Project (NLTP) being undertaken by Department of Planning, Lands and Heritage (DPLH). This access road crosses over the mine workings in one section and may be susceptible to accelerated subsidence resulting from increased heavy vehicle traffic.

In the following sections, the assessment methodology is presented including details of the desktop study, geotechnical assessment and LiDAR / photogrammetry survey. Findings are then presented for the site generally as well as for each individual feature.

This report should be read in conjunction with the General Notes provided in Appendix A.

1.1 Limitations

This report has been prepared by GHD for Department of Mines, Industry Regulation and Safety and may only be used and relied on by Department of Mines, Industry Regulation and Safety for the purpose agreed between GHD and the Department of Mines, Industry Regulation and Safety as set out this report.

GHD otherwise disclaims responsibility to any person other than Department of Mines, Industry Regulation and Safety arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no

responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

GHD has prepared this report on the basis of information provided by Department of Mines, Industry Regulation and Safety and others who provided information to GHD (including Government authorities), which GHD has not independently verified or checked beyond the agreed scope of work. GHD does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

2. Assessment methodology

2.1 Desktop review

A desktop study of the following information was undertaken to appreciate the geological context, mining history and specific shaft, open pit and subsidence features:

- Mine plans, sketch maps and historical documents provided by DMIRS.
- Mine feature points and identifiers (selected S0113xxx series) from the DMIRS Abandoned Mine Inventory.
- Feature and general site video and photographs from 2000 and 2020 provided by DMIRS.
- Geological maps.
- Historical aerial photographs from 1967, 1977, 1988.
- Recent (since 2002) aerial photographs access through Google Earth Pro.

Specific references for the above and other information sources referenced in this report are provided in Section 7.

Features such as watercourses and areas of possible subsidence were collated into an ArcGIS Project Map together with Abandoned Mine Inventory data, historical photos and mine plans. This process allowed the development of conceptual models for surface and subsurface conditions, assisting in the understanding of feature development and planning of the geotechnical walkover assessment.

Brief reviews of reports associated with site contamination, groundwater and the containment cell provided by DMIRS were also made to assess opportunities to use on-site and imported soils in the mitigation treatments.

2.2 Site works

2.2.1 Geotechnical walkover assessment

The site walkover was undertaken between 20 and 22 August 2020 by an Engineering Geologist and Graduate Geotechnical Engineer from GHD. Works associated with walkover met the requirements set out in Section 3.3.5 of GHD's proposal dated 9 July 2020 and comprised the following:

- Record observations and photograph significant geological features.
- 'Ground truth' the models developed during the desktop study with specific attention to watercourse and haul road crossings of the ore sub-crop and underground workings.
- Visual assessment of spoil piles that could be used in the remediation.

Key observations from the walkover are presented in Section 3 of this report.

2.2.2 LiDAR and photogrammetry survey

Survey was undertaken on 20th and 21st August 2020 by MINELiDAR under subcontract to GHD. The following was completed.

- Site wide aerial survey using multirotor UAV (drone) mounted LiDAR (Riegl Vus-1 mini) with photogrammetry and ground based survey for geo-referencing to GDA/MGA94.
- Individual feature survey using the UAV as above, supplemented with Optech V500 Caivty Monitoring System (CMS) survey to safely measure feature dimensions and better observe

/ measure potential connections to underground workings by lowering the scanner into features where they are not filled with water.

Survey data is available in a variety of formats as listed below and has been partially incorporated into the GHD ArcGIS Project Map and used to calculate volumes and produce the figures included in Appendix B of this report.

- Orthorectified georeferenced RGB imagery (*.ecw).
- CMS georeferenced point clouds.
- Reduced density/thinned model keypoints surface dataset suitable for CAD packages (dxf/ASCII).
- 3D digital data files in Autocad/GIS formats.

3. Surface conditions

3.1 Site identification

For the purposes of this assessment, the site boundary is as shown on Figure 1 in Appendix B. It includes part of Lot 11448 off Drage Road and the adjoining Lot 1146 to the southwest. Both lots are Crown land.

The mined area is defined by the lode sub-crop (where it intersect the ground surface) and continuation underground on the north western side of the sub-crop. Most of the mine features (shafts, pits and subsidence) are along or close to this sub-crop. Some shafts, particularly the deeper ones, are to the northwest. To the southeast of the sub-crop, there is no mining and so no mine shafts / pits or mine subsidence hazards.

3.2 Topography

The site typically falls from approximately 130 m above Australian Height Datum (AHD) in the north eastern corner to approximately 110 m AHD to the west and southwest. Depressions and subsidence from mining run in a northeast to southwest direction across the site. In the central area of the site, elevated ground associated with relict mine spoil were observed with ground levels ranging from 118 m AHD around the crest to 113 m AHD along the toe of the slopes.

Site topography is shown on Figure 2 in Appendix B.

3.3 Surface water

Two named ephemeral watercourses pass through the site: Wheal Ellen Creek East and Wheal Ellen Creek. These are tributaries of Nokanena Brook. A third watercourse, Wheal Ellen Creek South, extends into western side of Lot 5680, running southeast to northwest until it converges with Nokanena Brook. An unnamed ephemeral watercourse passes through the central portion of Lot 11448.

Watercourses have been generated from the August 2020 LiDAR survey data using ArcGIS software and are shown on Figure 2 in Appendix B. The purpose of this is to identify surface water flow paths. Where these coincide with the mined lode sub-crop, erosion and subsidence is more likely and additional remediation treatments may be required.

3.4 Stockpiles

Ten stockpiles were identified and are labelled on Figure 2 in Appendix B. Details are provided in Table 3-1.

Only the surface and near surface of stockpiles were observed. The below observations assume that the surface materials are representative of materials within.

Stockpiles 1 through 5 are located near the containment cell and predominantly comprised what appeared to be topsoil. Stockpile 4 contained coarser soils comprising sands, gravels, cobbles and boulders but was mixed with topsoil. Stockpiles 6 through 10 are in the Main Workings area. They comprised predominantly coarse soils (sands, gravels, cobbles and boulders).

As advised by DMIRS, only “non-contaminated” material will be approved for reuse as mine rehabilitation material. The contamination status and hence suitability for reuse of these stockpiles is yet to be confirmed and further assessment by Department of Planning, Lands and Heritage (DPLH) is understood to be occurring.

Assuming that all ten stockpiles listed are “non-contaminated”, all stockpile material would be considered suitable for reuse as listed in Table 3-1. Further information on material reuse will be provided in the Remediation Report.

Table 3-1 Summary of stockpiles

Stockpile number	Approximate dimensions (m)			Approximate volume (m^3) [4]	Material description	Reuse suitability [3]
	Height	Length	Width			
1	1.9	12.2	9.1	315	Topsoil: Gravelly sandy SILT	topsoil
2	2.1	28.5	12.8	780		topsoil
3[1]	1.5	8.5	6.0	100		topsoil
4	1.1	16.9	12.6	440	Gravelly BOULDERS and COBBLES	backfill
5	2.4	24.4	13.3	1265	Topsoil: Gravelly sandy SILT	topsoil or backfill
6	0.5	20.0	2.0	145	Sandy GRAVEL	backfill
7	2.0	13.6	3.2	55	Sandy GRAVEL	backfill
8[2]	0.9	5.2	6.3	30	Gravelly SAND, with boulders	backfill
9	4.5	24.0	20.3	2475	Gravelly SAND / Sandy GRAVEL, with cobbles	backfill
10	2.1	6.3	6.1	65	Sandy GRAVEL, with cobbles	backfill

[1] Mixed with topsoil
[2] Likely inert demolished infrastructure
[3] Subject to confirmation from DPLH that material is “non-contaminated”
[4] Sum 5670 m^3

3.5 Debris

A number of the shafts and open pits are partially filled with debris such as cars, sheet metal and wire. Observations are detailed in Table 6-1 in Section 6.

Potential Asbestos Containing Material (ACM) in the form of cemented sheeting was observed at two locations shown in Figure 6. The suspected ACM will need to be taken into consideration during remediation to manage risk to human health.

4. General sub-surface conditions

4.1 Geology

4.1.1 Regional geology and lode

According to the 1:250,000 scale Geraldton – Houtman Abrolhos geology map (Geological Survey of Western Australia, 1971), Northampton and its immediate surrounds are located on the Northampton Block which is comprised of Precambrian aged metasediments in the form of granulite, gneiss, feldspathic quartzite and pegmatite intruded by steeply dipping dolerite dykes estimated to be of Upper Proterozoic age (Jones and Noldart, 1961). Thin colluvial and alluvial sediments derived from these rocks are likely to be spread along watercourses.

Lead and other heavy metal mineralisation on the Northampton Block is understood to be the result of structurally controlled intrusion of metal bearing fluids orientated parallel with dolerite intrusions (Jones and Noldart, 1961).

Galena (lead sulphide) was the common ore mineral mined at Wheal Ellen. The origin of the mineralisation fluids is not conclusive however from mapping of mine workings around Northampton by the Geological Survey of Western Australia (GSWA), it appears there are spatial differences in copper and lead enriched areas and multiple fluids and mineralisation events. Mapping by Jones and Noldart (1961) and GSWA indicate that mineralised areas are thin, linear and orientated northeast to southwest.

The lode shear at Wheal Ellen strikes at 035° and dips west at 60-80° following the west contact of a thin dolerite dyke in granulite. The main ore is associated with a link structure in the lode which offsets the shear. The strongest inineralization is on the offset ends of the shear rather than in the link, (GSWA Resources Bulletin 15, 1999).

The Sketch Map of Geology (Ref. 1689) included in Figure 4 in Appendix B shows the dyke along fault lines and associated mine workings following the western intrusion.

4.1.2 Site observations

The geology observed during the site walkover is consistent with that reported by previous investigations and published data. Rock of igneous origin was observed and comprised what was interpreted as gneiss and dolerite. Lateritic gravels at surface indicate an increased likelihood for iron oxide cemented duricrusts being present near surface.

The faces forming mine shaft walls were observed as moderately to highly weathered, bleached and with frequent joints and fractures. It was assessed that small disturbances would likely cause instabilities in shaft walls where they are unsupported.

4.2 Soils (excluding stockpiles)

Descriptions of near surface soils are provided in URS 2015 and AECOM 2020 reports for the containment cell and Main Workings area. These reports include shallow subsurface investigations and geotechnical laboratory testing and soil samples. However, descriptions of soil origin or interpretations of ground conditions across the site are not provided.

Based on review of the above reports and our observations of soil exposures in the sides of features, the following soil profiles are anticipated.

- Surficial fill and disturbed ground from past mining operations in localised areas
- Thin to no topsoil generally

- Along primary watercourses as shown on Figure 2 in Appendix B, minor alluvial soils are anticipated however these are expected to be thin given the general erosional landscape
- Typically red-brown colluvial and residual Sandy CLAY with gravels grading to weathered rock between about 0.5 to 2 m depth.

4.3 Groundwater

As reported in Aurora, 2019 groundwater monitoring wells (MW1 through MW6) were installed in October 2017 within the fractured bedrock (described as granulite). The locations of these wells are shown on Figure 2. Logs of the boreholes and well installations were provided by DMIRS and are referenced as Aurora, 2017.

During the GHD site work, groundwater depths were measured in the wells and are presented in Table 4-1 together with water levels surveyed in features.

Table 4-1 Groundwater measurements – GHD August 2020

Location	Depth (m)	Ground surface level (m AHD)	Groundwater level (m AHD)	Monitoring interval (m)	Condition
MW1	10.16	137.19	127.03	11 – 29	Elevated
MW2	6.32	117.24	110.92	10 - 14	Artesian
MW3	1.68	112.16	110.48	6.5 - 11	Artesian
MW4S	0.77	110.62	109.85	3 - 8	
MW4D	0.22	110.70	110.48	7 - 11	Artesian
MW5S	1.23	109.46	108.23	1.5 - 8	
MW5D	- 0.61	109.40	110.01	7 - 11	Artesian
MW6S	6.55	116.75	110.20	9 - 14	
MW6D	6.44	116.75	110.31	12.5 - 17	artesian
S0113163	1.09	~ 119 *	118.0	unconfined	perched
S0113151	5.56	~ 116 *	111.3	unconfined	perched
S0113097	4.16	~ 115 *	110.3	unconfined	phreatic
S0113149	4.21	~ 116 *	112.4	unconfined	perched
S0113147	2.45	~ 114 *	111.8	unconfined	perched
S0113158	5.90	116.3	110.4	unconfined	phreatic
S0113130	6.71	~ 117 *	110.3	unconfined	phreatic
S0113141	6.65	~ 117 *	110.4	unconfined	phreatic
S0113143	1.55	~ 112 *	110.6	unconfined	phreatic
S0113145	3.14	~ 113 *	110.5	unconfined	phreatic
* Approximate south eastern crest level					

In well MW1, the groundwater level was about 16 m higher than recorded in MW2 indicating the elevated area to the east of the site is providing recharge.

In well MW5D, the groundwater level was above the surrounding ground surface indicating flowing artesian conditions. MW5D is the lowest well with MW4D about 76 m upstream showing a water level about 0.5 m higher and just below the ground surface. This is the same level as measured in the Old Main Shaft (S0113145). Artesian conditions were also observed in the

other “D” series wells and inferred to also be present in MW2 and MW3 as well as at the Old Workings Pass, Old Workings Shaft and within the Old Workings generally and to a lesser degree the southern portion of the Main Workings.

Within the features, the phreatic groundwater level is interpreted to be between 110.3 and 110.6 m AHD with the level higher in the Old Workings to the south, suggesting groundwater flow through the workings in a north easterly direction at the time of observation and poor hydraulic connectivity between the Old Workings (S0113143 and S0113145) and Main Workings.

No groundwater was observed in the features of the Northern Workings, principally because the ground surface elevations in that area are higher (over about 121 m AHD).

The perched water in four features indicates low hydraulic connectivity to the groundwater table below. That is, the base of these features is sufficiently intact and of low permeability to allow surface water to be retained for a period of at least a few days.

Overall, groundwater flow is expected to be to the northwest, following the topography with recharge of groundwater from the east, through the fractured rock. The workings will act as a reservoir and zone of high hydraulic conductivity, distributing water pressures along the lode sub-crop. At an elevation of about 110.5 m AHD, the Old Workings Pass is the lowest feature and only about 0.5 m lower than the surrounding ground surface. As such, it may act as a spring during and following periods of heavy rainfall.

4.4 Noxious and flammable gases

The mine workings are now largely filled with water and much of the workings above the groundwater phreatic surface are sufficiently open to be naturally ventilated.

No sources of noxious or flammable gas have been identified and no reports of gases being a problem during mining were found. Ventilation of the workings was important during mining for breathability, that is: to supply fresh air to areas of underground work.

Above the groundwater, small pockets of stale (low oxygen) air are likely to exist in underground voids. This is more likely in the Northern Workings area where the depth to the groundwater table is several metres lower due to the higher elevation in that area. During remediation, some of this air may be displaced and come to the surface. However, the volume would be insignificant and quickly diluted in the open air.

5. Mining history and features

5.1 Mining terminology

A selection of mining terms used in this report are defined in Gibbs (*ibid*), mostly taken from W.G. Orchard's 1990 Glossary of Mining Terms as follows:

Costean: An open-cut pit sunk to discover the line of the lode.

Levels: Galleries driven on the lode.

Main Shaft: The major route or pit for transporting ore and sometimes men and equipment from the lode. Usually also the shaft over which the headframe is built and the whim, winch or engine operates.

Shaft: A pit either on the lode or through the surrounding rock or earth.

Pass / Surface Pass: An opening or shaft to let stuff, material and equipment down from the surface.

