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OCEANA GOLD (NZ) LTD, MACRAES GOLD PROJECT
TOP TIPPERARY TAILINGS STORAGE FACILITY
DAM BREACH STUDY

Prepared for:

15 April 2011

Oceana Gold (NZ) Ltd
P O Box 5442
Dunedin
OTAGO

OCEANA GOLD (NZ) LTD, MACRAES GOLD PROJECT
TOP TIPPERARY TAILINGS STORAGE FACILITY
DAM BREACH STUDY

EXECUTIVE SUMMARY

1. Construction of the proposed Top Tipperary TSF (TTTSF) will create an impoundment capable of storing 36.7Mm^3 of tailings and between 200,000m^3 and 500,000m^3 of water. A breach of the dam could result in release of some of the tailings and the water.

2. A dam breach study have been undertaken to determine the effects of a hypothetical breach under both sunny day and flood induced (1 in 100 AEP flood event) conditions. The initiating event for a sunny day failure would most likely be an earthquake. Such a study determines the extent of flooding, and then assesses the incremental consequences resulting from the breach. The breach scenarios are hypothetical because the types of failures hypothesised and the consequences in terms of releases from the TTTSF should not be expected to occur.

3. The results of the dam breach study have been used to assess the Potential Impact Classification (PIC) of the TTTSF. The PIC has been assessed in accordance with the Building (Dam Safety) Regulations 2008. The PIC for both sunny day and flood induced conditions is assessed to be medium.

4. It is important to distinguish between the hazard potential (i.e. the effects of a dam breach were it to occur) and the risk or probability of a dam breach occurring. The risk of failure for a dam designed, constructed, operated and maintained in accordance with modern standards (e.g. NZSOLD Dam Safety Guidelines) would be extremely low.

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1.0 INTRODUCTION

Oceana Gold (New Zealand) Limited (OceanaGold) proposes an extension to the Macraes Gold Project. The Macraes Phase III Project will take the consented mine life through to 2020. A new tailings storage facility called the Top Tipperary Tailings Storage Facility (TTTSF) is proposed to be constructed in the upper Tipperary catchment basin. It will provide storage for approximately 50Mt (dry weight) of additional tailings and will impound up to a maximum of 500,000m³ of water during its service life. The TTTSF is formed by an embankment that is approximately 4.3km long and up to 70m high. The TTTSF will be required for tailings storage in May 2012 and construction is planned to commence in August 2011.

Engineering Geology Ltd (EGL) has been contracted by OceanaGold to assess the feasibility of the TTTSF and undertake the design. A Technical Report documenting the proposed design of the TTTSF and covering construction, operation and closure has been prepared to support an application for a Resource Consent (Ref.1). The requirements for design, construction and operation of dams in New Zealand are documented in Guidelines published by the New Zealand Society on Large Dams (NZSOLD) (Ref.2). The requirements are related to the Potential Impact Classification (PIC). The PIC is dependent on the incremental losses that could arise as a result of failure. The incremental losses are normally assessed by undertaking a dam breach study which involves evaluating the effects of a hypothetical breach of the dam. This report documents the results of a dam breach study of the proposed TTTSF. The study assesses the extent and depth of inundation associated with a breach under sunny day and flood induced conditions. The incremental effects of a breach are evaluated and an assessment of the PIC is provided.

2.0 DAM DESIGN STANDARDS AND REQUIREMENTS FOR DAM BREACH STUDY

The New Zealand Society on Large Dams (NZSOLD) publication 'New Zealand Dam Safety Guidelines' is the basis for design, construction and operation of dams in New Zealand. Requirements for design, construction and operations are related to the Potential Impact Classification (PIC). Four different potential impact categories are defined (very low, low, medium and high). The categories are based on the incremental losses which a failure might give rise to. Incremental losses are those additional losses that might have occurred for the same natural event if the dam had not failed. In assessing which category is appropriate consideration needs to be given to the consequences of failure (life, socio-economic, financial and environmental). To assess the incremental losses associated with dam failure it is necessary to undertake a dam breach study. Such a study considers a hypothetical breach of the dam and normally considers failure under both sunny and flood induced conditions. The extent of the flooding is determined and the incremental consequences resulting from the breach are assessed.

3.0 LOCATION

The location of the proposed TTTSF is shown in Figure 1. A larger scale plan of the TTTSF is shown in Figure 2. The plan grid on Figure 1 is New Zealand Map and the grid on Figure 2 is based on mine north which is approximately 45° degrees anti-clockwise from true north.

Hypothetical breach of the TTTSF could result in discharge of tailings and water into either Tipperary or Cranky Jims Creeks. Tipperary Creek is located on the southeast side of the TTTSF and Cranky Jims Creek is located on the northeast side. The embankment is about 60m high immediately upstream of Tipperary Creek, and about 40m high immediately upstream of Cranky Jims Creek. Both creeks are tributaries of the Shag River.

Downstream of the TTTSF the Tipperary Creek flows in the south east direction until it joins into McCormicks Creek which flows eastward and joins the Shag River about 19km from the TTTSF, just south of Dunback as shown in Figure 1.

Cranky Jims Creek flows in a north eastern direction from the TTTSF and joins into the Shag River about 7km from the TTTSF as shown in Figure 1.

There are no permanently inhabited structures (i.e. residential dwellings) situated along the Tipperary, McCormicks or Cranky Jims Creeks that would be affected by a breach of the TTTSF. There are a number of dwellings located adjacent to the Shag River that historically have been affected by floods and could be affected by a breach of the TTTSF. They are shown in Figure 3. The grid on Figure 3 is in terms of Observation Point 2000. The closest dwellings potentially at risk from a breach discharging into Cranky Jims Creek are located at Waynestown, approximately 23 km downstream of the TTTSF(refer to houses A and B on Figure 3). A breach discharging into Tipperary Creek would discharge into the Shag River just south of Dunback. The closest dwellings potentially at risk from a breach into Tipperary Creek are located south of Dunback, approximately 22km downstream of the TTTSF (refer to houses I, J and K on Figure 3).

There are also a number of bridges and a culvert crossing potentially at risk. They are shown in Figure 3. Most are located across the Shag River. There is also the existing SH85 Dunback-Palmerston road bridge across McCormicks Creek (Bowkers Bridge) and the abandoned historic stone arch bridge located about 100m upstream.

4.0 DAM BREAK SCENARIO

The dam break scenario assumes a hypothetical uncontrolled release of tailings and water from the tailings storage facility due to a breach of the dam. It is hypothetical because a dam designed, constructed and operated in accordance with modern practice would not be expected to fail. No assumptions are made about the mode of failure and it takes no account of the risk of failure or the type of failure.

The location of the largest breach that could potentially occur is expected where the embankment is highest. This is immediately upstream of the Tipperary Creek. We have also considered the possibility of a breach into Cranky Jims Creek.

