

PROJECT

**SUPPLEMENTARY
GROUNDWATER MODEL REPORT
TWEED SAND PLANT EXPANSION
CUDGEN, NEW SOUTH WALES**

PREPARED FOR

HANSON CONSTRUCTION MATERIALS PTY LTD

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SYNOPSIS This report was prepared to satisfy relevant aspects of a submission from the Department of Planning Industry and Environment – Water Division and the Natural Resource Access Regulator on the groundwater model contained in the Hanson Construction Materials Tweed Sand Plant Expansion, Environmental Impact Study April 2021. This report provides the outcomes of a review of the MODFLOW three-dimensional finite-difference groundwater flow model contained in the Environmental Impact Study, Tweed Sand Plant Expansion Phase 5 to Phase 11 against the Australian Groundwater Modelling Guidelines 2012 and where required provides additional explanation and assessment to ensure the model is 'fit for purpose'.

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SUMMARY

In March 2021, Hanson Construction Materials Pty Ltd (Hanson) submitted an Environmental Impact Study (EIS) for the proposed expansion of its Tweed Sand Plant (TSP) operation located in Cudgen, New South Wales. Hanson commissioned Gilbert & Sutherland (G&S) to prepare a number of technical assessments contained within the EIS, including a MODFLOW three-dimensional finite-difference groundwater flow model.

Following Public Exhibition of the EIS from 22 April to 20 May 2021, a total of 13 submissions were received. This supplementary Groundwater Model Report was prepared in response to the submission received from the Department of Planning, Industry and Environment's Water Department (herein 'DPIE Water') and the Natural Resource Access Regulator (NRAR), which requested the Proponent to prepare additional information to confirm the adequacy of the groundwater model.

This report constitutes the Supplementary Groundwater Model Report. It incorporates amendments and additional information as recommended by review of the MODFLOW three-dimensional finite-difference groundwater flow model (as reported in the Environmental Impact Study, Tweed Sand Plant Expansion Phase 5 to Phase 11) against the Australian Groundwater Modelling Guidelines 2012.

Outcomes of supplementary groundwater modelling

Given the nature of the site soils and groundwater characteristics observed to date, the most likely potential impacts on groundwater as a result of the development are:

- Localised and minor changes to pre-development groundwater flow regimes in the vicinity of the lake that will be largely contained within the development footprint. These changes in groundwater elevation are brought about by the changes in topography caused by extraction of sand. Essentially, reducing the land elevation and removing the substrate that contains the groundwater results in an associated lowering of the immediate groundwater table as it equilibrates with the surface water level of the extraction lake.

- Changes to groundwater elevation as a result of the proposed expansion are predominantly contained within the development footprint with minimal change occurring outside of the site boundary as a result of the TSP expansion.
- This iteration of the model incorporates a number of changes to the proposed buffer widths to minimise the predicted offsite impacts. The residual impacts are summarised below:
 - There is a maximum 0.5 m lowering of the water table in the northern portion of the expansion area. The impact is predominantly contained within the expansion footprint, however a decrease in groundwater elevation of up to 0.3 m is predicted within a small portion of the lands outside the northern perimeter of Lot 51 on DP1166990.
 - With respect to the Low Potential GDE (Drawing No. 12035-501) adjacent the southern boundary of the expansion footprint west of Lot 1 on DP1250570. The revised groundwater model incorporates an increased buffer distance of ~50 m between the limit of extraction and the site boundary. Whilst groundwater drawdown is still predicted to occur within this area the increased buffer distance has reduced the lateral extent of offsite drawdown from 170 m to 155 m and reduced the magnitude of drawdown to between 0.1 m and 0.5 m. The footprint of offsite drawdown in this area has reduced by ~4,300 m².
 - As the change in groundwater table predicted in this area is within the range of natural seasonal fluctuation, it is unlikely that the swamp sclerophyll forest (*Casuarina Glauca*) present in this area will experience negative impacts as a result of the localised change in groundwater conditions. Further consideration of the sensitivity of this species to groundwater drawdown of this magnitude is provided by JWA Ecological Consultants.
 - With respect to the High Potential GDE within the north-eastern corner of Lot 51 on DP1166990 (as shown on Drawing 12035-501), no change between the pre- and post-extraction groundwater table is predicted to occur within this area of the site. It is understood however that as portion of this vegetation is within the proposed extent of the extraction area some of the existing vegetation is likely to be removed. Removal of vegetation and offsets (where required) are considered in the Biodiversity Development

Assessment Report prepared by JWA Ecological Consultants, October 2021.

- Groundwater level changes resulting from the development are not predicted to cause impacts within proximity to any of the known registered bores.

Cumulative impact assessment

Drawing 12035-SUPP_GWM_007 (Appendix 8) shows the cumulative impact of the fully extracted TSP site and the fully extracted Cudgen Lakes Project. The drawing indicates that changes to groundwater elevation are predominantly contained within the respective development footprints and range from 0.1m up to 1.0m. These predictions align well with the predictions of groundwater modelling undertaken for the Cudgen Lake's Sand Extraction Project as reported in the 2008 Groundwater Assessment undertaken for that Project's EIS.

Similarly to the TSP expansion, the predicted changes in groundwater elevation are due to topography changes caused by extraction of sand. Reducing the land elevation and removing the substrate that contains the groundwater results in an associated lowering of the immediate groundwater table as it equilibrates with the surface water level of the extraction lake. The full extraction of sand at both sites does not result in an increase in the magnitude of drawdown caused by either operation (i.e. the impacts caused by each development are separate and do not exacerbate each other under steady state conditions).

Sea level rise

The model predicts that the groundwater level within the expansion area and throughout the model domain will increase by a minimum of 0.1 m up to a maximum of 1.0 m as a result of sea level rise for both the 2050 (0.4 m) and 2100 (0.9 m) sea level rise predictions. As anticipated by TSC's Climate Change Policy, the predicted sea-level rise will exacerbate tidal inundation and impede the site's drainage leading to increased waterlogging of soils.

Rehabilitation works at the site will necessarily include species that are tolerant of periodic waterlogging and can withstand the predicted rise in groundwater elevations. More detail of the site's rehabilitation, including species selection is contained in the site's Concept Rehabilitation and Landscape Management Plan prepared by JWA Ecological Consultants.

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DRAWING NO.	DESCRIPTION
Z19163 – F19 and F120	Concept Development Phasing
12035-003	Monitoring Locations
12035-101	NSW Wetlands (OEH)
12035-102	Coastal Wetlands SEPP (Coastal Management) 2018
12035-103	Groundwater Dependant Ecosystems
12035-104	High Priority Groundwater Dependant Ecosystems
12035-501	Registered Groundwater Bores
12035-502 to 12035-509	Potentiometric surfaces
12035 – SUPP_GWM_001	Conceptual Groundwater Model Location Plan
12035 – SUPP_GWM_002	Conceptual Groundwater Model
12035 – SUPP_GWM_003	Modelled existing groundwater conditions
12035 – SUPP_GWM_004	Modelled post-extraction groundwater conditions – Tweed Sand Plant Only
12035 – SUPP_GWM_005	Modelled cumulative post-extraction groundwater conditions– TSP Expansion and Cudgen Lakes
12035 – SUPP_GWM_006	Change in modelled groundwater elevation (Existing to Developed Site Conditions) Tweed Sand Plant only
12035 – SUPP_GWM_007	Cumulative change in modelled groundwater elevation (Existing to Developed Site Conditions) TSP Expansion and Cudgen Lakes
12035 – SUPP_GWM_008	Change in groundwater elevation with 0.4m sea level rise
12035 – SUPP_GWM_009	Change in groundwater elevation with 0.9m sea level rise

1 Introduction

In March 2021, Hanson Construction Materials Pty Ltd (Hanson) submitted an Environmental Impact Study (EIS) for the proposed expansion of its Tweed Sand Plant (TSP) operation located in Cudgen, New South Wales. Hanson instructed Gilbert & Sutherland (G&S) to prepare a number of technical assessments contained within the EIS including a MODFLOW three- dimensional finite-difference groundwater flow model.

Following Public Exhibition of the EIS from 22 April to 20 May 2021, a total of 13 submissions were received. This Supplementary Groundwater Model Report was prepared in response to the submission received from the Department of Planning, Industry and Environment's Water Department (herein 'DPIE Water') and the Natural Resource Access Regulator (NRAR), which requested the Proponent to prepare additional information to confirm the adequacy of the groundwater model against the Australian Groundwater Modelling Guidelines (2012).

1.1 Scope of this report

The DPIE and NRAR submission dated 18 June 2021 requested additional information be provided in respect of the groundwater assessment¹ within the EIS. Key items from the DPIE Water and NRAR submission to be addressed in this Supplementary Groundwater Model report are reproduced below in italic text.

2.1 Pre-approval Recommendations

The proponent should:

- a) *prepare a supplementary groundwater model report detailing how the model addresses requirements set out in the Australian Groundwater Modelling Guidelines (2012),*

OR

- b) *submit an independent review of the groundwater model that reports adherence with Australian Groundwater*

Modelling Guidelines (2012) requirements and advise if the independent expert's opinion is that the model is considered 'fit for purpose'.

Explanation

Potential water level impacts are predicted by numerical modelling. A MODFLOW three - dimensional finite-difference groundwater flow model was developed, however, there is no conceptual model and only limited information presented on the model setup, calibration, use and outputs. The available content is insufficient to complete an assessment of adequacy against the Australian Groundwater Modelling Guidelines (2012) and to resolve both the class category and whether the model is 'fit for purpose'.

The AIP requires an independent review of the groundwater model to accompany an impact assessment where development consent under Part 4, Division 4.1 of the Environmental Planning & Assessment Act 1979 applies. This project seeks development consent under Part 4, Division 4.7 of the Environmental Planning & Assessment Act 1979 therefore the AIP requirement for a complex modelling platform and independent review is not mandatory.

However, DPIE Water cannot determine if the model is 'fit for purpose' with doubts that steady state modelling is sufficient for a brownfield site with existing impact stressors and large evaporative losses.

This is important particularly for understanding the bounds of error in drawdown for assessment against the AIP 'high priority' Groundwater Dependent Ecosystem (GDE) minimal impact criteria...'

In line with option 2.1(a), this report constitutes the Supplementary Groundwater Model Report following review of the MODFLOW three-dimensional finite-difference groundwater flow

¹ Gilbert & Sutherland (March 2021). Groundwater Assessment, Tweed Sand Plant Expansion, Cudgen, New South Wales (Appendix C of EIS).

model (as reported in the Environmental Impact Study, Tweed Sand Plant Expansion Phase 5 to Phase 11) against the Australian Groundwater Modelling Guidelines 2012 (herein the 'AGM Guidelines 2012').

The supplementary report incorporates amendments and additional information regarding the set-up, inputs and outcomes of the model to ensure compliance with the AGM Guideline.

2 Model review outcomes

The MODFLOW three-dimensional finite-difference groundwater flow model (as reported in the Environmental Impact Study, Tweed Sand Plant Expansion Phase 5 to Phase 11) was internally reviewed by G&S' Principal Hydrogeologist Eric Rooke² with specific focus on the issues identified in the DPIE and NRAR Information request. For reference Eric Rooke's CV is contained in Appendix 1.

That review included an assessment of the model against the Compliance checklists contained in Tables 9-1 and 9-2 of the AGM Guidelines 2012. A summary of the findings is provided below:

- The model described herein conforms to the 'Model confidence level classification, Class 2' guideline.³ This is generally used for enabling prediction of impacts of proposed developments in medium value aquifers.
- The model should be supported by the preparation of a robust conceptual hydrogeological model
- Additional reporting with regard to model parameters and calibration is required.
- Further exploration of the application of recharge within the model is required to ensure inputs are robust.
- Cumulative impacts between the TSP expansion project and neighbouring sand extraction should be explored.
- The model should be reviewed in conjunction with the detailed site water balance prepared under separate cover⁴.
- The model is fit for purpose and suitable for impact prediction within the calibrated extents of the model domain.

