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TOP TIPPERARY TAILINGS STORAGE FACILITY

Preliminary Geotechnical Assessment

Submitted to:
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Report Number. 1078301051.002-R200A

REPORT

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Golder Associates

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APPENDICES

1.0 INTRODUCTION

OceanaGold (New Zealand) Limited (OceanaGold) requires an additional tailings storage facility (TSF) at the Macraes Gold Project to accommodate tailings through to the projected life of the mine. A recent study of storage options identified a new site (the "Top Tipperary" site, or "TTTSF") as being geometrically capable of storing the required volume of tailings. The proposed TTTSF comprises an embankment approximately 2.9 km long across the upper catchment of Tipperary Creek and a 1.3 km long embankment along the catchment divide between Tipperary Creek and Waikouaiti River on the western side of the impoundment (Figure 1). The proposed embankment height is up to about 70 m, though most of the embankment will be less than 40 m high.

Golder Associates (NZ) Limited has been contracted by OceanaGold to complete a preliminary geotechnical investigation of the TTTSF site (letter proposal to OceanaGold dated 15 April, 2010) to support preliminary design and consenting. The current investigation aimed to collect information on the geotechnical characteristics of the soil and rock strata underlying the impoundment, including strength and rock mass permeability. Design of the TTTSF is being undertaken by Engineering Geology Limited.

This report is provided subject to the limitations attached in Appendix A.

2.0 SCOPE OF INVESTIGATIONS

The preliminary investigation programme (locations of drill holes and test pits, target depths, packer test specifications, piezometer installation specifications, etc.) was specified by Golder in discussion with OceanaGold geologists. The drilling programme was managed and supervised by OceanaGold geologists, who also logged and photographed the core. Most test pits were logged by OceanaGold geologists, though some were logged and photographed by Tim McMorran (Golder Principal Engineering Geologist).

Investigations carried out as part of this assessment included:

- Review of aerial photographs. Stereopairs of aerial photographs were supplied by OceanaGold for this assessment:
  - T08 Run 1: 0215, 0216, 0217 (Terralink International, flown 2005)
  - T09 Run 2: 0227, 0228, 0229, 0230 (Terralink International, flown 2005)
- Copies of various oblique aerial photographs are presented in Appendix B along with general site photographs.
- Review of geological data held by OceanaGold.
- New geological mapping in the vicinity of the impoundment. Measurements of foliation and joint orientation are presented on stereonets in Appendix C.
- Excavation of 38 test pits, the distribution of which is shown on Figure 2. Logs and photographs of test pits are presented in Appendix D.
- Six exploratory trenches were excavated to investigate the Macraes Fault for the fault hazard study (Golder 2011). Trenches 100, 200, 300, 400 and 500 were excavated across the Macraes Fault immediately west of the impoundment. Trench 700 was excavated along the embankment footprint across the Macraes Fault. Locations of the trenches are shown in Figure 2 and logs are presented in Appendix D. A trench was also excavated to locate the Duke of Edinburgh lode, to site DDH5195. That trench, the location of which is shown on Figure 2, was not logged as it almost immediately filled with surface water and groundwater.