Two different initiating events have been considered for a hypothetical breach of the TTTSF. They are breaches under sunny day and flood induced conditions. In a sunny day failure the normal operating volume of water ponded on top of the TTTSF is assumed and flows in the downstream creeks and rivers are assumed to be at normal levels. In a flood induced situation a larger volume of water would be ponded on top of the TTTSF and the downstream creeks and rivers would be at flood levels. The most likely initiating event for a sunny day failure of the TTTSF is a large earthquake. For the flood induced condition a 1 in 100 Annual Exceedance Probability (AEP) flood event has been assumed.

A breach of the TTTSF would result in the release of both tailings and water. However, observations of historical breaches of tailings dams, supported by theoretical predictions, are that most of the tailings would be expected to be deposited close to the TSF while the water would flow downstream.

5.0 RELEASE OF TAILINGS

Historic breaches of tailings storage facilities indicate that only a portion of the tailings are released. This is attributed to the fact that unlike water, tailings have shear strength. The released tailings will usually come to rest at an angle which is dependent on the tailings residual strength. In addition, observations indicate that the tailings left remaining in the tailings storage facilities stand much steeper than the angle of repose of the tailings.

Released saturated tailings have been documented to come to rest at slopes of 1º to 4º (1:57 to 1:14, V:H) measured from the toe of the mobilised tailings back into the impoundment (Refs.3 and 4). These slope angles depend on the residual shear strength of the tailings after mobilisation and the topography of the dam's downstream area. Most of the documented breaches of tailings facilities are on relatively flat ground. In this study we have adopted a 1:16 (V:H) slope at which the tailings will come to rest after mobilisation. This takes into consideration the sandy nature of the tailings and the residual strength of the liquefied tailings. In particular it assumes the tailings will come to rest at an angle which is close to half of the liquefied friction angle.

Where embankments have been breached the eroded surface of the embankment sloping from the upstream shoulder to the downstream shoulder have been reported to have been between 1:7 to 1:35 (V:H) (Ref.3). This slope is dependent on the material used to construct the embankment. Given that coarse material (rockfill) is proposed to be used in the construction of the TTTSF embankment a 1:10 (V:H) grade is adopted in this study (i.e. it is assumed that the breach would erode through the embankment at approximately 1 in 10 sloping down from the upstream shoulder to the downstream shoulder). Empirical methods exist for estimating breach width and geometry for water storage embankments (Ref.4). Taking these into consideration we have adopted the width of the base of the dam breach as 50m with side slopes of 1:1. This is considered conservative. Figure 4 includes a plan and cross-section of the geometry assumed for the breach in this study.

The maximum volume of tailings that could be released from a breach of the TTTSF depends on the breach elevation, the profile of the displaced tailings and the topography of the ground downstream of the breach. The maximum volume of tailings that could be released was estimated by comparing the volume released from the TTTSF for breaches at different assumed levels with the volume that could be stored downstream of the breach. By iteration and interpolation the maximum volume is taken to be that obtained for a breach height where the volume of released tailings equals the volume occupied by tailings downstream of the breach. An example of such iteration is presented in Figure 4 which shows the released volume and the downstream volume capacity for a breach at RL540. The results of the iterations carried out for potential breaches into the Tipperary and Cranky Jims Creeks are presented in Figures 5 and 6 respectively.

The maximum potential volume of tailings that could be released into the Tipperary Creek is estimated to be 1.5Mm^3 of tailings and it would flow for a distance of 1.1km from the embankment. For the Cranky Jims Creek, the maximum potential volume of tailings that could be released is about 0.5Mm^3 and it would flow for a distance of about 1 km. Although most of the released tailings would be located within about 1km of the breach, some would be carried in suspension by the associated released pond water and settle out at various locations, until large flood events occurred and carried the tailings out to sea.

6.0 RELEASE OF WATER

6.1. General

The assessment of the effects of release of water from the TTTSF in the event of a breach has been evaluated using similar methods used for analysing the breach of a water storage dam. A key difference is that the depth of impounded water in the tailings dam is typically much shallower and the volume less compared to water storage dams. Assumptions and results are presented in the following sections.

6.2. Breach Hydrograph

A hydrograph for the breach is required to predict the potential effect of water released from the breach of the TTTSF. This requires estimates of peak flow, time for the full breach to form (time to failure) and volume of water released.

The TTTSF is expected to have a normal operational water volume of about 200,000m^3. This would be expected to increase by about 270,000m^3 from a 48 hour - 100 year return rainfall event. For a 1 in 100 AEP flood event it is conservatively assumed that 500,000m^3 of water would be stored in the TTTSF.

The dimensions of the breach are the same as assumed for the release of tailings. They are discussed in Section 5 and shown in Figure 4.

The peak flow and time to failure of a breach (defined as when breach is fully developed) are usually estimated using empirical methods derived from analysis of historical failures of water storage dams (Ref.5). The estimates are dependent on the volume of water stored and height of the dam or depth of water.

The time to failure was estimated by comparing estimates from three empirical methods: Froelich (Refs.6 and 7), MacDonald and Langridge-Monopolis (Ref.8) and Bureau of Reclamation (Refs. 9 and 10). The time to failure varied from 3 minutes to 105 minutes. The TTTSF stores more tailings than water. The tailings will be deposited so that the tailings surface slopes down from the upstream shoulder of the embankment at about 1 in 200(V: H). The water will be stored over an area of about 20-40ha. Consequently the average depth of stored water will be relatively shallow (less than 2m). Taking this into account and the type of embankment required to be eroded we adopted 60 minutes as the time for a full breach to form.

A breach hydrograph for the TTTSF was generated using BOSS DAMBRK (a dam break software programme) assuming a breach time of 60 minutes and the height-storage characteristics for the impounded water. The peak breach flow associated with the hydrograph is 90m³/s for the sunny day scenario and 140m³/s for the flood induced scenario.

6.3. Stream Flows and Levels without Dam Breach

In order to analyse the incremental effects of a hypothetical breach of the TTTSF it is necessary to establish the flood levels in both the Shag River and McCormicks Creek that would exist downstream of the TTTSF in the same conditions without a breach.

The headwaters of the Shag River are in the Kakanui Mountains. It has a catchment area of about 548km². The catchment is bounded by the Kakanui Mountains, Horse Range and Razorback Range to the north east and by the Taieri Ridge to the south (Ref.13).

The flow in the Shag River is monitored at two locations; The Grange (located just upstream of Waynestown) for high flows and at Craig Road for low flows that are less than 10m³/s. The ORC operates a flood warning system using the flow monitoring system at The Grange. Affected residents downstream are warned when there is an increase of the water level to 1.4m or about 31m³/s (Ref.12).

In the sunny day breach condition, flows in the Shag River are assumed to be normal, which are less than 1m³/s at The Grange. The mean annual flood flows at The Grange and Dunback are estimated to be about 147m³/s and 160m³/s respectively (Ref.13).

The sunny day flow in McCormicks Creek, at the confluence with the Shag River would be less than 1m³/s as the catchment area is only 43km². The mean annual flood at the same location is approximately 18m³/s and the 1 in 10 AEP flood flow is 35m³/s.

