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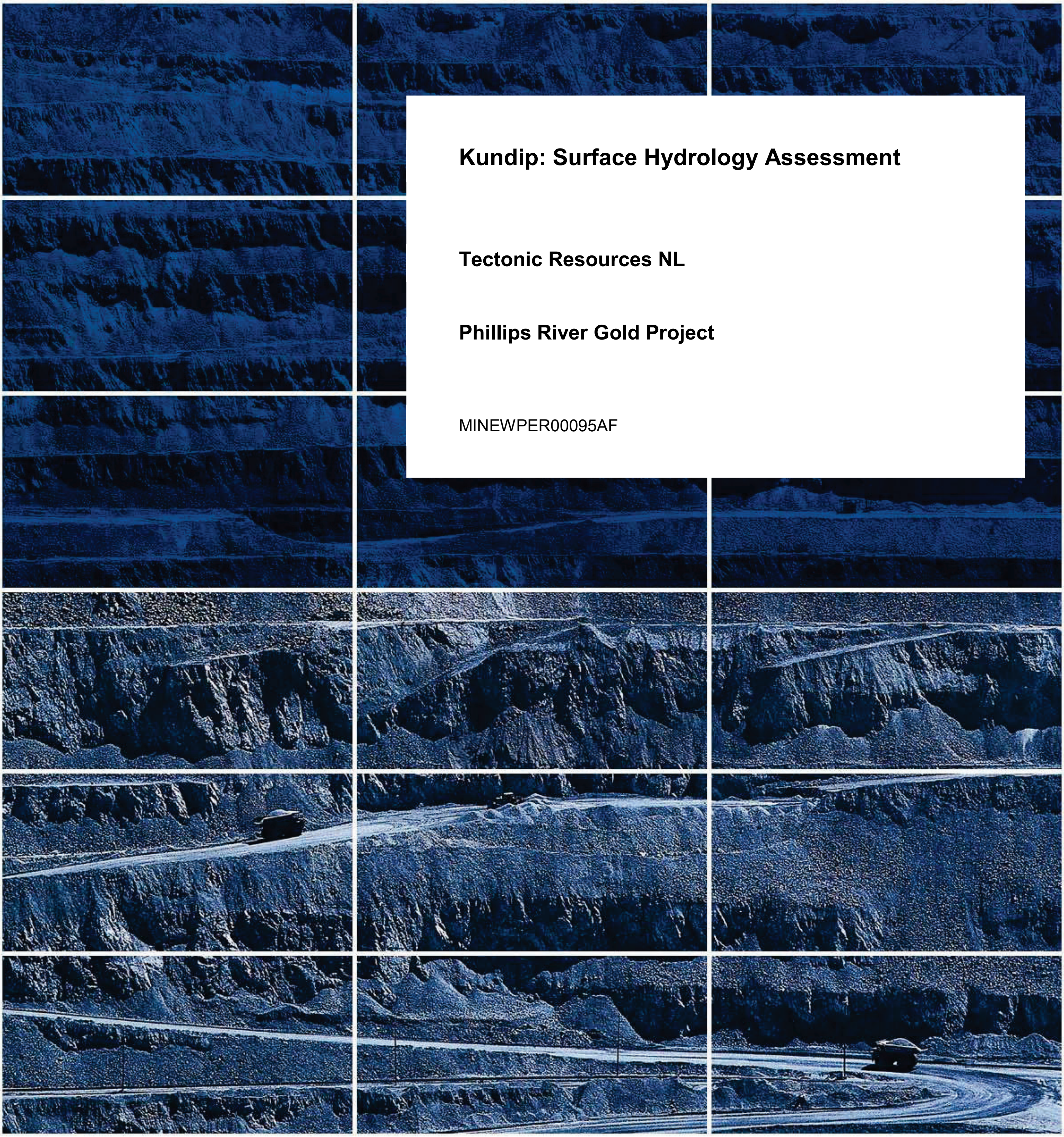
Kundip: Surface Hydrology Assessment

Tectonic Resources NL

Phillips River Gold Project

MINEWPER00095AF



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13 April 2011

Tectonic Resources NL
Unit 46
328 Albany Highway
Victoria Park, WA, 6100.

Attention: Mr Jason Stirbinskis

Dear Sir

RE: Kundip: Surface Hydrology Assessment

Please find attached two copies of our design report.

Should you have any queries, please don't hesitate to contact this office.

For and on behalf of Coffey Mining Pty Ltd

Christopher Hogg
Principal Civil / Geotechnical Engineer

Attachment: Kundip: Surface Hydrology Assessment – Design report

MINEWPER00095AF

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Document Review and Sign Off

Fanie van der Linde
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1 INTRODUCTION

Coffey Mining Pty Ltd were commission by Tectonic Resources NL to describe the surface hydrology of the Kundip Project site and recommend surface drainage controls appropriate to the proposed mine infrastructure as part of the preparation of the Mining Proposal for the project.

Kundip is located between Ravensthorpe and Hopetoun within the Shire of Ravensthorpe. The Kundip Project is a mining only operation with the ore intended to be transported to the Trilogy processing plant, located 27 kilometres south-east of Ravensthorpe on the Hopetoun – Ravensthorpe road.

The objectives of this study were to:

- Identify surface runoff catchments and drainage routes
- Estimate peak flows for existing conditions
- Assess proposed infrastructure layout and recommend surface water controls where necessary

JDA conducted a hydrology study of the Kundip project in 2005 (refer JDA, 2005[1]). This report updates that study and presents the results of new analysis for the changed project layout.

2 PHYSICAL SETTING

2.1 Location

The Kundip Project Area is largely contained within sub-catchments of the Steere River as shown in Figure 2. These sub-catchments are referred to as the ‘ Kundip Site ’ in this report. Tributaries from the sub-catchments flow west to the Steere River, with the main river channel crossing under Ravensthorpe- Hopetoun Rd 200m south of the Kundip site.

A portion of the Kundip mining leases are within the Jerdacuttup River catchment which drains to Jerdacuttup Lakes. The majority of disturbance will be within the Steere River Catchment.

2.2 Climate

The climate at Kundip is similar to Ravensthorpe and is characterised by consistent rainfall throughout the year with a mean annual rainfall of approximately 430mm per year (Table 1). Class A pan evaporation for Ravensthorpe of 1987mm is approximately 4 times mean annual rainfall (JDA, 2005[1]).

2.3 Soils

Soils across the Kundip site are generally characterised as gravelly loam topsoils overlying light to heavy clays. JDA, (2005[1]) indicates the topsoils have good physical properties making the soils stable. The underlying clays are much less stable and prone to slaking and dispersion during wetting.

Table 1

Climatological Summary for Ravensthorpe for Data 1901 to 2010

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Mean Daily Maximum Temperature	28.9	28.4	26.6	23.6	20.1	17.2	16.3	17.2	19.4	22.3	25.0	27.2	
Mean Daily Minimum Temperature	14.0	14.5	13.6	11.7	9.6	7.8	6.7	6.6	7.3	8.9	11.0	12.7	
Mean Monthly Rainfall (mm)	25.1	24.7	31.1	33.6	44.2	43.6	46.8	44.7	41.6	37.7	30.0	22.5	425.6

Source: Bureau of Meteorology

2.4 Topography

The topography of the Kundip Site is characterised by moderate slopes (5 to 10%). Stream channels within the landscape are moderately spaced forming an integrated network of convergent creeks (Figure 1).

The divide between the Steere River sub-catchments and Jerdacuttup River catchment to the east varies in elevation between 160 and 230m AHD. The Steere River main channel falls from 145 to 117m AHD north to south over a distance of 2.75 km adjacent to the Kundip Site (refer Figure 2).

2.5 Surface Drainage Features

Regionally, surface drainage is north to south from the Ravensthorpe Range towards the Southern Ocean. The main drainage arteries in the immediate Kundip area are the Phillips River, Steere River and Jerdacuttup River (Figure 1). The Phillips and Steere Rivers discharge to Culham Inlet 8km north-west of Hopetoun, while Jerdacuttup River discharges to Jerdacuttup Lakes 12km east of Hopetoun.

Historic mining at the Kundip Site has left a legacy of open pits and spoil heaps which create local surface drainage anomalies. These anomalies are too numerous to describe at the scale appropriate for this report.

2.6 Elverton Tailings Plume

The abandoned Elverton Mine and associated tailings dam are located at the northern boundary of the Steere River catchment (Figure 1). The tailings have been left unprotected and have progressively eroded to form an active sediment plume in the Steere River, extending downstream to the Kundip Site, which is being monitored by Department of Environment (JDA, 2005[1]).

The mobile sediment plume is likely to encroach on Steere River culverts constructed along the main access road for Kundip. Unless regular maintenance is performed, creek flow will probably be over the floodway at shallow depth rather than through the culverts.

3 RUNOFF ESTIMATES: EXISTING CATCHMENT

3.1 Sub-Catchments

Surface drainage across the Kundip Site is generally south-west towards the Steere River, with 11 sub- catchments of the Steere River identified as shown in Figure 2. The existing physical characteristics of each sub-catchment are presented in Table 2 below.

