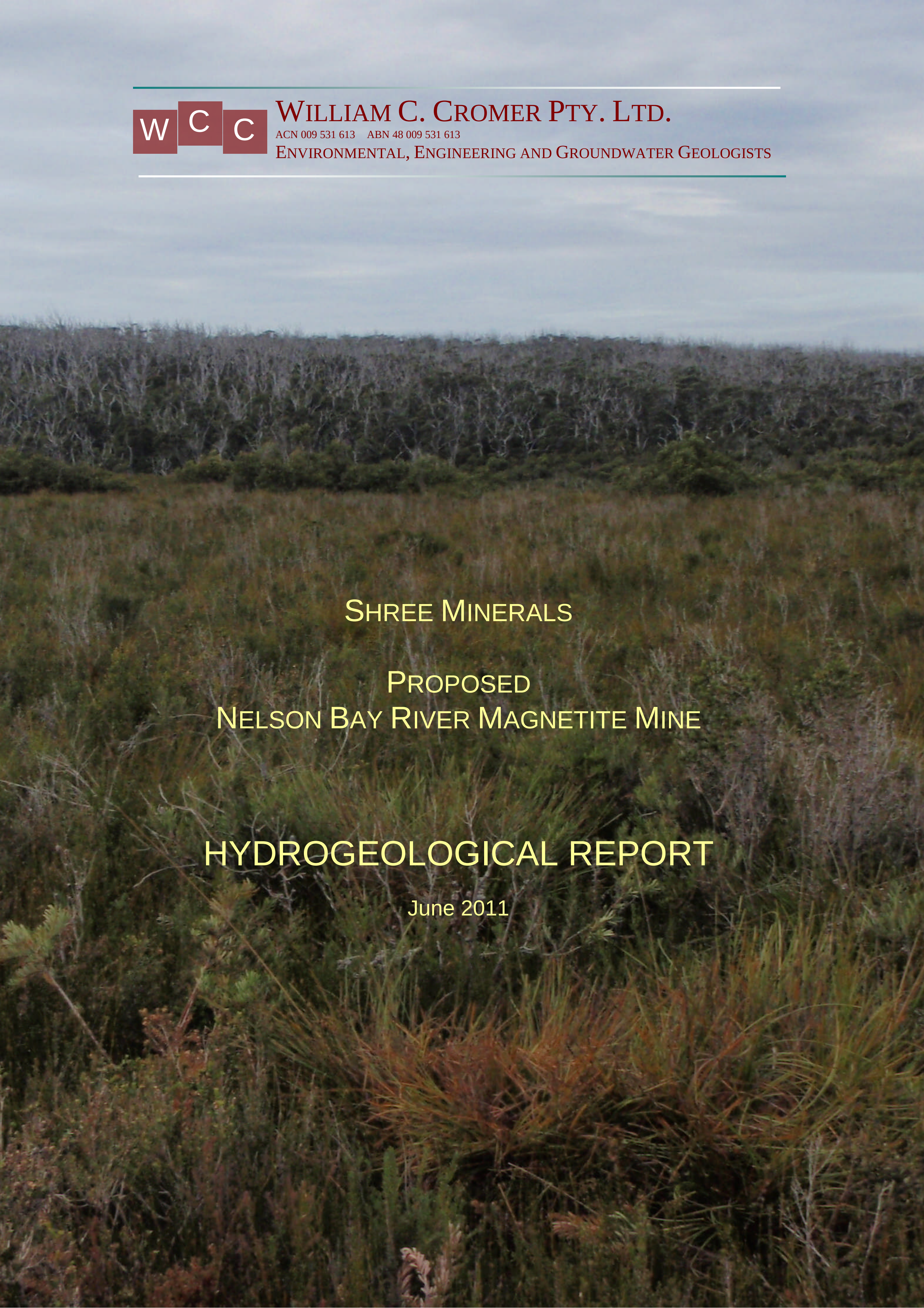
WILLIAM C. CROMER PTY. LTD.
ACN 009 531 613 ABN 48 009 531 613
ENVIRONMENTAL, ENGINEERING AND GROUNDWATER GEOLOGISTS



SHREE MINERALS

PROPOSED NELSON BAY RIVER MAGNETITE MINE

HYDROGEOLOGICAL REPORT

June 2011

Cover photo A view east-northeast across heathland and over the shallow valley of West Creek (middle ground) towards the proposed mine located behind the subdued timber line in the background.

.

Much of the gently sloping heathland in front of and behind the camera is regarded as a groundwater recharge area, where ecosystems are independent of groundwater conditions. Conversely, the valleys of West and East Creeks, and other drainage lines, are groundwater discharge areas where ecosystems are groundwater dependent.

Refer to this report as
Cromer, W. C. (2011). *Hydrogeological report, Proposed Nelson Bay River Magnetite Mine.* Unpublished report for Shree Minerals Ltd. by William C. Cromer Pty. Ltd., 28 June 2011; 22pp.

SUMMARY

This report proposes a hydrogeological model for Shree Minerals' magnetite project at Nelson Bay in northwestern Tasmania. At the current stage of operations, hydrogeological information is limited, and the model is conceptual and based mainly on fundamental groundwater principles supported by some early groundwater levels in monitoring bores.

Within the basement rocks and ore bodies, groundwater is stored in a single, unconfined, fractured rock aquifer. It moves from recharge areas (eg interfluves including most heathland) to discharge areas (eg creeks, Nelson Bay River).

Based on a mean annual rainfall of 1,300mm, discharge of surface water from West and East Creeks respectively to the Nelson Bay River is in the approximate range 1,650 – 2,400ML and 1,400 – 2,000ML annually. Proportions of these volumes would flow down any proposed diversion drains within their catchments – the annual volumes are directly related to the catchment area of the drains.

Estimates of groundwater inflow to the proposed Main Pit and DSO Pit are preliminary and depend on several assumptions about aquifer properties and pit design. For the near-end-of-mine-life Main Pit, annual inflow is estimated to be in the range 400 – 800ML +/-50% for aquifer hydraulic conductivities of 0.05 and 0.1m/day respectively. For the DSO Pit, for the same assumed hydraulic conductivities, annual inflow near-end-of-mine-life is estimated to be in the range 100 – 300ML+/-50%. These figures are intended as indicative only. Annual direct incident rain as a contributor to pit water is estimated to total 200ML and 30ML to the Main and DSO Pits respectively.

Pumping groundwater from either or both pits lowers the water table in their vicinity. For the same assumed aquifer hydraulic conductivities the area of influence affected by dewatering at near-end-of-mine-life is estimated to be limited to distances between about 800 – 1,200m+/-20% from the Main Pit, and (if pumped alone), between about 350 – 600m+/-20% from the DSO Pit.

The recorded locations of threatened floral species (and particularly the Pretty Leek Orchid, *Prasophyllum pulchellum*) on wet heathland southwest and west of the mine site are outside the estimated areas of influence of pit dewatering. Furthermore, they are inferred to be in groundwater recharge areas, where ecosystems are groundwater independent and soil moisture is derived from infiltrating rain only. The same conditions apply throughout the mapped extent of heathland, except for localised and separate groundwater discharge areas in the headwaters of minor tributaries draining its perimeter.

There is therefore no significant likelihood of the heathland soil water, and hence the ecosystems dependent on it, including threatened orchid species, being affected by the dewatering of the mine pits.

CONTENTS

1 INTRODUCTION

1.1 BACKGROUND

Shree Minerals Ltd. ("Shree") has submitted to Mineral Resources Tasmania a mining lease application (MLA) to extract iron ore from within its exploration licence 41/2004 in the Nelson Bay River district of northwestern Tasmania (Figure 1). The lease will be a much smaller area than the exploration licence area shown in Figure 1 and will be confined to an area surrounding the pits and mine infrastructure.

Shree has also submitted a Notice of Intent (NOI) to the Tasmanian Environment Protection Authority and an EPBC referral to the Commonwealth of Australia.

It is proposed[1] to mine magnetite from an open Main Pit to a depth of about 225m (-145mRL) and process it on site. A near-surface body of oxidised ore (haematite) is available as direct shipping ore (DSO) and will be extracted from an adjacent open pit about 40m deep. Each will be below the regional groundwater table, and pit dewatering is likely to be a component of mining.

The area between the proposed mining operations and the coast includes wet heathland with threatened flora species– including the Pretty Leek Orchid (*Prasophyllum pulchellum*; Figure 2).

Potential hydrogeological issues relating to mining include the effects (if any) of pit dewatering on the heathland, and on the surface hydrology of the area.