Overall, the model was found to be 'fit for purpose' with a number of areas identified as

requiring additional supporting information and reporting in order to better describe the model set-up, its calibration and predicted outcomes.

The completed checklists are contained in Appendix 2 of this report. The recommendations of the review have been fully implemented in a revised MODFLOW groundwater model and described in this Supplementary Groundwater Model Report.

2.1 Key revisions to groundwater model

Following review of the various submissions received on the TSP Expansion EIS and the findings of the model review, a number of key changes have been incorporated into this revision of the site's groundwater model. These are itemised below and discussed in greater detail in later sections of this report:

- A cumulative impact assessment of the fully extracted TSP expansion proposal and the fully completed Cudgen Lakes Sand Extraction Project have been modelled.
- Lake boundaries have been adjusted at a number of locations to incorporate offsets from the Pacific Motorway and existing infrastructure and to include wider buffer widths in some areas;
 - On the western perimeter the lake boundary has been offset from the Pacific Motorway by 40 metres.
 - The perimeter on the north-eastern corner of Lot 22 on DP1082435 has been adjusted to avoid disturbance of existing electricity infrastructure.
 - The buffer width on part of the south-western perimeter of Lot 1 on DP1250570 (Phase 9 of extraction) has been increased to from ~10m up to ~50m to reduce previously reported offsite drawdown in this area and associated impacts on mapped low-potential GDE's.

² Principal Hydrogeologist Eric Rooke (who had no input into the original model concept, design, inputs and outputs).

³ Barnett et al, 2012, *Australian groundwater modelling guidelines*, Waterlines report, National Water Commission, Canberra. ISBN: 978-1-921853-91-3.

⁴ Gilbert & Sutherland (October, 2021). Revised Water Balance Modelling, Tweed Sand Plant Expansion, Cudgen, New South Wales.

3 Model set-up

This section provides the methodology followed in preparation of the MODFLOW three-dimensional finite-difference groundwater flow model. It includes additional explanation, and a more detailed explanation of the modelling methodology in response to the findings of the model review.

Groundwater modelling was undertaken using MODFLOW (McDonald and Harbaugh, 1988) the United States Geological Survey (USGS) three-dimensional finite-difference groundwater flow model.

MODFLOW is a modular groundwater resources package with components for predicting subsurface flow and simulating the effects of wells, rivers, drains, head-dependent boundaries, recharge, and evapotranspiration. The data requirements of the constructed model are described in the following sections. For the purposes of this assessment a steady-state groundwater model was developed.

3.1 Model objectives

The model's objectives seek to investigate the impacts of an extractive industry, namely the planned expansion of the existing Hanson Tweed Sand Plant (TSP) to access a sand resource of 30-35 million tonnes and provide production and transport of a maximum 950,000 tonnes of sand per annum. It seeks to accomplish this by determining the:

- likely impacts to the groundwater flow system;
- impact, if any, to high priority groundwater dependent ecosystems.
- Impacts, if any, to other groundwater users in the locale.
- Cumulative impacts associated with the expansion of the TSP operation along with the neighbouring Cudgen Lakes Sand Extraction Project to the east.

- Assessment against the minimal impact considerations of the NSW Aquifer Interference Policy.

3.2 Hydrogeological conceptual model

Drawings 12035_SUPP_GWM_001 and 002 illustrate the hydrogeological conceptual model for the site (refer to Appendix 3). The conceptual model is based on data collected from the site as described in the following reports contained in the EIS;

- Groundwater Assessment, Tweed Sand Plant Expansion, Cudgen, New South Wales, March 2021 (Appendix C of the EIS).
- Acid Sulfate Soils Assessment, Tweed Sand Plant Expansion, Cudgen, New South Wales, January 2021 (Appendix K of the EIS).

The conceptual model provides an east-west cross section of the layered stratigraphy of the site based on the boreholes logged for the acid sulfate soil assessment. Groundwater levels indicated on the conceptual model are as encountered during drilling and noted on the borelogs. The relevant logs are included in Appendix 4.

The hydrogeological conceptual model was used as the basis for the set-up of the MODFLOW groundwater flow model as described in the following sections.

3.3 Model confidence level classification

The existing TSP and proposed expansion area are located within the Tweed Brunswick Coastal Sands (TBCS) of the Tweed Coastal Sands Groundwater Management Area (GMA).

The target confidence level classification for the model is Class 2 noting that some aspects of the model may be classified as Class 1⁵.

3.4 Model domain

The model grid was orientated at azimuth 0° in a northern alignment, comprising 271 columns over 5420m by 216 rows over 4,320m with a total of

⁵ The AGM Guidelines 2012 provide that '... It is not expected that any individual model will have all the defining characteristics of Class 1, 2 or 3 models. The characteristics described in Table 2-1 (of the Guideline) are typical features

that may have a bearing on the confidence with which a model can be used. A model can fall into different classes for the various characteristics and criteria...'

58,536 cells within the domain. In plan-view, the grids comprised uniform cells of 20m x 20m.

The active model grid domain reflects the conceptual hydrogeological model and encompasses the Quaternary sands bounded to the north by the Tweed River and the residual soils and rock of the Lamington Volcanics to the south. The system represented is an unconfined aquifer.

The thickness of the cells was defined by the topography based on the digital terrain model (forming the top of the cells) whilst the on-site drilling program (completed for the Acid Sulfate Soil Assessment) was used to define the thickness of the Quaternary sands.

To maintain simplicity in the model the Quaternary clays underlying the sands were set at a basement of -30mAHD. Table 3.4.1 details the range of depths used in the model.

Table 3.4.1 – Depth of modelled stratigraphy

Depth	Stratigraphic Medium
6.5m AHD (top of layer) to -19m AHD (bottom of layer)	Quaternary sands. Aeolian, alluvial, and estuarine deposits (unconsolidated)
-19m AHD (top of layer) to -30.0m AHD (bottom of layer)	Quaternary clays. Semi-consolidated alluvial/marine deposits
38m AHD (top of layer) to -30.0m AHD (bottom of layer)	Tertiary Basalts of the Lamington Volcanics/ Neranleigh Fernvale Beds

3.5 Topography

The surface grid was interpolated from 1m Lidar (Tweed Heads 2013-09-18 1 metre Digital Elevation Model) sourced from Spatial Services, a unit of the NSW Department of Finance, Services, and Innovation.

⁶ Gilbert & Sutherland, 2020. Acid Sulfate Soil Assessment, Tweed Sand Plant Expansion, Cudgen, New South Wales.

3.6 Stratigraphy

The model required the input of stratigraphic (layer) data together with the hydrogeological properties of the layer(s). This information was obtained from the drilling program undertaken primarily for the acid sulfate soil investigation⁶ undertaken for the TSP expansion proposal and reflects the conceptual hydrogeological model for the site.

To maintain simplicity within the steady-state model two layers were used to define the stratigraphy of interest being the Quaternary sands overlying Quaternary clays in the floodplain. The presence of marine clays intersected at around -19m AHD in several boreholes in the alluvial plain would be expected to have a hydraulic conductivity at several orders of magnitude lower than the overlying sands; therefore, in the context of numerical modelling can be considered effectively impermeable.

A third formation was added for the ridges to the south which form the Cudgen Plateau comprised of soils and rocks of the Lamington Volcanics.

3.7 Boundary conditions

The Tweed River was used as a constant-head boundary forming the northern extent of the model. The boundary was set at 0.1m AHD based on a review of tidal information.⁷ To the east of the site local drainage features were also defined as constant head boundaries of 0.1m AHD. A 'constant head' boundary is a fixed boundary condition in which the hydraulic head is unvarying. The use of 'constant head' boundaries is appropriate as these water bodies can be regarded as essentially infinite water bodies capable of absorbing, or supplying, any volume of water as necessary. The constant head boundaries are distant from key areas of interest within the model and thus should not unduly influence modelling outcomes.

A 'no-flow' boundary (which does not permit exchange of water across the model boundaries)

⁷ NSW Government, Public Works Manly Hydraulics Laboratory, October 2012. OEH NSW Tidal Planes Analysis, 1990 – 2010 Harmonic Analysis, Report MHL2053.

was set at the catchment divide formed by the Lamington Volcanics to the south of the TSP site. The base of the model at -30 mAHD was also defined as a 'no-flow' boundary.

Drainage cells were incorporated into the model to simulate groundwater discharge to the network of agricultural drains in the alluvial areas. The elevation of the drains was set between 0.1 mAHD and 0.4 mAHD (based on interrogation of Lidar data), which represents the current drainage regime. To represent runoff within the model, drainage cells were draped across the remainder of the model domain at the elevation of the current ground surface (i.e., the topography). The exception is the dredge lakes in which drainage cells were set at 0.3 mAHD to approximate the long-term lake level as measured on site.

3.8 Initial heads

Initial heads for the groundwater model were based on groundwater level monitoring at a total of 27 groundwater bores located across the existing and proposed expansion areas.

Long term level monitoring data for bores throughout the existing TSP site were used to establish initial head conditions in this area. For bores located within the expansion area eight rounds of level monitoring data from March to October 2020 were used to establish an initial head condition at each monitoring point. No groundwater level monitoring data was available for the Cudgen Plateau, therefore calibration of the model in this area was not possible.

A description of each available monitoring location is provided in sections 3.8.1 and 3.8.2.

3.8.1 TSP ongoing monitoring program

A program of groundwater monitoring has been ongoing at the TSP site since 2001. This program includes sampling at fifteen groundwater monitoring locations within the existing TSP site bounds for various parameters including groundwater levels.

Groundwater monitoring locations are shown on Drawing No. 12035-003 (Appendix 5). A description of each bore location and its

approximate depth below Near Surface Level (NSL) is given below:

- MB1B – North west corner of the Phase 2 extraction area (12 m below NSL)
- MB2A – South west corner of the Phase 2 extraction area (total depth 20 m below NSL)
- MB2B – South west corner of the Phase 2 extraction area (total depth 5 m below NSL)
- MB3 – South west corner of the Phase 1 extraction area (total depth 7 m below NSL)
- MB4 – Mid way along the southern boundary of the Phase 1 extraction area (total depth 7 m below NSL)
- MB5A – North eastern corner of the Phase 1 extraction area, near wash plant (total depth 20 m below NSL)
- MB5B – North eastern corner of the Phase 1 extraction area along the eastern boundary of the site (total depth 5 m below NSL)
- MB7 – Midway along the eastern boundary of the site on the adjacent property (total depth 6 m below NSL)
- MB8A – South west corner of the site (bore depth 6 m below NSL)
- MB8B – South west corner of the site (bore depth 19 m below NSL)
- MB9A – Midway along western boundary of the site (bore depth 6 m below NSL)
- MB9B – (Now damaged and/or destroyed) – located midway along western boundary of the site (bore depth 19 m below NSL)
- MB10A – North west corner of the site (bore depth 6 m below NSL)
- MB10B – North west corner of the site (bore depth 19 m below NSL)
- MB11A – North east corner of the site (bore depth 6 m below NSL)
- MB11B – North east corner of the site (bore depth 19 m below NSL)
- MB12A – (Now damaged and/or destroyed) - previously located midway along Phase 1 excavation area western boundary (bore depth 6 m below NSL)
- MB12B – (Now damaged) - previously located midway along western boundary of Phase 1 excavation area (bore depth 19 m below NSL).