Table 2
Sub-Catchment Characteristics: Existing Condition

Sub-Catchment	Estimated Area (ha)	% Cleared
1	23.0	15
2	18.1	15
3	49.7	18
4	23.7	5
5	91.0	15
6	9.9	17
7	179.9	9
8	2.9	10
9	11.5	15
10	3.4	6
11	81.3	10
Total	**494.4**	**12**

Table 3
Sub-Catchment 7 Characteristics: Existing Condition

Sub-Catchment	Estimated Area (ha)	% Cleared
7a	43.1	7
7b	59.6	9
7c	27.6	6
7d	22.8	20
7e	26.9	10
Total	**180.0**	**9**
7a & 7b	102.7	8

3.2 Land Use

As indicated in Table 2, currently the Study Area is largely uncleared and supports a range of native vegetation which varies from Mallee open forest to woodland.

Evidence of previous mining activity includes mine shafts and old diggings along with three small open pits that have been abandoned at the northern side of the Study Area, namely: Western Gem Pit, Two Boys Pit, and Kaolin Pit. In one of the abandoned areas around Flag Deposit, the surface soils are heavily disturbed, in particular around the creek line at the western end of the deposit (JDA,2005[1]).

3.3 Estimated Peak Flows

Due to the lack of gauged flow data on the Steere River, the Rational Method of flood estimation was adopted as recommended in Australian Rainfall and Runoff (AR&R, 2000[3]). The Rational Method provides peak flow estimates up to the 50 year Average Recurrence Interval (ARI). For the 100 year ARI, the peak flow was estimated by extrapolation. The extrapolation to the 100yr ARI is based on a linear extension between the 50yr and 100yr ARI using a ratio of 1.4.

The Kundip Site is within the Wheatbelt Zone for flood estimation (AR&R, 2000[3]). Based on the catchment characteristics of the Study Area, equations for loamy and lateritic soils were adopted (AR&R, 2000[3]). Analysis of rainfall intensity and duration (Figure 3) was carried out using procedures described in Book 2 of AR&R (2000[3]).

Data sheets for flood estimation for each sub-catchment are included as Appendix A, with calculated flows presented in Tables 4 and 5.

Table 4
Peak Flow Estimates: Existing Condition

Sub-Catchment No.	Flow Peaks (m^3/s)	
	50 year ARI	100 year ARI
1	0.9	1.2
2	1.1	1.5
3	2.0	2.7
4	0.8	1.0
5	2.1	2.9
6	0.6	0.9
7	6.1	8.3
8	0.2	0.3
9	0.7	1.0
10	0.2	0.3
11	1.7	2.4
Steere River [1]	19.8	28.0

Notes: 1. Steere River Flow is calculated at the downstream end of the Kundip Site where catchment 11 tributary meets Steere River

Table 5
Peak Flow Estimates Sub-Catchment 7: Existing Condition

Sub-Catchment No.	Flow Peaks (m^3/s)	
	50 year ARI	100 year ARI
7a	1.4	1.9
7b	2.0	2.7
7c	0.9	1.2
7d	0.9	1.3
7e	0.9	1.3
7a & 7b	3.4	8.4

The accuracy of the Rational Method in predicting floods on ungauged catchments, such as the Steere River, is only known for the 10 year ARI. For this event we can be 68% sure that the true value is between half and twice the estimated value (JDA, 2005[1]). Rarer flood estimates have a greater uncertainty associated with them.

4 PROPOSED MINES & INFRASTRUCTURE

4.1 Site Access & Layout

Access to the Kundip site is from Ravensthorpe-Hopetoun Road to the west of the site. The general layout of the site includes site offices and workshops, three open cut pits with potential for underground declines, two waste dumps and a surface water storage dam (refer Figure 4). Associated with the pits are Run of Mine (ROM) pads where the ore is stockpiled for haulage to Trilogy.

4.2 Roads

The main access road from the Ravensthorpe – Hopetoun is approximately 2.7kms in length. The haulage road extends South, for the ore from the Kundip mine will be hauled to Trilogy. The other roads within the site can be seen in Figure 4. The main linkages are the offices/workshop and pits to the main access road and haulage road.

All the roads will have a proposed running width of 11m with 1:3 side batters.

4.3 Offices & Workshop

The offices and workshop are proposed to be located at the western end of the site, just south off the main access road. Incorporated into the workshop area will be a fuel storage facility and a parking area suitable for heavy earthmoving vehicles.

4.4 Pit & Waste Rock Landform

The development includes three open cut pits and two waste rock landforms (refer Figure 4).

- **Kaolin Pit**: An open cut pit with proposed underground decline at base of pit. ROM pad adjacent.
- **Harbour View Pit**: An open cut with proposed underground decline at base of pit. ROM pad adjacent.
- **Flag Pit**: An open cut pit with proposed underground decline at base of pit. ROM pad adjacent.
- **Waste Landfrom No 1**: Located in the centre of the development covering an area of approximately 19ha.
- **Waste Landform No 2**: Located at the northern end of the development covering an area of approximately 44ha.

4.5 Flag Pit Flood Protection

The proposed location of Flag Pit overlays the junction of sub-catchment creeks 7a and 7b. To provide flood protection for the Flag Area it is necessary to construct new infrastructure to control these two creeks.

Detail designs of the proposed new infrastructure are presented in a separate Coffey Mining report dated 28 February 2011 “Mining Proposal documentation – Kundip Water Storage Facility” MINEWPER00095AF.

The primary purpose of the new dams will be flood control to prevent inundation of Flag Pit. Mine water supply will be the secondary function.

5 RUNOFF ESTIMATES: DURING MINING OPERATIONS

5.1 Sub-Catchments

Based on the proposed mine site layout the sub-catchment areas and level of clearing will change due the construction of infrastructure.

Generally the level of clearing in all sub-catchments will increase during mining. Some sub-catchment areas will be reduced due to internal drainage within pits. Diversion of runoff around the infrastructure, particularly pits, will occur which will cross sub-catchment boundaries.

Table 6 presents sub-catchment characteristics during mining operations indicating revised catchment areas and percentage cleared to the confluence with Steere River. Total catchment area reduces due to internal drainage within bunds around the pits.

Table 6
Sub-Catchment Characteristics: During Mining Operations

Sub-Catchment	Estimated Area (ha)	% Cleared
1	49.0	35
2	18.1	15
3	16.1	60
4	23.2	30
5	80.0	25
6	9.9	17
7	173.0	24
8	2.9	10
9	11.4	15
10	3.4	6
11	81.3	10
Total	**468.3**	**22**

Table 7, which includes Flag Pit, shows catchment characteristics for sub-catchment 7 during mining operations. The catchment areas described in Table 7 for sub-catchment 7a and 7b are upstream of the proposed flood control diversions (see Chapter 7).

Table 7
Sub-Catchment 7 Characteristics: During Mining Operations

Sub-Catchment	Estimated Area (ha)	% Cleared
7a (to proposed dam)	24.1	60
7b (to spillway)	49.9	25
7c	27.6	6
7d	22.5	25
7e	26.9	10
7f	22.1	15
Total	**173.1**	**24**
7a & 7b	74	43

5.2 Estimated Peak Flows

Peak flows have been estimated based on the revised sub-catchment characteristics and are presented in Tables 8 and 9.

Table 8
Peak Flow Estimates: During Mining Operations

Sub-Catchment No.	Flow Peaks (m^3/s)	
	50 year ARI	100 year ARI
1	2.2	3.0
2	1.0	1.5
3	2.0	2.9
4	1.1	1.5
5	2.2	3.0
6	0.6	0.9
7	7.7	10.6
8	0.2	0.3
9	0.7	1.0
10	0.2	0.3
11	1.7	2.4

Table 9
Peak Flow Estimates Sub-Catchment 7: During Mining Operations

Sub-Catchment No.	Flow Peaks (m^3/s)	
	50 year ARI	100 year ARI
7a (to proposed dam)	1.9	2.6
7b (to diversion)	2.2	3.0
7c	0.9	1.2
7d	1.0	1.4
7e	0.9	1.3
7f	0.8	1.1
7a & 7b	4.1	5.6

Using the Rational Method of calculation for peak flow estimates the effect of totally clearing an uncleared catchment increases estimated runoff by a factor of 2.6. There is some uncertainty regarding this factor, but other studies in the South-West of WA have concluded a factor of between 2 and 4 (refer JDA, 2005[1]).

A similar increase in annual runoff can be expected. The increased flow rates will need to be managed to ensure mine site safety from flood risk and to protect the environment from increased flooding and erosion.

6 RELEVANT DESIGN CRITERIA

The Department of Industry and Resources (2006[2]) Mining Environmental Management Guidelines for mining projects in WA includes the following specific requirements relevant to this report.

- **Existing Environment – Hydrology (page 15)**
  - "A brief description of surface and sub-surface water flows with assessment for flood potential…"
  - "Provide details of any water management areas such as water reserves, declared or proposed water supply catchment areas...in or near the project area."
- **Existing Environment – Climate (page 15)**
  - "The MP should contain meteorological information necessary to adequately assess and manage all climatic impacts that could have significant impact on the project. Minimum drainage design should be based on at least the one in 100 year 72 hour duration rainfall event."
- **Environmental Impacts and Management – Land Clearing (page 19)**
  - "The impacts of land clearing and vegetation removal on soil erosion, salinity and hydrology should be assessed and described…."
  - "Land management and drainage strategies should be considered along with factors like the cleared area's shape and landform profile, water control…"
- **Environmental Impacts and Management – Water (page 19)**
  - "The impact of flooding on the mine site, if applicable, should be addressed."
  - "Any potential impacts of any hydrological changes on vegetation, habitat or aquatic ecosystems should also be discussed."