1.2 STUDY BRIEF

William C. Cromer Pty. Ltd. was commissioned by Shree to:

1. Inspect the area including the proposed mine site and heathland
2. Develop a conceptual groundwater model for the site, showing likely groundwater movements as they relate to the mining pits and to the wet heathland and specifically also to the threatened species sites
3. Determine the significance of the potential risks from mining activities on the water table regime of the wet heathland and specifically to the threatened species sites
4. Estimate likely flow rates for surface water catchments and proposed diversion drains, and the likely groundwater inflow rates that could be expected for the DSO pit and for the Main Pit

[1] For background information, see Woodward, I. and Pollington, M. (2011). *Project Description, Nelson Bay River Magnetite Mine*. Prepared by Pitt & Sherry for Shree Minerals, 18 February 2011.

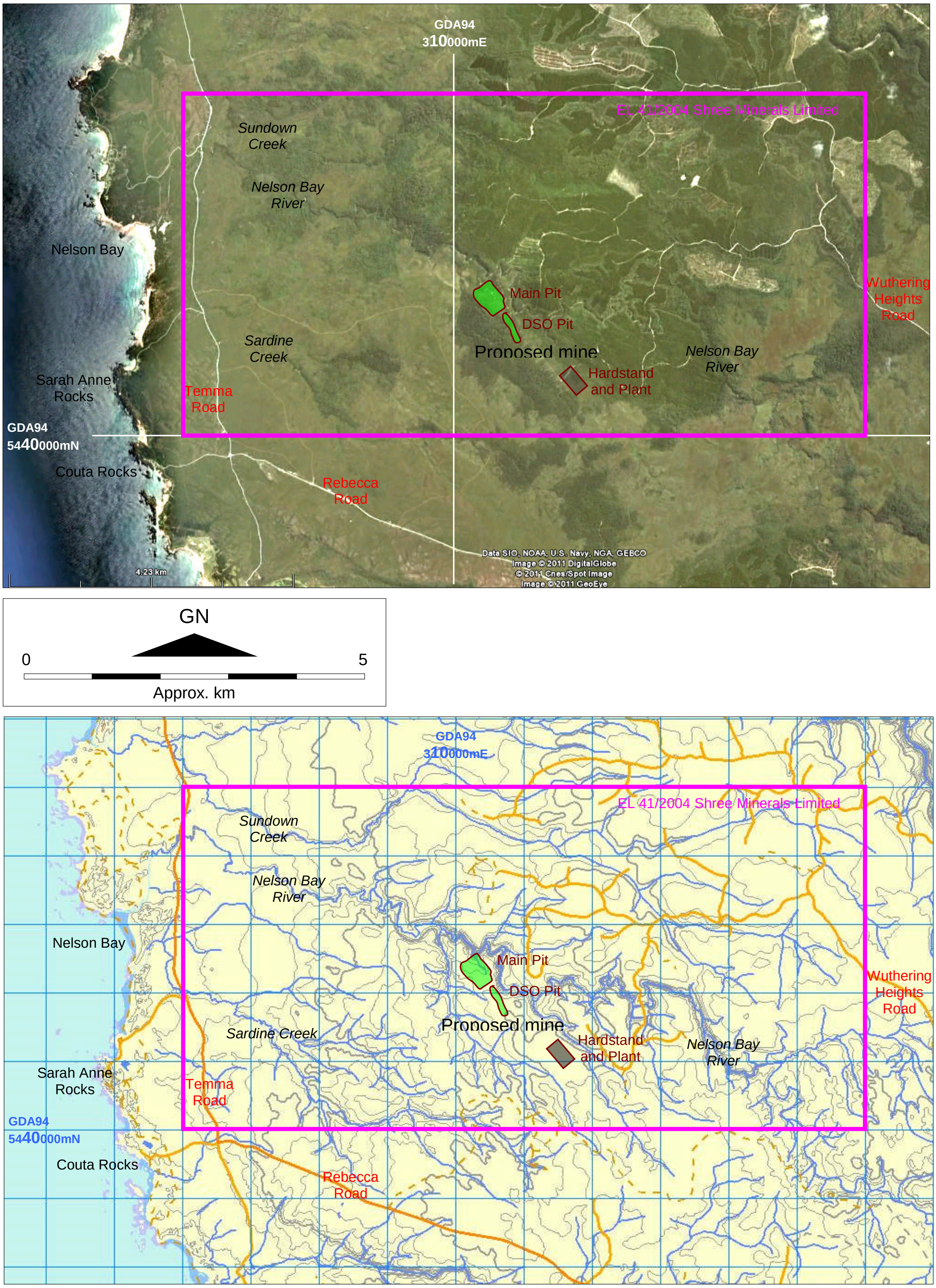


Figure 1. **Location map, proposed Nelson Bay River Mine**
Source: Google Earth and wwwthelist.tas.gocv.au

2 HYDROGEOLOGICAL SITE DESCRIPTION

2.1 TOPOGRAPHY, RELIEF AND SURFRACE DRAINAGE

The mine site and environs are located on a coastal surface dissected by a dendritic drainage system. The surface is at elevations of about 80 – 100mASl near the proposed open pits, and on average slopes gently west at about 1^0.

The surface streams include Nelson Bay River and its tributaries West Creek and East Creek, and, in separate catchments to the southwest and north, Sardine Creek and Sundown Creek respectively (Figure 2).

Near the mine site, Nelson Bay River has cut through the coastal surface to base levels between 40 and 50m ASL, so the local relief is up to 50m and hillsides are steep. West and East Creeks are incised in valleys whose sides are up to about 20 – 30m deep.

The approximate surface water catchment areas of West and East Creeks are 320ha and 270ha respectively (Figure 2).

2.2 CLIMATE

The mean annual rainfall of 1,300mm at Temma (10km southwest of the mine site; Table 1) has been adopted in this report. Annual evapotranspiration (ET) at Smithton Airport totalled 945mm and 988mm for 2009 and 2010 respectively, and exceeded mean monthly rain from November to March. Effective annual rain (total monthly rain less ET for the period April to October) is therefore about 570mm.

Table 1. Climatic summary for Temma and Smithton Airport
Sources: BOM, and Table 3 of Pitt & Sherry Project Description Report

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual
Rainfalll (mm) Temma													
Mean	57	58	74	106	135	152	166	152	123	100	85	81	**1300**
Highest	134	186	221	219	283	238	278	266	217	213	166	245	**1745**
Lowest	8	7	14	31	50	60	56	39	48	34	14	3	**929**
Evapotranspiration (ET; mm) Smithton Airport													
2009	160	111	80	62	43	24	30	55	69	102	73	136	**945**
2010	154	127	105	63	44	29	27	44	64	91	109	131	**988**
Effective rain (ean rain less 2010 ET)*													
	-97	-69	-31	43	91	123	139	108	59	9	-24	-50	**572**

2.3 GEOLOGY

The geology and mineralisation of the district has been well-described by others[2], and will not be repeated in detail here. Essentially, the basement rocks are Precambrian-age siltstones and sandstones of the Cowrie Siltstone. The beds strike roughly 135^0M and dip east at about 60^0, are slightly metamorphosed and moderately fractured.

The Prospect comprises skarn-related magnetite-haematite mineralisation in a 320^0M-trending fault zone dipping roughly 70^0 to the southwest.

[2] See, for example, Reid, R. (2010). *Nelson Bay River (EL41/2004) Resource Drilling Report.* Report produced for Shree Minerals Limited, October 2010.