In order to estimate flow levels in the Shag River under the 1 in 100 AEP flood conditions, a HEC-RAS flood routing model was utilised. Ground levels were determined from an aerial survey specifically undertaken for the dam breach study over the potential flood plain. The model was calibrated against historic flood levels compiled by the Otago Regional Council (ORC) (Refs.11 and 13).

ORC have identified areas of historic flooding from witness accounts, photograph records and physical evidence. There also have been expert estimates of flows during floods at specific locations (Ref.11). There are records for three recent significant floods. The flood of 5 June 1980 has been considered as the recent worst flood with an estimated flow at Dunback of 590m³/s. The flood of 13 March 1986 had an estimated flow at Dunback of 445m³/s (Refs.11 and 13). The 22 December 1993 flood was measured at The Grange to have a maximum flow of 472m³/s (Ref.14).

A Stage to Flow rating chart has been developed for The Grange Station and the 1 in 100 AEP flow has been recently estimated to be 958m³/s (Ref.14). This has been adopted as the 1 in 100 AEP flood flow in the flood induced breach scenario.

The 1 in 100 AEP flows at other locations downstream of The Grange have been estimated by relating the flow at The Grange to its catchment area and then using the Regional Flood Procedure to determine flows at other locations with different catchments (Ref.15). The flows obtained for each location were compared with and adjusted if necessary. Summaries of the 1 in 100 AEP flood levels at houses and bridge sites identified in Figure 3 are presented in Tables 1 and 2 respectively. The flood levels at bridge sites could be higher than indicated because the flood levels have been determined ignoring any constriction to flow caused by the presence of the bridges. The results in Table 1 indicate that the 1 in 100 AEP flood event on its own will result in water level exceeding floor level at 12 houses. This is not surprising as historically a number of properties are known to have been affected by lesser floods. The results in Table 2 indicate that the 1 in 100 AEP flood event on its own will result in water level exceeding bridge deck level at 7 bridges or culvert crossings.

6.4. Breach Flows and Levels

The 1 in 100 AEP flow from the McCormicks Creek at the confluence with the Shag River was estimated by scaling flows recorded in the Shag River using the catchment area-flow relationship in the Regional Flood Estimation Procedure (Ref.15). The catchment area of McCormicks Creek at the confluence with the Shag River is $40km^2$. The estimated 1 in 100 AEP flood flow is $130m^3/s$.
Flood routing to determine the flood flows and levels from a hypothetical breach was carried out using HEC-RAS. The peak breach flow associated with a sunny day failure is estimated to be 90m³/s. This flow would attenuate significantly and by the time it reached Waynestown or the confluence of McCormicks Creek and the Shag River is estimated to be less than 40m³/s. Flows in the Shag River and McCormicks Creek are less than 1m³/s in sunny day conditions and so a breach of the TTTSF under sunny day conditions would only result in flows in the Shag River at Waynestown and in the McCormicks Creek at the confluence with the Shag River of no more than 40m³/s. This is much less than the annual flood flow in the Shag River (147m³/s at The Grange, just upstream of Waynestown) and is equivalent to about the 1 in 12 AEP flood event in McCormicks Creek. No houses would be inundated or bridges overtopped under this flow.

The depth of water associated with a breach for the flood induced condition in the Shag River has been evaluated by analysing flood water levels with an additional $140m^3/s$ flow on top of the 1 in 100 AEP flood flow. This is conservative as it makes no allowance for attenuation of the breach flow. For evaluating effects in the McCormicks Creek the breach flow has been attenuated. It is estimated to be about $98m^3/s$ at the confluence with the Shag River so that the total flow with the 1 in 100 AEP flood event would be $228m^3/s$. The predicted flood water levels during both a 1 in 100 AEP flood event on its own and with a dam breach are summarised for houses and bridges in Tables 1 and 2 respectively. The incremental depth of water in the Shag River due to a breach in a 1 in 100 AEP flood event is small where houses are located (up to 0.2m, refer to Table 1). One additional house is inundated by a flood induced breach, but the water above the floor level is only 0.17m. The incremental depth of water where bridges across the Shag River are inundated varies from between 0.09m to 0.3m (refer Table 2). No additional bridges are affected by a breach of the TTTSF compared to the 1 in 100 AEP flood event on its own.

7.0 ASSESSMENT OF PIC

7.1. Criteria for Assessment of PIC

The PIC is dependent on the damage level and the population at risk (PAR). Criteria for assessing damage levels are defined in Table 1 of the Building (Dam Safety) Regulations 2008. Four different categories of damage are specified (residential house, critical or major infrastructure, natural environment and community recovery time). The PIC is determined from Table 2 of the Regulations.

7.2. Sunny Day Breach

The level of damage due to a breach under sunny day conditions is assessed to be minimal for residential houses and infrastructure as the water level in the Shag River is assessed to be less than the annual flood event and below existing house and bridge levels. Damage to the natural environment is considered major (heavy damage and costly restoration), a result of the effects associated with release of tailings and pond water into Cranky Jims, Tipperary and McCormicks Creeks and the Shag River. Some people could be affected due to potential contamination of water in the Shag River (e.g. people taking water from Shag River for irrigation purposes) and there could be a loss of recreational amenity (e.g. fishing or swimming). Consequently the community recovery time damage level is assessed to be moderate to major (months to years).

The PAR for a sunny day breach is likely to be low (in the range of 1 to 5) as water levels in the Shag River would not be greater than what occurs quite regularly under flood conditions. Flows in the Tipperary or McCormicks Creeks would be more significant. However, these creeks have no to minimal recreation use as most sections of the watercourses are only accessible from private land. In the Shag River the number of people potentially at risk is very low because the expectation is that people would move away if they saw the water level rising. However, due to the short warning time associated with a breach some population could be at risk (e.g. people swimming or fishing). The PIC for a sunny day breach is **medium** according to Table 2 of the Dam Safety Regulations (PAR of less than 5 and a major damage level). The moderate damage assessment arises due to the potential environmental consequences, not as a result of risk to people.

7.3. Flood Induced Breach

A breach under flood induced conditions is predicted to only result in up to a 0.2m rise on top of the 1 in 100 AEP flood level in the Shag River. This is because the 1 in 100 AEP flood event results in significantly greater flows in the Shag River, than flows associated with a dam breach. Incremental damage to houses has been assessed by considering the incremental change in parameter ‘dv’ where d is the depth of flow above house floor level and v is the velocity of water. The damage parameter ‘dv’ for the houses and bridges for the 1 in 100AEP flood event on its own and with a breach of the TTTSF are provided in Tables 1 and 2 respectively. The incremental change in ‘dv’ as a result of a flood induced breach is relatively small. Estimates of damage and potential hazard to life based on ‘dv’ are provided by Reiter (Ref.16) and Amos et al. (Ref.17) are presented in Tables 3 and 4 respectively. In the 1 in 100 AEP flood event 12 houses are estimated to have water levels above floor level. With a breach one more house is predicted to have water level above floor level, but only by 0.17m. The analyses indicate that there are 8 houses in a 1 in

100AEP flood event (i.e. without a dam breach) where dv >1.0 and there would be significant danger to life according to the criteria recommended by Amos et al.(Ref.16). A breach of the TTTSF does not result in an increased number of houses with significant danger to life (i.e. no other houses have dv > 1.0 as a result of a dam breach). There are 2 houses where there is some danger to life in a 1 in 100 AEP flood event (0.5 < dv <1.0) and 2 where there is no danger to life (dv <0.5). A breach of the TTTSF would result in 1 house moving from the no danger level to some danger resulting in 3 houses where there is some danger to life. There would be 2 houses in the no danger level. This indicates that the incremental effect of a dam breach is minimal.