3.8.2 Expansion area monitoring program

Building on the existing water quality monitoring program a further 8 rounds of groundwater monitoring were conducted across the TSP proposed expansion area between March and October 2020, to establish background conditions.

A total of six groundwater monitoring locations were selected for this monitoring program, at sites with adequate spatial distribution to provide an understanding of groundwater gradients, flow directions, recharge processes, water quality and levels within each hydrogeological unit within the project area. Two monitoring bores of different depths (shallow and deep aquifers) were installed at each location, resulting in a total of twelve bores throughout the expansion area. These monitoring locations are identified on Drawing 12035-003 (Appendix 5). Monitoring bores were surveyed on 29 September 2020 and are described in tables 3.8.2.1 and 3.8.2.2.

Table 3.8.2.1 Shallow groundwater monitoring bore survey and depth details

Borehole	Easting	Northing	Ground mAHD	Total depth (mbgl)
MB13B	552742.04	6873904.64	0.99	6
MB14B	552709.52	6872597.55	0.96	6
MB15B	551808.92	6873425.47	0.65	6
MB16B	552131.84	6874378.74	1.10	6
MB17B	552302.42	6874904.13	1.08	6
MB18B	552978.27	6874673.15	0.88	6

Table 3.8.2.2 Deep groundwater monitoring bore survey and depth details

Borehole	Easting	Northing	Ground mAHD	Total depth (mbgl)
MB13A	552740.07	6873905.19	1.10	20
MB14A	552711.53	6872597.36	1.04	20
MB15A	551808.90	6873422.44	0.64	20
MB16A	552130.24	6874378.67	1.11	20
MB17A	552301.08	6874902.89	1.17	20
MB18A	552979.83	6874672.57	0.88	21.5

⁸ <https://www.longpaddock.qld.gov.au/silo/>

Where available borelogs for each location are contained in Appendix 4.

3.9 Preparation of potentiometric surfaces

Groundwater flow directions and levels are assessed through the preparation of monthly potentiometric surface drawings (Appendix 4). These surfaces are prepared using groundwater levels data collected on a monthly basis by TSP staff for monitoring locations within the current operations area, and G&S staff throughout the expansion footprint. The data is converted to metres AHD and plotted to depict the groundwater contours across the site.

3.10 Recharge, evaporation and throughflow

Climate data including rainfall and evaporation statistics were sourced from the sourced from the Queensland Government's *The Long Paddock* website.⁸ This online facility generates a climatic profile for a given length of time based on a number of records in the site vicinity. Table 3.9.1 provides a range of statistics for rainfall and evaporation for reference purposes.

Table 3.9.1 Rainfall and evaporation statistics

	Rainfall (mm)	Evaporation (mm)
Minimum	802	1,276
Median	1,670	1,551
Average	1,709	1,543
Maximum	2,934	1,896

Recharge to the Quaternary sands occurs by direct rainfall infiltration through the sandy soils and by inflow from the Tertiary basalt aquifer that forms the Cudgen Plateau to the south.

For this exercise, groundwater recharge was reduced to account for losses from evaporation. Three different recharge zones were apportioned to the model domain.

Initially, groundwater recharge was derived for the Quaternary sands using a chloride balance model known as Cook's Method as described in Appendix 6. An initial recharge of 330 mm/year was applied which increased to 660 mm/year following calibration of the model to the measured groundwater heads. Note that a recharge rate of 420mm/year (~25% of mean annual rainfall) for the alluvial plain has been previously reported.⁹

The Lamington Volcanics were assumed to have a recharge of 150 mm/year (Cudgen plateau previously reported as 84 mm/yr for the slopes and 168 mm/yr for the top).⁵ The waterbodies (dredge lakes) were assumed to have a recharge of 100 mm/year being the approximate difference between annual rainfall (1709 mm) and evaporation (1543 mm).

Plots of bore hydrographs of the deep and shallow monitoring bores are presented in Figures 1 to 3 in Appendix 7. The Cumulative Rainfall Departure (CRD) is also plotted. The CRD is the cumulative difference between average monthly and actual observed rainfall and can be used to assess recharge to an aquifer. For the CRD assessment rainfall data was derived from BoM station 58137, Kingscliff (Woram Place).

3.11 Hydraulic characteristics

The aim of assigning aquifer parameters to the model is to ensure the simplest representation of the actual regime. The waters of the existing dredge lake were represented by adopting an extremely high permeability (10,000 m/day) and an effective porosity and specific yield of 1 (100%).

Table 3.10.1 shows the adopted porosity, specific yield and permeabilities.

3.12 Calibration and sensitivity analysis

Calibration or parameter estimation is the process of determining a set of parameters, boundary conditions and stresses that produce simulated heads and fluxes in order to match field-measured

Table 3.10.1 Porosity, yield and permeability ranges used for calibration and modelling

Sequence	Porosity	Specific yield	Permeability (m/d)
Quaternary sands	0.3	20%	Kx 9 Ky 9 Kz 1
Quaternary clays	0.01	1%	Kx 1x10 ⁻⁶ Ky 1x10 ⁻⁶ Kz 1x10 ⁻⁶
Lamington Volcanics (Cudgen Plateau)	0.01	5%	Kx 1 Ky 1 Kz 0.1
Dredge lake	1.0	100%	Kx 10,000 Ky 10,000 Kz 10,000

values within a pre-established range of error, so that the model can be accepted as a good representation of the groundwater flow system.

During the calibration process, key model parameters are adjusted, within realistic limits, to produce the best match between simulated and observed site data. The process begins with an initial estimation of parameters (hydraulic conductivity - horizontal and vertical, specific yield, recharge, boundary conditions, initial heads.) for each active element in the model mesh. Adjustment of parameters can be done manually through trial and error or automatically using the MODFLOW module 'WINPEST'.

The model was calibrated by adjustment of rainfall recharge and hydraulic conductivity under steady-state conditions to obtain an approximation of the site's groundwater levels. A match was achieved between observed and simulated groundwater levels.

To further assess and quantify the inherent uncertainty in the model calibration process, a sensitivity analysis was undertaken. The aquifer parameters were assessed using the WINPEST software to rank them in order of greatest effect on calibrated model outcome.

⁹ Australasian Groundwater & Environmental Consultants Pty Ltd, 2008. GALES-KINGSCLIFF PTY LTD Part 1 –

3.13 Prediction

Following calibration and sensitivity analyses, the calibrated steady-state model for the existing (pre-expansion) site conditions was used as the baseline condition for predicting development impacts. The model was adjusted to represent the final form of the site following completion of sand extraction throughout the existing TSP site and the proposed expansion area as depicted in Drawing Z19163-F119 and F20 (Appendix 5).

To represent creation of the expansion dredge lakes by sand removal, the permeability of the cells within the lake boundaries was increased to 10,000 m/day in all directions. The recharge over the surface of the waterbody was adjusted to 100 mm to represent the approximate average annual difference between rainfall and evaporation.

3.13.1 Key changes to lake boundary

A number of changes to the lake's boundary have been incorporated into this revision of the groundwater model as described below:

- On the western perimeter the lake boundary has been offset from the Pacific Motorway by 40 metres.
- The perimeter on the north-eastern corner of Lot 22 on DP1082435 has been adjusted to avoid disturbance of existing underground infrastructure.
- The buffer width on part of the south-western perimeter of Lot 1 on DP1250570 (Phase 9 of extraction) has been increased to from ~10m up to ~50m to reduce previously reported offsite drawdown in this area and associated impacts on mapped low-potential GDE's.

3.14 Cumulative impact assessment

To assess the cumulative impact of the TSP expansion proposal and the neighbouring Cudgen Lakes Sand Extraction Project a scenario was run whereby the model was adjusted to represent the fully extracted TSP expansion lakes and the fully extracted Cudgen Lake.

The spatial extent of the Cudgen Lakes Sand Extraction Project was adopted from Figure 3 of the Groundwater Assessment prepared for the Cudgen Lakes Sand Extraction Project, April 2008 prepared by Australasian Groundwater & Environmental Consultants (included in Appendix 9 for reference). The Cudgen extraction lake was represented in the model using the same methodology adopted for the TSP lakes (i.e. the permeability of the cells within the lake boundaries was increased to 10,000 m/day in all directions to represent removal of the sand resource and creation of a waterbody).

3.15 Assessment of climate change

The TSC Climate Change Policy¹⁰ adopts a sea level rise of 0.4m by 2050 and 0.9m by 2100 and anticipates an increase in the frequency and depth of tidal inundation of low-lying lands and poor drainage in low lying areas.

The proposed expansion area is a low-lying coastal floodplain and is currently subject to tidal inflows from the Tweed River in parts of the site. To assess the possible changes to groundwater level as a result of sea-level rise the relevant hydraulic boundary conditions of the pre- and post-extraction groundwater models were adjusted to reflect increased water levels. Specifically, the Tweed River level was adjusted upward by 0.4 m AHD to represent the anticipated rise by 2050 and then upward by 0.9 m to a level of 1.0 m AHD to represent the anticipated rise by 2100. A comparison was then made between the existing site and the post-extraction site to explore the combined impact of sea-level rise and the presence of the extraction lake.

3.16 Model limitations

The groundwater model described in this report is limited by the constraints of the MODFLOW model itself (which are well known in the industry) as well as by the quality and availability of input data. The model for this groundwater assessment is sound in that it is accurate within the limitations of the data and assumptions used in developing it.

¹⁰Tweed Shire Council (undated). *Climate Change Policy – Net Zero by 2030* Version 1.0

4 Results

The following sub-sections describe the findings of the steady-state MODFLOW numerical groundwater model.

4.1 Potentiometric surfaces

Potentiometric surface profiles were prepared from the results of groundwater level monitoring conducted from May to October 2020 within the proposed TSP expansion area. The groundwater potentiometric surfaces were prepared using Golden Software's Surfer and are presented as contour plots in Appendix 4.

The contour plots of relative potentiometric level, represented in metres Australian Height Datum (mAHD), indicate a relatively flat groundwater gradient across the site with the general flow direction being away from the extraction lake in a west/north-westerly direction.

Groundwaters in the northern paddock (Phase 11 extraction area) tend to flow to the east/south-east along a shallow hydraulic gradient culminating at the main agricultural drainage line in this area. This flow path was observed throughout the monitoring period, while groundwaters across the remaining lots (Phase 6 to 9 extraction areas) to the south and west of the extraction lake appeared to generally flow in a westerly direction and culminate in agricultural drainage lines adjacent the M1 motorway.

Potentiometric surface profiles were prepared from the results of groundwater level monitoring conducted from May to October 2020 within the proposed TSP expansion area. The groundwater potentiometric surfaces were prepared using Golden Software's Surfer and are presented as contour plots in Appendix 4.

4.2 Steady-state calibration results and sensitivity

Observed vs calculated average groundwater levels for each of the monitoring bores used to calibrate the model are presented in Table 4.2.1.

Table 4.2.1 – Observed vs calculated average groundwater level

Bore	Observed GW level (mAHD)	Calculated GW level (mAHD)	Residual (m)
MB10A	0.22	0.18	0.04
MB10B	0.16	0.18	-0.02
MB11A	0.33	0.17	0.16
MB11B	0.20	0.17	0.03
MB13A	0.235	0.13	0.105
MB13B	0.28	0.13	0.15
MB14A	0.585	0.48	0.105
MB14B	0.55	0.49	0.06
MB15A	0.03	0.13	-0.1
MB15B	0.055	0.13	-0.075
MB16A	0.255	0.27	-0.015
MB16B	0.415	0.27	0.145
MB17A	0.27	0.43	-0.16
MB17B	0.355	0.43	-0.075
MB18A	0.28	0.20	0.08
MB18B	0.27	0.19	0.08
MB1B	0.515	0.34	0.175
MB3	0.59	0.42	0.17
MB5A	0.62	0.52	0.1
MB5B	0.6	0.50	0.1
MB7	0.57	0.50	0.07
MB8A	0.40	0.33	0.07
MB8B	0.26	0.33	-0.07
MB9A	0.44	0.28	0.16

A summary of residuals analysis of the steady state calibrated model versus the measured (observed) groundwater levels from the site is provided in Table 4.2.2.