Coffey Mining Pty Ltd understands that all other MP requirements will be addressed separately to this report.

7 SURFACE WATER CONTROLS

7.1 General

An outlay of the proposed surface water control treatments as described below are presented in Figure 5. The aim is to optimise flood control and surface water resources. Mining operations will generate additional surface runoff associated with clearing of vegetation. This additional runoff can be used by the mine operation, while seeking to maintain environmental flows in the creeks at existing rates as far as possible.

7.2 Flag Pit Flood Control

Flag pit is located at the junction of Creek 7a and 7b. It is proposed to dam both creeks 7a and 7b upstream of the Flag Area, diverting flood events from catchments 7a and 7b by gravity into catchment 7e to the south west. A diversion structure and open drain to divert creek 7b into 7a is shown on Figure 5. The proposed dam on Creek 7a will have a spillway and overflow channel to the south, discharging into creek 7e.

Downstream of the diversions on creeks 7a and 7b will be a sump and pump-back facility installed to capture run-off occurring between these structures and Flag Pit bund.

Chapter 6 guidelines suggest 100 year ARI design criterion as a minimum for flood control.

Based on Table 9 the design of the diversion from creek 7b to 7a should be based on 3.7m³/s and the dam spillway from creek 7a to 7b should be based on 6.6m³/s, taken additional sheet flow next to channels into account. Table 10 presents indicative dimensions for these diversion drains assuming a Manning's Roughness Co-efficient of 0.06 and side batters of 1:3.

Tnnnnable 10
Estimated Open Drain Dimensions

Diversion Drain no.	Design Flow (m³/s)	Base Width (m)	Side Batter (v:d)	Mainstream Average Grade (v:d)	Roughness 'n'	Flow Depth (m)
1	2.8	0.5	1:3	1:17	0.06	0.7
2	1.4	0	1:3	1:15	0.06	0.6
3	2.2	0.5	1:3	1:27	0.06	0.7
4	3.0	1.0	1:3	1:24	0.06	0.7
5	2.7	1.0	1:3	1:32	0.06	0.7
6	0.4	0	1:3	1:53	0.06	0.5
7	0.6	0	1:3	1:25	0.06	0.5
8	3.7	1	1:3	1:40	0.06	0.8
9	0.3	0	1:3	1:24	0.06	0.4
Dam Spillway	6.6	12	1:1	1:500	0.06	0.9

7.3 Offices & Workshops

Approximately 4.2ha would need to be cleared to accommodate the buildings, service car park and fuel storage area associated with the offices and workshops. Drainage from this area will need to be managed using sediment traps, hydrocarbon traps and erosion controls. Refer to Appendix B, Drawing No. 8130-C-201, done by CID Consultants, regarding Complex - Internal Infrastructure.

Due to the location of the proposed site, water from creek 4 (north east), will have to be controlled by an open drain built along the northern boundary of the site directing the water west and then south towards creek 4. Refer to Table 6 – Diversion channel 4.

7.4 Roads

Road drainage within the Kundip Site will need to be managed by incorporating road side drains into road designs. With the road drains, flows can be controlled by use of energy dissipaters, drop structures and sediment controls. Any existing roads with erosion damage that Tectonic Resources NL intends to utilise should be resurfaced with erosion control structures installed to stabilise the road.

7.4.1 Road Crossings

Road crossings are required where the proposed roads intersect creek lines (Figure 5).

Crossing 1: Main access road crosses Steere River. Table 4 shows a 100 year ARI flow for Steere River of 28m³/s. It is proposed the crossing consist of a bank of low flow culverts and a floodway. Note that maintenance will be required to prevent the culverts from becoming blocked by the active sediment plume from the Elverton Tailings upstream.

Proposed concrete pipe culvert details for road crossing 2-14 are summarised in Table 11:

Table 11
Concrete Pipe Culvert Details – Assuming Inlet Control

Road Crossing no.	Design Flow (m^3/s)	Design Capacity (m^3/s)	Pipe Diameter (mm)	Mainstream Average Grade (v:d)	Roughness 'n'	Number of barrels
2	3.0	3.0	900	1:50	0.012	2
3	1.4	1.5	900	1:50	0.012	1
4	2.0	2.0	1050	1:50	0.012	1
5	0.4	0.4	450	1:50	0.012	1
6	2.7	3.0	900	1:50	0.012	2
7	3.7	3.9	1050	1:50	0.012	2
8	0.6	0.7	600	1:50	0.012	1
9	1.3	1.5	900	1:50	0.012	1
10	8.5	8.7	1350	1:50	0.012	3
11	0.15	0.2	300	1:50	0.012	1
12	0.9	0.9	675	1:50	0.012	1
13	0.3	0.4	450	1:50	0.012	1
14	2.4	2.6	825	1:50	0.012	2

7.5 Runoff Erosion Controls

Due to the physical characteristics of the soil identified by Outback Ecology (2004) – (JDA, 2005[1]) runoff erosion controls will be required for all cleared areas. We recommend these controls be considered at the design stage of the infrastructure. Where runoff from the Waste Rock Landforms is concentrated detention basins should be constructed to attenuate peak flows from each catchment to pre-developments rates.

7.6 Pit and Waste Rock Landform Flood Mitigation and Ponding Controls

Due to the particular importance of flood mitigation and ponding controls for the Pits and Waste Rock Landforms they are discussed separately below. The proposed mine site layout will allow adequate spacing between the pits, waste rock landforms and other infrastructure (roads) to enable construction of drainage structures. The discussion below outlines the required drainage management plan for the pits and waste rock landforms. Refer to Table 10 for estimated dimensions of open drains discussed.

7.6.1 Kaolin Pit

Drainage Design Considerations: The pit will be situated across the sub-catchment boundary of Creek 3 and 5. Some surface flows are expected towards the north east corner of the pit from higher in the catchment of Creek 3.

Flood Mitigation Controls: Appropriate control bunds should be installed around the pit to prevent any surface water flows entering in the pit. As Waste Rock Landform No 2 develops, drains will be required to ensure runoff from the Waste Rock Landform does not flow towards Kaolin Pit. This drainage can be directed west to Creek 4 (Open drain 3, Figure 5).

Ponding Controls: A drain should be constructed along the eastern pit boundary to prevent ponding against the abandonment bund (Open drain 2, Figure 5). Runoff should be directed south along the eastern boundary of the abandonment bund to Creek 5.

7.6.2 Harbour View Pit

Drainage Design Considerations: The pit will be situated close to the sub-catchment boundaries of 5, 7a and 7d.

Flood Mitigation Controls: Appropriate control bunds should be installed around the pit to prevent any surface water flows entering in the pit.

Ponding Controls: An open drain should be constructed to prevent surface water ponding along the abandonment bund at the southern end of the pit (Open drain 6, Figure 5). The drain will direct flows west towards creek 5.

7.6.3 Flag Pit

Drainage Design Considerations: The Flag Pit will be located in a valley at the junction of Creek 7a and Creek 7b. The catchment area draining to this junction is significant and a creek diversion of both creeks is required to prevent flooding of the pit.

Flood Mitigation Controls: Appropriate water control bunds should be installed around the pit to prevent surface water flows entering in the pit. It is proposed to divert large flows from both creeks west to sub-catchment 7e via an open drain and spillway arrangement (Open drain 8 and spillway, Figure 5). The dam will store minor runoff events which can be opportunistically used for mine operations. The dam sizing is discussed further in Section 7.7.

A sump will be required at the lowest point on the north side of the Flag Area to collect runoff from the small area downstream of the diversions. The water collecting in the sump can then be pumped back to the storage dam on creek 7a.

Ponding Controls: Ponding controls will be required at the northern edge of the pit. The sump and pump back scheme will accommodate this area as discussed above. An open drain will be required to prevent surface flows from the southern side of the pit ponding against the abandonment bund. The flows will be directed west to creek 7e downstream of the pit.

7.6.4 Waste Rock Landform No 1

Drainage Design Considerations: Waste Rock Landform No 1 will encompass an area of 19ha within sub-catchment 7a and overlays the creek line, cutting off the upper reach of the creek. As a result runoff will pond against at the north east side of the dump. The design of the waste dump is assumed to direct the runoff from the dump into creek 7a and 7b respectively.

Flood Mitigation Controls: The Waste Rock Landform spans the width of Catchment 7a with topography falling from the dump along the north and south long sides and the western side. Appropriate control bunds should be installed around the rock landform to prevent surface water flows reaching the toe of the rock landform.

Ponding Controls: Water is expected to collect along the north west side of the Waste Landform. There should be sufficient grade to construct an open drain to direct the flow into the proposed dam in Creek 7a (Open drain 5, Figure 5).