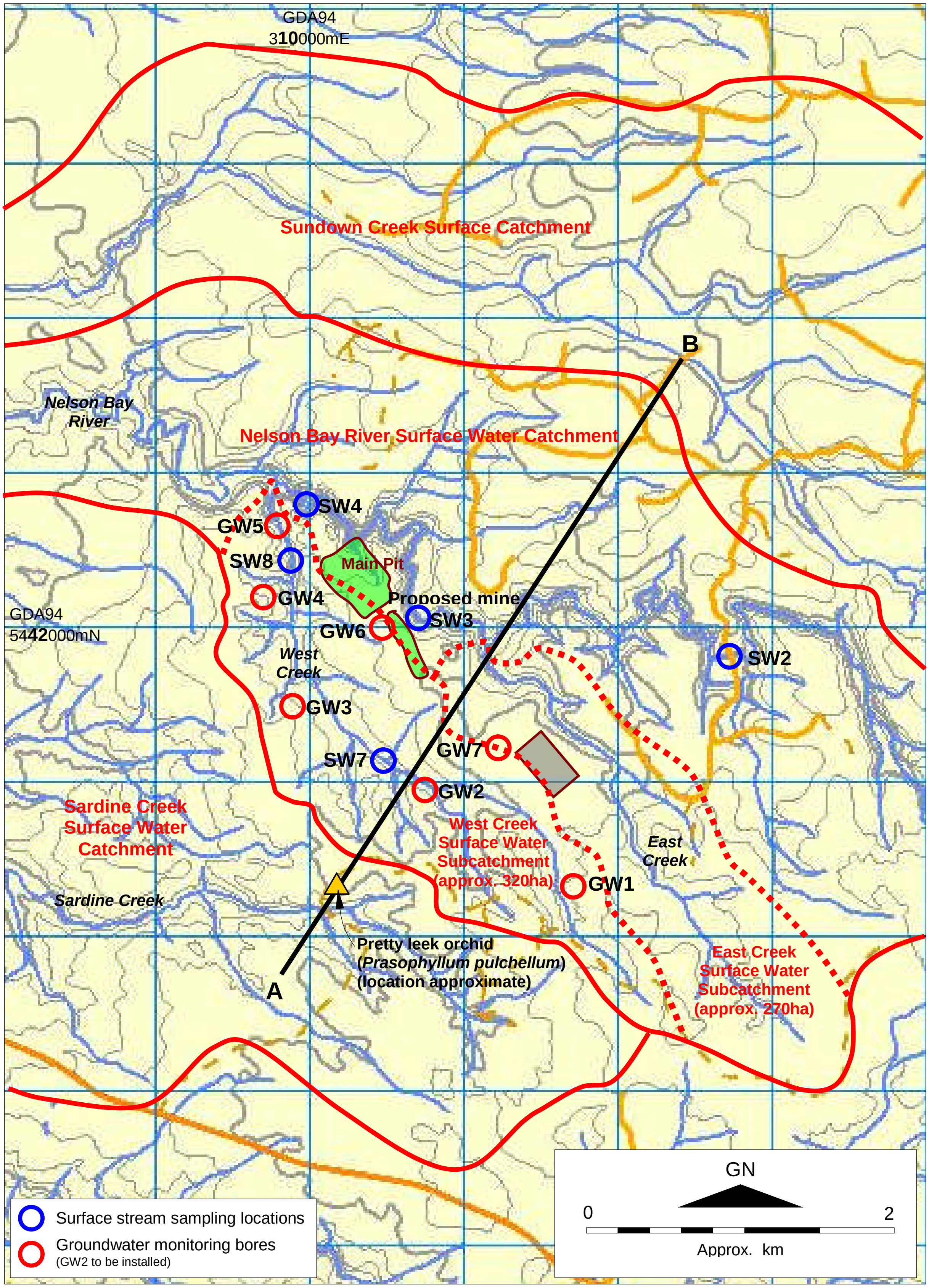


Figure 2. **Surface water catchments near the proposed Nelson Bay River Mine. Mining operations will be contained within the Nelson Bay River catchment. A schematic showing inferred hydrogeological conditions along Section line A – B is depicted in Figure 4.**
Source: wwwthelist.tas.gocv.au

2.4 HYDROGEOLOGICAL SETTING

2.4.1 Fundamentals of groundwater movement and occurrence

Based on general hydrogeological principles, the geology of the district, and a review of drill core photographs, the rocks and ores of the mine site and environs are regarded as a single, fractured, hard-rock, unconfined aquifer (Attachment 1).

In such an environment, Figure 3 illustrates different components of the land-based part of the hydrological cycle[3] at the scale of a single catchment (eg West Creek) or smaller. Effective rain (precipitation less evapotranspiration) flows overland to surface streams, or infiltrates through the unsaturated zone to the water table.

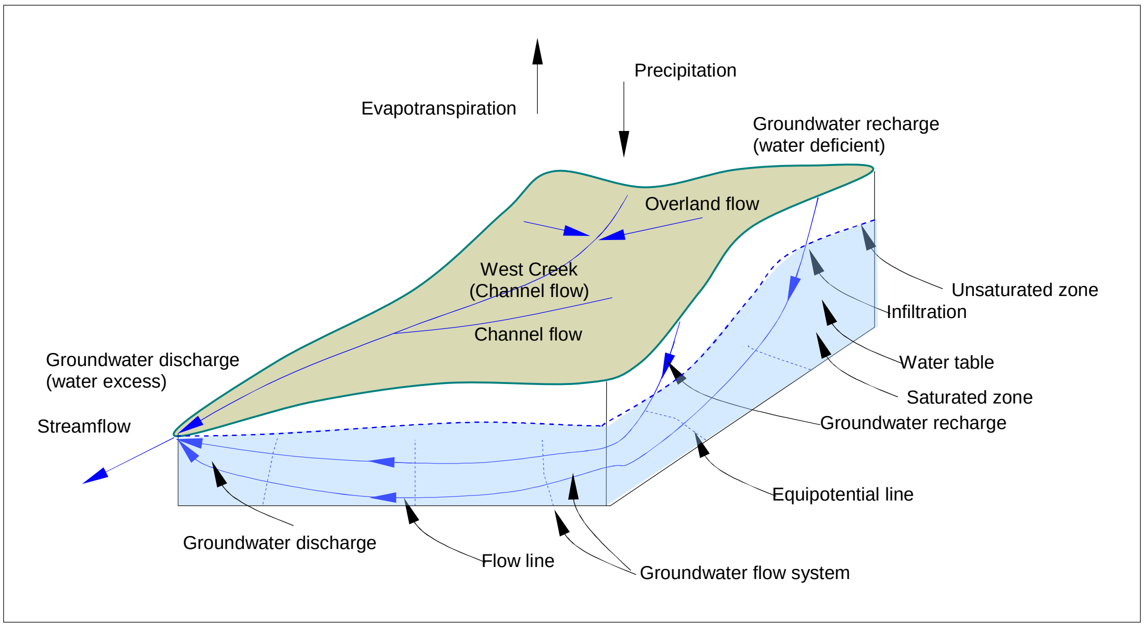


Figure 3. Aspects of the land-based hydrological cycle

The fundamentals of groundwater movement in an unconfined, gravity-driven groundwater system similar to that at Nelson Bay River are depicted schematically in Figure 4.

In Figure 4, the hydraulic heads in the recharge area are relatively high and decrease with depth. In discharge areas, the energy and flow conditions are reversed: heads are low and increase with depth. In between, the throughflow is almost horizontal as shown by the steeply dipping equipotential lines.

Figure 4 also illustrates the concept of a groundwater system[4] – fundamental to understanding practical problems like open pit mining at Nelson Bay River. Given the locally high relief of the area, it can be expected that the near-surface dominant groundwater flows to depths of the

[3] The *hydrological cycle* is the circulation of water in various phases through the atmosphere, over and under the earth, to the oceans, and back to the atmosphere. The cycle is solar-powered. Because water is a solvent it dissolves elements, and geochemistry is a fundamental part of the cycle, which is a flux for water, energy, and chemicals.
Water enters the land-based cycle as precipitation; it leaves as surface streamflow (runoff) or evapotranspiration. The route which groundwater takes from a recharge point to a discharge point is a *flow path.*

[4] Sophocleous (2004) cited in Figure 3 defines a groundwater system as “a set of groundwater flow paths with common recharge and discharge areas. Flow systems are dependent on the hydrogeologic properties of the soil/rock material, and landscape position. Areas of steep or undulating relief tend to have dominant lo*cal flow systems* (discharging to nearby topographic lows such as ponds and streams). Areas of gently sloping or nearly flat relief tend to have dominant *regional flow systems* (discharging at much greater distances than local systems in major topographic lows or oceans).” A three-dimensional closed groundwater flow system that contains all the flow paths is called the *groundwater basin*.

order of a hundred metres or so will be as local to intermediate systems, with recharge on most elevated areas discharging to streams like West and East Creeks. However, the magnetite ore body extends to depths below sea level (the coast lies some 5 – 6km to the west), and with deeper and deeper mining, it is expected that the dominant groundwater flows will become increasingly regional in nature, and that with continued dewatering the base level at the coast (a constant head boundary) may increasingly affect groundwater flows.