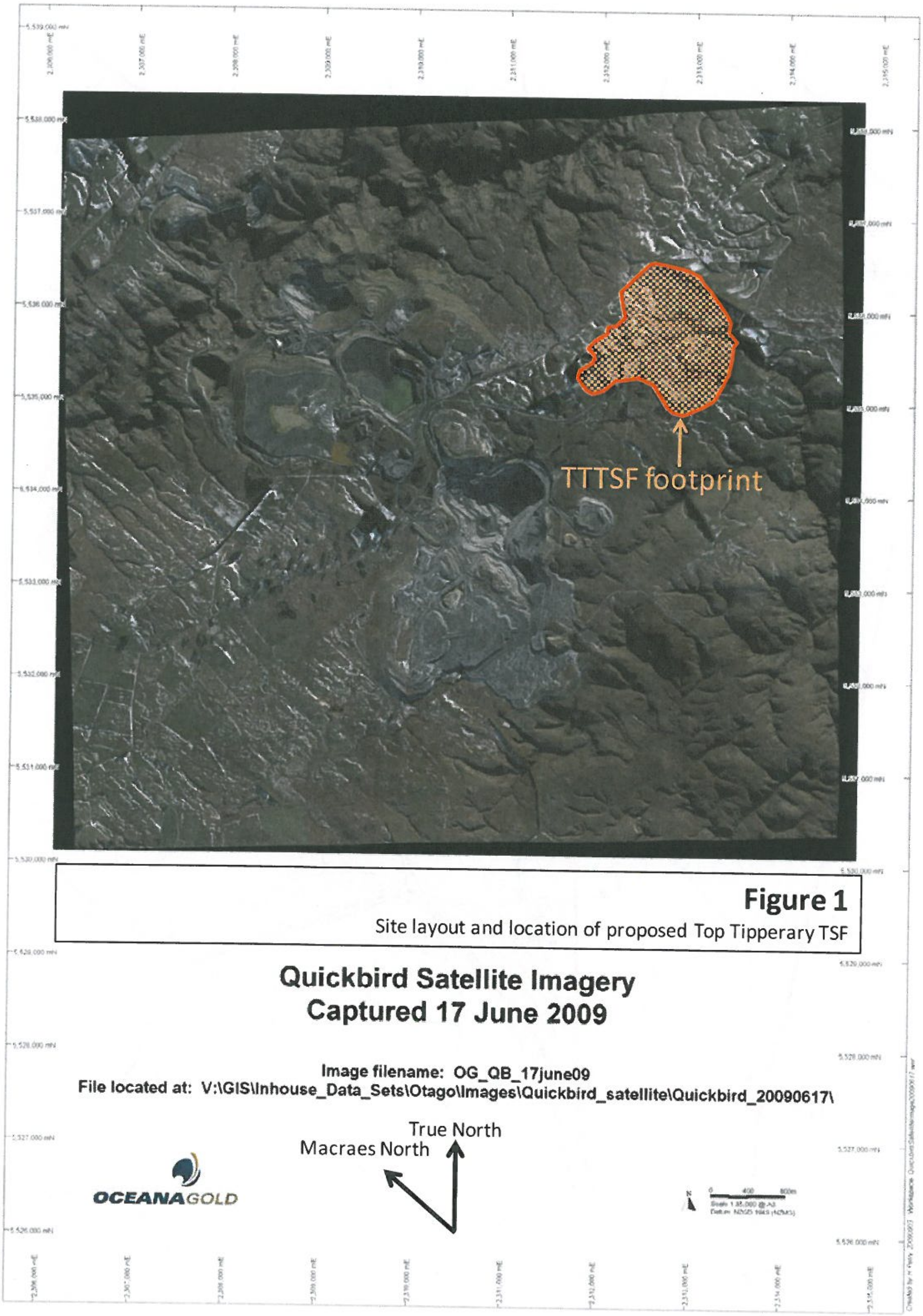
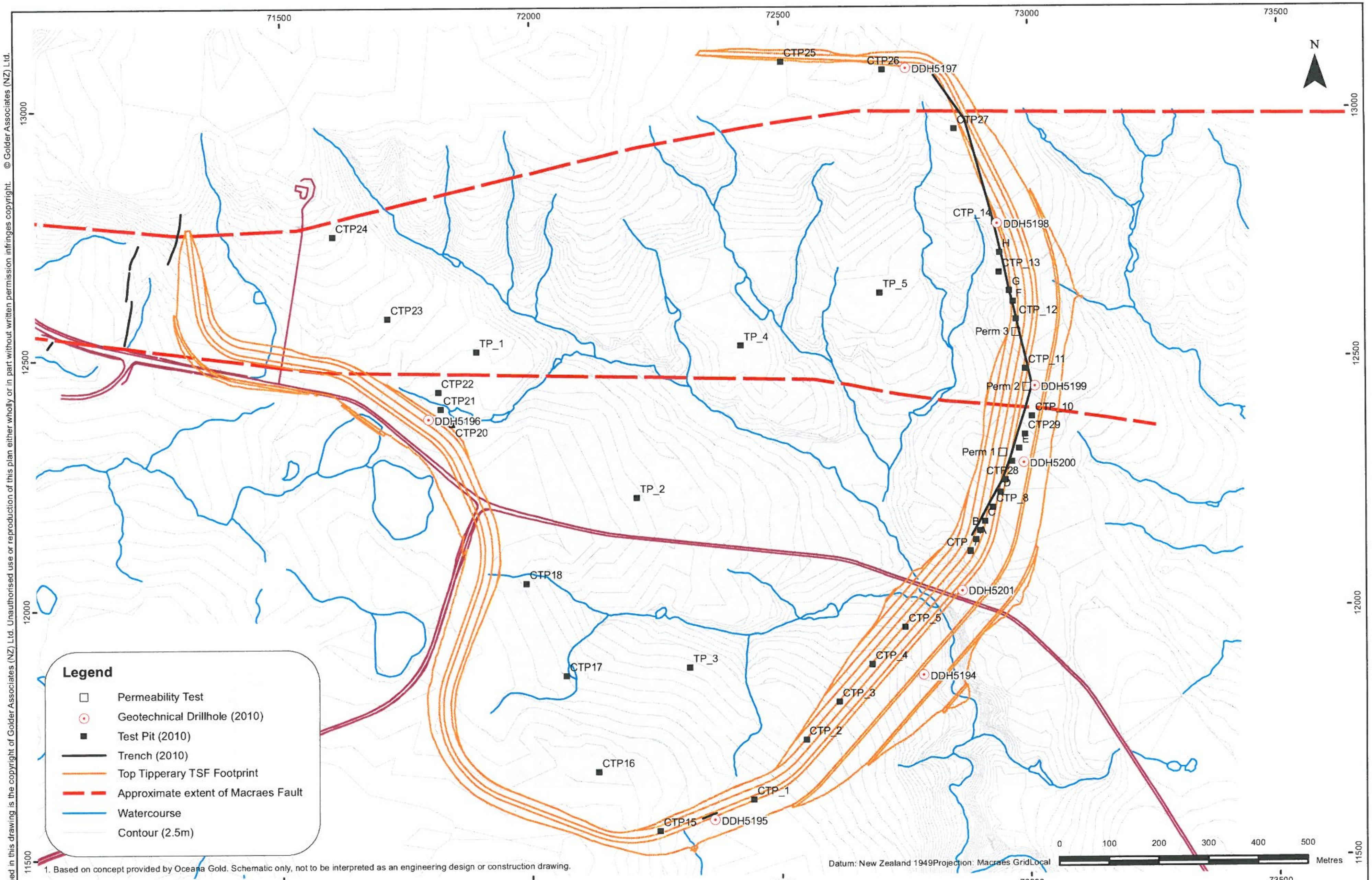


Figure 1: Layout plan and location of Top Tipperary Tailings Storage Facility.



1. Based on concept provided by Oceana Gold. Schematic only, not to be interpreted as an engineering design or construction drawing.