7.6.5 Waste Rock Landform No 2

Drainage Design Considerations: Waste Rock Landform No 2 will encompass a large area of the upper part of sub- catchment 3.

Flood Mitigation Controls: The runoff from the waste rock landform will need to be controlled along the southern boundary to prevent flows to Kaolin Pit. The flows can be directed west via an open drain to discharge into creek 4 downstream of the rock landform (Open Drain 3, Figure 5). The increased flow in Creek 4 from the Waste Rock Landform runoff should be attenuated to pre-mining levels by a detention basin. Appropriate water control bunds should be installed around the rock landform to prevent surface water flows reaching the toe of the rock landform.

Ponding Controls: An open drain to the east of the waste rock landform (open drain 2) will prevent ponding from occurring by discharging the water south past Kaolin pit to creek 5.

7.7 Surface Water Supply

The primary purpose of the dam above Flag Pit is to provide flood control, but the water stored within the dam could be used opportunistically to meet part of the mine water supply.

The dam concept design, done by Coffey Mining Pty Ltd, has an approximate capacity of 12,000m³ below the spillway level.

With an annual average rainfall of 430mm/yr and an expected average runoff coefficient on an annual basis of between 2 and 10%, the estimated average annual runoff will be between 3000 and 20 000m³/yr. Allowing for dam evaporation of approximately 70% of Class A pan or 1391 mm annually, a large proportion of the storage will be lost to evaporation if left in storage. It may be several years after dam construction before a wet year fills this size of dam. As such it would probably be more efficient to use the stored water on an opportunistic basis rather than at a constant rate to minimise evaporation loses.

It is not possible to provide firmer estimates of the water resource potential as the runoff volumes are sensitive to the runoff coefficient, of which there is some uncertainty (refer JDA (2005)).

8 CONCLUSIONS

- The Kundip Project is a mining only development with the ore transported south to Trilogy for processing.
- The proposed development area is within the catchment of the Steere River.
- There are 11 sub-catchments within the Study Area which are tributaries of the Steere River.
- Peak flows have been estimated for each sub-catchment based on the rational method described in Australian Rainfall & Runoff (2000[3]).
- Due to the lack of gauged data for rivers in the Esperance Coast area, the peak flows are indicative only.
- The diversion of creek 7b and 7a into 7e is required to prevent flooding of the Flag pit.
- Road crossings are required on several placed on the Main Access Rd and service road.

9 RECOMMENDATIONS

Based on the preliminary investigations presented in this report we recommend the following:

- Flood estimates contained in this report should be reviewed as the site planning and construction progresses.

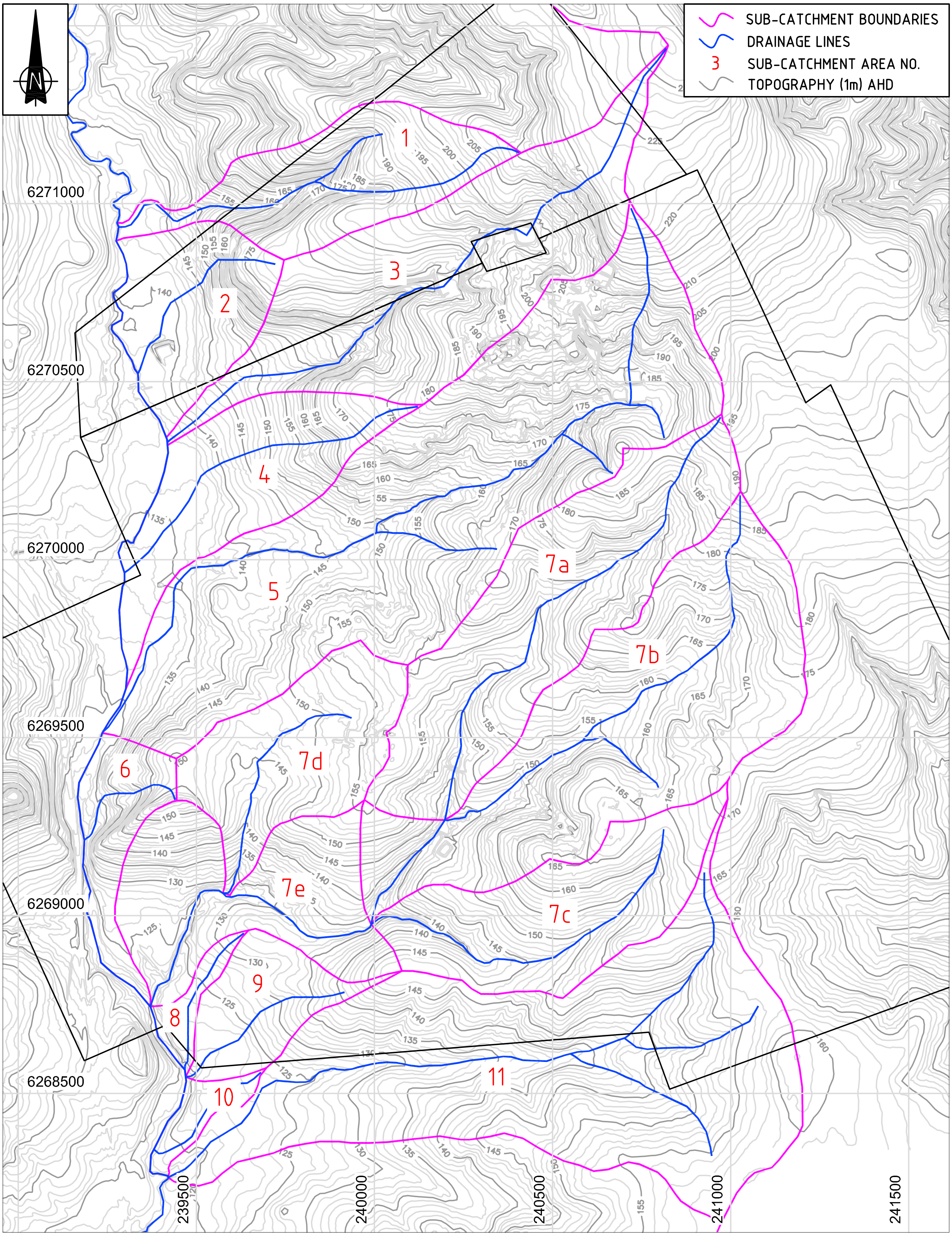
10 REFERENCES

1. JDA, Consultant Hydrologists (2005) *Kundip Notice of Intent: Surface Hydrology Assessment*. Report to Tectonic Resources NL.
2. Department of Industry and Resources (2006) *Mining Environmental Management Guidelines* Environmental Division. Mining Proposals in WA.
3. The Institution of Engineers Australia (2000) *Australian Rainfall & Runoff. Volume 1: A Guide to Flood Estimation*. The Institution of Engineers Australia.
4. The Institution of Engineers Australia (1987) *Australian Rainfall & Runoff. Volume 2: A Guide to Flood Estimation*. The Institution of Engineers Australia.
5. Bureau of Meteorology – Western Australia

Figures

drawn	LL	client:	TECTONIC RESOURCES NL
approved	CH	project:	SURFACE WATER HYDROLOGY - KUNDIP
date	13/04/2011	title:	KUNDIP PROJECT LOCATION
scale	1:250,000		
original size	A4	project no: MINWPER00095AF	figure no: 1 rev: A

coffey mining
SPECIALISTS FROM BOARDROOM TO MINE FACE



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Drawn:	FVDL
Approved:	CH
Date:	2011-02-18
Scale:	1:15000
Original size:	