In a 1 in 100 AEP flood there are seven bridges or culvert crossings across the Shag River where the water level exceeds bridge deck level (refer to Table 2). We note that the three most important bridges, which are part of the state highway (SH85 Dunback-Morrison Road, SH85 Dunback-Palmerston and SH1 Hampden-Palmerston Road), would not be inundated by the 1 in 100 AEP flood event and neither with a dam breach. All other bridges are on minor roads that have low traffic volumes. The analysis indicates that the incremental increase of 'dv' for the inundated bridges due to the breach of the TTTSF is not significant and so the incremental effect of a dam breach on bridges is minimal. Consequently the incremental effect of a flood induced dam breach on critical or major infrastructure is minimal.

Incremental damage to the natural environment is considered major (heavy damage and costly restoration), a result of the effects associated with release of tailings and pond water. This is similar to that for a sunny day failure.

Community recovery time is assessed to be moderate to major (months to years), similar to that for a sunny day failure.

The incremental population at risk as a result of a dam breach is assessed to be low (in the range of 1 to 5) because in a flood induced condition it is highly unlikely that there would be any recreational users present in Cranky Jims, Tipperary or McCormicks Creeks or in the Shag River. In addition, the dam breach analysis does not indicate a significant incremental effect and the ORC have a warning system that is activated when flood events occur (Ref. 11). . Consequently the PIC for a flood induced breach is **medium** according to Table 2 of the Dam Safety Regulations (PAR of less than 5 and a major damage level). The major damage assessment arises due to the potential environmental consequences in Cranky Jims, Tipperary and McCormicks Creeks and the Shag River.

7.4. Summary

In summary the PIC for a hypothetical breach of the dam under both sunny and flood induced conditions is **medium**.

8.0 DAM BREAK MITIGATION

This section provides information on the potentially inundated areas and warning time.

8.1. Inundation Area

The largest inundation occurs for the flood induced breach condition. Maps indicating the extent of inundation are provided in Appendix A.

8.2. Warning Time

The warning time has a significant influence on the loss of life in a dam breach event. Brown and Graham (Ref.18) indicate that the loss of life can vary from 0.02% of the population at risk when the varying time is 90 minutes to 50% of the population at risks when the warning time is less than 15 minutes. Table 5 presents a summary of the time from the start of the dam breach to the time the flood wave would arrive at different locations downstream of the dam. Table 5 also shows the time it would take from the start of the breach for the peak flow to occur. In the unlikely event of a dam breach it would take approximately 55 minutes for flood waters to reach the nearest dwelling at risk at Waynestown and about 70 minutes for peak flows to occur.

The warning time has no bearing on the PIC but is important for emergency planning.

9.0 CONCLUSIONS

The dam breach study shows that the Top Tipperary TSF should be categorised as medium PIC. This assessment is largely driven by the assessment of damage to the natural environment, a result of the effects associated with release of tailings and associated pond water.

In the unlikely event of a dam breach it would take approximately 55 minutes for flood waters to reach the nearest dwelling at risk at Waynestown and about 70 minutes for peak flows to occur.

It is important to distinguish between the hazard potential (i.e. effects of a dam breach were it to occur) and the risk or probability of a dam breach occurring. The risk of failure for a dam designed, constructed, operated and maintained in accordance with modern standards (e.g. NZSOLD Dam Safety Guidelines (Ref. 2) would be extremely low.

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TABLES

Table 1. Summary of 100 Year and Dam Breach Flood Levels at Houses

House	Estimated House Floor Level	100yr Flood Level	100yr & Dam Break Flood Level	Depth for 100year flood level	Depth for 100yr & Dam Break Floods	velocity for 100 year flood	velocity for 100 year and dambreak	Damage Parameter *dv* for 100 year flood only	Damage Parameter *dv* for 100 year flood and Dam Break
A	61.25	62.86	62.99	1.61	1.74	1.32	1.33	2.12	2.31
B	61.12	62.62	62.75	1.50	1.63	1.42	1.42	2.13	2.31
C	51.69	51.58	51.68	-0.11	-0.01				
D	51.97	51.58	51.68	-0.39	-0.29				
E	53.02	51.58	51.68	-1.44	-1.34				
F	53.39	51.58	51.68	-1.81	-1.71				
G	47.64	47.80	47.93	0.16	0.16	0.82	0.87	0.13	0.25
H	50.51	47.80	47.93	-2.71	-2.58				
I	44.30	43.58	43.77	-0.72	-0.53				
J	43.60	43.58	43.77	-0.02	0.17		1.09		0.18
K	43.88	43.58	43.77	-0.30	-0.11				
L	38.38	36.66	36.76	-1.72	-1.62				
M	34.55	33.58	33.76	-0.97	-0.79				
N	31.91	33.32	33.51	1.41	1.60	0.56	0.56	0.79	0.90
O	31.13	33.32	33.51	2.20	2.38	0.56	0.56	1.23	1.33
P	30.59	32.70	32.87	2.11	2.28	1.27	1.30	2.68	2.96
Q	30.64	32.54	32.70	1.90	2.10	1.09	1.14	2.08	2.39
R1N	30.35	31.84	32.00	1.49	1.65	1.00	1.11	1.49	1.83
R	30.28	31.84	32.00	1.56	1.72	1.00	1.11	1.56	1.91
R2	30.36	31.84	32.00	1.48	1.64	1.00	1.11	1.48	1.82
S	30.18	30.88	31.02	0.70	0.84	0.88	0.93	0.62	0.78
T	28.79	29.37	29.54	0.58	0.75	0.66	0.68	0.38	0.51

Table 2. Summary of 100 Year and Dam Breach Flood Levels at Bridges and Culvert Crossings