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TITLE TOP TIPPERARY TSF GEOTECHNICAL INVESTIGATIONS PLAN

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- Drilling of 8 new fully cored drillholes to depths of up to 50 m, including packer testing and installation of piezometers. The locations of the drillholes are presented in Figure 2. Logs, core photographs and piezometer installation diagrams are presented in Appendix E.
- Interpretation of the packer test results is presented in Appendix F along with the results of test pit scale permeability tests.

This report summarises the investigation findings.

3.0 SITE SETTING

3.1 Regional Geology

The eastern area of Otago is underlain principally by Mesozoic age schist of the Torlesse Terrane (Forsyth 2001). Weathering and erosion over a long period formed the distinctive low relief of the Otago peneplain. Deposition of alluvium, rich in quartz gravel occurred in east Otago during the Eocene (Hogburn Formation) and Miocene (Manuherikia Group). Miocene age volcanics were also widespread. Post-Miocene tectonic deformation and erosion has removed much of the Tertiary age formations, along with an unknown thickness of schist. The resulting landscape in the Macraes area comprises widespread outcrops of schist and thin cover soils.

The general landscape in the vicinity of the Macraes Gold Project is very flat (generally ranging from 500 to 580 m elevation). The North Branch Waikouaiti River flows along a broad valley to the west across Macraes Flat before turning south into a deeply incised gorge. Valley floor alluvium exposed in exploratory pits near to Frasers Pit was described as 5.5 m thickness of gravel, sand and silt overlying schist (Craw & Chappell 1999). Radiocarbon dates indicate that the alluvium is at least 28,000 years old.

Tributaries of Deepdell Creek and Tipperary Creek flowing to the north and east have steep sided channels incised tens of metres into the schist.

A key feature of the impoundment geology is the Macraes Fault, which strikes east-west and crosses the impoundment. A series of structures parallel to the Macraes Fault, including Taieri Ridge and the Rock and Pillar Range, show evidence of late Quaternary tectonic deformation (i.e., during the last 125,000 years) (Norris and Nicolls, 2004). This deformation comprises tilting, faulting and folding of late Quaternary deposits over a wide zone rather than along a discrete fault. An assessment of the Macraes Fault undertaken as part of the current investigation did not find evidence of deformation associated with movement of the Macraes Fault during the late Quaternary including no deformation of a loess layer inferred to be 11,500 years old (Golder 2011).

The Hyde-Macraes Shear Zone, which is the gold bearing structure mined by OceanaGold, dips gently (~15°) to the east and is about 1000 m below surface in the area of the proposed impoundment.

3.2 Seismic Hazard

A recent probabilistic seismic hazard study was completed for OceanaGold by GNS Science (Litchfield et al. 2005). The objectives of that study included:

- Compile an earthquake source catalogue based on existing data held by GNS.
- Compute probabilistic ground motions for the Macraes Gold Project for return periods up to 10,000 years.
- Identify the major earthquake sources contributing to the seismic hazard.

- Provide suitable earthquake time histories for use in engineering evaluations of tailings storage facilities.

Tables and graphs summarising the findings of the GNS study are presented in Appendix G.

An assumption in the probabilistic seismic hazard model was that the Macraes Fault is a potential earthquake source structure with an average return period between surface rupturing earthquakes of 6375 years. The Golder (2011) study of the Macraes Fault found that it has not been active during the last 11,500 years (and no evidence has been found of movement during the last 125,000 years), suggesting that the average return period assumed by GNS is too short. The resulting change in seismic hazard as a result of the increased return period for the Macraes Fault is expected to be minor.

4.0 FINDINGS OF THE GEOTECHNICAL INVESTIGATION

4.1 Site Geomorphology

The main geomorphic features of the site include the incised Tipperary Creek and ridges that form catchment divides between Tipperary Creek, North Branch Waikouaiti River, Deepdell Creek and Cranky Jim's Creek. Slopes are generally gentle (<5°), except adjacent to incised streams where slopes can locally approach 30°. Streams are mainly incised by about 20 m and Tipperary Creek is incised by about 30 m at the main dam site.