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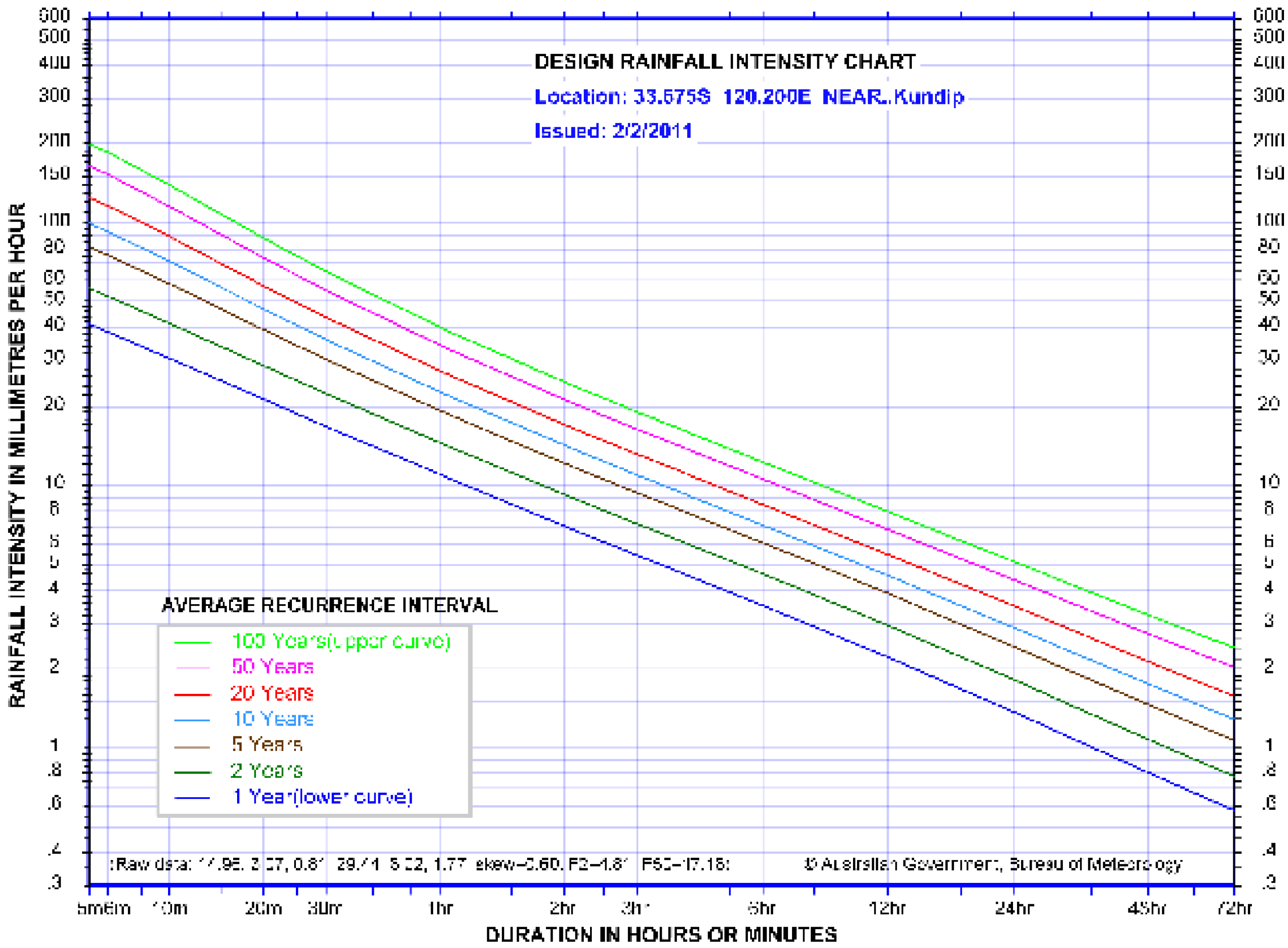
SPECIALISTS FROM BOARDROOM TO MINE FACE

Client:	TECTONIC RESOURCES NL		
Project:	SURFACE WATER HYDROLOGY - KUNDIP		
Title:	SURFACE DRAINAGE CATCHMENT PLAN		
Project no: MWP00095AF	Fig no: 2	Rev: A	



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Approved:	CH
Date:	2011-02-18
Scale:	N.T.S.
Original size:	

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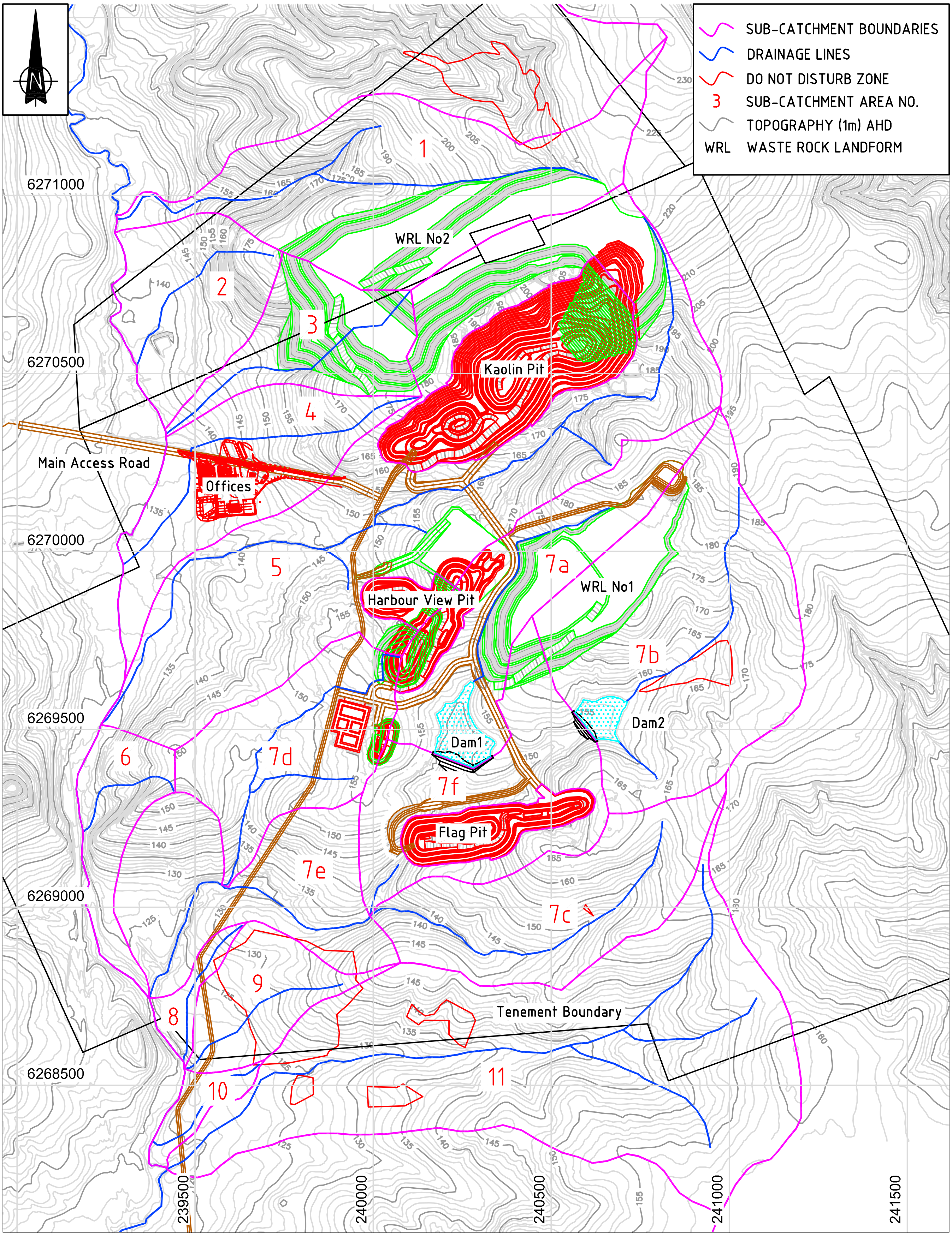
SPECIALISTS FROM BOARDROOM TO MINE FACE

Client:	TECTONIC RESOURCES NL
Project:	SURFACE WATER HYDROLOGY - KUNDIP
Title:	KUNDIP INTENSITY FREQUENCY DURATION (IFD) CURVE
Project no:	MWP00095AF
Fig no:	3
Rev:	A



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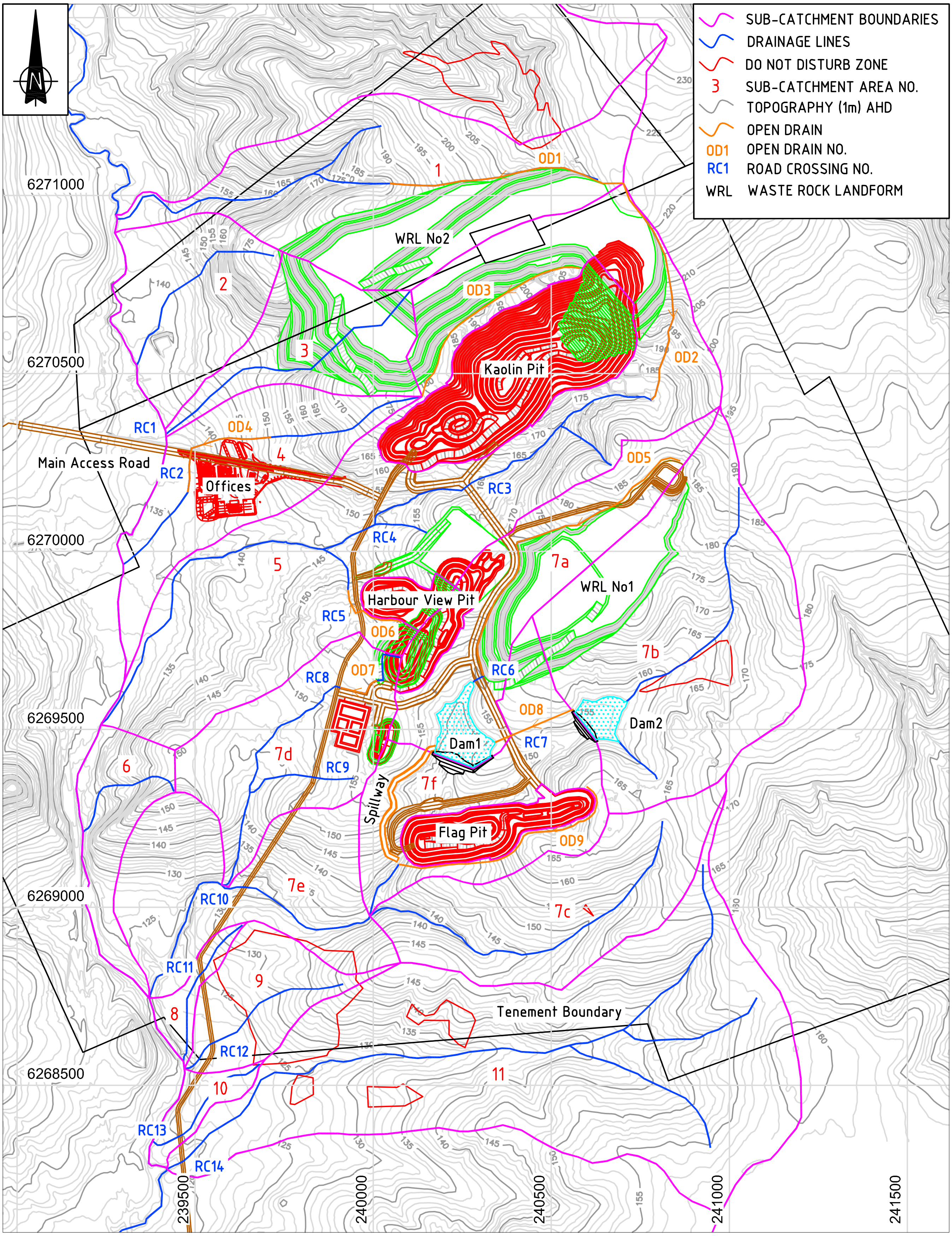
Approved:	CH		Project:	SURFACE WATER HYDROLOGY - KUNDIP
Date:	2011-02-18			
Scale:	1:15000		Title:	PROPOSED SITE LAYOUT PLAN
Original size:			Project no: MWP00095AF	Fig no: 4 Rev: A