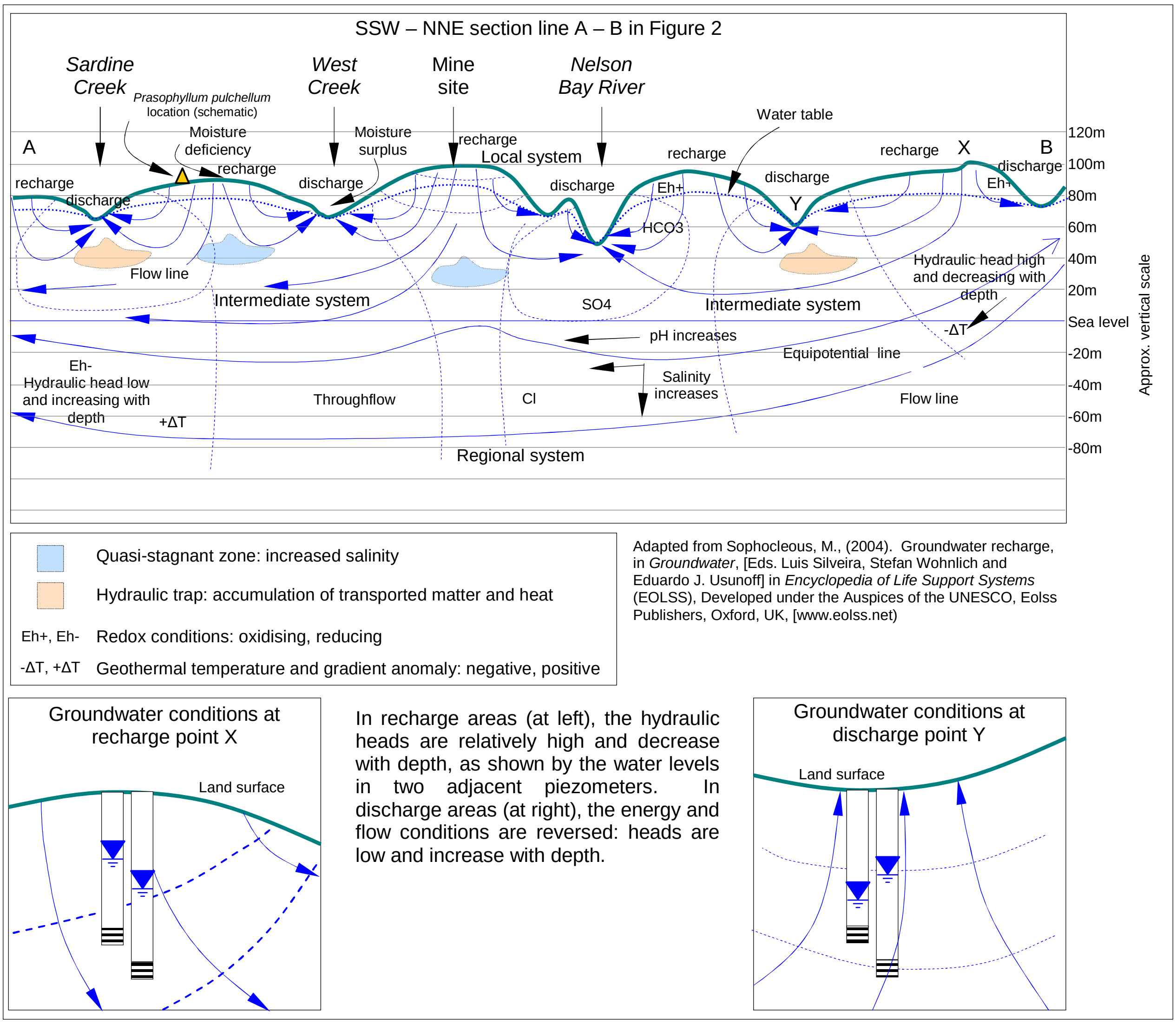


Figure 4. **Fundamentals of groundwater hydrology in a gravity-driven groundwater system like that at and near the Nelson Bay River mine**
Do not scale: cross section is schematic; vertical exaggeration for top section is about 5

It is therefore important to place the local site in the context of the larger groundwater system, and an understanding of Figure 4 is critical to understanding the relationship between groundwater dependent ecosystems (GDE's) and non – GDE's[5].

2.4.2 Current hydrogeological investigations

Hydrogeological investigations to date include surface water sampling at six of eight selected stream sites, and groundwater sampling and water level monitoring at six bore sites (Figure 2).

[5] For example, see http://www.connectedwater.gov.au/framework/ground_dependant_ecosystems.html

The results of surface water sampling are reported elsewhere.

Field parameters and depths to the water table from the first groundwater sampling event in May 2011 are summarised in Table 2, and laboratory results are presented in Table 3.

From a hydrogeological perspective, the depth to water in Table 2 is of interest: shallow water less than a metre or so from the ground surface was reported from bores GW5 and GW7. The former is in the lower reaches of West Creek, and the latter on almost flat, poorly drained ground. The remaining bores recorded water tables between about 5 and 10m below ground.

Chemically, all groundwaters are of the sodium chloride type, of low salinity, and acidic (pH range 5.3 – 5.8) except for GW7 (pH 7.7).

Table 2. Summary of the groundwater monitoring and sampling event, May 2011

				Field parameters					
Site ID	**Easting (GDA 94)**	**Northing (GDA 94)**	**Date**	**SWL (mbg)**	**DO (%)**	**EC (µS/cm)**	**pH**	**T (°C)**	Est K (m/day)
GW1	310690	5440320	18-May-11	9.01	na	na	na	na	0.025
GW2	311950	5440950	na	to be installed					No data
GW3	309893	5441461	19-May-11	8.70	28.5	332	5.3	13.7	1
GW4	309720	5442195	20-May-11	6.50	34.9	287	5.8	13.7	No data
GW5	309797	5442651	20-May-11	0.97	19.6	310	5.7	13.7	0.008
GW6	310487	5441962	19-May-11	9.83	19.8	447	5.7	13.7	No useful data
GW7	311249	5441240	18-May-11	0.80	8.6	383	7.7	12.8	1.5
					Geometric mean of K values				0.13

Notes
SWL = Standing water level in metres below ground
DO = Dissolved oxygen
EC = Electrical conductivity
Est K = Permeability (hydraulic conductivity) estimated using the Theis equation on 5 minute recovery tests
Information (except for est K) from Pitt & Sherry

2.4.3 Groundwater study area

In the medium to long term, the groundwater study area for the Nelson Bay River Mine will necessarily encompass the groundwater basin which controls groundwater flow to mining operations. The groundwater basin may therefore be intermediate or regional in scale, and importantly may not correspond to surface water catchments.

In the short term, detailed hydrogeological investigations will focus on local groundwater systems centred on the Main and DSO pits, and include the catchment areas of West and East Creeks.

Table 3. **Laboratory results from the first groundwater sampling event in May 2011**

		Groundwater monitoring bores					
		GW1	GW3	GW4	GW5	GW6	GW7
	Easting	311690	309893	309720	309797	310487	311249
	Northing	5440320	5441461	5442195	5442651	5441962	5441240
Field results							
pH			5.26	5.82	5.74	5.67	7.72
EC	µS/cm		332	287	310	447	383
Dissolved oxygen	% sat		28.5	34.9	19.6	19.8	8.6
Temperature	^{0}C		13.7	13.7	13.7	13.7	12.8
Lab results							
TSS	mg/L	9,360	26	101	154	283	214
Turbidity	NTU	26,400	58	3,220	320	1,060	272
Total hardness	mgCaCO3/L	38	24	37	23	38	19
Alkalinity H2O2	mgCaCO3/L	<1	<1	<1	<1	<1	<1
Alkalinity CO3	mgCaCO3/L	<1	<1	<1	<1	<1	<1
Alkalinity H2CO3	mgCaCO3/L	10	33	24	23	6	24
Total Alkalinity	mgCaCO3/L	10	33	24	23	6	24
Acidity	mgCaCO3/L	60	15	12	21	31	4
Sulphate	mg/L	14	9	11	12	10	14
Chloride	mg/L	72	93	69	69	123	86
Ca dissolved	mg/L	2	3	5	1	2	1
Mg dissolved	mg/L	8	4	6	5	8	4
Na dissolved	mg/L	54	25	31	34	56	60
K dissolved	mg/L	2	2	2	2	2	4
As total	mg/L	0.036	0.003	0.040	0.099	0.013	0.240
Ba total	mg/L	0.035	0.011	0.018	0.013	0.021	0.023
Be total	mg/L	0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Cd total	mg/L	0.0004	<0.0001	0.0042	0.001	<0.0001	0.0002
Co total	mg/L	0.039	0.002	0.011	0.010	0.002	0.014
Cr total	mg/L	0.037	0.002	0.014	0.012	0.004	0.003
Cu total	mg/L	0.266	0.004	0.073	0.939	0.010	0.003
Hg total	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Mn total	mg/L	0.238	0.156	0.120	0.423	0.064	0.271
Ni total	mg/L	0.054	0.002	0.017	0.010	0.004	0.016
Pb total	mg/L	0.199	0.005	0.088	0.356	0.009	0.022
V total	mg/L	0.05	<0.01	0.01	<0.01	<0.01	<0.01
Zn total	mg/L	0.048	<0.005	0.334	0.255	0.038	0.015
Fluoride	mg/L	<0.1	0.1	<0.1	<0.1	<0.1	<0.1
Ammonia	mg/L-N	<0.01	<0.01	0.11	<0.01	<0.01	0.17
Nitrite	mg/L-N	0.02	<0.01	0.01	<0.01	<0.01	<0.01
Nitrate	mg/L-N	<0.01	0.02	0.02	<0.01	<0.01	<0.01
Nitrite+Nitrate	mg/L-N	<0.01	0.02	0.02	<0.01	<0.01	<0.01
Total Kjeldahl N	mg/L-N	7.7	0.3	2.0	0.9	0.8	1.2
Total Nitrogen	mg/L-N	7.7	0.3	2.0	0.9	0.8	1.2
Total phosphorus	mg/L-P	2.69	0.08	0.35	0.29	0.10	0.17
Total Anions	meq/L	2.53	3.46	2.66	2.66	3.79	3.20
Total cations	meq/L	3.14	1.68	2.14	2.03	3.29	3.11