Stope: A horizontal bed of ore adjacent to the level. See clarification below.

Winze: A sink on the lode for communicating one level with another, for proving a lode, or for ventilation.

The above definition for stope is misleading. The stope or act of stoping is extraction of ore above or below a level, along the lode. The result is a void, in this case roughly tabular in shape.

5.2 Identification of mined areas and workings

Wheal Ellen mine operated intermittently from about 1872 until its closure in 1924 (Wilson, 1926). Mining was initially concentrated in the southern portion of Loc. 1146 under mining lease ML 14) by a John Hosken and soon after by Messrs Crowther and Mitchell (Gibbs *et al,* 1996) and may have extended further southwest into the adjoining lot which was part of ML 14 (Maitland, 1896) as Wheal Ellen South as shown in Image 1.

In 1898 the Fremantle Smelting Company purchased the land and separate workings (not connected to the old workings) were commenced to the north with access via a new main shaft (Gibbs, ibid). During this period, water inflow hampered mining to deeper drives and required pumping out.

A 1901 report by a Mr Woodward referenced in Montgomery, 1908 states that the lode had been worked to a depth of 158 feet.

A 1906 report by W.G. Sutherland also referenced in Montgomery states that the lode had been worked from the surface to a depth of about 70 feet, the lode varying in width from 1 foot to 6 feet.

By 1908 the new main shaft had been sunk to 63 feet and timbered to 30 feet depth. "A No. 1 Prospect Shaft" had been sunk to 33 feet depth on the north end of the property and at this depth a drive was carried at 15 ft. (Montgomery, 1908 referencing a report by Mr Lockhart). No other mention of this "No. 1 Prospect Shaft" and associated 15 ft drive are made on mine plans and sections reviewed. As discussed later, these workings are thought to be part of the Wheal Ellen North mine described in Montgomery.

The new or main workings described above are mostly within Lot 1146 but extend northeast through the corner of what was Mining Lease ML 17 and into ML 143 (formerly ML 13, Maitland 1898).

In September 1907, ML 13 was replaced by ML 113 and granted to William Shepherd for Wheal Ellen North mine. This covered the same 20 acres as ML 13. Montgomery (*ibid*) includes a description of Wheal Ellen North mine on ML 113 as being, “immediately north of the old Wheal Ellen mine.” However, these workings are: “..not supposed to be the main Wheal Ellen lode.” Reference to the 1898 geology map by Maitland, shows two mining leases at that time being ML 14 and ML 13 with two diorite dykes crossing them. An extract from this geology map is shown in Image 1. The mine workings that are the subject of this assessment are along the western lode as shown below.

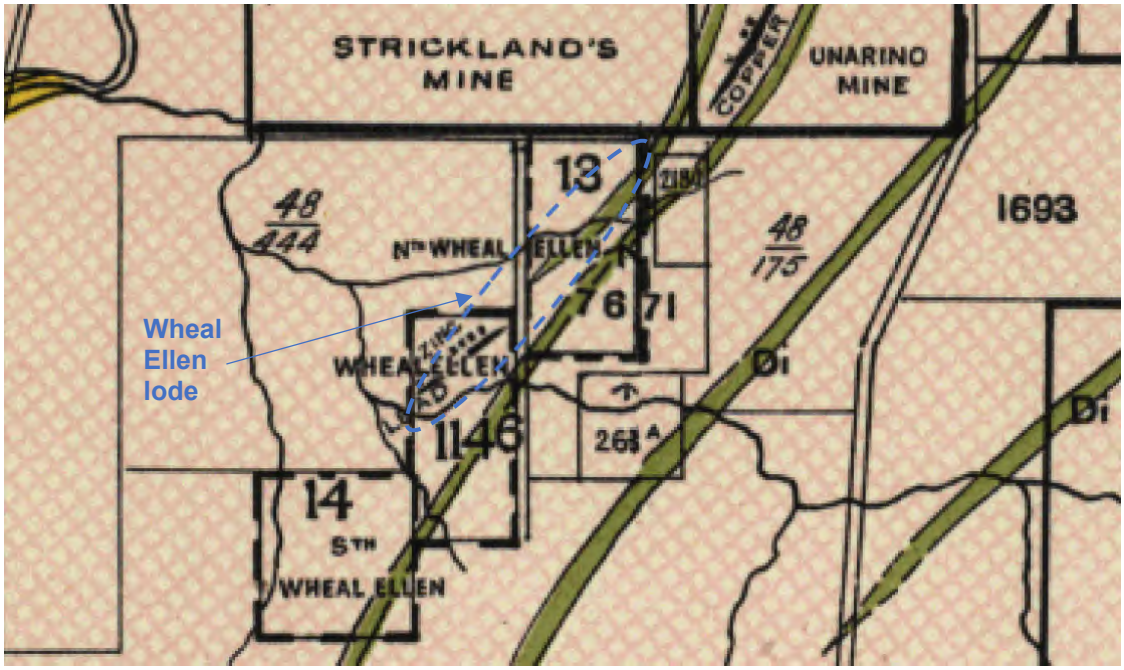

Image 1 Geology map extract showing leases and dykes (Maitland, 1898)

As shown in Image 2, using an extract from the Geology Sketch Map (Ref. 1689), the lode and surface features extend northeast across ML 13 / ML 113. That is, the north part of Lot 11448.

Further evidence of their location can be drawn from the Geology Sketch Map (Ref. 1689) and locations of surface features as shown in Image 2. Here the locations of passes or shafts shown on the Sketch Map that are attributed to being part of Wheal Ellen North are circled. While the identified feature S0113122 is attributed to one of these passes, the other three passes are not at identified feature locations.

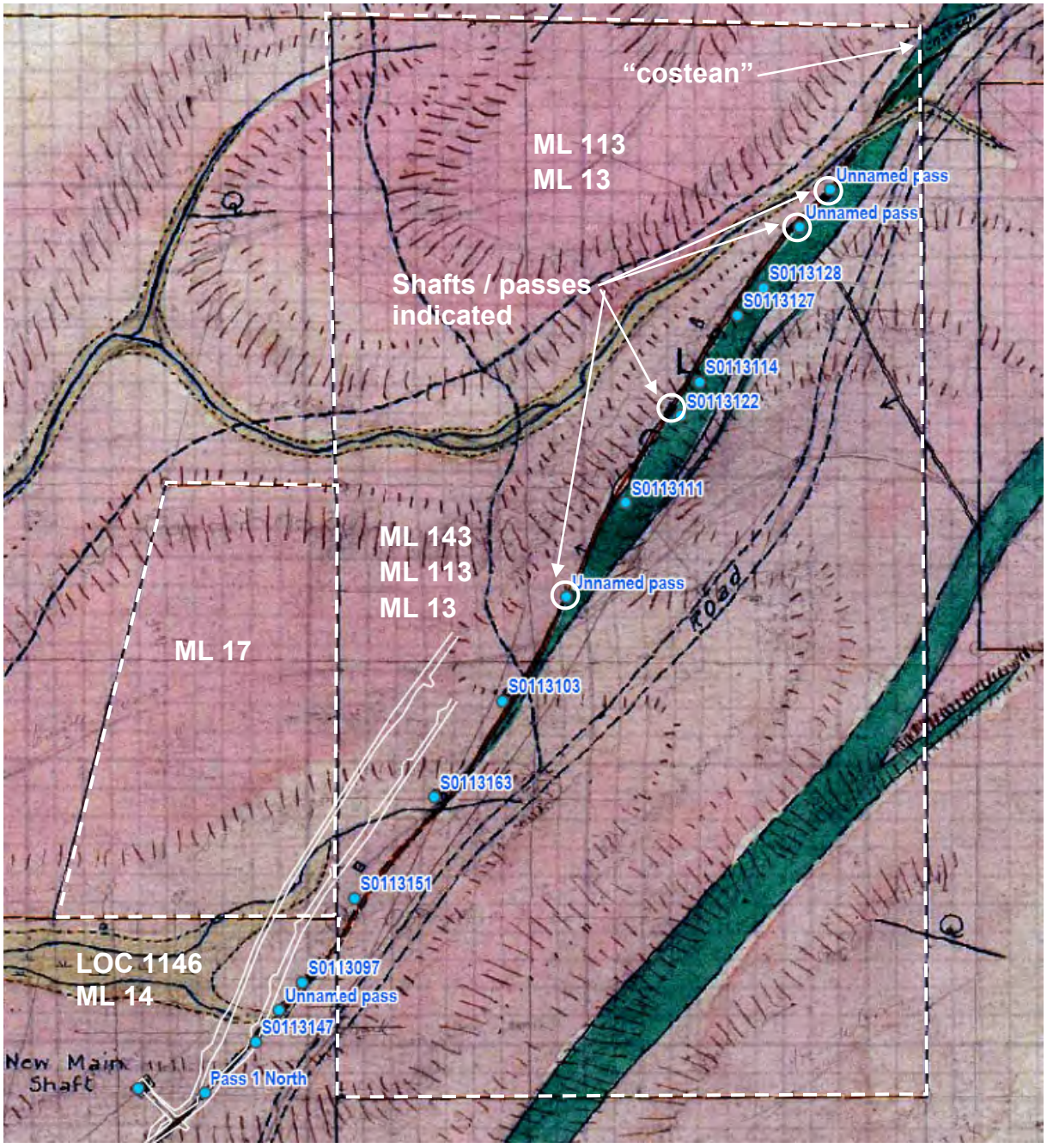

Image 2 Geology Sketch map extract (Ref. 1689) and features in ML 113

From 1917 to 1924, mining was undertaken by the Fremantle Trading Company using the same "new main shaft" to 270 feet (82 m) depth with levels at 125, 195 and 264 feet (38.1, 59.4 and 80.4 m depth) – Gibbs, *ibid* referencing Blockley, 1971).

The 1924 Department of Mines annual report includes a report by T. Blatchford dated 18 July 1924 on page 70 and 71. This states:

- "…the Wheal Ellen mine is almost depleted of ore above the 195 ft. level" and:
- "…the country rock is the typical garnetiferous gneiss of the Northampton district."
- In driving the 125 foot level: "there seems to have been a desire to leave the foot wall and incline the drive toward the hanging wall. This is particularly noticeable in the sections immediately north and south of the shaft, where there is a greater width in the lode formation".

- “I was not at all satisfied that the dip of the lode as shown on the mine plan is a true representation of what really occurs”.
- Regarding the No. 2 level: “Generally speaking the width of the stopes are almost as erratic as the mineral contents, and vary from two to occasionally 10 feet, but four feet would be a liberal average”.

Wilson (*ibid*) reports the normal dip of the lode is northwest at about 60° from the horizontal but practically vertical for a length of about 300 feet in the vicinity of the main shaft where, “The lode is considerably impoverished where it is vertical.” Wilson also states: “The present main shaft is about 600 feet north of an old shaft from which the lode was worked about 40 years ago”.

The 1971 GSWA Resources Bulletin 9, includes a description of Wheal Ellen. The following points are relevant to this assessment.

- “The main part of the mine workings are in sheared, strongly brecciated granulite.”
- “The principal ore shoots are on either side of a prominent S-bend in the lode on which the strike locally changes from 35 to 50 degrees, and the dip steepens from 60 to 90 degrees.”
- “The surface of the lode has been worked from a number of open-cuts, each about 40 to 50 feet (12 to 15 m) deep. Later, these were probably used as sand passes to fill stopes.”
- “Workings north of the old main shaft were inaccessible when the existing plans were made.”

Survey drawings and sketch maps provided by DMIRS are listed below.

- 1685 Wheal Ellen Lead Mine - Plan of workings and longitudinal section – undated.
- 1689 Wheal Ellen – Sketch Map of Geology – undated.
- 5744 Wheal Ellen – Plan and Section – undated.
- 10836 Fremantle Trading Co. Ltd. Wheal Ellen longitudinal section – 1924, 1925.
- 10837 Fremantle Trading Co. Ltd. Wheal Ellen plan and locality sketch – 1924.

The 1926 plan of workings and longitudinal section and undated Sketch Map of Geology were imported into the ArcGIS Project Map and are shown in Figure 3 and Figure 4 in Appendix B. The other referenced plans and sections are mostly consistent with these although reference to all plans and sections is needed as each shows different details.

The Old Workings, Main Workings and Northern Workings are summarised under the following sub-headings. Descriptions of shafts and other features are provided in Section 6.

5.3 Old Workings

Prior to 1898, two working levels were mined as the “Old Workings” being at 23 m (75 ft) and 41 m (135 ft) depth. These are shown in longitudinal section as Image 3 and Image 4 with annotations by GHD.

The Old Workings included the following surface connections:

- 1 x Old Main Shaft (feature S0113145).
- 1 x pass with associated 75 ft level workings.
- 1 x shaft with apparent level workings above 75 ft.

The areas of cross hatching or dashed lines in the below images represent areas of stoping.

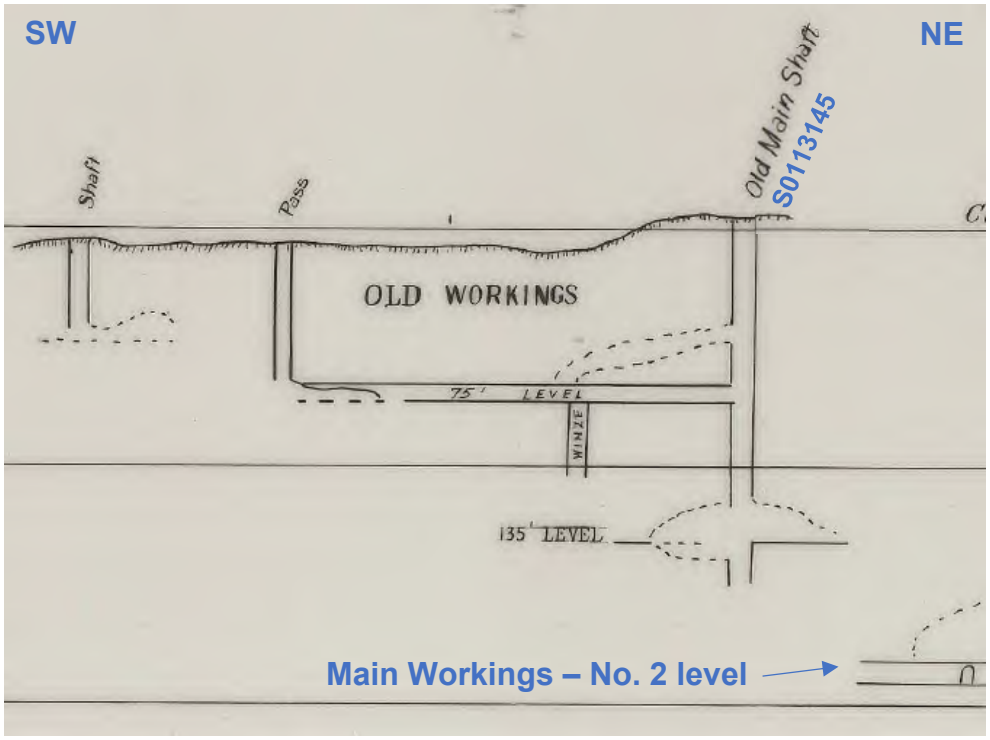

Image 3 Old Workings (Ref. 10836 dated 1924, 1925) – annotations by GHD

The Old Workings are not shown to be connected to the Main Workings. However, the comment in the 1971 GSWA Resources Bulletin 9: “Workings north of the old main shaft were inaccessible when the existing plans were made”, suggests that the old workings may extend further north than shown in Image 3. Image 4 also suggests this and shows parts of the Old Workings were access after 1925.

