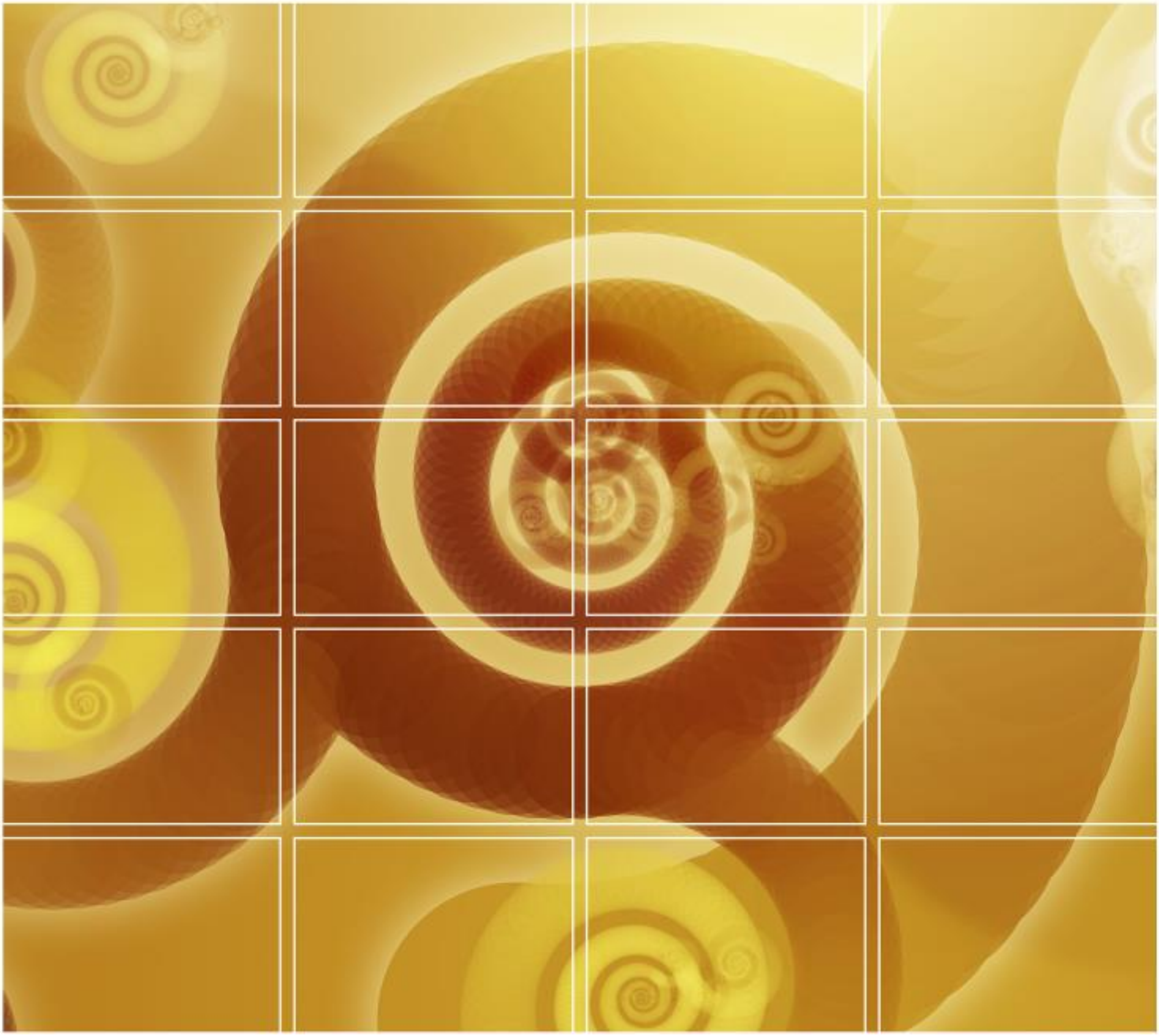
Annex F

Groundwater Assessment



Sancrox Quarry Expansion

Groundwater Assessment

Hanson Construction Materials Pty Ltd

August 2019

0418291_Final

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Sancrox Quarry Expansion

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Approved by:	*Thomas Buchan*
Position:	Project Manager
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Environmental Resources Management Australia Pty Ltd

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1 *INTRODUCTION*

1.1 *BACKGROUND*

Environmental Resources Management Australia Pty Ltd (ERM) was engaged by Hanson Construction Materials Pty Ltd (Hanson) to conduct a Groundwater Assessment to inform the Environmental Impact Assessment (EIA) for the proposed Sancrox Quarry Expansion Project (the Project). The Project is a State Significant Development (SSD #7293) and therefore the planning approvals process is regulated under the *Environmental Planning and Assessment Act 1979* (the EP&A Act), which requires Department of Planning and Environment (DP&E) approval for development consent, supported by an Environmental Impact Statement (EIS).

The Project will extend the life of Sancrox Quarry (the quarry site) by expanding the approved extraction boundary and increasing approved extraction limits. The Project proposes to increase the current approved annual maximum extraction limit from 455, 000 tonnes per annum (tpa) to 750 000 tpa. The Project will involve an upgrade and relocation of the existing infrastructure area including the processing plant, offices, weighbridge and workshop. The Project also includes the construction of a new concrete batching plant, concrete recycling facility, asphalt production plant and pug mill on site.

Note that the groundwater modelling presented in this report was based on the original final pit extent as presented on *Figure 3.1*. Following completion of the groundwater modelling works, the pit design needed to be altered to prevent potential surface water inflow during a probable maximum flood event as identified through the Hydrology Assessment. The revised pit design was selected to avoid additional design work as well as mitigating visual impacts due to the retention of some forest, providing a visual screen from parts of the residential property to the west of the quarry.

As the revised pit design has a smaller footprint and volume than the original design, the groundwater modelling results presented in this report is seen as conservative. Note that all references to the final pit extent in this report refer to the "Original Final Pit Extent" shown on the figures (with the figures also showing the "Revised Final Pit Extent" for comparison purposes.

1.2 *OBJECTIVES AND SCOPE OF WORKS*

The objective of this Groundwater Assessment is to meet the requirements of the Secretary's Environmental Assessment Requirements (SEARs). Water related SEARs are outlined below:

Table 1.1 Groundwater Assessment Requirements

Item	SEARs	Where addressed
1	A detailed site water balance, including a description of site water demands, water disposal methods (inclusive of volume and frequency of any water discharges), water supply infrastructure and water storage structures	Hydrology Assessment
2	Identification of any licensing requirements or other approvals under the *Water Act 1912* and/or *Water Management Act 2000*	*Section 2* and Hydrology Assessment
3	Demonstration that water for the construction and operation of the development can be obtained from an appropriately authorised and reliable supply in accordance with the operating rules of any relevant Water Sharing Plan (WSP)	Hydrology Assessment
4	A description of the measures proposed to ensure the development can operate in accordance with the requirements of any relevant WSP or water source embargo	Hydrology Assessment
5	An assessment of any likely flooding impacts of the development; an assessment of the likely impacts on the quality and quantity of existing surface and groundwater resources, including a detailed assessment of proposed water discharge quantities and quality against receiving water quality and flow objectives	*Section 6* and Hydrology Assessment
6	An assessment of the likely impacts of the development on aquifers, watercourses, riparian land, water-related infrastructure, and other water users	*Section 6.1* and Hydrology Assessment
7	A detailed description of the proposed water management system (including sewage), water monitoring program and other measures to mitigate surface and groundwater impacts	*Section 6.2* and Hydrology Assessment

Of the 7 items outlined above, items 1, 3 and 4 relate predominantly to the surface water assessment given the dynamics of the quarry site and the Project and these SEARS are addressed in the Hydrology Assessment (ERM, 2018). In order to meet the objectives of the groundwater related aspects of items 2 and 5 through to 7 outlined above (and to provide input to the site water balance) ERM conducted the following scope of works:

- A desktop assessment to describe the environmental site setting, including a search for groundwater users (both registered groundwater bores and groundwater dependant ecosystems) using publically available database sources;

- A groundwater field program to undertake aquifer parameter testing and groundwater and surface water sampling to characterise the aquifer system underlying the Project site; and

- Groundwater modelling to evaluate groundwater inflow rates into the expanded quarry as well as potential groundwater drawdown proximal to the quarry and the potential magnitude of drawdown at identified groundwater users.

1.3 REPORT STRUCTURE

The report is organized as follows:

Section 2 – Regulatory Considerations outlines regulatory framework and describes the impact assessment requirements of the New South Wales (NSW) Aquifer Interference Policy.

Section 3 - Site Setting provides a description of the quarry site, the environmental setting as well as identified groundwater use within the vicinity of the quarry site.

Section 4 - Fieldwork Program outlines the field methodology and results of the fieldwork undertaken which included groundwater level gauging, pumping tests on available bores and water quality sampling.

Section 5 – Groundwater Flow Modelling describes the methodology and results of the groundwater flow modelling undertaken to assess the potential impact of the quarry expansion.

Section 6 – Assessment Outcomes and Monitoring Recommendations summarises the groundwater assessment that follows from the groundwater modelling and stipulates the recommended monitoring requirements for the Project.

Section 7 – References provides the list of references cited in this report.

2 *REGULATORY CONSIDERATONS*

2.1 *REGULATORY FRAMEWORK*

2.1.1 *Water Act 1912*

Section 10 of the *Water Act 1912* requires that:

(1) Any occupier of land whereon any work to which this Part extends (not being a joint water supply scheme) is constructed or used, or is proposed to be constructed or used, for the purpose of:

(a) water conservation, irrigation, water supply or drainage, or

(b) (Repealed)

(c) changing the course of a river

May apply to the Ministerial Corporation in the form prescribed for a licence to construct and use the said work, and to take and sue for the purposes specified in the application the water, if any, conserved or obtained thereby, and to dispose of such water for the use of occupiers of land for any purpose.

Implications for the Project

In addition to Section 10 of the *Water Act 1912* outline above, the NSW Aquifer Interference Policy (see *Section 2.2* of this report) specifies that a water licence is required irrespective of whether water is taken for consumptive use (i.e. for water supply purposes) or whether water is taken incidentally in the course of undertaking the activity. Aquifer interference activities taking water outside of Water Sharing Plan (WSP) areas require a license under the *Water Act 1912* and the water take estimation provided by the groundwater modelling (see *Section 5.3*) should be taken into consideration during the water licence application process. Hanson currently hold a Water Access Licence (WAL42524) for water supply works undertaken on site. The predicted water take of the quarry extension would be compared to the current licence allowance prior to submitting a request for a revised or new licence.

2.1.2 *Water Management Act 2000*

The *Water Management Act 2000* (WMA) was introduced to provide for a comprehensive singular piece of legislation to effectively manage and regulate access, and use of, the State's water resources. The objectives of the WMA include:

- to protect, enhance and restore water sources, their associated ecosystems, ecological processes and biological diversity and the water quality; and
- to recognise and foster the significant social and economic benefits to the state that result from the sustainable and efficient use of water.

The sections of the Act that pertain to groundwater related aspects of the Project are outlined below.

Activity Approvals

Section 91 of the WMA states the following in relation to activity approvals:

(1) There are two kinds of activity approvals, namely, controlled activity approvals and aquifer interference approvals.

(2) A controlled activity approval confers a right on its holder to carry out a specified controlled activity at a specified location in, on or under waterfront land.

(3) An aquifer interference approval confers a right on its holder to carry out one or more specified aquifer interference activities at a specified location, or in a specified area, in the course of carrying out specified activities.

Chapter 3 part 3 of the WMA requires that approval be granted for works that are classified as "controlled activities" within waterfront land (generally being land within 40m of a waterway). A controlled activity is defined as:

(a) the erection of a building or the carrying out of a work (within the meaning of the Environmental Planning and Assessment Act 1979), or

(b) the removal of material (whether or not extractive material) or vegetation from land, whether by way of excavation or otherwise, or

(c) the deposition of material (whether or not extractive material) on land, whether by way of landfill operations or otherwise, or

(d) the carrying out of any other activity that affects the quantity or flow of water in a water source.

Section 91E (1) of the WMA states:

A person:

(a) who carries out a controlled activity in, on or under waterfront land, and

(b) who does not hold a controlled activity approval for that activity, is guilty of an offence.

An aquifer interference activity means an activity involving any of the following:

(a) the penetration of an aquifer,

(b) the interference with water in an aquifer,

(c) the obstruction of the flow of water in an aquifer,

(d) the taking of water from an aquifer in the course of carrying out mining, or any other activity prescribed by the regulations,

(e) the disposal of water taken from an aquifer as referred to in paragraph (d).

Implications for the Project

Part 4 Division 4.1 Section 89 (J)(g) of the EP&A Act states that authorisations are not required should the Project be granted SSD approval, including:

- *a water use approval under section 89, a water management work approval under section 90 or an activity approval (other than an aquifer interference approval) under section 91 of the Water Management Act 2000.*

Therefore the Project is exempt under Section 89(J) of the EP&A Act for the need to obtain all water approvals, except for an aquifer interference approval. As the Project will involve the penetration of an aquifer and extraction of water from the aquifer through the dewatering effect of the quarry expansion, an aquifer interference approval will be required from the NSW Office of Water. Requirements of the NSW Aquifer Interference Policy are described further in *Section 2.2*.

Water Sharing Plans

The draft WSP for the Hastings Unregulated and Alluvial Water Sources 2016 under the Water Management Act 2000 includes proposed rules for protecting the environment, water extractions, managing licence holders' water accounts, and water trading in the plan area. The draft plan area comprises all streams and alluvial aquifers within the Hastings River Valley.

Since 1 July 2004 licensing and approvals under the WMA has been in effect in specific areas of NSW covered by operational WSPs. These areas cover most of the State's major regulated river systems. Currently, outside these areas, licensing provisions of the *Water Act 1912* are still in force.

Implications for the Project

The Project does not currently fall within a gazetted WSP area[1], therefore any access to groundwater would be applied for under the *Water Act 1912*.

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[1] http://www.water.nsw.gov.au/water-management/water-sharing/plans_commenced

2.2 *AQUIFER INTERFERENCE POLICY*

The NSW Aquifer Interference Policy (NSW DPI, 2012) describes the assessment process for protecting and managing potential impacts of aquifer interference activities on the water resources of NSW. The three key parts to the Policy include:

1. All water taken during the activity must be accounted for (and the project proponent must be able to appropriately licence this take where required);
2. The activity must address minimal impact considerations (as defined in the Policy) for impacts on water levels, water pressure and water quality; and
3. Planning measures are required in the event that actual impacts are greater than predicted, with planning measures including sufficient monitoring requirements.

These parts are described further below.

2.2.1 *Water Take - Licencing Requirements*

The Policy specifies that all water taken during the aquifer interference activity must be accounted for, and that a water licence is required irrespective of whether the water is taken for consumptive use (i.e. for water supply purposes) or whether water is taken incidentally in the course of undertaking the activity.

Implications for the Project

Incidental water take from an aquifer through quarrying below the pre-activity water table presents an aquifer interference activity (which includes consideration of water flow into a void as a result of evaporation). In line with the WMA, aquifer interference activities taking water outside of water sharing plan areas require a license under the *Water Act 1912*.

As part of this assessment, potential water take was accounted for by groundwater modelling, with the take estimation providing supporting information for the water licence requirements.

2.2.2 *Minimal Impact Considerations*

The assessment criteria that are specified within the Policy are called "minimal impact considerations" and include criteria for assessing potential impact on water table levels, water pressure levels (i.e. potentiometric levels) and water quality. Impacts on water-dependent assets should be considered including water supply bores, groundwater-dependent ecosystems and culturally significant sites that are dependent on groundwater.

The Policy distinguishes between so called "highly productive" and "less productive" groundwater resources, with highly productive groundwater resources requiring groundwater with total dissolved solids (TDS) concentrations of less than 1 500 mg/L and water supply works that can yield water at a rate greater than 5 L/sec. Based on the relatively elevated salinity of groundwater and the low permeability of the underlying aquifer system (see *Section 4.2.3* and *4.2.2* respectively), the groundwater resources underlying the site is classified as less productive.

The relevant assessment criteria for the Project are summarised in *Table 2.1*.

***Table 2.1 Minimal Impact Considerations for Aquifer Interference Activities*[1]**

Water Table	Water Pressure	Water Quality
1. Less than or equal to 10% cumulative variation in the water table, allowing for typical climatic "post-water sharing plan" variations, 40m from any: a) high priority groundwater dependant ecosystem; or b) high priority culturally significant site; c) listed in the schedule of the relevant water sharing plan. A maximum of a 2m decline cumulatively at any water supply network. 2. If more than 10% cumulative variation in cumulative variation in the water table, allowing for typical climatic "post-water sharing plan" variations, 40m from any: a) high priority groundwater dependant ecosystem; or b) high priority culturally significant site; listed in the schedule of the relevant water sharing plan if appropriate studies demonstrate to the Minister's satisfaction that the variation will not prevent the long term viability pf the dependant ecosystem or significant site. If more than a 2m decline cumulatively at any water supply work then make good provisions would apply	1. A cumulative pressure head decline of not more than a 2m decline, at any water supply work. 2. If the predicted pressure head decline is greater than requirement 1 above, then appropriate studies are required to demonstrate to the Minister's satisfaction that the decline will not present the long term viability of the affected water supply works unless make good provisions apply.	1. Any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40m from the activity. 2. If condition 1 is not met than appropriate studies will need to demonstrate to the Minister's satisfaction that the change in groundwater quality will not prevent the long term viability of the dependent ecosystem, significate site or affected water supply works.

[1]Minimum requirements for *Porous and Fractured Rock Water Resources - Less Productive Groundwater Resources* as per the NSW Aquifer Interference Policy (NSW DPI, 2012).

Implications for the Project

Based on the Policy specifications the minimal impact considerations summarised above form the basis of the groundwater assessment. The groundwater flow modelling was undertaken to assess potential impacts against these considerations.

2.2.3 Monitoring

Monitoring requirements will be specified to enable the monitoring of actual impacts compared to predicted impacts. Contingency plans can then be enacted in a timely manner if actual impacts are higher than predicted and these impacts are found to be significant.

Implications for the Project

Monitoring requirements in-line with the specifications outlined above will be developed for the Project.

2.3 CONSULTATION

The SEARs require consultation with relevant local, State and Commonwealth Government authorities. These agencies as relevant to the groundwater assessment are outlined in *Table 2.2*, along with the response received.

Table 2.2 Stakeholder Consultation

Relevant Stakeholder	Consultation Method	Response
Environment Protection Agency	Letter advising that the EIS process is underway and the assessment will address the SEARs. Request for additional comments made.	No further comments at this stage.
Department of Primary Industries (Office of Water)	Same as above.	No further comments at this stage.

3 *SITE SETTING*

3.1 *SITE DESCRIPTION*

The site is an operational hard rock quarry, located in Sancrox approximately 8 km to the west of Port Macquarie. The quarry has been owned and operated by Hanson since 1998. Hanson owns approximately 145 ha of land, of which approximately 12 ha has been in use for the extraction, processing and storage of aggregates. Infrastructure associated with the existing quarry includes the processing plant, offices, weighbridge and workshop.

The Study Area includes the existing quarry site, the area identified for the quarry expansion and a 2 km radius from the perimeter of the final pit to identify groundwater users that may be impacted by the proposed activity. The eastern portion of the Study Area has been disturbed by active quarrying activities while the west and northwest portions of the Study Area are largely undisturbed and predominantly covered with remnant woodland vegetation and some smaller sections of ground covering pasture. *Figure 3.1* shows the location of the existing quarry site in relation to the proposed final footprint of the quarry expansion.

3.2 *ENVIRONMENTAL SETTING*

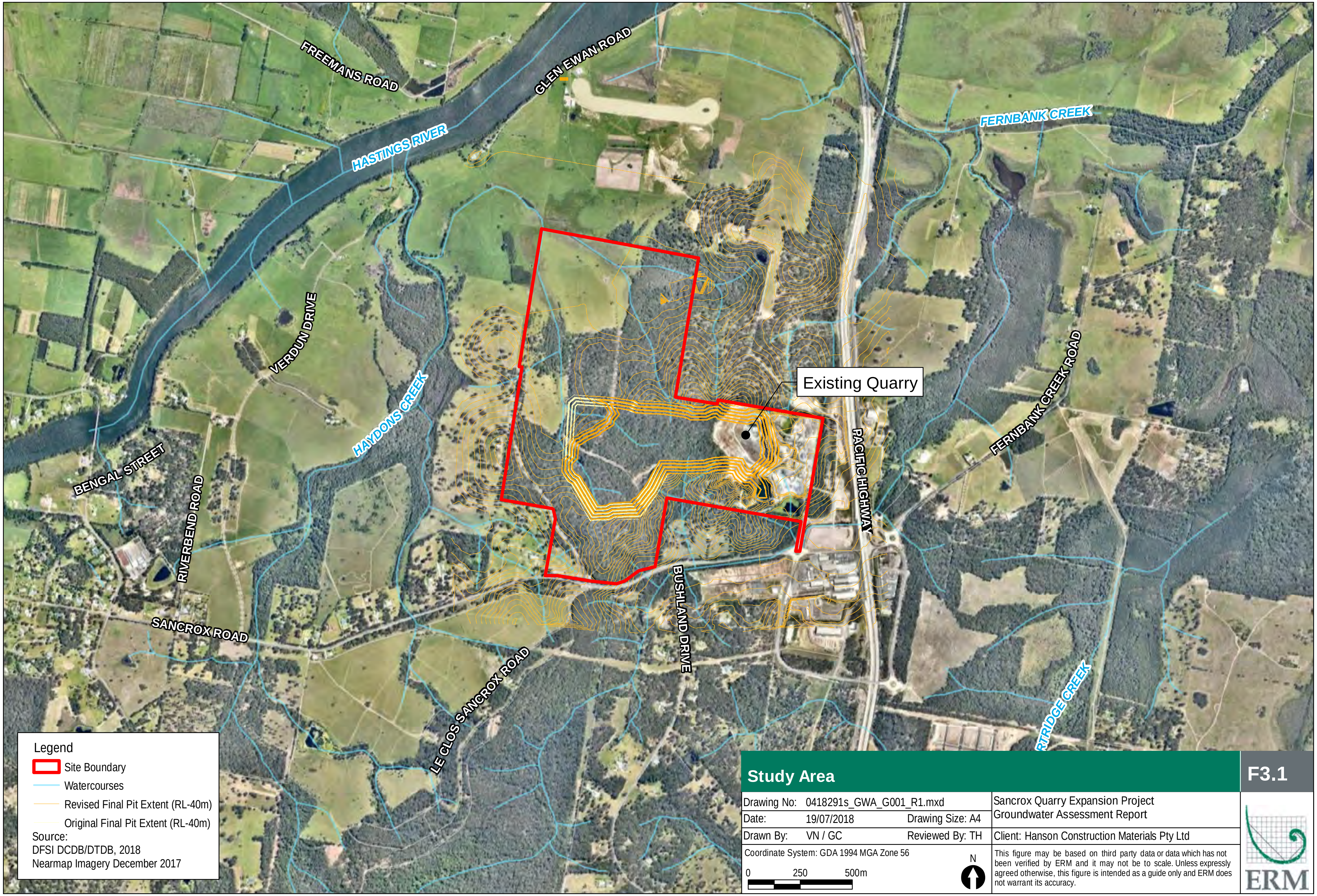
3.2.1 *Climate*

Long-term climate data is available from a Bureau of Meteorology (BoM) weather station located in Telegraph Point (Farrawells Road, 060031), approximately 11 km north of the site. The weather station has been operational since 1910 and has a weather record of over a 100 years. While the Port Macquarie Airport BoM weather station is located closer to the site (approximately 5 km east of the site) the Airport weather station has been in operation for 22 years and the Telegraph Point weather station is considered to have a more robust dataset reflective of long-term conditions. Note that the annual rainfall averages at both locations are similar, with 1,315 mm reported for the Telegraph Point station and 1,428 mm reported for the Port Macquarie Airport weather station.

The nearest BoM weather station with mean monthly evaporation data available was Yarras (Mount Seaview, 060085), approximately 44 km to the south west of the site. The mean annual evaporation rate reported for the Yarras weather station is 960 mm.

3.2.2 *Topography*

The topography surrounding the Study Area is characterised by flood plains and low lying hills up to approximately 60m Australian Height Datum (mAHD) which is the highest point of the Study Area. The eastern portion of the Study Area has been disturbed by active quarrying activities while, the west and northwest portions of the Study Area are largely undisturbed.



Source:
DFSI DCDB/DTDB, 2018
Nearmap Imagery December 2017

Study Area

F3.1

Drawing No: 0418291s_GWA_G001_R1.mxd
Date: 19/07/2018 Drawing Size: A4
Drawn By: VN / GC Reviewed By: TH
Coordinate System: GDA 1994 MGA Zone 56

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Groundwater Assessment Report

Client: Hanson Construction Materials Pty Ltd

This figure may be based on third party data or data which has not been verified by ERM and it may not be to scale. Unless expressly agreed otherwise, this figure is intended as a guide only and ERM does not warrant its accuracy.

3.2.3 *Geology*

The regional geological map indicates that the Study Area is underlain by the Byabbara Beds of the Carboniferous Period. Regionally the Byabbara Beds consists of interbedded lithic sandstone, siltstone, tuff, shale and limestone. Towards the Hastings River, to the north and west of the Study Area, Quaternary age alluvial sediments consisting of sand, silt, mud and gravel overlie the Byabbara Beds (Brunker et al., 1970). The surface expression of the aforementioned geological units, as drawn from the regional geological map, is presented in *Figure 3.2*.

The sedimentary units comprising the Byabbara Beds have undergone a degree of metamorphosis. Drilling undertaken at the Study Area indicates that the geology comprises a sequence of meta-sediments dipping at 70 degrees to the north to north northeast. The meta-sediments are further considered to be weathered to a depth of approximately 10 to 30 metres (Hanson, 2016).

The existing pit has a defined fault line trending southwest to northeast, and the approximate location of the fault line (Hanson, 2016) is presented in *Figure 3.2* along with the regional surface geology as drawn from Brunker et al (1970). The Byabbara Beds geology has been inferred to comprise conglomerate, sandstone and siltstone to the north of the fault line and predominantly shale to the south of the fault line. Drilling completed at the Study Area further suggests that there are fault zones at depth as indicated by intervals of breccia identified in the rock core (Hanson, 2016). Borelogs for monitoring bores SA1501 – SA1503 are presented in *Annex A*.

3.2.4 *Hydrogeology*

The meta-sediments of the Byabbara Beds underlying the Study Area are considered to present a fractured rock aquifer, with groundwater storage and flow largely controlled by secondary porosity. While at a regional scale the groundwater flow direction would be expected to be similar to the slope of the topography. Influence on local groundwater flow directions would include the orientation and connectivity of the fracture network, as well as the influence of the existing open pit on hydrodynamics. Quarrying in the existing open pit has proceeded to below the groundwater level in the surrounding bedrock (see *Section 4.2.1)* and groundwater flow in the immediate vicinity of the quarry workings would be towards the pit. According to site management, no active dewatering takes place at the pit with groundwater seepage into the pit being negligible, indicating that the permeability of the meta-sediments is low.

The Quaternary alluvial sediments overlying the Byabbara Beds sediments to the north and west of the Study Area (in proximity to the Hastings River) present an unconsolidated aquifer where water storage and flow is governed by the primary porosity of the sediments.

The alluvial sediments would be expected to be in direct hydraulic connection with surface water features such as the Hastings River, with the direction of water flow controlled by relative water levels in the surface water features and surrounding alluvial sediments. When compared the Quaternary alluvial sediments would be expected to present a significantly more productive aquifer than the consolidated meta-sediments.

Legend

🟥 Site Boundary

— Revised Final Pit Extent (RL -40m)

— Original Final Pit Extent (RL -40m)

- - - Inferred Fault Line

🟨 Qa - Quaternary Alluvial Sediments (Sand, Silt, Mud, Gravel)

▨ Cb - Byabbara Beds (Lithic Sandstone, Siltstone, Tuff, Shale, Limestone)

Sources:

- Geology map reference: Brunker R.L., Offenberg A.C. and Cameron R.G., 1970: Hastings 1:250 000 Geological Sheet SH/56-14, 1st edition, Geological Survey of New South Wales, Sydney.
- Reference for inferred fault line: Hanson, 2016: Geology Report - Geology, Drill Results and Resources 2015. Sancrox Quarry, NSW.

Regional Surface Geology

F 3.2

Drawing No: 0418291s_GWA_C002_R0.cdr
Date: 19/07/2018 Drawing size: A4
Drawn by: GC Reviewed by: WG

Drawing Not to Scale

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3.2.5 *Hydrology*

The existing quarry and the proposed expansion area fall within the Hastings River catchment, with the Hastings River flowing towards the coast in a north-easterly direction to the north of the quarry site. The Hastings River is located approximately 1.3 km to the northeast of the perimeter of the final pit at its closest point.

Haydon's Creek presents the closest waterway to the proposed expansion area, located approximately 650 m to the west of the perimeter of the final pit at its closest point. Haydon's Creek drains in a northerly direction and forms a tributary to the Hastings River.

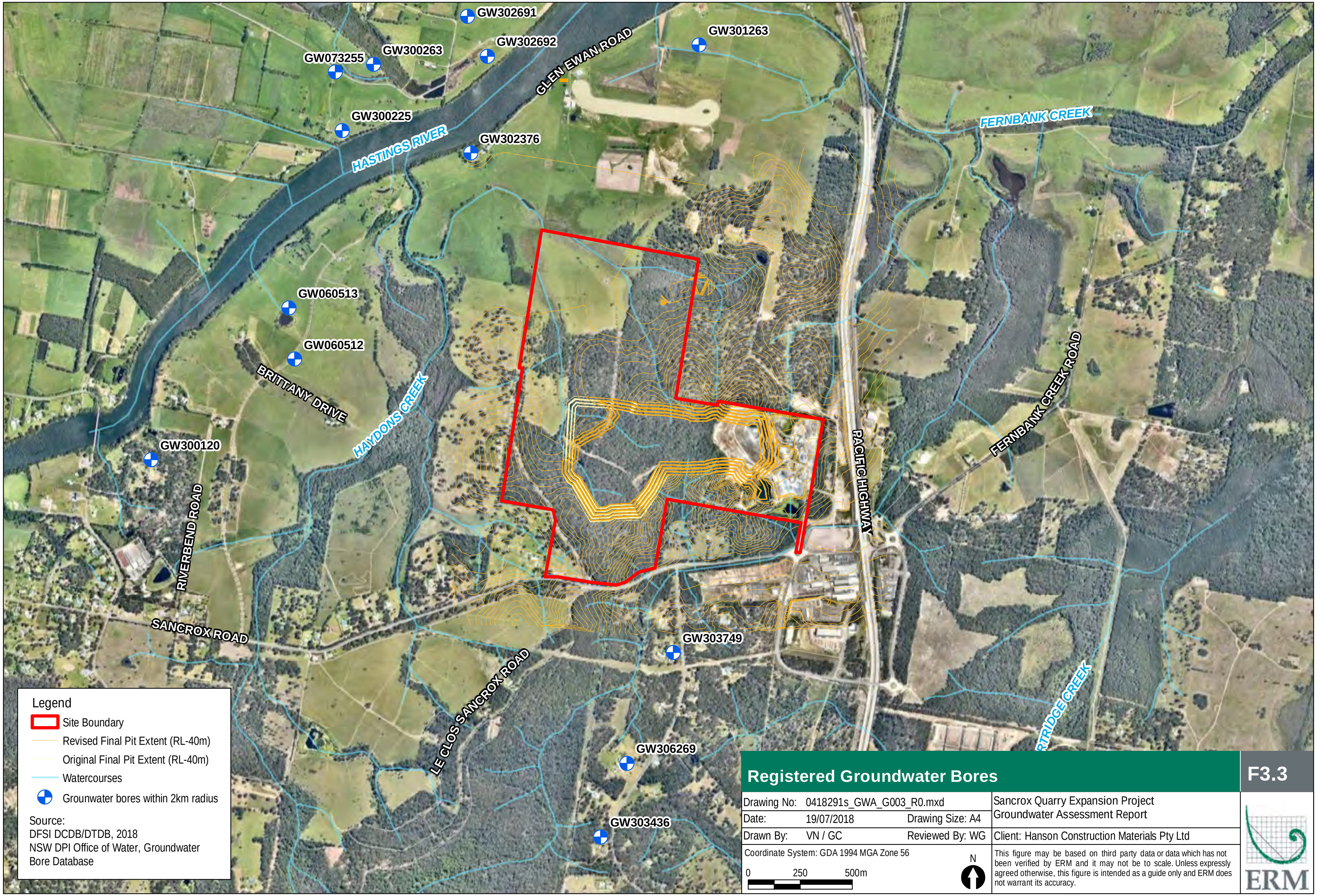
A more detailed description of the site hydrology and catchment characteristics is provided in the Hydrology Assessment (ERM, 2018).

3.3 *GROUNDWATER USE*

3.3.1 *Groundwater Bores*

A desktop search was conducted to identify existing groundwater users through the NSW Department of Primary Industries (DPI) Office of Water Groundwater Bore Database (NSW DPI, 2018). The search area included a 2 km radius from the perimeter of the final pit.