Table 4.2.2 Residuals analysis

Parameter	Results
Number of data points	24
Standard error of the estimate	0.02m
Root mean squared	0.106m
Maximum residual	-0.176m (MB1BA)
Minimum residual	0.013m (MB16A)
Residual mean	-0.048m
Normalised root mean squared	16.3%
Correlation coefficient	0.844

The calibration criteria commonly adopted for groundwater modelling (Spitz and Moreno, 1996) specifies the variance between predicted and observed data should be less than about 10% of the range of observations. The range of observations was 0.59m with a residual mean of -0.048m which is approximately 7.6%.

The results indicate that the model is well calibrated to site conditions and is suitable for prediction of groundwater behaviour at the site within the known limitations of the model software and baseline data.

The calibration is illustrated graphically in the '*Calculated vs. Observed Head: Steady state*' figure in Appendix 7. Sensitivity analysis was conducted on the calibrated model which indicated that the model was most sensitive to the recharge parameter.

4.3 Zone budget

The steady-state simulation's 'Zone Budget' or water balance is presented in the Zone Budget figure in Appendix 7. The Zone budget indicates that the volumetric budget error (inputs-outputs) in the model was 0%.

Interrogation of the results indicates that under steady-state conditions, a flux of some 29ML/day is experienced. Notably, approximately 69% of rainfall recharge applied to the model is removed (discharged) via the agricultural drainage network. This is anticipated as the drainage network is designed to drain groundwater away from the root zone of crops and discharge this water off-site. A comparably smaller proportion of rainfall recharge ~ 29% is discharged to the lake.

4.4 Groundwater level impacts at completion of 30 year extraction period

Drawing No. 12035-SUPP_GWM_003 (Appendix 8) depicts the existing groundwater levels at the site as represented by the steady-state groundwater model. Within the footprint of the proposed TSP expansion area and the current TSP site, groundwater levels range from approximately 0.0m AHD up to 1.0m AHD. To the

south of the site, groundwater levels rise corresponding with the rise in elevation which represents the Cudgen Plateau.

Predicted groundwater levels at the completion of sand extraction at the site (full extraction of Phases 1 to 11) are shown in Drawing No. 12035-SUPP_GWM_004 (Appendix 8). In this post-extraction scenario, the potentiometric surface across the extraction lake is predicted to be approximately 0.0 – 0.25 mAHD under steady-state conditions. Groundwater levels external to the site remain largely the same as the pre-extraction scenario ranging from 0m AHD to 1.0 m AHD within the immediate vicinity of the site and increasing with elevation to the south of the site within the Cudgen Plateau.

Drawing No. 12035-SUPP_GWM_006 (also in Appendix 8) compares the pre- and post-extraction groundwater contours to allow an interrogation of the changes in groundwater level that are predicted to occur as a result of the development. The drawing indicates that changes to groundwater elevation are predominantly contained within the development footprint occurring within the northern and southern sections of the expansion area and across the footprint of the existing TSP site. The predicted changes in groundwater level range from around 0.1m up to 1.0m.

Areas within the model domain that are unshaded indicate negligible change in groundwater level (within ± 0.1 m of the pre-development model scenario).

There is a maximum 0.5 m lowering of the water table in the northern portion of the expansion area. The impact is predominantly contained within the expansion footprint, however a decrease in groundwater elevation of up to 0.3m is predicted within a small portion of the lands outside the northern perimeter of Lot 51 on DP1166990.

In the southern extent of the site (Lot 1 on DP1250570 or Phase 9 of extraction) the steady-state model indicates a maximum 1.0 m lowering of the groundwater table predominantly within the expansion footprint. This revision of the groundwater model incorporated an increased

buffer width on part of the south-western perimeter of this lot as indicated on phasing plan Z19163-F120. This buffer has been increased from ~10 m up to ~50 m to reduce previously reported offsite drawdown in this area. Increasing the width of the buffer in this area has reduced the lateral extent of offsite drawdown from a previous extent of 170 m from the site boundary down to 155 m. The footprint of offsite drawdown in this area has reduced by ~4,300 m².

A minor offsite drawdown can be seen on the north-eastern corner of Lot 22 on DP1082435 (within the Phase 5 extraction footprint). This revision of the model incorporates an increased buffer on this boundary has been adjusted to avoid disturbance of existing electricity infrastructure. Increasing the width of the buffer in this area has reduced the lateral extent of offsite drawdown from 88 m down to 46 m. The footprint of offsite drawdown in this area has reduced by ~11,100 m².

These changes in groundwater elevation predicted by the model are brought about by the changes in topography caused by extraction of sand. Essentially, reducing the land elevation and removing the substrate that contains the groundwater results in an associated lowering of the immediate groundwater table as it equilibrates with the surface water level of the extraction lake.

4.4.1 Cumulative impact assessment

Drawing No. 12035-SUPP_GWM_005 (Appendix 8) shows the predicted groundwater levels at the completion of sand extraction at the TSP site (full extraction of Phases 1 to 11) and completion of sand extraction on the neighbouring Cudgen Lake's Sand Extraction Project. In this post-extraction scenario, the potentiometric surface across the TSP extraction lake is predicted to be approximately 0.0 – 0.25m AHD and ~ 0.25 – 0.5m AHD across the Cudgen Lakes site (under steady-state conditions).

Groundwater levels external to the site remain largely the same as the pre-extraction scenario

ranging from 0m AHD to 1.0m AHD within the immediate vicinity of the site and increasing with elevation to the south of the site within the Cudgen Plateau.

Drawing 12035-SUPP_GWM_007 (Appendix 8) is a comparison of the pre- and post-extraction groundwater contours for the cumulative impact scenario (i.e. the cumulative impact of the fully extracted TSP site and the fully extracted Cudgen Lakes Project). This comparison allows an interrogation of the cumulative changes in groundwater level that are predicted to occur as a result of the developments. Areas within the model domain that are unshaded indicate negligible change in groundwater level (within ± 0.1 m of the pre-development model scenario).

The drawing indicates that changes to groundwater elevation are predominantly contained within the respective development footprints. The predicted changes in groundwater level range from around 0.1 m up to 1.0 m.

The groundwater predictions of the steady-state model were compared to the groundwater modelling undertaken for the Cudgen Lake's Sand Extraction Project as reported in the 2008 Groundwater Assessment undertaken for the Project's EIS.¹¹ The lateral extent and magnitude of drawdown predicted in the TSP steady-state model aligns well with the drawdown predictions made in the Cudgen Lakes EIS. It stated:

'The model predicts that drawdown extends to a maximum distance of about 500m to the north of the alluvial floodplain. At Year 7¹², a drawdown of between 0.5m and 1.0m extends 500m to the south in the Cudgen Plateau'.

The simulated water table drawdown figures presented in the Cudgen Lakes Groundwater Assessment are provided in Appendix 9 for reference.

Similarly to the TSP expansion, the predicted changes in groundwater elevation are brought

¹¹ Groundwater Assessment prepared for the Cudgen Lakes Sand Extraction Project, April 2008 prepared by Australasian Groundwater & Environmental Consultants

¹² Year 7 represented the proposed completion of sand extraction at the site.

about by the changes in topography caused by extraction of sand. Essentially, reducing the land elevation and removing the substrate that contains the groundwater, results in an associated lowering of the immediate groundwater table as it equilibrates with the surface water level of the extraction lake.

The full extraction of sand at both sites does not result in an increase in the magnitude of drawdown caused by either operation (i.e. the impacts caused by each development are separate and do not exacerbate each other under steady state conditions).

4.5 Impacts on existing groundwater users

Drawing 12035-501 summarises the extent of existing registered groundwater use in close proximity of the site. There are no registered groundwater bores within the footprint of the expansion area and those located within the footprint of the existing TSP operation were installed and are monitored by TSP management. Groundwater level changes resulting from the development are not predicted to cause impacts proximal to any of the known registered bores.

4.6 Impacts on groundwater dependent ecosystems

Sensitive receptors with the potential to be affected by the proposed development include GDE's and wetlands.

A review of the following data sources was undertaken to investigate the presence and characteristics of wetlands and GDEs located within and nearby the proposed expansion footprint:

- NSW Wetlands vector dataset, Office of Environment and Heritage, State Government of NSW and Department of Planning, Industry and Environment 2010;
- State Environmental Planning Policy (Coastal Management) 2018;
- NSW Environmental Data, the Bureau of Meteorology's Groundwater Dependant Ecosystems Atlas; and

- High-priority GDE mapping contained in the Water Sharing Plan for the North Coast Coastal Sands Groundwater Sources 2016 ('Water Sharing Plan NCCSGS').

G&S drawings numbered 12035-101 to 12035-104 showed the site in its regional context and its proximity to these environmental features. This mapping exercise indicated:

- The NSW Wetlands Vector data set mapped wetlands within the centre of the existing TSP extraction lake and within two isolated locations outside the boundaries of the site to the south (Drawing 12035-101).
- There were no Coastal Wetlands within the boundary of the subject site and the subject site was outside of the Coastal Wetland Proximity Area (a 100 m zone plotted around the outer extent of the mapped Coastal Wetlands, see Drawing 12035-102).
- The Bureau of Meteorology Groundwater Dependant Ecosystems Atlas identifies a High-Potential Terrestrial (Paperbark) GDE was located on the northern perimeter of the proposed expansion area (see Drawing 12035-103).
- An area of low-potential Terrestrial GDEs were mapped on the southern perimeter of the proposed expansion area (refer to Drawing 12035-103).
- The closest high-priority GDE's to the site mapped under the 'Water Sharing Plan NCCSGS' are the 'Blacks Creek Swamps' to the south being approximately 2km away, and the 'Cudgen Creek Swamps' to the east being approximately 5 km from the site (refer to Drawing 12035_104).

With respect to the Low Potential GDE (Drawing No. 12035-501) adjacent the southern boundary of the expansion footprint west of Lot 1 on DP1250570, the revised groundwater model incorporates an increased buffer distance of ~50m between the limit of extraction and the site boundary. Whilst groundwater drawdown is still predicted to occur within this area, the increased buffer distance has reduced the lateral extent of offsite drawdown from ~170 m to 155 m and

reduced the magnitude of drawdown to between 0.1 m and 0.5 m (within the range of natural seasonal fluctuations). The footprint of offsite drawdown in this area has reduced by ~4,300 m².

The BDAR report prepared by JWA Ecological Consultants indicates that the vegetation communities encountered in this area consist of mid-high swamp sclerophyll forest (*Casuarina Glauca*). As the change in groundwater table predicted in this area is within the range of natural seasonal fluctuation it is unlikely that this vegetation will experience negative impacts as a result of the localised change in groundwater conditions. Further consideration of the sensitivity of this species to groundwater drawdown of this magnitude is provided by JWA Ecological Consultants.

With respect to the High Potential GDE within the north-eastern corner of Lot 51 on DP1166990 (as shown on Drawing 12035-501), no change between the pre- and post-extraction groundwater table is predicted to occur within this area. It is understood however that as a portion of this vegetation is within the proposed extent of the extraction area, some of the existing vegetation is likely to be removed. Removal of vegetation and offsets (where required) are considered in the Biodiversity Development Assessment Report prepared by JWA Ecological Consultants, October 2021.