Bridge/Culvert	Stream	Estimated Bridge Deck Level	100yr Flood Level	100yr Dam Break Flood Level	Depth for 100year flood above Bridge deck Level (m)	Depth above bridge deck level for 100yr & Dam Break Floods (m)	velocity for 100 year flood (m/s)	velocity for 100 year and Dam Break (m/s)	Damage Parameter (dv) for 100 year flood only	Damage Parameter (dv) for 100 year flood and Dam Break
SH85-Dunback-Palmerston Rd Bridge (Bowkers Bridge)	McCormicks Creek	48.7	48.2	48.65	-0.5	-0.05				
McCormicks Creek Historic Stone Arch Bridge	"	49	48.2	48.65	-0.8	-0.35				
Loop Road Culvert	Shag River	106	112.8	113.0	6.8	7.0	3.85	4.00	26.2	28
SH85-Dunback-Morrison Rd Bridge	"	67.6	65.71	65.95	-1.89	-1.65				
Murphy Street Walk Bridge	"	51.0	51.59	51.68	0.59	0.68	1.96	1.95	1.16	1.33
Domain Road Bridge	"	46.6	47.64	47.93	1.04	1.33	2.83	2.38	2.94	3.16
Grange Hill Rd Bridge	"	37.7	43.30	43.47	5.60	5.77	2.49	2.72	13.94	15.69
McLew Rd Bridge	"	36.5	36.66	36.76	0.16	0.26	2.41	2.52	0.39	0.65
Craig Rd Bridge	"	27.4	32.70	2.87	5.3	5.6	2.95	2.95	15.6	16.5
Switch Back Rd Bridge	"	15.5	16.14	16.32	0.64	0.82	2.05	2.09	1.31	1.71
Horse Range Rd Bridge	"	12.65	10.76	10.80	-1.89	-1.85				
SH1-Hampden Palmerston Rd Bridge	"	7.1	4.91	4.92	-2.19	-2.18				

Table 3. Critical Structural Damage and Loss of Life Parameters (Reiter, Ref. 15)

Risk for loss of life classes of houses	Damage Parameter *dv* (m^2/s)		
	Small damages, small danger	**Medium damages, medium danger**	**Total damages, very high danger**
Lightly constructed detached one family house	<1.5	1.3-2.5	>2.5
Well Constructed wooden houses	<2.0 (v>2.0m/s)	2.0-5.0 (v>2.0m/s)	>5.0
Brick houses, concrete structures	<3.0 (v>3.0m/s)	3.0-7.0 (v>2.0m/s)	>7.0

Table 4. Potential Hazard (Amos et al., Ref. 16)

dv	**Potential Hazard**
$dv < 0.5$	No danger to life
$0.5<dv<1.0$	Some danger to life exists
$dv>1.0$	Danger to life significant

Table 5. Summary of Time for Flood Wave to Arrive and Time for Peak Water Depth

Location	Flood Breach Pathway	Distance Downstream of Dam (km)	Time for Flood Wave to Arrive (minutes)	Time for Peak Water Depth to Occur (minutes)
Waynestown	Via Cranky Jims	23	55	70
Dunback	“	28	75	90
SH1 Hampden-Palmerston Bridge	“	48	115	120
SH85 Dunback- Palmerston Rd Bridge	Via Tipperary Creek	20	45	60
SH1 Hampden-Palmerston Bridge	“	38.5	90	100

FIGURES

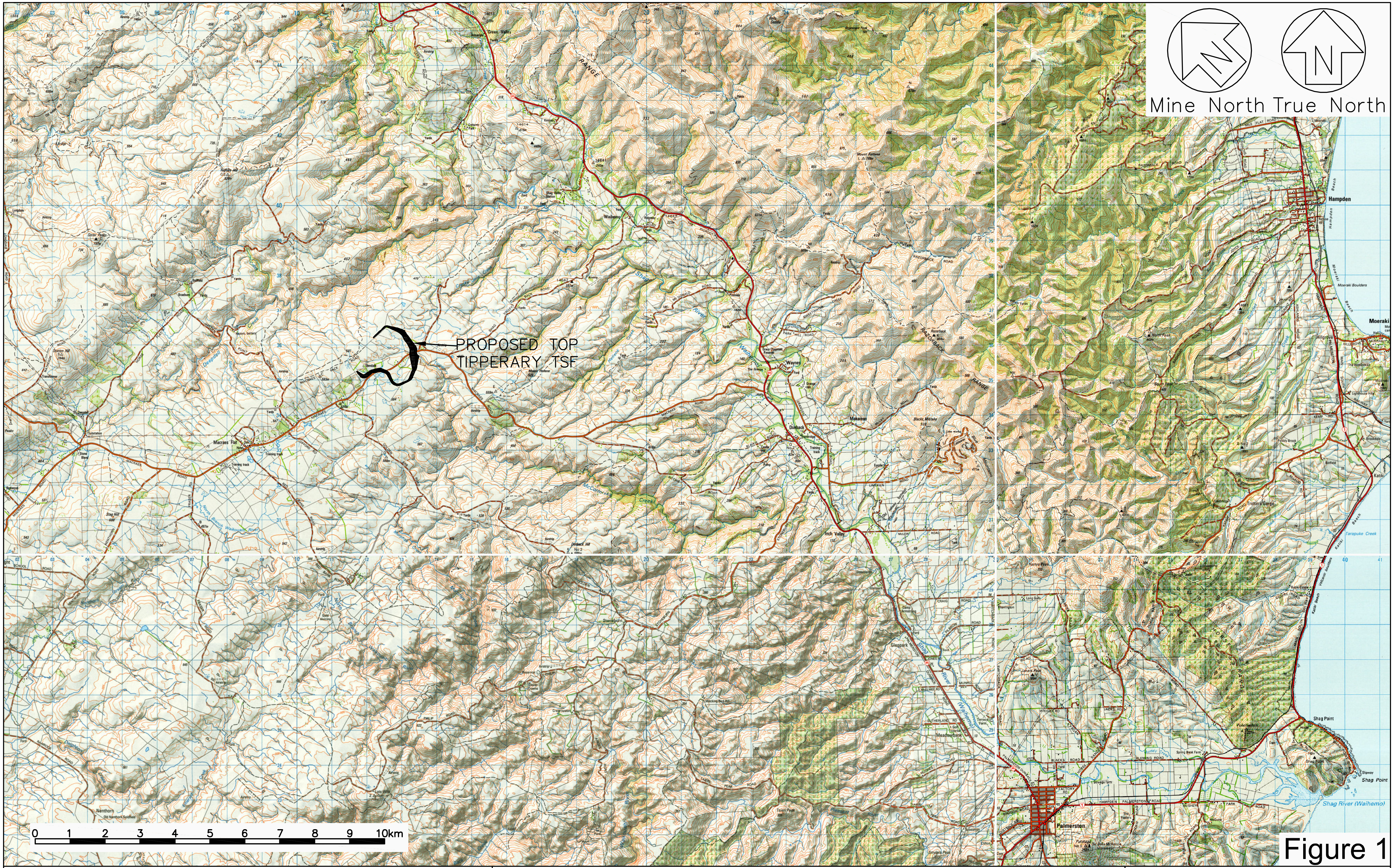

Figure 1

ENGINEERING GEOLOGY LTD
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OCEANA GOLD (NZ) LTD, MACRAES GOLD PROJECT
Top Tipperary TSF Dam Breach Study
Locality Plan