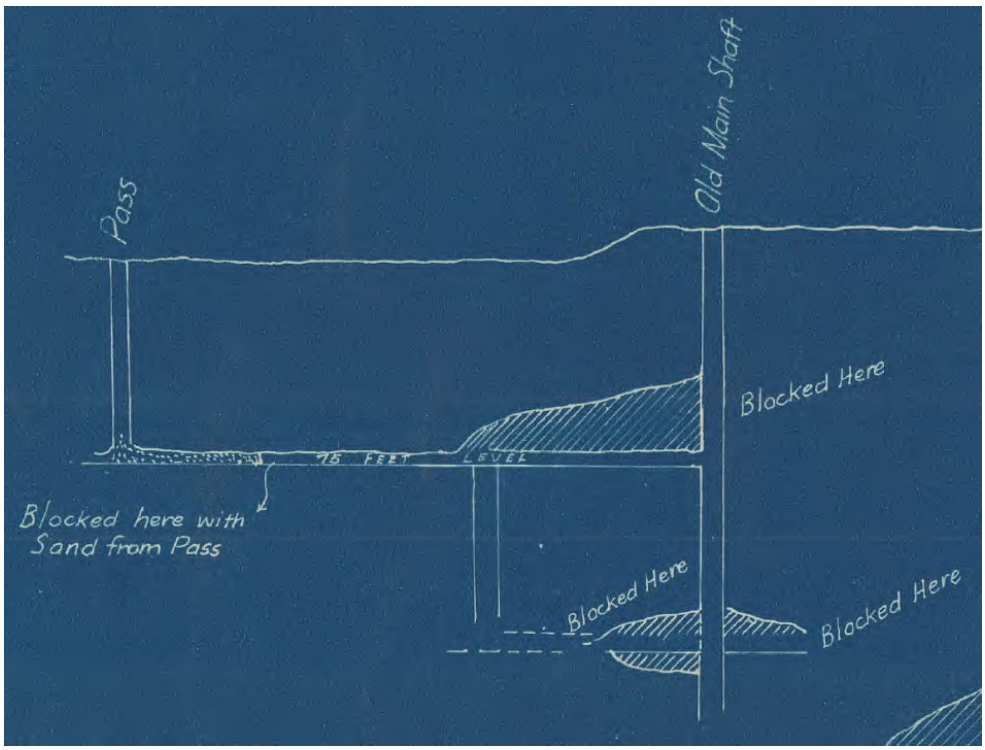

Image 4 Old Workings (Ref. 1685, undated) – annotations by GHD

5.4 Main Workings

The Main Workings comprise three levels at 38 m (125 ft), 59 m (195 ft) and 80 m (264 ft) as well as an “old level” and “old workings” above the No. 1 level. These are shown in section as Image 5 and Image 6 with annotations by GHD. The Main Workings included the following surface connections:

- 1 x Main Shaft (S0113158)
- 6 x named passes
- Several unnamed passes and open pits.

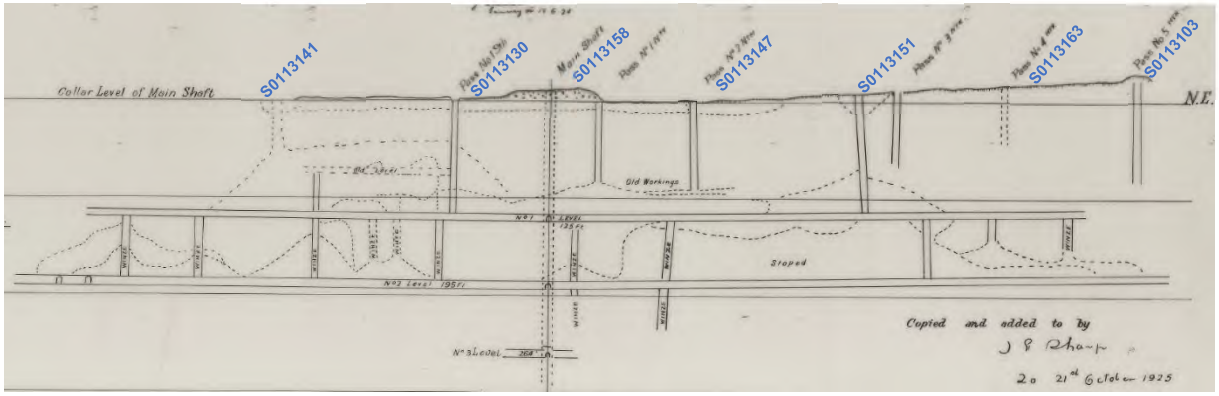

Image 5 Main Workings (Ref. 10836 dated 1924, 1925) – annotations by GHD

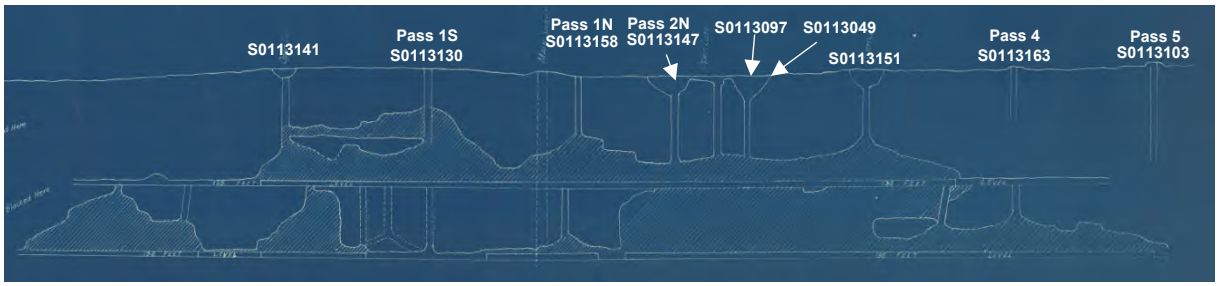

Image 6 Main Workings (Ref. 1685, undated) – annotations by GHD

5.5 Northern Workings – Wheal Ellen North

No plans or sections of Wheal Ellen North mine were provided or have been found during this assessment. The below description by Montgomery (1908) is transposed.

“This lease is on Crown lands immediately north of the old Wheal Ellen mine. A shaft has lately been sunk 60 ft. deep, in which a 6 in. seam of fair dressing lead ore was cut in hard greenstone country, but this is not supposed to be the main Wheal Ellen lode. At the bottom of the shaft this little lode has been followed about 10 ft. north and 12 ft. south, and there is a crosscut about 8 ft. At the time of my visit the bottom of the shaft was under water, which is too heavy to allow working to proceed without the aid of machinery. Further north there are fairly extensive old workings, at the north end of which a recent cut shows 12 in. in width of galena ore [in] greenstone dyke rock”. Montgomery (*ibid*).

The “recent cut” mentioned by Montgomery may be the costean in the very north eastern corner of Lot 11448 that is shown on the Geology Sketch Map (Ref. 1689) and in Image 2.

Also shown on the Geology Sketch Map and circled in Image 2 are four rectangles that represent shafts or passes along the lode.

A statutory declaration made by miner Henry Jenkins on 19 February 1910, referring to ML 113 and Wheal Ellen North mine, states:

> *"2 That I have been in charge of the mining operations on the said lease and during the last two years 150 feet of sinking 60 feet of driving besides considerable amount of costeaning has been done"* and;
>
> *"3 There are three shafts on the property each of which has been sunk to the depth of 50 feet at this depth water is encountered which comes in from the old workings of the Wheal Ellen the adjoining mine which is situated on private property owned by the Fremantle Smelting Works."*

6. Mine surface features

6.1 Introduction

A total of 18 features were investigated during the site walkover. The location of each is shown on the figures in Appendix B. Photographs from August 2020 are provided in Appendix C. Additional passes and shafts were identified during the assessment and are also shown.

A summary of the features is provided in Table 6-1 together with surveyed dimensions. Descriptions of each feature are provided under the below sub-headings, split into three areas.

6.2 Old Workings

6.2.1 Feature (S0113143)

This feature is a steep sided excavation or depression on the edge of the mine spoil "dump" and on the lode sub-crop. An exposed cast iron pipe is present along the north western crest.

Water was present at 1.55 m depth, measured from the void crest. The feature was dipped using a weighted tape measure to confirm the presence of a base below the water. The base of the feature is at the same level as the adjacent infilled shaft (S0113145).

As shown in the below images, minor deterioration of spoil around the feature has occurred over the past 20 years. The main difference in these photos is the amount of water present. The water depth observed by GHD in August 2020 being similar to the 2000 image.

Image 7 S0113143: 2000 and 2020 comparison photos (DMIRS)

Gibbs (*ibid*) includes the following description:

"Immediately north of the original shaft is an open cut area to a depth of over five metres. It is not clear whether this was intentionally excavated to explore or remove ore along the line of the lode (a 'costean'), or is it was partially a result of water erosion such as along the south-west side of the shaft. A large cast iron water pipe (one foot external diameter, 10 inch internal) which was possibly the means by which waste water was pumped from the shaft, runs along the top western edge of this pit."

It is likely this feature is the remnants of an open pit, excavated after the Old Workings were abandoned. Given its proximity to the Old Main Shaft, it is unlikely to have incorporated a pass.

The unstable material around this feature, particularly along the pipe make it more hazardous. However, the feature is of limited depth and not so steep sided to make climbing out of it difficult.

6.2.2 Old Main Shaft (S0113145)

The original depth of this shaft is about 41 m with levels at about 23 m and 41 m depths.

The shaft was partially collapsed with wooden beams at 3.2 m depth and loose spoil around the collar. Water was present at 3.1 m depth, measured from the void crest. The feature was dipped using a weighted tape to confirm the base where it was obscured by water. The backfilling in the shaft is at the same level as the adjacent pit (S0113143).

As shown in the below image from 2000 in comparison to the 2020 photos in Appendix C, the timber around the shaft collar has been removed or collapsed and the surrounding spoil fallen into the shaft to form a crater shape. Timber and steel remain in the upper portion of the shaft.

Image 8 S0113145: 2000 photo (DMIRS)

Gibbs (*ibid*) includes the following description:

"The original (1870s) shaft survives on a low pedestal of clay and rock. The shaft itself is open and the surrounding timbering appears to be in fair condition, although entry would be inadvisable. Water is clearly visible within the shaft, and is pumped for use on adjacent agricultural properties. Unfortunately, a broken water pipe has resulted in severe erosion of the soil pedestal along the south-west side of the shaft, exposing the exterior of the top two metres of timbering. A modern pump and remnants of a winch are adjacent to the shaft. There is no evidence of footings for a headframe above the mine."

The unstable spoil material around this feature make it particularly hazardous and climbing out of it would be very difficult.

6.2.3 Old workings pass and old workings shaft (no identifiers)

The Old Workings Pass and Old Workings Shaft are located within a vegetated area in the far south of Loc. 1146. This area is also within a watercourse where Wheal Ellen Creek East flows into Wheal Ellen Creek South.

The Old Workings Pass is estimated to have been about 24 m deep and the Old Workings Shaft about 15 m deep. They are both close to the lode sub-crop although the Pass is slightly west of the sub-crop line.

Both appear to have been backfilled and that fill subsided to form depressions. The Old Working Pass depression is shallow, not steep sided and well vegetated with grass. In comparison, the Old Workings Shaft has steeper un-vegetated sides indicating erosion and subsidence processes are continuing. Given the location of the shaft, surface water flows during heavy rainfall events are likely to be the primary trigger for instability.

Photos of these features from 2000 are not available. Photos provided by DMIRS from 2020 are shown below.

Image 9 Old Workings Pass: 2020 photo (DMIRS)

Image 10 Old Workings Shaft: 2020 photo (DMIRS)

6.3 Main Workings

6.3.1 Pass No. 5 North (S0113103)

Pass No. 5 North is located at the northern end of the Main Workings just west of the lode sub-crop and near a watercourse (as indicated on the Geology Sketch Map). Here the lode dips less steeply at about 60°. The original depth is shown on mine sections to be about 30 m although the pass is drawn open at the base. It's likely this and Pass No. 4 North were planned to extend to the No. 1 level at 125 feet (38 m) for future ventilation.

The pass has collapsed or been filled to a depth not exceeding 4.5 m. Erosion caused by surface water has resulted in the feature increasing slightly in size over the past 20 years although the sides have remained steep and the crest abrupt.

Image 11 S0113103: 2000 and 2020 comparison photos (DMIRS)

The dip of the lode can be seen in the below image with fretting of blocks from the hanging wall.

Between the hanging wall and debris is a deeper area which was surveyed to about 5 m depth. It is likely this connects with deeper voids. The lack of fine grained sediment indicates water does not pond in the feature and there is strong hydraulic connection to voids below.

Image 12 S0113103: 2020 photo (DMIRS)

While an attempt to fill this pass may have been made, the fill appears to have washed underground. The resulting feature is likely to be the surface expression of the collapsed stope.

6.3.2 Pass No. 4 North (S0113163)

Pass No. 4 North is located near the northern end of the Main Workings just west of the lode sub-crop and near a watercourse (as indicated on the Geology Sketch Map). Here the lode dips at about 60°. The original depth is shown on mine sections to be about 15 m although the pass is drawn open at the base. It's likely this and Pass No. 5 North were planned to extend to the No. 1 level for future ventilation.

The pass has subsided to a depth of 1.1 m. Little evidence of surface erosion was observed during the walkover and comparison between the 2000 and 2020 images below show little change other than vegetation.

Image 13 S0113163: 2000 and 2020 comparison photos (DMIRS)

It appears this pass has been backfilled and the backfill subsided to form a depression with steep sides. Further subsidence or erosion of the fill does not appear to be occurring.

6.3.3 Pass No. 3 North, unnamed pass (S0113151) and open pit

This open pit is located west of the lode and is associated with Pass No. 3 North and an unnamed pass at S0113151. Here the lode dips at about 60°.

Pass No. 3 North is only shown in one section (Ref. 10836) and is separate from the deeper unnamed pass at S0113151 as shown in Image 5. While Pass No. 3 North is shown to extend to about 24 m depth, the unnamed pass is shown to extend to the No. 1 level at 38 m depth and to have a surface open cut and stope above the No. 1 level.

In plan, Pass No. 3 North is only shown on the sketch map (Ref. 5744) whereas the unnamed pass is not shown. This is the opposite on other plans as shown in the below images.