4.7 Groundwater levels in response to sea level rise

The TSC Climate Change Management Policy, version 1.0 adopts a sea level rise of 0.4 m by 2050 and 0.9 m by 2100 and anticipates an increase in the frequency and depth of tidal inundation of low-lying lands and poor drainage in low lying areas.

The proposed expansion area is a low-lying coastal floodplain and is currently subject to tidal inflows from the Tweed River in parts of the site. To assess the possible changes to groundwater level as a result of sea-level rise, the relevant

hydraulic boundary conditions of the post-extraction cumulative¹³ groundwater models were adjusted to reflect increased water levels. Specifically, the Tweed River level was adjusted upward to 0.4 m to reflect the 2050 predictions and 0.9 m to represent the anticipated rise by 2100. A comparison was then made between the models to explore the combined impact of sea-level rise and the presence of the extraction lake.

Drawing 12035-SUPP_GWM_008 shows the outcomes of the 2050 sea-level rise modelling scenario. The model predicts that the groundwater level within parts of the TSP expansion area and throughout the broader model domain will increase by a minimum of 0.1 m up to a maximum of 0.5 m.

Groundwater levels throughout the more eastern portions of the TSP development (Phases 1 to 5, Phase 9) and parts of Phase 10 and 11 exhibit negligible change as a result of this sea level rise simulation.

Drawing 12035-SUPP_GWM_009 shows the outcomes of the 2100 sea-level rise modelling scenario. The model predicts that the groundwater level throughout the expansion area and throughout the model domain will increase by a minimum of 0.1 m up to a maximum of 1.0 m. Levels within the existing TSP site (Phases 1 to 4) exhibit negligible change as a response to the 2100 sea level rise simulation.

As anticipated by TSC's Climate Change Policy, the predicted sea-level rise will exacerbate tidal inundation and impede the site's drainage leading to increased waterlogging of soils.

¹³ The fully extracted TSP Expansion (Phases 1 to 11) and fully extracted Cudgen Lakes Sand Extraction Project.

5 Discussion and conclusions

5.1 Groundwater level changes

Given the nature of the site soils and groundwater characteristics observed to date, the most likely potential impacts on groundwater as a result of the development are:

- Localised and minor changes to pre-development groundwater flow regimes in the vicinity of the lake that will be largely contained within the development footprint. These changes in groundwater elevation are brought about by the changes in topography caused by extraction of sand. Essentially, reducing the land elevation and removing the substrate that contains the groundwater results in an associated lowering of the immediate groundwater table as it equilibrates with the surface water level of the extraction lake.
- Changes to groundwater elevation as a result of the proposed expansion are predominantly contained within the development footprint occurring within the northern and southern sections of the extraction footprint (Lot 51 on DP1166990 and Lot 1 on DP1250570 respectively). This iteration of the model incorporates a number of changes to the buffer widths to minimise the predicted offsite impacts. The residual impacts are summarised below:
 - There is a maximum 0.5 m lowering of the water table in the northern portion of the expansion area. The impact is predominantly contained within the expansion footprint, however a decrease in groundwater elevation of up to 0.3 m is predicted within a small portion of the lands outside the northern perimeter of Lot 51 on DP1166990.
 - With respect to the Low Potential GDE (Drawing No. 12035-501) adjacent the southern boundary of the expansion footprint west of Lot 1 on DP1250570, the revised groundwater model incorporates an increased buffer distance of ~50 m between the limit of extraction and the site boundary. Whilst groundwater drawdown is still predicted to occur within this area the increased buffer distance has reduced the lateral extent of offsite drawdown from 170 m to 155 m and reduced the magnitude of drawdown to between 0.1 m and 0.5 m. The footprint of offsite drawdown in this area has reduced by ~4,300 m².
 - As the change in groundwater table predicted in this area is within the range of natural seasonal fluctuation it is unlikely that the swamp sclerophyll forest (*Casuarina Glauca*) present in this area will experience negative impacts as a result of the localised change in groundwater conditions. Further consideration of the sensitivity of this species to groundwater drawdown of this magnitude is provided by JWA Ecological Consultants.
 - With respect to the High Potential GDE within the north-eastern corner of Lot 51 on DP1166990 (as shown on Drawing 12035-501), no change between the pre- and post-extraction groundwater table is predicted to occur within this area of the site. It is understood however that as portion of this vegetation is within the proposed extent of the extraction area some of the existing vegetation is likely to be removed. Removal of vegetation and offsets (where required) are considered in the Biodiversity Development Assessment Report prepared by JWA Ecological Consultants, October 2021.
 - Groundwater level changes resulting from the development are not predicted to cause impacts within proximity to any of the known registered bores.

5.2 Cumulative impacts

Drawing 12035-SUPP_GWM_007 (Appendix 8) shows the cumulative change in water table resulting from the fully extracted TSP site and the fully extracted Cudgen Lakes Project. The drawing indicates that changes to groundwater elevation are predominantly contained within the

respective development footprints and range from 0.1 m up to 1.0 m.

These predictions align well with the predictions of groundwater modelling undertaken for the Cudgen Lake's Sand Extraction Project as reported in the 2008 Groundwater Assessment undertaken for that Project's EIS.

Similarly to the TSP expansion, the predicted changes in groundwater elevation are brought about by the changes in topography caused by extraction of sand. Essentially, reducing the land elevation and removing the substrate that contains the groundwater, results in an associated lowering of the immediate groundwater table as it equilibrates with the surface water level of the extraction lake.

The full extraction of sand at both sites does not result in an increase in the magnitude of drawdown caused by either operation (i.e. the impacts caused by each development are separate and do not exacerbate each other under steady state conditions).

5.3 Sea level rise

The model predicts that the groundwater level throughout the expansion area and throughout the

model domain will increase by a minimum of 0.1 m up to a maximum of 1.0 m as a result of sea level rise for both the 2050 (0.4 m) and 2100 (0.9 m) sea level rise predictions. As anticipated by TSC's Climate Change Policy, the predicted sea-level rise will exacerbate tidal inundation and impede the site's drainage leading to increased waterlogging of soils.

Rehabilitation works at the site will necessarily include species that are tolerant of periodic waterlogging and can withstand the predicted rise in groundwater elevations. More detail of the site's rehabilitation, including species selection is contained in the site's Concept Rehabilitation and Landscape Management Plan prepared by JWA Ecological Consultants.

5.4 Groundwater management

Groundwater will be managed in accordance with the measures prescribed in the Soil and Water Management Plan (Gilbert & Sutherland, 2021). This management plan outlines monitoring regimes and mitigation measures for the management of impacts to surface and groundwaters.

6 Limitations of reporting

Gilbert & Sutherland Pty Ltd has made every effort to ensure that the information provided in this report is accurate. The interpretation of scientific data, however, involves professional judgment and as such is open to error.

In recognising the potential for errors in scientific interpretation, Gilbert & Sutherland Pty Ltd does not guarantee that the information is totally accurate or complete and clients are advised not to rely solely on this information when making commercial decisions. Any representation, statement, opinion or advice, expressed or

implied is made in good faith and on the basis that the authors, Gilbert & Sutherland Pty Ltd, their agents or employees are not liable (whether by reason of lack of care or otherwise) to any person for any damage or loss whatsoever which has occurred or may occur in relation to that person taking or not taking (as the case may be) action in respect of any representation, statement or advice referred to above.

Furthermore, this information should not be relied upon by any persons other than the client, for whom it has been compiled. This information reflects the specific brief and the budget of the client concerned, who enjoys an individual tolerance of risk.

7 Appendix 1 – Curriculum Vitae – Eric Rooke

Curriculum Vitae: Eric Richard Rooke

Contact Details:

Email: rooke.er@access.gs

Experience (post – 2000):

09/2014 – present	Gilbert & Sutherland Pty Ltd – Consulting Hydrogeologist
06/2012 – 09/2014	Gilbert & Sutherland Pty Ltd – Principal Hydrogeologist The firm specialises in hydraulics and hydrology, soil and water assessments and providing environmental management services and specialist advice to miners, planners, engineers, developers, surveyors, financial institutions, farmers, statutory authorities, community groups and courts and tribunals
2011 – 2012	Principal Hydrogeologist, Melbourne – Australian Groundwater Technologies Pty Ltd, a specialist managed aquifer recharge (MAR) / aquifer storage and recovery (ASR) consultancy
2008 - 2011	Specialist Hydrogeologist, Melbourne – Entura; the consulting arm of Hydro Tasmania offering power engineering, renewable energy, water and environmental solutions throughout Asia-Pacific and southern Africa
2002 – 2008	Principal Hydrogeologist, Adelaide – Australian Groundwater Technologies Pty Ltd, a specialist MAR / ASR consultancy
2000 – 2002	Associate Hydrogeologist – Water Studies, Adelaide; a boutique hydrological consultant acquired by Coffey Ltd in 2000

Education and Qualifications:

Master of Science (Hydrogeology) – University of Birmingham, 1982
Bachelor of Science (Geology) (Hons) – King's College, University of London 1976

Project Experience:

- Over 30 years experience as a Hydrogeologist / Hydrologist in the consulting and the public service sectors; in UK, Australia, Papua New Guinea, Indian Ocean and Arabian Gulf regions
- Arid, semi-arid, tropical and oceanic island hydrogeology and hydrology
- Managed aquifer recharge specialist including in fractured rock aquifers
- Peer review and mentoring
- Preparation of some 250 technical reports, professional opinions and non-technical pamphlets, concept illustrations and maps
- **Hydrogeology – environmental**
 - acid sulphate soils
 - aquifer system conceptual modelling
 - environmental impact assessment
 - geological mapping in diverse terrains
 - groundwater dependent ecosystems
 - hydro-geochemistry
 - impacts of climate change on aquifer sustainable yields
 - water resource assessment, development and management
- **Hydrogeology - numerical**
 - aquifer and well test pumping
 - aquifer, well and well-field hydraulics analytical modelling
 - definition of well-field protection zones, and aquifer vulnerability assessment
 - groundwater abstraction, dewatering, injection
 - groundwater engineering including its application to fractured rock aquifers
 - water mass balance accounting
- **Managed aquifer recharge (MAR) / aquifer storage and recovery (ASR)**
 - pilot investigations and trials (ASR and soil aquifer treatment)
 - regulatory and licensing approvals
 - operational philosophy, audit, advice and troubleshooting
- **Data analysis**
 - statistics/interpretation of geological, hydrogeological and hydrological data sets
- **Drilling technology, engineering geology and geomorphological mapping**
 - supervision of water-well and geotechnical drilling and drilling rigs
 - foundations and tunnels
 - hazard assessment of landslides
 - the extractive industry

- **Geophysics**

- environmental geophysics practice & interpretation
- geophysical logging practice & interpretation

- **Hydrography**

- design and installation of flow-measurement weirs and flumes
- hydrometric fieldwork including gaugings and ratings

- **Remote sensing**

- (hydro)geological interpretation of aerial photographs and satellite imagery

Selected project examples (post-2007):

- Yulara Town Water Supply, NT – construction of new wells, southern borefield
- Arckaringa Basin, SA – desktop review of evidence for Arckaringa Basin hydrogeological interconnection with the Great Artesian Basin
- Alekarenge Farm Water Supply, NT – wellfield design
- Christies Beach Wastewater Treatment Plant's Sludge Lagoon Reserve, Adelaide – pore water sampling and analysis
- Callie Deeps Mine Project, NT – water supply options study
- Angas Zinc Mine, Adelaide hills – mine dewatering reinjection
- Plenty Highway, NT – GIS desktop hydrogeological survey, community water supplies
- Bird-In-Hand proposed mine, Adelaide hills – water production disposal options
- Upper Nepean Borefield Project, Kangaloon, NSW – environmental assessment review
- Orford Water Supply Contingency, TAS – channel losses estimates via river diversion
- Catagunya Dam Upgrade, TAS – geotechnical assessment
- Victorian Desalinisation Project, VIC – geotechnical issues for transmission line
- Flemington Racecourse, Melbourne – geophysical Investigations to site desalination wells. Annual audit and monitoring report for in-situ desalination trials
- Arthurs Lake Pipeline, TAS – work plan to estimate water transmission losses
- Western Davenport Plains Water Control District, NT – assessment of groundwater resources and sustainable yields
- Circular Head landfill sites, TAS – review of effectiveness of decommissioning and remediation works
- Hornsby, Sydney – groundwater sustainable yields study