4.2 Soils

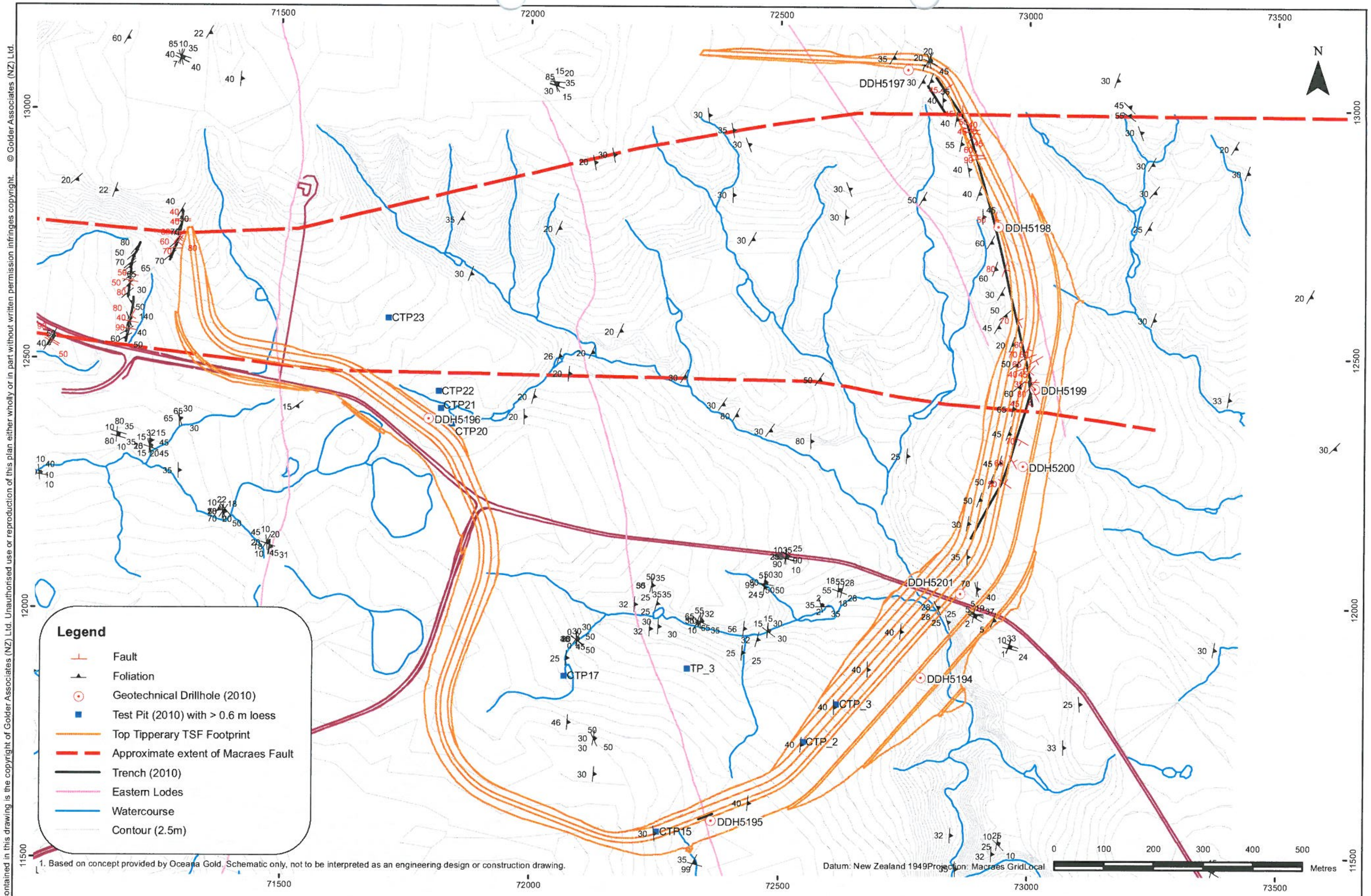
The subsurface investigations identified a surficial cover of loess and colluvium. The investigations typically exposed 0.2 to 0.4 m of soil materials, with a maximum identified thickness of 1.8 m. The loess soils comprise a very stiff, light yellow grey silt, sandy silt or silty fine sand (refer photographs in Appendix D). Colluvium mainly comprises fine angular schist gravel in a sandy or silty matrix, with the matrix mainly derived from reworked loess. Test pits where the total thickness of cover soils (excluding highly weathered and easily excavated schist) exceeds 0.6 m are shown on Figure 3. The total depth excavated by a 12 tonne excavator ranged between 0.3 m and about 2.7 m, with the average being about 1.5 m.

Trenches 100 to 500 identified loess and colluvium typically in the range 0.2 to 0.6 m thickness, but locally up to about 2.5 m in thickness.

Trench 700 exposed a continuous soil profile that mainly comprised about 0.4 m thickness of loess and topsoil. The maximum soil thickness identified in Trench 700 was about 1.0 m, including 0.2 m of topsoil.

4.3 Schist

The soils are directly underlain by schist comprising well foliated, fine grained pelite to coarser grained psammite. North and south of the impoundment, foliation typically dips at 20° - 40° towards the east, which is consistent with the regional foliation pattern (Figure 3). Foliation locally dips towards the southeast as a result of drag folding adjacent to the Macraes Fault. Figure 4 and Figure 5 summarise the geology of the main embankment in cross sections.