Drawing No.	6846-Figure 1
Date:	4 Mar 2011
Drawn:	BL
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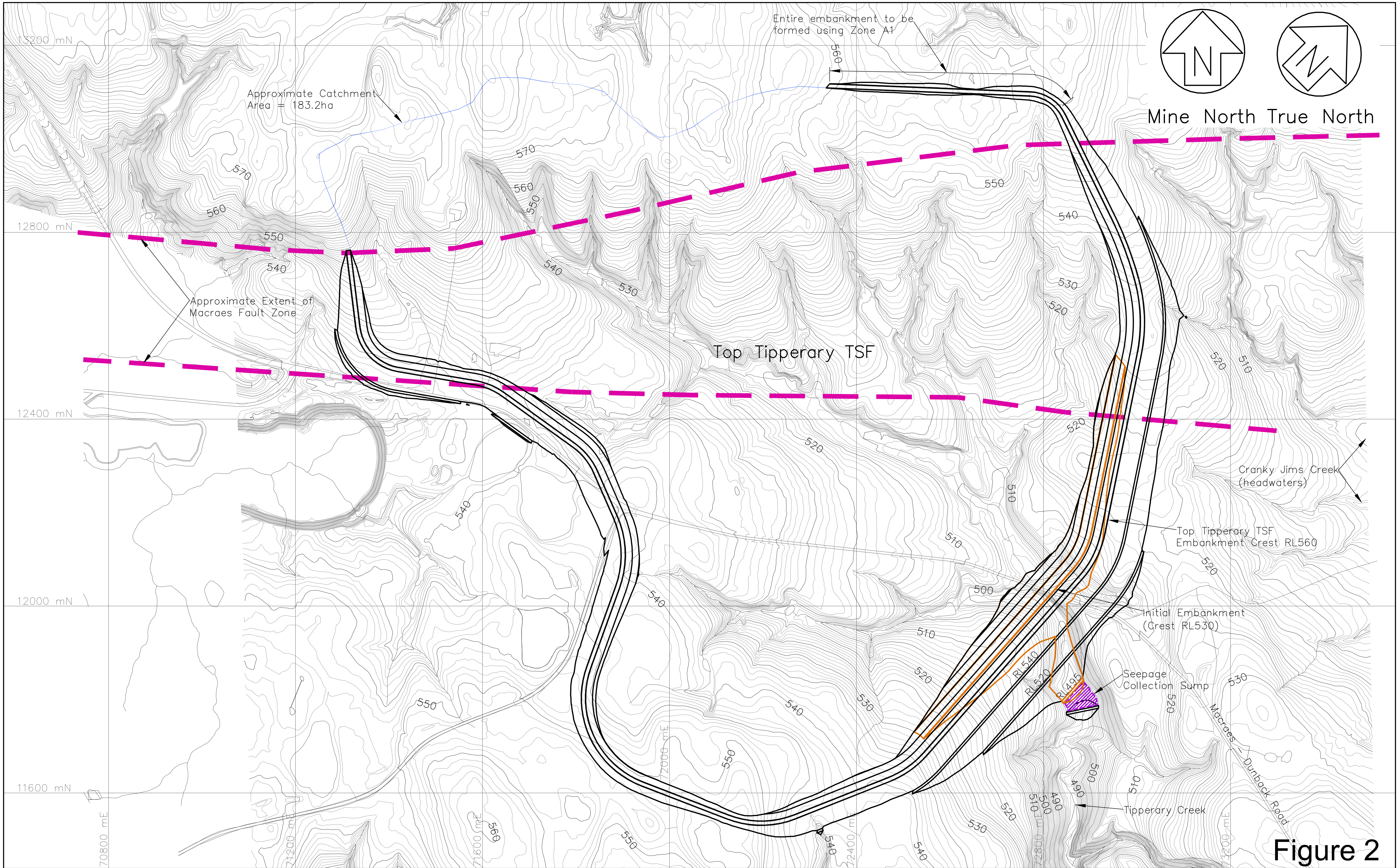

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OCEANA GOLD (NZ) LTD, MACRAES GOLD PROJECT
Top Tipperary TSF
Site Plan

Drawing No. 6846–Fig 3
Date: 13 Jan 2011
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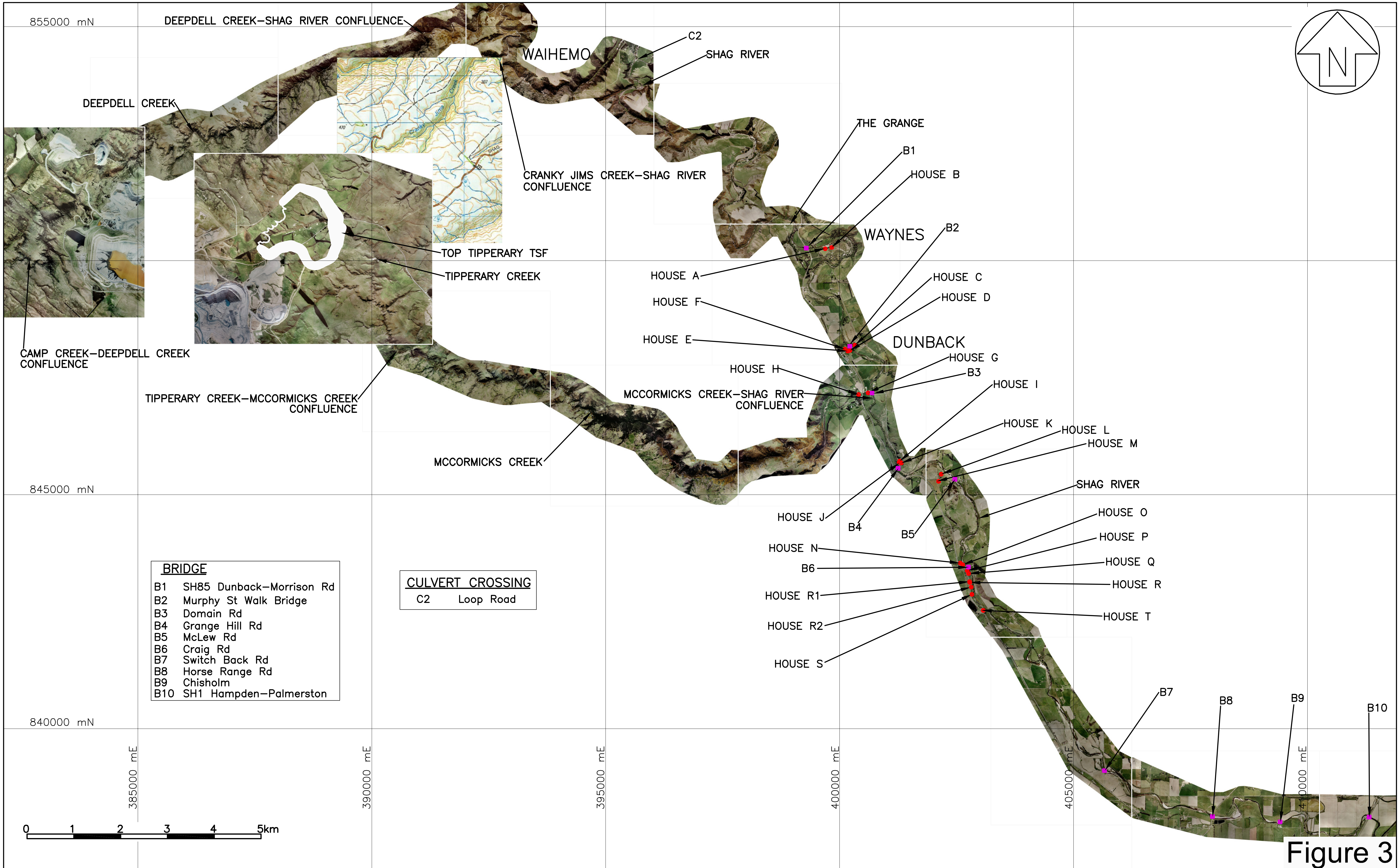