- Territory Grapes, Ti Tree, NT – wellfield infrastructure condition assessment
- Burdekin Hydropower Station Development, QLD – hydrogeology & soils assessment
- Nadzab new town development, Papua New Guinea – high-level capex/opex estimates for water and wastewater infrastructure including source identification
- Perth Shallow Groundwater System Investigation – hydrogeological reports
- Joy Springs, east Kimberley community water supply – hydrogeological investigations
- McMinns public water supply borefield, Darwin – wellhead protection zone review
- Mitchell River ASR Scheme, E Gippsland, VIC – strategic review and operational audit
- Cooke Plains and Lake Fowler, SA – salt harvesting – hydrogeological study
- Karinga Creek Potash, NT – peer review - hydrogeological conceptual model and concept design for salt recovery
- Werribee / Wyndham Vale ASR scheme(s) – indicative costs to set up an ASR scheme
- Yulara, NT – hydrological assessment of potential water use for a proposed development - referral under the EPBC Act

Other related hydrology and water supply experience:

- Embedded as a Hydrogeologist into SA Water Corporation
- Project Manager, Barkly/Gulf Water Resources Assessment
 - Prepared project submission; secured funding (together with a sister project, Gulf Fall region); managed project budget; prepared annual reports for NLP's auditor
 - Mapped water resources and hydrogeology, Barkly Tableland (area 2.5 times the size of Tasmania) comprising pastoral properties and indigenous communities
 - Liaised with land-holders and disseminated information to stakeholders
 - Prepared a technical report and associated water resource development maps
 - Educated pastoral companies, pastoralists & communities on water use and pollution control
- Scientific decision support for water management strategies and policies;
 - Alice Springs water supply, Rocky Hill augmentation borefield – managed hydrogeological and land assessment program (with Geosciences Department, University of Wollongong) for a water allocation plan. Presented technical results seminars; advised Controller of Water to extend Water Management District
 - NT part of Great Artesian Basin (GAB; Simpson Desert);
 - Contributed to hydrogeological studies of 85,000 km² of the NT portion of GAB – mapped NT GAB's aquifer limits; artesian production bore sites

selected, designed, cost estimated

- Managed NHT funding for planning, investigation and rehabilitation of artesian bores under GAB Consultative Council's (GABCC) Basin Sustainability Initiative
- GAB Technical Working Group and GABCC NT Government representative
- As Regional Technical Manager, National Well-Inventory Project (NWIP). The NWIP (1992-5) registered all water wells (167,000). Field verification provided a groundwater resource database (water levels, water quality, pump types, discharges, water use and irrigated areas).
 - Managed a regional office including reporting to headquarters (Muscat); operational and staff performance reviews, and community liaison
 - Trained on-the-job and in-the-office technical, and professional counterparts
 - Supervised field, data processing and quality control teams, and associated equipment and supplies requisition
 - Compiled catchment water resource surveys and audits. Achievements · Attained consistently the best quality control record of all regional offices · Provided snap-shot catchment reports and what-if scenarios of relocating farms to lessen water stress on coastal aquifers
- Advised on re-injection of production brine for pressurisation, Mereenie oilfield, Amadeus Basin
- Experience in site-specific engineering geological assessments; study on a mega-landslide in Papua New Guinea

Professional Affiliations:

- Fellow, Geological Society of London
- Member, International Association of Hydrogeologists

Author Eric Rooke

Our Reference CV_Rooke_Consulting 2015.docx

Your Reference –

By ☐ Courier ☒ Email ☐ Facsimile ☐ Post

Enclosures -

8 Appendix 2 – AGM Guidelines – Completed Review Checklists

Tweed Sand Plant EIS

Review of the TSP Expansion numerical MODFLOW groundwater model against the Australian Groundwater Modeling Guidelines, 2012 – Section 9 Checklist.

Table 9-1: Compliance checklist

Question	Yes/No	Comment
1. Are the model objectives and model confidence level classification clearly stated?	Yes	This was not defined in the EIS Model report but is included in the supplementary report. Model is 'Class 2'
2. Are the objectives satisfied?	Yes	
3. Is the conceptual model consistent with objectives and confidence level classification?	Yes	The supplementary report contains the required conceptual model which is consistent with the requirements for a Class 2 model.
4. Is the conceptual model based on all available data, presented clearly and reviewed by an appropriate reviewer?	Yes	A conceptual model is now contained in the Supplementary report. Data sources are noted, substantial volume of site based measurements available for creation of conceptual model.
5. Does the model design conform to best practice?	Yes	Reliable model platform adopted, design aligns with conceptual model, substantial site-based input data and measurements available.
6. Is the model calibration satisfactory?	Yes	24 wells head values, calibration stats contained in report
7. Are the calibrated parameter values and estimated fluxes plausible?	Yes	Further examination of recharge and zone budgets is contained in this supplementary report and also in the Revised Water Balance Report prepared under separate cover. Calibrated parameter values appear reasonable for the characteristics of the site and stratigraphy.
8. Do the model predictions conform to best practice?	Yes	Improved documentation of predictions is contained in the supplementary report.
9. Is the uncertainty associated with the predictions reported?	No	No.
10. Is the model fit for purpose?	Yes	'Class 2' model.

Table 9-2: Review checklist

Review questions	Yes/No	Comment
1. Planning		
1.1 Are the project objectives stated?	Yes	
1.2 Are the model objectives stated?	Yes	
1.3 Is it clear how the model will contribute to meeting the project objectives?	Yes	
1.4 Is a groundwater model the best option to address the project and model objectives?	Yes	Multiple assessments of soil and water prepared for this project and need to be considered as a whole. The GWM report should be interpreted alongside the Revised Water Balance Report.
1.5 Is the target model confidence-level classification stated and justified?	Yes	This was not defined in the EIS Model report but is included in

		the supplementary report. Model is 'Class 2'
1.6 Are the planned limitations and exclusions of the model stated?	Yes	Basic model limitations are included and the boundaries of the modelled area clearly defined.
2. Conceptualisation		
2.1 Has a literature review been completed, including examination of prior investigations?	Yes	Including review of neighbouring site's groundwater model report for comparison and verification of results.
2.2 Is the aquifer system adequately described?	Yes	Yes
2.2.1 hydrostratigraphy including aquifer type (porous, fractured rock ...)	Yes	Yes
2.2.2 lateral extent, boundaries and significant internal features such as faults and regional folds	Yes	Bound by river & ridgeline Cudgen Plateau
2.2.3 aquifer geometry including layer elevations and thicknesses	Yes	A conceptual model cross-section is included in the Supplementary report to illustrate these features.
2.2.4 confined or unconfined flow and the variation of these conditions in space and time?	Yes	Unconfined.
2.3 Have data on groundwater stresses been collected and analysed?	Yes	Uses existing head conditions – measured SWLs in 26 wells over extended period of time in some instances (up to 20 years).
2.3.1 recharge from rainfall, irrigation, floods, lakes	Yes	Rainfall and river most relevant in this instance
2.3.2 river or lake stage heights	Yes	River levels based on NSW Government, Public Works Manly Hydraulics Laboratory, October 2012. OEH NSW Tidal Planes Analysis, 1990 – 2010 Harmonic Analysis, Report MHL2053.
2.3.3 groundwater usage (pumping, returns etc)	No	Evaporative losses considered. Pumping and returns not incorporated into steady state model as these activities would not be occurring when lake is fully extracted i.e the scenario modelled in modflow. Groundwater useage more appropriately considered in the revised Water Balance report.
2.3.4 evapotranspiration	Yes	Open water evaporation.
2.3.5 other?	-	-
2.4 Have groundwater level observations been collected and analysed?	Yes	Up to 20 years of data.
2.4.1 selection of representative bore hydrographs	Yes	Contained in appendix of supplementary report
2.4.2 comparison of hydrographs	No	
2.4.3 effect of stresses on hydrographs	No	
2.4.4 Watertable maps/piezometric surfaces?	Yes	Potentiometric surfaces plotted for site.
2.4.5 If relevant, are density and barometric effects taken into account in the interpretation of groundwater head and flow data?	-	NA
2.5 Have flow observations been collected and analysed?	-	NA
2.5.1 baseflow in rivers	-	NA
2.5.2 discharge in springs	-	NA
2.5.3 location of diffuse discharge areas?	-	NA
2.6 Is the measurement error or data uncertainty reported?	Yes	Calibration statistics reported. Std error of model estimate is 0.02m
2.6.1 measurement error for directly measured quantities (e.g. piezometric level, concentration, flows)	No	Long term (~20 year) data set, error in field measurement not quantified. Mean conditions assumed in steady-state model,