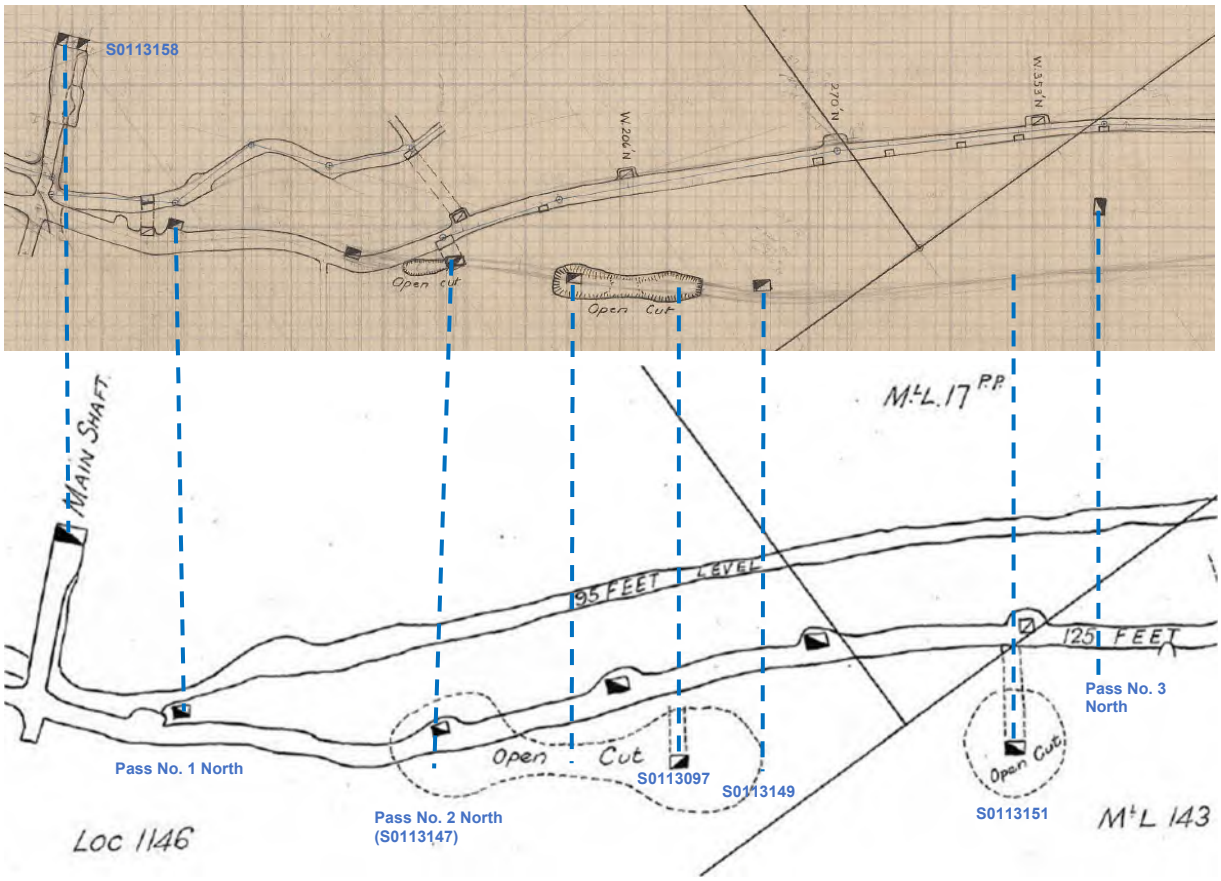

Image 14 Comparison of sketch map Ref. 5744 and plan Ref. 10836

The open cut at S0113151 was extended or grew to encompass Pass No. 3 North.

The base of the pit was obscured by waste such as sheet metal and car bodies. A small amount of water was observed in the base.

A tension crack about 10 m long was observed along the northern wall of the pit indicating instability of that wall. The crack may have been deepened and widened by erosion.

Comparison between photos from 2000 to 2020 show an increase in waste but generally not much change. The 2000 photo shows water in the base of the pit.

Image 15 S0113151: 2000 and 2020 comparison photos (DMIRS)

Given the depth of the pit and position along the lode sub-crop, it's likely the pit was excavated as an open cut and has not been backfilled. If connections to underground voids are present, they would be along the western wall (hanging wall) where the car bodies are piled in the 2000 photo above.

6.3.4 Passes and open pit (S0113097, S0113149)

Feature S0113149 and S0113097 are located along the lode sub-crop. Here the lode dips at about 60°.

As shown in Image 14, feature S0113149 is thought to be associated with a pass which extended to the No. 1 level at 38 m. Feature S0113097 is thought to be associated with another pass immediately to the southwest.

At S0113097 evidence of surface erosion caused by water runoff from the east is present with finer materials being washed to the base.

A comparison of the below photos between 2000 and 2020 shows little change at either feature other than vegetation.

Image 16 S0113149: 2000 and 2020 comparison photos (DMIRS)

Image 17 S0113097: 2000 and 2020 comparison photos (DMIRS)

Although now part of the same pit, it is clear in the below point cloud image that feature S0113149 is separate and more likely a backfilled pass which has subsided.

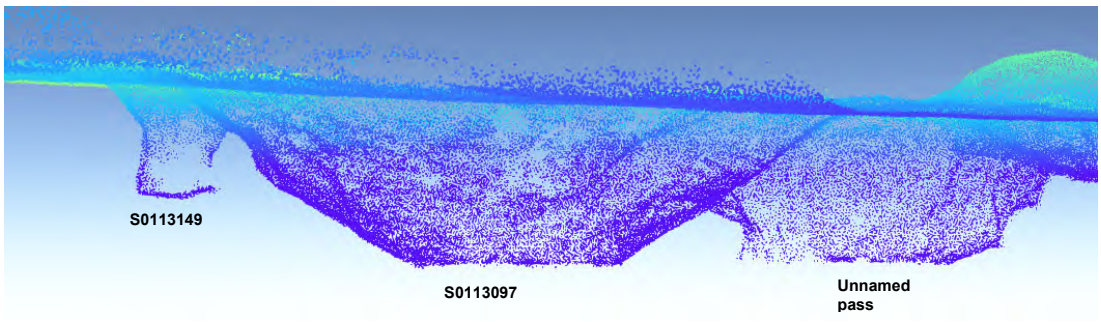

Image 18 S0113149 and S0113097: Point cloud elevation view

The base of S0113149 is about 2.1 m higher than the water in the base of S0113097 which is obscuring its base. The slopes of the pit suggest it has been open cut but it is distinct from the pit associated with an unnamed pass to the immediate southwest.

If connections to underground voids are present, they would be along the western wall. However water in the base of S0113097 (including the pit to the southwest) has obscured them.

6.3.5 Pass No. 2 North (S0113147)

This feature has previously been identified by DMIRS as Pass No. 1 North. However, our assessment has concluded it is Pass No. 2 North.

Pass No. 2 North is the southwestern extension of the “barbell” shaped open cut. It extended to “old workings” at about 29 m depth with stoping below this as is the case of the adjacent workings. It is currently about 3 m deep, shallower than the adjacent pits to the northeast. This is because it has been filled with fines (soil). The original depth is expected to have been similar to the adjacent pit at about 6.7 m.

The interpreted relationship between Pass No. 1 North, Pass No. 2 North and the Main Shaft (S0113158) is shown in the below point cloud image.

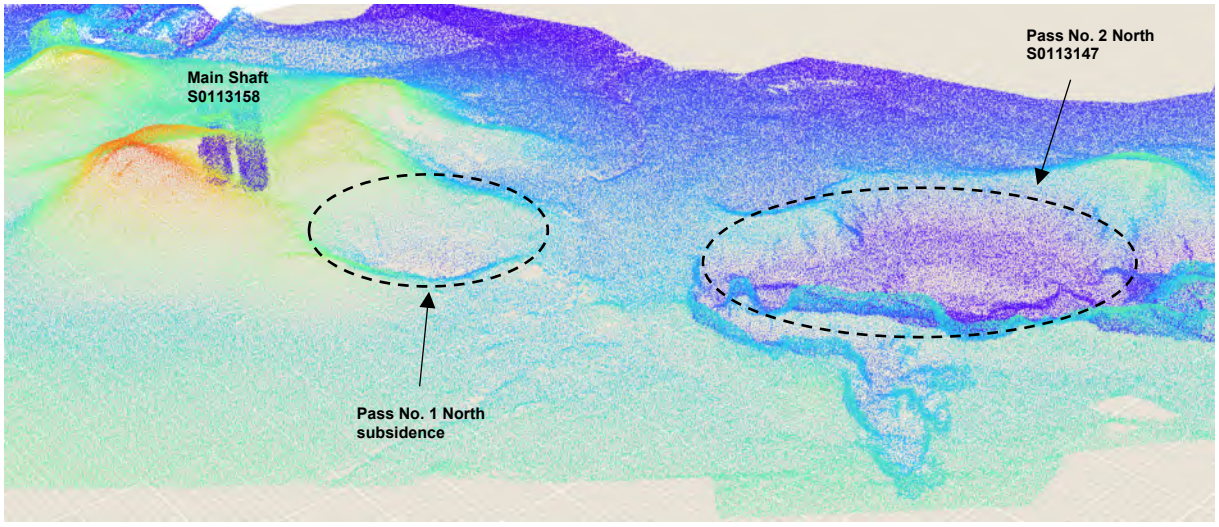

Image 19 S0113147 and Pass No. 1 North: Point cloud elevation view

A comparison of the below photos between 2000 and 2020 shows a sinkhole formed within the fines since 2000.

Image 20 S0113147: 2000 and 2020 comparison photos (DMIRS)

As shown in the August 2020 photo in Appendix C, surface runoff from the east has caused significant surface erosion which has extended to the adjacent road. Despite this additional erosion, the sinkhole does not appear to have deepened significantly but rather increased in plan area. The 2020 drone footage shows only ponded water partially across the sinkhole base.

Based on the observed sinkhole formation and behaviour since, it appears that soil fines migrated into underground voids under the action of hydraulic gradient due to water ponding in the pit and seeping through the fines. The resulting piping failure allowed the pit to drain into the workings, providing relief from the hydraulic gradient and return to unsaturated conditions with the accompanying suctions increasing strength and halting growth of the sinkhole. Reoccurrence of the sinkhole would be expected with inundation of the pit.

6.3.6 Pass No. 1 North

Pass No. 1 North is not identified as a feature and is expected to be buried in the mine spoil ‘dump’ about 21 m east of the Main Shaft. Similar to Pass No. 2 North, it is likely to have extended to the “old workings” level at about 29 m depth and has been stoped above and below the No. 1 level.

The approximate position of Pass No. 1 North is shown on the Figures included in Appendix B. Here a bowl shaped depression about 2 m deep and 20 m in diameter has formed at the toe of the mine spoil pile and it is likely this is due to subsidence of the spoil into the pass below.

In this area, the dip of the lode is near vertical with three levels of workings present.

6.3.7 Main Shaft (S0113158)

The Main Shaft is about 19 m northwest of the lode sub-crop and reported to have extended vertically to about 80 m depth.

In August 2020, the shaft was dipped to 60.5 m depth, (the limit of the tape measure) with the base of the shaft not encountered. Groundwater was at 5.9 m depth.

The condition of the shaft collar appears to have changed little from 2000 to 2020 as shown in the below photos.

Image 21 S0113158: 2000 and 2020 comparison photos (DMIRS)

Gibbs (*ibid*) includes the following description in part:

"The 1890s shaft is located approximately 200 metres NNE of the 1870s shaft, with the collar standing on a pedestal of clay several metres higher than the surrounding land surface. This is visible in the 1918 photograph of the site, although it is difficult to determine if this indicates the original land surface or is artificial. The shaft and timberwork appear to be in good condition, although no attempt was made to enter. The shaft itself appears was originally three-chambered (with provision for worker access, pumps, and winding gear) such as would have been common in mines throughout the area and similar to those from contemporary Cornish mines (Earl, 1994). The two western chambers have been filled with soil up to surface level, although the wooden timbering along the collar at the top can be still be seen."

The three chambers are visible but the filling is not and is assumed to have subsided. A laser point cloud and video within both the western and eastern chambers shows timber boards extending to the water. Some of the boards have fallen away to reveal the rock behind.

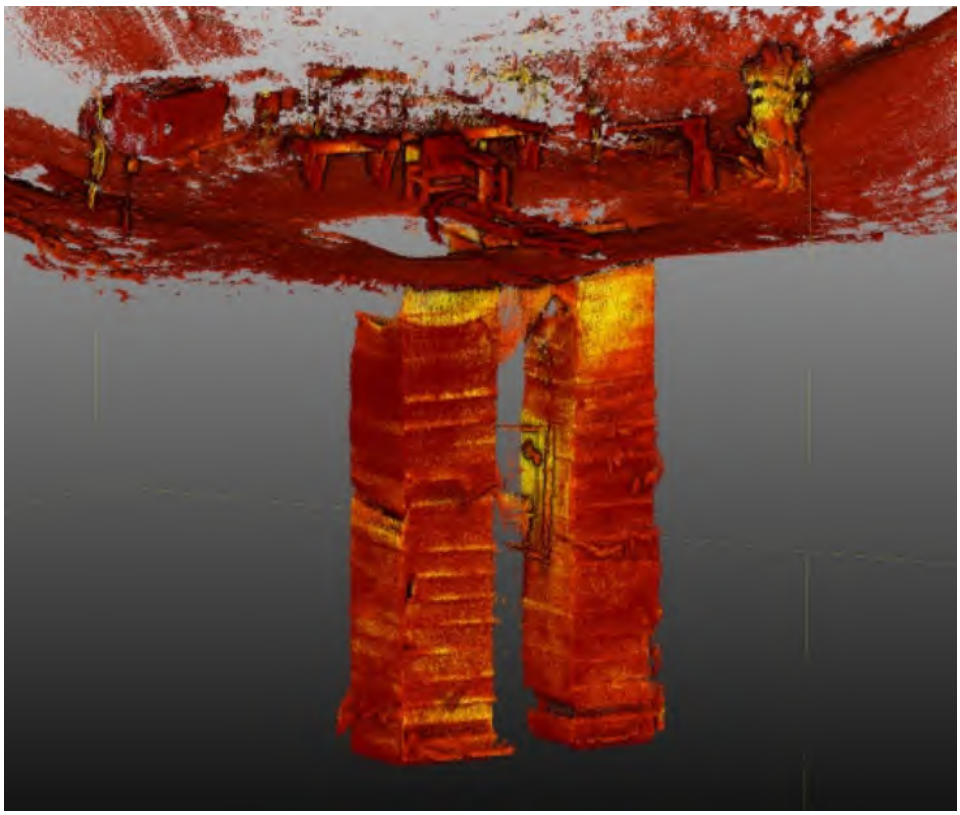

Image 22 Main Shaft (S0113158) point cloud

The western and eastern chambers are open and unobstructed whereas the central chamber is partially obstructed with cross supports, pipe and hoses. Some of these obstructions are visible in the above point cloud image.

6.3.8 Pass No. 1 South (S0113130)

Pass No. 1 South is located on the lode sub-crop where the lode dip is near vertical. The pass originally extended to a shallower “old level” at about 22 m depth and then the No. 1 level at 38 m and was stoped above this level, up to about 14 m from the surface.

While only about 2.5 m in diameter, it is currently about 7 m deep with vertical sides and no water in the base. Erosion caused by surface water and fretting appears to have increased the diameter of the pass near the ground surface, making the crest more distinct and less vegetated as shown in the below image.

Image 23 S0113130: 2000 and 2020 comparison photos (DMIRS)

It appears that backfilling of the pass has subsided with the 2020 plan dimensions likely to be similar to the original pass.

6.3.9 Open cut and unnamed pass (S0113141)

The open cut and unnamed pass at S0113141 is located on the lode sub-crop in an area where the lode dips less steeply again, in the order of 50° to 60° judging by the difference in the level traces as shown on the mine plans.

Similar to Pass No. 1 South, this pass is expected to have extended to the No. 1 level at 38 m depth and been stoped above this to a similar height. The subsequent open cut formed an elongated funnel shaped pit about 6.5 m deep. The western side of which is a near vertical face.

The pit was filled with water in the base which was dipped using a weighted tape measure to confirm the base where it was obscured by the ponded water.

Evidence of surface erosion caused by water runoff from the east is present with finer materials being washed to the base of the feature. However, comparison of the below 2000 and 2020 images indicates only minor erosion.

Image 24 S0113141: 2000 and 2020 comparison photos (DMIRS)

It appears that backfilling of the pass has subsided although it is not clear to what extent the open cut was previously filled, if at all.

6.4 Northern workings

6.4.1 Features S0113128 and S0113127 (probable subsidence)

These two northern most features are on or just east of the lode sub-crop as shown on the Geology Sketch Map (Ref. 1689). The dip of the lode here is less certain due to the absence of a plan of working levels but is likely to be in the order of 60°.

These features form part of a chain of bowl shaped depressions not exceeding 1.9 m depth. Neither feature contained ponded water although they are both expected to collect surface water runoff from the slope to the southeast during periods of rainfall.