A total of 13 registered groundwater bores were identified as summarised in *Table 3.1*. The locations of the bores relative to the quarry are presented in *Figure 3.3*.



Legend

🟥	Site Boundary
—	Revised Final Pit Extent (RL-40m)
—	Original Final Pit Extent (RL-40m)
—	Watercourses
●	Grounwater bores within 2km radius

Source:
DFSI DCDB/DTDB, 2018
NSW DPI Office of Water, Groundwater
Bore Database

Registered Groundwater Bores

F3.3

Drawing No: 0418291s_GWA_G003_R0.mxd
Date: 19/07/2018
Drawing Size: A4
Drawn By: VN / GC
Reviewed By: WG
Coordinate System: GDA 1994 MGA Zone 56

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ERM

Table 3.1 *Groundwater Bores Identified within 2km radius of final pit perimeter*

Bore ID	Registered Use	Distance and Direction		Depth (m)
		Distance (km)	Direction	
GW060512	Stock Watering/Domestic	1.32	WNW	25
GW060513	Stock Watering/Domestic	1.42	WNW	4.6
GW073255	Stock Watering	1.94	NW	15.5
GW300120	Domestic	1.97	W	38
GW300225	Stock Watering/Domestic	1.7	NW	20
GW300263	Stock Watering	1.87	NW	15.5
GW301263	Stock Watering (potential Domestic)	1.72	N	10
GW302376	Stock Watering/Domestic	1.27	NW	23
GW302691	Stock Watering	1.92	NNW	-
GW302692	Stock Watering	1.7	S	-
GW303436	Domestic	1.5	S	40.5
GW303749	Stock Watering/Domestic	0.6	S	34.5
GW306269	Domestic	1.1	S	30

3.3.2 *Groundwater Dependent Ecosystems*

The Australian groundwater dependent ecosystems (GDE) toolbox (National Water Commission, 2011) identifies the following three types of GDEs:

- Type 1 – Aquifer and Cave Ecosystems (inhabited by subterranean fauna including troglofauna and stygofauna).
- Type 2 – Ecosystems Dependent on the Surface Expression of Groundwater (such as wetlands and creeks/rivers fed by baseflow).
- Type 3 – Ecosystems Dependent on the Subsurface Expression of Groundwater (with groundwater typically encountered within the rooting zone).

The BoM Atlas of GDEs (BoM, 2018) was used for the identification of groundwater environmental receptors in the Study Area. The Atlas was used to search a 2 km radius from the perimeter of the final pit and the following GDEs were identified:

- Type 2 – Ecosystems: The Hastings River, located approximately 1.3 km to the northwest of the perimeter of the final pit (at its closest distance from the pit).

- Type 3 – Ecosystems: Multiple ecosystems with high to moderate GDEs potential including:

  - Several areas of Paperbark ecosystems with the closest located approximately 500 m to the west of the outer perimeter of the final pit (and adjacent to Haydon's Creek). Additional occurrences of Paperbark ecosystems have been mapped by BoM approximately 800 m to the north east, 900 m to the east north east and 1,700 m east south east of the perimeter of the final pit.

  - Low Relief Coastal Blackbutt ecosystems located approximately 1,100 m to the east and 1,300 m to the south east on the perimeter of the final pit.

No Type 1 ecosystems were identified through the BoM GDE Atlas.

While the Project does not currently fall within a gazetted WSP area, a *Draft Water Sharing Plan for the Hastings Unregulated and Alluvial Water Sources 2016* (NSW Government, 2016) has been developed which includes a *High priority Groundwater-Dependent Ecosystem Map* (GDE011_Version 1). This map was reviewed as part of the groundwater assessment and no high priority GDEs were identified within a 2km radius of the perimeter of the final pit. Note that groundwater dependent culturally significant sites were under investigation at the time of the development of the draft WSP and the locations of any such sites had not been identified.

4 *FIELDWORK PROGRAM*

4.1 *FIELD METHODOLOGY*

4.1.1 *Pre-Pumping Test Groundwater Level Gauging*

ERM undertook manual water level gauging of static water levels (SWLs) with a dip meter prior to the pumping tests commencing on 28 November 2017. In addition to the water level data gathered through manual gauging, Hanson deployed pressure transducers (automated level loggers) in three monitoring bores (SA1501 – SA1503) for the collection of long-term baseline groundwater levels. The locations of the monitoring bores are presented in *Figure 4.1*.

Based on data files made available by Hanson, the level loggers were deployed from:

- October 2015 to September 2017 for SA1501.
- December 2016 to September 2017 for SA1502.
- December 2016 to July 2017 for SA1503.

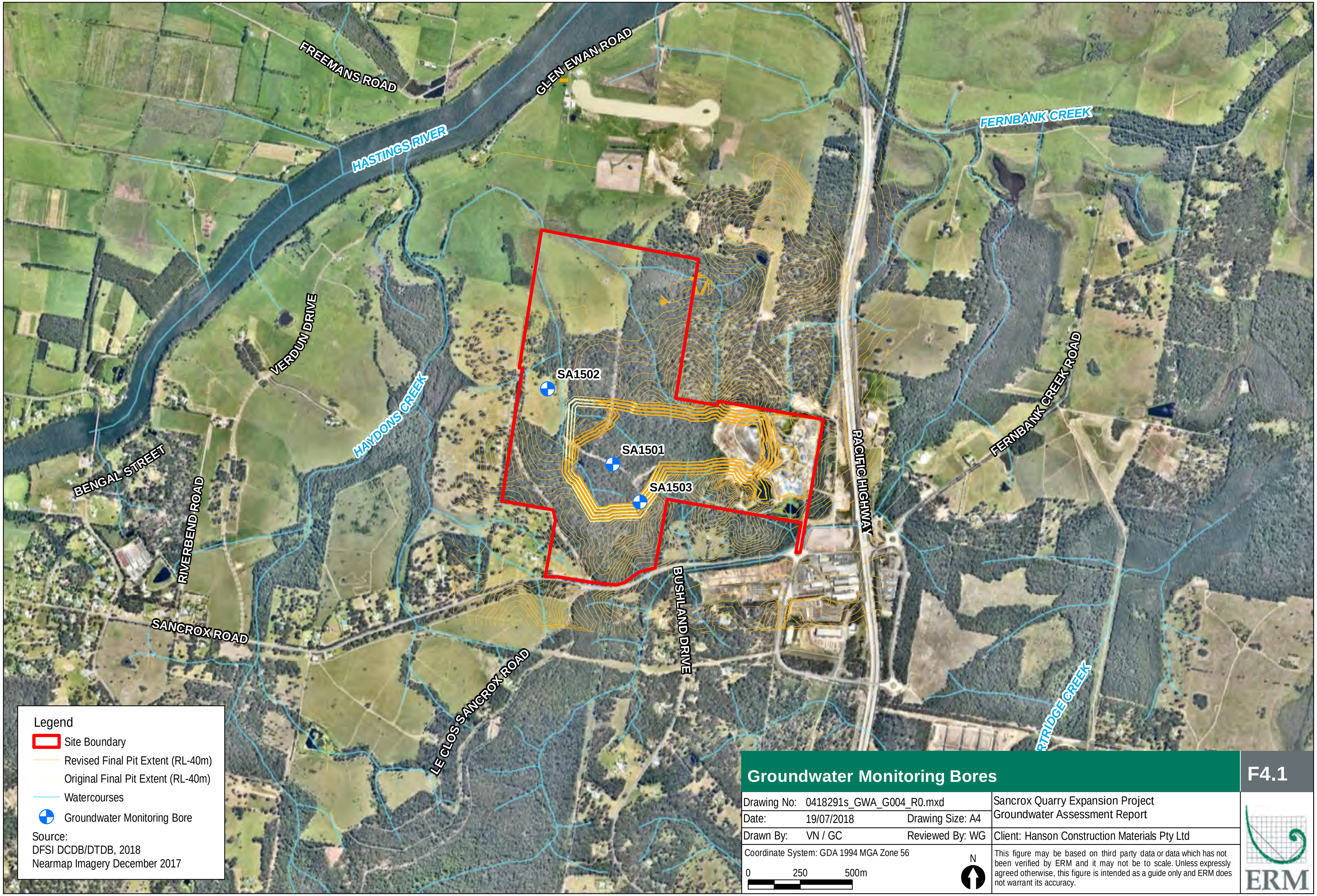
At all three locations, the level loggers were programmed to collect water level measurements at 12 hour intervals.

Water level data collected manually and through the level loggers are summarised in *Section 4.2.1.*

4.1.2 *Pumping Tests*

Two short-term constant discharge pumping tests and associated recovery tests were undertaken at the site to estimate aquifer hydraulic properties. Of the three available monitoring bores, SA1502 and SA1503 were originally earmarked for test pumping. In the field, monitoring bore SA1503 had a blockage at approximately 6 metres below ground level (m bgl) that prevented the pump from being lowered to below the standing water level. For this reason, pumping tests were undertaken on bores SA1501 and SA1502.

Prior to the first constant discharge pumping test commencing, a preliminary pumping test was undertaken at SA1502 on 28 November 2017 as an equipment test and to assess an appropriate pumping rate for the constant discharge test. The pumping equipment included a Grundfos MP1 electrical submersible pump suitable for the 50 mm diameter monitoring bore casing, a variable frequency drive to control pumping rates and a mobile generator to power the pump.



Legend
- 🟥 Site Boundary
- Revised Final Pit Extent (RL-40m)
- Original Final Pit Extent (RL-40m)
- Watercourses
- ● Groundwater Monitoring Bore

Source:
DFSI DCDB/DTDB, 2018
Nearmap Imagery December 2017

Groundwater Monitoring Bores

F4.1

Drawing No: 0418291s_GWA_G004_R0.mxd		Sancrox Quarry Expansion Project Groundwater Assessment Report
Date: 19/07/2018	Drawing Size: A4	
Drawn By: VN / GC	Reviewed By: WG	Client: Hanson Construction Materials Pty Ltd

Coordinate System: GDA 1994 MGA Zone 56

ERM

The constant discharge pumping test at SA1502 was undertaken on 28 November 2017 and the constant discharge test at SA1501 on 29 November 2017. Both constant discharge tests were run for a period of 3 hours, at pumping rates of 1 L/minute and 3 L/minute at SA1502 and SA1501 respectively. At this point in the pumping tests, respective groundwater level drawdowns of 28.02 and 4.89 m had been achieved in SA1502 and SA1501. To maximise drawdown in the aquifer for the recovery tests, the pumping rate for the SA1502 test was increased to approximately 3 L /min for a duration of 15 minutes (achieving a total drawdown of 43.73 m), while the pumping rate for the SA1501 test was increased to 6 L/min for a further 2 hours (achieving a total drawdown of 22.49 m). From the total drawdown depths, the time period for 90% recovery to pre-test static water levels were approximately 30 minutes for the test conducted at SA1501 and 4 hours 20 minutes for the test conducted at SA1502.

Groundwater level responses during pumping and during recovery following the cessation of pumping were measured using down-hole absolute (i.e. non-vented) pressure transducers. In-Situ Level TROLL pressure transducers were pre-programmed to collect data at 30 second intervals and an In-Situ Baro TROLL was used to collect data for barometric pressure corrections. The barometric pressure correction completed post testing assumed 100% efficiency and instantaneous response (i.e. the full barometric pressure was subtracted from the water level pressure).

The Level TROLL pressure transducers were deployed in the pumping bores as well as observation bores. During the pumping of monitoring bore SA1501, SA1502 and SA1503 were utilised as observations bores and during the pumping of SA1502, SA1501 and SA1503 were utilised as observations bores. In addition, manual water level measurements were taken with a dip meter from the pumping bores for real time monitoring of water levels during the tests. Flow rates were measured periodically with a stopwatch, 0.5 L container and a graduated water bucket.

The pumping test data interpretation and results are presented in *Section 4.2.2.*

4.1.3 Groundwater Sampling

Monitoring bores SA1501 and SA1502 were sampled during the pumping tests, with samples taken once field parameters measured during pumping (which included pH, electrical conductivity [EC], oxidation reduction potential [ORP], dissolved oxygen [DO] and temperature) had stabilised.

Due to a blockage encountered in SA1503, this monitoring bore could not be sampled with the submersible pump and this specific bore was sampled with a single use disposable bailer. Due to purging limitations posed by the bailer method, the sample taken with the bailer effectively represents a grab sample.

In addition to the groundwater monitoring bores, surface water samples were taken from the two surface water holding ponds/dams on site, the in-pit sump, and a water seep located to the northeast of the existing aggregate processing and storage area. The surface water holding pond samples were taken from the western most dam in the south eastern corner of the site (sample ID: Holding Pond 1) and the eastern most dam in the south eastern corner of the site (sample ID: Holding Pond 2).

Stabilised field parameters and laboratory results of the groundwater and surface water sampling are presented in *Section 4.2.3*.

4.2 RESULTS

4.2.1 *Water Level Gauging*

The pre-pumping tests water levels gauged on 28 November 2017 are summarised in *Table 4.1* below.

Table 4.1 Pre-Pumping Test Groundwater Levels

Monitoring Bore	Date	Groundwater Level	
		m BTOC[1]	m BGL[2]
SA1501	28 / 11 / 2017	11.54	10.72
SA1502	28 / 11 / 2017	2.32	1.53
SA1503	28 / 11 / 2017	12.15	11.43

1 = metres below top of casing

2 = metres below ground level

Baseline water level data collected with the level loggers are summarised in *Table 4.2*. This table includes water elevation data relative to the AHD. The available groundwater level elevation data indicate a groundwater flow direction towards the northwest. While monitoring bores SA1501 - SA1503 are located in a near straight line (see *Figure 4.1*), which is not ideal for tri-angulating and inferring groundwater flow direction, the inferred groundwater flow direction does align with general expectations of regional groundwater flow which would be from elevated elevations towards the Hastings River.

Table 4.2 *Level Logger Baseline Groundwater Levels*

Monitoring Bore	Date Range	Groundwater Level					
		m BGL[1]			m AHD[2]		
		Min Depth	Max Depth	Av Depth	Min Depth	Max Depth	Av Depth
SA1501	10/2015 – 9/2017	9.69	10.67	10.52	12.81	11.83	11.98
SA1502	12/2016 – 9/2017	1.42	2.26	1.74	1.98	1.14	1.66
SA1503	12/2016 – 7/2017	0.39	12.11	9.69	32.61	20.89	23.31

1 = metres below top of casing

2 = metres Australian Height Datum (approximate values with an accuracy of ~1m).

Given that survey co-ordinates were not available for the monitoring bores, monitoring bore elevation levels were derived by plotting available GPS co-ordinates on to a high resolution 1 m contour topographic map and estimating elevation levels for the three monitoring bores. The GPS coordinates along with the estimated elevations levels are provided in *Table 4.3*.

Table 4.3 *GPS Coordinates and Estimated Elevations for Monitoring Bores*

Monitoring Bore	Coordinates[1]		
	East	South	Elevation (m AHD)[2]
SA1501	482014	6521966	22.5
SA1502	481703	6522327	3.4
SA1503	482145	6521786	33

1 = UTM 56J

2 = metres Australian Height Datum (approximate values with an accuracy of ~1m).

4.2.2 *Pumping Tests*

Data Interpretation

No pumping related water level changes were seen in observations bores during the pumping tests (with observations bores being located >>100m from a pumping well). The data interpretation was therefore focussed on deriving aquifer parameter estimates from water level changes in the pumping bores only. As pumping induced water level changes in observations bores are required to estimate aquifer storativity (S) values, the data interpretation focussed on deriving transmissivity (T) estimates based on the pumping test data. Hydraulic conductivity (K) values where then also estimated from the transmissivity values while factoring in the assumed aquifer thickness (b), with K = T/b.

Data collected during the pumping tests were interpreted utilising methods incorporated in the AQTESOLV Professional (version 4.50) software application. This included curve matching performed using type-curve methods on log-log plots as well as straight-line methods on semi-log plots of water level change over time.

As noted in *Section 3.2.3* the borelogs (showing geology encountered during drilling) are presented in *Annex A*. With measured water levels in the bores being well above the depth of the water bearing zones encountered during drilling (refer to the Form A particulars in *Annex B*), indications are that the interbedded meta-sediments of the Byabbara Beds present a confined aquifer system and confined aquifer methods were therefore utilised to interpret the pumping test data as described below. While the aquifer is fractured in nature with primary porosity expected to be limited due to the metamorphic nature of the meta-sediments, the aquifer was treated as an equivalent porous medium. This approach is typically adopted as industry standard, particularly for bores with long screens interesting multiple fractures.

For the pumping phase of the tests, the confined aquifer data interpretation methods applied included the straight line Cooper and Jacob method (Cooper & Jacob, 1946) and the Theis method (Theis, 1935) as extended by Hantush (1961) to allow for partially penetrating bores.

For the recovery stage of the tests, the residual drawdown data were interpreted using the Theis method for recovery data (Theis, 1935) and the straight line Cooper and Jacob method (Cooper, & Jacob, 1946) applied to the Agarwal transformation (Agarwal, 1980).

Bore construction details were drawn from the Form A particulars associated with the completion of the drilling work as presented in *Annex B*. The aquifer thickness values used for SA1501 and SA1502 (70 m and 36 m respectively) are based on the water bearing zones presented on the *Form A* documents. Note that monitoring bore SA1501 has two separate screen lengths intersecting two zones identified as water bearing, from 20 – 50 m bgl and 70 to 110 m below ground level. These were added together when specifying the aquifer thickness and screen length for the pumping test interpretation. The hydraulic conductivity anisotropy ratio (Kz/Kr) was set as 1, assuming that the folded nature of the meta-sediments would have negated the relatively higher horizontal conductivity that is typical of planar (unfolded) sedimentary units.

Pumping Test Results

The results of the pumping test data interpretation are summarised in *Table 4.4* below. The groundwater level displacement-time graphs with associated curve matching are provided in *Annex C*.

Table 4.4 *Pumping Test Data Interpretation Results*

Monitoring Bore	**Transmissivity Estimate (m²/day)#**				
	Pumping Stage		**Recovery Stage**		
	Cooper Jacob¹	**Theis/Hantush²**	**Cooper Jacob³**	**Theis Recovery⁴**	**Range**
SA1501	0.06*	NV	0.07	0.07	0.06 – 0.07
SA1502	0.007	0.006	0.01	0.01	0.006 – 0.01

#All values reported to one significant figure

1 Cooper and Jacob straight line method (Cooper & Jacob, 1946)

2 Theis method (Theis, 1935) as extended by Hantush (1961)

3 Cooper and Jacob method (Cooper, & Jacob, 1946) applied to the Agarwal transformation (Agarwal, 1980)

4 Theis method for recovery data (Theis, 1935)

* For SA1501 the constant discharge pumping displacement – time graph did not provide the means for reasonable type curve fitting using the Cooper Jacob method. A composite displacement – time graph did however result in a reasonable type curve fit with the second stage of pumping (6 L/sec) and the value presented here is based on that fit (refer to Annex C to view the composite displacement – time graph and associated type curve fit).

NV = No value as neither the first stage of pumping or the composite pumping displacement – time graphs provided the means for reasonable type curve fitting for the pumping test conducted at SA1501 using the Theis/Hantush method.

Higher reliance can be placed on the recovery results compared to the constant discharge pumping results, as the recovery data interpretation is not dependant on the maintenance of a constant pumping rate which is approximated in the field. Recovery data is also not influenced by bore storage affects. Nevertheless, as can be seen in *Table 4.4* the results derived from the pumping stages compared to recovery stages of the tests align relatively well for the tests.

When comparing the recovery stage derived transmissivity results at the two monitoring bores the results indicate a transmissivity value approximately a factor of seven higher for the test undertaken at SA1501 compared to the pumping test conducted at SA1502. The comparative results of the pumping tests undertaken at SA1501 and SA1502 align with the field observations, with groundwater level drawdown being significantly more rapid in SA1502 compared to SA1501 (even when pumping SA1502 at a lower rate than SA1501). Relatively speaking, groundwater level recovery following cessation of pumping in SA1502 was also significantly slower than the observed recovery in SA1501.

Based on the recovery phase derived transmissivity values of 0.07 m^2/day and 0.01 m^2/day and assumed aquifer thicknesses of 70 m and 36 m for SA1501 and SA1502 respectively, the estimated hydraulic conductivity of the screened lithology at SA1501 would be 0.001 m/day and 0.0003 m /day at SA1502. In units of m/sec this would equate to hydraulic conductivities of approximately 1 X 10^{-8} m/sec and 3 X 10^{-9} m/sec for the tests conducted at SA1501 and SA1502 respectively. These low hydraulic conductivity values align with the observations from the existing pit where groundwater seepage to the pit is reportedly negligible with no active dewatering required according to site management.

4.2.3 *Groundwater Sampling*

The field parameters measured during sampling are summarised in *Table 4.5.*

Table 4.5 ***Water Quality Field Parameters***

Monitoring Bore	Date	pH	EC (µS/cm)	TDS¹ (mg/L)	ORP (mV)	DO (mg/L)	Temperature (°C)
SA1501	29/11/2017	6.6	2513	1633	111	<0.1	20.8
SA1502	28/11/2017	6.9	4563	2966	909	<0.1	22.3
SA1503	30/11/2017	6.9	1912	1243	223	6.39	20.4
Seep	30/11/2017	7.6	2161	1405	185	6.44	28.5
Quarry Sump	30/11/2017	7.0	2694	1751	241	5.74	24.6
Holding Pond 1	30/11/2017	8.0	1659	1078	187	9.95	25.1
Holding Pond 2	30/11/2017	7.9	1289	838	200	4.32	26.8

¹ = TDS estimated from EC field measurements through following equation:

EC (µS/cm) X 0.65 = TDS (mg/L).

The pH values for all water samples were circum-neutral, ranging between 6.6 and 8.0. EC measurements ranged between 1 289 to 4 563 µS/cm, with TDS concentrations estimated from EC measurements ranging between 838 to 2,966 mg/L. Indications are that groundwater sampled from SA1501 – SA1503, the seep location and water sampled from the quarry sump was brackish with the water samples from the holding ponds being less saline in comparison. DO measurements indicate that, with the exception of the grab sample taken from SA1503, groundwater in the Byabbara Beds is anoxic. In comparison the measurements indicate that surface expressions of water are well oxygenated.

The laboratory results for major ions, alkalinity and TDS are provided in *Table 4.6* and the trace metal results are provided in *Table 4.7*. Given the registered use for domestic supply and stock watering of identified groundwater bores (see *Section 3.3.1*) the results were compared to the Australian drinking water guidelines (NHMRC NRMMC, 2011) and livestock drinking water quality criteria (ANZECC/ARMCANZ, 2000).

Table 4.6 ***Reported Major Ions (in mg/L) for Samples taken on 30 November 2017***

AC[1] / Sample ID[2]	Ca	Mg	Na	K	Cl	Alk	SO_4^{2-}	NO_3^-	TDS
DC[3]	NV[5]	NV	180*	NV	250*	NV	NV	50	600/1200*
LC[4]	1 000	NV[5]	NV	NV	NV	NV	1 000	400	V[6]
SA1501	132	57	299	6	673	299	142	<0.05	1690
SA1502	267	136	475	4	1250	311	1	<0.05	3520
SA1503	18	3	20	2	15	70	52	<0.05	133
SEEP	176	97	176	9	111	165	816	0.09	1550
Quarry Sump	235	117	225	7	148	255	1140	17.2	1980
Holding Pond 1	129	78	116	6	60	104	588	17.1	1150
Holding Pond 2	106	59	83	6	41	143	447	<0.05	888

1 = Assessment Criteria

2 = Sample Identification`

3 = Drinking Water Criteria - Human Health and/or Aesthetic* Criteria (NHMRC NRMMC, 2011). For TDS, 600 mg/L presents the good palpability threshold and 1 200 mg/L the unacceptable threshold

4 = Livestock Drinking Water Quality Criteria (ANZECC/ARMCANZ, 2000)

5 = No Value

6 = Variable as TDS dependant on livestock type: No adverse effects for beef cattle, (0 – 4 000 mg/L), dairy cattle (0 – 2 500 mg/L), sheep (0 – 5 000 mg/L), horses (0 – 4 000 mg/L), pigs (0 – 4 000 mg/L) and poultry (0 – 2 000 mg/L)

With the exception of the reported results for groundwater sampled from SA1503, laboratory results for TDS align relatively strongly with TDS concentrations estimated from EC measurements taken during sampling. As noted in Section *4.1.3*, the sample from SA1503 was effectively a grab sample due to the casing blockage not allowing the pump to be lowered to the water column within the bore casing. Of the samples taken from the monitoring bores, the samples taken from SA1501 and SA1502 are therefore seen as being most representative of groundwater conditions.

Of the major ions, reported sodium and chloride concentrations exceeded aesthetic drinking water criteria in water sampled from SA1501 and SA1502. TDS concentrations exceeded the good palpability threshold of 600 mg/L in all samples, while the unacceptable threshold of 1 200 mg/L threshold was exceeded in all samples except SA1503 (noted as an anomaly when considering the field EC measurement) and the surface water samples taken from Holding Pond 1 and Holding Pond 2. For the livestock drinking water criteria, exceedances are limited to criteria for poultry and dairy cattle when considering TDS concentrations for SA1502.

Table 4.7 ***Reported Trace Metal Concentrations (in mg/L) for Samples taken on 30 November 2017***

AC[1] / Sample ID[2]	As	Cd	Cr	Cu	Pb	Hg	Ni	Zn
DC[3]	0.01	0.002	0.05	2	0.01	0.001	0.02	NV[5]
LC[4]	0.5	0.01	1	NV	0.1	0.002	1	20
SA1501	0.003	<0.0001	<0.001	<0.001	<0.001	<0.0001	<0.001	<0.005
SA1502	0.001	<0.0001	<0.001	<0.001	<0.001	<0.0001	0.001	<0.005
SA1503	<0.001	<0.0001	0.001	0.003	<0.001	<0.0001	0.008	0.061
SEEP	<0.001	<0.0001	<0.001	<0.001	<0.001	<0.0001	<0.001	0.007
Quarry Sump	<0.001	<0.0001	<0.001	<0.001	<0.001	<0.0001	0.002	<0.005
Holding Pond 1	<0.001	<0.0001	<0.001	<0.001	<0.001	<0.0001	<0.001	<0.005
Holding Pond 2	0.001	<0.0001	<0.001	<0.001	<0.001	<0.0001	<0.001	<0.005

1 = Assessment Criteria

2 = Sample Identification

3 = Drinking Water Criteria - Human Health Criteria (NHMRC NRMMC, 2011)

4 = Livestock Drinking Water Quality Criteria (ANZECC/ARMCANZ, 2000)

5 = No Value

For trace metal analysis, the majority of results were below the laboratory limit of reporting (LoR). Where detected above the LoR, reported concentrations were well below the assessment criteria for groundwater and surface water samples.

5 GROUNDWATER FLOW MODELLING

5.1 APPROACH

Groundwater flow modelling was undertaken to address the impact assessment requirements of the NSW Aquifer Interference Policy. This included:

- Estimating water take through groundwater inflows to the pit; and
- Predicting groundwater level drawdown associated with pit development at groundwater user locations (both registered groundwater bores and the closest identified groundwater dependent ecosystem).

While the Project will include the expansion of the existing pit in multiple stages, the modelling was undertaken for a steady state scenario taking into consideration the full extent of the final planned pit void (at which stage steady state groundwater flow to the pit will be greatest and potential groundwater level drawdown proximal to the quarry will be greatest).

The conceptual hydrogeological model on which the numerical groundwater flow model is based is outlined in *Section 5.2*, while the methodology and results of the numerical model are presented in *Section 5.3.*

5.2 CONCEPTUAL HYDROGEOLOGICAL MODEL

5.2.1 *Aquifer Framework*

The bedrock aquifer comprising the meta-sediments of the Byabbara Beds underlying the Study Area is considered to be fractured in nature, with groundwater storage and flow controlled by secondary porosity. To the north and west of the Study Area, a Quaternary alluvial aquifer overlies the Byabbara Beds. Water storage and flow in the unconsolidated aquifer is governed by the primary porosity of the sediments. Regionally the Quaternary alluvial sediments consist of sand, silt, mud and gravel (Brunker et al., 1970) and the most productive sections of the aquifer will consist of the courser grained sediments including sand and gravel.

5.2.2 *Hydraulic Properties*

Pumping tests undertaken as part of the groundwater assessment indicates that transmissivity values for the meta-sediments comprising the bedrock aquifer range between 0.01 m^2/day and 0.07 m^2/day (based on the recovery phase of the tests which are considered to present the most reliable data).

When factoring in the assumed aquifer thicknesses of 70 m and 36 m at monitoring bores SA1501 and SA1502 respectively, the estimated hydraulic conductivity ranges between be 0.001 m/day at SA1501 and 0.0003 m /day at SA1502. In units of m/sec, this would equate to hydraulic conductivities of approximately 1 X 10^{-8} m/sec and 3 X 10^{-9} m/sec for the tests conducted at SA1501 and SA1502 respectively.

No aquifer parameter testing has been undertaken for the alluvial sediments located to the north and west of the Study Area. As these sediments fall within the modelling domain, hydraulic properties were sourced from literature sources. These values can vary by severed orders of magnitude; for instance, Freeze and Cherry (1979) cites a hydraulic conductivity range of 10^{-7} m/sec to 10^{-3} m/sec for silty sand and Domenico and Schwartz (1990) references a range of 2 X 10^{-7} m/sec to 2 X 10^{-4} m/sec for fine sand. As the more permeable sand and gravel layers within the sediments are likely to control groundwater flow, a high-end hydraulic conductivity value (8 m/day, or ~ 9 X 10^{-5} m/sec) relative to the aforementioned literature values was used for the modelling.

5.2.3 *Groundwater Flow Direction*

The groundwater monitoring bore network from which to infer groundwater flow directions are limited to SA1501 through to SA1503 and available groundwater level elevation data indicate a groundwater flow direction towards the northwest. While monitoring bores SA1501 – SA1502 are located in a near straight line (see *Figure 4.1*), which is not ideal for tri-angulating and inferring groundwater flow direction, the inferred groundwater flow direction does align with general expectations of regional groundwater flow which would be from elevated elevations towards the Hastings River.

5.2.4 *Influence of Structural Features*

As noted in *Section 0*, the existing quarry pit has a fault line trending south west to northeast, and the available borelogs suggest that there are fault zones at depth as indicated by intervals of breccia identified in the rock core (Hanson, 2016).

Depending on the nature of the fault zones, these structural features could act as groundwater flow conduits (e.g. if faulting has significantly increased secondary porosity) or as groundwater flow barriers (e.g. if fractures are closed or infilled by low permeability material). With no specific hydraulic testing data available for the fault zones, the modelling assumes that the structural features do not significantly affect the groundwater flow field in the model.

5.2.5 *Aquifer Interconnectivity*

Available aquifer characterisation data are restricted to the meta-sediments comprising the Byabbara Beds. While a level of interconnectivity between the Byabbara Beds and adjoining Quaternary alluvial sediments would be expected, the degree of connectivity is unknown. For the purpose of the modelling the Byabbara Beds and alluvial sediments are considered to be hydraulically connected.

Given the nature of the unconsolidated sediments comprising the Quaternary alluvial sediments and the direct association of these sediments with the surface water features adjacent to the Study Area, the degree of groundwater-surface water connectivity between these sediments and the surface water features would be expected to be high.

5.2.6 *Groundwater Chemistry*

The water quality sampling results indicate that the geology intersected by the quarry and targeted during quarry expansion (based on sampling results from SA1501 – SA1503) is largely inert, with no acidity impact identified at the existing quarry operations and no exceedances of trace metals in any of the samples identified.

Potential water quality impacts are considered to be associated primarily with salinity, with the groundwater sampling indicating that groundwater within the Byabbara Beds is brackish. As the groundwater flow model focusses on physical processes, the potential water quality related impacts associated with encountering brackish groundwater during quarry pit expansion is considered further in *Section 6.1.3.*

5.2.7 *Groundwater Users*

The identified groundwater users are summarised in *Section* 3.2*3.3.* These include groundwater bores registered for stock watering and domestic use. A total of 13 groundwater bores were identified within a 2 km radius from the perimeter of the final pit, with one of these located within a 1 km radius of the final pit. The closest registered bore, GW303749 (registered for stock water and domestic use), is located approximately 600 m to the south of the perimeter of the final pit.

From a GDE perspective, several areas of Paperbark ecosystems were identified with the closest located approximately 500 m to the west of the perimeter of the final pit (and adjacent to Haydon's Creek). No high priority GDEs (as specified in the *Draft Water Sharing Plan for the Hastings Unregulated and Alluvial Water Sources 2016*) were identified within a 2km radius of the perimeter of the final pit. Note that groundwater dependent culturally significant sites were under investigation at the time of the development of the draft WSP and the locations of any such sites had not been identified.

5.3 GROUNDWATER MODELLING

5.3.1 *Approach and Objectives*

A numerical groundwater flow model (Model) was created to simulate the current hydrogeologic conditions and at final quarry expansion. The modelling activities were based on the conceptual model as presented above.