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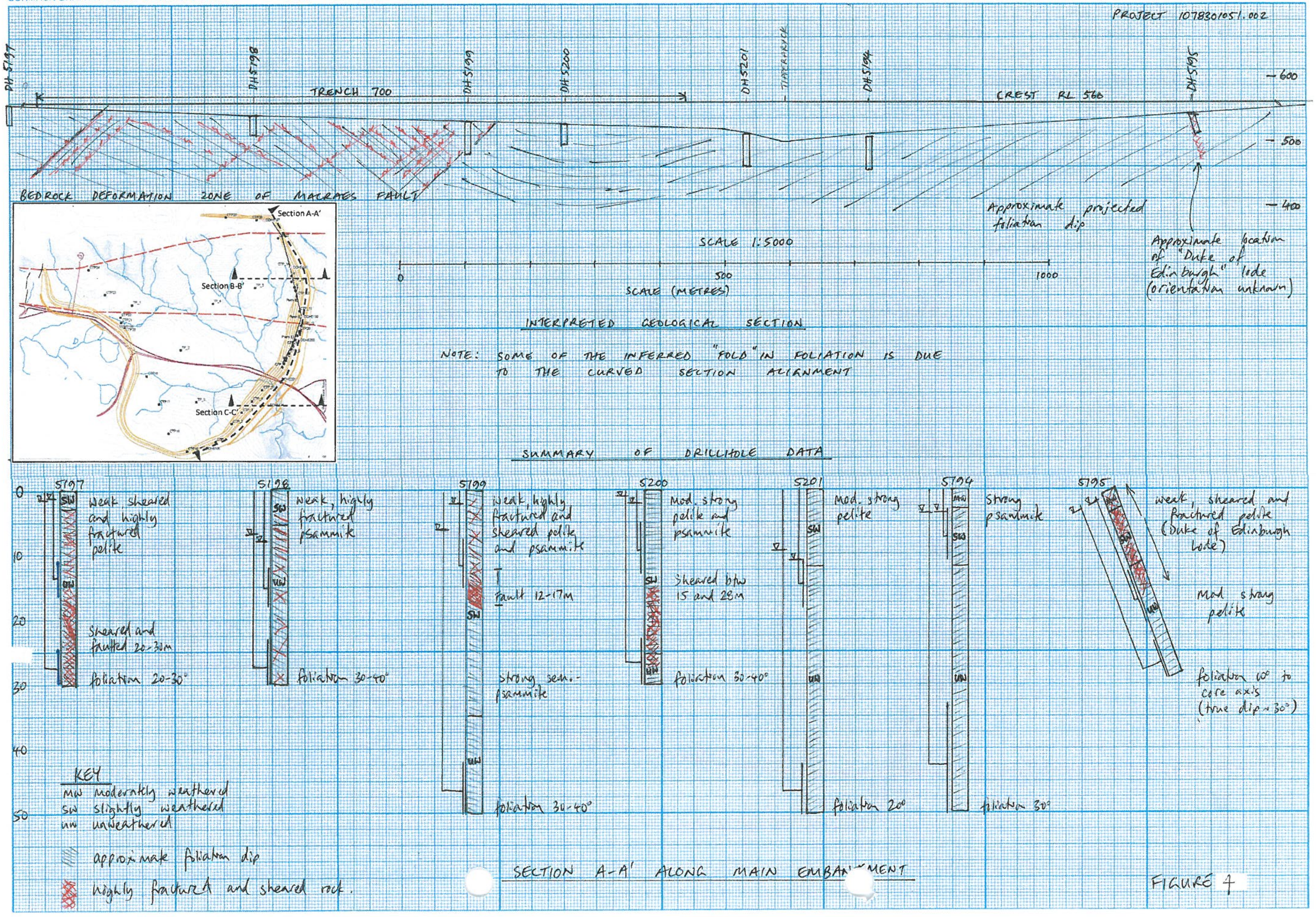

SECTION A-A' ALONG MAIN EMBANKMENT

FIGURE 4

GORMACK GRAPH PAPERS : CHRISTCHURCH N.Z. C102X 40 cm x 28 cm x 1 mm

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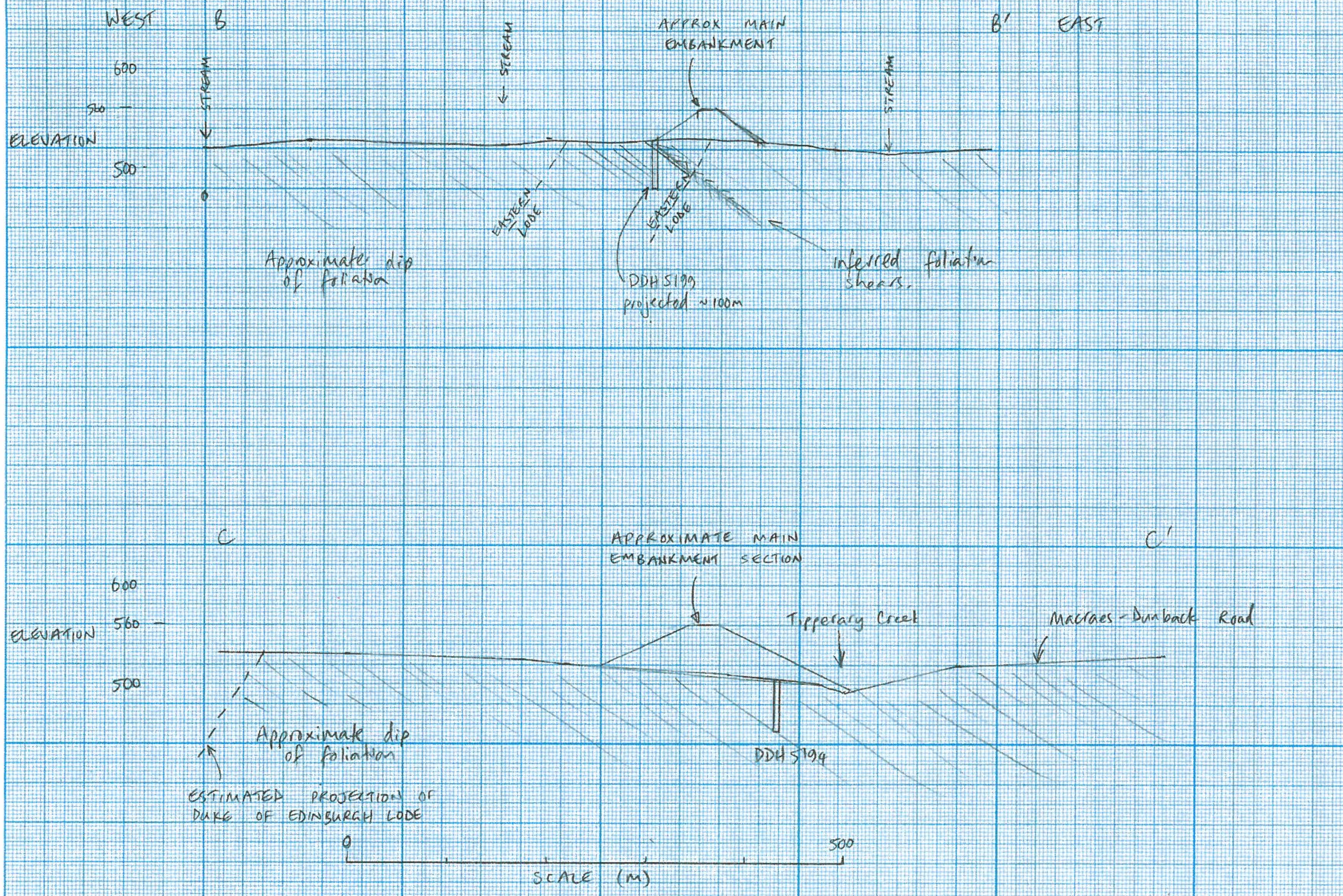