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OCEANA GOLD (NZ) LTD, MACRAES GOLD PROJECT
Top Tipperary TSF Dam Breach Study
Site Plan

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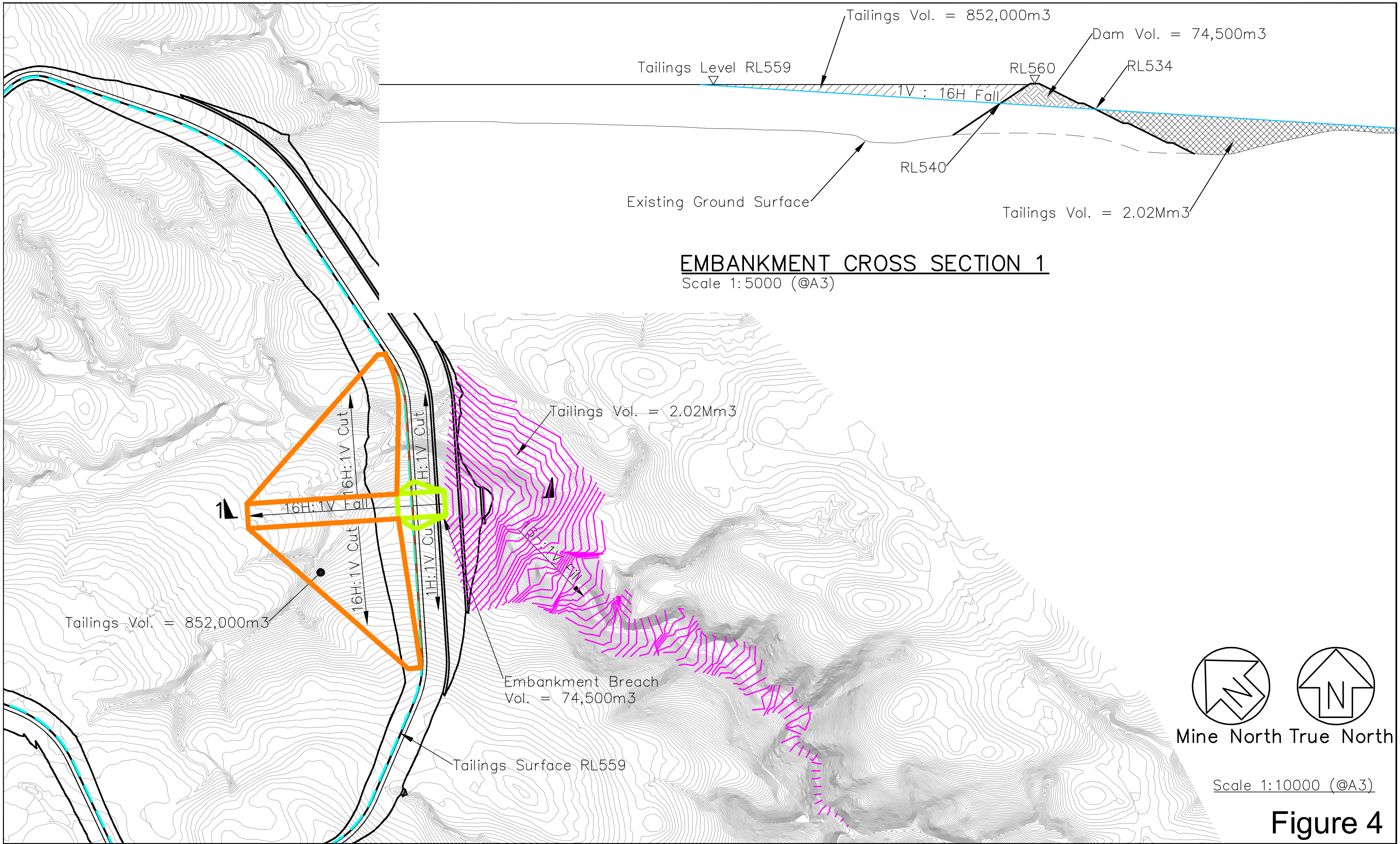

Figure 4

ENGINEERING GEOLOGY LTD
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OCEANA GOLD (NZ) LTD, MACRAES GOLD PROJECT
Top Tipperary TSF Dam Breach Study
Trial Breach