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Approved:	CH	Project:	SURFACE WATER HYDROLOGY - KUNDIP
Date:	2011-02-18	Title:	SURFACE WATER CONTROL TREATMENTS
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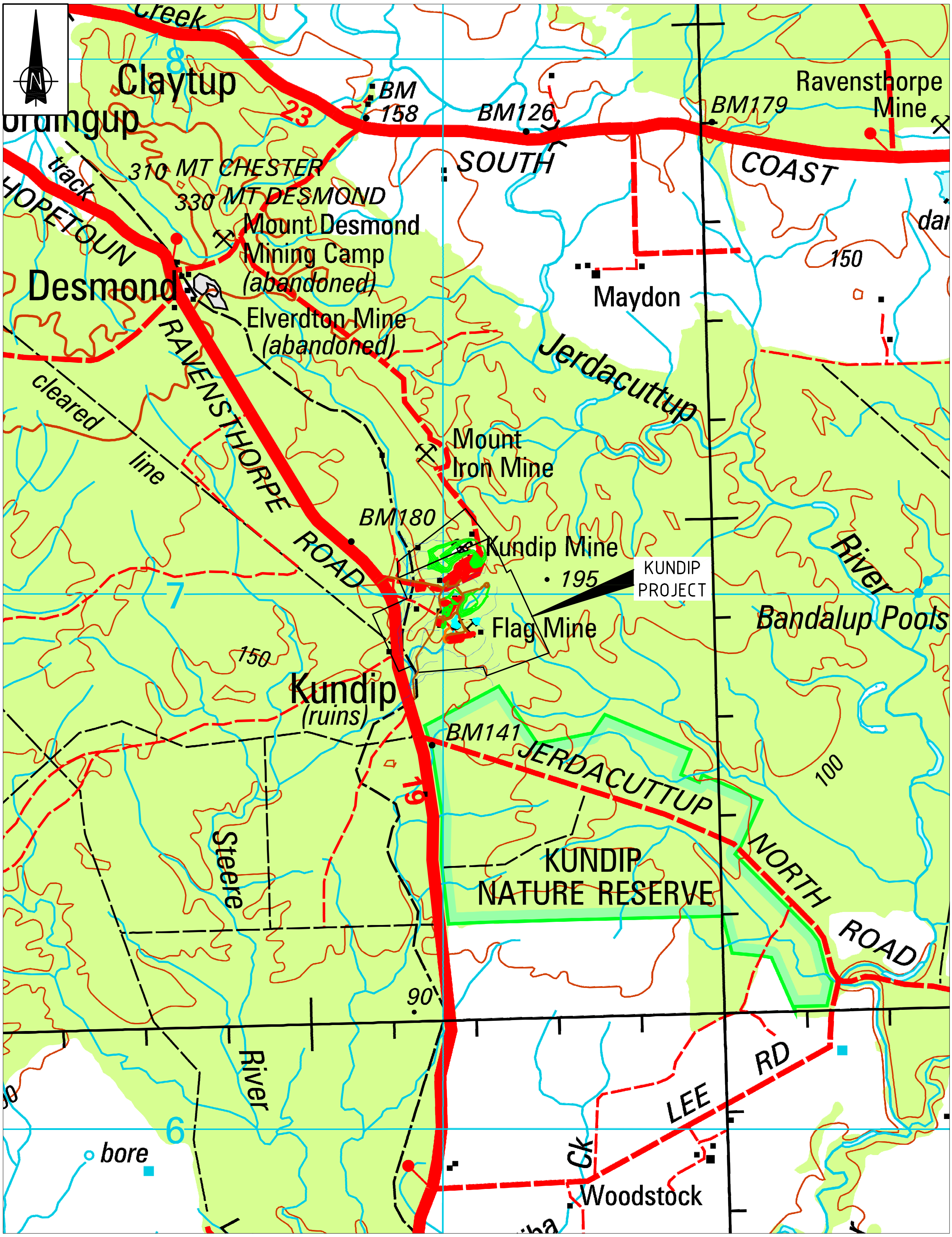
coffey mining
SPECIALISTS FROM BOARDROOM TO MINE FACE



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Approved:	CH		Project:	SURFACE WATER HYDROLOGY - KUNDIP
Date:	2011-06-01		Title:	SURFACE WATER DRAINAGE - REGIONAL CONTEXT
Scale:	1:10000		Project no: MWP00095AF	Fig no: 6 Rev: A
Original size:				

Appendix A

Flood Estimation Data Sheets

Detailed calculation of Peak Flow Rates
Tectonic: Kundip

Time of Concentration (tc):

Description	Label	Catchment area, *A* (m2)	Catchment area, *A* (km2)	Clearing, C_L (% of A)	Time of concentration t_c (min)	C_{10}	C_Y/C_{10} for ARI (years)							$I_{tc,Y}$ for ARI (years), (mm/h)							Q_Y for ARI (years), (m^3/s)						
							1	**2**	**5**	**10**	**20**	**50**	**100**	**1**	**2**	**5**	**10**	**20**	**50**	**100**	**1**	**2**	**5**	**10**	**20**	**50**	**100**
Kundip Pre-project:																											
Catchment 1	1	229,853	0.230	15%	63	0.28	0.45	0.57	0.80	1.00	1.20	1.42	1.65	11	15	19	23	27	34	40	0.09	0.15	0.27	0.40	0.58	0.86	1.16
Catchment 2	2	180,823	0.181	15%	55	0.28	0.45	0.57	0.80	1.00	1.20	1.42	1.65	17	22	30	36	44	55	66	0.11	0.18	0.34	0.50	0.73	1.09	1.50
Catchment 3	3	497,156	0.497	18%	95	0.29	0.45	0.57	0.80	1.00	1.20	1.42	1.65	11	15	19	23	27	34	40	0.20	0.33	0.62	0.91	1.31	1.95	2.65
Catchment 4	4	237,478	0.237	5%	64	0.23	0.45	0.57	0.80	1.00	1.20	1.42	1.65	11	15	19	23	27	34	40	0.08	0.13	0.24	0.35	0.50	0.75	1.02
Catchment 5	5	909,625	0.910	15%	132	0.28	0.45	0.57	0.80	1.00	1.20	1.42	1.65	7	9	12	14	17	21	25	0.22	0.37	0.68	1.00	1.44	2.12	2.87
Catchment 6	6	98,611	0.099	17%	40	0.29	0.45	0.57	0.80	1.00	1.20	1.42	1.65	17	22	30	36	44	55	66	0.06	0.10	0.19	0.28	0.41	0.62	0.85
Catchment 7a	7a	431,100	0.431	7%	88	0.24	0.45	0.57	0.80	1.00	1.20	1.42	1.65	11	15	19	23	27	34	40	0.14	0.24	0.45	0.66	0.95	1.40	1.91
Catchment 7b	7b	595,870	0.596	9%	105	0.25	0.45	0.57	0.80	1.00	1.20	1.42	1.65	11	15	19	23	27	34	40	0.21	0.34	0.64	0.94	1.35	2.01	2.73
Catchment 7c	7c	275,566	0.276	6%	69	0.24	0.45	0.57	0.80	1.00	1.20	1.42	1.65	11	15	19	23	27	34	40	0.09	0.15	0.28	0.41	0.59	0.88	1.20
Catchment 7d	7d	227,812	0.228	20%	62	0.30	0.45	0.57	0.80	1.00	1.20	1.42	1.65	11	15	19	23	27	34	40	0.09	0.16	0.29	0.43	0.62	0.92	1.25
Catchment 7e	7e	269,349	0.269	10%	68	0.25	0.45	0.57	0.80	1.00	1.20	1.42	1.65	11	15	19	23	27	34	40	0.09	0.16	0.29	0.43	0.62	0.92	1.25
Catchment 8	8	29,416	0.029	10%	21	0.25	0.45	0.57	0.80	1.00	1.20	1.42	1.65	21	29	39	47	58	74	88	0.02	0.03	0.07	0.10	0.14	0.22	0.30
Catchment 9	9	114,882	0.115	15%	43	0.28	0.45	0.57	0.80	1.00	1.20	1.42	1.65	17	22	30	36	44	55	66	0.07	0.11	0.21	0.32	0.46	0.70	0.95
Catchment 10	10	33,764	0.034	6%	22	0.24	0.45	0.57	0.80	1.00	1.20	1.42	1.65	21	29	39	47	58	74	88	0.02	0.04	0.07	0.10	0.15	0.23	0.32
Catchment 11	11	812,914	0.813	10%	124	0.25	0.45	0.57	0.80	1.00	1.20	1.42	1.65	7	9	12	14	17	21	25	0.18	0.30	0.56	0.82	1.18	1.74	2.36