FIGURE 5

4.3.1 Weathering

The weathering profile encountered by the drill holes is summarised in Table 1. The weathering intensity described in Table 1 and shown graphically in Figure 4, has been interpreted by Golder based on the descriptions on the logs, inspection of the core photographs and observations of the core. The weathering terms used in Table 1 follow the commonly used classification system in New Zealand (NZGS 2005).

The weathering characteristics of the schist is complicated at this site by the presence of the Macraes Fault. Within the deformation zone of the Macraes Fault, the schist is mainly of lower strength than elsewhere due to zones of shearing (refer to Section 3.3.5), but it is not strongly weathered. The depth of highly or moderately weather schist (i.e. where weathering has not significantly affected the strength of the schist) is relatively shallow at the impoundment site. Five out of eight drill holes encountered 0.5 m or less of highly or moderately weathered schist and the maximum depth of highly or moderately weathered schist encountered was 5 m. Slightly weathered rock (having some discolouration, but not significant strength loss) was encountered to a depth of up to about 35 m.

Most of the rock encountered at depths of up to about 2 m in Trench 700 was moderately weathered, with some zones comprising highly weathered or slightly weathered rock.

Table 1: Weathering depth in drillholes.

Drill hole	Total depth (m)	Soil thickness (m)	Depth by weathering grade (m)		
			HW	MW	SW
DDH5194	49.94	1.00	-	1.0 – 3.0	3.0 – 12.0
DDH5195	30.50	0.55	-	0.55 – 2.0	2.0 – 4.5
DDH5196	30.61	0.80	0.8 – 1.5	1.5 – 5.0	5.0 – 30.61
DDH5197	30.12	0.00	-	0.0 – 0.5	0.5 – 3.0
DDH5198	30.82	0.20	-	-	0.2 – 5.5
DDH5199	50.13	0.25	-	0.25 – 0.5	0.5 – 35.0
DDH5200	30.36	0.62	-	0.62 – 1.0	1.0 – 23.0
DDH5201	50.13	0.40	-	0.4 – 1.0	1.0 – 12.0

Note: These weathering profiles have been interpreted by Golder based on OceanaGold logs, core photographs and observations of the core.

HW – highly weathered, MW – moderately weathered, SW – slightly weathered.

4.3.2 Strength

No new strength testing has been undertaken as part of this investigation and strength description has been based on observation of outcrop and core. Unweathered schist encountered by the drill holes outside the deformation zone of the Macraes Fault has mainly been described as moderately strong or strong. Observation of the core suggests that the rock strength is comparable to schist encountered elsewhere on the Macraes Gold Project. Typical unconfined compressive strength for unweathered schist is between about 20 MPa and 40 MPa, normal to foliation, which is consistent with the description of moderately strong. Schist typically has a lower unconfined compressive strength along foliation, which reflects the layered nature of the rock and the presence of weak, mica-rich rich laminations.

Much of the rock encountered within the northern half of the embankment footprint has been affected by faulting associated with the Macraes Fault (refer to the zone of deformation in Figure 3). The fault-affected schist is typically described as weak or very weak and is estimated to have an unconfined compressive strength in the range 1 to 5 MPa.

Detailed logs of trenches are presented in Appendix D. These logs record rock mass strength at all locations across the fault zone, and indicate that, within the Macraes Fault zone of deformation, approximately 50% of the rock mass comprises zones of weak or moderately strong schist and the remaining rock mass comprises very weak, highly weathered or sheared schist.

4.3.3 Rock mass discontinuities

Joints

Joint orientations have been measured from outcrops and excavations. The most common joint orientations measured in the impoundment are steeply dipping (>70°) with a dip direction to the south or southwest. Other joints typically dip steeply to the west or northwest. Figure 6 presents all discontinuity data (foliation and joints) collected from test pits and trenches from the embankment footprint. Discontinuity data from individual test pits and trenches is presented in Appendix C.