Comparison of the below 2000 and 2020 images show little change in the past 20 years other than vegetation.

Image 25 S0113127: 2000 and 2020 comparison photos (DMIRS)

Image 26 S0113128: 2000 and 2020 comparison photos (DMIRS)

These features are not associated with any known shafts or passes and probably represent subsidence resulting from movement of soil into stopes below under the action of water flows.

6.4.2 Feature S0113114 (possible shaft)

This feature may be the 60 ft (~18 m) shaft described by Montgomery (*ibid*). It is on or just east of the lode sub-crop as shown on the Geology Sketch Map (Ref. 1689). The dip here is less certain due to the absence of a plan of working levels but is likely to be in the order of 60°.

Unlike the broader feature S0113127 to the north, this feature is small and isolated although it is along the lode sub-crop like the other features. The origin of timber inside the feature is not known but may be shaft timbers.

The feature did not contain ponded water although it is expected to collect surface water runoff from the slope to the southeast during periods of rainfall.

Comparison of the below 2000 and 2020 images show some removal of sticks, changes to vegetation and also a flattening of the pit sides since 2000. This is attributed to erosion from surface water during periods of heavy rain.

Image 27 S0113114: 2000 and 2020 comparison photos (DMIRS)

The origin of this feature is difficult to ascertain. Possibilities are a shaft or subsidence resulting from movement of soil into a stope below under the action of water flows.

6.4.3 Feature S0113122 (possible pass)

This feature is on or just east of the lode sub-crop as shown on the Geology Sketch Map (Ref. 1689). The dip of the lode here is less certain due to the absence of a plan of working levels but is likely to be in the order of 60°.

The feature is about 3.6 m deep and did not contain ponded water although it is likely to collect surface water runoff from the adjacent slope during heavy rain.

The shape of the feature is similar to Pass No. 5 North with the western face noticeably steeper and the base sloping down to the northwest in the same direction as the lode dip. However, S0113122 is elongated along the lode sub-crop with a secondary and shallower depression on the southern end and a narrow undercut section on the northern end. This undercut section is visible in the 2000 photo as well as the below point cloud image.

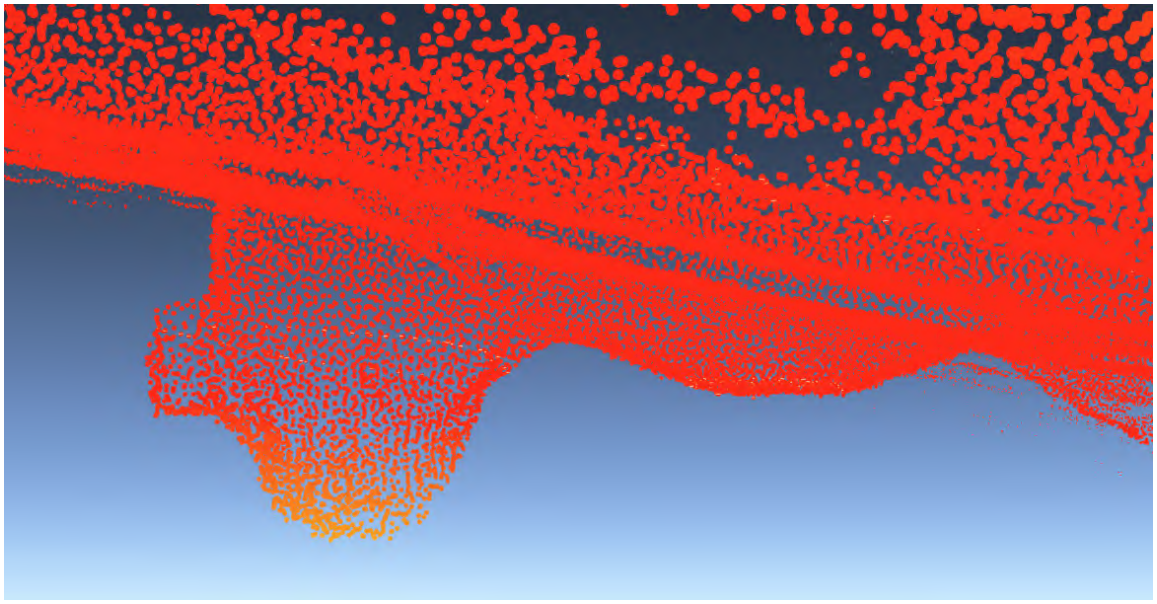

Image 28 S0113122 point cloud

Comparison of 2000 and 2020 photos below show little change in the past 20 years. Some collapse of the undercut section has occurred with the loss of a group of swallow nests that are visible in the 2000 photo but not the 2020 photo.

Image 29 S0113122: 2000 and 2020 comparison photos (DMIRS)

Image 30 S0113122: 2020 photo (DMIRS)

The pass may have been backfilled but this material has since subsided or been washed into a stope below. The resulting feature is likely the surface expression of the stope.

6.4.4 Feature (S0113111)

This feature is on the lode sub-crop as shown on the Geology Sketch Map (Ref. 1689) and forms part of a chain of shallow depressions along the sub-crop. The dip of the lode here is less certain due to the absence of a plan of working levels but is likely to be in the order of 60°.

The feature is about 3.6 m deep and roughly circular in plan. It did not contain ponded water although it is expected to collect surface water runoff from the slope to the southeast during periods of rainfall.

Comparison of the below 2000 and 2020 images show removal of some timber, changes to vegetation and possible erosion of material from the base of the feature since 2000, deepening it although this may be from removal of the timber.

Image 31 S0113111: 2000 and 2020 comparison photos (DMIRS)

The likely origin is a subsidence feature resulting from movement of soil into a stope under the action of water flows.

6.4.5 Sinkhole 1 and Sinkhole 2

These features were identified through review of the higher resolution aerial image captured during the August 2020 survey and confirmed through review of point cloud data. Both appear to be small steep sided but shallow sinkholes along the lode sub-crop.

6.4.6 Other depressions

In the Northern Workings area, several other shallow depressions along the lode sub-crop were identified from the survey. For the purpose of estimating their volume for filling they have been included in Table 6-1.

6.5 Summary table of features

Table 6-1 below provide a summary of feature attributes, including coordinates and references to the photographs in Appendix C.

Table 6-1 Summary of mine features

Area	Feature	Type / Name	Coordinates (GDA/MGA94)		Approximate Dimensions (m)			Approximate fill volume (m^3) [2]	Depth to water (m)	Debris present	Comments
			Easting	Northing	Depth	Length	Width				
Northern Workings	-	Unnamed Pass	266809	6860189	0	0	0	0	N/A	N/A	Not visible
	-	Unnamed Pass	266798	6860176	0	0	0	0	N/A	N/A	Not visible
	S0113**128**	Stope subsidence	266786	6860153	0.8	13.1	7.8	9	Not present	None	Subsidence next to road running parallel with these features
	S0113**127**	Stope subsidence	266777	6860143	1.1	21.0	5.2	12	Not present	None	
	S0113**114**	Shaft ?	266763	6860119	1.0	3.3	2.6	10	Not present	Timbers	
	S0113**122**	Pass ?	266756	6860107	3.6	5.5	3.7	120	Not present	None	Collapsed shaft
	S0113**111**	Stope subsidence	266737	6860075	1.8	32.8	3.5	23	Not present	Timber removed	Subsidence parallel to road
	-	Unnamed Pass	266716	6860041	0	0	0	17	N/A	N/A	
	-	Sinkhole 1	266799	6860170	0.5	1.0	0.6	0.6	unknown	unknown	Identified from aerial photograph
	-	Sinkhole 2	266726	6860063	0.3	1.7	1.0	16	unknown	unknown	Identified from aerial photograph
	-	Other depressions [1]	N/A	N/A	-	-	-	160	Not present	None	Identified from aerial survey
Main Workings	S0113**103**	Pass No. 5 North / stope	266694	6860003	4.5	5.1	4.5	47	Not present	Metal scrap / tyres	Erosion may result in shaft extending to road presenting a hazard. Sloping base down dip of lode.
	S0113**163**	Pass No. 4 North	266670	6859968	1.1	6.8	6.8	24	base wet from rain	None	Shallow subsidence feature. Wet in base – ponded water from rainfall
	S0113**151**	Open Cut / Pass No. 3 North and unnamed pass	266641	6859930	5.5	22.0	15.5	1090	5.2	Car body/ scrap/ tyres. suspected ACM	Recent active erosion caused by surface water expanding void. Tension crack and instability of northern wall.
	S0113**097**	Open Cut / Unnamed Passes x 2	266623	6859899	6.7	25.0	18.4	1370	5.8	Extensive. Scrap metal, suspected ACM	Recent active erosion caused by surface water drainage expanding void to form single pit.
	S0113**149**	Unnamed Pass	266632	6859906	3.7	2.0	1.1	25	Not present	None	
	S0113**147**	Pass No. 2 North	266607	6859878	3.0	50	30	865	3.0 partial	None	Severe erosion of fines extending to haul road.
	-	Pass No. 1 North	266589	6859859	0	0	0	0	N/A	N/A	Buried in spoil dump
	S0113**158**	Main Shaft	266565	6859860	> 60.5	3.3	1.1	250	5.9	None	Timber supported sidewalls of shaft which remains open. Assumed for 70 m for volume estimate.
	S0113**130**	Pass No. 1 South	266558	6859825	7.0	1.9	2.5	35	Not present	None or very little	Slight erosional features.
	S0113**141**	Open Cut / Unnamed Pass	266543	6859781	6.6	17.1	8.4	550	6.5	None or very little	Slight erosional features.
Old Workings	S0113**143**	Open Cut	266498	6859704	1.5	12.8	7.1	175	1.5	Inert waste from stockpile	Exposed pipe along western crest
	S0113**145**	Old Main Shaft	266490	6859699	3.2	3.8	3.2	26	3.1	None	Collapsed timbers at 3.2 m
	Old Workings Pass	Pass	266466	6859645	0.6	4.2	2.5	10	Not present	None	Heavily vegetated and subsided
	Old Workings Shaft	Shaft	266457	6859621	0.7	3.4	2.5	16	Not present	Metal wire	Heavily vegetated and subsided

[1] Added for volume estimate for remediation filling
[2] Sum 4,850 m^3

7. Hazards from past mining

7.1 Context and limitations

This section documents existing hazards that present dangers to people accessing the site which should be communicated to those people and managed until remediation is complete.

The hazards considered and documented are limited to:

- Subsidence / collapse of the ground above mine workings.
- Instability around the crest of existing shafts, pits or subsidence features.
- Existing features observed by GHD in August 2020.
- Potential subsidence events occurring after August 2020 that we have been able to identify by the assessment presented herein.

The Department of Industry and Resources guideline, *Safety Bund Walls Around Abandoned Open Pit Mines* (Ref. ZMA048HA, Dec 1997), is not directly applicable to Wheal Ellen as the guideline is intended for long term abandonment of pits deeper than 5 m where the Mine Safety and Inspection Act 1994 and 1995 Regulation apply. The context of this section is short term hazard reduction where public access to the site is restricted by existing fencing such that a mechanism is available to induct people accessing the site, making them aware of the below hazards and controls.

7.2 Known (visible) hazards

The identified features listed in Table 7-1 present known hazards which are visible in daylight provided grass does not obscure them. The danger they present to people include:

- Shallow depressions, the base of which may subside or collapse
- Open cuts with passes in the base which may subside or collapse
- Shafts with steep sides and water
- Open cuts or pits with steep sides, some of which are partially filled with water, especially following rain.

Further description of the identified hazard at each location is provided in Table 7-1 together with possible consequences and minimum controls.

The minimum controls are intended to limit access to areas of elevated danger. Should access into these areas be required, additional risk assessment and controls would need to be developed and these approved by DMIRS.

Table 7-1 Known (visible) hazards and minimum controls

Location	Type / Name	Hazards identified	Possible consequences	Minimum controls
S0113**128**	Stope subsidence	Unstable crest	Slip, minor fall	Do not enter depression
S0113**127**				
S0113**114**	Shaft ?	Collapse of base into bridged void	Fall, entrapment	Remain at least 2 m from crest
S0113**122**	Pass ?	Unstable crest, fall from height	Fall, entrapment	Remain at least 2 m from crest
S0113**111**	Stope subsidence	Unstable crest	Slip, minor fall	Do not enter depression
S0113**103**	Pass 5N / stope	Unstable crest, fall from height	Fall, entrapment	Remain at least 2 m from crest
S0113**163**	Pass 4N	Unstable crest	Slip, minor fall	Do not enter depression
S0113**151**	Cut / Pass 3N, pass	Unstable crest, fall from height	Fall	Remain at least 3 m from crest
S0113**097**	Open Cut / Passes	Unstable crest, fall from height	Fall	Remain at least 2 m from crest
S0113**149**	Unnamed Pass	Unstable crest, fall from height	Fall, entrapment	Remain at least 2 m from crest
S0113**147**	Pass 2N	Eroding backfill, unstable crest	Minor fall	Remain at least 2 m from crest
[1]	Pass 1N	Collapse of base into bridged void	Fall, entrapment, drowning	Do not enter depression
S0113**158**	Main Shaft	Collapse, fall from height, water filled	Fall, entrapment, drowning	Remain at least 2 m from crest
S0113**130**	Pass 1S	Unstable crest, fall from height	Fall, entrapment	Remain at least 2 m from crest
S0113**141**	Open Cut / Unnamed Pass	Unstable crest, fall from height	Fall	Remain at least 2 m from crest
S0113**143**	Open Cut	Unstable crest, water filled	Minor fall, drowning	Remain at least 2 m from crest
S0113**145**	Old Main Shaft	Unstable crest, water filled	Fall, entrapment, drowning	Remain at least 3 m from crest
Old Working Pass	Pass	Collapse of base into bridged void	Fall, entrapment, drowning	Do not enter depression
Old Workings Shaft	Shaft	Collapse of base into bridged void	Fall, entrapment, drowning	Remain at least 2 m from crest
Other depressions / sinkholes within mined area [1]		Unstable crest	Slip, minor fall	Do not enter depression
[1] Refer to Figures in Appendix B and coordinates in Table 6-1.				

7.3 Potential (hidden) sinkhole hazards

Subsided stopes have been interpreted to have occurred and other shallow stope voids may remain. The danger presented to people is collapse of the ground into a stope (void) beneath. Such hazards exist where the ground bridges over the void. This often occurs where a subsurface void migrates toward the ground surface through caving of the void roof until the roof is not able to span over the void and collapses into it. Collapse may be triggered by surface water flow, vibration or vehicular traffic or may occur without an obvious trigger. Such events are often called sinkholes.

In the context of Wheal Ellen, sinkholes would be more likely to occur and be more hazardous where the lode dip is steep and surface disturbance through erosion or excavation occurs. This includes borehole drilling, particularly with air percussion tools which both vibrate and pressurise the ground and with water flush drilling techniques which may cause erosion.

Where the lode is less steep, as is typically the case, caved roof material is more likely to remain as fallen (rather than migrate deeper into the workings) and bulk in volume, to effectively prevent further roof caving. However, the action of surface water flowing underground tends to transport caved material deeper into the workings and allow the propagation of voids higher.

Taking the above likelihood and magnitude (severity) into consideration, zones of potential sinkhole hazard have been defined as follows:

- **Low** sinkhole hazard: within the mined area generally
- **Moderate** sinkhole hazard: lode sub-crop with surface water where the lode is not steep
- **High** sinkhole hazard: mined area where the lode is vertical / near vertical.

Zones of Low, Moderate and High sinkhole hazards are shown on Figure 6 in Appendix B.