Results from ALS report EM105336

3 DISCUSSION

3.1 CONCEPTUAL HYDROGEOLOGICAL MODEL

Figure 5 is a site-specific conceptual hydrogeological model along part of Section line A – B in Figure 2. Some of the main components of the hydrogeological water balance are shown in blue type in the diagram, and estimates of expected values or ranges are summarised in Table 4.

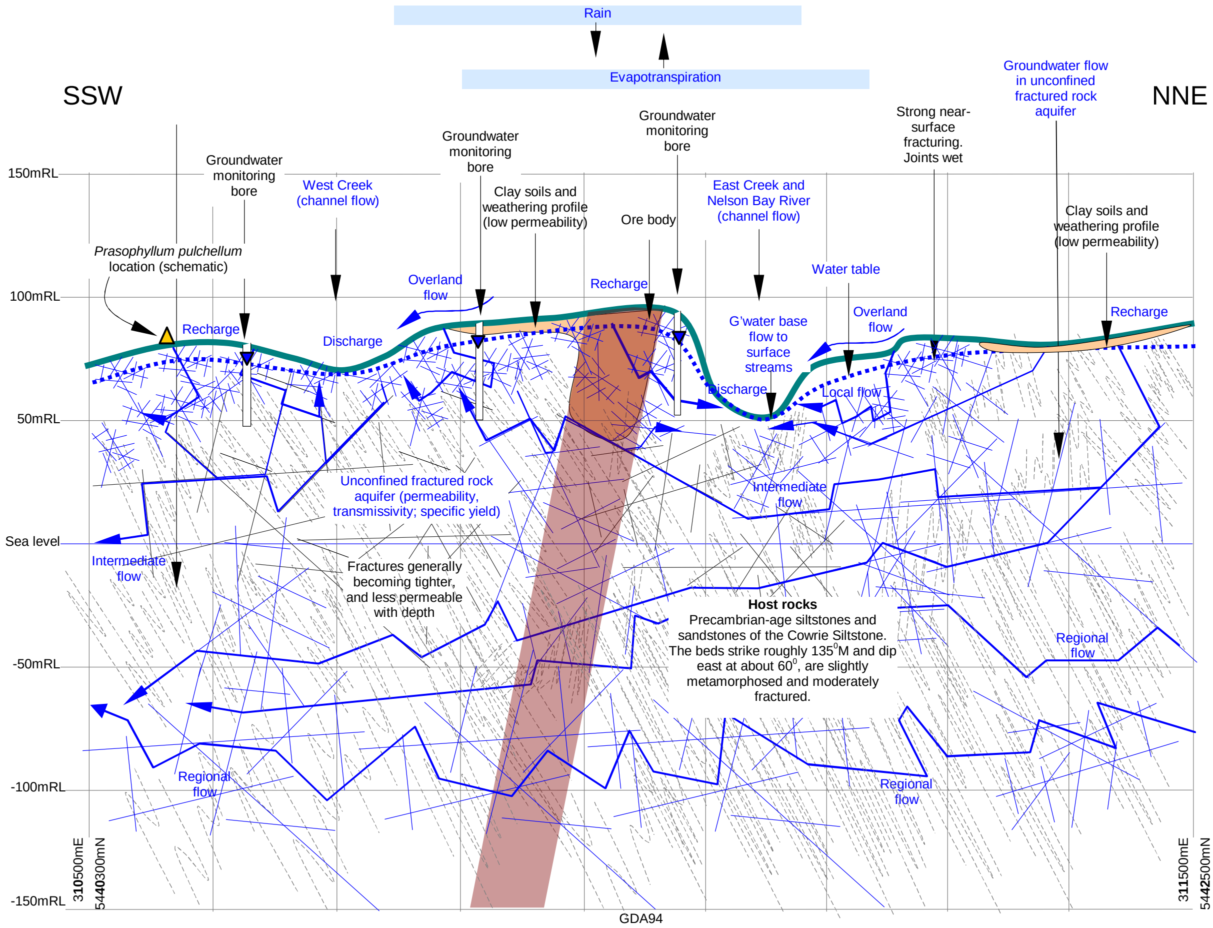


Figure 5. A conceptual hydrogeological model for the Nelson Bay River Project. The cross section is along part of the line A – B in Figure 2.
Do not scale: cross section is schematic; vertical exaggeration about 5.

The key features of the model are:

- No distinctive basement rocks but at depth overburden pressure will increasingly tend to close joints and other openings and at an intermediate-scale or regional-scale constitute a lower boundary to the groundwater system.
- The steeply easterly-dipping Cowrie Siltstone which constitutes a fractured rock aquifer. Fracturing is expected to be relatively intense at and near the surface, becoming less intense with depth. Permeability and specific yield are expected to be variable, but generally decreasing with depth. Groundwater moves only through the fractures, which separate essentially dry rock. (Other secondary porosity development might include vuggy dissolution `zones in carbonates within the Cowrie Formation)

- The steeply-west dipping mineralised zone, which is locally oxidised and weathered, and probably of lower permeability, near the surface

- Fault zones, where present, may be more permeable than the country rock and the ore bodies

- A regional water table is expected to be a subdued replica of the land surface, and intersects the land surface along drainage lines, at least in wet periods

Near-surface groundwater flow is controlled by local systems, where flow lines are steep (equipotential lines are gently inclined) and recharge and discharge occur on hills and intervening valleys respectively. Such conditions are likely to extend beneath the level of West and East Creeks.

At increasing depths, flow becomes intermediate and then regional in scale, with equipotential lines steepening to near-vertical, and flow lines almost horizontal.

Figure 6 is a variation of Figure 5 showing potential effects of mine pits on the water table towards the end of open cut operations. The shape of the drawn-down water table is conjectural pending information on aquifer permeability and storativity. Outputs from numerical modelling would be considerably more sophisticated than this cross section.