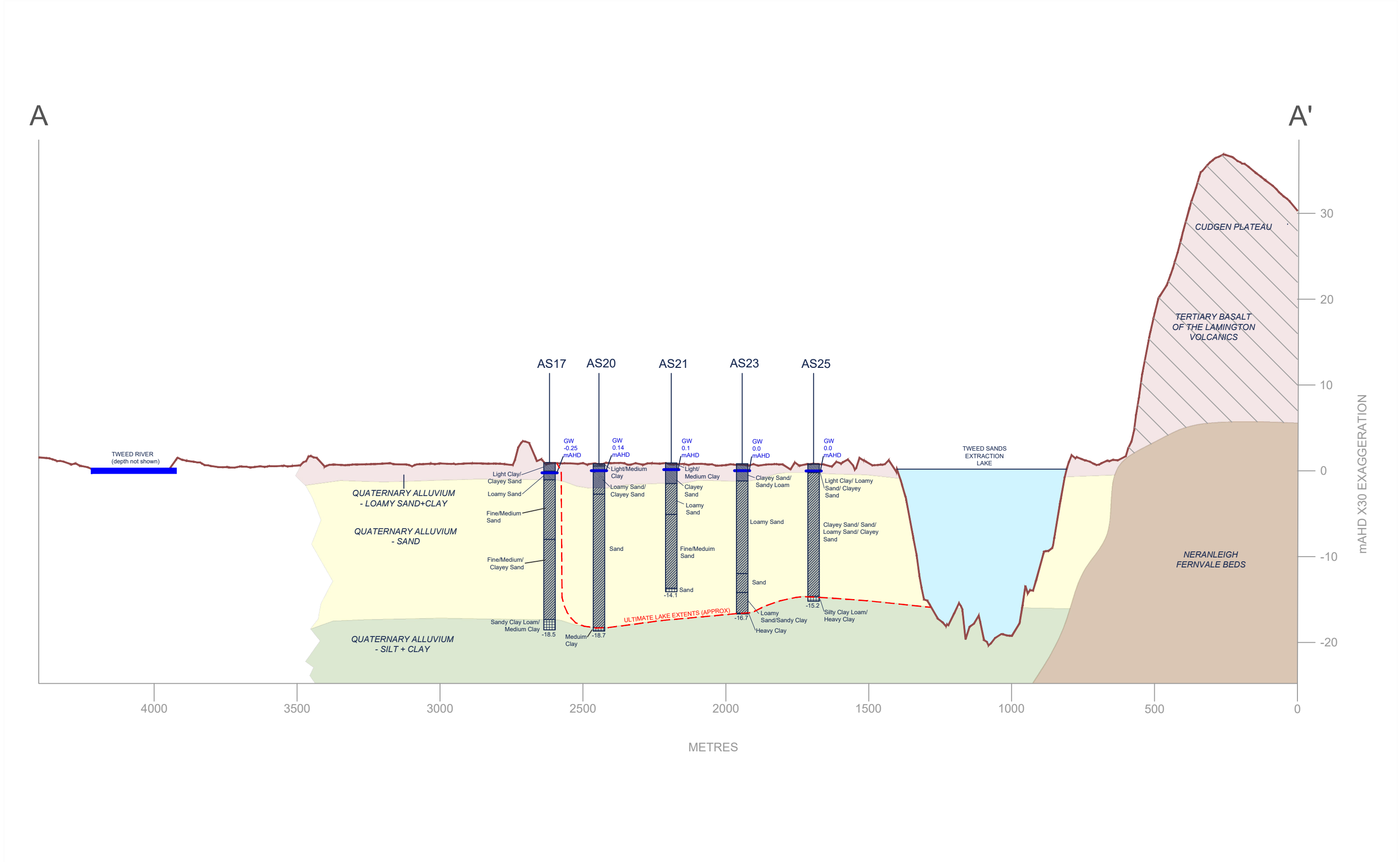
		error in field measurement (where/if present) considered to be within tolerance and negligible effect in context of steady state model.
2.6.2 spatial variability/heterogeneity of parameters	Yes	Kh & Kz 3 layers with varying S & K
2.6.3 interpolation algorithm(s) and uncertainty of gridded data?	-	-
2.7 Have consistent data units and geometric datum been used?	Yes	
2.8 Is there a clear description of the conceptual model?	Yes	This was not included in the original model but has now been included in the Supplementary Model.
2.8.1 Is there a graphical representation of the conceptual model?	Yes	As above.
2.8.2 Is the conceptual model based on all available, relevant data?	Yes	Available data from various investigations have been used. References of source information are contained in the report and associated drawings.
2.9 Is the conceptual model consistent with the model objectives and target model confidence level classification?	Yes	Yes
2.9.1 Are the relevant processes identified?	Yes	Climatic processes have been incorporated
2.9.2 Is justification provided for omission or simplification of processes?	Yes	
2.10 Have alternative conceptual models been investigated?	No	All sufficient site information is available and has been used to establish the conceptual model contained in the supplementary report.
3. Design and construction		
3.1 Is the design consistent with the conceptual model?	Yes	Yes
3.2 Is the choice of numerical method and software appropriate (Table 4-2)?	Yes	Visual MODFLOW
3.2.1 Are the numerical and discretisation methods appropriate?	Yes	Yes
3.2.2 Is the software reputable?	Yes	
3.2.3 Is the software included in the archive or are references to the software provided?	Yes	
3.3 Are the spatial domain and discretisation appropriate?	Yes	20 x 20m grid; 58,536 cells
3.3.1 1D/2D/3D	Yes	3D
3.3.2 lateral extent	Yes	5.42 x 4.32 km
3.3.3 layer geometry?	Yes	3
3.3.4 Is the horizontal discretisation appropriate for the objectives, problem setting, conceptual model and target confidence level classification?	Yes	
3.3.5 Is the vertical discretisation appropriate? Are aquitards divided in multiple layers to model time lags of propagation of responses in the vertical direction?	Yes	No aquitards
3.4 Are the temporal domain and discretisation appropriate?	Yes	
3.4.1 steady state or transient	Yes	SS
3.4.2 stress periods	-	SS - 1
3.4.3 time steps?	-	SS - 1
3.5 Are the boundary conditions plausible and sufficiently unrestrictive?	Yes	Boundary conditions reported adequately.
3.5.1 Is the implementation of boundary conditions consistent with the conceptual model?	Yes	
3.5.2 Are the boundary conditions chosen to have a minimal impact on key model outcomes? How is this ascertained?	Yes	Yes. Boundary conditions are distal from the site to dampen effects in the areas of interest.
3.5.3 Is the calculation of diffuse recharge consistent with model objectives and confidence level?	Yes	

3.5.4 Are lateral boundaries time-invariant? 3.6 Are the initial conditions appropriate?	Yes	
3.6.1 Are the initial heads based on interpolation or on groundwater modelling?	Yes	Initial heads based on observed SWLs in monitoring bores.
3.6.2 Is the effect of initial conditions on key model outcomes assessed?	Yes	
3.6.3 How is the initial concentration of solutes obtained (when relevant)?	-	NA
3.7 Is the numerical solution of the model adequate?	-	Yes
3.7.1 Solution method/solver	-	BiCGSTAB-P Matrix Solver WHS, CGSTAB-P Linear solver
3.7.2 Convergence criteria	-	Head change criterion (HCLOSE) = 0.01 Residual criterion (RCLOSE) = 0.01
3.7.3 Numerical precision	-	
4. Calibration and sensitivity		
4.1 Are all available types of observations used for calibration?	Yes	
4.1.1 Groundwater head data	Yes	24 wells
4.1.2 Flux observations	-	-
4.1.3 Other: environmental tracers, gradients, age, temperature, concentrations etc.	-	NA
4.2 Does the calibration methodology conform to best practice?	Yes	
4.2.1 Parameterisation	Yes	
4.2.2 Objective function	-	-
4.2.3 Identifiability of parameters	Yes	
4.2.4 Which methodology is used for model calibration?	Yes	MODFLOW PEST
4.3 Is a sensitivity of key model outcomes assessed against?		
4.3.1 parameters	Yes	
4.3.2 boundary conditions	No	
4.3.3 initial conditions	Yes	
4.3.4 stresses	Yes	
4.4 Have the calibration results been adequately reported?	Yes	Further documentation including a graphical depiction of calibration results is included in the supplementary report.
4.4.1 Are there graphs showing modelled and observed hydrographs at an appropriate scale?	NA	Not applicable to SS.
4.4.2 Is it clear whether observed or assumed vertical head gradients have been replicated by the model?	Yes	Evidenced by calibration statistics
4.4.3 Are calibration statistics reported and illustrated in a reasonable manner?	Yes	Tables and graph.
4.5 Are multiple methods of plotting calibration results used to highlight goodness of fit robustly? Is the model sufficiently calibrated?	Yes	Further documentation including a graphical depiction of calibration results is included in the supplementary report.
4.5.1 spatially	Yes	
4.5.2 temporally	-	NA for SS
4.6 Are the calibrated parameters plausible?	Yes	Additional assessment of recharge now included in supplementary report (is it?).
4.7 Are the water volumes and fluxes in the water balance realistic?	-	-
4.8 has the model been verified?	No	Predictive. Verification not undertaken for steady state model.
5. Prediction		
5.1 Are the model predictions designed in a manner that meets the model objectives?	Yes	
5.2 Is predictive uncertainty acknowledged and addressed?	Yes	
5.3 Are the assumed climatic stresses appropriate?	Yes	'TSC Climate Change Policy'
5.4 Is a null scenario defined?	Yes	- Existing Conditions

5.5 Are the scenarios defined in accordance with the model objectives and confidence level classification?	Yes	Scenarios modelled are designed to predict impacts on groundwater users – well defined and discussed in model. Basic information on confidence level classification.
5.5.1 Are the pumping stresses similar in magnitude to those of the calibrated model? If not, is there reference to the associated reduction in model confidence?	-	NA
5.5.2 Are well losses accounted for when estimating maximum pumping rates per well?	-	NA
5.5.3 Is the temporal scale of the predictions commensurate with the calibrated model? If not, is there reference to the associated reduction in model confidence?	?	Not documented
5.5.4 Are the assumed stresses and timescale appropriate for the stated objectives?	Yes	Existing vs full development
5.6 Do the prediction results meet the stated objectives?	Yes	
5.7 Are the components of the predicted mass balance realistic?	-	
5.7.1 Are the pumping rates assigned in the input files equal to the modelled pumping rates?	-	NA
5.7.2 Does predicted seepage to or from a river exceed measured or expected river flow?	-	NA
5.7.3 Are there any anomalous boundary fluxes due to superposition of head dependent sinks (e.g. evapotranspiration) on head-dependent boundary cells (Type 1 or 3 boundary conditions)?	-	NA
5.7.4 Is diffuse recharge from rainfall smaller than rainfall?	Yes	
5.7.5 Are model storage changes dominated by anomalous head increases in isolated cells that receive recharge?	-	NA
5.8 Has particle tracking been considered as an alternative to solute transport modelling?	-	NA
6. Uncertainty		
6.1 Is some qualitative or quantitative measure of uncertainty associated with the prediction reported together with the prediction?	Yes	
6.2 Is the model with minimum prediction-error variance chosen for each prediction?	-	NA
6.3 Are the sources of uncertainty discussed?	Yes	
6.3.1 measurement of uncertainty of observations and parameters	No	
6.3.2 structural or model uncertainty	Yes	
6.4 Is the approach to estimation of uncertainty described and appropriate?	Yes	
6.5 Are there useful depictions of uncertainty?	No	
7. Solute transport		
7.1 Has all available data on the solute distributions, sources and transport processes been collected and analysed?	-	NA
7.2 Has the appropriate extent of the model domain been delineated and are the adopted solute concentration boundaries defensible?	-	NA
7.3 Is the choice of numerical method and software appropriate?	-	NA
7.4 Is the grid design and resolution adequate, and has the effect of the discretisation on the model outcomes been systematically evaluated?	-	NA
7.5 Is there sufficient basis for the description and parameterisation of the solute transport processes?	-	NA
Comment	-	NA
7.6 Are the solver and its parameters appropriate for the problem under consideration?	-	NA
7.7 Has the relative importance of advection, dispersion and diffusion been assessed?	-	NA
7.8 Has an assessment been made of the need to consider variable density conditions?	-	NA

7.9 Is the initial solute concentration distribution sufficiently well-known for transient problems and consistent with the initial conditions for head/pressure?	-	NA
7.10 Is the initial solute concentration distribution stable and in equilibrium with the solute boundary conditions and stresses?	-	NA
7.11 Is the calibration based on meaningful metrics?	-	NA
7.12 Has the effect of spatial and temporal discretisation and solution method taken into account in the sensitivity analysis?	-	NA
7.13 Has the effect of flow parameters on solute concentration predictions been evaluated, or have solute concentrations been used to constrain flow parameters?	-	NA
7.14 Does the uncertainty analysis consider the effect of solute transport parameter uncertainty, grid design and solver selection/settings?	-	NA
7.15 Does the report address the role of geologic heterogeneity on solute concentration distributions?	-	NA
8. Surface water–groundwater interaction	Yes	
8.1 Is the conceptualisation of surface water–groundwater interaction in accordance with the model objectives?	Yes	
8.2 Is the implementation of surface water–groundwater interaction appropriate?	Yes	Drainage cells draped across the land surface
8.3 Is the groundwater model coupled with a surface water model?	No	A detailed surface and groundwater balance model has been prepared and reported under separate cover.
8.3.1 Is the adopted approach appropriate?	Yes	
8.3.2 Have appropriate time steps and stress periods been adopted?	-	NA
8.3.3 Are the interface fluxes consistent between the groundwater and surface water models?	Yes	Head defined.