The objectives of the Model were to:

- Create a calibrated 3-Dimensional numerical groundwater flow model to existing static water levels at monitoring bores SA1501, SA1502 and SA1503.
- Simulate the final quarry expansion to -40 m AHD.
- Predict the seepage rate into the pit at steady state conditions associated with the final pit extent.
- Predict the water level drawdown at identified groundwater users including the closest identified GDE associated with the final pit extent (when groundwater drawdown proximal to the quarry would be at its greatest).

5.3.2 *Code Selection*

MODFLOW-NWT (Niswonger et. al., 2011), a Newton formulation of MODFLOW-2005 (Harbaugh, 2005) was selected to simulate groundwater flow at the Site. MODFLOW-NWT linearization approach uses a continuous function of groundwater head to solve the system of non-linear equations representing an unconfined aquifer with the Upstream-Weighting (UPW) Package rather than the drying and rewetting discrete method used in other packages provided in MODFLOW-2005.

MODFLOW-NWT does not set dewatered cells as no-flow, or inactive, so rewetting variables are not necessary. The UPW Package maintains a smooth and continuous function by using the upstream head to calculate the flow between cells so that flow from a dewatered cell is not possible and creating inactive cells is not necessary. This code was selected because of the drain cells will dry the overlaying two layers.

The USGS MODFLOW code and associated packages have been widely used and accepted for simulated groundwater flow. Documentation can be found at https://water.usgs.gov/ogw/modflow/.

The Graphical User Interface (GUI) Visual MODFLOW Classic (Waterloo Hydrogeologic version 4.6, 2015) was used for model construction, calibration and output interpretation.

5.3.3 *Model Domain and Grid*

The model domain is 4400 m x 4400 m and encompasses 19.36 km^2. The model domain is aligned with the primary groundwater flow direction across the Site towards the Hastings River. The grid is constructed of 4 layers, 220 rows, and 220 columns, evenly spaced resulting in 20 m square cells. Land surface elevations are from a detailed digital elevation map (DEM) with 2 m resolution. Layer 1 was set to a constant 10 m thickness to represent quaternary alluvium and weathered meta-sediments. Layers 2 and 3 are a combined 100 m to represent the fractured meta-sediments, the full depth of the monitoring bores. Layer 4 is a constant 20 m thickness to allow for interaction of deeper meta-sediments if simulated pumping of the monitoring bores is required.

5.3.4 *Boundary Conditions*

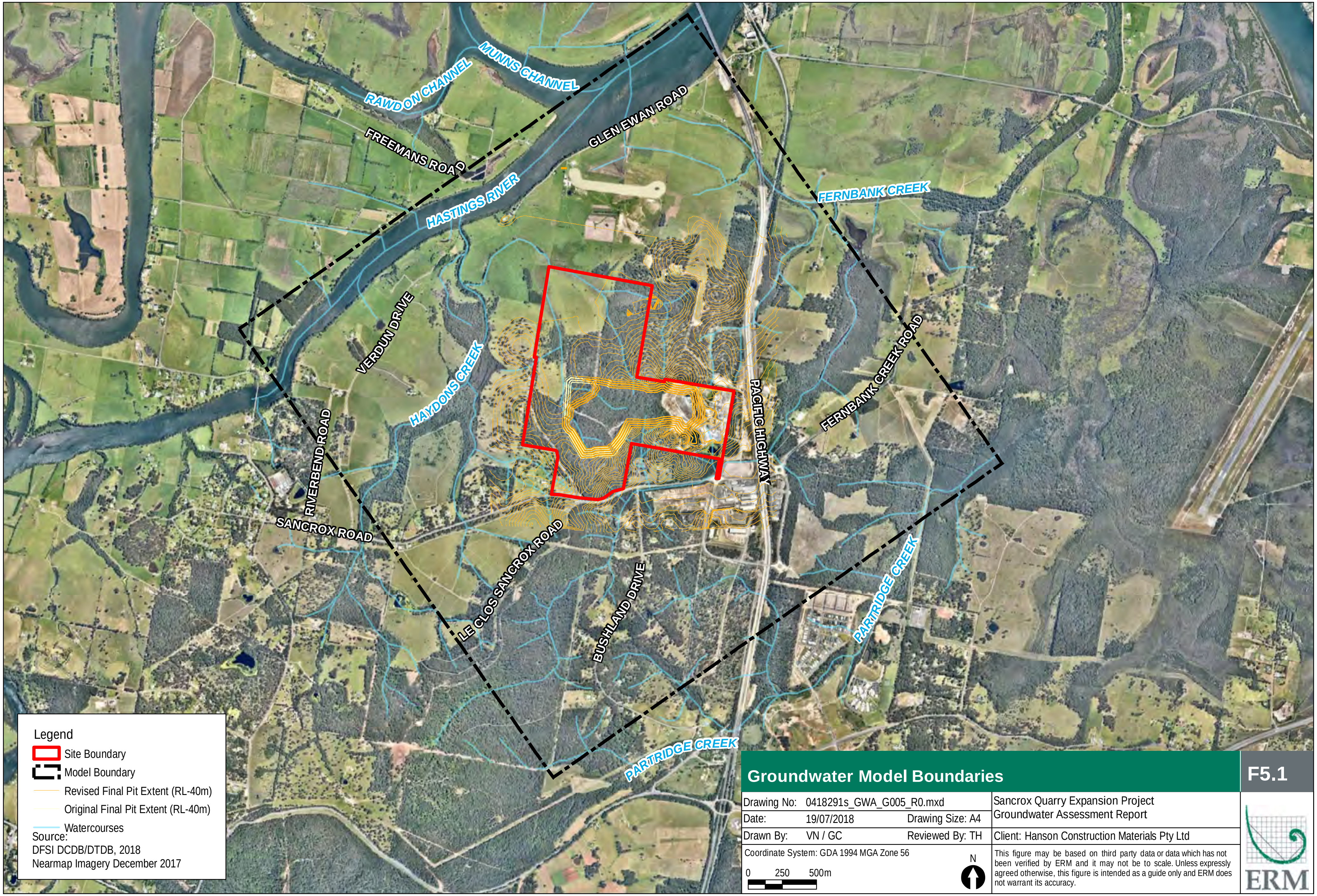
Boundary conditions are an essential component of a groundwater flow model and represent the external hydrology outside the model domain. The boundary conditions establish the external geometry for the model domain and control the inflow and outflow of the model. The solution to the groundwater flow equation, the head at a given point in space and time, must satisfy the equation and the boundary conditions (Franke et al. 1987).

The boundary conditions used for the Model are: no-flow, constant head, drain, and constant flux (recharge) boundaries. The locations of the boundaries can be seen in the *Figure 5.1*. No-flow boundaries are set as the bottom of the layer 4 and the northwest, southwest, and southeast boarders. A constant head boundary (CHB) is set in layer 1 as the domain outflow on the northwest boundary of the model domain to represent discharge to the Hastings River and the southwest corner to represent discharge to quaternary materials. Inactive cells are used to the northwest of this boundary. The drain boundary condition was used to represent the quarry expansion to -40 m AHD. Details of these boundaries are provided below.

The Model was calibrated and run as a steady state simulation, assuming that water table condition variations during the year do not affect the long-term average gradients.

5.3.5 *Model Inflow*

The groundwater inflow into the model is represented with aerial recharge over the terrestrial domain. It is common to use a recharge rate of approximately 5-10% of the mean annual precipitation. However, the model is very sensitive to the recharge rate and, due to the low permeability of the meta-sedimentary units, a lower recharge rates was used. Recharge rates of 2.7 and 40 mm/year were determined during model calibration over the meta-sedimentary and quaternary alluvial units respectively.



Source:
DFSI DCDB/DTDB, 2018
Nearmap Imagery December 2017

Groundwater Model Boundaries

F5.1

Drawing No:	0418291s_GWA_G005_R0.mxd		Sancrox Quarry Expansion Project Groundwater Assessment Report
Date:	19/07/2018	Drawing Size: A4	
Drawn By:	VN / GC	Reviewed By: TH	Client: Hanson Construction Materials Pty Ltd

Coordinate System: GDA 1994 MGA Zone 56

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5.3.6 *Model Outflow*

In the conceptual model, groundwater flow leaves the model domain through discharges to the Hastings River (eventually discharging to the ocean). Numerically, flows out of the model are represented with constant head cells and drain cells. A constant head cell is used where the head at the corresponding cell is known and does not change as a result of the flow solution (Harbaugh, 2005). As much water as required may enter or leave the domain through this cell to maintain this specified head. The constant head boundaries are set in layer 1 to represent groundwater discharge to the Hastings River and the quaternary alluvium in the southwest corner of the model.

The drain boundary removes water from the aquifer above a specified elevation. The flow to the drain is calculated as the difference between the head in the aquifer and the drain elevation multiplied by a drain conductance used to limit the flow to the drain (Harbaugh, 2005). A drain boundary in layer 3 was used to represent the full expansion extent of the bottom of the quarry pit to by setting the drain elevation to -40 m ADH. The drain conductance was set to 40,000 m^2/day (conductance per unit area of 100 day^{-1} times the area of the cell bottom), which allows for water to be readily removed and accounted for in the mass balance.

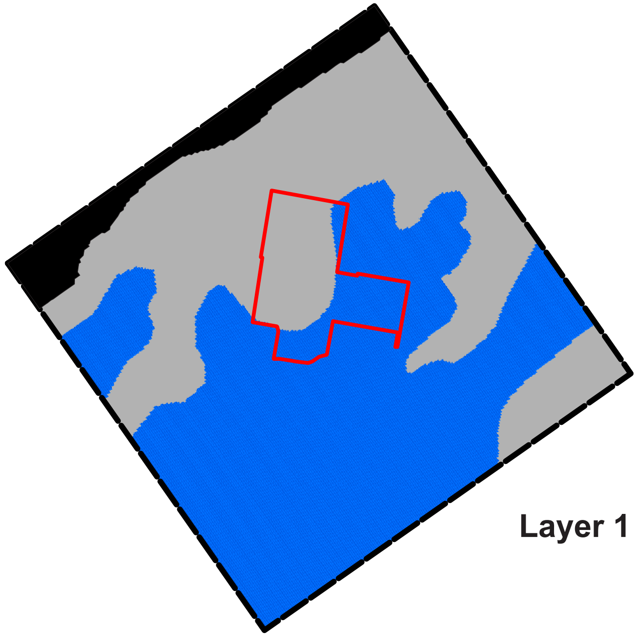
5.3.7 *Model Properties*

The Model hydraulic conductivities were originally determined from the aquifer tests conducted at SA1501 and SA1502 and then adjusted during Model calibration. The hydraulic conductivity geometric mean calculated from aquifer test data is 0.00053 m/day for fractured meta-sedimentary units. The geologic report prepared by Hanson (2015) shows an increased amount of shale present to the south of a fault trending northwest. Although no borings were hydraulically tested south of the fault, the material was represented in the Model as having lower hydraulic conductivity to reflect this conceptualisation.

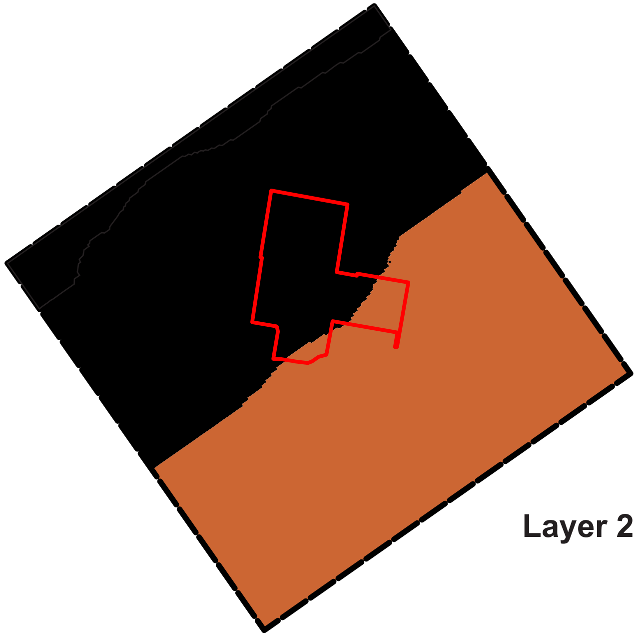
Aquifer storage and porosity are not used in steady state groundwater flow simulations. The base case Model hydraulic conductivities are presented in *Table 5.1* and in *Figure 5.2*.

Table 5.1 Base Case Model Hydraulic Conductivity

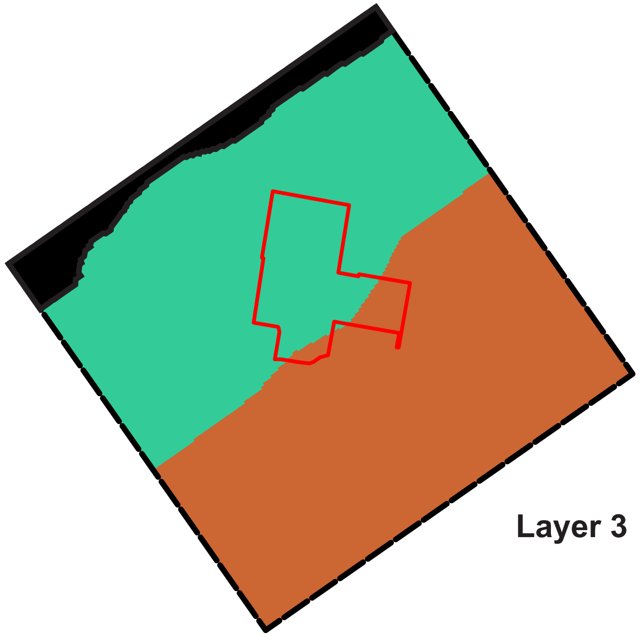
Kx (m/day)	Layer	Hydrostratigraphic Unit
8	1	Quaternary Alluvium
0.012	1	Weathered Meta-Sedimentary
0.00085	2	Meta-Sedimentary (upper)
0.00049	3	Meta Sedimentary (lower)
0.0002	2&3	Meta Sedimentary (increased shale)
0.001	4	Meta Sedimentary (deep)



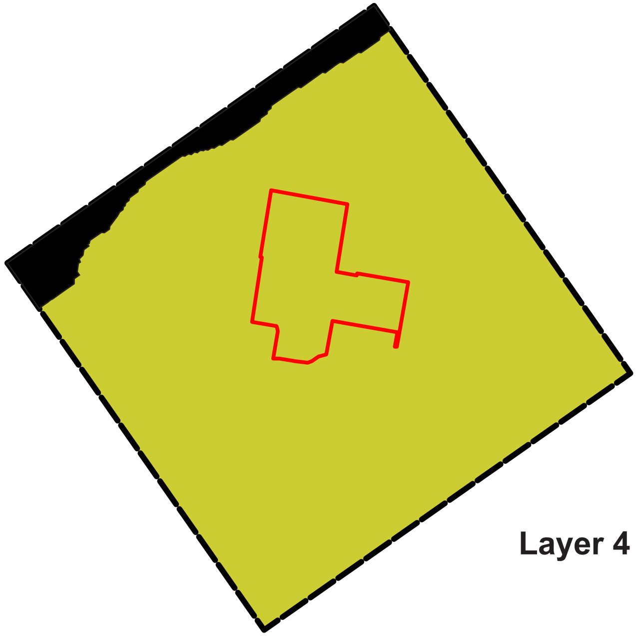
Layer 1



Layer 2



Layer 3



Layer 4

Conductivity				
Zone		Kx [m/d]	Ky [m/d]	Kz [m/d]
▨	1	8	8	4
🟦	2	0.028	0.028	0.028
🟩	3	0.00049	0.00049	0.00049
🟨	4	0.001	0.001	0.001
🟫	5	0.0002	0.0002	0.0002
⬜	6	0.00085	0.00085	0.00085

Legend

🟥 Site Boundary

▭ Model Boundary

Model Hydraulic Conductivities for Base Case

F5.2

Drawing No: 0418291s_GWA_C001_R1.cdr

Date: 19/07/2018 Drawing size: A4

Drawn by: GC Reviewed by: WG

Drawing Not to Scale

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Sancrox Quarry Expansion Project
Groundwater Assessment Report

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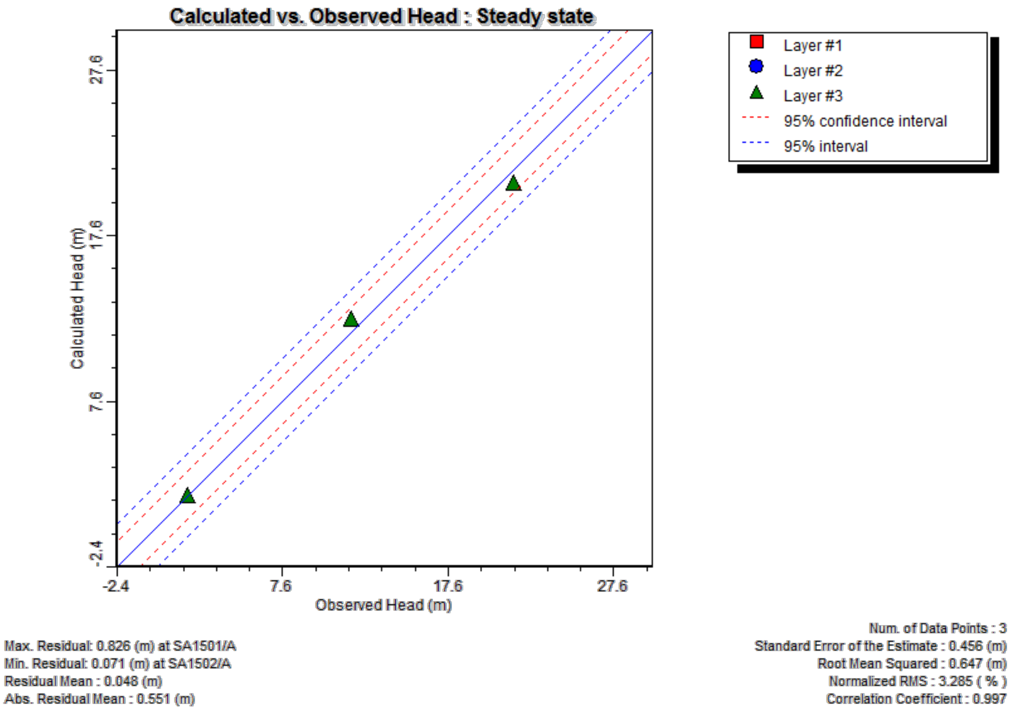
Model properties were implemented in the model using regional property zones that pertain to the hydrostratigraphic units as presented in lithologic bore logs and the available regional geological map (Brunker et al., 1970). Within these zones, properties are kept the same (i.e. piecewise constant zonation). Location and values for these zones were modified during model calibration.

5.3.8 *Model Calibration*

Model calibration is the process of adjusting model boundaries and properties within reason to produce a satisfactory match of the model simulation to field observation data (Anderson, 2015). In a steady state model, a satisfactory match is met when summary statistics quantitatively expressing the goodness of fit between the measured water level elevations and the modelled potentiometric surface are minimized. When plotting measured water level elevations against simulated water levels a perfect fit would represent a straight line with a slope of one.

The Model was calibrated to static groundwater elevation data collected prior to the start of the pumping tests conducted on 28 November 2017. Model parameters were adjusted by hand to increase the goodness of fit until a reasonable model was constructed. Results of the model calibration indicate a good match between calculated and observed groundwater elevations at the existing site monitoring wells. Model basic statistical measures are within the typically industry accepted parameters, including a low mean residual error, and a normalized root mean squared (NRMS) error of 3.28% (the target NRMS is 10% or less for most sites). The Model summary statistics are presented in *Figure 5.3*.



```
Max. Residual: 0.826 (m) at SA1501/A
Min. Residual: 0.071 (m) at SA1502/A
Residual Mean : 0.048 (m)
Abs. Residual Mean : 0.551 (m)

Num. of Data Points : 3
Standard Error of the Estimate : 0.456 (m)
Root Mean Squared : 0.647 (m)
Normalized RMS : 3.285 ( % )
Correlation Coefficient : 0.997
```

Figure 5.3 ***Calculated versus Observed Head***

5.3.9 *Flow Model Results*

Simulated groundwater equipotentials for the fractured rock aquifer are presented in *Figure 5.4*. The results of the calibrated flow model provide a reasonable fit to measured water level elevations. The Model was calibrated based on groundwater elevations at three monitoring bores which are situated in a line. This prevents the three-point estimation method for determining a precise groundwater flow direction and calculation of groundwater gradient. However, conceptually speaking, it is reasonable for local groundwater flow in the near surface fractured rock aquifer to discharge to the Hastings River.

As described in *Section 1.1*, the groundwater modelling was completed prior to the change in pit design with the revised final pit extent covering a smaller area than the original final pit design that the modelling outcomes are based on. The results, in terms of inflow predictions and extent of groundwater drawdown proximal to the pit, should therefore be seen as being conservative.

5.3.10 *Quarry Expansion Simulation Results*

The simulated steady state drawdown created by the addition of the pit is presented in *Figure 5.5.* Due to the low permeability of the meta-sedimentary unit, the drawdown gradient is steep and does not extend significantly away from the pit. The higher permeability materials associated with the quaternary alluvium do not have significant water level changes because water in these units are sourced primarily from local recharge and runoff (i.e. streams). According to the Model, on average approximately 40 m^3/day of groundwater will seep into the final pit expansion. This does not include surface water run-off into the pit.

The simulated predicted drawdown at identified groundwater users and the closest sensitive ecosystem is presented in the *Table 5.2* below.

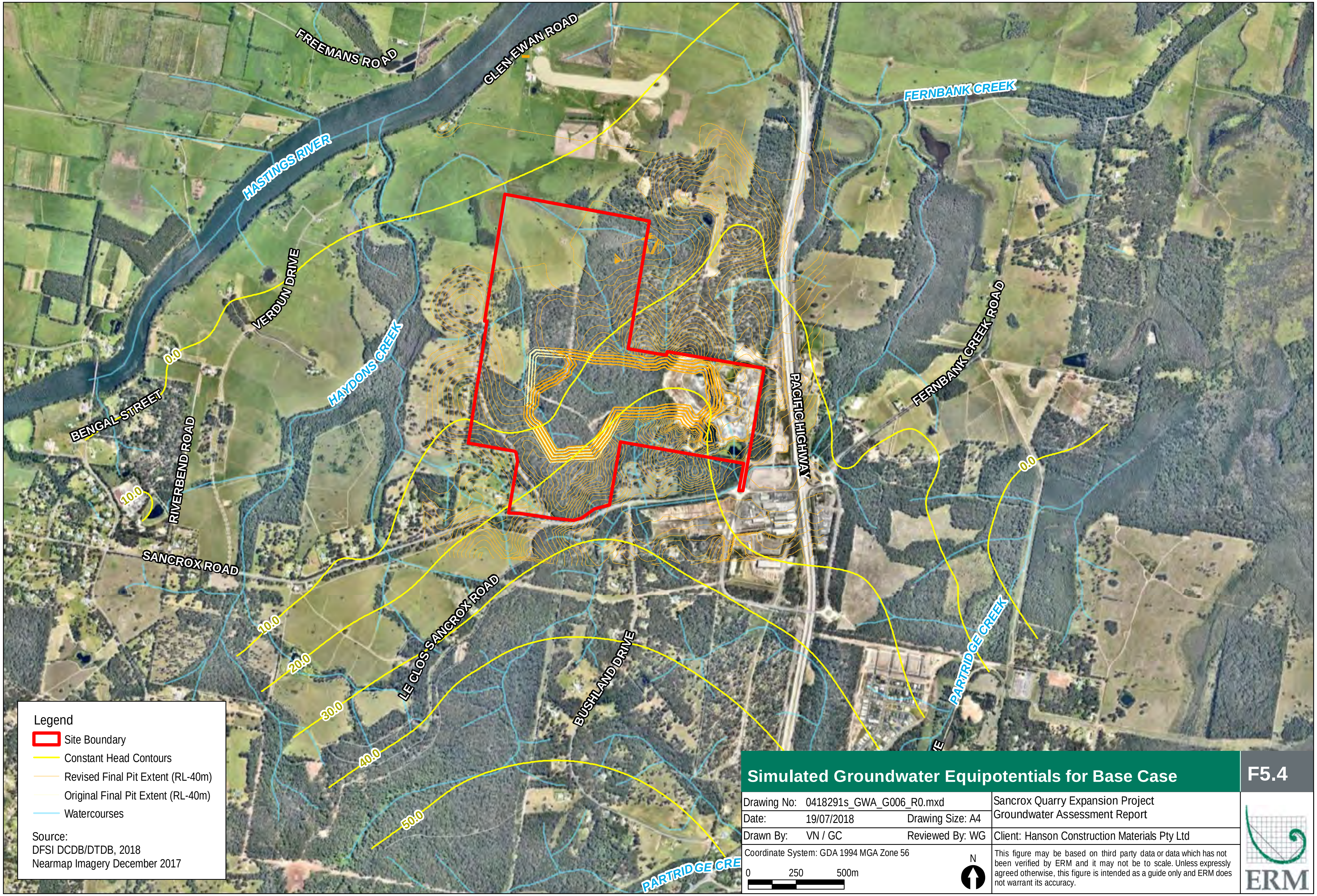
Table 5.2 ***Simulated Water Levels at identified Groundwater Users and the closest GDE***

Bore ID	Simulated Current Water Level Elevation (m)	Simulated Pit Expansion Water Level Elevation (m)	Simulated Drawdown Impact from Pit Expansion (m)
GW060512	1.04	0.96	0.08
GW060513	-0.71	-0.77	0.06
GW300120	-0.113	-0.114	0.001
GW301263	-0.68	-0.73	0.05
GW302376	-1.38	-1.43	0.05
GW303436	49.59	48.98	0.62
GW303749	34.04	31.14	2.90
GW306269	44.35	43.42	0.93
GDE	1.56	1.38	0.18

5.3.11 *Sensitivity Analysis*

A limited sensitivity analysis was run to determine the effects of parameter uncertainty on model predictions. The most important parameters in this model that control pit inflows or modify the predicted drawdown extents are the recharge rate and hydraulic conductivities of the meta-sedimentary unit.

The model was run to simulate higher hydraulic conductivities in the meta-sedimentary unit reflecting the maximum hydraulic conductivity calculated from the pumping test presented in *Table 5.3*.



Legend

- 🟥 Site Boundary
- Constant Head Contours
- Revised Final Pit Extent (RL-40m)
- Original Final Pit Extent (RL-40m)
- Watercourses

Source:
DFSI DCDB/DTDB, 2018
Nearmap Imagery December 2017

Simulated Groundwater Equipotentials for Base Case

F5.4

Drawing No:	0418291s_GWA_G006_R0.mxd		Sancrox Quarry Expansion Project Groundwater Assessment Report
Date:	19/07/2018	Drawing Size: A4	
Drawn By:	VN / GC	Reviewed By: WG	Client: Hanson Construction Materials Pty Ltd

Coordinate System: GDA 1994 MGA Zone 56

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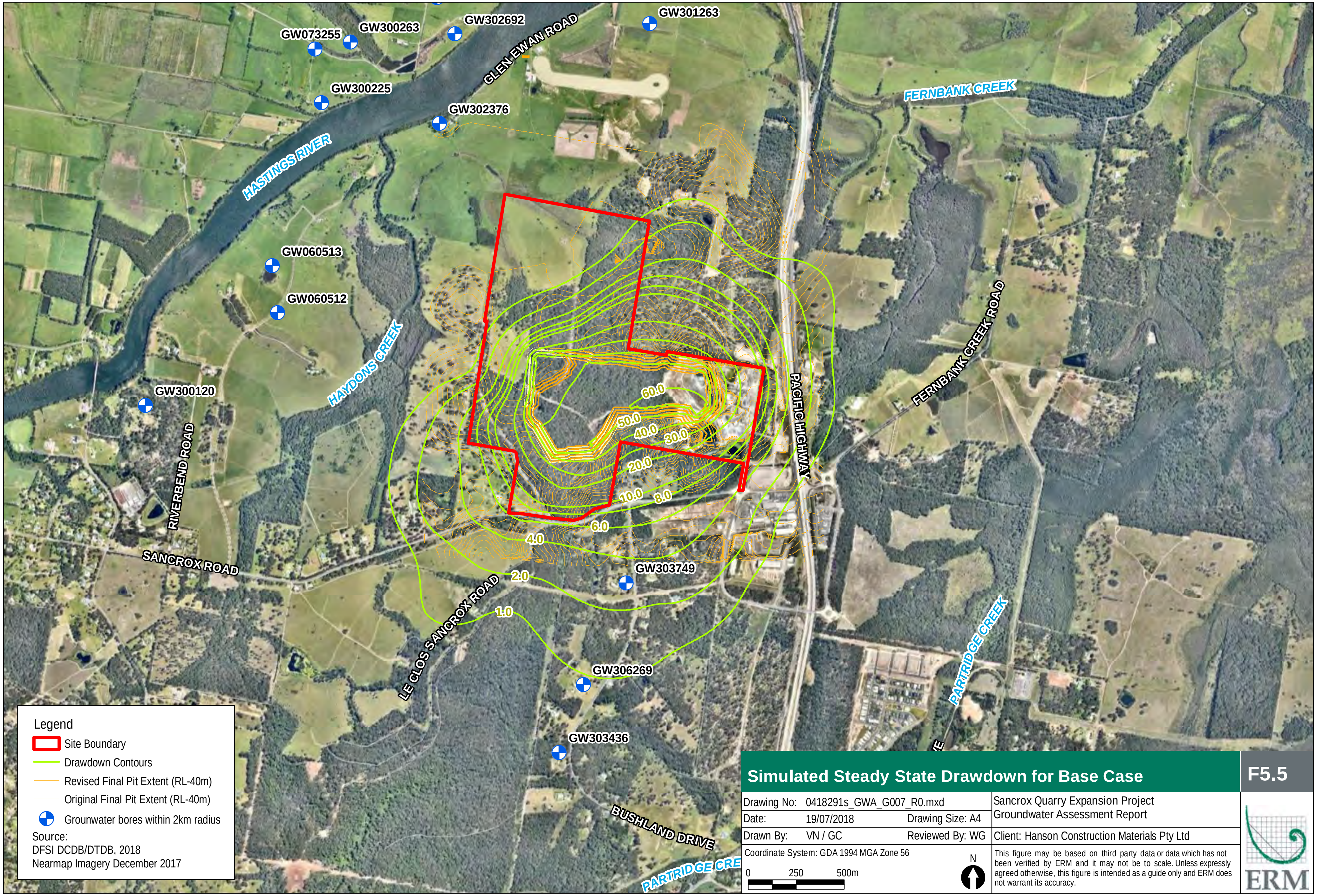

Legend

- 🟥 Site Boundary
- Drawdown Contours
- Revised Final Pit Extent (RL-40m)
- Original Final Pit Extent (RL-40m)
- ● Grounwater bores within 2km radius

Source:
DFSI DCDB/DTDB, 2018
Nearmap Imagery December 2017

Simulated Steady State Drawdown for Base Case

F5.5

Drawing No: 0418291s_GWA_G007_R0.mxd		Sancrox Quarry Expansion Project Groundwater Assessment Report
Date: 19/07/2018	Drawing Size: A4	
Drawn By: VN / GC	Reviewed By: WG	Client: Hanson Construction Materials Pty Ltd

Coordinate System: GDA 1994 MGA Zone 56

0 250 500m

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ERM

Table 5.3 *Model Hydraulic Conductivity*

Kx (m/day)	Layer	Hydrostratigraphic Unit
8	1	Quaternary Alluvium
0.01	1	Weathered Meta-Sedimentary
0.0014	2	Meta-Sedimentary (upper)
0.001	3	Meta-Sedimentary (lower)
0.0005	2&3	Meta-Sedimentary (increased shale)
0.001	4	Meta-Sedimentary (deep)

The Model was expanded 1,000 m to the southwest and southeast because the increased drawdown of the sensitivity run was impacted by the no flow boundary at the model domain. The recharge rate was maintained the same as the base model and the resulting NRMS error was 3.61%. The change in hydraulic conductivity did not significantly decrease model fit.

The drawdown contours from this sensitivity run are shown in *Figure 5.6*. The drawdown from this simulation expands to the south where quaternary alluvium is not present. According to the sensitivity run, on average approximately 60 m^3/day of groundwater will seep into the final pit expansion.

The simulated predicted drawdown for the sensitivity run at identified groundwater users and the closest sensitive ecosystem is presented in the *Table 5.4* below.

Table 5.4 *Comparison of Simulated Drawdown from Pit Expansion*

Bore ID	Drawdown from base model (m)	Drawdown from sensitivity model (m)
GW060512	0.08	0.11
GW060513	0.06	0.09
GW300120	0.001	0.001
GW301263	0.05	0.08
GW302376	0.05	0.08
GW303436	0.62	1.52
GW303749	2.90	7.23
GW306269	0.93	2.65
Ecosystem	0.18	0.25

5.3.12 *Modelling Limitations and Assumptions*

The limitations to the Model are provided below:

- The measured hydraulic conductivities were extrapolated throughout the model domain with the assumption that there are no structural or other geological features present with hydraulic characteristics significantly different to the pumping test results.

- Hydraulic conductivity of weathered rock and quarrying impacted rock and its effect on recharge rates are unknown.