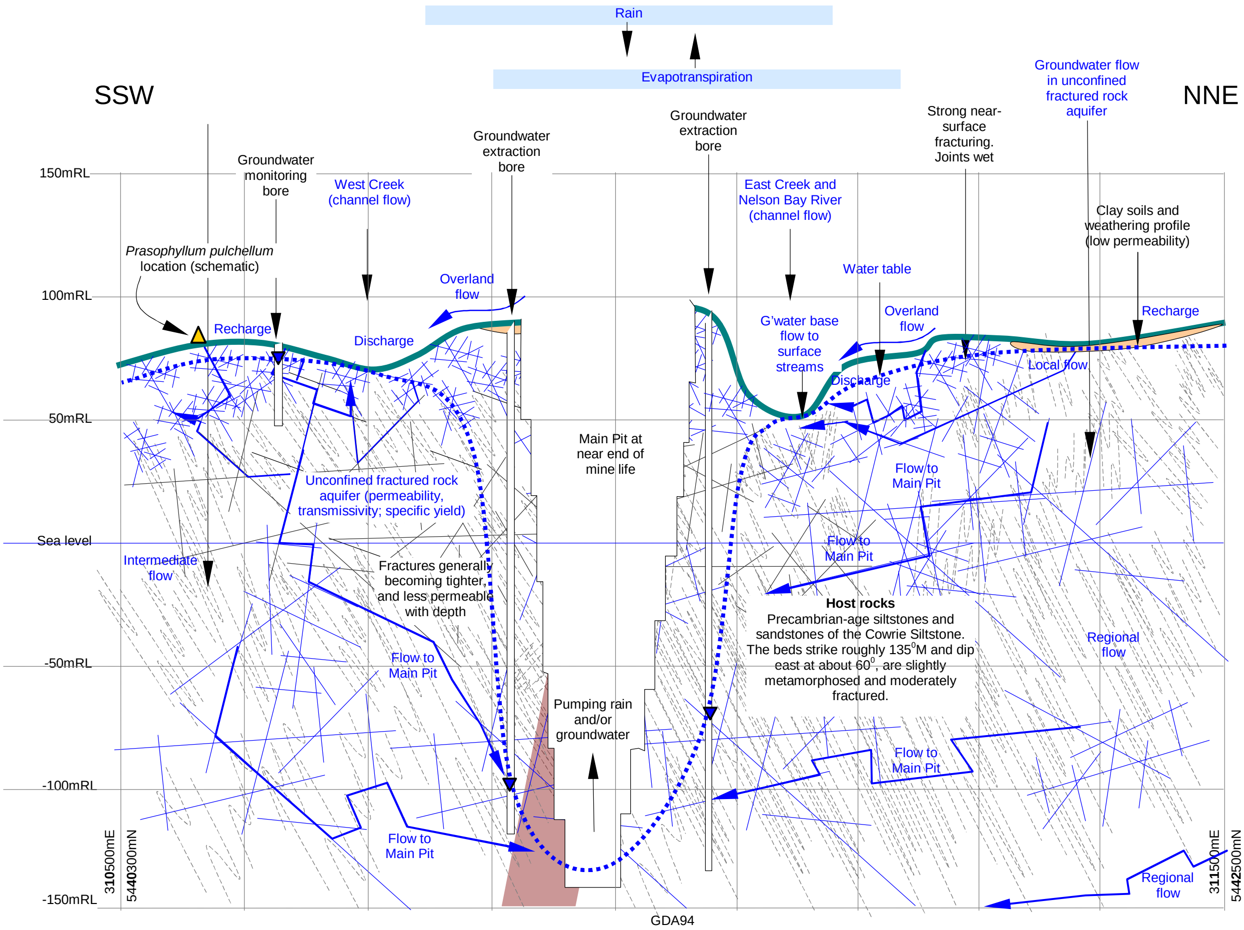


Figure 6. **Conceptual effects of mine pits on the water table and mining operations. The cross section is along part of the line A – B in Figure 2.**
Do not scale: cross section is schematic; vertical exaggeration about 5.

Table 4. Reasonable estimates for some components of the hydrogeological water balance for the Nelson Bay River Project

Component	Units	Reasonable range of values for the Nelson Bay River Project	Remarks, and/or field monitoring or testing to refine range of values during mine detailed design and operations
Precipitation (total)	mm/year	1,300	Instigate and maintain daily rainfall readings
Surface runoff (overland flow)	mm/year	500 to 800	Instigate and maintain stream gauging on West and East Creeks
Surface evaporation	mm/year	Combined, 1,000	Instigate and maintain daily evaporation readings
Transpiration from vegetation	mm/year		Estimate from general published data
Direct groundwater recharge	mm/year	50 to 100	Rain which infiltrates uniformly to the water table. Use more than one method of estimation [eg water table response to rainfall, isotopic tracers, chemical (eg chloride) mass balance from analyses]
Macropore ("preferential") recharge	Kilolitre or megalitre per rain event		Rain which infiltrates preferentially through joints, clay fractures, root holes, etc rather than via uniform vertical percolation. Estimate from soil texture and near surface joint distribution in drill core
Depth to water table	metre	0 to 10m	Instigate and maintain water level monitoring
Surface storage	megalitre		Design of water storage/process dam (if required) will provide estimate
Groundwater inflow to the system	mm/year	Nil	Assumed to be zero if the system is well-defined; otherwise, for open system assumed to be equal to groundwater outflow
Groundwater outflow from the system	mm/year	50 to 100	Estimate from water balance
Groundwater recharge from streams	mm/year	0 to 50	Estimate. Seasonally variable
Groundwater discharge to streams (baseflow)	mm/year	0 to 50	Estimate from stream base flow. Seasonally variable
Groundwater extraction from bores	megalitre	Potentially significant	Record any significant groundwater extraction
Evaporation from shallow water tables	mm/year	Potentially significant	Estimate
Vertical leakage between aquifers	mm/year	Probably not applicable	Only one aquifer is inferred to be present
Unconfined aquifer permeability	m/day	0.01 to 0.1	Will locally vary by orders of magnitude but decrease with depth. Permeability testing of selected bores is required
Unconfined aquifer specific yield	% volume	1 to 3	Pump testing of selected bores is required
Groundwater flow to open pits	cubic metres per day	Currently very uncertain	Theis estimate from assumed aquifer properties, hydraulic gradient and dimensions of open pit, etc

3.2 Estimates of discharges from surface water catchments and diversion drains

3.2.1 General comments

The lack of surface water discharge data in streams draining the Nelson Bay River mine site prohibits developing a direct relationship between rainfall and catchment yield.

Estimates of discharges from surface water catchments therefore variously involve assumptions of monthly or annual rainfall (total or effective), runoff coefficients and evapotranspiration.

The catchment size of West Creek is about 320ha, and that of East Creek about 270ha. Mean annual rainfall is 1,300mm, distributed monthly according to Table 1.

On this basis, the catchment of West Creek receives on average about 4,200ML of rain each year, and that of East Creek 3,500ML.

3.2.2 Using a runoff coefficient to estimate stream discharge

Assuming the monthly rainfall at Temma (Table 1) also applies to the mine site, a mean annual rainfall to annual catchment yield ratio ("runoff coefficient) of 0.58 (for fully vegetated catchments) has been used[6]. This method does not take account of evapotranspiration (which exceeds rain in five months) or infiltration to groundwater.

Results are summarised in Table 5 for West and East Creeks, and also for a diversion drain of various catchment sizes. Using this method, West Creek discharges about 2,400ML annually to Nelson Bay River, and East Creek discharges about 2,000ML to the river. Depending on length and location, diversion drain(s) on the mine site could discharge 70 – 560ML annually to West Creek, reflecting the drainage catchment area. For the purpose of Table 5, a diversion drain paralleling West Creek for the length of the mine site has been assumed.

Table 5. Estimates of stream discharge volumes for West and East Creeks, and a diversion drain, using a runoff coefficient of 0.58

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual
Rainfalll (mm) Temma													
Mean	57	58	74	106	135	152	166	152	123	100	85	81	**1300**
Mean discharge (ML), West Creek at Nelson Bay River**													
	106	108	137	197	251	282	308	282	228	186	158	150	**2390**
Mean discharge (ML), East Creek at Nelson Bay River**													
	89	91	116	166	211	238	260	238	193	157	133	127	**2020**
Mean discharge (ML), Diversion drain into West Creek*													
Catchment 10ha	3	3	4	6	8	9	10	9	7	6	5	5	**70**
Catchment 20ha	7	7	9	12	16	18	19	18	14	12	10	9	**150**
Catchment 50ha	17	17	21	31	39	44	48	44	36	29	25	23	**370**
Catchment 75ha	25	25	32	46	59	66	72	66	54	44	37	35	**560**

* Assumes no extraction for process water from storage dams in catchment

[6] See Ling F L N, Gupta V, Willis M, Bennett J C, Robinson K A, Paudel K, Post D A and Marvanek S (2009). River modelling for Tasmania. Volume 1: the Arthur-Inglis-Cam region. *A report to the Australian Government from the CSIRO Tasmania Sustainable Yields Project, CSIRO Water for a Healthy Country Flagship, Australia*

3.2.3 Using effective rain to estimate stream discharge

Effective rain as used in this report is defined as monthly rain less monthly evapotranspiration, which is then applied to the catchment areas to estimate discharge as summarised in Table 6. Ten percent of effective rain is also assumed to infiltrate to groundwater[7].

On this basis, the mean annual discharges of West and East Creeks to Nelson Bay River are about 1,650ML and 1,400ML respectively, and 50 – 390ML to West Creek, depending on drain catchment area.