Detailed calculation of Peak Flow Rates
Tectonic: Kundip

Time of Concentration (tc):

Description	Label	Catchment area, *A* (m2)	Catchment area, *A* (km2)	Clearing, C_L (% of A)	Time of concentration t_c (min)	C_{10}	C_Y/C_{10} for ARI (years)							$I_{tc,Y}$ for ARI (years), (mm/h)							Q_Y for ARI (years), (m^3/s)						
							1	2	5	10	20	50	100	1	2	5	10	20	50	100	1	2	5	10	20	50	100
Kundip Post-project:																											
Catchment 1	1	429,633	0.430	35%	88	0.39	0.45	0.57	0.80	1.00	1.20	1.42	1.65	11	15	19	23	27	34	40	0.23	0.38	0.71	1.05	1.51	2.24	3.04
Catchment 2	2	180,823	0.181	15%	55	0.28	0.45	0.57	0.80	1.00	1.20	1.42	1.65	17	22	30	36	44	55	66	0.11	0.18	0.34	0.50	0.73	1.09	1.50
Catchment 3	3	160,867	0.161	60%	52	0.59	0.45	0.57	0.80	1.00	1.20	1.42	1.65	17	22	30	36	44	55	66	0.20	0.34	0.64	0.95	1.39	2.07	2.85
Catchment 4	4	232,385	0.232	30%	63	0.36	0.45	0.57	0.80	1.00	1.20	1.42	1.65	11	15	19	23	27	34	40	0.11	0.19	0.35	0.52	0.75	1.11	1.51
Catchment 5	5	799,702	0.800	25%	123	0.33	0.45	0.57	0.80	1.00	1.20	1.42	1.65	7	9	12	14	17	21	25	0.23	0.39	0.71	1.04	1.49	2.20	2.99
Catchment 6	6	98,611	0.099	17%	40	0.29	0.45	0.57	0.80	1.00	1.20	1.42	1.65	17	22	30	36	44	55	66	0.06	0.10	0.19	0.28	0.41	0.62	0.85
Catchment 7a	7a	240,566	0.241	60%	64	0.59	0.45	0.57	0.80	1.00	1.20	1.42	1.65	11	15	19	23	27	34	40	0.20	0.33	0.61	0.89	1.29	1.91	2.60
Catchment 7b	7b	498,917	0.499	25%	95	0.33	0.45	0.57	0.80	1.00	1.20	1.42	1.65	11	15	19	23	27	34	40	0.22	0.38	0.70	1.03	1.48	2.20	2.99
Catchment 7c	7c	275,566	0.276	6%	69	0.24	0.45	0.57	0.80	1.00	1.20	1.42	1.65	11	15	19	23	27	34	40	0.09	0.15	0.28	0.41	0.59	0.88	1.20
Catchment 7d	7d	224,840	0.225	25%	62	0.33	0.45	0.57	0.80	1.00	1.20	1.42	1.65	11	15	19	23	27	34	40	0.10	0.17	0.31	0.46	0.67	0.99	1.35
Catchment 7e	7e	269,349	0.269	10%	68	0.25	0.45	0.57	0.80	1.00	1.20	1.42	1.65	11	15	19	23	27	34	40	0.09	0.16	0.29	0.43	0.62	0.92	1.25
Catchment 7f	7f	221,108	0.221	15%	61	0.28	0.45	0.57	0.80	1.00	1.20	1.42	1.65	11	15	19	23	27	34	40	0.08	0.14	0.26	0.38	0.56	0.82	1.12
Catchment 8	8	29,416	0.029	10%	21	0.25	0.45	0.57	0.80	1.00	1.20	1.42	1.65	21	29	39	47	58	74	88	0.02	0.03	0.07	0.10	0.14	0.22	0.30
Catchment 9	9	114,882	0.115	15%	43	0.28	0.45	0.57	0.80	1.00	1.20	1.42	1.65	17	22	30	36	44	55	66	0.07	0.11	0.21	0.32	0.46	0.70	0.95
Catchment 10	10	33,764	0.034	6%	22	0.24	0.45	0.57	0.80	1.00	1.20	1.42	1.65	21	29	39	47	58	74	88	0.02	0.04	0.07	0.10	0.15	0.23	0.32
Catchment 11	11	812,914	0.813	10%	124	0.25	0.45	0.57	0.80	1.00	1.20	1.42	1.65	7	9	12	14	17	21	25	0.18	0.30	0.56	0.82	1.18	1.74	2.36

Detailed calculation of Peak Flow Rates
Tectonic: Kundip

Time of Concentration (tc):

Description	Label	Catchment area, *A* (m2)	Catchment area, *A* (km2)	Clearing, C_L (% of A)	Time of concentration t_c (min)	C_{10}	C_Y/C_{10} for ARI (years)							$I_{tc,Y}$ for ARI (years), (mm/h)							Q_Y for ARI (years), (m^3/s)						
							1	**2**	**5**	**10**	**20**	**50**	**100**	**1**	**2**	**5**	**10**	**20**	**50**	**100**	**1**	**2**	**5**	**10**	**20**	**50**	**100**
Kundip Post-project Open Drain Channels:																											
Channel 1	OD1	156,268	0.156	60%	51	0.59	0.45	0.57	0.80	1.00	1.20	1.42	1.65	17	22	30	36	44	55	66	0.19	0.33	0.62	0.92	1.35	2.01	2.77
Channel 2	OD2	91,248	0.091	50%	38	0.50	0.45	0.57	0.80	1.00	1.20	1.42	1.65	17	22	30	36	44	55	66	0.10	0.16	0.31	0.45	0.66	0.99	1.37
Channel 3	OD3	126,688	0.127	60%	45	0.59	0.45	0.57	0.80	1.00	1.20	1.42	1.65	17	22	30	36	44	55	66	0.16	0.27	0.50	0.75	1.09	1.63	2.24
Channel 4	OD4	54,949	0.055	30%	29	0.36	0.45	0.57	0.80	1.00	1.20	1.42	1.65	21	29	39	47	58	74	88	0.05	0.09	0.17	0.26	0.38	0.57	0.79
Channel 5	OD5	139,401	0.139	65%	48	0.64	0.45	0.57	0.80	1.00	1.20	1.42	1.65	17	22	30	36	44	55	66	0.19	0.32	0.60	0.89	1.31	1.95	2.69
Channel 6	OD6	12,447	0.012	50%	13	0.50	0.45	0.57	0.80	1.00	1.20	1.42	1.65	31	42	59	72	89	116	140	0.02	0.04	0.08	0.12	0.18	0.28	0.40
Channel 7	OD7	18,768	0.019	50%	16	0.50	0.45	0.57	0.80	1.00	1.20	1.42	1.65	31	42	59	72	89	116	140	0.04	0.06	0.12	0.19	0.28	0.43	0.60
Channel 8	OD8	35,097	0.035	50%	23	0.50	0.45	0.57	0.80	1.00	1.20	1.42	1.65	21	29	39	47	58	74	88	0.05	0.08	0.15	0.23	0.34	0.51	0.70
Channel 9	OD9	33,223	0.033	10%	22	0.25	0.45	0.57	0.80	1.00	1.20	1.42	1.65	21	29	39	47	58	74	88	0.02	0.04	0.07	0.11	0.16	0.25	0.34
Channel 10	OD10	15,232	0.015	20%	14	0.30	0.45	0.57	0.80	1.00	1.20	1.42	1.65	31	42	59	72	89	116	140	0.02	0.03	0.06	0.09	0.14	0.21	0.29