- The rate of recharge was determined during model calibration and has significant uncertainty.

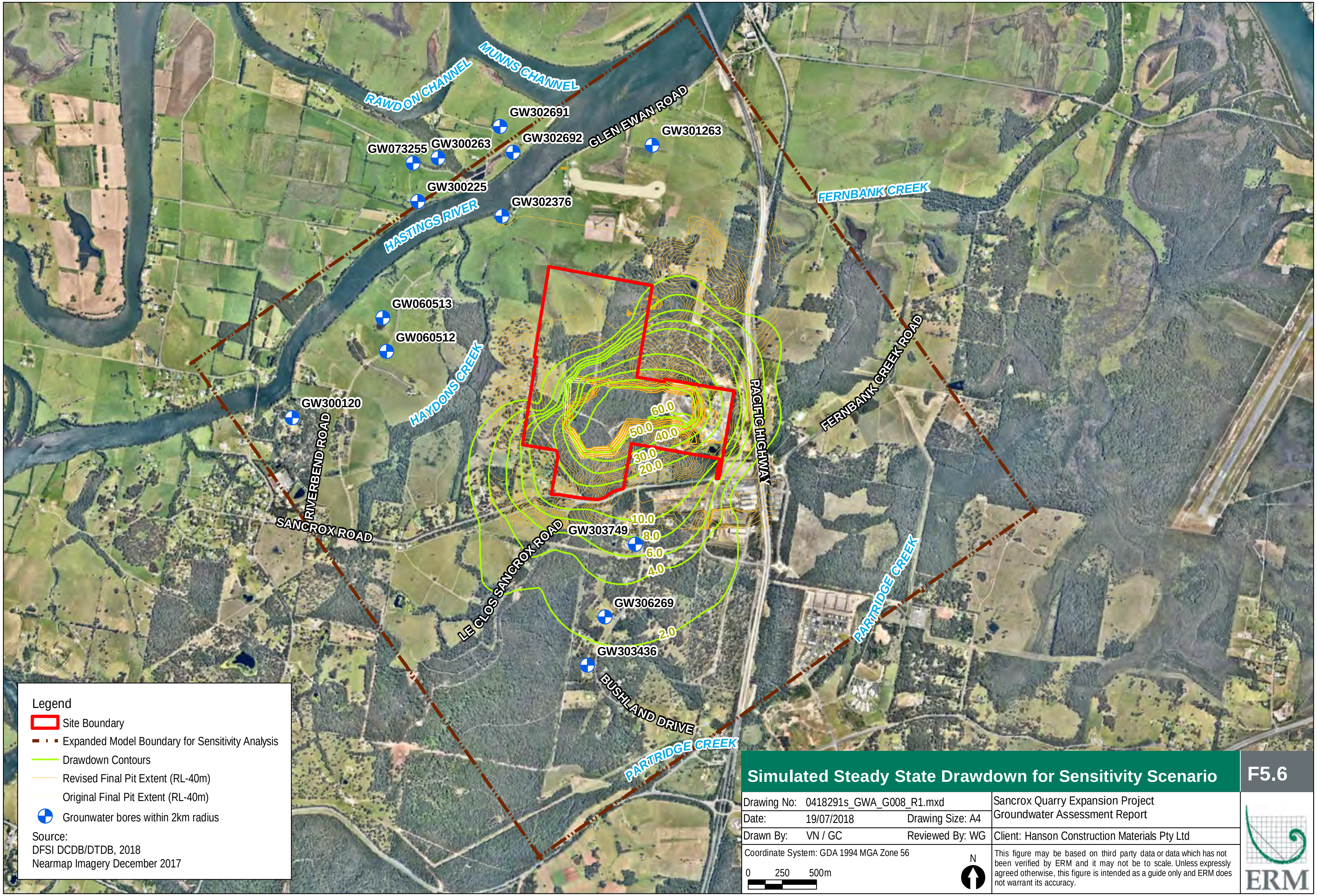
- A topographic high occurs in the southern portion of the domain which may present a groundwater flow divide creating flow to the southwest as well as towards the Hastings River. There is no groundwater elevation information in this portion of the model to establish model outflows boundaries. This may result in overly elevated heads in the southwest portion of the Model.

- This model does not include a transient analysis (groundwater level and flow estimates varying over time). Therefore, the model-calculated pit inflows are stabilized, long-term values that do not include groundwater in storage effects. These storage effects, although temporary, could increase the current estimates significantly within the initial stages of the quarry expansion where large amounts may be released from aquifer storage.

- Similarly, the drawdown estimates are long-term, stabilized estimates that represent the largest cone to be formed by the quarry dewatering. In reality, the cone of depression will expand gradually over time.

- Pit inflow estimates are based on groundwater seepage only, and do not include directly precipitated waters or surface water runoff into pit, with direct precipitation through rainfall likely being the major component of pit dewatering requirements.

- The current model is not sufficiently detailed to identify pit wall-groundwater issues, and does not include additional estimates for pit slope pore pressure reduction. Should such systems (e.g. horizontal pit wall wells) be required, groundwater flows would be higher than current estimates. A more detailed analysis including transient flows and more detailed pit geometry configuration would be required to assess such issues.



Legend

- 🟥 Site Boundary
- Expanded Model Boundary for Sensitivity Analysis
- Drawdown Contours
- Revised Final Pit Extent (RL-40m)
- Original Final Pit Extent (RL-40m)
- Grounwater bores within 2km radius

Source:
DFSI DCDB/DTDB, 2018
Nearmap Imagery December 2017

Simulated Steady State Drawdown for Sensitivity Scenario

F5.6

Drawing No: 0418291s_GWA_G008_R1.mxd		Sancrox Quarry Expansion Project Groundwater Assessment Report
Date: 19/07/2018	Drawing Size: A4	
Drawn By: VN / GC	Reviewed By: WG	Client: Hanson Construction Materials Pty Ltd

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6 ASSESSMENT OUTCOMES AND MONITORING RECOMMENDATIONS

6.1 ASSESSMENT OUTCOMES

6.1.1 Estimated Water Take and Licencing Considerations

The groundwater flow modelling indicates a steady state groundwater inflow rate of approximately 40 to 60 m^3/day to the final pit void, which equates to approximately 15 to 22 ML/year. The predicted steady state inflows are modest for a pit void of the proposed size, and the relatively low predicted inflow rates align with observations from the existing quarry where no active dewatering takes place and groundwater seepage into the pit is reportedly negligible.

The NSW Aquifer Interference Policy specifies that all water taken during an activity must be accounted for, and that a water licence is required irrespective of whether the water is taken for consumptive use or whether water is taken incidentally in the course of undertaking the activity. In line with the WMA, aquifer interference activities taking water outside of water sharing plan areas require a license under the *Water Act 1912*. Depending on specifics of licences currently held by Hanson (WAL42524), a new licence may need to be applied for.

6.1.2 Water Levels / Potentiometric Levels

Taking into consideration the impact assessment requirements of the NSW Aquifer Interference Policy, the predicted 2 m level drawdown contour for the stabilised cone of depression is of particular significance (as the minimal impact considerations specify a maximum of a 2 m decline at any water supply network). The modelling indicates that at its furthest extent (from the outer perimeter of the final pit) the 2 m drawdown contour may

extend to approximately 800 to 1,100 m from the final pit (based on the base case and sensitivity run scenarios respectively).

When considering the locations of the identified groundwater bores, 1 of the 13 bores fall within the footprint of the > 2 m drawdown contour for the base case scenario (GW303749, see *Figure 5.5*), and 2 of the 13 bores for the sensitivity run scenario (GW303749 and GW306269, see *Figure 5.6*). The modelling outputs indicate that the magnitude of drawdown may vary between approximately 3 m and 7 m at GW303749, and 1 m to 3 m at GW306269 (see *Table 5.2* and *Table 5.4*). The likely impacts of this potential drawdown would depend on the:

- pump installation specifics at each bore (specifically pump depth in relation to the pre-quarry water level and total bore depth);
- intensity of use of the bore (the rates the bore is pumped at and how frequently water is drawn from the bore); and
- remaining water column within the bore following potential drawdown.

Potential impacts may vary from negligible (if drawdown does not affect the operation and use of the bore) to significant if water level drawdown is such that it affects the useability of the bore. Mitigation measures would vary (as deemed necessary) from lowering the bore pump in the bore casing, drilling a deeper bore, or providing an alternative water source as part of "make good" arrangements.

The predicted drawdown at the GDE located closest to the Project is considered negligible.

6.1.3 Water Quality

The water quality sampling results indicate that the geology intersected by the quarry and targeted during quarry expansion (based on sampling results from SA1501 – SA1503) is largely inert, with no acidity impact identified at the existing quarry operations and no exceedances of trace metals in any of the samples identified.

Potential water quality impacts are considered to be associated primarily with salinity, with the groundwater sampling indicating that groundwater within the Byabbara Beds is brackish. If off-site discharge of groundwater seepage to the pit was required, this would potentially impact on beneficial use categories off site (i.e. if the water was disposed to offsite surface water features).

To get a sense for potential impact on water quality a simplified mass balance approach was applied, recognising that groundwater would not be the only source of water (and solutes) to the pit. With dissolved solute mass flux to the pit mainly attributed to groundwater inflow and precipitation, the mass balance can be specified in terms of Equation 1:

$$Ct \times Vt = (Cgw \times Vgw) + (Crf \times Vrf)$$

Where: Ct = Concentration in the total volume

Vt = Total volume

Cgw = Concentration groundwater

Vgw = Groundwater volume

Crf = Concentration rainfall

Vrf = Rainfall volume

Re-arranging the above equation to solve for Ct provides Equation 2:

$$Ct = \frac{(\mathrm{Cgw\ X\ Vgw}) + (\mathrm{Crf\ X\ Vrf})}{\mathrm{Vt}}$$

Input parameters for the mass balance estimation are specified in *Table 6.1.*

Table 6.1 1 Final Pit Mass Balance Estimation Input Parameters

Descriptor	Unit	Value	Comments
Groundwater volume	m^3/year	15,267	Base Case groundwater flow model prediction
Estimated footprint of final pit	m^2	257,856	Estimate based on quarry extension plans provided by Hanson
Annual rainfall	mm/year	1,315	Sourced from closest weather station (see Section 3.2.1)
Rainfall volume	m^3/year	339,081	Annual rainfall times footprint of final pit
GW concentration	mg/L	3,520	Highest reported TDS concentration 3,520 mg/L for groundwater sampled from SA1502.
Concentration rainfall	mg/L	20	TDS of rainfall is typically < 20 mg/L

When factoring in the above specified input parameters to Equation 2, the estimated average TDS concentration in water within the pit would be approximately 170 mg/L. While other processes (such as solute leaching from exposed material in the pit) would further contribute to TDS levels, the mass balance calculation demonstrates the relatively low contribution of salinity by groundwater in itself, with the total volumetric contribution of groundwater to the pit presenting approximately 4.5% of the volume contributed by rainfall. Brackish groundwater seeping into the pit is therefore expected to have limited impact on the overall quality of water that may be discharged from the Project.

6.2 MONITORING RECOMMENDATIONS

6.2.1 Development of Monitoring Plan

The NSW Aquifer Interference Policy specifies that monitoring requirements need to be developed that allow for the monitoring of actual impacts compared to predicted impacts, allowing for contingency plans to be enacted in a timely manner if actual impacts are higher than predicted and these impacts are found to be significant. It is recommended that a groundwater monitoring plan be developed that includes specifics of such a monitoring program, including threshold trigger values as well as a contingency strategy if triggers are exceeded. While the development of such a plan falls outside the scope of this assessment, recommendations for monitoring requirements are outlined in *Section 6.2.2* through to *Section 6.2.4*.

6.2.2 *Water Take*

Where predicted inflow rates are low, and a substantial volume of water may be lost to evaporation on pit walls, monitoring of the water take is challenging in practice. It is recommended that monitoring of inflows be undertaken to the extent feasible as part of water balance activities. This can be done by metering water being pumped from the in-pit sumps. An estimation of rainfall contribution to water being pumped from the in-pit sumps can then be made on an annual basis by factoring in rainfall data and the pit extent after which the groundwater component can be estimated. Groundwater take would be estimated and reported in this manner on an annual basis.

It is important to identify and monitor unusually high inflows to the quarry during the quarry extension, especially if structural features are encountered during quarrying that carry high inflows. Such occurrences would be documented with the magnitude and duration of high flows compared to trigger values specified in the groundwater monitoring plan.

If geological/hydrogeological observations during quarry extension vary significantly from that considered for the groundwater flow model the groundwater flow model will be re-evaluated. The model re-evaluation may include running the existing groundwater model for different stages of pit development and including transient analysis in the modelling to evaluate contributions from aquifer storage (which may require additional pumping tests and observations bore installation).

6.2.3 *Water Levels*

The groundwater monitoring program will include monitoring of water levels at the potentially affected groundwater bores. The results of the sensitivity scenario (showing higher drawdown than base case scenario) will be taken into account given the sensitivity scenario include reasonable variation in key input parameters for the model. In order to be able to identify over or under predictions by the modelling in a reasonable way, it is recommended that all bores showing a > 0.5 m of simulated drawdown be included in the monitoring program. This would include bores GW303436, GW303749 and GW306269.

As the predicted drawdown is based on steady state drawdown associated with the final stage of pit extension (the maximum drawdown expected over the life of the Project), initial monitoring of water levels can serve as a baseline against which to compare future water level measurements. Monitoring frequency of should be adaptable (depending on trends observed and stages of the quarry development) with twice annual monitoring recommended for the first year of monitoring. Water level data will be reported on an annual basis along with the reporting of the water take estimates.

6.2.4 *Water Quality*

Water quality monitoring is recommended at the in-pit sump(s) and existing monitoring bores while they remain accessible. Parameters monitored would include standard field parameters (pH, EC, temperature, ORP and DO) and laboratory analysis of TDS. Monitoring frequency of these sampling locations should be adaptable (depending on trends observed) with twice annual monitoring recommended for the first year of monitoring. Water quality results will be reported on an annual basis along with the reporting of the water take estimates.

Monitoring water quality of water discharges from the site would continue as per the conditions specified in the site Environmental Protection Licence (EPL). In addition to the current suite of parameters, it is recommended that consideration be given to including EC and TDS in the EPL related compliance monitoring.

6.3 *FURTHER RECOMMENDATIONS*

Following eventual cessation of quarrying activities (and pumping from pit sumps stopping) the final pit void would be expected to fill with water to some degree. The annual rainfall exceeded evaporation in the region coupled with the relatively low hydraulic conductivity of the host rock would likely result in water levels in the pit rising above pre-quarrying groundwater levels.

The magnitude of water level rise in the pit (and potential for overtopping) and long-term evolution of water quality will depend largely on the interplay between groundwater inflow to and outflow from the pit, rainfall and evaporative processes. If assessment of potential groundwater impact post-closure is required, pit lake modelling will be undertaken.

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Annex A

Borelogs

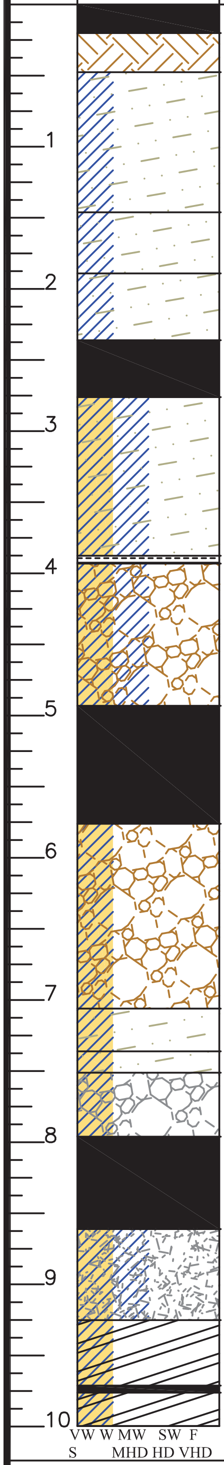
HANSON CONSTRUCTION MATERIALS

GRAPHIC DRILL LOG

HOLE: SA-1501-DH
PROJECT: SANCROX EXTENSION, ZONE 56
PAGE 1 OF 6

LOCATION: 481984,6521978 GDA
DRILLED: MACQUARIE DRILLING
LOGGED: P BROWNE 19/5/15

DPH | LOG | DESCRIPTION



NO CORE

BROWN SUBSOIL

GREY BROWN FINE GRAINED SANDSTONE HIGHLY FRACTURED

GREY BROWN FINE GRAINED SANDSTONE FRACTURED, VERTICAL AND 45° TO CORE AXIS

GREY BROWN FINE GRAINED SANDSTONE HIGHLY FRACTURED

NO CORE

GREY BROWN FINE GRAINED SANDSTONE FRACTURES 11cm APART

WHITE WEATHERED CLAY

BROWN COARSE GRAINED CONGLOMERATE POORLY WELDED , FRACTURES 14cm APART

NO CORE

BROWN COARSE GRAINED CONGLOMERATE WELDED , FRACTURES 11cm APART

GREY BROWN FINE GRAINED SANDSTONE FRACTURES 7cm APART AND FRACTURES AT 85° TO CORE AXIS

GREY BROWN FINE GRAINED SANDSTONE FRACTURES 7cm APART

LIGHT GREY CONGLOMERATE FRAGMENTS TO 50mm HIGHLY FRACTURED BUT WELDED

NO CORE

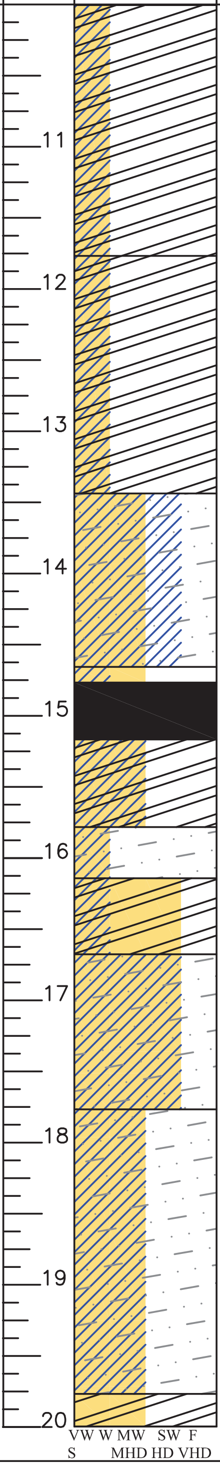
GREY CONGLOMERATE FRAGMENTS TO 50mm BRECCIATED

BLACK SHALE, HIGHLY FRACTURED

NO CORE

BLACK SHALE, FRACTURES 10cm APART, CALCITE IN GROUNDMASS

DPH | LOG | DESCRIPTION



BLACK SHALE, FRACTURES 8cm APART, CALCITE IN GROUNDMASS

BLACK SHALE, FRACTURES 12cm APART, CALCITE IN GROUNDMASS, HIGHLY FRACTURED AT 11.6m

GREY COARSE GRAINED SANDSTONE POORLY SORTED FELDSPAR & SANDSTONE FRAGMENTS TO 7mm MINOR BLACK SHALE LAMINAE PERPENDICULAR TO CORE AXIS, FRACTURES 30cm APART, AND A VERTICAL FRACTURE FROM 14.4m

BLACK SHALE, FRACTURES 8cm APART, CALCITE IN GROUNDMASS

NO CORE

BLACK SHALE, FRACTURES 8cm APART, CALCITE IN GROUNDMASS, FRACTURE 30° TO CORE AXIS

GREY COARSE GRAINED SANDSTONE POORLY SORTED FELDSPAR & SANDSTONE FRAGMENTS, HIGHLY FRACTURED

BLACK SHALE, FRACTURES 8cm APART, CALCITE IN GROUNDMASS

GREY COARSE GRAINED SANDSTONE POORLY SORTED FELDSPAR & SANDSTONE FRAGMENTS TO 7mm MINOR BLACK SHALE LAMINAE PERPENDICULAR TO CORE AXIS, FRACTURES 20cm APART, AND A VERTICAL FRACTURE FROM 16..7m

GREY COARSE GRAINED SANDSTONE WITH LAYERS OF FINE GRAINED SANDSTONE, POORLY SORTED FELDSPAR & SANDSTONE FRAGMENTS TO 4mm, FRACTURES 30 TO 50cm APART HIGHLY FRACTURED @ 18.8m

BLACK SHALE, FRACTURES 10cm APART, CALCITE IN GROUNDMASS, FRACTURE 80° TO CORE AXIS

COMMENTS:

LEGEND: VW VERY WEATHERED, W WEATHERED, MW MODERATELY WEATHERED, SW SLIGHTLY WEATHERED, F FRESH 🟨
S SOFT, MHD MEDIUM HARD, HD HARD, VHD VERY HARD ▨

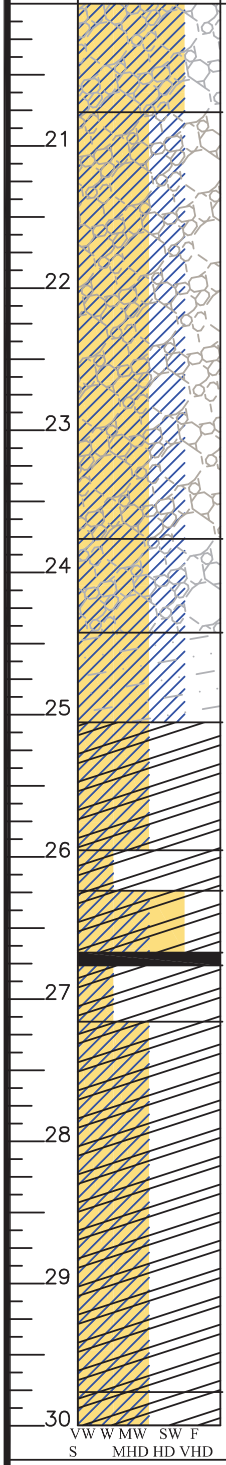
HANSON CONSTRUCTION MATERIALS

GRAPHIC DRILL LOG

HOLE: SA-1501-DH
PROJECT: SANCROX EXTENSION, ZONE 56
PAGE 2 OF 6

LOCATION: 481984,6521978 GDA
DRILLED: MACQUARIE DRILLING
LOGGED: P BROWNE 19/5/15

DPH | LOG | DESCRIPTION



LIGHT GREY COARSE GRAINED CONGLOMERATE POORLY SORTED FELDSPAR & SANDSTONE FRAGMENTS TO 14mm, FRACTURES 15cm APART, CALCITE VEIN 45° TO CORE AXIS

LIGHT GREY BROWN COARSE GRAINED CONGLOMERATE POORLY SORTED FELDSPAR & SANDSTONE FRAGMENTS TO 40mm, FRACTURES 25cm APART

LIGHT GREY COARSE GRAINED CONGLOMERATE POORLY SORTED FELDSPAR & SANDSTONE FRAGMENTS TO 40mm, FRACTURES 25cm APART, FRACTURE 45° TO CORE AXIS AT BASE

LIGHT GREY MEDIUM GRAINED SANDSTONE POORLY SORTED FELDSPAR & SANDSTONE FRAGMENTS TO 7mm MINOR BLACK SHALE LAMINAE PERPENDICULAR TO CORE AXIS, FRACTURES 40cm APART

BLACK SHALE CALCITE IN GROUNDMASS FRACTURES FRACTURE 9cm APART PERPENDICULAR TO CORE AXIS

BROWN SHALE CALCITE IN GROUNDMASS FRACTURES 3cm APART PERPENDICULAR TO CORE AXIS

BLACK SHALE CALCITE IN GROUNDMASS FRACTURES FRACTURE 15cm APART PERPENDICULAR TO CORE AXIS

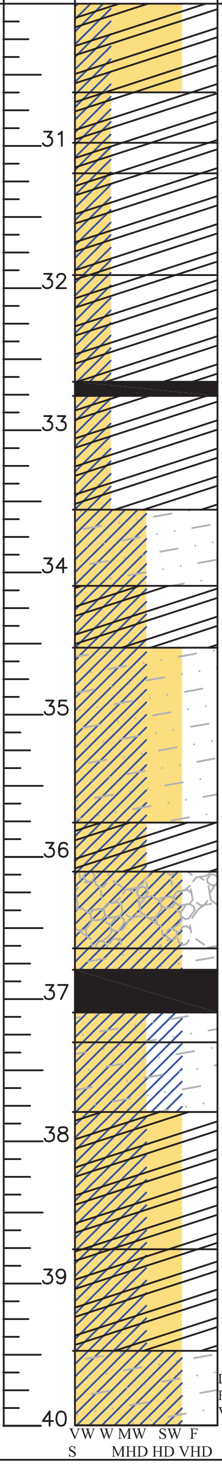
NO CORE

BROWN SHALE CALCITE IN GROUNDMASS FRACTURES FRACTURE 3cm APART PERPENDICULAR TO CORE AXIS

BLACK SHALE CALCITE IN GROUNDMASS FRACTURES 6cm APART PERPENDICULAR TO CORE AXIS, CALCITE VEINS 45° TO CORE AXIS AND SOME INTERVALS HAVE MULTIPLE VERTICAL CALCITE VEINS

BLACK SHALE CALCITE IN GROUNDMASS FRACTURES 15cm APART PERPENDICULAR TO CORE AXIS

DPH | LOG | DESCRIPTION



BLACK SHALE CALCITE IN GROUNDMASS FRACTURES 6 TO 15cm APART PERPENDICULAR TO CORE AXIS, CALCITE VEINS 45° TO CORE AXIS

BROWN SHALE CALCITE IN GROUNDMASS HIGHLY FRACTURED

BROWN SHALE CALCITE IN GROUNDMASS FRACTURES 3cm APART PERPENDICULAR TO CORE AXIS

BLACK SHALE CALCITE IN GROUNDMASS FRACTURES 6 TO 15cm APART PERPENDICULAR TO CORE AXIS, CALCITE VEINS 45° TO CORE AXIS

NO CORE

BLACK SHALE CALCITE IN GROUNDMASS FRACTURES 4cm APART PERPENDICULAR TO CORE AXIS, CALCITE VEINS 85° TO CORE AXIS

LIGHT GREY SANDSTONE POORLY SORTED FELDSPAR HIGHLY FRACTURED

BLACK SHALE CALCITE IN GROUNDMASS FRACTURES 15m APART 30° TO CORE AXIS, CALCITE VEINS 45° TO CORE AXIS

LIGHT GREY SANDSTONE POORLY SORTED, HIGHLY FRACTURED

BLACK SHALE CALCITE IN GROUNDMASS FRACTURES 15m APART 30° TO CORE AXIS, CALCITE VEINS 85° TO CORE AXIS

LIGHT GREY CONGLOMERATE POORLY SORTED, FRACTURED, CALCITE ON FRACTURES

LIGHT GREY SANDSTONE POORLY SORTED, HIGHLY FRACTURED

NO CORE

LIGHT GREY SANDSTONE POORLY SORTED, HIGHLY FRACTURED

LIGHT GREY SANDSTONE POORLY SORTED, HIGHLY FRACTURED

BLACK SHALE WITH BANDS OF FINE GREY SANDSTONE CALCITE IN SHALE GROUNDMASS FRACTURES 15m APART 30° TO CORE AXIS, CALCITE VEINS 45° TO CORE AXIS

BLACK SHALE WITH BANDS OF FINE GREY SANDSTONE CALCITE IN SHALE GROUNDMASS FRACTURES 15m APART 30° TO CORE AXIS, CALCITE VEINS 45° AND PARALLEL TO CORE AXIS

LIGHT GREY SANDSTONE POORLY SORTED, HIGHLY FRACTURED FRACTURES FILLED WITH CALCITE VEINS

COMMENTS:

LIGHT BROWN CONGLOMERATE POORLY SORTED FELDSPAR & SANDSTONE FRAGMENTS TO 40mm, FRACTURES 30 TO 100cm APART

LEGEND: VW VERY WEATHERED, W WEATHERED, MW MODERATELY WEATHERED, SW SLIGHTLY WEATHERED, F FRESH 🟨
S SOFT, MHD MEDIUM HARD, HD HARD, VHD VERY HARD ▨

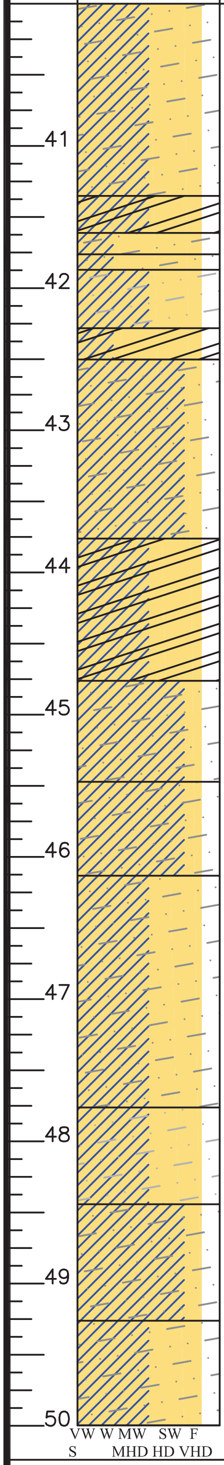
HANSON CONSTRUCTION MATERIALS

GRAPHIC DRILL LOG

HOLE: SA-1501-DH
PROJECT: SANCROX EXTENSION, ZONE 56
PAGE 3 OF 6

LOCATION: 481984,6521978 GDA
DRILLED: MACQUARIE DRILLING
LOGGED: P BROWNE 19/5/15

DPH LOG DESCRIPTION



GREY FINE TO COARSE GRAINED SANDSTONE POORLY SORTED WITH SHALE AND SANDSTONE FRAGMENTS, HIGHLY FRACTURED, FRACTURES PERPENDICULAR TO CORE AXIS

BLACK SHALE CALCITE IN GROUNDMASS FRACTURED

GREY FINE TO COARSE GRAINED SANDSTONE POORLY SORTED WITH SHALE AND SANDSTONE FRAGMENTS, HIGHLY FRACTURED

LIGHT GREY BRECCIA WITH SHALE AND CALCITE IN THE GROUNDMASS

BLACK SHALE CALCITE IN GROUNDMASS FRACTURED

GREY FINE GRAINED SANDSTONE WITH BANDS OF BLACK SHALE @ 42.7 FRACTURES 10cm APART

BLACK SHALE CALCITE IN GROUNDMASS AT ALL ANGLES, FRACTURES 20cm APART 85° TO CORE AXIS

GREY FINE GRAINED SANDSTONE, FRACTURES 8cm APART

GREY MEDIUM GRAINED SANDSTONE, WITH BANDS CONTAINING SHALE FRAGMENTS PERPENDICULAR TO THE CORE AXIS

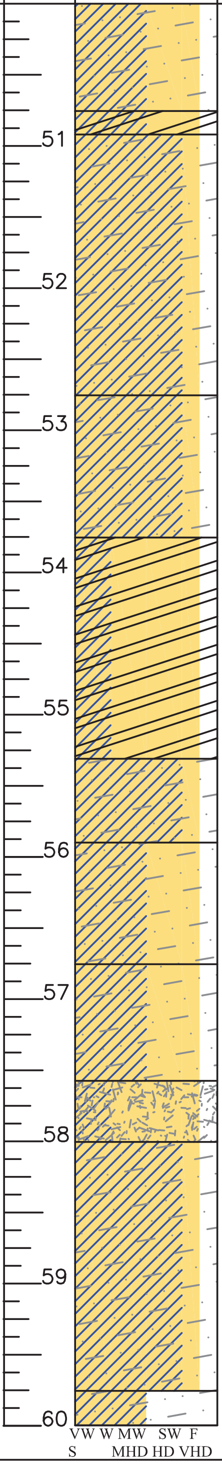
GREY FINE GRAINED SANDSTONE, WITH BANDS CONTAINING SHALE FRAGMENTS AND DOMINANT SHALE @46.8m. BANDS 80° TO CORE AXIS. FRACTURES 20cm APART GENERALLY ALONG THE BANDS BUT SOME ARE IRREGUALAR CROSSING THE BANDING

LIGHT GREY FINE GRAINED SANDSTONE, WITH BANDS 75° TO CORE AXIS. FRACTURES 30cm APART

GREY FINE GRAINED SANDSTONE AND SHALE INTERBEDS,. BANDS 80° TO CORE AXIS. FRACTURES 30cm APART GENERALLY ALONG THE BAND

GREY FINE GRAINED SANDSTONE POORLY SORTED WITH SHALE AND SANDSTONE FRAGMENTS, FRACTURES 30cm APART

DPH LOG DESCRIPTION



GREY FINE GRAINED SANDSTONE POORLY SORTED WITH SHALE AND SANDSTONE FRAGMENTS, FRACTURES 30cm APART

BLACK SHALE CALCITE IN GROUNDMASS FRACTURED

GREY FINE GRAINED SANDSTONE WITH MINOR VERY FINE GRAINED SHALE AND SANDSTONE FRAGMENTS, FRACTURES 30cm APART. MINOR CALCITE VEINS PRESENT 45° TO CORE AXIS

GREY FINE GRAINED SANDSTONE WITH MINOR VERY FINE GRAINED SHALE AND SANDSTONE FRAGMENTS, FRACTURES 30cm APART. MANY CALCITE VEINS PRESENT PERPENDICULAR TO CORE AXIS

BLACK SHALE DOMINANT WITH CALCITE IN THE GROUNDMASS WITH BANDS AND BANDS OF FINE GRAINED SANDSTONE, FRACTURES 10cm APART

GREY MEDIUM GRAINED SANDSTONE WITH MINOR VERY FINE GRAINED SHALE AND SANDSTONE FRAGMENTS, FRACTURES 30cm APART.