Table 6. Estimates of stream discharge volumes for West and East Creeks, and a diversion drain, using effective rain (rain less ET)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual
Rainfalll (mm) Temma													
Mean	57	58	74	106	135	152	166	152	123	100	85	81	**1300**
Evapotranspiration (ET; mm) Smithton Airport for the year 2010													
	154	127	105	63	44	29	27	44	64	91	109	131	**988**
Effective rain (mean rain less ET)*													
	-97	-69	-31	43	91	123	139	108	59	9	-24	-50	**572**
Mean discharge (ML), West Creek at Nelson Bay River**													
	0	0	0	124	262	354	400	311	170	26	0	0	**1650**
Mean discharge (ML), East Creek at Nelson Bay River**													
	0	0	0	104	221	299	338	262	143	22	0	0	**1390**
Mean discharge (ML), Diversion drain into West Creek***													
Catchment 10ha	0	0	0	4	8	11	13	10	5	1	0	0	**50**
Catchment 20ha	0	0	0	8	16	22	25	19	11	2	0	0	**100**
Catchment 50ha	0	0	0	19	41	55	63	49	27	4	0	0	**260**
Catchment 75ha	0	0	0	29	61	83	94	73	40	6	0	0	**390**

* Annual total is sum of all positive monthly effective rain
** Assumes 10% orf effective rain infiltated to the water table
*** Assumes no extraction for process water from storage dams in catchment

3.3 PRELIMINARY ESTIMATES OF GROUNDWATER DISCHARGE TO OPEN PITS AT THE NELSON BAY RIVER MINE

Apart from preliminary hydraulic conductivities (Table 2) estimated from the May 2011 groundwater sampling event, no aquifer properties are known for the groundwater system at and near the Nelson Bay Rive mine. Accordingly, estimates of inflow to open pits are unavoidably approximate and are based on a range of simplifying assumptions. At this stage of planning, the inflows summarised in Table 7 are intended to be broadly indicative only, and should not be used for detailed mine design without further hydrogeological site investigations.

The estimates were made using the Theis equation, an analytical solution (ie non-spatial) whereby the pit was assumed to be a circular feature of approximate dimensions to the proposed pit. The extent and depth of draw-down in the solution was assigned to the proposed pit dimensions. The solution assumed the following:

- all groundwater inflow was via lateral flow rather than upward flow,
- the circular dimension adequately approximates the proposed pit,
- and aquifer parameters used are reasonable approximations of the regional aquifer.

[7] There are many approaches to estimating groundwater recharge based on rainfall, catchment area, water chemistry and land use. See, for example, Cook, P., Staffacher, M., Therrien, T., Halihan, R., Richardson, P., Williams, P. and Bradford, A. (2001). Groundwater recharge and discharge in a saline urban catchment; Wagga Wagga, New South Wales. *CSIRO Land and Water Technical report 39/01;* Cromer, W. C. (2003). The geology and groundwater resources of Nine Mile Beach, eastern Tasmania. *Tasmanian Geological Survey Record 2003/07. Mineral Resources Tasmania;* Hocking, *et al.* (2010). South-eastern Flinders Island groundwater study. *Unpublished report for Flinders Island Council;* Zhang L, Dawes WR, Walker GR. (2001). The response of mean annual evapotranspiration to vegetation changes at catchment scale. *Water Resources Research*, 37:701-708

Calculated inflow volumes are made based upon long-term average rates of groundwater inflow (eg. non-temporal) and should be considered as the approximate long-term average groundwater inflow into the proposed pits. Initial groundwater inflow volumes into the pit are likely to exceed the estimated long-term average described in this report.

Table 7. Estimates of groundwater inflow to the Main and DSO pits at the Nelson Bay River Mine, assuming two values of hydraulic conductivity

	Approximate steady state	
	Inflow (l/s)	**Inflow (ML/year)**
Main pit (Hy = 0.1)	25	800 +/-50%
Main pit (Hy = 0.05)	14	400 +/-50%
DSO pit (Hy = 0.1)	8	300 +/-50%
DSO pit (Hy = 0.05)	4	100 +/-50%

Notes
1. Hy = permeability (hydraulic conductivity)
2. Theis equation used to calculate inflow
3. The uncertainty in the estimated inflows arises because
   aquifer permeability (hydraulic conductivity) is not known
   aquifer storativity is not known
   groundwater gradient (local and regional) is not known
   pit orientation relative ot groundwater flow lines has not been considered
   catchment recharge has not been considered

3.4 EFFECT OF MINING ON WET HEATHLAND GROUNDWATER CONDITIONS

3.4.1 General comments

Dewatering the Main Pit, and to a lesser extent the shallower DSO Pit, will lower ("drawdown") the water table in their vicinity, and if pumping is continued for a sufficiently long period, a near steady state condition will emerge where the lowering of the water table will cease. If pumping is stopped, the water table will rise (Attachment 1). On the cessation of mining, both pits wil therefore eventually flood naturally.

Drawdown is greatest at the pumped bore or pit, and it decreases radially away from it.

The area of influence of a pumped bore or pit is contained within the radial distance to the point beyond which groundwater levels are unaffected by pumping.

Estimates for area of influence (Table 8) depend on aquifer hydraulic conductivity and storativity, and the final drawdown in the pit or bore. All parameters are assumptions at the current stage of mine operations, and the estimates in Table 8 carry similar qualifications to those in Table 5.

3.4.2 Effect on threatened flora species

Groundwater dependent and groundwater independent ecosystems
Floral species which grow in groundwater discharge areas (eg rivers, creek beds, swamps, wetlands) rely on surface water and upward groundwater flow (Figure 4[8]). They are

[8] Figure 4 also illustrates the field technique (pairs of piezometers at different depths) for determining whether a location is a groundwater recharge or discharge area.

groundwater dependent and are part of the groundwater dependent ecosystem (GDE) in that area. Conversely, floral species in groundwater recharge areas (such as the wet heathlands west of the proposed mine) are groundwater independent, since all their water requirements are provided by rain.

Table 8. Estimates of groundwater areas of influence for near steady state dewatering of the Main and DSO pits

	Approximate steady state	
	Inflow (l/s)	**Radius (m) of influence**
Main pit (Hy = 0.1)	25	1200 +/-20%
Main pit (Hy = 0.05)	14	800 +/-20%
DSO pit (Hy = 0.1)	8	800 +/-20%
DSO pit (Hy = 0.05)	4	350 +/-20%

Notes
1. Hy = permeability (hydraulic conductivity)
2. Theis equation used to calculate radius of influence
3. The uncertainty in the estimated radii arises because
   aquifer permeability (hydraulic conductivity) is not known
   aquifer storativity is not known
   catchment recharge has not been considered

Groundwater conditions in wet heathland west of the mine site

An overlay of the distribution of heathland[9] on the surface drainage system in the area west of West Creek shows the habitat to be almost wholly located on a broad, gently-sloping interfluve in a groundwater recharge area (Figure 4) ie groundwater beneath the heathland flows away from the heathland, not towards it, and groundwater therefore makes no contribution to the soil water of the heathland.

Localised parts of the heathland – mostly near the heads of minor drainage lines leading to West and Sardine Creeks – are inferred to be groundwater discharge areas.

Dewatering of the pits during mining will lead to a drawdown of the water table in areas surrounding the pits. The effect diminishes with increasing distance from the pits. Depending on the period and extent of dewatering the area of influence of the pit drawdowns may extend beneath the margins of the wet heathland west of West Creek.

However, as stated, the heathland is in a groundwater recharge area, not a discharge area, and its soil water is therefore not dependent on the underlying water table. The heathland plants are shallow rooted species reliant on soil water from infiltrating rainfall, not from the underlying water table.

There is therefore no significant likelihood of the heathland soil water, and hence the ecosystems dependent on it, including threatened orchid species[10], being affected by the dewatering of the mine pits.

[9] See Figure 2 of *Flora and Fauna Habitat Assessment: Nelson River – Shree Minerals Mine & Infrastructure Proposal*. Unpublished report for Shree Minerals by North Barker Ecosystem Services, 22 March 2001.

[10] Mine dewatering is expected to have no impact on soil water conditions at and in the vicinity of the recorded location for the Pretty Leek Orchid (*Prasophyllum pulchellum*) because the location is not only in a groundwater recharge area but is also outside the estimated area of influence of pumping.