Table 7-2 presents recommended minimum controls for each hazard zone. These are intended to limit activity. Should other activities be required, additional risk assessment and controls would need to be developed and these approved by DMIRS.

Table 7-2 Sinkhole hazard zones and minimum controls

Sinkhole hazard zone	Permitted activities	Minimum controls for permitted activities	Specifically prohibited activities
Low	Foot traffic Test pitting with backhoe / excavator or hand tools Borehole drilling – auger, coring, washboring In-situ geotechnical testing: SPTs, DCPs, CPTs Vehicle traffic and daytime parking Excavation of stockpiles	Activity specific risk assessment and development of SWMS. . Table 7-1 access restrictions. Daily pre-start meeting to inspect work area for changed conditions, review hazards, risks and controls. Suspension of activities during flooding with reassessment to allow recommencement [2]	Lone working Air percussion or sonic drilling Drill water sumps / disposal Packer testing Amenities / compounds / tanks / structures Placement of stockpiles / filling Water soaks / infiltration Rollers / compactors Cranes
Moderate	Foot traffic Test pitting with backhoe / excavator or hand tools Borehole drilling – auger In-situ geotechnical testing: SPT's, DCPs, CPTs Light vehicle traffic Heavy vehicle traffic on access road only [3] Excavation of stockpiles		As above plus: Drilling by washbore / coring Vehicle parking / unloading
High	Foot traffic Test pitting / auger with backhoe / excavator or hand tools Excavation of stockpiles [4]		As above plus: Vehicular traffic Borehole drilling – drill rig In-situ geotechnical testing: SPT's, DCPs, CPTs

[1] Refer to Figures 6 in Appendix B for sinkhole zone extents.

[2] Reassessment by a suitability experienced and qualified Geotechnical Engineer or Engineering Geologist approved by DMIRS.

[3] Additional controls for the access road, if considered warranted, could include modification of drainage paths to avoid water ponding and / or; excavation of the pavement and subgrade to about 1 m depth, followed by subgrade replacement with granular fill incorporating a polyester geogrid layer at subgrade level with ultimate tensile strength of at least 80 kN/m at 10% strain (e.g. ACEGrid GG80-11). Further geotechnical engineering advice would be recommended to progress such a control.

[4] Stockpile removal may increase danger by exposing new hazards. Following stockpile excavation, hazards, risks and controls should be reassessed.

If non-permitted or specifically prohibitive activities need to be undertaken, specific geotechnical advice should be sought to assess the risks for that activity and develop appropriate mitigations (controls). Examples of controls which may be appropriate are:

- Creation of work pads by excavation and replacement to a depth of 1 m to confirm the absence of voids. This could be combined with Ground Penetrating Radar survey in the base of excavations to check for large voids and/or inclusion of polyester geogrid layers within the backfill material
- Use of temporary ground beams and or matts to distribute load under outrigger pads or wheels
- Use of scaffold planks on the ground to act as walkways.

Concentration of load, particularly where there is not redundancy and consequences of support failure are greater, should be avoided. For example, failure of a drill rig outrigger would result in sudden leaning of the rig. The likelihood of this occurring could be effectively reduced by supporting the outrigger on an in ground beam that is capable of spanning over a small (less than 1 m diameter) void occurring beneath part of it.

8. References

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Appendices

Appendix A – General Notes

GENERAL NOTES

GHD
Specialist Services in Geotechnical Engineering, Geology, Field/Laboratory Testing and Hydrogeology
www.ghd.com/Geotechnical

The report contains the results of a geotechnical investigation or study conducted for a specific purpose and client. The results may not be used or relied on by other parties, or used for other purposes, as they may contain neither adequate nor appropriate information. In particular, the investigation does not cover contamination issues unless specifically required to do so by the client.

To the maximum extent permitted by law, all implied warranties and conditions in relation to the services provided by GHD and the report are excluded unless they are expressly stated to apply in the report.

TEST HOLE LOGGING

The information on the test hole logs (boreholes, test pits, exposures etc.) is based on a visual and tactile assessment, except at the discrete locations where test information is available (field and/or laboratory results). The test hole logs include both factual data and inferred information. Moreover, the location of test holes should be considered approximate, unless noted otherwise (refer report). Reference should also be made to the relevant standard sheets for the explanation of logging procedures (Soil and Rock Descriptions, Core Log Sheet Notes etc.).

GROUNDWATER

Unless otherwise indicated, the water depths presented on the test hole logs are the depths of free water or seepage in the test hole recorded at the given time of measuring. The actual groundwater depth may differ from this recorded depth depending on material permeabilities (i.e. depending on response time of the measuring instrument). Further, variations of this depth could occur with time due to such effects as seasonal, environmental and tidal fluctuations or construction activities such as a change is ground surface level. Confirmation of groundwater levels, phreatic surfaces or piezometric pressures can only be made by appropriate surveys, instrumentation techniques and monitoring programmes.

INTERPRETATION OF RESULTS

The discussion or recommendations contained within this report normally are based on a site evaluation from discrete test hole data, often with only approximate locations (e.g. GPS). Generalised, idealised or inferred subsurface conditions (including any geotechnical cross-sections) have been assumed or prepared by interpolation and/or extrapolation of these data. As such these conditions are an interpretation and must be considered as a guide only.

CHANGE IN CONDITIONS

Local variations or anomalies in ground conditions do occur in the natural environment, particularly between discrete test hole locations or available observation sites. Additionally, certain design or construction procedures may have been assumed in assessing the soil-structure interaction behaviour of the site. Furthermore, conditions may change at the site from those encountered at the time of the geotechnical investigation through construction activities and constantly changing natural processes.

Any change in design, in construction methods, or in ground conditions as noted during construction, from those assumed or reported should be referred to GHD for appropriate assessment and comment.

GEOTECHNICAL VERIFICATION

Verification of the geotechnical assumptions and/or model is an integral part of the design process - investigation, construction verification, and performance monitoring. Variability is a feature of the natural environment and, in many instances, verification of soil or rock quality, or foundation levels, is required. There may be a requirement to extend foundation depths, to modify a foundation system and/or to conduct monitoring as a result of this natural variability. Allowance for verification by appropriate geotechnical personnel must be recognised and programmed for construction.

FOUNDATIONS

Where referred to in the report, the soil or rock quality, or the recommended depth of any foundation (piles, caissons, footings etc.) is an engineering estimate. The estimate is influenced, and perhaps limited, by the fieldwork method and testing carried out in connection with the site investigation, and other pertinent information as has been made available. The material quality and/or foundation depth remains, however, an estimate and therefore liable to variation. Foundation drawings, designs and specifications should provide for variations in the final depth, depending upon the ground conditions at each point of support, and allow for geotechnical verification.

REPRODUCTION OF REPORTS

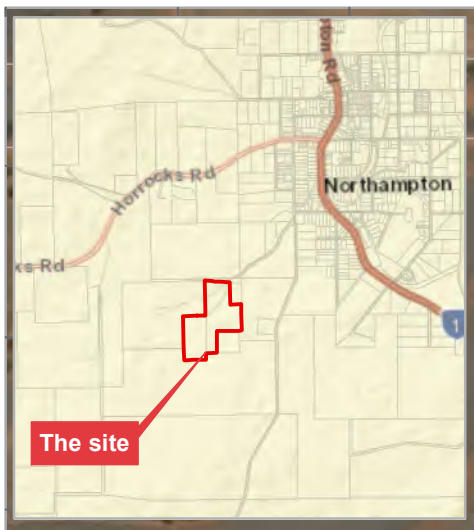
Where it is desired to reproduce the information contained in our geotechnical report, or other technical information, for the inclusion in contract documents or engineering specification of the subject development, such reproductions must include at least all of the relevant test hole and test data, together with the appropriate Standard Description sheets and remarks made in the written report of a factual or descriptive nature.

Ref: DS5.5.1 Issue 0 Date: 05/10/2018

Appendix B – Figures

266396 266496 266596 266696 266796 266896 266996

6860180
6860080
6859980
6859880
6859780
6859680
6859580
6859480



Drage St
Site acess
ML 13
Lot 5680
ML 143
ML 13
ML 17
LOC 1146
ML 14
Lot 1146
R52194
Proposed
containment cell
Lot 11448
R7671

Legend

- Site boundary
- Cadastre
- Main access track
- MineLiDAR imagery capture extent (Aug 2020); Outside areas are old imagery (Oct 2019)
- Indicative mining lease areas are labelled

Paper Size ISO A3

0 50 100

Meters

N

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 50

DMIRS
Wheal Ellen Mine Shafts and Open Pits Remediation

Site Location

Project No. **12535209**
Revision No.
Date **23/09/2020**

FIGURE 1

N:\AU\Newcastle\Projects\22\12535209\GIS\Maps\Deliverables\12535209_Z001_SiteLocationPlan_RevB.mxd
Print date: 23 Sep 2020 - 16:07

Data source: Site boundary, GHD 2020; Mining Leases, DMIRS 2020; Cadastre, LANDGATE 2020; Aerial imagery - MineLiDAR 2020; Basemap Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community. Created by: Imanasan

266396 266496 266596 266696 266796 266896 266996

6860180 6860080 6859980 6859880 6859780 6859680 6859580 6859480

Site access
Unnamed pass1
Unnamed pass2
Sinkhole1
S0113128
S0113127
S0113114
S0113122
S0113111
Sinkhole2
Unnamed pass3
S0113103
S0113163
S0113151
S0113149
S0113097
Stockpile 10
Unnamed pass4
S0113147
S0113158
Pass 1 North
Stockpile 9
S0113130
Waste tailings "dump"
S0113141
MW6D
MW6S
Wheal Ellen Creek East
Wheal Ellen Creek South
MW5D
MW5S
Stockpile 6
Stockpile 1
Stockpile 8
Stockpile 7
Stockpile 2
S0113143
S0113145
MW4D
MW4S
Containment cell
Old Workings Pass
Old Workings Shaft
Stockpile 5
MW3
Stockpile 4
Stockpile 3
MW1
MW2

Notes

Mine feature locations adjusted from DMIRS database based on desktop review and MineLIDAR survey. Mine Photogrammetry basemap provided by MineLiDAR.

Legend

- Site boundary
- Mine surface features
- Stockpile locations
- Monitoring wells
- Main access track
- Watercourse
- Contour - 0.25m interval
- MineLiDAR imagery capture extent (2020); Outside areas are old imagery (Oct 2019)

Paper Size ISO A3

0 50 100

Meters

N

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 50

GHD

DMIRS
Wheal Ellen Mine Shafts and Open Pits Remediation

Site topography, watercourses and stockpiles

Project No. **12535209**
Revision No.
Date **23/09/2020**

FIGURE 2

N:\AU\Newcastle\Projects\22\12535209\GIS\Maps\Deliverables\12535209_Z002_SiteGeoTopoFeatures_RevB.mxd
Print date: 23 Sep 2020 - 15:56

Data source: Site boundary, main access track, stockpile, watercourse - GHD 2020; mine surface features, elevation, aerial imagery - MineLiDAR 2020; Monitoring well - DPLH 2020; Basemap Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community. Created by: Imanasan

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6860180 6860080 6859980 6859880 6859780 6859680 6859580 6859480

Unnamed pass1
Unnamed pass2
Sinkhole1
S0113128
S0113127
S0113114
S0113122
S0113111
Sinkhole2
Unnamed pass3
S0113103
S0113163
S0113151
S0113149
S0113097
Unnamed pass4
S0113147
S0113158
Pass 1 North
S0113130
S0113141
S0113143
S0113145
Old Workings Pass
Old Workings Shaft

Lot 5680
Lot 11448 R7671
Lot 1146 R52194

Notes

Mine feature locations adjusted from DMIRS database based on desktop review and MineLIDAR survey. Mine Photogrammetry basemap provided by MineLiDAR.Trace of historical mine workings based on Wheal Ellen Lead Mine Survey.

Legend

- Site boundary
- Mine surface features
- Trace of workings
- MineLiDAR imagery capture extent (2020); Outside areas are old imagery (Oct 2019)

Paper Size ISO A3

0 50 100

Meters

N

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 50

GHD

DMIRS
Wheal Ellen Mine Shafts and Open Pits Remediation

Trace of mine workings (Ref. 1685, undated)

Project No. **12535209**
Revision No.
Date **23/09/2020**

FIGURE 3

N:\AU\Newcastle\Projects\22\12535209\GIS\Maps\Deliverables\12535209_Z003_TraceofWorking_RevB.mxd
Print date: 23 Sep 2020 - 15:56

Data source: Site boundary - GHD 2020; Trace of workings - DMIRS 2020; Mine surface features, aerial imagery, elevation - MineLiDAR 2020; Basemap Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community. Created by: Imanasan

266395 266495 266595 266695 266795 266895 266995

6860179 6860079 6859879 6859779 6859579 6859479

Dolerite dykes

Unnamed pass1
Unnamed pass2
Sinkhole1
S0113128
S0113127
S0113114
S0113122
S0113111
Sinkhole2
Unnamed pass3
S0113103
S0113163
S0113151
S0113149
S0113097
Unnamed pass4
S0113147
S0113158
Pass 1 North
S0113130
S0113141
S0113143
S0113145
Old Workings Pass
Old Workings Shaft

Lot 5680
Lot 11448 R7671
Lot 1146 R52194

New Main Shaft
Track
Dump
Road

Notes

Mine feature locations adjusted from DMIRS database based on desktop review and MineLIDAR survey.

Legend
- Site boundary
- Mine surface features
- Main access track

Paper Size ISO A3

0 50 100

Meters

N

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 50

DMIRS
Wheal Ellen Mine Shafts and Open Pits Remediation

Geology sketch map (Ref. 1689, undated)

Project No. **12535209**
Revision No.
Date **23/09/2020**

FIGURE 4

N:\AU\Newcastle\Projects\22\12535209\GIS\Maps\Deliverables\12535209_Z004_GeologySketchMap_RevB.mxd
Print date: 23 Sep 2020 - 15:57

Data source: Site boundary, main access track - GHD 2020; Geology sketch map - DMIRS 2020; Mine surface features - MineLiDAR 2020; Basemap Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community. Created by: Imanasan

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6860180 6860080 6859980 6859880 6859780 6859680 6859580

A B C-D E

Unnamed pass1
Unnamed pass2
Sinkhole1
S0113128
S0113127
S0113114
S0113122
S0113111
Sinkhole2
Unnamed pass3
S0113103
S0113163
S0113151
S0113149
S0113097
Unnamed pass4
S0113147
S0113158
Pass 1 North
S0113130
S0113141
S0113145
S0113143
Old Workings Pass
Old Workings Shaft

Wheal Ellen Creek South
Wheal Ellen Creek East

Legend
Data percentage: 4.2*
LAS point elevation
- 123.97 - 130.75
- 122.34 - 123.97
- 120.73 - 122.34
- 118.99 - 120.73
- 117.55 - 118.99
- 116.33 - 117.55
- 114.97 - 116.33
- 113.55 - 114.97
- 112.23 - 113.55
- 110.08 - 112.23

Notes

Mine feature locations adjusted from DMIRS database based on desktop review and MineLIDAR survey. Mine Photogrammetry basemap provided by MineLiDAR.