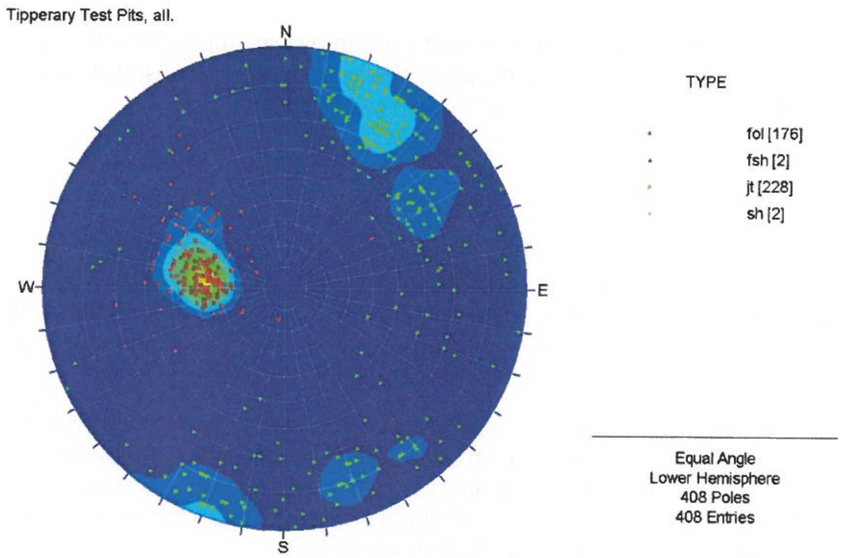

Figure 6: Stereographic projection of all discontinuity data collected from embankment footprint.

In the drill core joints are typically described as rough and planar to undulating. Most core breaks are along foliation, and many of these could have been induced during drilling or handling.

The widest spacing between adjacent joints or foliation partings is about 500 mm. Much of the core is highly fractured, or sheared particularly within the deformation zone of the Macraes Fault.

Foliation

Foliation typically dips at about 40° to the east in the vicinity of the proposed impoundment, which is consistent with the regional trend. Figure 6 shows that the greatest concentration of foliation measurements (red symbols) dip towards about 100°, however, a significant number of measurements indicate foliation dipping to the southeast. This is consistent with the folding within the deformation zone of the Macraes Fault. Figure 3 shows the distribution of foliation attitudes around the reservoir in plan view.

4.4 Faults

4.4.1 Macraes Fault

The Macraes Fault has offset the Hyde-Macraes Shear Zone by about 250 m in a reverse sense (refer Golder 2011). This deformation has been accommodated by a number of faults, both parallel to foliation and cutting across foliation.

Trenches (100 to 700) excavated near to the right abutment and along the footprint of the main embankment expose a number of faults inferred to have accommodated deformation associated with the Macraes Fault. The trenches suggest a widening zone of deformation approximately 250 m wide at the right abutment and 600 m wide at the main embankment. Faults exposed in these trenches include the following:

- Several faults dipping about 45° to the north, striking parallel to the overall trend of the Macraes Fault at the northern margin of the deformation zone.
- Several moderately to steeply dipping faults up to 600 mm across, striking parallel to the trend of the Macraes Fault, and cutting across foliation.
- Numerous foliation parallel faults striking obliquely to the overall trend of the Macraes Fault (but parallel to the local foliation orientation). Foliation-parallel faults are common in schist, particularly where tectonic deformation has resulted in flexural slip during folding.

4.4.2 Eastern Lodes

DDH5195 was targeted to intersect the "Duke of Edinburgh Lode", which is a mineralised shear zone identified from previous gold exploration investigations (Figure 3), and a member of the "Eastern Lodes". An exploratory drill hole located within the impoundment (RCD5086) intersected the Duke of Edinburgh Lode at about 50 m depth. This hole encountered a significant water-bearing zone at that depth and subsequently flowed artesian.

The shear zone was targeted to evaluate whether it could represent a significant aquifer that could lead to leakage from the impoundment. A shallow trench was excavated to confirm the location of the shear zone, and it exposed approximately 20 m of fractured and sheared schist and quartz veins. The trench filled with groundwater before being logged. DDH5195 was inclined 70° to towards 250° in order to intersect the lode and it exposed sheared and broken schist to a depth of about 20 m.

An exploratory drill hole located within the impoundment (RCD5086) intersected the Duke of Edinburgh Lode at about 50 m depth. This hole encountered a significant water-bearing zone at that depth and subsequently flowed artesian.

Other Eastern Lodes are inferred to cross the proposed impoundment (Figure 3), but were not specifically identified during the current investigations.

4.5 Slope Stability

Some local shallow instability of the soil slopes occurs where they steepen around incised channels. However, no evidence of large scale slope instability was observed within the embankment footprint or impoundment and none is evident in aerial photographs.

4.6 Hydrogeology

4.6.1 Piezometer data

Two standpipe piezometers were installed in each drill hole on completion. One piezometer was installed to the maximum depth of the hole and the second piezometer was installed at shallower depth to evaluate vertical groundwater gradient. The piezometer details are presented in Table 2, along with depth to groundwater measurements taken on 10 August 2010.

Table 2: Piezometer construction details.

Drill hole #	Stickup (m)	Piezometer	Sand pocket interval (m)	Depth to water (m) 10 August 2010	Differential (m) (-ve if upward gradient)
DDH5194	0.24	A	32.8 – 49.94	3.52	-0.21
		B	2.78 – 10.62	3.31	
DDH5195	0.1	A	24.01 – 30.54	0.54	-0.01
		B	13.39 – 20.77	0.55	
DDH5196	0.2	A	23.19 – 30.65	3.35	0.00
		B	11.06 – 18.96	3.35	
DDH5197	0.2	A	23.61 – 30.04	1.53	-0.20
		B	10.62 – 16.54	1.73	
DDH5198	0.1	A	23.18 – 30.80	6.77	-0.96
		B	12.16 – 18.13	7.73	
DDH5199	0.08	A	42.07 – 50.17	6.58	4.51
		B	7.55 – 14.62	2.07	
DDH5200	0.15	A	23.58 – 29.95	0.70	-1.18
		B	5.16 – 12.91	1.88	
DDH5201	0.05	A	42.52 – 50.21	9.38	-1.78
		B	10.83 – 18.55	11.16	

4.6.2 Rock mass permeability

An evaluation of the packer tests conducted in the investigation drill holes has been undertaken by Golder and a brief report is presented in Appendix F. The rock mass permeability inferred from the packer tests is in the range $5x10^{-6}$ to $3x10^{-9}$ ms^{-1}. The report concludes that rock mass permeability within the impoundment is similar to other sites around the Macraes Gold Project. The test results also suggest that the permeability of the rock mass within faulted schist (approximately half of the tests) is the same as unfaulted schist.