ATTACHMENT 1
(3 pages)
Groundwater principles

1.1 Origin of groundwater

All earth's water was formed deep underground by magmatic processes, and has over aeons been released at the surface and on ocean floors by volcanism. The mechanism continues today. With the exception of this 'new' water, all groundwater is derived from that part of precipitation which, after surface runoff and evaporation, infiltrates the soil. Some of the infiltrating water is transpired by plants, some is drawn upward by capillary action and evaporated, and some remains indefinitely in microscopic voids in the soil profile. During and after continuous and wetting rain, the remainder infiltrates downwards, intermittently and successively saturating the material through which it passes, until the water reaches the zone of saturation. Here, the soil or rock voids (openings) are completely filled with water. The water is then called groundwater, and the upper surface of the zone of saturation is known as the water table. The water table is usually a subdued replica of the land surface, being almost flat under gently undulating ground and deeper and sloping under hills.

The proportion of rain infiltrating into the soil is very variable, ranging from a few percent on steep, rocky slopes, to perhaps 50% or more in sandy or gravelly areas with little runoff. The proportion also changes seasonally, and infiltration would be expected to be a maximum when evaporation is least – at night in winter. Of the water which enters the soil, only a fraction avoids transpiration or retention in soil voids, and infiltrates to the water table.

Groundwater is therefore a part of the general hydrological cycle, and is directly related to the surface movement of water.

1.2 Unconfined and confined aquifers

An aquifer is a body of rock, or unconsolidated material such as sand, capable of supplying useful amounts of groundwater. An aquifer has two purposes: it stores, and transmits, groundwater. The relative importance of each function is determined by the nature of each aquifer. Some aquifers (eg hard sandstone) may store only a small amount of water in a network of thin fractures, but might transmit it freely, and remain reliable suppliers, if the fractures are sufficiently interconnected. Other materials like fine-grained and porous clays may contain larger amounts of water, but yield only small amounts because the water is not transmitted easily through their microscopic voids.

Aquifers may be unconfined, confined or semi-confined. An unconfined or water table aquifer exists in unconsolidated sediments or hard, fractured rock whenever the water table is in contact with air at atmospheric pressure. Unconfined aquifers therefore receive recharge from infiltrating rain over their full areal extent. Groundwater in a bore tapping an unconfined aquifer is encountered at the level of the water table. A bore drilled into an unconfined fractured rock aquifer may remain dry to depths below the water table if no water-bearing fractures are intersected[11], but once they are, the water will rise to the level of the water table. Since fractured rock aquifers are largely solid, dry rock separated by a network of fractures, it is possible for two bores side by side to yield different amounts of water, or either or both might remain dry.

A confined aquifer is a saturated, permeable zone bounded above and below by relatively impermeable materials (rock or soil). The zone therefore cannot receive recharge by directly infiltrating rain, but must get it from a recharge area elsewhere, where the permeable zone is exposed at the land surface, and where at least local unconfined conditions exist. The infiltrating groundwater in the zone of recharge moves crossgradient or downgradient beneath the confining impermeable layer. The water in confined zones of aquifers is therefore not in contact with the atmosphere, and is at a pressure greater than atmospheric. Water in bores tapping confined aquifers rises up the bore under pressure, and may overflow at the land surface. If the water in the bore rises above the land surface (so that groundwater flows without the need for a pump), the groundwater (and the bore) are said to be artesian. If the groundwater rises but not sufficiently for the bore to flow, the groundwater is sub-artesian.

A semi-confined aquifer receives vertical groundwater leakage from a higher aquifer down via a semi-permeable (rather than impermeable zone) zone separating them.

It is possible for an aquifer to be unconfined in one part of it, confined in another, and semi-confined elsewhere. The zone of confinement or semi-confinement may be relatively small, so that locally the

[11] At this local scale, groundwater conditions are confined.

aquifer behaves in a confined manner, but on a broader scale, unconfined conditions dominate. An example is a fractured hard rock aquifer where water is contained only within joints and similar defects which extend and are open to the land surface, separated by impermeable rock where no water is present. The water in the joints is unconfined. Drilling through the rock produces no water, which is only struck (and which rises to the level of the water table) when a water bearing fracture is intersected.

1.3 Storage capabilities of fractured rock aquifers

Groundwater in fractured rock aquifers is stored in fractures within the rock mass. Usually, the volume of fractures as a proportion of the rock mass is low, and commonly less than a few percent.

These aquifers therefore often have low storage capabilities, in comparison to unconsolidated aquifers like coastal sands. In these materials, the water is stored in voids between the sand grains, and the voids are interconnected (ie the aquifer is intergranular). The voids may constitute from 25% to 35% of the volume of sand (ie the porosity, θ, of the sand is 25% to 35%, or 0.25 to 0.35 expressed as a fraction). Each cubic metre of saturated sand below the water table therefore contains 250L to 350L of groundwater.

1.4 Primary and secondary porosity

The voids between sand grains in a coastal sand body, or the vesicles in otherwise hard basalt, for example, constitute primary porosity, because they were formed at the same time as the sand was deposited, or the basalt flowed as lava. As the sand becomes progressively cemented and consolidated in the process of becoming hard rock, the primary porosity is reduced. Most hard rocks have very little remaining primary porosity. However, if the hard rock becomes fractured and otherwise jointed, the fractures constitute secondary porosity.

1.5 Groundwater gradient

Groundwater is rarely stationary. It moves in response to gravity, and hydrostatic and lithostatic pressures, from recharge areas to discharge zones. Discharge occurs wherever the water table intersects the land surface in springs, swamps, rivers and the sea, provided the water table slopes towards the feature. If the water table is lower than the feature, water may flow from the spring or river to the groundwater body. The slope of the water table is called the water table gradient[12], which determines the direction and rate at which groundwater moves. The greater the gradient, the more rapid the flow. Groundwater usually flows in the direction of steepest gradient.

1.6 Aquifer permeability and transmissivity

Permeability (symbol K) is a measure of how readily an aquifer transmits water, and is defined as the rate at which groundwater will flow from a unit area (eg one square metre) of aquifer under a unit gradient (ie the gradient is 1). It is expressed as cubic metres per day per square metre ($m^3/day/m^2$, which reduces to m/day).

Permeabilities of fractured rock aquifers are a function of the intensity of fracturing, their openness, and the degree to which they interconnect. Since these features are often very variable, permeability also varies widely. Typical ranges for fractured, hard rock might be 0.01 – 100m/day. Transmissivity (T) is defined as the product of permeability and saturated aquifer thickness, and is therefore the rate at which groundwater will flow from a vertical, one-metre wide strip of the aquifer under a unit hydraulic gradient.

1.7 Volume of groundwater flow

The groundwater flow through a unit area (eg one square metre) of an aquifer is determined by the aquifer permeability and the water table gradient, and is calculated from Darcy's Law: Flow = permeability x gradient.

[12] The gradient is usually expressed as the difference in elevation of the water table between two points, divided by the distance between them. For example, a fall of one metre in water table elevation over a horizontal distance of 50 metres is a gradient of 1:50 (ie 0.02, expressed as a fraction).

1.8 Rate of groundwater travel

The rate at which groundwater travels through an aquifer is determined by the aquifer permeability, the water table gradient, and the aquifer porosity (expressed as a fraction). Rate of flow = permeability x gradient / effective porosity[13].

1.9 Groundwater quality

Groundwater acquires soluble matter from the aquifer in which it is stored, and through which it moves. Generally, the longer the water remains in the aquifer, the more soluble constituents it acquires, and the poorer its quality. So, other things being equal, aquifers with relatively high permeability tend to have better quality water than low permeability aquifers. Also, other things being equal, better quality groundwater is found in aquifers in high rainfall areas, where groundwater recharges the aquifer more frequently, and aquifers are “flushed” more often.

In shallow unconfined aquifers, it is usual to find better quality groundwater near the water table where direct infiltration of rain has occurred. Quality typically decreases with depth.

A common measure of groundwater quality (‘salinity’) is its Total Dissolved Solids (TDS), expressed in milligrams per litre (mg/L; essentially the same as the older measure, parts per million, ppm). Typical TDS ranges of waters are:

	TDS (mg/L)
Tasmanian rain	<50
Tasmanian river water	<100
Drinking water starts to have ‘taste’	250 – 500
Generally accepted desirable upper limit for drinking water	1,000
Range of commercially available mineral waters	100 – 1,500
Groundwater in coastal sands	450 – 800
Sea water	34,000

[13] For example, if the aquifer permeability is $2m^3/day/m^2$, the gradient is 0.01 and the effective porosity is 0.1, the rate of flow would be 2 x 0.01 / 0.1 = 0.2m/day.