GREY FINE GRAINED SANDSTONE BRECCIA WITH THE GROUNDMASS HEAVILY BROKEN UP, HIGHLY FRACTURED

GREY FINE GRAINED SANDSTONE WITH THE GROUNDMASS CONTAINING CALCITE VEINS, FRACTURES 10cm APART

GREY FINE GRAINED SANDSTONE BRECCIA WITH THE GROUNDMASS HEAVILY BROKEN UP, HIGHLY FRACTURED

GREY FINE GRAINED SANDSTONE WITH MINOR VERY FINE GRAINED SHALE AND SANDSTONE FRAGMENTS, FRACTURES 30cm APART. MINOR CALCITE VEINS PRESENT 45° TO CORE AXIS

GREY BROWN FINE GRAINED SANDSTONE, FRACTURES 10cm APART.

COMMENTS:

LEGEND: VW VERY WEATHERED, W WEATHERED, MW MODERATELY WEATHERED, SW SLIGHTLY WEATHERED, F FRESH 🟨
S SOFT, MHD MEDIUM HARD, HD HARD, VHD VERY HARD ▨

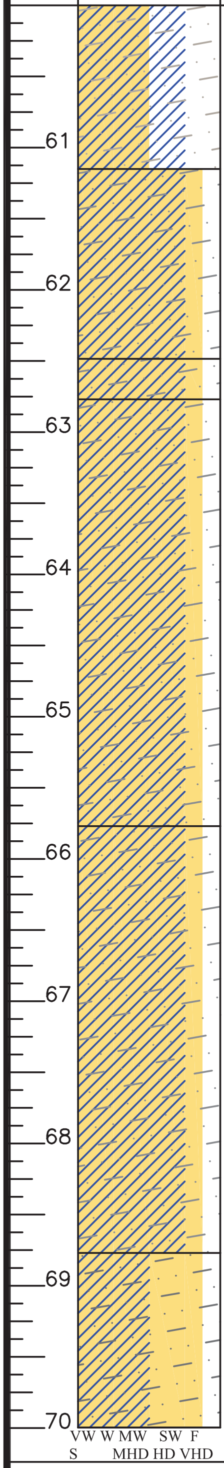
HANSON CONSTRUCTION MATERIALS

GRAPHIC DRILL LOG

HOLE: SA-1501-DH
PROJECT: SANCROX EXTENSION, ZONE 56
PAGE 4 OF 6

LOCATION: 481984,6521978 GDA
DRILLED: MACQUARIE DRILLING
LOGGED: P BROWNE 19/5/15

DPH LOG DESCRIPTION



GREY BROWN MEDIUM GRAINED SANDSTONE, FRACTURES 25 TO 80cm APART CALCITE IN GROUNDMASS

GREY VERY FINE GRAINED SANDSTONE, FRACTURES 25 TO 50cm APART CALCITE VEINS IN PLACES, BANDING 45° TO CORE AXIS, FRACTURES CALCITE FILLED, BASE BRECCIATED BUT WELDED

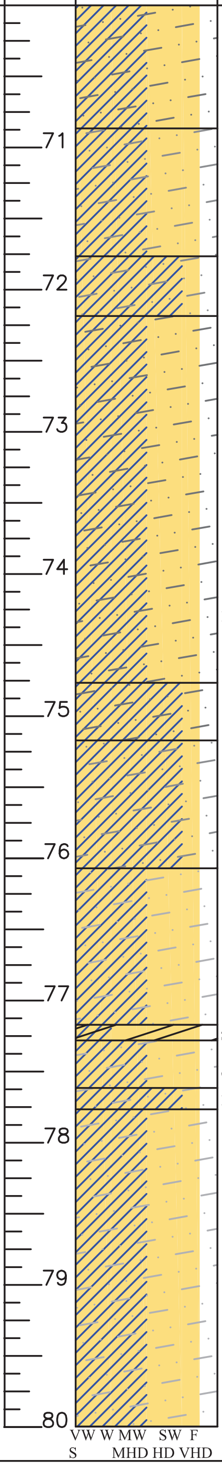
GREY VERY FINE GRAINED SANDSTONE, BANDING 45° TO CORE AXIS, FRACTURES CALCITE FILLED

GREY VERY FINE GRAINED SANDSTONE, BANDING 45° TO CORE AXIS, FRACTURES 30cm APART CALCITE IN GROUNDMASS AND BANDING SOME WITH MORE SHALE FRAGMENTS, 45° TO CORE AXIS

GREY VERY FINE GRAINED SANDSTONE, BANDING 45° TO CORE AXIS, FRACTURES 30cm APART CALCITE IN GROUNDMASS AND BANDING SOME WITH MORE SHALE FRAGMENTS, 45° TO CORE AXIS

DARK GREY VERY FINE GRAINED SANDSTONE, BANDING 80° TO CORE AXIS WITH SOME SHALE FRAGMENTS AND LIGHT GREY BANDS, FRACTURES 15cm APART CALCITE IN GROUNDMASS AND BANDING SOME WITH MORE SHALE FRAGMENTS, 80° TO CORE AXIS

DPH LOG DESCRIPTION



DARK GREY VERY FINE GRAINED SANDSTONE, BANDING 80° TO CORE AXIS WITH SOME SHALE FRAGMENTS, FRACTURES 8cm APART CALCITE IN GROUNDMASS

GREY VERY FINE GRAINED SANDSTONE, BANDING 85° TO CORE AXIS, FRACTURES 30cm APART CALCITE IN GROUNDMASS AND BANDING SOME WITH MORE SHALE FRAGMENTS, 85° TO CORE AXIS

GREY VERY FINE GRAINED SANDSTONE, BANDING 85° TO CORE AXIS, FRACTURES 30cm APART CALCITE IN GROUNDMASS AND BANDING SOME WITH MORE SHALE FRAGMENTS, 85° TO CORE AXIS

DARK GREY VERY FINE GRAINED SANDSTONE, BANDING 70° TO CORE AXIS WITH SOME SHALE FRAGMENTS AND LIGHT GREY BANDS, FRACTURES 15 TO 40cm APART CALCITE IN GROUNDMASS AND BANDING SOME WITH MORE SHALE FRAGMENTS, 45° TO CORE AXIS

FRACTURED ZONE SHALE DOMINANT

DARK GREY VERY FINE GRAINED SANDSTONE, FRACTURES 15cm APART CALCITE IN GROUNDMASS

DARK AND LIGHT GREY VERY FINE GRAINED SANDSTONE, WITH SOME SHALE FRAGMENTS AND LIGHT GREY BANDS, FRACTURES 15 TO 40cm APART CALCITE IN GROUNDMASS AND MINOR BRECCIATION

LIGHT GREY FINE GRAINED SANDSTONE,WITH SOME SHALE FRAGMENTS, FRACTURES 40cm APART. CALCITE IN GROUNDMASS AND BANDING SOME WITH MORE SHALE FRAGMENTS, 45° TO CORE AXIS

SHALE BAND

CALCITE BAND

LIGHT GREY FINE GRAINED SANDSTONE

LIGHT GREY FINE GRAINED SANDSTONE,WITH RARE SHALE FRAGMENTS, FRACTURES 40cm APART. CALCITE IN GROUNDMASS VEINS 45° TO CORE AXIS

COMMENTS:

LEGEND: VW VERY WEATHERED, W WEATHERED, MW MODERATELY WEATHERED, SW SLIGHTLY WEATHERED, F FRESH 🟨
S SOFT, MHD MEDIUM HARD, HD HARD, VHD VERY HARD ▨

HANSON CONSTRUCTION MATERIALS

GRAPHIC DRILL LOG

HOLE: SA-1501-DH
PROJECT: SANCROX EXTENSION, ZONE 56
PAGE 5 OF 6

LOCATION: 481984,6521978 GDA
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LOGGED: P BROWNE 19/5/15

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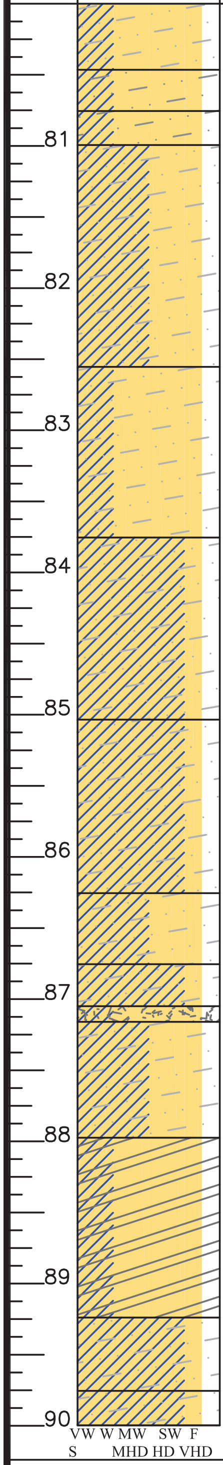


LIGHT GREY FINE GRAINED SANDSTONE,WITH RARE SHALE FRAGMENTS, FRACTURES 40cm APART. CALCITE IN GROUNDMASS VEINS 45° TO CORE AXIS

GREY VERY FINE GRAINED SANDSTONE BRECCIATED

GREY VERY FINE GRAINED SANDSTONE BRECCIATED WELDED

LIGHT GREY FINE GRAINED SANDSTONE,WITH RARE SHALE FRAGMENTS, HIGHLY FRACTURED CALCITE IN GROUNDMASS VEINS AT ALL ANGLES.

LIGHT GREY FINE GRAINED SANDSTONE, FRACTURES 40cm APART. CALCITE IN GROUNDMASS VEINS 45° TO CORE AXIS

HIGHLY FRACTURED

LIGHT GREY FINE GRAINED SANDSTONE, FRACTURES 40cm APART. CALCITE IN GROUNDMASS VEINS 25° TO CORE AXIS, FRACTURES ALSO 35° TO CORE AXIS

LIGHT GREY MEDIUM GRAINED SANDSTONE WITH MINOR SHALE FRAGMENTS, FRACTURES 20cm APART. CALCITE IN GROUNDMASS

LIGHT GREY FINE GRAINED SANDSTONE, FRACTURES 40cm APART. HIGH PERCENTAGE OF CALCITE IN GROUNDMASS 85° TO CORE AXIS, SLIGHTLY BRECCIATED

LIGHT GREY FINE GRAINED SANDSTONE,SHALE FRAGMENTS, CALCITE IN GROUNDMASS , SLIGHTLY BRECCIATED

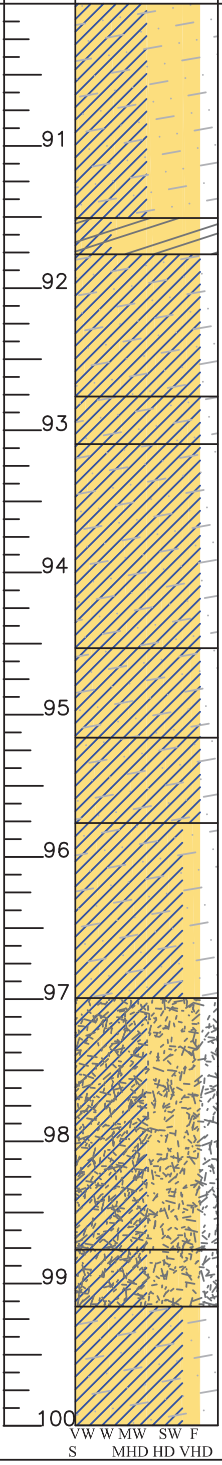
LIGHT GREY FINE GRAINED SANDSTONE,SHALE FRAGMENTS, CALCITE IN GROUNDMASS AND VEINS 45° TO CORE AXIS AND PERPENDICULAR TO BANDING

DARK GREY SHALE, CALCITE IN GROUNDMASS AND VEINS 85° TO CORE AXIS FRACTURES 10cM APART

LIGHT GREY FINE GRAINED SANDSTONE,SHALE FRAGMENTS, CALCITE IN GROUNDMASS AND VEINS 45° TO CORE AXIS AND PERPENDICULAR TO BANDING

LIGHT GREY FINE GRAINED SANDSTONE,SHALE FRAGMENTS, CALCITE IN GROUNDMASS AND VEINS 45° TO CORE AXIS AND PERPENDICULAR TO BANDING

DPH LOG DESCRIPTION



LIGHT GREY FINE GRAINED SANDSTONE,SHALE FRAGMENTS, CALCITE IN GROUNDMASS AND VEINS 45° TO CORE AXIS AND PERPENDICULAR TO BANDING

DARK GREY SHALE, MINOR CALCITE IN GROUNDMASS AND VEINS 25° TO CORE AXIS FRACTURES 10cm APART

LIGHT GREY FINE GRAINED SANDSTONE,WITH RARE SHALE FRAGMENTS, FRACTURES 40cm APART. CALCITE IN GROUNDMASS VEINS 45° TO CORE AXIS

LIGHT GREY FINE GRAINED SANDSTONE,WITH RARE SHALE FRAGMENTS, FRACTURES 40cm APART. CALCITE IN GROUNDMASS VEINS 45° TO CORE AXIS

LIGHT GREY MEDIUM GRAINED SANDSTONE,WITH RARE SHALE FRAGMENTS, FRACTURES 40cm APART. CALCITE IN GROUNDMASS VEINS 45° TO CORE AXIS

LIGHT GREY VERY FINE GRAINED SANDSTONE,WITH RARE SHALE FRAGMENTS, FRACTURES 40cm APART. CALCITE IN GROUNDMASS BANDING 45° TO CORE AXIS

LIGHT GREY FINE GRAINED SANDSTONE,WITH RARE SHALE FRAGMENTS, FRACTURES 40cm APART. CALCITE IN GROUNDMASS VEINS 45° TO CORE AXIS

LIGHT GREY MEDIUM GRAINED SANDSTONE,WITH RARE SHALE FRAGMENTS, FRACTURES 40cm APART. CALCITE IN GROUNDMASS VEINS 45° TO CORE AXIS

DARK GREY VERY FINE GRAINED BRECCIA WITH SHALE AND SANDSTONE MIXTURE, AND MULTIPLE CALCITE VEINS, FRACTURES 15cm APART.

DARK GREY VERY FINE GRAINED BRECCIA WITH SHALE AND SANDSTONE MIXTURE, AND MULTIPLE CALCITE VEINS, FRACTURES 15cm APART.

LIGHT GREY MEDIUM GRAINED SANDSTONE,WITH RARE SHALE FRAGMENTS, FRACTURES 40cm APART. CALCITE IN GROUNDMAS SOME BRECCIATION

COMMENTS:

LEGEND: VW VERY WEATHERED, W WEATHERED, MW MODERATELY WEATHERED, SW SLIGHTLY WEATHERED, F FRESH 🟨
S SOFT, MHD MEDIUM HARD, HD HARD, VHD VERY HARD ▨

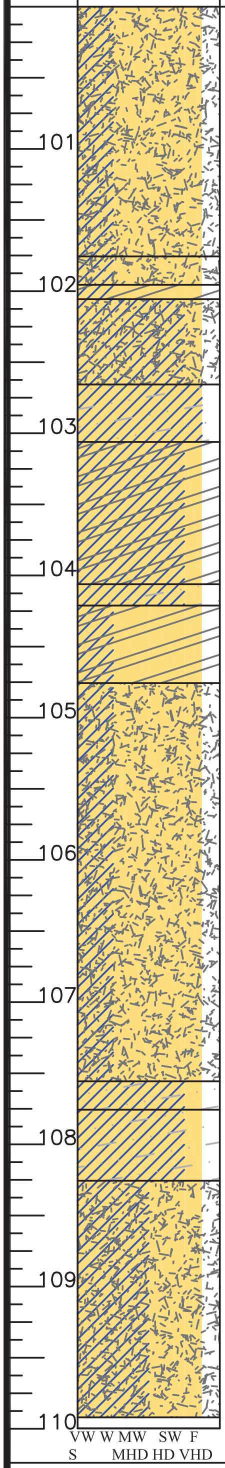
HANSON CONSTRUCTION MATERIALS

GRAPHIC DRILL LOG

HOLE: SA–1501–DH
PROJECT: SANCROX EXTENSION, ZONE 56
PAGE 6 OF 6

LOCATION: 481984,6521978 GDA
DRILLED: MACQUARIE DRILLING
LOGGED: P BROWNE 19/5/15

DPH | LOG | DESCRIPTION



LIGHT GREY MEDIUM GRAINED SANDSTONE BRECCIA WITH RARE SHALE FRAGMENTS, FRACTURES 10 TO 40cm APART. SIGNIFICANT CALCITE IN GROUNDMASS

DARK GREY SHALE

LIGHT GREY MEDIUM GRAINED SANDSTONE BRECCIA WITH RARE SHALE FRAGMENTS, FRACTURES 10 TO 40cm APART. SIGNIFICANT CALCITE IN GROUNDMASS

LIGHT GREY VERY FINE GRAINED SANDSTONE

DARK GREY SHALE WITH SANDSTONE BANDS, MINOR CALCITE IN GROUNDMASS AND VEINS 25° TO CORE AXIS FRACTURES 10cm APART

LIGHT GREY MEDIUM GRAINED SANDSTONE

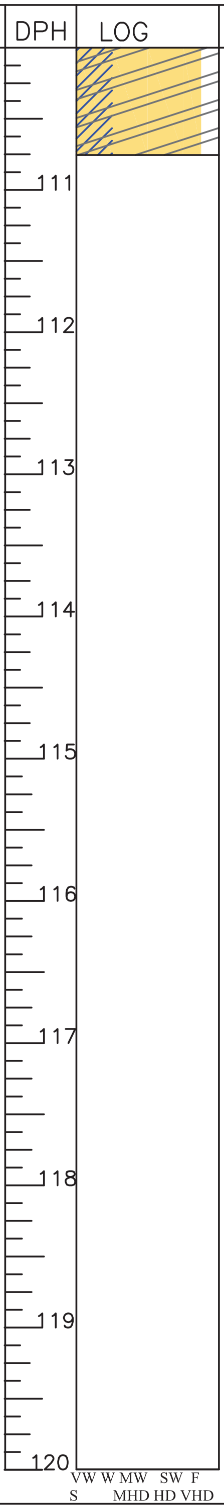
DARK GREY SHALE WITH SANDSTONE BANDS, MINOR CALCITE IN GROUNDMASS AND VEINS 25° TO CORE AXIS FRACTURES 10cm APART

DARK GREY BRECCIA,RARE SHALE AND FINE SANDSTONE BEDS, FRACTURES 20cm APART. CALCITE IN GROUNDMASS VEINS 45° TO CORE AXIS

LIGHT GREY VERY FINE GRAINED SANDSTONE WITH RARE SHALE FRAGMENTS, FRACTURES 10 TO 20cm APART.

DARK GREY BRECCIA,RARE SHALE AND FINE SANDSTONE BEDS, FRACTURES 20cm APART. CALCITE IN GROUNDMASS VEINS 45° TO CORE AXIS

DPH | LOG | DESCRIPTION



DARK GREY SHALE CALCITE IN GROUNDMASS

COMMENTS:

LEGEND: VW VERY WEATHERED, W WEATHERED, MW MODERATELY WEATHERED, SW SLIGHTLY WEATHERED, F FRESH 🟨
S SOFT, MHD MEDIUM HARD, HD HARD, VHD VERY HARD ▨

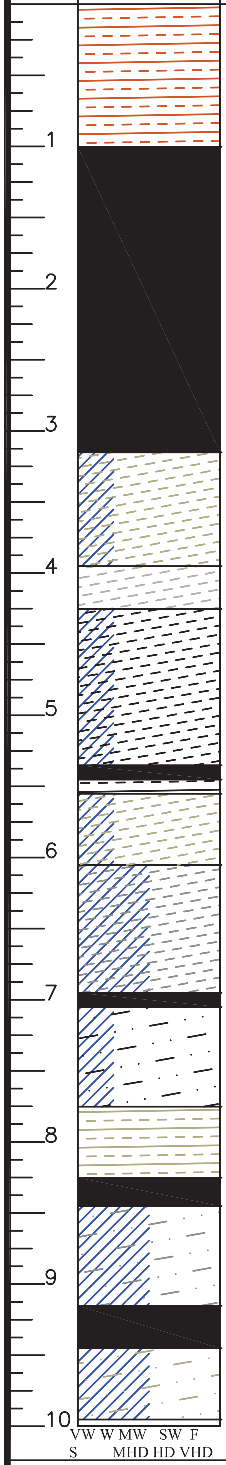
HANSON CONSTRUCTION MATERIALS

GRAPHIC DRILL LOG

HOLE: SA-1502-DH
PROJECT: SANCROX EXTENSION, ZONE 56
PAGE 1 OF 5

LOCATION: 4821703,6522320GDA
DRILLED: MACQUARIE DRILLING
LOGGED: P BROWNE 2/7/15

DPH | LOG | DESCRIPTION



BROWN SUBSOIL

RED BROWN CLAY WHITE AT BASE

NO CORE

GREY BROWN FINE GRAINED SILTSTONE FRACTURES 8cm APART, WEATHERED MEDIUM SOFT BROWN CLAYS PRESENT

LIGHT GREY BROWN FINE GRAINED SILTSTONE FRACTURES 11cm APART, WEATHERED MEDIUM SOFT BROWN CLAYS PRESENT

GREY BLUE FINE GRAINED SILTSTONE FRACTURES 10cm APART, WEATHERED MEDIUM SOFT BROWN CLAYS PRESENT ON FRACTURES, RUBBLE AT BASE

NO CORE

BROWN CLAY

GREY BROWN VERY FINE GRAINED SILTSTONE WELDED , FRACTURES 10cm APART WEATHERED MEDIUM HARD

GREY FINE GRAINED SILTSTONE FRACTURES 10cm APART VERY WEATHERED MEDIUM SOFT

NO CORE

GREY BROWN FINE GRAINED LAYERED SILTSTONE FRACTURES 11cm APART MODERATELY WEATHERED MEDIUM HARD

GREY BROWN RUBBLE AND CLAY

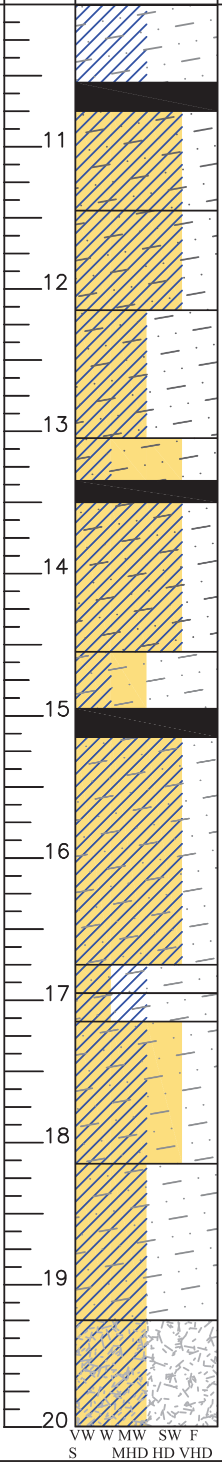
NO CORE

GREY VERY FINE GRAINED SANDSTONE SLIGHTLY WEATHERED MEDIUM HARD

NO CORE

GREY BROWN VERY FINE GRAINED SANDSTONE SLIGHTLY WEATHERED MEDIUM HARD

DPH | LOG | DESCRIPTION



GREY COARSE GRAINED SANDSTONE POORLY SORTED FELDSPAR & SANDSTONE FRAGMENTS, HIGHLY FRACTURED, CLAYS ON FRATURES

NO CORE

DARK GREY MEDIUM GRAINED SANDSTONE POORLY SORTED FELDSPAR & SANDSTONE FRAGMENTS, CALCITE VEINS 45° TO CORE AXIS FRACTURES 15cm APART SLIGHTLY WEATHERED, HARD

DARK GREY MEDIUM GRAINED SANDSTONE POORLY SORTED FELDSPAR & SANDSTONE FRAGMENTS, CALCITE VEINS 45° TO CORE AXIS FRACTURES 10cm APART

DARK GREY MEDIUM GRAINED SANDSTONE POORLY SORTED FELDSPAR & SANDSTONE FRAGMENTS, CALCITE VEINS 45° TO CORE AND CALCITE IN GROUNDMASS AXIS FRACTURES 10cm APART FRESH MEDIUM HARD

DARK GREY MEDIUM GRAINED SANDSTONE POORLY SORTED FELDSPAR & SANDSTONE FRAGMENTS, HIGHLY FRACTURED

NO CORE

DARK GREY FINE GRAINED SANDSTONE MINOR BLACK SHALE LAMINAE PERPENDICULAR TO CORE AXIS, FRACTURES 15cm APART, AND FRACTURED FROM 14.4m

GREY COARSE GRAINED SANDSTONE POORLY SORTED FELDSPAR & SANDSTONE FRAGMENTS, HIGHLY FRACTURED, CLAYS ON FRATURES

NO CORE

GREY COARSE GRAINED SANDSTONE POORLY SORTED FELDSPAR & SANDSTONE FRAGMENTS, HIGHLY CALCITE VEINS AT ALL ANGLES WITH PARTINGS ALONG SOME OF THE FRACTURES, SLIGHTLY WEATHERED, MEDIUM HARD, FRACTURES 20cm APART

HIGHLY FRACTURED ZONE

HIGHLY FRACTURED ZONE

GREY COARSE GRAINED SANDSTONE POORLY SORTED FELDSPAR & SANDSTONE FRAGMENTS TO 4mm MINOR BLACK SHALE LAMINAE, FRACTURES 15cm APART, MANY CALCITE VEINS AT ALL ANGLES TO CORE AXIS

GREY FINE GRAINED LAMINATED SANDSTONE WITH LAYERS OF VERY FINE GRAINED SANDSTONE, FRACTURES 30cm APART HIGHLY FRACTURED @ 18.8m

LIGHT GREY FINE GRAINED BRECCIA WITH FRAGMENTS TO 8mm MODERATELY ALTERED FRACTURES 20cM APART

COMMENTS:

LEGEND: VW VERY WEATHERED, W WEATHERED, MW MODERATELY WEATHERED, SW SLIGHTLY WEATHERED, F FRESH 🟨
S SOFT, MHD MEDIUM HARD, HD HARD, VHD VERY HARD ▨

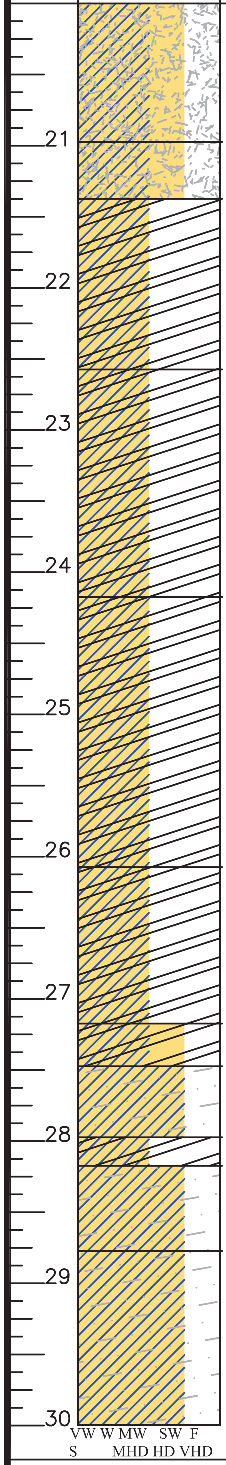
HANSON CONSTRUCTION MATERIALS

GRAPHIC DRILL LOG

HOLE: SA-1502-DH
PROJECT: SANCROX EXTENSION, ZONE 56
PAGE 2 OF 5

LOCATION: 4821703,6522320GDA
DRILLED: MACQUARIE DRILLING
LOGGED: P BROWNE 2/7/15

DPH | LOG | DESCRIPTION



LIGHT GREY BRECCIA , FRACTURES 20cm APART, SLIGHTLY WEATHERED MEDIUM HARD

LIGHT GREY BRECCIA , HIGHLY FRACTURED, SLIGHTLY WEATHERED MEDIUM HARD

BLACK SHALE CALCITE IN GROUNDMASS FRACTURES 15cm APART PERPENDICULAR TO CORE AXIS. MINOR BANDS OF WEATHERED SANDSTONE

BLACK SHALE CALCITE IN GROUNDMASS AND IN VEINS AT ALL ANGLES, FRACTURES 15cm APART PERPENDICULAR TO CORE AXIS, MODERATELY FRESH MEDIUM SOFT

BLACK SHALE CALCITE IN GROUNDMASS AND IN VEINS AT ALL ANGLES, FRACTURES 15cm APART PERPENDICULAR TO CORE AXIS, MODERATELY FRESH MEDIUM SOFT, VERY FRACTURES @ 26.9m

BLACK SHALE CALCITE IN GROUNDMASS AND IN VEINS AT ALL ANGLES, FRACTURES 15cm APART PERPENDICULAR TO CORE AXIS, MODERATELY FRESH MEDIUM SOFT

BLACK SHALE CALCITE IN GROUNDMASS FRACTURES 10cm APART PERPENDICULAR TO CORE AXIS

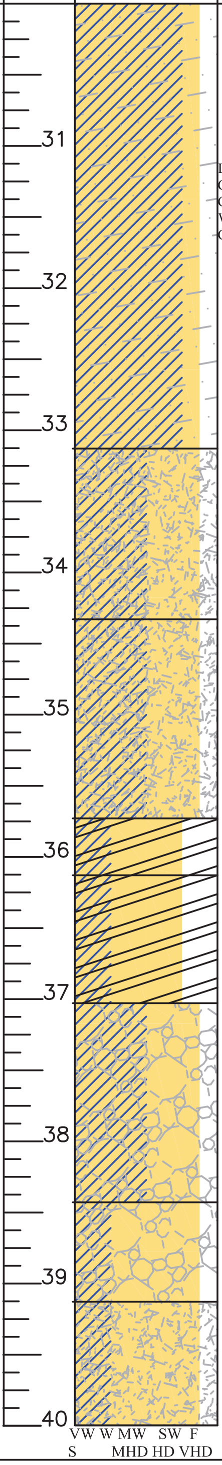
LIGHT GREY MEDIUM TO FINE GRAINED SANDSTONE MINOR BLACK SHALE LAMINAE PERPENDICULAR TO CORE AXIS, FRACTURES 20cm APART

BLACK SHALE CALCITE IN GROUNDMASS FRACTURES 10cm APART PERPENDICULAR TO CORE AXIS

LIGHT GREY MEDIUM TO FINE GRAINED SANDSTONE MINOR BLACK SHALE FRAGMENTS, FRACTURES 30cm APART, SLIGHTLY WEATHERED, HARD

LIGHT GREY MEDIUM GRAINED SANDSTONE POORLY SORTED FELDSPAR & SANDSTONE FRAGMENTS TO 7mm MINOR VERTICAL FRACTURE CALCITE FILLED, FRACTURES 30cm APART, HARD SLIGHTLY WEATHERED

DPH | LOG | DESCRIPTION



LIGHT GREY COARSE SANDSTONE TO CONGLOMERATE WITH EQUANT SUB ANGULAR FINE GRAINED SANDSTONE FRAGMENTS, FRESH HARD WITH SOME FRACTURES 10° TO CORE AXIS, MINOR CALCITE VEINS

BRECCIA WITH BLACK SHALE IN VERTICAL FRACTURE FRACTURES 15cm APART 30° TO CORE AXIS, CALCITE VEINS AT ALL ANGLES TO CORE AXIS, FRESH MODERATELY HARD

LIGHT GREY BRECCIA, FRACTURES 15cm APART 30° TO CORE AXIS, CALCITE VEINS AT ALL ANGLES TO CORE AXIS, FRESH, MODERATELY HARD

BLACK SHALE CALCITE IN GROUNDMASS FRACTURES 15cm APART 30° TO CORE AXIS, CALCITE VEINS 65° TO CORE AXIS, SLIGHTLY WEATHERED, MEDIUM HARD

BLACK SHALE WITH BANDS OF FINE GREY SANDSTONE CALCITE IN SHALE GROUNDMASS FRACTURES 15cm APART 30° TO CORE AXIS, CALCITE VEINS 45° TO CORE AXIS

LIGHT GREY CONGLOMERATE POORLY SORTED, FRACTURED, CALCITE VEINS COMMON AND ON FRACTURES, FRESH MODERATELY HARD

LIGHT GREY CONGLOMERATE POORLY SORTED, FRACTURED, CALCITE VEINS COMMON AND ON FRACTURES, FRESH MODERATELY HARD

LIGHT GREY BRECCIA, FRACTURES 15cm APART 30° TO CORE AXIS, CALCITE VEINS AT ALL ANGLES TO CORE AXIS, FRESH, MODERATELY HARD

COMMENTS:

LIGHT BROWN CONGLOMERATE POORLY SORTED FELDSPAR & SANDSTONE FRAGMENTS TO 40mm, FRACTURES 30 TO 100cm APART

LEGEND: VW VERY WEATHERED, W WEATHERED, MW MODERATELY WEATHERED, SW SLIGHTLY WEATHERED, F FRESH 🟨
S SOFT, MHD MEDIUM HARD, HD HARD, VHD VERY HARD ▨

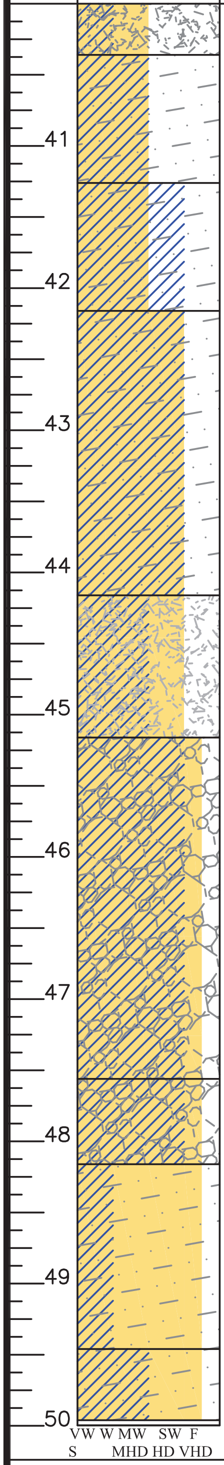
HANSON CONSTRUCTION MATERIALS

GRAPHIC DRILL LOG

HOLE: SA-1502-DH
PROJECT: SANCROX EXTENSION, ZONE 56
PAGE 3 OF 5

LOCATION: 4821703,6522320GDA
DRILLED: MACQUARIE DRILLING
LOGGED: P BROWNE 2/7/15

DPH | LOG | DESCRIPTION



GREY BRECCIA WITH SHALE BANDS, HIGHLY FRACTURED, FRACTURES AT ALL ANGLES TO TO CORE AXIS, MODERATELY WEATHERED MEDIUM HARD

GREY BRECCIA CONTACTED WITH MEDIUM SANDSTONE CONTACT 10° TO CORE AXIS, SLIGHTLY WEATHERED, HARD

GREY FINE TO COARSE GRAINED SANDSTONE POORLY SORTED WITH FELDSPAR AND SANDSTONE FRAGMENTS, MINOR CALCITE

GREY FINE GRAINED SANDSTONE, FINE AT THE TOP GRADING TO COARSE AT THE BASE. FRACTURES 40cm APART GENERALLY ALONG THE BANDS BUT SOME ARE IRREGUALAR CROSSING THE BANDING

LIGHT GREY MEDIUM GRAINED BRECCIA, CALCITE VEINS AT ALL ANGLES IN THE GROUNDMASS, FRESH MEDIUM SOFT

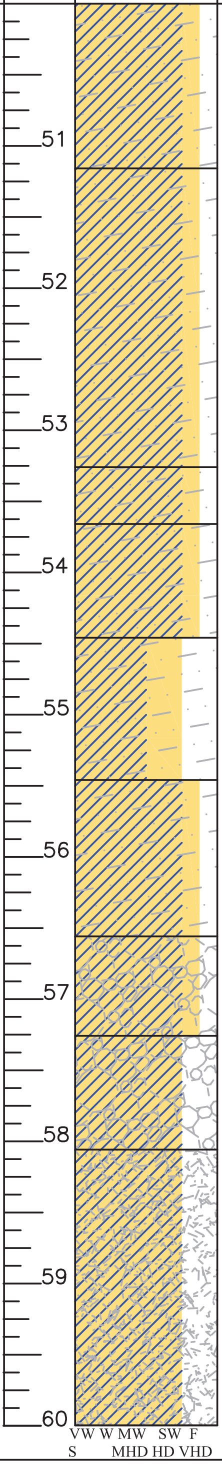
GREY COARSE GRAINED CONGLOMERATE, COMPRISING SANDSTONE FRAGMENTS ANGULAR TO SUB ROUNDED TO 80mm FRESH HARD, SOME CALCITE IN GROUNDMASS

GREY COARSE GRAINED CONGLOMERATE, COMPRISING SANDSTONE FRAGMENTS ANGULAR TO SUB ROUNDED TO 80mm, SOME CALCITE IN GROUNDMASS, FRESH HARD

GREY MEDIUM TO COARSE GRAINED SANDSTONE WITH SAME LARGER ROUNDED SANDSTONE PEBBLES. FRACTURES 30cm APART , FRESH HARD

GREY FINE GRAINED SANDSTONE POORLY SORTED WITH SHALE AND SANDSTONE FRAGMENTS, FRACTURES 30cm APART, HIG CALCITE VEIN CONTENT, FRESH MEDIUM HARD

DPH | LOG | DESCRIPTION



LIGHT GREY FINE GRAINED SANDSTONE POORLY SORTED WITH SHALE AND SANDSTONE FRAGMENTS, FRACTURES 30cm APART, FRESH, HARD

LIGHT GREY FINE GRAINED SANDSTONE WITH MINOR SANDSTONE FRAGMENTS, FRACTURES 30cm APART. MINOR CALCITE VEINS PRESENT 55° TO CORE AXIS, FRESH, HARD

LIGHT GREY FINE GRAINED SANDSTONE WITH MINOR VERY FINE GRAINED SHALE AND SANDSTONE FRAGMENTS, FRACTURES 30cm APART.

LIGHT GREY FINE GRAINED SANDSTONE WITH MINOR VERY FINE GRAINED SHALE AND SANDSTONE FRAGMENTS, CONTACT AT BASE 30° TO CORE AXIS

LIGHT GREY GREEN MEDIUM GRAINED SANDSTONE WITH MINOR VERY FINE GRAINED SHALE AND SANDSTONE FRAGMENTS, FRACTURES 30cm APART. SLIGHTLY WEATHERED MEDIUM HARD.

LIGHT GREY FINE GRAINED SANDSTONE MEDIUM GRAINED WITH SHALE AND SANDSTONE FRAGMENTS TO 5mm SOME CALCITE IN GROUNDMASS, FRACTURES 40cm APART , FRESH HARD.

LIGHT GREY CONGLOMERATE WITH PEBBLES TO 80mm, BRECCIATED AT BASE. SOME SHALE FRAGMENTS AS WELL. MINOR CALCITE. HARD FRESH

LIGHT GREY CONGLOMERATE WITH PEBBLES TO 40mm. MINOR CALCITE. HARD, FRESH CONTACT AT BASE 10° TO CORE AXIS

LIGHGT GREY FINE GRAINED BRECCIA WITH MINOR VERY FINE GRAINED SHALE AND SANDSTONE FRAGMENTS, FRACTURES 30cm APART. AND VERTICAL FRACTURE CALCITE LINED.
CALCITE VEINS PRESENT 45° TO CORE AXIS AT BASE, SLIGHTLY WEATHERED, MEDIUM HARD

COMMENTS:

LEGEND: VW VERY WEATHERED, W WEATHERED, MW MODERATELY WEATHERED, SW SLIGHTLY WEATHERED, F FRESH 🟨
S SOFT, MHD MEDIUM HARD, HD HARD, VHD VERY HARD ▨

Hanson
HEIDELBERGCEMENT Group

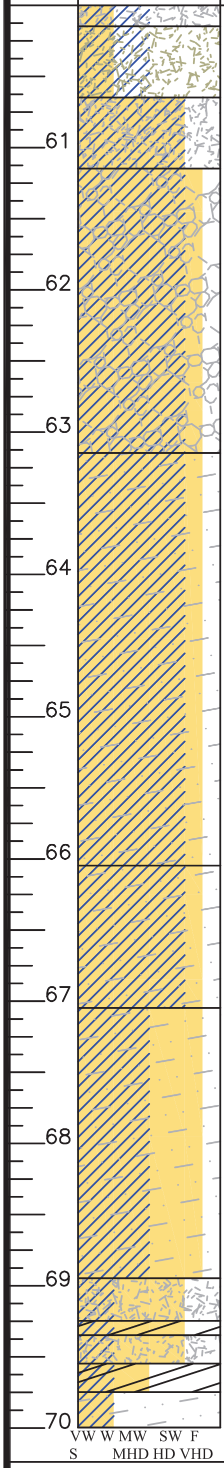
HANSON CONSTRUCTION MATERIALS

GRAPHIC DRILL LOG

HOLE: SA-1502-DH
PROJECT: SANCROX EXTENSION, ZONE 56
PAGE 4 OF 5

LOCATION: 4821703,6522320GDA
DRILLED: MACQUARIE DRILLING
LOGGED: P BROWNE 2/7/15

DPH | LOG | DESCRIPTION



GREY BROWN MEDIUM GRAINED BRECCIA, FRACTURES 25 TO 20cm APART CALCITE IN GROUNDMASS, MODERATELY WEATHERED MEDIUM HARD

LIGHT GREY MEDIUM GRAINED BRECCIA, PEBBLES TO 80mm SLIGHTLY WEATHERED, HARD CONTACT AT BASE 10° TO CORE AXIS

LIGHT GREY VERY FINE GRAINED CONGLOMERATE, FRACTURES 25 TO 50cm APART CALCITE VEINS IN PLACES, BANDING 15° TO CORE AXIS, FRACTURES CALCITE FILLED, FRESH MODERATELY HARD

LIGHT GREY CONGLOMERATE WITH SANDSTONE PEBBLES ANGULAR EQUANT, BANDING 75° TO CORE AXIS, FRACTURES 30cm APART CALCITE IN GROUNDMASS AND BANDING HIGHLY FRACTURED @ BASE AND AT 65m.

LIGHT GREY CONGLOMERATE WITH SANDSTONE PEBBLES ANGULAR EQUANT, FRACTURES 40cm APART CALCITE IN GROUNDMASS, FRESH, HARD

LIGHT GREY FINE GRAINED SANDSTONE, BANDING 45° TO CORE AXIS, FRACTURES 20cm APART CALCITE IN GROUNDMASS AND BANDING SOME 45° TO CORE AXIS, FRESH , MEDIUM HARD

LIGHT GREY BRECCIA HIGH CALCITE CONTENT MEDIUM SOFT

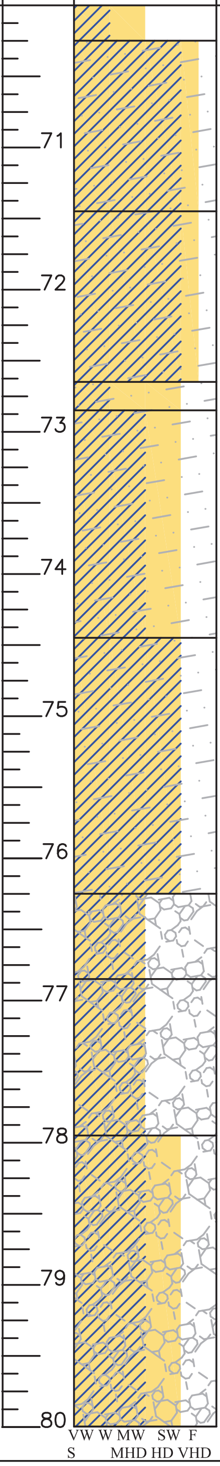
BLACK SHALE

LIGHT GREY BRECCIA HIGH CALCITE CONTENT MEDIUM SOFT

BLACK SHALE

LIGHT GREY FINE SANDSTONE MEDIUM SOFT , WEATHERED

DPH | LOG | DESCRIPTION



SHALE BAND

PREDOMINANT BLACK SAHLE WITH BEDS OF FINE GRAINED SANDSTONE. HIGHLY FRACTURED MEDIUM HARD FRESH

LIGHT GREY VERY FINE GRAINED SANDSTONE, BANDING 85° TO CORE AXIS, FRACTURES 10cm APART CALCITE IN GROUNDMASS

FRACTURED ZONE SHALE AND CALCITE PRESENT

LIGHT GREY VERY FINE GRAINED SANDSTONE, BANDING 70° TO CORE AXIS, FRACTURES 15 TO 40cm APART CALCITE IN GROUNDMASS AND BANDING SOME, 45° TO CORE AXIS, MODERATELY HARD

LIGHT GREY VERY FINE GRAINED SANDSTONE, WITH SOME CALCITE VEINS, FRACTURES 15 TO 40cm APART CALCITE IN GROUNDMASS AND MINOR BRECCIATION, MODERATELY FRESH, HARD

LIGHT GREY FINE GRAINED BRECCIATED CONGLOMERATE,WITH SOME SHALE FRAGMENTS ANGULAR SANDSTONE, HIGHLY FRACTURED MODERATELY WEATHERED MEDIUM SOFT

LIGHT GREY FINE GRAINED BRECCIATED CONGLOMERATE,WITH SOME SHALE FRAGMENTS ANGULAR SANDSTONE, HIGHLY FRACTURED MODERATELY WEATHERED MEDIUM SOFT

LIGHT GREY CONGLOMERATE,WITH RARE SHALE FRAGMENTS AND SANDSTONE FRAGMENTS TO 40mm SUB ANGULAR , FRACTURES 40cm APART. CALCITE IN GROUNDMASS, FRESH MODERATELY HARD, HIGHLY FRACTURED AT BASE.

COMMENTS:

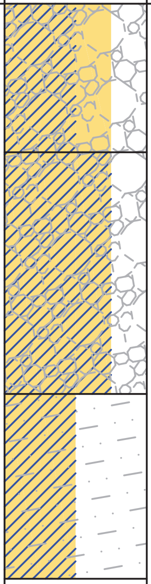
LEGEND: VW VERY WEATHERED, W WEATHERED, MW MODERATELY WEATHERED, SW SLIGHTLY WEATHERED, F FRESH 🟨
S SOFT, MHD MEDIUM HARD, HD HARD, VHD VERY HARD ▨

HANSON CONSTRUCTION MATERIALS

GRAPHIC DRILL LOG

HOLE: SA-1502-DH
PROJECT: SANCROX EXTENSION, ZONE 56
PAGE 5 OF 5

LOCATION: 4821703,6522320GDA
DRILLED: MACQUARIE DRILLING
LOGGED: P BROWNE 2/7/15

DPH	LOG	DESCRIPTION
		LIGHT GREY CONGLOMERATE WITH FRAGMENTS TO 140mm BUT MAINLY 30mm, PREDOMINANTLY FINE GRAINED SANDSTONES. GROUNDMASS CALCITE PRESENT IN PLACES, FRACTURES 20 TO 80cm APART SLIGHTLY WEATHERED HARD
81		
		LIGHT GREY CONGLOMERATE WITH FRAGMENTS TO 30mm, PREDOMINANTLY FINE GRAINED SANDSTONES. GROUNDMASS CALCITE PRESENT IN PLACES, FRACTURES 20cm APART SLIGHTLY WEATHERED HARD
82		
83		LIGHT GREY FINE GRAINED SANDSTONE, FRACTURES 40cm APART. CALCITE IN GROUNDMASS VEINS 45° TO CORE AXIS
		HIGHLY FRACTURED
84		
85		
86		
87		
88		
89		
90	VW W MW SW F S MHD HD VHD	

DPH	LOG	DESCRIPTION
91		
92		
93		
94		
95		
96		
97		
98		
99		
100	VW W MW SW F S MHD HD VHD	

COMMENTS:

LEGEND: VW VERY WEATHERED, W WEATHERED, MW MODERATELY WEATHERED, SW SLIGHTLY WEATHERED, F FRESH 🟨
S SOFT, MHD MEDIUM HARD, HD HARD, VHD VERY HARD ▨

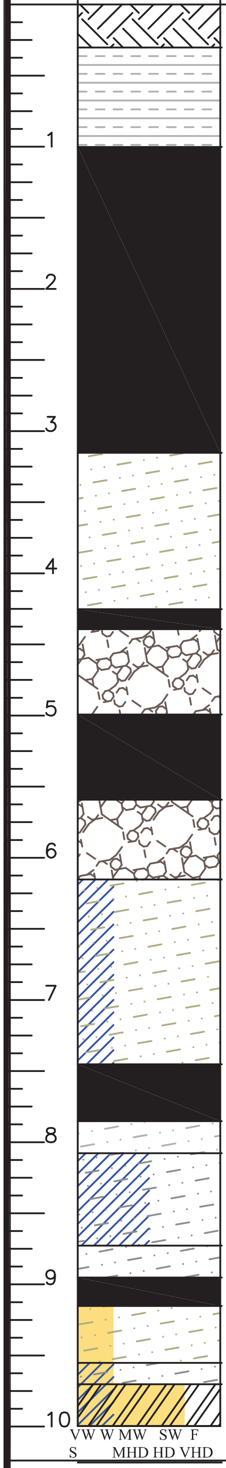
HANSON CONSTRUCTION MATERIALS

GRAPHIC DRILL LOG

HOLE: SA-1503-DH
PROJECT: SANCROX EXTENSION, ZONE 56
PAGE 1 OF 6

LOCATION: 482127,6521775 GDA
DRILLED: MACQUARIE DRILLING
LOGGED: P BROWNE 2/6/15

DPH	LOG	DESCRIPTION



BROWN SUBSOIL

LIGHT GREY CLAY

NO CORE

GREY BROWN FINE GRAINED GRAVELLY SANDSTONE

NO CORE

BROWN GREY COARSE GRAINED CONGLOMERATE POORLY WELDED , FRACTURED

NO CORE

BROWN GREY COARSE GRAINED CONGLOMERATE POORLY WELDED , FRACTURED

GREY BROWN FINE GRAINED SANDSTONE FRACTURES 7cm APART AND VERTICAL FRACTURE AT 85° TO CORE AXIS

NO CORE

LIGHT GREY SANDSTONE VERY FINE GRAINED

GREY SANDSTONE VERY FINE GRAINED, FRACTURES 15cm APART

GREY SANDSTONE RUBBLE

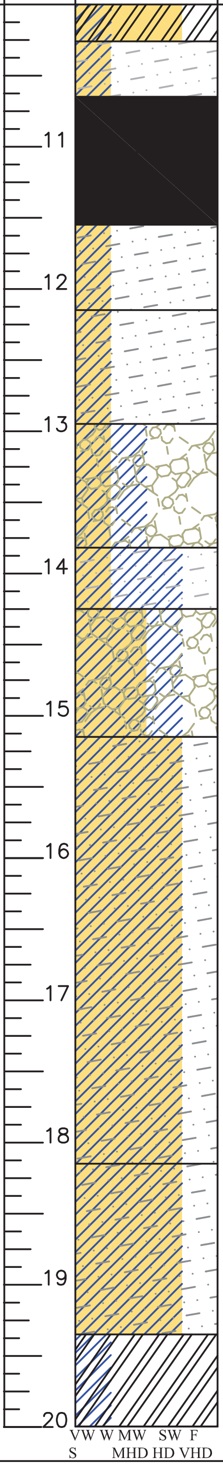
NO CORE

BROWN GREY SANDSTONE RUBBLE

GREY SANDSTONE RUBBLE

BLACK SHALE, FRACTURES 10cm APART, CALCITE IN GROUNDMASS

DPH	LOG	DESCRIPTION



BLACK SHALE, FRACTURES 10cm APART, CALCITE IN GROUNDMASS, FRACTURE 80° TO CORE AXIS

LIGHT GREY SANDSTONE RUBBLE

NO CORE

GREY SANDSTONE VERY FINE GRAINED BRECCIATED

GREY FINE GRAINED SANDSTONE POORLY, FRACTURES 10cm APART

GREY BROWN COARSE GRAINED CONGLOMERATE POORLY SORTED FELDSPAR & SANDSTONE FRAGMENTS TO 10mm, FRACTURES 10cm APART

LIGHT GREY MEDIUM GRAINED SANDSTONE POORLY SORTED FELDSPAR & SANDSTONE FRAGMENTS, HIGHLY FRACTURED

GREY BROWN COARSE GRAINED CONGLOMERATE POORLY SORTED FELDSPAR & SANDSTONE FRAGMENTS TO 10mm, FRACTURES 20cm APART

GREY COARSE GRAINED SANDSTONE POORLY SORTED FELDSPAR & SANDSTONE FRAGMENTS TO 7mm, FRACTURES 20cm APART, CALCITE IN THE GROUNDMASS GENERALLY 45° TO CORE AXIS

GREY COARSE GRAINED SANDSTONE POORLY SORTED FELDSPAR & SANDSTONE FRAGMENTS TO 7mm, FRACTURES 20cm APART, CALCITE IN THE GROUNDMASS GENERALLY 45° TO CORE AXIS

BLACK SHALE, FRACTURED RUBBLE

COMMENTS:

LEGEND: VW VERY WEATHERED, W WEATHERED, MW MODERATELY WEATHERED, SW SLIGHTLY WEATHERED, F FRESH 🟨
S SOFT, MHD MEDIUM HARD, HD HARD, VHD VERY HARD ▨

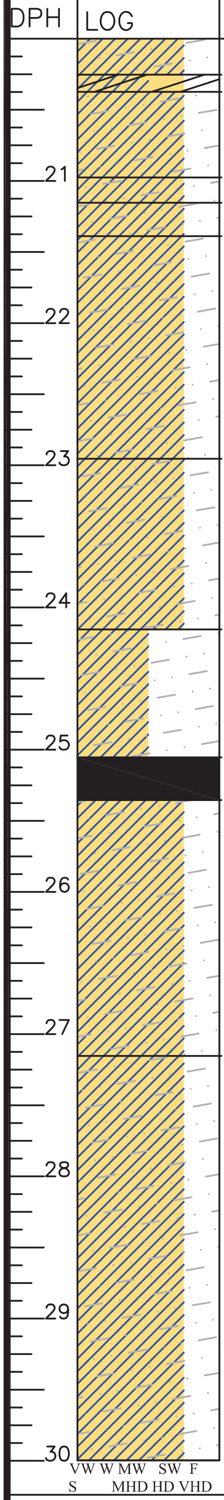
HANSON CONSTRUCTION MATERIALS

GRAPHIC DRILL LOG

HOLE: SA-1503-DH
PROJECT: SANCROX EXTENSION, ZONE 56
PAGE 2 OF 6

LOCATION: 482127,6521775 GDA
DRILLED: MACQUARIE DRILLING
LOGGED: P BROWNE 2/6/15

DESCRIPTION



LIGHT GREY COARSE GRAINED SANDSTONE POORLY SORTED, FRACTURES 10cm APART,ALSO VERTICAL FRACTURE

BLACK SHALE CALCITE IN GROUNDMASS FRACTURES 15cm APART PERPENDICULAR TO CORE AXIS

LIGHT GREY COARSE GRAINED SANDSTONE POORLY SORTED, FRACTURES 10cm APART,CALCITE VEINS 35° TO CORE AXIS

LIGHT GREY FINE GRAINED SANDSTONE, CALCITE VEINS 35° TO CORE AXIS

LIGHT GREY FINE GRAINED SANDSTONE, CALCITE VEINS 35° TO CORE AXIS

LIGHT GREY MEDIUM GRAINED SANDSTONE POORLY SORTED FELDSPAR & SANDSTONE FRAGMENTS TO 40mm, FRACTURES 15cm APART 45° TO CORE AXIS, SOME SECONDARY FRACTURING

LIGHT GREY MEDIUM GRAINED SANDSTONE POORLY SORTED FELDSPAR & SANDSTONE FRAGMENTS, FRACTURES 8cm APART,CALCITE VEINS IN GROUNDMASS

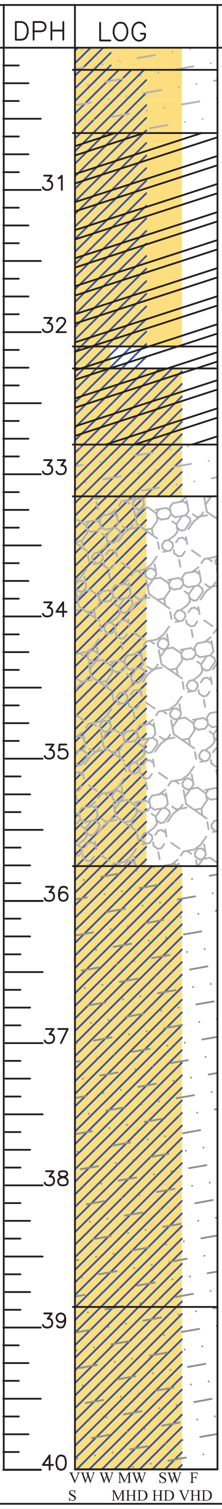
LIGHT GREY MEDIUM GRAINED SANDSTONE POORLY SORTED FELDSPAR & SANDSTONE FRAGMENTS, HIGHLY FRACTURED FRACTURES AT ALL ANGLES, CALCITE VEINS IN GROUNDMASS

NO CORE

LIGHT GREY FINE GRAINED SANDSTONE, FRACTURED FRACTURE 20 cm APART, CALCITE VEINS IN GROUNDMASS

LIGHT GREY FINE GRAINED SANDSTONE, FRACTURED FRACTURE 20 cm APART, CALCITE VEINS IN GROUNDMASS

DESCRIPTION



LIGHT GREY SANDSTONE POORLY SORTED FELDSPAR HIGHLY FRACTURED

LIGHT GREY SANDSTONE POORLY SORTED FELDSPAR HIGHLY FRACTURED

BLACK SHALE CALCITE IN GROUNDMASS FRACTURES 6 TO 15cm APART 35° TO CORE AXIS, CALCITE VEINS MAINLY 45° TO CORE AXIS BUT WITH OTHER ANGLES

BLACK SHALE HIGHLY FRACTURED

BLACK SHALE CALCITE IN GROUNDMASS FRACTURES 8cm APART PERPENDICULAR TO CORE AXIS, CALCITE VEINS 45° TO CORE AXIS

LIGHT GREY COARSE SANDSTONE POORLY SORTED FELDSPAR ROUNDED FRAGMENTS CALCITE IN GROUNDMASS

LIGHT GREY CONGLOMERATE, POORLY SORTED, HIGHLY FRACTURED AND BRECCIATED

GREY VERY FINE GRAINED SANDSTONE FRACTURES 40 TO 80cm APART, CALCITE VEINS 45° TO CORE AXIS AND IN GROUNDMASS

GREY VERY FINE GRAINED SANDSTONE FRACTURES 40 TO 80cm APART, CALCITE VEINS 45° TO CORE AXIS AND IN GROUNDMASS

COMMENTS:

LEGEND: VW VERY WEATHERED, W WEATHERED, MW MODERATELY WEATHERED, SW SLIGHTLY WEATHERED, F FRESH 🟨
S SOFT, MHD MEDIUM HARD, HD HARD, VHD VERY HARD ▨

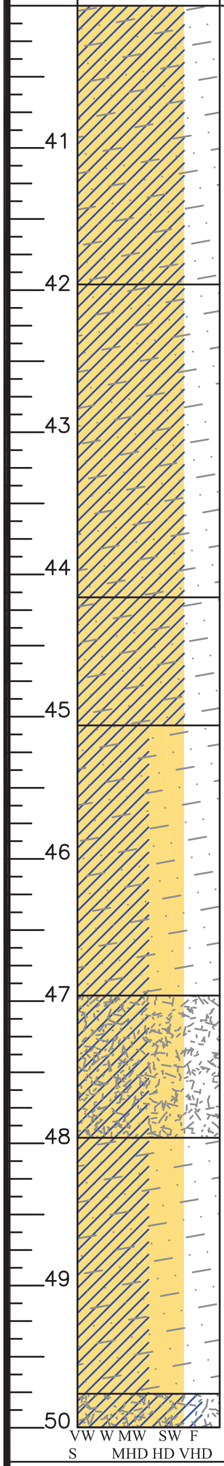
HANSON CONSTRUCTION MATERIALS

GRAPHIC DRILL LOG

HOLE: SA-1503-DH
PROJECT: SANCROX EXTENSION, ZONE 56
PAGE 3 OF 6

LOCATION: 482127,6521775 GDA
DRILLED: MACQUARIE DRILLING
LOGGED: P BROWNE 2/6/15

DPH LOG DESCRIPTION



GREY FINE GRAINED SANDSTONE, FRACTURES 13cm APART PERPENDICULAR TO CORE AXIS, CALCITE VEINS 45° TO CORE AXIS AND SMALLER ONES IN THE GROUNDMASS

GREY FINE GRAINED SANDSTONE, FRACTURES 40cm APART PERPENDICULAR TO CORE AXIS,CALCITE VEINS IN THE GROUNDMASS

GREY FINE GRAINED SANDSTONE, FRACTURES 20cm APART PERPENDICULAR TO CORE AXIS,CALCITE VEINS IN THE GROUNDMASS AND IN LARGE VEINS 45° TO CORE AXIS

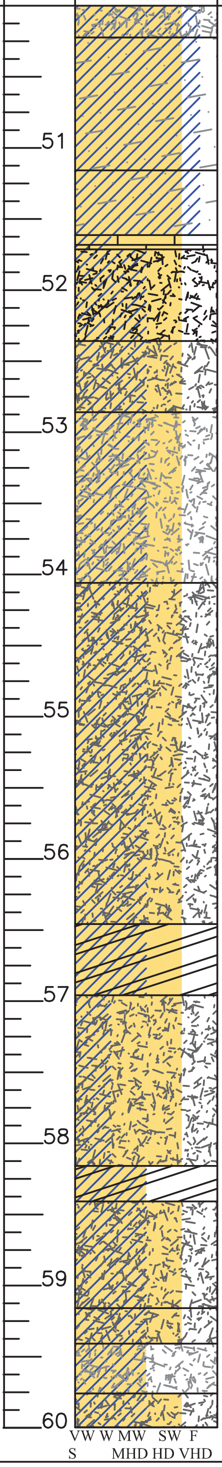
GREY FINE GRAINED SANDSTONE, FRACTURES 20cm APART CALCITE VEINS IN THE GROUNDMASS AT ALL ANGLES

GREY FINE GRAINED SANDSTONE BRECCIA WITH THE GROUNDMASS HEAVILY BROKEN UP, HIGHLY FRACTURED AND MANY CALCITE VEINS

GREY FINE GRAINED SANDSTONE BRECCIA WITH THE GROUNDMASS HEAVILY BROKEN UP, HIGHLY FRACTURED AND MANY CALCITE VEINS

GREY FINE GRAINED SANDSTONE BRECCIA WITH THE GROUNDMASS HEAVILY BROKEN UP, HIGHLY FRACTURED AND MANY CALCITE VEINS

DPH LOG DESCRIPTION



GREY FINE GRAINED SANDSTONE BRECCIAWITH FRACTURE 45° TO CORE AXIS

GREY VERY FINE GRAINED SANDSTONE POORLY SORTED WITH SHALE AND SANDSTONE BANDS, FRACTURES 30cm APART, CALCITE VEINS IN GROUNDMASS

GREY VERY FINE GRAINED SANDSTONE POORLY SORTED WITH SHALE AND SANDSTONE BANDS, FRACTURES 30cm APART, CALCITE VEINS IN GROUNDMASS

CALCITE VEIN 45° TO CORE AXIS

BLACK FINE GRAINED BRECCIA WITH FRACTURES 45° TO CORE AXIS

DARK GREY FINE GRAINED BRECCIA HIGHLY FRACTURED

GREY FINE GRAINED SANDSTONE AND SHALE BRECCIA WITH FRACTURES 20cm APART

DARK GREY FINE GRAINED SANDSTONE BRECCIA WITH THE GROUNDMASS HEAVILY BROKEN UP, FRACTURES 10cm APART SHALE INTERBEDS AND GROUNDMASS FILLED WITH CALCITE VEINS FRACTURES GENERALLY 45° TO CORE AXIS

BLACK SHALE BRECCIATED WITH MULTIPLE CALCITE VEINS FRACTURES 20cm APART

DARK GREY FINE GRAINED BRECCIA WITH THE GROUNDMASS HEAVILY BROKEN UP, FRACTURES 10cm AND GROUNDMASS FILLED WITH CALCITE VEINS FRACTURES GENERALLY 45° TO CORE AXIS

BLACK SHALE BRECCIATED WITH MULTIPLE CALCITE VEINS FRACTURES 20cm APART

DARK GREY FINE GRAINED BRECCIA FRACTURED

DARK GREY FINE GRAINED BRECCIA FRACTURE 30cm APART HIGH SHALE CONTENT

GREY FINE GRAINED SANDSTONE BRECCIAHIGHLY FRACTURED

DARK GREY FINE GRAINED BRECCIA FRACTURE 30cm APART HIGH SHALE CONTENT

COMMENTS:

LEGEND: VW VERY WEATHERED, W WEATHERED, MW MODERATELY WEATHERED, SW SLIGHTLY WEATHERED, F FRESH 🟨
S SOFT, MHD MEDIUM HARD, HD HARD, VHD VERY HARD ▨