Drawing No.	6846-Fig 4
Date:	18 Mar 2011
Drawn:	PHH/BL
Scale:	As shown
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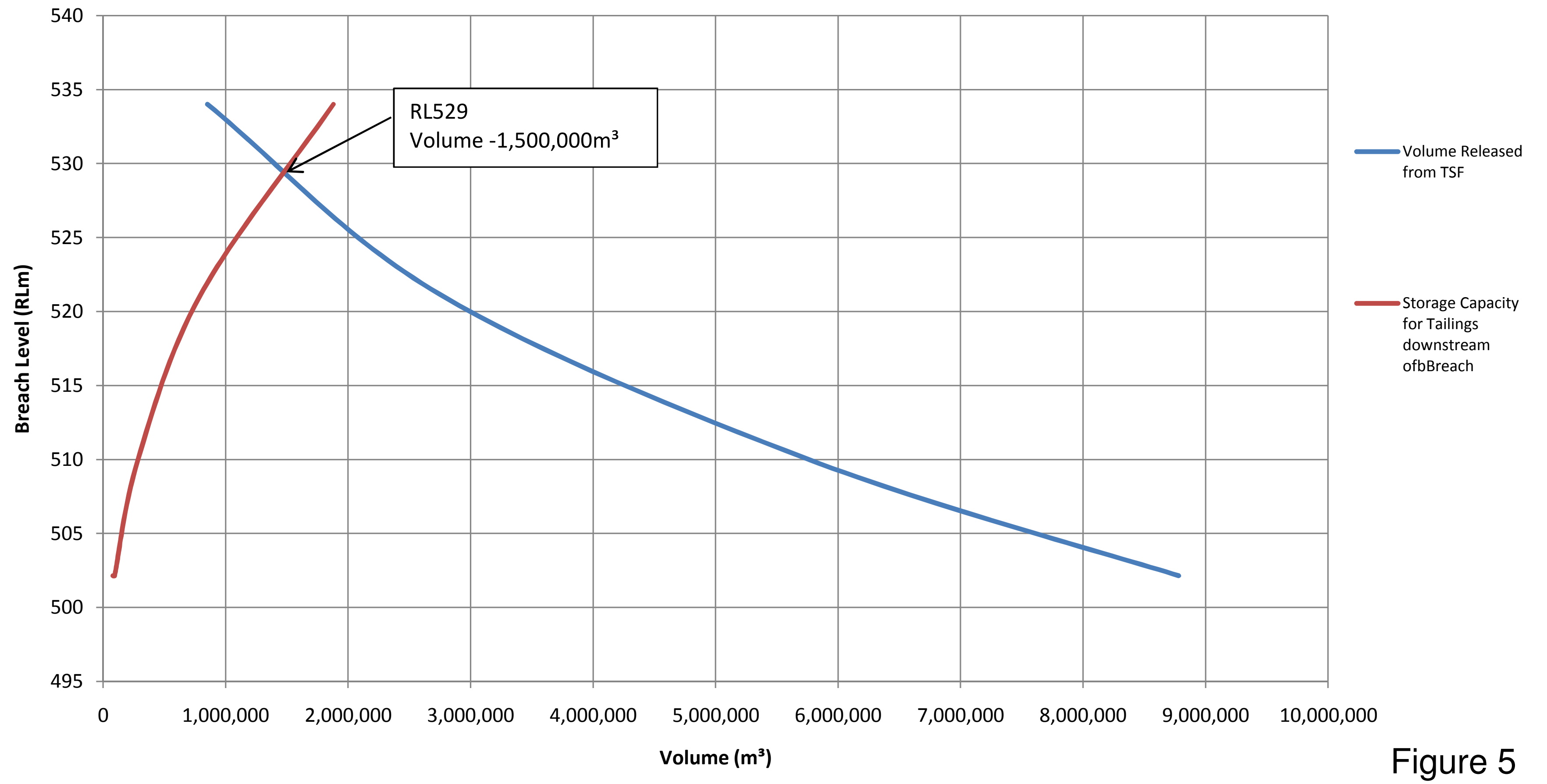

Figure 5

Engineering Geology Ltd
Unit 7C, 331 Rosedale Rd, PO Box 01054, Albany
Ph (09) 4862546 Fax (09) 4862556

OCEANA GOLD (NZ) LTD, MACRAES GOLD PROJECT
Top Tipperary TSF Dam Break
Deposition of Tailings in Tipperary Creek

Ref. No: 6846
Date: Jan 2011
Drawn: SFC
File: 6486 - Fig 5

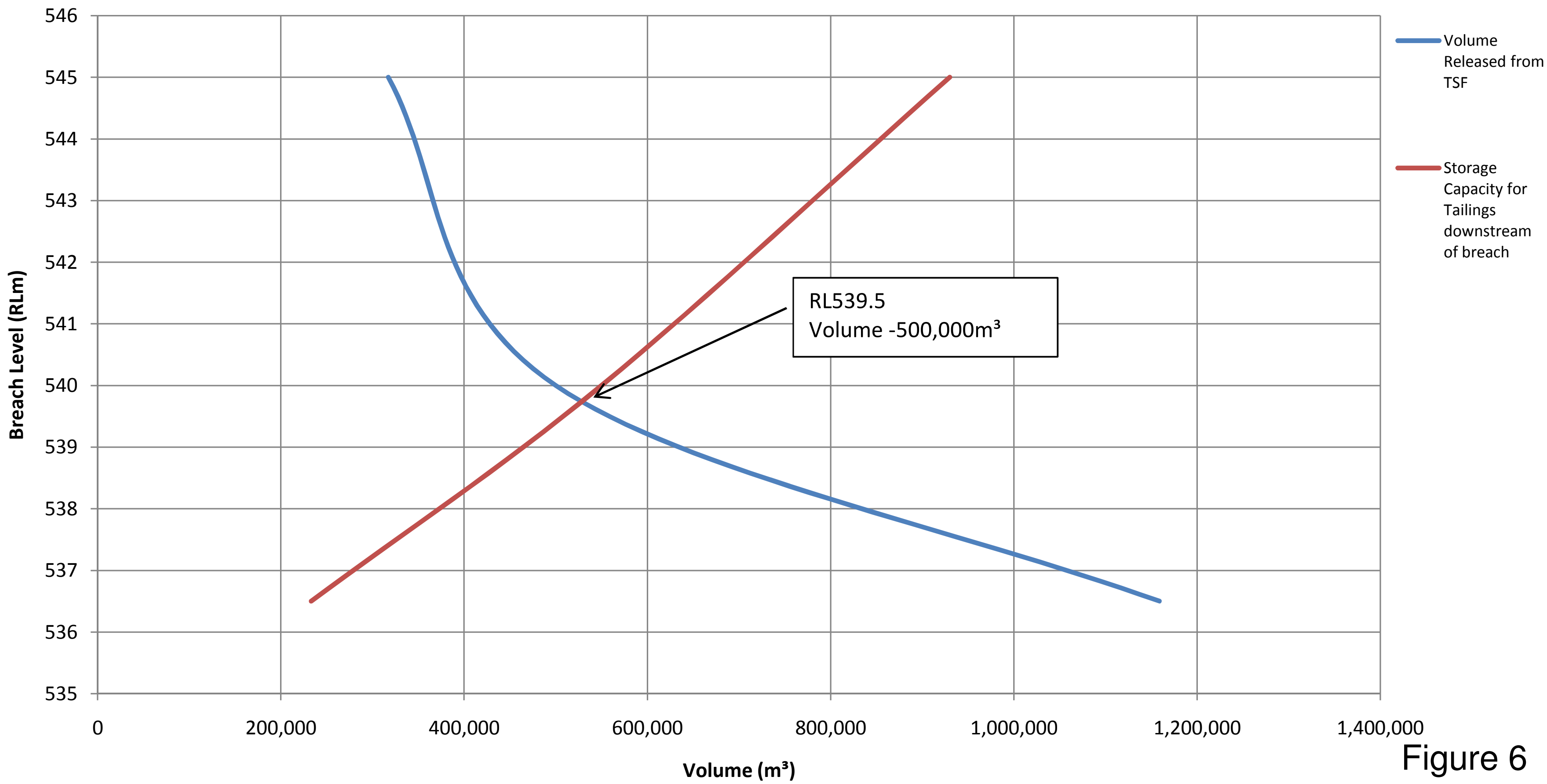

Figure 6

Engineering Geology Ltd Unit 7C, 331 Rosedale Rd, PO Box 01054, Albany Ph (09) 4862546 Fax (09) 4862556	OCEANA GOLD (NZ) LTD, MACRAES GOLD PROJECT Top Tipperary TSF Dam Break Deposition of Tailings in Cranky Jims Creek	Ref. No: 6846 Date: Jan 2011 Drawn: SFC File: 6486 - Fig 6

APPENDIX A
INUNDATION MAPS FOR 1 IN 100 AEP FLOOD INDUCED BREACH