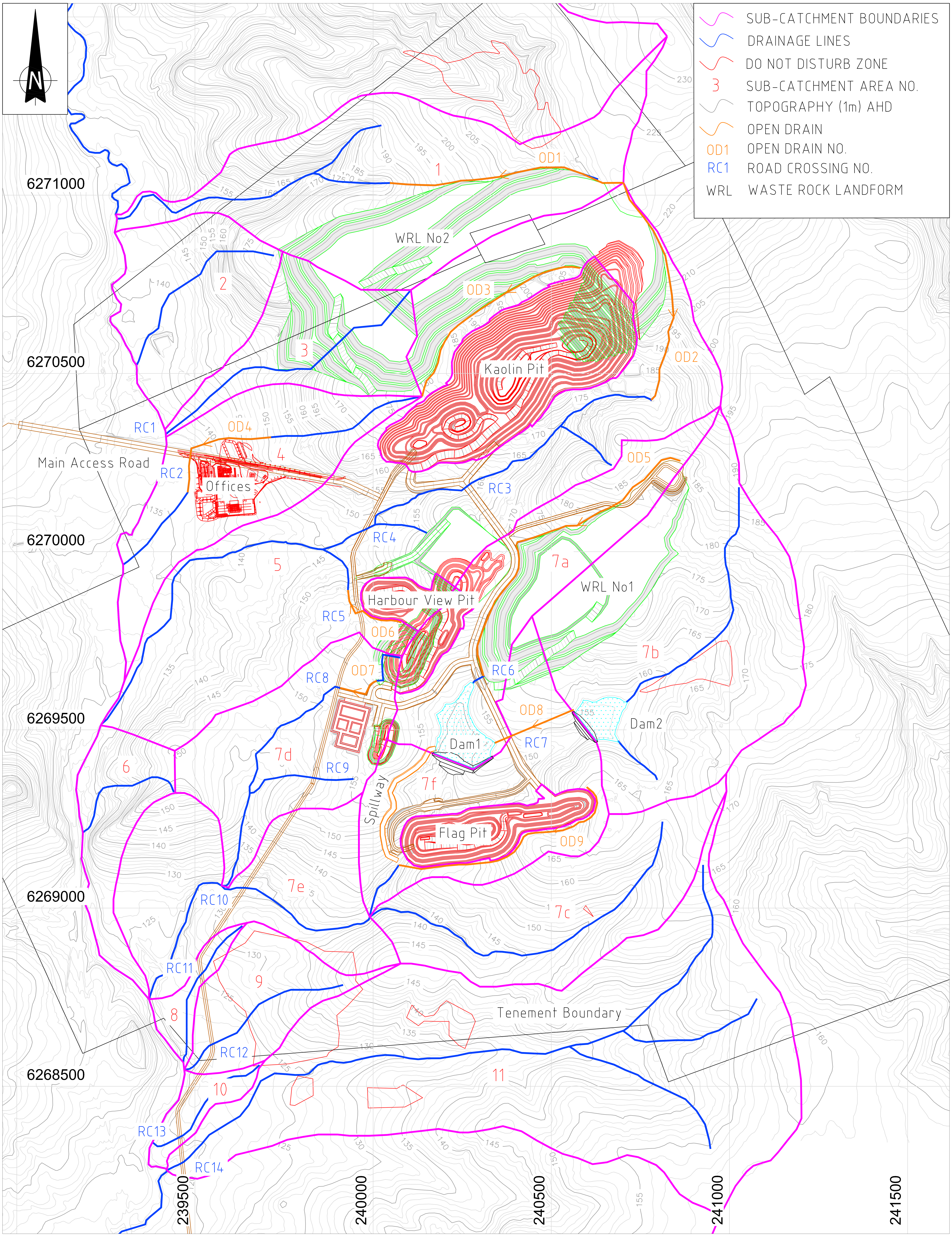
Detailed calculation of Peak Flow Rates
Tectonic: Kundip

Time of Concentration (tc):

Description	Label	Catchment area, *A* (m2)	Catchment area, *A* (km2)	Clearing, C_L (% of A)	Time of concentration t_c (min)	C_{10}	C_Y/C_{10} for ARI (years)							$I_{tc,Y}$ for ARI (years), (mm/h)							Q_Y for ARI (years), (m^3/s)						
							1	**2**	**5**	**10**	**20**	**50**	**100**	**1**	**2**	**5**	**10**	**20**	**50**	**100**	**1**	**2**	**5**	**10**	**20**	**50**	**100**
Kundip Post-project Road Crossings:																											
Road Crossing 1	RC1	Steere River																									
Road Crossing 2	RC2	CH3 + CH4																								2.20	3.03
Road Crossing 3	RC3	231,800	0.232	25%	63	0.33	0.45	0.57	0.80	1.00	1.20	1.42	1.65	11	15	19	23	27	34	40	0.10	0.17	0.32	0.48	0.69	1.02	1.39
Road Crossing 4	RC4	332,459	0.332	25%	76	0.33	0.45	0.57	0.80	1.00	1.20	1.42	1.65	11	15	19	23	27	34	40	0.15	0.25	0.46	0.68	0.99	1.46	1.99
Road Crossing 5	RC5	CH6																								0.28	0.40
Road Crossing 6	RC6	CH5																								1.95	2.69
Road Crossing 7	RC7	C7b + CH8																								2.71	3.69
Road Crossing 8	RC8	CH7																								0.43	0.60
Road Crossing 9	RC9	53,212	0.053	60%	28	0.59	0.45	0.57	0.80	1.00	1.20	1.42	1.65	21	29	39	47	58	74	88	0.08	0.14	0.27	0.41	0.60	0.91	1.26
Road Crossing 10	RC10	C a,b,c,f,0.5e																								6.27	8.53
Road Crossing 11	RC11	8,629	0.009	10%	11	0.25	0.45	0.57	0.80	1.00	1.20	1.42	1.65	31	42	59	72	89	116	140	0.01	0.01	0.03	0.04	0.07	0.10	0.14
Road Crossing 12	RC12	104,741	0.105	15%	41	0.28	0.45	0.57	0.80	1.00	1.20	1.42	1.65	17	22	30	36	44	55	66	0.06	0.10	0.20	0.29	0.42	0.63	0.87
Road Crossing 13	RC13	21,943	0.022	6%	18	0.24	0.45	0.57	0.80	1.00	1.20	1.42	1.65	31	42	59	72	89	116	140	0.02	0.03	0.07	0.10	0.16	0.24	0.34
Road Crossing 14	RC14	810,053	0.810	10%	124	0.25	0.45	0.57	0.80	1.00	1.20	1.42	1.65	7	9	12	14	17	21	25	0.18	0.30	0.56	0.82	1.18	1.73	2.35

Appendix B

Drawings



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Drawn:	FVDL	Client:	TECTONIC RESOURCES NL
Approved:	CH	Project:	SURFACE WATER HYDROLOGY - KUNDIP
Date:	2011-02-18	Title:	SURFACE WATER CONTROL TREATMENTS
Scale:	1:15000	Project no:	MWP00095AF
Original size:		Fig no:	5
		Rev:	A

coffey mining
SPECIALISTS FROM BOARDROOM TO MINE FACE

NOTES:

1. DESIGN VEHICLES:
   - 1.1. FUEL TANKER: B-DOUBLE
   - 1.2. PLANT DELIVERY VEHICLE: LOW LOADER W. PRIME MOVER
   - 1.3. DELIVERY VEHICLE: 12.5m SINGLE UNIT TRUCK
   - 1.4. MINE VEHICLE: CAT 777D
2. EARTHWORKS BATTERS AND CLEARED AREAS ARE INDICATIVE ONLY AND WILL VARY ACCORDING TO FINAL APPROVED LAYOUT
3. ALL VEHICLE ACCESS THROUGH MAIN ENTRY ONLY. ALL VEHICLES TO BE THOROUGHLY CLEANED, INSPECTED AND APPROVED BY TECTONIC RESOURCES P/L BEFORE ENTRY IS PERMITTED.
4. VEHICLES REJECTED MAYBE REQUIRED TO ACCESS SITE FROM SECONDARY ENTRY WITH MANUAL WASH DOWN.
5. TOTAL AREA OF CLEARING 3.5ha.

LEGEND:

- 6m WIDE FIREBREAK
- OPEN EARTH CUT OFF DRAIN
- VEHICLE DIRECTION
- VEHICLE BOLLARDS
- DOUBLE HEADER STREET LIGHT
- 1.8m HIGH CYCLONE MESH FENCE (NOT IN THIS CONTRACT)
- PEDESTRIAN ACCESS
- DIEBACK MANAGEMENT DEMARCATION
- LIMIT OF CLEARING

Rev.	Issue Description	Drn by	Chk'd	Proj. Eng	Proj. Dir.	Date
E	GENERAL DRAWING AMMENDMENTS	A.S	A.E	C.F	C.F	14.05.10
D	ISSUED FOR COMMENTS	A.S	A.E	C.F	C.F	01.02.10
C	LAYOUT REVISED	A.S	A.E	C.F	C.F	26.08.09
B	LAYOUT REVISED, RE-ISSUED FOR COMMENT	A.S	A.E	C.F	C.F	22.07.09
A	ISSUED FOR COMMENT	A.S	A.E	C.F	C.F	26.06.09

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8130.10	8130C201

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Project Name: PHILLIPS RIVER GOLD PROJECT
KUNDIP MINE INFRASTRUCTURE

Drawing Title: INTERNAL INFRASTRUCTURE COMPLEX
GENERAL ARRANGEMENT

Scale: 1:500
Dwg Size: A1
Date: JUNE 2009
Drawing No.: 8130-C-201
Rev.: E
Datum: AHD

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