Legend
- Site boundary
- Mine surface features
- Watercourse
- Cadastre
- MineLiDAR imagery capture extent (Aug 2020); Outside areas are old imagery (Oct 2019)

Paper Size ISO A3
0 50 100
Meters
Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 50

N

DMIRS
Wheal Ellen Mine Shafts and Open Pits Remediation

Point Cloud Survey

Project No. **12535209**
Revision No.
Date **23/09/2020**

FIGURE 5.0

N:\AU\Newcastle\Projects\22\12535209\GIS\Maps\PointCloud.aprx
Print date: 23 Sep 2020 - 16:35

266696

266796

6860180

6860080

A

B

C-D

E

Unnamed pass1

Unnamed pass2

Sinkhole1

S0113128

S0113127

S0113114

S0113122

S0113111

Sinkhole2

Unnamed pass3

S0113103

Legend

Data percentage: 4.2*

LAS point elevation

- 123.97 - 130.75
- 122.34 - 123.97
- 120.73 - 122.34
- 118.99 - 120.73
- 117.55 - 118.99
- 116.33 - 117.55
- 114.97 - 116.33
- 113.55 - 114.97
- 112.23 - 113.55
- 110.08 - 112.23

Notes

Mine feature locations adjusted from DMIRS database based on desktop review and MineLIDAR survey. Mine Photogrammetry basemap provided by MineLiDAR.

Legend

- Site boundary
- Mine surface features
- Watercourse
- Cadastre
- MineLiDAR imagery capture extent (Aug 2020); Outside areas are old imagery (Oct 2019)

Paper Size ISO A3

0 10 20

Meters

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 50

N

GHD

DMIRS
Wheal Ellen Mine Shafts and Open Pits Remediation

Point Cloud Survey Area A

Project No. **12535209**
Revision No.
Date **23/09/2020**

FIGURE 5.1

N:\AU\Newcastle\Projects\22\12535209\GIS\Maps\PointCloud.aprx
Print date: 23 Sep 2020 - 16:23

Data source: Site boundary, watercourse - GHD 2020; Cadastre - LANDGATE 2020; Mine feature location, aerial imagery, point cloud - MineLiDAR 2020; Basemap World_Imagery: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
World Imagery: Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community. Created by: lmanasan

266696

6859980

6859880

A

B

C-D

E

S0113103

S0113163

S0113151

S0113149

S0113097

Unnamed pass4

Legend

Data percentage: 4.2*

LAS point elevation

- 123.97 - 130.75
- 122.34 - 123.97
- 120.73 - 122.34
- 118.99 - 120.73
- 117.55 - 118.99
- 116.33 - 117.55
- 114.97 - 116.33
- 113.55 - 114.97
- 112.23 - 113.55
- 110.08 - 112.23

Notes

Mine feature locations adjusted from DMIRS database based on desktop review and MineLIDAR survey. Mine Photogrammetry basemap provided by MineLiDAR.

Legend

- Site boundary
- Mine surface features
- Watercourse
- Cadastre
- MineLiDAR imagery capture extent (Aug 2020); Outside areas are old imagery (Oct 2019)

Paper Size ISO A3

0 10 20

Meters

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 50

N

DMIRS
Wheal Ellen Mine Shafts and Open Pits Remediation

Point Cloud Survey Area B

Project No. **12535209**
Revision No.
Date **23/09/2020**

FIGURE 5.2

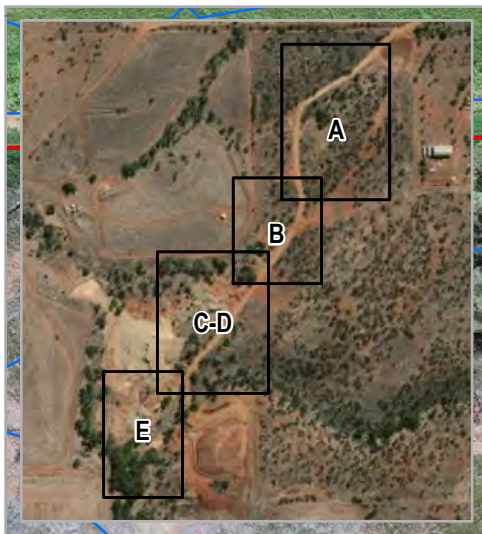
N:\AU\Newcastle\Projects\22\12535209\GIS\Maps\PointCloud.aprx
Print date: 23 Sep 2020 - 16:24

Data source: Site boundary, watercourse - GHD 2020; Cadastre - LANDGATE 2020; Mine feature location, aerial imagery, point cloud - MineLiDAR 2020; Basemap World_Imagery: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
World Imagery: Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community. Created by: lmanasan

266596

6859880

6859780



S0113151

S0113149

S0113097

Unnamed pass4

S0113147

S0113158

Pass 1 North

S0113130

S0113141

Wheal Ellen Creek East

Legend
Data percentage: 4.2*
LAS point elevation
123.97 - 130.75
122.34 - 123.97
120.73 - 122.34
118.99 - 120.73
117.55 - 118.99
116.33 - 117.55
114.97 - 116.33
113.55 - 114.97
112.23 - 113.55
110.08 - 112.23

Notes

Mine feature locations adjusted from DMIRS database based on desktop review and MineLIDAR survey. Mine Photogrammetry basemap provided by MineLiDAR.

Legend
Site boundary
Mine surface features
Watercourse
Cadastre
MineLiDAR imagery capture extent (Aug 2020); Outside areas are old imagery (Oct 2019)

Paper Size ISO A3
0 10 20
Meters
Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 50

N

GHD

DMIRS
Wheal Ellen Mine Shafts and Open Pits Remediation

Point Cloud Survey Area C-D

Project No. **12535209**
Revision No.
Date **23/09/2020**

FIGURE 5.3

N:\AU\Newcastle\Projects\22\12535209\GIS\Maps\PointCloud.aprx
Print date: 23 Sep 2020 - 16:24

266496

6859680

A
B
C-D
E

Ellen Creek South
Wheal Ellen Creek East
Wheal Ellen Creek South
Wheal Ellen Creek East

S0113143
S0113145
Old Workings Pass
Old Workings Shaft

Legend
Data percentage: 4.2*
LAS point elevation
123.97 - 130.75
122.34 - 123.97
120.73 - 122.34
118.99 - 120.73
117.55 - 118.99
116.33 - 117.55
114.97 - 116.33
113.55 - 114.97
112.23 - 113.55
110.08 - 112.23

Notes

Mine feature locations adjusted from DMIRS database based on desktop review and MineLiDAR survey. Mine Photogrammetry basemap provided by MineLiDAR.

Legend
Site boundary
Mine surface features
Watercourse
Cadastre
MineLiDAR imagery capture extent (Aug 2020); Outside areas are old imagery (Oct 2019)

Paper Size ISO A3
0 10 20
Meters
Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 50

N

GHD

DMIRS
Wheal Ellen Mine Shafts and Open Pits Remediation

Point Cloud Survey Area E

Project No. **12535209**
Revision No.
Date **23/09/2020**

FIGURE 5.4

N:\AU\Newcastle\Projects\22\12535209\GIS\Maps\PointCloud.aprx
Print date: 23 Sep 2020 - 16:24

Data source: Site boundary, watercourse - GHD 2020; Cadastre - LANDGATE 2020; Mine feature location, aerial imagery, point cloud - MineLiDAR 2020; Basemap World_Imagery: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
World Imagery: Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community. Created by: lmanasan

266395 266495 266595 266695 266795 266895 266995

6860179 6860079 6859979 6859879 6859779 6859679 6859579 6859479

Unnamed pass1
Unnamed pass2
Sinkhole1
S0113128
S0113127
S0113114
S0113122
S0113111
Sinkhole2
Unnamed pass3
S0113103
S0113163
S0113151
S0113097
S0113149
Unnamed pass4
S0113147
S0113158
Pass 1 North
S0113130
S0113141
S0113145
S0113143
Old Workings Pass
Old Workings Shaft

Lot 5680
Lot 1146 R52194
Lot 11448 R7671

Notes

Mine feature locations adjusted from DMIRS database based on desktop review and MineLiDAR survey. Mine Photogrammetry basemap provided by MineLiDAR.

Legend

- Site boundary
- Mine surface features
- Asbestos location
- Watercourse

Sinkhole hazard zones
- High
- Moderate
- Low

MineLiDAR imagery capture extent (Aug 2020); Outside areas are old imagery (Oct 2019)

Paper Size ISO A3

0 50 100

Meters

N

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 50

GHD

DMIRS
Wheal Ellen Mine Shafts and Open Pits Remediation

Subsidence Hazard Plan

Project No. **12535209**
Revision No.
Date **23/09/2020**

FIGURE 6

N:\AU\Newcastle\Projects\22\12535209\GIS\Maps\Deliverables\12535209_Z006_SubsidenceHazardPlan.mxd
Print date: 23 Sep 2020 - 16:08

Data source: Site boundary, asbestos locations, sinkhole zones - GHD 2020; Mine surface features, aerial imagery - MineLiDAR 2020; Basemap Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community. Created by: Imanasan

Appendix C – Site photographs – August 2020

Plate 1: S0113128

Notes:
Photographs taken by Matthew Stewart, GHD Pty Ltd

GHD Pty Ltd
GHD Pty Ltd
999 Hay Street Perth WA 6000
PO Box 3106 Perth WA 6832
T 61 8 6222 8222 F 61 8 6222 8555
E permail@ghd.com.au www.ghd.com.au

Drawn: K Wong	Date: 27/08/2020	Job Number: 22/12535209	A4	Title: Shaft Photographs	Client: Department of Mines, Industry, Regulation & Safety (DMIRS)
Checked: Matthew Stewart	Date: 27/08/2020				Project: Wheal Ellen Mine Shafts and Open Pits
Revision:	Date: 27/08/2020	Cad Reference:		S0113128	

Plate 2: S0113127

Notes:
Photographs taken by Matthew Stewart, GHD Pty Ltd

GHD Pty Ltd
GHD Pty Ltd
999 Hay Street Perth WA 6000
PO Box 3106 Perth WA 6832
T 61 8 6222 8222 F 61 8 6222 8555
E permail@ghd.com.au www.ghd.com.au

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Checked: Matthew Stewart	Date: 27/08/2020				Project: Wheal Ellen Mine Shafts and Open Pits
Revision:	Date: 27/08/2020	Cad Reference:		S0113127	

Plate 3: S0113114

Notes:
Photographs taken by Matthew Stewart, GHD Pty Ltd

GHD Pty Ltd
GHD Pty Ltd
999 Hay Street Perth WA 6000
PO Box 3106 Perth WA 6832
T 61 8 6222 8222 F 61 8 6222 8555
E permail@ghd.com.au www.ghd.com.au

Drawn	Date	Job Number		Title
K Wong	27/08/2020	22/12535209	A4	Shaft Photographs
Checked	Date			
Matthew Stewart	27/08/2020			S0113114
Revision	Date	Cad Reference		
	27/08/2020			

Client
Department of Mines, Industry, Regulation & Safety (DMIRS)

Project
Wheal Ellen Mine Shafts and Open Pits

Plate 4: S0113122

Notes:
Photographs taken by Matthew Stewart, GHD Pty Ltd

GHD Pty Ltd
GHD Pty Ltd
999 Hay Street Perth WA 6000
PO Box 3106 Perth WA 6832
T 61 8 6222 8222 F 61 8 6222 8555
E permail@ghd.com.au www.ghd.com.au

Drawn: K Wong	Date: 27/08/2020	Job Number: 22/12535209	A4	Title: Shaft Photographs	Client: Department of Mines, Industry, Regulation & Safety (DMIRS)
Checked: Matthew Stewart	Date: 27/08/2020				Project: Wheal Ellen Mine Shafts and Open Pits
Revision:	Date: 27/08/2020	Cad Reference:		S0113122	

Plate 5: S0113111

Notes:
Photographs taken by Matthew Stewart, GHD Pty Ltd

GHD Pty Ltd
GHD Pty Ltd
999 Hay Street Perth WA 6000
PO Box 3106 Perth WA 6832
T 61 8 6222 8222 F 61 8 6222 8555
E permail@ghd.com.au www.ghd.com.au

Drawn: K Wong	Date: 27/08/2020	Job Number: 22/12535209	A4	Title: Shaft Photographs	Client: Department of Mines, Industry, Regulation & Safety (DMIRS)
Checked: Matthew Stewart	Date: 27/08/2020				Project: Wheal Ellen Mine Shafts and Open Pits
Revision:	Date: 27/08/2020	Cad Reference:		S0113111	

Plate 6: S0113103

Notes:
Photographs taken by Matthew Stewart, GHD Pty Ltd

GHD Pty Ltd
GHD Pty Ltd
999 Hay Street Perth WA 6000
PO Box 3106 Perth WA 6832
T 61 8 6222 8222 F 61 8 6222 8555
E permail@ghd.com.au www.ghd.com.au

Drawn: K Wong	Date: 27/08/2020	Job Number: 22/12535209	A4	Title: Shaft Photographs	Client: Department of Mines, Industry, Regulation & Safety (DMIRS)
Checked: Matthew Stewart	Date: 27/08/2020				Project: Wheal Ellen Mine Shafts and Open Pits
Revision:	Date: 27/08/2020	3		S0113103	

Plate 7: S0113163

Notes:
Photographs taken by Matthew Stewart, GHD Pty Ltd

GHD Pty Ltd
GHD Pty Ltd
999 Hay Street Perth WA 6000
PO Box 3106 Perth WA 6832
T 61 8 6222 8222 F 61 8 6222 8555
E permail@ghd.com.au www.ghd.com.au

Drawn: K Wong	Date: 27/08/2020	Job Number: 22/12535209	A4	Title: Shaft Photographs
Checked: Matthew Stewart	Date: 27/08/2020			S0113163
Revision:	Date: 27/08/2020	3		

Client: Department of Mines, Industry, Regulation & Safety (DMIRS)

Project: Wheal Ellen Mine Shafts and Open Pits

Plate 8: S0113151

Notes:
Photographs taken by Matthew Stewart, GHD Pty Ltd

GHD Pty Ltd
GHD Pty Ltd
999 Hay Street Perth WA 6000
PO Box 3106 Perth WA 6832
T 61 8 6222 8222 F 61 8 6222 8555
E permail@ghd.com.au www.ghd.com.au

Drawn: K Wong	Date: 27/08/2020	Job Number: 22/12535209	A4	Title: Shaft Photographs	Client: Department of Mines, Industry, Regulation & Safety (DMIRS)
Checked: Matthew Stewart	Date: 27/08/2020				Project: Wheal Ellen Mine Shafts and Open Pits
Revision:	Date: 27/08/2020	Cad Reference:		S0113151	

Plate 9: S0113097

Notes:
Photographs taken by Matthew Stewart, GHD Pty Ltd

GHD Pty Ltd
GHD Pty Ltd
999 Hay Street Perth WA 6000
PO Box 3106 Perth WA 6832
T 61 8 6222 8222 F 61 8 6222 8555
E permail@ghd.com.au www.ghd.com.au

Drawn: K Wong	Date: 27/08/2020	Job Number: 22/12535209	A4	Title: Shaft Photographs	Client: Department of Mines, Industry, Regulation & Safety (DMIRS)
Checked: Matthew Stewart	Date: 27/08/2020				Project: Wheal Ellen Mine Shafts and Open Pits
Revision:	Date: 27/08/2020	Cad Reference:		S0113097	

Plate 10: S0113149

Notes:
Photographs taken by Matthew Stewart, GHD Pty Ltd

GHD Pty Ltd
GHD Pty Ltd
999 Hay Street Perth WA 6000
PO Box 3106 Perth WA 6832
T 61 8 6222 8222 F 61 8 6222 8555
E permail@ghd.com.au www.ghd.com.au

Drawn: K Wong	Date: 27/08/2020	Job Number: 22/12535209	A4	Title: Shaft Photographs
Checked: Matthew Stewart	Date: 27/08/2020			
Revision:	Date: 27/08/2020	Cad Reference:		S0113149

Client: Department of Mines, Industry, Regulation & Safety (DMIRS)