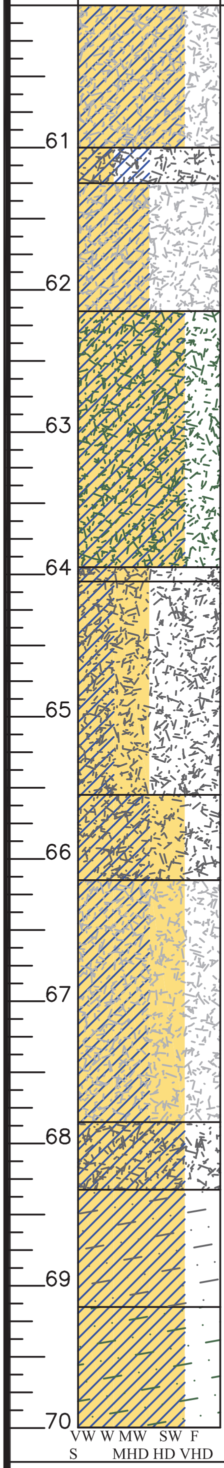
HANSON CONSTRUCTION MATERIALS

GRAPHIC DRILL LOG

HOLE: SA-1503-DH
PROJECT: SANCROX EXTENSION, ZONE 56
PAGE 4 OF 6

LOCATION: 482127,6521775 GDA
DRILLED: MACQUARIE DRILLING
LOGGED: P BROWNE 3/6/15

DPH | LOG | DESCRIPTION



LIGHT GREY BRECCIA, FRACTURES 25cm APART CALCITE IN GROUNDMASS, ALSO VERY FRACTURED @ 60 TO 60.25m

DARK GREY BRECCIA, HIGHLY FRACTURED

LIGHT GREY BRECCIA, FRACTURES 15cm APART CALCITE IN GROUNDMASS, ALSO VERY FRACTURED AT BASE

GREY GREEN BRECCIA, FRACTURES 18cm APART CALCITE IN GROUNDMASS VEINS AT 45° TO CORE AXIS

DARK GREY BRECCIA, HIGHLY FRACTURED

DARK GREY BRECCIA, FRACTURES 25cm APART CALCITE IN GROUNDMASS, FRAGMENTS OF FINE SANDSTONE PRESENT

DARK GREY BRECCIA, FRACTURES 25cm APART CALCITE IN GROUNDMASS, FRACTURES GENERALLY 45° TO CORE AXIS

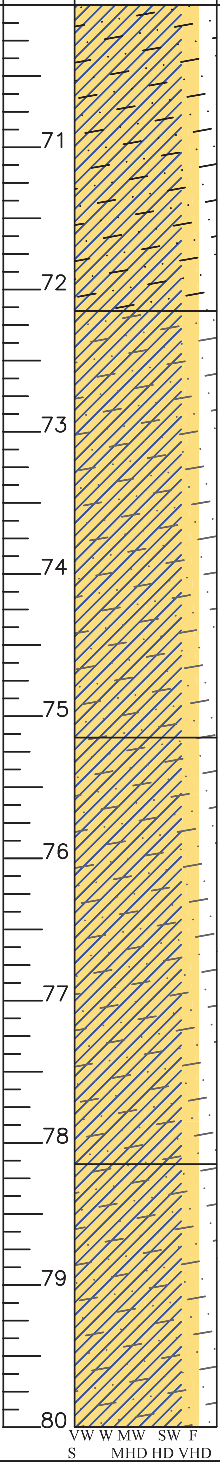
LIGHT GREY BRECCIA, FRACTURES 15cm APART CALCITE IN GROUNDMASS, ALSO VERY FRACTURED TO 66.55m, SOME LARGE MEDIUM GRAINED SANDSTONE FRAGMENTS

DARK GREY BRECCIA, FRACTURES 25cm APART CALCITE IN GROUNDMASS, FRACTURES GENERALLY 45° TO CORE AXIS

DARK GREY VERY FINE GRAINED SANDSTONE, BANDING 45° TO CORE AXIS WITH SOME SHALE FRAGMENTS AND LIGHT GREY BANDS, FRACTURES 25cm APART CALCITE IN GROUNDMASS, 45° TO CORE AXIS

GREY GREEN VERY FINE GRAINED SANDSTONE, BANDING 45° TO CORE AXIS WITH SOME SHALE FRAGMENTS AND LIGHT GREY BANDS, FRACTURES 25cm APART CALCITE IN GROUNDMASS AT ALL ANGLES

DPH | LOG | DESCRIPTION



GREY VERY FINE GRAINED SANDSTONE, FRACTURES 30cm APART CALCITE IN GROUNDMASS. GROUNDMASS FRACTURED

DARK GREY VERY FINE GRAINED SANDSTONE, SOEM MINOR SHALE BANDS, FRACTURES 30cm APART CALCITE IN GROUNDMASS. GROUNDMASS FRACTURED, CALCITE @ 75m

DARK GREY VERY FINE GRAINED SANDSTONE, WITH SOME SHALE FRAGMENTS AND LIGHT GREY BANDS, FRACTURES 40cm APART CALCITE IN GROUNDMASS AND MINOR BRECCIATION,

CALCITE BAND

DARK GREY VERY FINE GRAINED SANDSTONE, WITH SOME SHALE FRAGMENTS AND LIGHT GREY BANDS, FRACTURES 40cm APART CALCITE IN GROUNDMASS AND MINOR BRECCIATION,

COMMENTS:

LEGEND: VW VERY WEATHERED, W WEATHERED, MW MODERATELY WEATHERED, SW SLIGHTLY WEATHERED, F FRESH 🟨
S SOFT, MHD MEDIUM HARD, HD HARD, VHD VERY HARD ▨

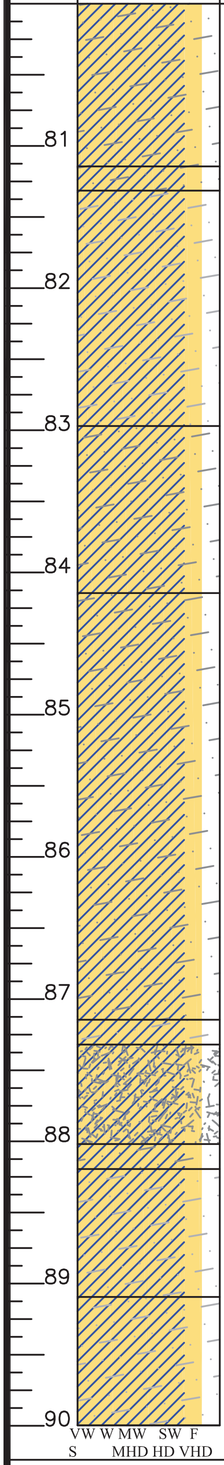
HANSON CONSTRUCTION MATERIALS

GRAPHIC DRILL LOG

HOLE: SA-1503-DH
PROJECT: SANCROX EXTENSION, ZONE 56
PAGE 5 OF 6

LOCATION: 482127,6521775 GDA
DRILLED: MACQUARIE DRILLING
LOGGED: P BROWNE 3/6/15

DPH | LOG | DESCRIPTION



GREY FINE GRAINED SANDSTONE,WITH RARE SHALE FRAGMENTS, FRACTURES 40cm APART. CALCITE IN GROUNDMASS VEINS AT ALL ANGLES

GREY VERY FINE GRAINED SANDSTONE BRECCIATED

GREY VERY FINE GRAINED SANDSTONE CALCITE VEINS IN GROUNDMASS

LIGHT GREY FINE GRAINED SANDSTONE,WITH RARE SHALE FRAGMENTS, FRACTURES 30cm APART CALCITE IN GROUNDMASS VEINS AT ALL ANGLES.

GREY FINE GRAINED SANDSTONE, FRACTURES 30cm APART. CALCITE IN GROUNDMASS VEINS 35° TO CORE AXIS

GREY FINE GRAINED SANDSTONE, FRACTURES 20 TO 40cm APART. HIGH PERCENTAGE OF CALCITE IN GROUNDMASS 85° TO CORE AXIS, SLIGHTLY BRECCIATED

LIGHT GREY FINE GRAINED SANDSTONE,SHALE FRAGMENTS, CALCITE IN GROUNDMASS

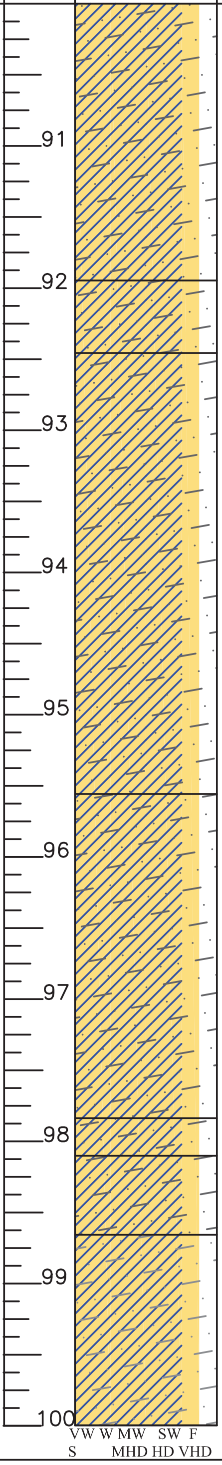
GREY FINE GRAINED BRECCIA,SHALE FRAGMENTS, CALCITE IN GROUNDMASS AND VEINS 45° TO CORE AXIS

GREY FINE GRAINED SANDSTONE HIGHLY FRACTURED

LIGHT GREY SANDSTONE, CALCITE IN GROUNDMASS AND VEINS 85° TO CORE AXIS FRACTURES 10cm APART

LIGHT GREY FINE GRAINED SANDSTONE,SHALE FRAGMENTS, CALCITE IN GROUNDMASS AT ALL ANGLES, FRACTURES 20cm APART

DPH | LOG | DESCRIPTION



DARK GREY FINE GRAINED SANDSTONE,SHALE FRAGMENTS, CALCITE IN GROUNDMASS AND VEINS 45° TO CORE AXIS AND PERPENDICULAR TO BANDING, SOME BRECCIATION

DARK GREY FINE GRAINED SANDSTONE HIGHLY FRACTURED

DARK GREY VERY FINE GRAINED SANDSTONE,WITH SHALE FRAGMENTS, FRACTURES 80cm APART. CALCITE IN GROUNDMASS VEINS 55° TO CORE AXIS

DARK GREY VERY FINE GRAINED SANDSTONE,WITH SHALE FRAGMENTS, FRACTURES 40cm APART. CALCITE IN GROUNDMASS VEINS 45° TO CORE AXIS

DARK GREY VERY FINE GRAINED BRECCIA WITH SHALE AND SANDSTONE MIXTURE, AND MULTIPLE CALCITE VEINS, FRACTURES 15cm APART.

DARK GREY VERY FINE GRAINED SANDSTONE,WITH SHALE FRAGMENTS, FRACTURES 80cm APART. CALCITE IN GROUNDMASS VEINS 55° TO CORE AXIS

GREY MEDIUM GRAINED SANDSTONE,WITH RARE SHALE FRAGMENTS, FRACTURES 40cm APART. CALCITE IN GROUNDMASS COMMON AT ALL ANGLES SOME BRECCIATION

COMMENTS:

LEGEND: VW VERY WEATHERED, W WEATHERED, MW MODERATELY WEATHERED, SW SLIGHTLY WEATHERED, F FRESH 🟨
S SOFT, MHD MEDIUM HARD, HD HARD, VHD VERY HARD ▨

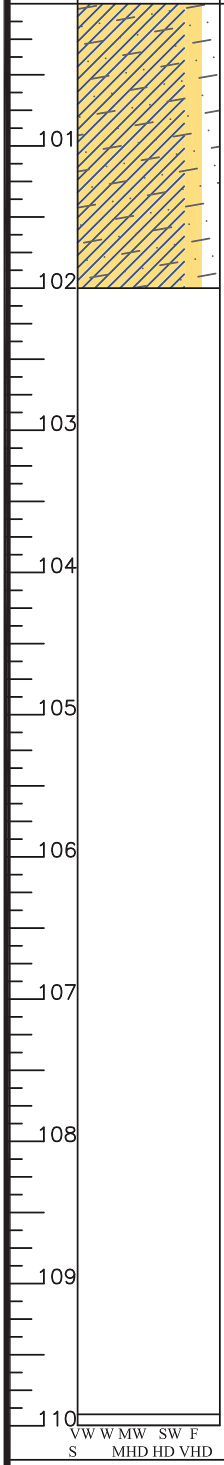
HANSON CONSTRUCTION MATERIALS

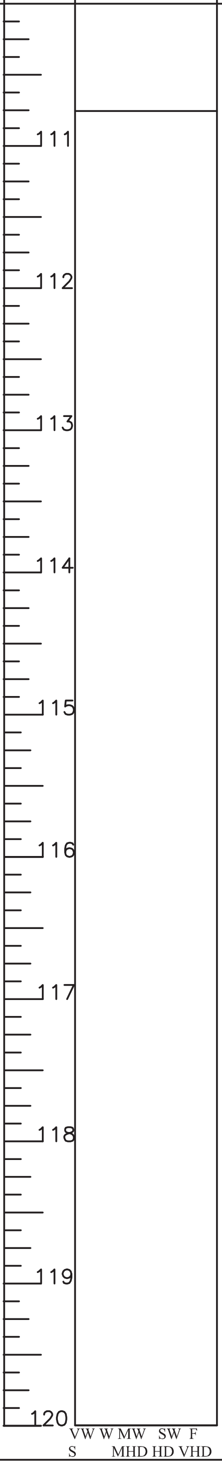
GRAPHIC DRILL LOG

HOLE: SA-1503-DH
PROJECT: SANCROX EXTENSION, ZONE 56
PAGE 6 OF 6

LOCATION: 482127,6521775 GDA
DRILLED: MACQUARIE DRILLING
LOGGED: P BROWNE 3/6/15

DPH	LOG	DESCRIPTION
101–102	🟨▨	DARK GREY VERY FINE GRAINED SANDSTONE, SHALE AND FINE SANDSTONE BEDS, FRACTURES 50cm APART. CALCITE IN GROUNDMASS ALL ANGLES





COMMENTS:

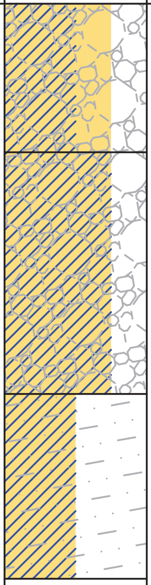
LEGEND: VW VERY WEATHERED, W WEATHERED, MW MODERATELY WEATHERED, SW SLIGHTLY WEATHERED, F FRESH 🟨
S SOFT, MHD MEDIUM HARD, HD HARD, VHD VERY HARD ▨

HANSON CONSTRUCTION MATERIALS

GRAPHIC DRILL LOG

HOLE: SA-1502-DH
PROJECT: SANCROX EXTENSION, ZONE 56
PAGE 1 OF 5

LOCATION:4821703,6522320GDA
DRILLED: MACQUARIE DRILLING
LOGGED: P BROWNE 2/7/15

DPH	LOG	DESCRIPTION	DPH	LOG	DESCRIPTION
		LIGHT GREY CONGLOMERATE WITH FRAGMENTS TO 140mm BUT MAINLY 30mm, PREDOMINANTLY FINE GRAINED SANDSTONES. GROUNDMASS CALCITE PRESENT IN PLACES, FRACTURES 20 TO 80cm APART SLIGHTLY WEATHERED HARD			
81			91		
82		LIGHT GREY CONGLOMERATE WITH FRAGMENTS TO 30mm, PREDOMINANTLY FINE GRAINED SANDSTONES. GROUNDMASS CALCITE PRESENT IN PLACES, FRACTURES 20cm APART SLIGHTLY WEATHERED HARD	92		
83		LIGHT GREY FINE GRAINED SANDSTONE, FRACTURES 40cm APART. CALCITE IN GROUNDMASS VEINS 45° TO CORE AXIS	93		
84		HIGHLY FRACTURED	94		
85			95		
86			96		
87			97		
88			98		
89			99		
90	VW W MW SW F S MHD HD VHD		100	VW W MW SW F S MHD HD VHD	

COMMENTS:

LEGEND: VW VERY WEATHERED, W WEATHERED, MW MODERATELY WEATHERED, SW SLIGHTLY WEATHERED, F FRESH 🟨
S SOFT, MHD MEDIUM HARD, HD HARD, VHD VERY HARD ▨

Annex B

Form A Documents

(Showing Bore Construction Details)

NSW GOVERNMENT
Department of Primary Industries
Office of Water

Form A Particulars of completed work

1

Driller's Licence No: DL 2266
Class of Licence: 4
Driller's Name: Steven Baker
Assistant Driller: Darran marko
Contractor: LcR contractors

New bore	☒	Replacement bore	☐
Deepened	☐	Enlarged	☐
Reconditioned	☐	Other (specify)	☐

Final Depth 110 m SA1501

2

Work Licence No: 20BL173794
Name of Licensee: Handson
Intended Use: water monitoring
Completion Date: 19.10.2015

DRILLING DETAILS

3

From (m)	To (m)	Hole Diameter (mm)	Drilling Method See Code 3
0	11.40	165.1	9
11.4	110	120	9

WATER BEARING ZONES

4

From (m)	To (m)	Thickness (m)	S W L (m)	Estimated Yield (L/s) Individual Aquifer	Estimated Yield (L/s) Cumulative	Test method See Code 4		D D L at end of test (m)	Duration Hrs	Duration min	Salinity (Conductivity or TDS) Cond (μS/cm)	Salinity (Conductivity or TDS) TDS (mg/L)
20	50	30	-	—	Damp	—	—	—	—	—	—	—
70	110	40	6		0.101		H	—	—	30	1080	—

CASING / LINER DETAILS

5

Material Code 5	OD (mm)	Wall Thickness (mm)	From (m)	To (m)	Method Fixing Code 5
4	125	5.5	0	11.4	1
6	50		71	50	5
6	50		20	0	5

Casing support method See Code 5 2
Type of casing bottom See Code 5 2
Centralisers installed (Yes/No) no (indicate on sketch)
Sump installed (Yes/No) no From m To m
Pressure cemented (Yes/No) no From m To m
Casing Protector cemented in place yes

WATER ENTRY DESIGN

6

General Material Code 5	OD (mm)	Wall Thickness (mm)	From (m)	To (m)	Opening type See Code 6	Fixing See Code 5	Screen Aperture (mm)	Slot Details Length (mm)	Width (mm)	Alignment See Code 6
6	50		110	71	5	5	1	27600	3	H
6	50		50	20	5	5	1	2600	3	H

GRAVEL PACK

7

Type		Grade		Grain size (mm) From	Grain size (mm) To	Depth (m) From	Depth (m) To	Quantity Litres	Quantity m^3
Rounded	☐	Graded	☒	5	7	110	70	338.4	0.33
Crushed	☐	Ungraded	☐	5	7	50	19	262.4	0.26
Bentonite/Grout seal (Yes/No)		Yes				70	50	169.3	0.17
Method of placement of Gravel Pack		See Code 7		1		19	0	160.8	0.16

For Departmental use only: GW ☐☐☐☐☐☐☐

Form A Particulars of completed work

Work Licence No:

BORE DEVELOPMENT 8

Chemical used for breaking down drilling mud (Yes/No) Yes Name:

Method	Bailing/Surging	Jetting	Airlifting	Backwashing	Pumping	Other:
Duration	hrs	hrs	1 hrs	hrs	hrs	hrs

DISINFECTION ON COMPLETION 9

Chemical(s) used	Quantity applied (Litres)	Method of application
chlorine	200 Lts	flushed

PUMPING TESTS ON COMPLETION 10

Test type		Date	Pump intake depth (m)	Initial Water Level (SWL) (m)	Pumping rate (L/s)	Water Level at end of pumping (DDL) (m)	Duration of Test (hrs)	Recovery Water level (m)	Recovery Time taken (hrs)	Recovery Time taken (mins)
Multi stage (stepped drawdown)	Stage 1									
	Stage 2									
	Stage 3									
	Stage 4									
Single stage (constant rate)										

Height of measuring point above ground level m Test Method See Code 4

WORK PARTLY BACKFILLED OR ABANDONED 11

Original depth of work: m Is work partly backfilled: (Yes/No)

Is work abandoned: (Yes/No) Method of abandonment: Backfilled ☐ Plugged ☐ Capped ☐

Has any casing been left in the work (Yes/No) From m To m

Sealing / fill type	From depth (m)	To depth (m)	Sealing / fill type	From depth (m)	To depth (m)
See Code 11			See Code 11		

Site chosen by: Hydrogeologist ☐ Geologist ☐ Driller ☐ Diviner ☐ Client ☒ Other 12

13

Lot No 2 DP No 574308

Work Location Co ordinates Easting 481984 Northing 6521978 Zone

GPS: (Yes/No) Yes >> AMG/AGD or MGA/GDA (See explanation)

Longitude Latitude

Please mark the work site with "X" on the CLID provided map.
Indicate also the distances in metres from two (2) adjacent boundaries, and attach the map to this Form A package.

Signatures:

Driller:

Date: 20-10-2015

Licensee:

Date:

NSW GOVERNMENT
Department of Primary Industries
Office of Water

Form A Particulars of completed work

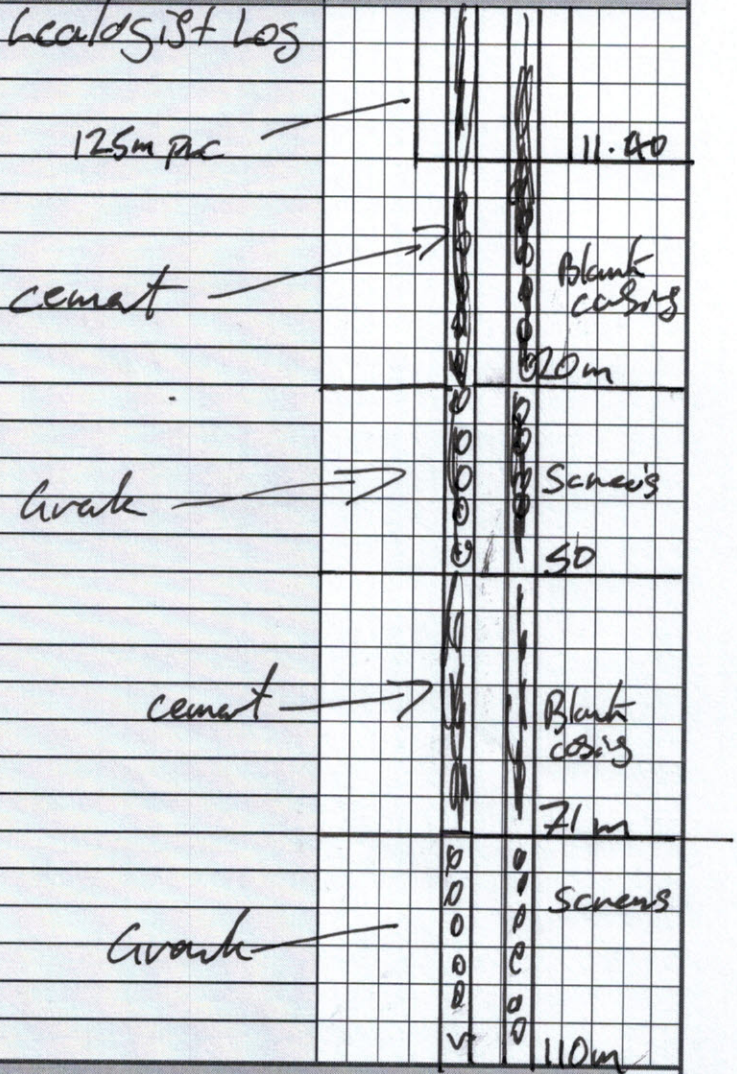
Work Licence No:

DRILLER'S ROCK/STRATA DESCRIPTION (LITHOLOGY)

15

Depth From (m)	Depth To (m)	Description (See Code 15)
0		~~The~~ See Attached Gealogist Log

WORK CONSTRUCTION SKETCH



WORK NOT CONSTRUCTED BY DRILLING RIG

16

Method of excavation: Hand dug ☐ Back hoe ☐ Dragline ☐ Dozer ☐ Other

Depth (m)	Length (m)	Width (m)	Diameter (m)	Lining material	Dimentions of liner (m)	From Depth (m)	To Depth (m)

Please attach copies of the following if available

17

Geologist log (Yes/No)	Yes	Laboratory analysis of water Sample (Yes/No)	no	Pumping test(s) (Yes/No)	no
Geophysical log (Yes/No)	no	Sieve analysis of aquifer material (Yes/No)	no	Installed Pump details (Yes/No)	no

SA 1502

Department of Primary Industries
Office of Water

Form A Particulars of completed work

Page 1

1

Driller's Licence No: DL 2266
Class of Licence: 4
Driller's Name: S Baker
Assistant Driller: J Dodds J Willcockson
Contractor: LRC contracting

New bore	☒	Replacement bore	☐
Deepened	☐	Enlarged	☐
Reconditioned	☐	Other (specify)	☐

Final Depth 84.05 m SA1502

2

Work Licence No: 20 BL173794
Name of Licensee: HAndSon
Intended Use: water monitoring
Completion Date: 20/08/2015

DRILLING DETAILS 3

From (m)	To (m)	Hole Diameter (mm)	Drilling Method See Code 3
0	9	123	7
9	84.05	96	13

WATER BEARING ZONES 4

From (m)	To (m)	Thickness (m)	S W L (m)	Estimated Yield (L/s) Individual Aquifer	Estimated Yield (L/s) Cumulative	Test method See Code 4	D D L at end of test (m)	Duration Hrs	Duration min	Salinity (Conductivity or TDS) Cond (µS/cm)	Salinity TDS (mg/L)
45	81	36	15		0.16	1	16	2	30		

CASING / LINER DETAILS 5

Material Code 5	OD (mm)	Wall Thickness (mm)	From (m)	To (m)	Method Fixing Code 5
6	50	8	81	84	5
6	50	8	0	45	5

Casing support method See Code 5: 2
Type of casing bottom See Code 5: 2
Centralisers installed (Yes/No) no (indicate on sketch)
Sump installed (Yes/No) no From m To m
Pressure cemented (Yes/No) no From m To m
Casing Protector cemented in place

WATER ENTRY DESIGN 6

General Material Code 5	OD (mm)	Wall Thickness (mm)	From (m)	To (m)	Opening type See Code 6	Fixing See Code 5	Screen Aperture (mm)	Slot Details Length (mm)	Width (mm)	Alignment See Code 6
6	50	8	45	81	5	5	1			H

GRAVEL PACK 7

Type		Grade		Grain size (mm) From	Grain size (mm) To	Depth (m) From	Depth (m) To	Quantity Litres	Quantity m^3
Rounded	☐	Graded	☒	5	7	30	84	284	0.28
Crushed	☐	Ungraded	☐						
Bentonite/Grout seal (Yes/No)		yes				0	30	158	0.16

Method of placement of Gravel Pack See Code 7: 1

For Departmental use only: G W

Please submit forms to water.gds@dpi.nsw.gov.au or to the local NSW Office of Water agency

SA 1502

NSW GOVERNMENT | **Department of Primary Industries** Office of Water

Form A Particulars of completed work

Work Licence No:

BORE DEVELOPMENT 8

Chemical used for breaking down drilling mud (Yes/No) Yes Name: CHLOQine

Method	Bailing/Surging ☐	Jetting ☐	Airlifting ☒	Backwashing ☐	Pumping ☒	Other:
Duration	hrs	hrs	2-5 hrs	hrs	1 hrs	hrs

DISINFECTION ON COMPLETION 9

Chemical(s) used	Quantity applied (Litres)	Method of application

PUMPING TESTS ON COMPLETION 10

Test type		Date	Pump intake depth (m)	Initial Water Level (SWL) (m)	Pumping rate (L/s)	Water Level at end of pumping (DDL) (m)	Duration of Test (hrs)	Recovery Water level (m)	Recovery Time taken (hrs)	Recovery Time taken (mins)
Multi stage (stepped drawdown)	Stage 1									
	Stage 2									
	Stage 3									
	Stage 4									
Single stage (constant rate)										

Height of measuring point above ground level m Test Method See Code 4

WORK PARTLY BACKFILLED OR ABANDONED 11

Original depth of work: 84-05 m Is work partly backfilled: (Yes/No) ☐

Is work abandoned: (Yes/No) ☐ Method of abandonment: Backfilled ☐ Plugged ☐ Capped ☐

Has any casing been left in the work (Yes/No) ☐ From m To m

Sealing / fill type See Code 11	From depth (m)	To depth (m)	Sealing / fill type See Code 11	From depth (m)	To depth (m)

Site chosen by: Hydrogeologist ☐ Geologist ☐ Driller ☐ Diviner ☐ Client ☒ Other 12

13

Lot No 2 DP No 574308

Work Location Co ordinates Easting Northing Zone

GPS: (Yes/No) ☐ >> AMG/AGD ☐ or MGA/GDA ☐ (See explanation)

Longitude Latitude

Please mark the work site with "X" on the CLID provided map.
Indicate also the distances in metres from two (2) adjacent boundaries, and attach the map to this Form A package.

Signatures:

Driller: **Licensee:**

Date: 24/08/2015 **Date:**

Please submit forms to water.gds@dpi.nsw.gov.au or to the local NSW Office of Water agency

SK 1502

NSW GOVERNMENT | Department of Primary Industries Office of Water

Form A Particulars of completed work

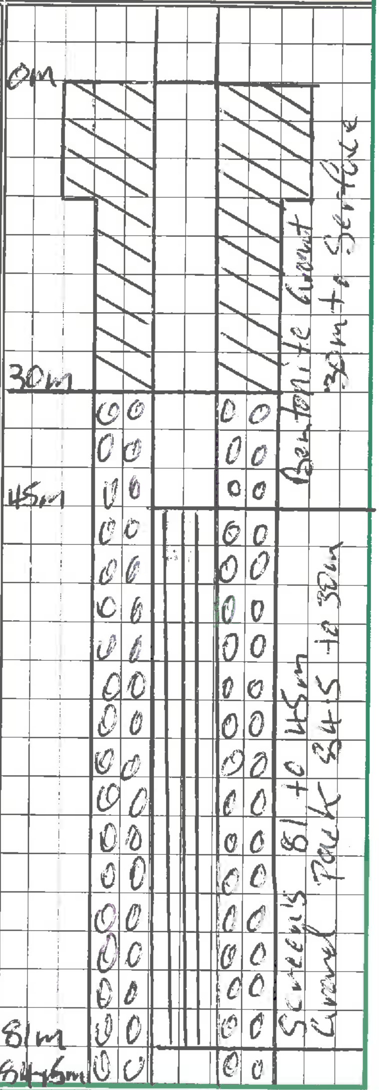
Work Licence No:

DRILLER'S ROCK/STRATA DESCRIPTION (LITHOLOGY)

Depth From (m)	Depth To (m)	Description See Code 15
0		See Attached Geologist Log

WORK CONSTRUCTION SKETCH

15



WORK NOT CONSTRUCTED BY DRILLING RIG

16

Method of excavation: Hand dug ☐ Back hoe ☐ Dragline ☐ Dozer ☐ Other ☐

Depth (m)	Length (m)	Width (m)	Diameter (m)	Lining material	Dimentions of liner (m)	From Depth (m)	To Depth (m)

Please attach copies of the following if available

17

Geologist log	(Yes/No) yes	Laboratory analysis of water Sample	(Yes/No) no	Pumping test(s)	(Yes/No) no
Geophysical log	(Yes/No) no	Sieve analysis of aquifer material	(Yes/No) no	Installed Pump details	(Yes/No) no

Please submit forms to water.gds@dpi.nsw.gov.au or to the local NSW Office of Water agency

SA1503

NSW GOVERNMENT
Department of Primary Industries
Office of Water

Form A Particulars of completed work

Page 1

1

Driller's Licence No: DL 2266
Class of Licence: 4
Driller's Name: S Baker
Assistant Driller: J COX T willcockson
Contractor: LCR contracting

New bore ☒ Replacement bore ☐
Deepened ☐ Enlarged ☐
Reconditioned ☐ Other (specify) ☐

Final Depth 101.75 m SA1503

2

Work Licence No: 20BL173794
Name of Licensee: HandSon
Intended Use: water monitoring
Completion Date: 22/08/2015

DRILLING DETAILS 3

From (m)	To (m)	Hole Diameter (mm)	Drilling Method See Code 3
0	9	123	7
9	101.75	96	13

WATER BEARING ZONES 4

From (m)	To (m)	Thickness (m)	S W L (m)	Estimated Yield (L/s) Individual Aquifer	Estimated Yield (L/s) Cumulative	Test method See Code 4	D D L at end of test (m)	Duration Hrs	Duration min	Salinity (Conductivity or TDS) Cond (µS/cm)	Salinity (Conductivity or TDS) TDS (mg/L)
30	10175	71.75	15		0.2	1	16	2	30		

CASING / LINER DETAILS 5

Material Code 5	OD (mm)	Wall Thickness (mm)	From (m)	To (m)	Method Fixing Code 5
6	50	8	0	30	5

Casing support method See Code 5: 2
Type of casing bottom See Code 5: 2
Centralisers installed (Yes/No) no (indicate on sketch)
Sump installed (Yes/No) no From m To m
Pressure cemented (Yes/No) no From m To m
Casing Protector cemented in place

WATER ENTRY DESIGN 6

General Material Code 5	General OD (mm)	General Wall Thickness (mm)	General From (m)	General To (m)	General Opening type See Code 6	General Fixing See Code 5	Screen Aperture (mm)	Slot Details Length (mm)	Slot Details Width (mm)	Slot Details Alignment See Code 6
6	50	8	30	101.75	5	5	1			H

GRAVEL PACK 7

Type		Grade		Grain size (mm) From	Grain size (mm) To	Depth (m) From	Depth (m) To	Quantity Litres	Quantity m³
Rounded		Graded	☒	5	7	29	101.75	374	0.37
Crushed		Ungraded	☐						
Bentonite/Grout seal (Yes/No)			Yes			0	29	163	0.16

Method of placement of Gravel Pack See Code 7: 1

For Departmental use only: GW

Please submit forms to water.gds@dpi.nsw.gov.au or to the local NSW Office of Water agency

SA 1503

NSW GOVERNMENT
Department of Primary Industries
Office of Water

Form A Particulars of completed work

Work Licence No:

BORE DEVELOPMENT — 8

Chemical used for breaking down drilling mud (Yes/No) Yes Name: CHLoRine

Method	Bailing/Surging ☐	Jetting ☐	Airlifting ☒	Backwashing ☐	Pumping ☒	Other:
Duration	hrs	hrs	1.5 hrs	hrs	1 hrs	hrs

DISINFECTION ON COMPLETION — 9

Chemical(s) used	Quantity applied (Litres)	Method of application

PUMPING TESTS ON COMPLETION — 10

Test type		Date	Pump intake depth (m)	Initial Water Level (SWL) (m)	Pumping rate (L/s)	Water Level at end of pumping (DDL) (m)	Duration of Test (hrs)	Recovery Water level (m)	Recovery Time taken (hrs)	(mins)
Multi stage (stepped drawdown)	Stage 1									
	Stage 2									
	Stage 3									
	Stage 4									
Single stage (constant rate)										

Height of measuring point above ground level ☐ m Test Method ☐ See Code 4

WORK PARTLY BACKFILLED OR ABANDONED — 11

Original depth of work: ☐ m Is work partly backfilled: (Yes/No) ☐

Is work abandoned: (Yes/No) ☐ Method of abandonment: Backfilled ☐ Plugged ☐ Capped ☐

Has any casing been left in the work (Yes/No) ☐ From ☐ m To ☐ m

Sealing / fill type See Code 11	From depth (m)	To depth (m)	Sealing / fill type See Code 11	From depth (m)	To depth (m)

12

Site chosen by: Hydrogeologist ☐ Geologist ☐ Driller ☐ Diviner ☐ Client ☒ Other ☐

13

Lot No 2 DP No 574308

Work Location Co ordinates Easting 482127 Northing 6521775 Zone ☐

GPS: (Yes/No) ☐ >> AMG/AGD ☐ or MGA/GDA ☐ (See explanation)

Longitude ☐ ☐ ☐ Latitude ☐ ☐ ☐

Please mark the work site with "X" on the CLID provided map.
Indicate also the distances in metres from two (2) adjacent boundaries, and attach the map to this Form A package.