Three test pit scale permeability tests were undertaken to measure the permeability of the shallow rock mass. The locations are within the embankment footprint, near the southern margin of the Macraes Fault (Figure 2). Locations included faulted and unfaulted schist. Reports summarising the findings of the tests are presented in Appendix F. These tests involved filling each test pit to a depth of about 0.5 m and measuring the rate of fall of the water surface over a period of a few hours. Estimated hydraulic values for each test were calculated using SEEP/W. The results indicate that the rock mass at the test depth has a hydraulic conductivity of less than 10^{-9} m/s, which is practically the lowest hydraulic conductivity that can be measured by this method.

Table 3: Summary of the results of packer tests.

Drillhole	Test interval			Hydraulic conductivity		Comments
	Top	Base	Length	(Golder 1997)	(Sharp 1975)	
	(mbgl)	(mbgl)	(m)	(m/s)	(m/s)	
TT001 (DDH5201)	14.23	20.23	6.00	4×10^{-6}	7×10^{-6}	
	44.23	50.13	5.90	4×10^{-7}	7×10^{-7}	
TT002 (DDH5194)	11.10	17.10	6.00			Flows exceed pump capacity at 50 kPa.
	32.10	38.10	6.00			Flows bypass packer and discharge to surface.
TT003 (DDH5200)	5.31	11.31	6.00	5×10^{-6}	8×10^{-6}	
	25.36	31.36	6.00	1×10^{-6}	2×10^{-6}	
TT004 (DDH5195)	5.00	11.00	6.00	1×10^{-6}	2×10^{-6}	
	23.00	30.50	7.50	3×10^{-7}	5×10^{-7}	
TT005 (DDH5199)	20.11	25.83	5.72	3×10^{-7}	5×10^{-7}	
	44.13	50.13	6.00			Flows exceed pump capacity at 20 kPa.
TT006 (DDH5198)	11.00	17.00	6.00	3×10^{-9}	5×10^{-9}	Hydraulic conductivity value is considered a maximum as no flows recorded.
	23.00	30.82	7.82	3×10^{-9}	5×10^{-9}	Hydraulic conductivity value is considered a maximum as no flows recorded.
TT007 (DDH5197)	11.22	17.22	6.00			Flows bypass packer and discharge to surface.
	23.22	30.12	6.90	2×10^{-7}	4×10^{-7}	
TT008 (DDH5196)	11.00	17.00	6.00	4×10^{-7}	6×10^{-7}	
	23.12	30.62	7.50	4×10^{-7}	5×10^{-7}	

5.0 CONCLUSIONS

1) The impoundment area is mainly flat or gently sloping, with streams incised into gullies. The gullies are up to about 30 m deep and have moderately steep sides (up to about 30° slopes).

2) The impoundment area is underlain by schist with a cover of loess and colluvial soils to an average depth of about 0.4 m and a maximum depth of about 1.8 m. Colluvial soils comprise schist gravel in a loess-dominated matrix.

3) The rock mainly comprises psammitic (coarse grained) or pelitic (fine grained), laminated schist. Most of the schist is strong or moderately strong. However, faulting affects part of the impoundment footprint. Faulted schist is generally highly fractured, contains a significant proportion of gouge material and is typically described as weak or very weak.

4) Several faults cross the impoundment area. These include the Macraes Fault, which is inferred to affect an east trending zone about 250 m wide at the right abutment and 600 m wide beneath the main embankment. In addition, several north to north-west striking faults ("Eastern Lodes") that have been recognised from gold exploration, cross the impoundment.

5) The zone affected by faulting includes much of the main embankment footprint north of Tipperary Creek. Trench 700 presented nearly continuous exposure over this area and exposed approximately 50% weak or moderately strong schist, and 50% very weak, sheared schist. It is inferred that the embankment footprint will comprise zones of faulted schist and zones of intact schist.

6) Discontinuities observed in the schist comprise mainly foliation partings. These typically dip about 40° towards the east or south east. Foliation orientation measurements appear to define a broad, open fold associated with the Macraes Fault. Joints are typically steeply dipping, rough and planar to undulating. The most common strike of joints is approximately southeast.

7) An assessment summarised in a separate report (Golder 2011) concluded that the Macraes Fault has not ruptured in the last 11,500 years, and no evidence was found of movement during the last 125,000 years.

8) No evidence of large scale slope instability affecting the impoundment or embankment footprint has been observed.

9) Packer testing has been utilised to measure rock mass permeability. The testing indicates that faulted schist does not have a significantly different rock mass permeability from non-faulted schist. The testing also indicates that the estimated rock mass permeability at the Top Tipperary TSF site is the same as elsewhere at the Macraes Gold Project.

10) Test pit scale permeability tests were undertaken to measure hydraulic conductivity of the rock mass at approximately foundation level. The tests indicate that hydraulic conductivity at this level is very low, less than about 10^{-9} m/s.

11) Piezometric levels are generally within about 5 m of the ground surface. Piezometers around the impoundment indicate both small upward and small downward groundwater gradients.

6.0 REFERENCES

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