Project: Wheal Ellen Mine Shafts and Open Pits

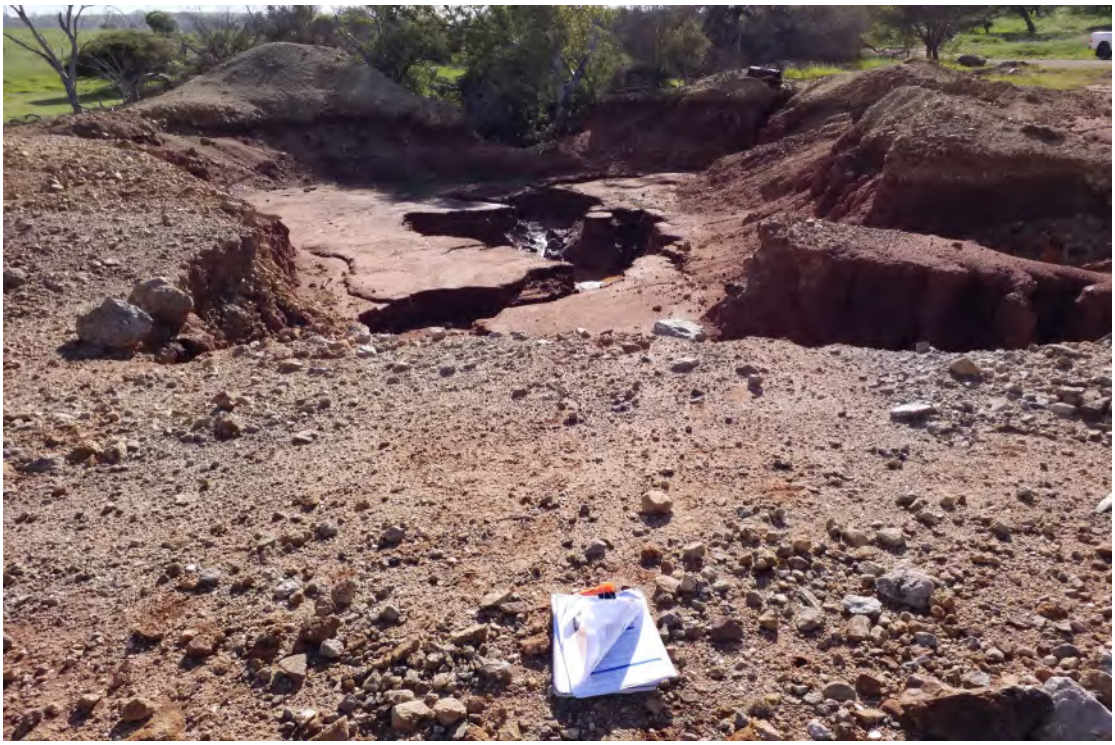

Plate 11: S0113147

Notes:
Photographs taken by Matthew Stewart, GHD Pty Ltd

GHD Pty Ltd
GHD Pty Ltd
999 Hay Street Perth WA 6000
PO Box 3106 Perth WA 6832
T 61 8 6222 8222 F 61 8 6222 8555
E permail@ghd.com.au www.ghd.com.au

Drawn	Date	Job Number		Title
K Wong	27/08/2020	22/12535209	A4	Shaft Photographs
Checked	Date			
Matthew Stewart	27/08/2020			
Revision	Date	Cad Reference		S0113147
	27/08/2020			

Client: Department of Mines, Industry, Regulation & Safety (DMIRS)

Project: Wheal Ellen Mine Shafts and Open Pits

Plate 12: S0113158

Notes:
Photographs taken by Matthew Stewart, GHD Pty Ltd

GHD Pty Ltd
GHD Pty Ltd
999 Hay Street Perth WA 6000
PO Box 3106 Perth WA 6832
T 61 8 6222 8222 F 61 8 6222 8555
E permail@ghd.com.au www.ghd.com.au

Drawn: K Wong	Date: 27/08/2020	Job Number: 22/12535209	A4	Title: Shaft Photographs	Client: Department of Mines, Industry, Regulation & Safety (DMIRS)
Checked: Matthew Stewart	Date: 27/08/2020				Project: Wheal Ellen Mine Shafts and Open Pits
Revision:	Date: 27/08/2020	Cad Reference:		S0113158	

Plate 13: S0113130

Notes:
Photographs taken by Matthew Stewart, GHD Pty Ltd

GHD Pty Ltd
GHD Pty Ltd
999 Hay Street Perth WA 6000
PO Box 3106 Perth WA 6832
T 61 8 6222 8222 F 61 8 6222 8555
E permail@ghd.com.au www.ghd.com.au

Drawn: K Wong	Date: 27/08/2020	Job Number: 22/12535209	A4	Title: Shaft Photographs	Client: Department of Mines, Industry, Regulation & Safety (DMIRS)
Checked: Matthew Stewart	Date: 27/08/2020				Project: Wheal Ellen Mine Shafts and Open Pits
Revision:	Date: 27/08/2020	Cad Reference:		S0113130	

Plate 14: S0113141

Notes:
Photographs taken by Matthew Stewart, GHD Pty Ltd

GHD Pty Ltd
GHD Pty Ltd
999 Hay Street Perth WA 6000
PO Box 3106 Perth WA 6832
T 61 8 6222 8222 F 61 8 6222 8555
E permail@ghd.com.au www.ghd.com.au

Drawn: K Wong	Date: 27/08/2020	Job Number: 22/12535209	A4	Title: Shaft Photographs	Client: Department of Mines, Industry, Regulation & Safety (DMIRS)
Checked: Matthew Stewart	Date: 27/08/2020				Project: Wheal Ellen Mine Shafts and Open Pits
Revision:	Date: 27/08/2020	Cad Reference:		S0113141	

Plate 15: S0113143

Notes:
Photographs taken by Matthew Stewart, GHD Pty Ltd

GHD Pty Ltd
GHD Pty Ltd
999 Hay Street Perth WA 6000
PO Box 3106 Perth WA 6832
T 61 8 6222 8222 F 61 8 6222 8555
E permail@ghd.com.au www.ghd.com.au

Drawn: K Wong	Date: 27/08/2020	Job Number: 22/12535209	A4	Title: Shaft Photographs	Client: Department of Mines, Industry, Regulation & Safety (DMIRS)
Checked: Matthew Stewart	Date: 27/08/2020				Project: Wheal Ellen Mine Shafts and Open Pits
Revision:	Date: 27/08/2020	Cad Reference:		S0113143	

Plate 16: S0113145

Notes:
Photographs taken by Matthew Stewart, GHD Pty Ltd

GHD Pty Ltd
GHD Pty Ltd
999 Hay Street Perth WA 6000
PO Box 3106 Perth WA 6832
T 61 8 6222 8222 F 61 8 6222 8555
E permail@ghd.com.au www.ghd.com.au

Drawn: K Wong	Date: 27/08/2020	Job Number: 22/12535209	A4	Title: Shaft Photographs	Client: Department of Mines, Industry, Regulation & Safety (DMIRS)
Checked: Matthew Stewart	Date: 27/08/2020				Project: Wheal Ellen Mine Shafts and Open Pits
Revision:	Date: 27/08/2020	Cad Reference:		S0113145	

Plate 17: Old Workings Pass

Notes:
Photographs taken by Matthew Stewart, GHD Pty Ltd

GHD Pty Ltd
GHD Pty Ltd
999 Hay Street Perth WA 6000
PO Box 3106 Perth WA 6832
T 61 8 6222 8222 F 61 8 6222 8555
E permail@ghd.com.au www.ghd.com.au

Drawn: K Wong	Date: 27/08/2020	Job Number: 22/12535209	A4	Title: Shaft Photographs	Client: Department of Mines, Industry, Regulation & Safety (DMIRS)
Checked: Matthew Stewart	Date: 27/08/2020				Project: Wheal Ellen Mine Shafts and Open Pits
Revision:	Date: 27/08/2020	Cad Reference:		Old Workings Pass	

Plate 18: Old Workings Shaft

Notes:
Photographs taken by Matthew Stewart, GHD Pty Ltd

GHD Pty Ltd
GHD Pty Ltd
999 Hay Street Perth WA 6000
PO Box 3106 Perth WA 6832
T 61 8 6222 8222 F 61 8 6222 8555
E permail@ghd.com.au www.ghd.com.au

Drawn	Date	Job Number		Title	Client
K Wong	27/08/2020	22/12535209	A4	Shaft Photographs	Department of Mines, Industry, Regulation & Safety (DMIRS)
Checked: Matthew Stewart	Date: 27/08/2020				Project
Revision	Date: 27/08/2020	Cad Reference		Old Workings Shaft	Wheal Ellen Mine Shafts and Open Pits

Plate 19: Stockpile 1

Plate 20: Stockpile 2

Notes:
Photographs taken by Matthew Stewart, GHD Pty Ltd

GHD Pty Ltd
GHD Pty Ltd
999 Hay Street Perth WA 6000
PO Box 3106 Perth WA 6832
T 61 8 6222 8222 F 61 8 6222 8555
E permail@ghd.com.au www.ghd.com.au

Drawn: K Wong	Date: 27/08/2020	Job Number: 22/12535209	A4	Title: Stockpile Photographs	Client: Department of Mines, Industry, Regulation & Safety (DMIRS)
Checked: Matthew Stewart	Date: 27/08/2020				Project: Wheal Ellen Mine Shafts and Open Pits
Revision:	Date: 27/08/2020	Cad Reference:		Stockpile 1 and 2	

Plate 21: Stockpile 3

Plate 22: Stockpile 4

Notes:
Photographs taken by Matthew Stewart, GHD Pty Ltd

GHD Pty Ltd
GHD Pty Ltd
999 Hay Street Perth WA 6000
PO Box 3106 Perth WA 6832
T 61 8 6222 8222 F 61 8 6222 8555
E permail@ghd.com.au www.ghd.com.au

Drawn: K Wong	Date: 27/08/2020	Job Number: 22/12535209	A4	Title: Stockpile Photographs
Checked: Matthew Stewart	Date: 27/08/2020			
Revision:	Date: 27/08/2020	Cad Reference:		Stockpile 3 an 4

Client: Department of Mines, Industry, Regulation & Safety (DMIRS)

Project: Wheal Ellen Mine Shafts and Open Pits

Plate 23: Stockpile 5

Plate 24: Stockpile 6

Notes:
Photographs taken by Matthew Stewart, GHD Pty Ltd

GHD Pty Ltd
GHD Pty Ltd
999 Hay Street Perth WA 6000
PO Box 3106 Perth WA 6832
T 61 8 6222 8222 F 61 8 6222 8555
E permail@ghd.com.au www.ghd.com.au

Drawn: K Wong	Date: 27/08/2020	Job Number: 22/12535209	A4	Title: Stockpile Photographs	Client: Department of Mines, Industry, Regulation & Safety (DMIRS)
Checked: Matthew Stewart	Date: 27/08/2020				Project: Wheal Ellen Mine Shafts and Open Pits
Revision:	Date: 27/08/2020	Cad Reference:		Stockpile 5 and 6	

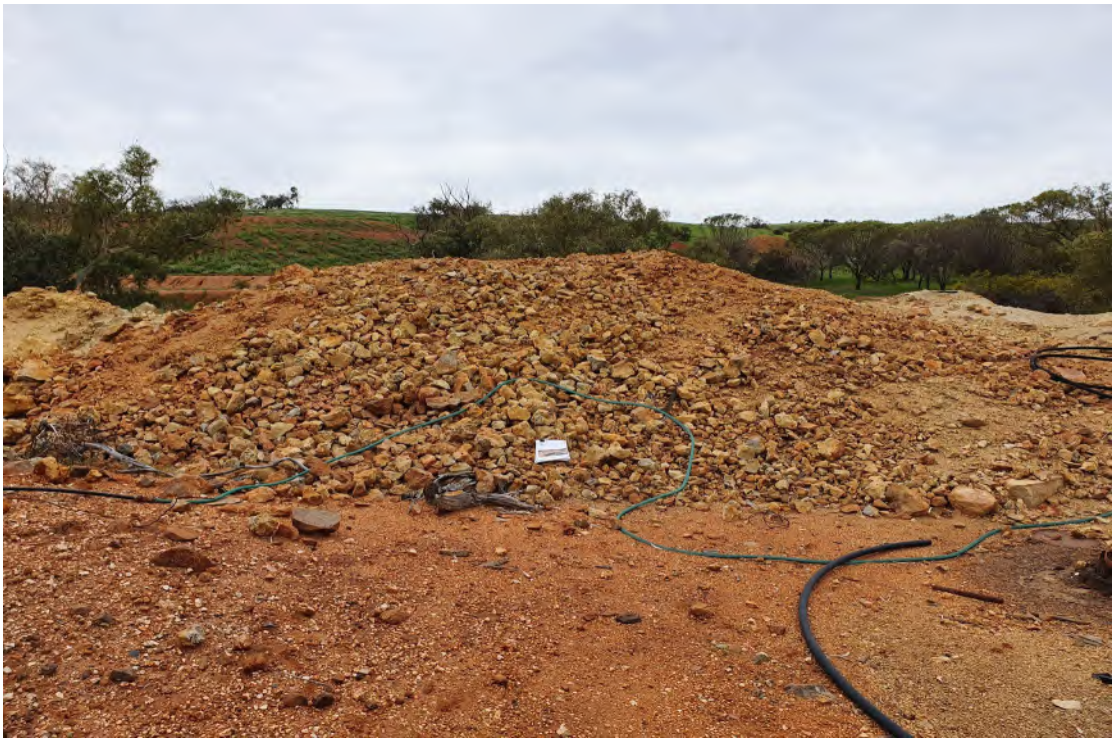

Plate 25: Stockpile 7

Plate 26: Stockpile 8

Notes:
Photographs taken by Matthew Stewart, GHD Pty Ltd

GHD Pty Ltd
GHD Pty Ltd
999 Hay Street Perth WA 6000
PO Box 3106 Perth WA 6832
T 61 8 6222 8222 F 61 8 6222 8555
E permail@ghd.com.au www.ghd.com.au

Drawn: K Wong	Date: 27/08/2020	Job Number: 22/12535209	A4	Title: Stockpile Photographs	Client: Department of Mines, Industry, Regulation & Safety (DMIRS)
Checked: Matthew Stewart	Date: 27/08/2020				Project: Wheal Ellen Mine Shafts and Open Pits
Revision:	Date: 27/08/2020	Cad Reference:		Stockpile 7 and 8	

Plate 27: Stockpile 9

Plate 28: Stockpile 10

Notes:
Photographs taken by Matthew Stewart, GHD Pty Ltd

GHD Pty Ltd
GHD Pty Ltd
999 Hay Street Perth WA 6000
PO Box 3106 Perth WA 6832
T 61 8 6222 8222 F 61 8 6222 8555
E permail@ghd.com.au www.ghd.com.au

Drawn: K Wong	Date: 27/08/2020	Job Number: 22/12535209	A4	Title: Stockpile Photographs	Client: Department of Mines, Industry, Regulation & Safety (DMIRS)
Checked: Matthew Stewart	Date: 27/08/2020				Project: Wheal Ellen Mine Shafts and Open Pits
Revision:	Date: 27/08/2020	Cad Reference:		Stockpile 9 and 10	

GHD

Level 10, 999 Hay Street
Perth WA 6000
T: 61 8 6222 8222 F: 61 8 9463 6012 E: permail@ghd.com

12535209-50132-10/https://projectsportal.ghd.com/sites/pp01_01/whealellenmineshafts/ProjectDocs/12535209_REP-Wheal Ellen Geotechnical Report.docx

Document Status

Revision	Author	Reviewer		Approved for Issue		
		Name	Signature	Name	Signature	Date
A	M.Stewart S.Mackenzie	A Jennings		A Jennings		17/09/2020
0	S.Mackenzie	A Jennings		A Jennings		24/09/2020

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