Signatures:

Driler:
Date: 24/08/2015

Licensee: ------------------------------
Date: ------------------------------

Please submit forms to water.gds@dpi.nsw.gov.au or to the local NSW Office of Water agency

SA 1503

NSW GOVERNMENT Department of Primary Industries Office of Water

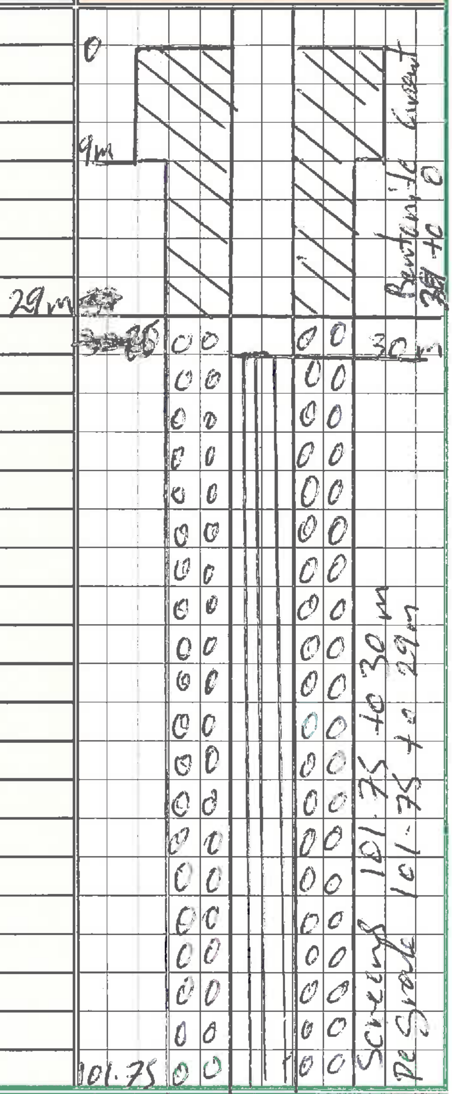
Form A Particulars of completed work

Work Licence No:

DRILLER'S ROCK/STRATA DESCRIPTION (LITHOLOGY)

Depth		Description
From (m)	To (m)	See Code 15
0		See Attached Geologist Log

15 WORK CONSTRUCTION SKETCH



WORK NOT CONSTRUCTED BY DRILLING RIG

16

Method of excavation: Hand dug ☐ Back hoe ☐ Dragline ☐ Dozer ☐ Other ☐

Depth (m)	Length (m)	Width (m)	Diameter (m)	Lining material	Dimentions of liner (m)	From Depth (m)	To Depth (m)

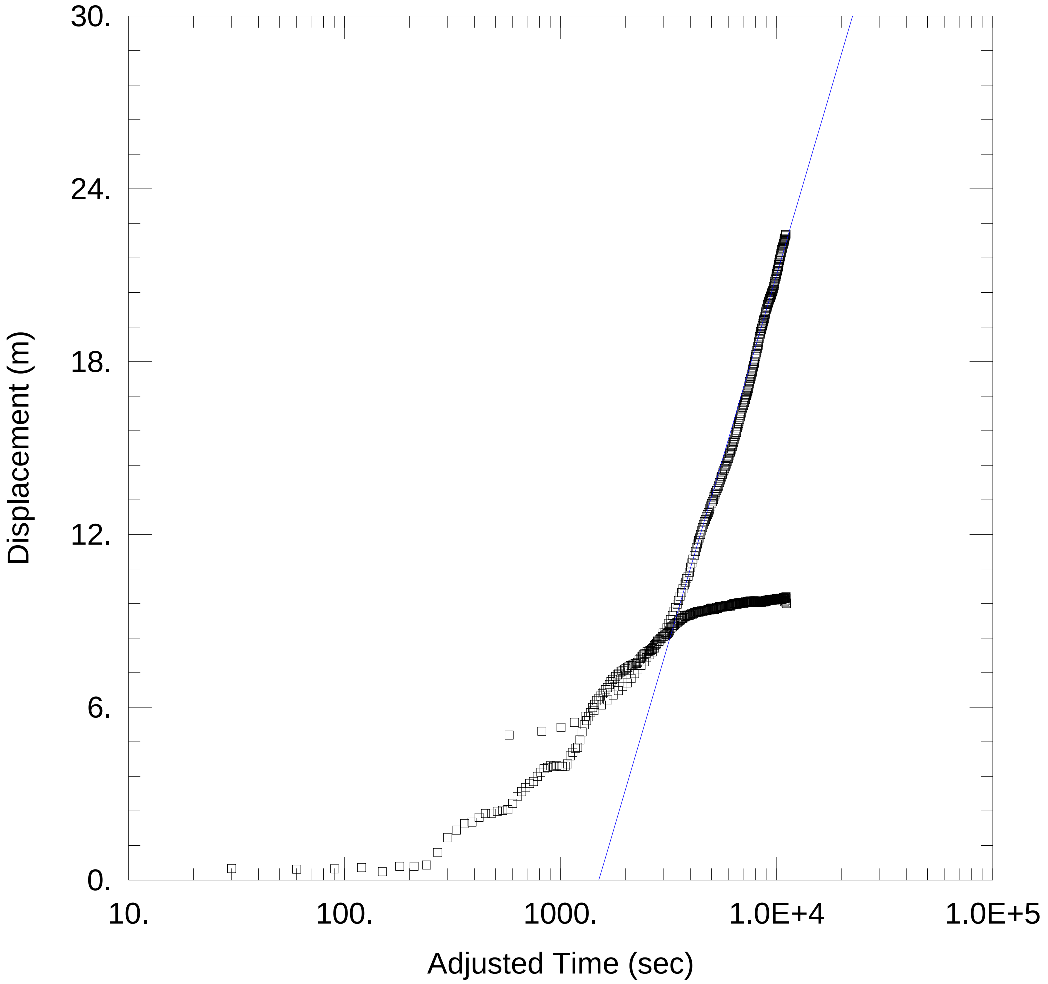
Please attach copies of the following if available

17

Geologist log	(Yes/No) YES	Laboratory analysis of water Sample	(Yes/No) no	Pumping test(s)	(Yes/No) no
Geophysical log	(Yes/No) no	Sieve analysis of aquifer material	(Yes/No) no	Installed Pump details	(Yes/No) no

Annex C

AQTESOLV Outputs



WELL TEST ANALYSIS

Data Set: P:\...\SA1501 - Both Pumping Stages - Cooper Jacob.aqt

Date: 02/01/18 Time: 10:42:42

PROJECT INFORMATION

Company: ERM
Client: Hanson
Project: 0418291
Location: Sancrox
Test Well: SA1501
Test Date: 29 November 2017

AQUIFER DATA

Saturated Thickness: 70. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
SA1501	0	0

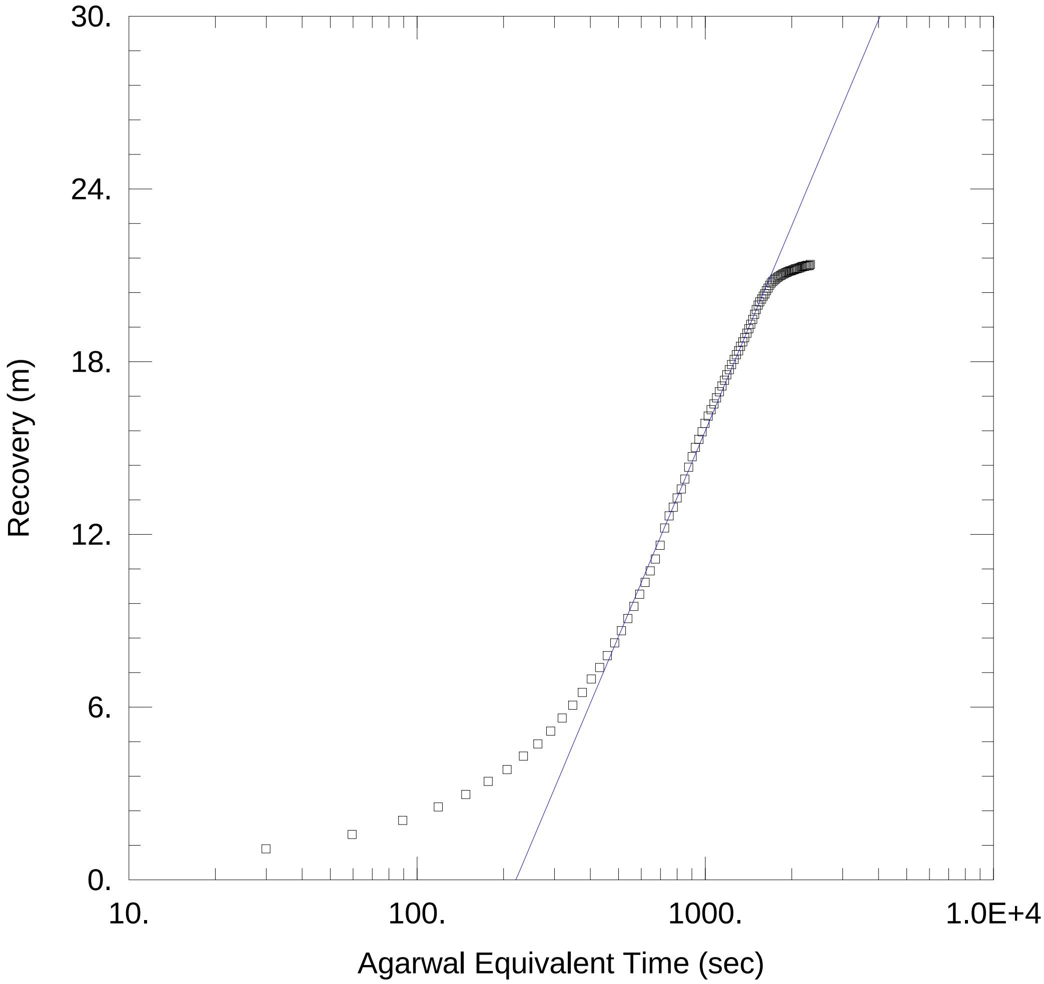
Observation Wells

Well Name	X (m)	Y (m)
□ SA1501	0	0

SOLUTION

Aquifer Model: Confined Solution Method: Cooper-Jacob

T = 0.062 m^2/day S = 3.878



WELL TEST ANALYSIS

Data Set: P:\...\SA1501 - Recovery Stage - Cooper Jacob.aqt
Date: 02/01/18 Time: 10:44:47

PROJECT INFORMATION

Company: ERM
Client: Hanson
Project: 0418291
Location: Sancrox
Test Well: SA1501
Test Date: 29 November 2017

AQUIFER DATA

Saturated Thickness: 70. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
SA1501	0	0

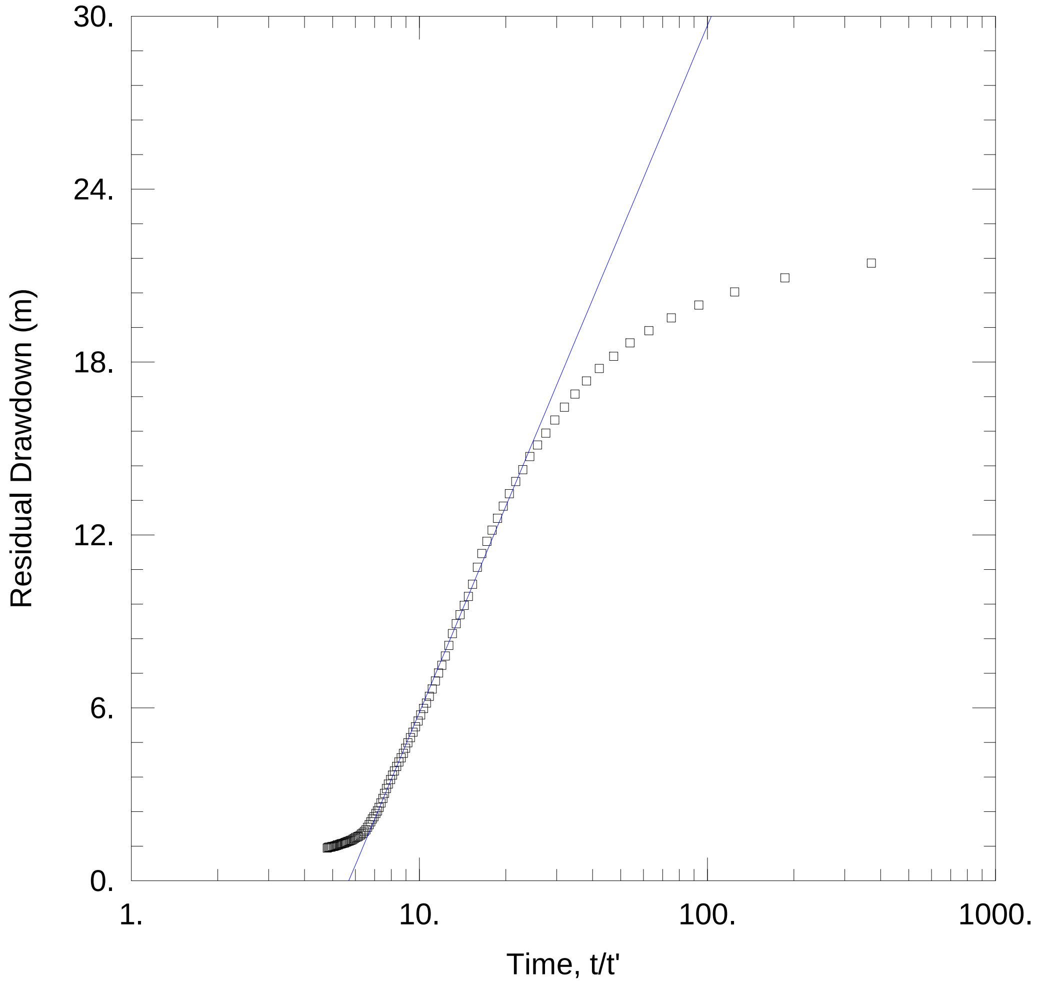
Observation Wells

Well Name	X (m)	Y (m)
□ SA1501	0	0

SOLUTION

Aquifer Model: Confined Solution Method: Cooper-Jacob

T = 0.06667 m^2/day S = 0.6113



WELL TEST ANALYSIS

Data Set: P:\...\SA1501 - Recovery Stage - Theis Recovery.aqt
Date: 02/01/18 Time: 10:46:02

PROJECT INFORMATION

Company: ERM
Client: Hanson
Project: 0418291
Location: Sancrox
Test Well: SA1501
Test Date: 29 November 2017

AQUIFER DATA

Saturated Thickness: 70. m
Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
SA1501	0	0

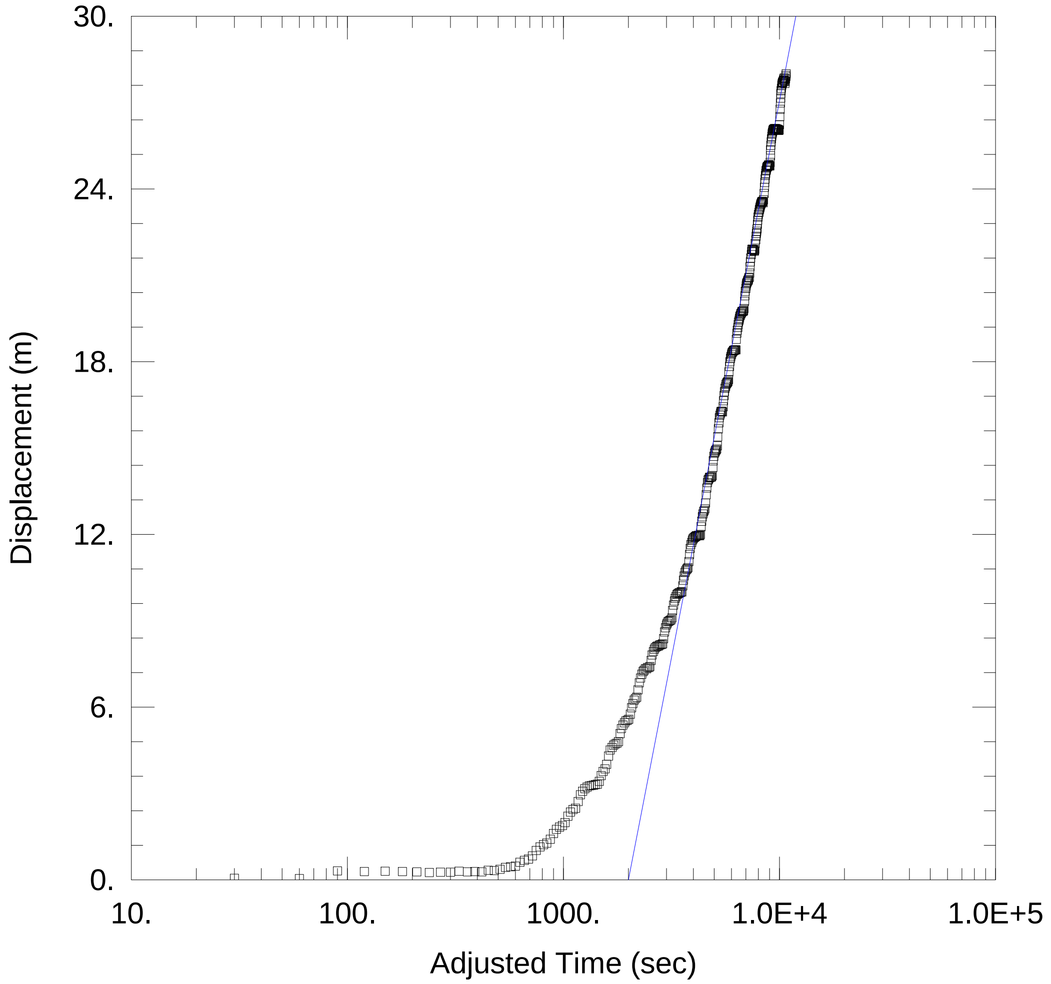
Observation Wells

Well Name	X (m)	Y (m)
□ SA1501	0	0

SOLUTION

Aquifer Model: Confined
Solution Method: Theis (Recovery)

T = 0.06643 m^2/day
S/S' = 5.693



WELL TEST ANALYSIS

Data Set: P:\...\SA1502 - 1st Pumping Stage - Cooper Jacob.aqt
Date: 02/01/18 Time: 10:47:13

PROJECT INFORMATION

Company: ERM
Client: Hanson
Project: 0418291
Location: Sancrox
Test Well: SA1502
Test Date: 28 November 2017

AQUIFER DATA

Saturated Thickness: 36. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
SA1502	0	0

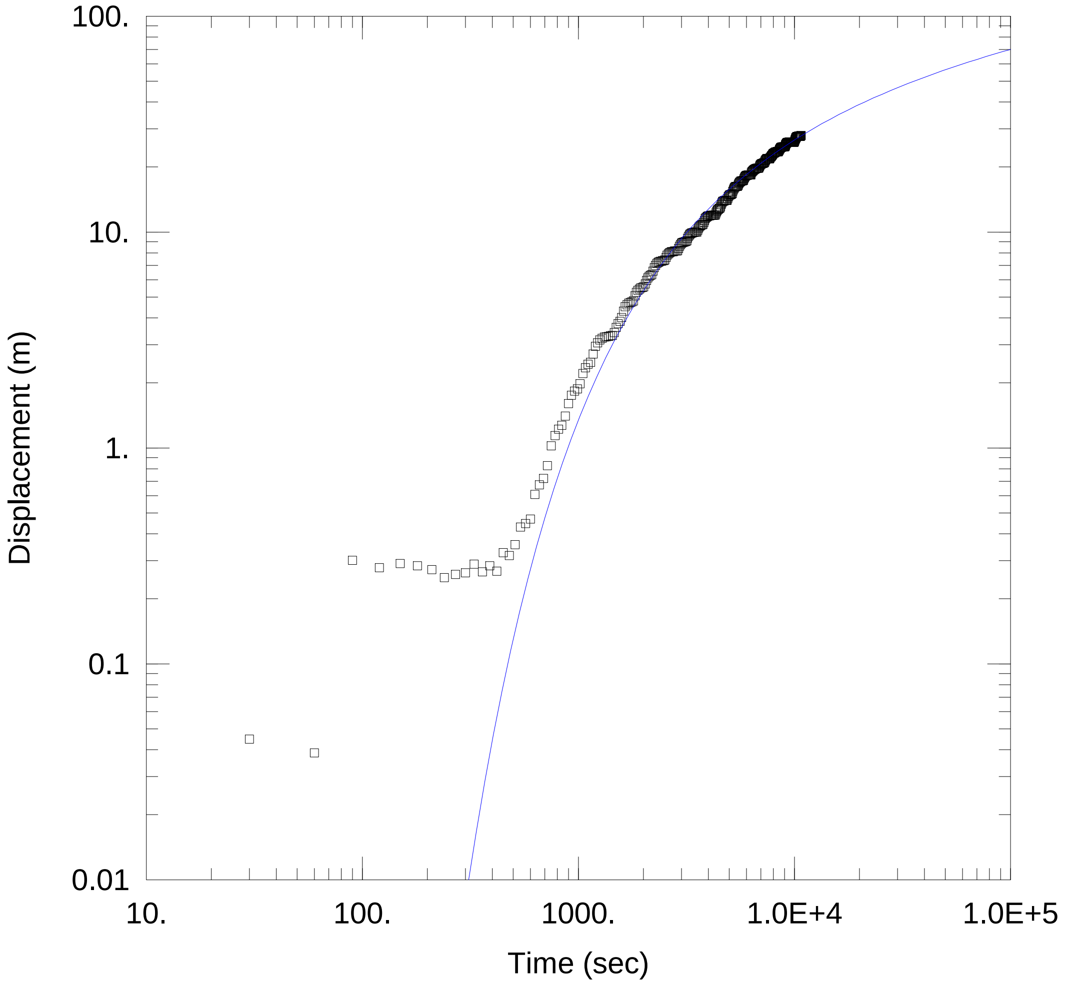
Observation Wells

Well Name	X (m)	Y (m)
□ SA1502	0	0

SOLUTION

Aquifer Model: Confined Solution Method: Cooper-Jacob

T = 0.006819 m^2/day S = 0.5673



WELL TEST ANALYSIS

Data Set: P:\...\SA1502 - 1st Pumping Stage - Theis Hantush.aqt
Date: 02/01/18 Time: 10:48:07

PROJECT INFORMATION

Company: ERM
Client: Hanson
Project: 0418291
Location: Sancrox
Test Well: SA1502
Test Date: 28 November 2017

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
SA1502	0	0

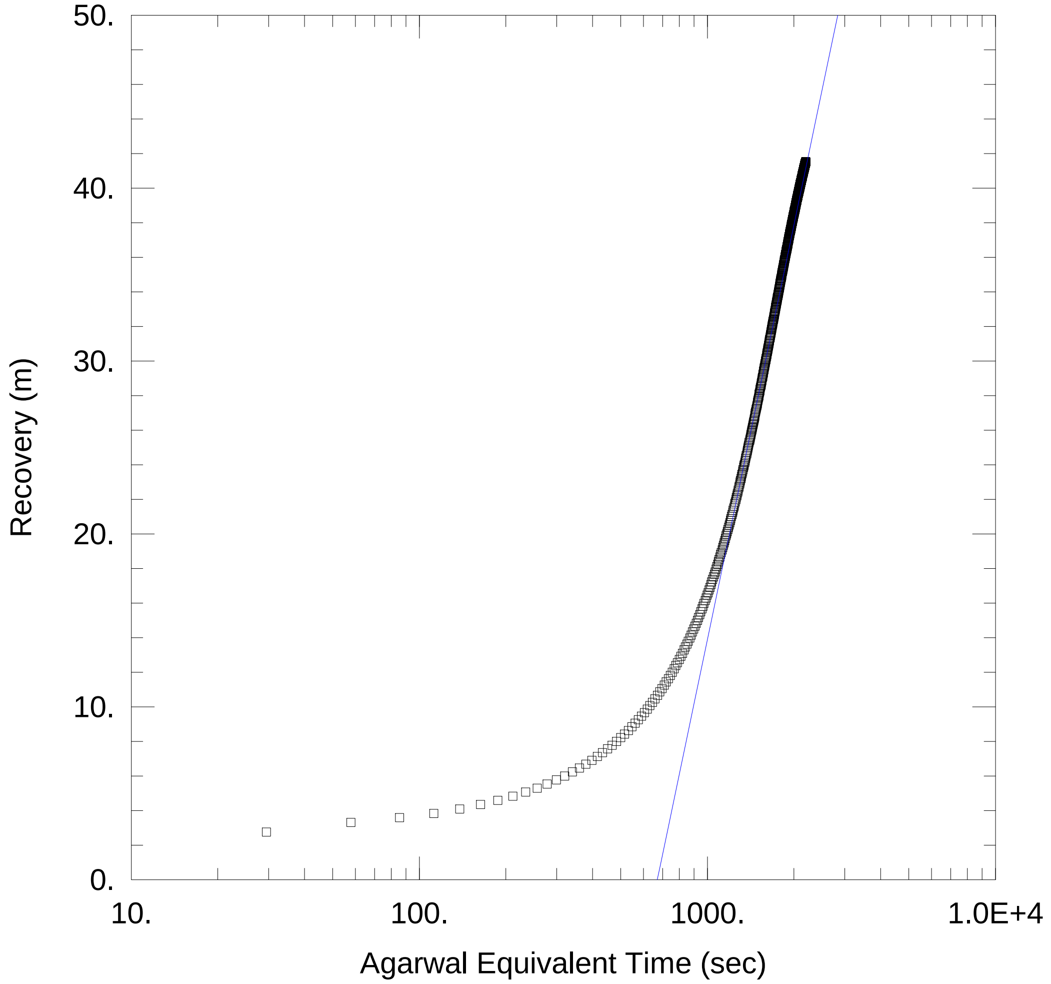
Observation Wells

Well Name	X (m)	Y (m)
□ SA1502	0	0

SOLUTION

Aquifer Model: Confined
Solution Method: Theis

T = 0.005671 m^2/day
S = 0.7479
Kz/Kr = 1.
b = 36. m



WELL TEST ANALYSIS

Data Set: P:\...\SA1502 - Recovery Stage - Cooper Jacob.aqt
Date: 02/01/18 Time: 10:49:01

PROJECT INFORMATION

Company: ERM
Client: Hanson
Project: 0418291
Location: Sancrox
Test Well: SA1502
Test Date: 28 November 2017

AQUIFER DATA

Saturated Thickness: 36. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
SA1502	0	0

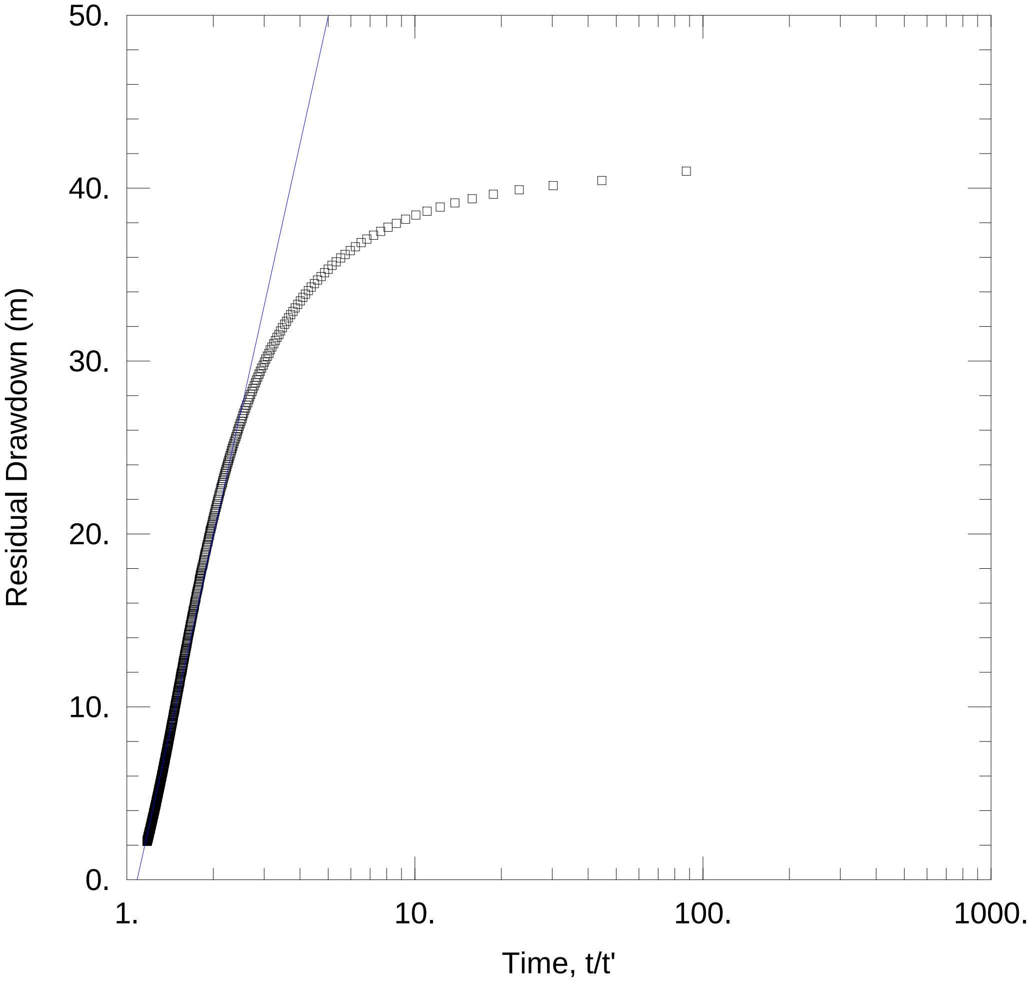
Observation Wells

Well Name	X (m)	Y (m)
□ SA1502	0	0

SOLUTION

Aquifer Model: Confined Solution Method: Cooper-Jacob

T = 0.009913 m^2/day S = 0.2763



WELL TEST ANALYSIS

Data Set: P:\...\SA1502 - Recovery Stage - Theis Recovery.aqt
Date: 02/01/18 Time: 10:50:14

PROJECT INFORMATION

Company: ERM
Client: Hanson
Project: 0418291
Location: Sancrox
Test Well: SA1502
Test Date: 28 November 2017

AQUIFER DATA

Saturated Thickness: 36. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
SA1502	0	0

Observation Wells

Well Name	X (m)	Y (m)
□ SA1502	0	0

SOLUTION

Aquifer Model: Confined Solution Method: Theis (Recovery)

T = 0.01051 m^2/day S/S' = 1.087

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