9 Appendix 3 – Conceptual hydrogeological model



10 Appendix 4 - Borelogs

DEPTH (mBGL)	GROUNDWATER	GRAPHIC LOG	SOIL DESCRIPTION	ORIGIN
0			Very dark brown (10YR 2/2) sandy clay loam ; no coarse fragments; moderately moist; massive structure; very weak consistence; no segregations; change to;	NATURAL
0.2				
0.4				
0.6			Grey (10YR 6/1) loamy sand ; no coarse fragments; moderately moist; massive structure; very weak consistence; no segregations; change to;	NATURAL
0.8				
1				
1.2	▼			
1.4				
1.6			Very dark greenish grey (10Y 3/1) clayey sand ; no coarse fragments; wet; massive structure; very weak consistence; no segregations; change to;	NATURAL
1.8				
2			Dark greenish grey (10Y 4/1) loamy sand ; no coarse fragments; wet; massive structure; very weak consistence; no segregations; change to;	NATURAL
2.2				
2.4				
2.6				
2.8				
3				
3.2				
3.4				
3.6				
3.8				
4			Olive grey (5Y 5/2) loamy sand ; no coarse fragments; wet; massive structure; very weak consistence; no segregations; change to;	NATURAL
4.2				
4.4				

BOREHOLE
MB13a

CLIENT	HANSON CONSTRUCTION MATERIALS	PROJECT No.	12035	TOTAL DEPTH	20mBGL	DRILL DATE	15-Apr-20
PROJECT	TWEED SAND PLANT EXPANSION	SURFACE RL	Not surveyed	DRILLED BY	PACIFIC GEOTECH	EASTING	552740.07
LOCATION	CUDGEN, NSW	DRILL METHOD	AUGER	LOGGED BY	GLH	NORTHING	6873905.19



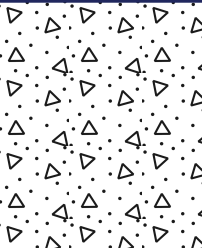
DEPTH (mBGL)	GROUNDWATER	GRAPHIC LOG	SOIL DESCRIPTION	ORIGIN
4.6				
4.8				
5				
5.2				
5.4				
5.6				
5.8				
6			Olive grey (5Y 5/2) loamy sand ; very few, coarse gravelly, rounded calcareous sand fragments; wet; massive structure; very weak consistence; no segregations; change to;	NATURAL
6.2				
6.4			Olive grey (5Y 5/2) loamy sand ; no coarse fragments; wet; massive structure; very weak consistence; no segregations; change to;	NATURAL
6.6				
6.8				
7				
7.2				
7.4				
7.6				
7.8				
8				
8.2				
8.4				
8.6				
8.8				
9				

BOREHOLE

MB13a

CLIENT	HANSON CONSTRUCTION MATERIALS	PROJECT No.	12035	TOTAL DEPTH	20mBGL	DRILL DATE	15-Apr-20
PROJECT	TWEED SAND PLANT EXPANSION	SURFACE RL	Not surveyed	DRILLED BY	PACIFIC GEOTECH	EASTING	552740.07
LOCATION	CUDGEN, NSW	DRILL METHOD	AUGER	LOGGED BY	GLH	NORTHING	6873905.19



DEPTH (mBGL)	GROUNDWATER	GRAPHIC LOG	SOIL DESCRIPTION	ORIGIN
9.2				
9.4				
9.6				
9.8				
10			Grey (5Y 6/1) fine sand ; very few, coarse gravelly, rounded calcareous sand fragments; wet; massive structure; very weak consistence; no segregations; change to;	NATURAL
10.2				
10.4				
10.6				
10.8				
11				
11.2				
11.4				
11.6				
11.8				
12				
12.2				
12.4				
12.6				
12.8				
13				
13.2				
13.4				



DEPTH (mBGL)	GROUNDWATER	GRAPHIC LOG	SOIL DESCRIPTION	ORIGIN
13.6				
13.8				
14				
14.2				
14.4				
14.6				
14.8				
15				
15.2				
15.4				
15.6				
15.8				
16				
16.2				
16.4				
16.6				
16.8				
17				
17.2				
17.4			Dark grey (10YR 4/1) clayey sand ; very few, coarse gravelly, rounded calcareous sand fragments; wet; massive structure; very weak consistence; no segregations; change to;	NATURAL
17.6			Very dark greenish grey (10Y 3/1) silty medium clay ; very few, coarse gravelly, rounded calcareous sand fragments; moist; massive structure; firm consistence; no segregations; borehole terminated at 20mBGL.	NATURAL
17.8				
18				

BOREHOLE MB13a	CLIENT	HANSON CONSTRUCTION MATERIALS	PROJECT No.	12035	TOTAL DEPTH	20mBGL	DRILL DATE	15-Apr-20
	PROJECT	TWEED SAND PLANT EXPANSION	SURFACE RL	Not surveyed	DRILLED BY	PACIFIC GEOTECH	EASTING	552740.07
	LOCATION	CUDGEN, NSW	DRILL METHOD	AUGER	LOGGED BY	GLH	NORTHING	6873905.19

+GILBERT
SUTHERLAND

DEPTH (mBGL)	GROUNDWATER	GRAPHIC LOG	SOIL DESCRIPTION	ORIGIN
18.2				
18.4				
18.6				
18.8				
19				
19.2				
19.4				
19.6				
19.8				
20				
20.2				
20.4				
20.6				
20.8				
21				
21.2				
21.4				
21.6				
21.8				
22				
22.2				
22.4				

BOREHOLE

MB13a

CLIENT HANSON CONSTRUCTION MATERIALS

PROJECT No. 12035

TOTAL DEPTH 20mBGL

DRILL DATE 15-Apr-20

PROJECT TWEED SAND PLANT EXPANSION

SURFACE RL Not surveyed

DRILLED BY PACIFIC GEOTECH

EASTING 552740.07

LOCATION CUDGEN, NSW

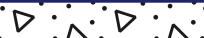
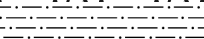
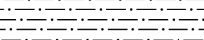
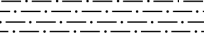
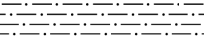
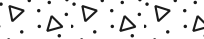
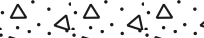
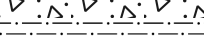
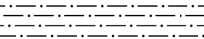
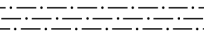
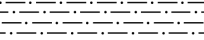
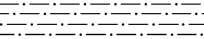
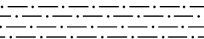
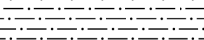
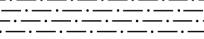
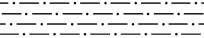
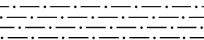
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+GILBERT

SUTHERLAND

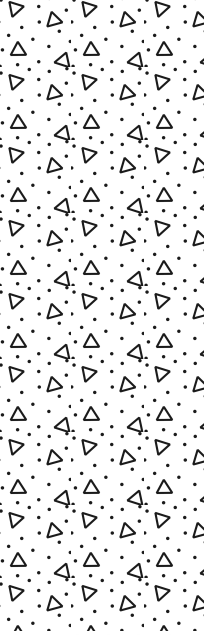
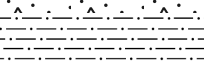
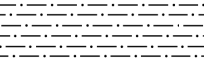
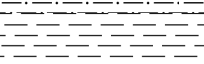
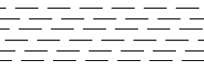
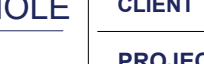
DEPTH (mBGL)	GROUNDWATER	GRAPHIC LOG	SOIL DESCRIPTION	ORIGIN
0			Very dark grey (10YR 3/1) sandy loam ; no coarse fragments; moist; massive structure; weak consistence; no segregations; change to;	NATURAL
0.2			Reddish grey (5YR 5/2) sandy clay loam ; no coarse fragments; moist; massive structure; very weak consistence; no segregations; change to;	NATURAL
0.4				
0.6				
0.8	▼		Light brownish grey (10YR 6/2) loamy sand ; no coarse fragments; moist; massive structure; loose consistence; no segregations; change to;	NATURAL
1				
1.2				
1.4				
1.6				
1.8				
2				
2.2			Grey (2.5Y 5/1) clayey sand ; no coarse fragments; wet; massive structure; very weak consistence; no segregations; change to;	NATURAL
2.4				
2.6				
2.8				
3				
3.2				
3.4				
3.6				
3.8				
4			Grey (2.5Y 5/1) loamy sand ; no coarse fragments; wet; massive structure; loose consistence; no segregations; change to;	NATURAL
4.2				
4.4				

BOREHOLE

MB14a

CLIENT	HANSON CONSTRUCTION MATERIALS	PROJECT No.	12035	TOTAL DEPTH	20mBGL	DRILL DATE	16-Apr-20
PROJECT	TWEED SAND PLANT EXPANSION	SURFACE RL	Not surveyed	DRILLED BY	PACIFIC GEOTECH	EASTING	552711.53
LOCATION	CUDGEN, NSW	DRILL METHOD	AUGER	LOGGED BY	GLH	NORTHING	6872597.36



DEPTH (mBGL)	GROUNDWATER	GRAPHIC LOG	SOIL DESCRIPTION	ORIGIN
4.6				
4.8				
5				
5.2				
5.4				
5.6				
5.8				
6				
6.2				
6.4				
6.6				
6.8				
7				
7.2			Grey (2.5Y 5/1) clayey sand ; very few, medium gravelly, subangular calcareous sand fragments; wet; massive structure; very weak consistence; no segregations; change to;	NATURAL
7.4				
7.6			Very dark greenish grey (10Y 3/1) silty medium clay ; very few, medium gravelly, subangular calcareous sand fragments; moist; massive structure; firm consistence; no segregations; change to;	NATURAL
7.8				
8				
8.2				
8.4				
8.6				
8.8				
9				

BOREHOLE

MB14a

CLIENT	HANSON CONSTRUCTION MATERIALS	PROJECT No.	12035	TOTAL DEPTH	20mBGL	DRILL DATE	16-Apr-20
PROJECT	TWEED SAND PLANT EXPANSION	SURFACE RL	Not surveyed	DRILLED BY	PACIFIC GEOTECH	EASTING	552711.53
LOCATION	CUDGEN, NSW	DRILL METHOD	AUGER	LOGGED BY	GLH	NORTHING	6872597.36



DEPTH (mBGL)	GROUNDWATER	GRAPHIC LOG	SOIL DESCRIPTION	ORIGIN
9.2				
9.4				
9.6				
9.8				
10				
10.2				
10.4				
10.6				
10.8				
11				
11.2				
11.4				
11.6				
11.8				
12				
12.2				
12.4				
12.6				
12.8				
13				
13.2				
13.4				

BOREHOLE

MB14a

CLIENT HANSON CONSTRUCTION MATERIALS

PROJECT No. 12035

TOTAL DEPTH 20mBGL

DRILL DATE 16-Apr-20

PROJECT TWEED SAND PLANT EXPANSION

SURFACE RL Not surveyed

DRILLED BY PACIFIC GEOTECH

EASTING 552711.53

LOCATION CUDGEN, NSW

DRILL METHOD AUGER

LOGGED BY GLH

NORTHING 6872597.36

+GILBERT

SUTHERLAND

DEPTH (mBGL)	GROUNDWATER	GRAPHIC LOG	SOIL DESCRIPTION	ORIGIN
13.6				
13.8				
14				
14.2				
14.4				
14.6				
14.8				
15				
15.2				
15.4				
15.6				
15.8				
16				
16.2				
16.4				
16.6				
16.8				
17				
17.2				
17.4				
17.6				
17.8				
18				

BOREHOLE

MB14a

CLIENT HANSON CONSTRUCTION MATERIALS

PROJECT No. 12035

TOTAL DEPTH 20mBGL

DRILL DATE 16-Apr-20

PROJECT TWEED SAND PLANT EXPANSION

SURFACE RL Not surveyed

DRILLED BY PACIFIC GEOTECH

EASTING 552711.53

LOCATION CUDGEN, NSW

DRILL METHOD AUGER

LOGGED BY GLH

NORTHING 6872597.36

+GILBERT

SUTHERLAND

DEPTH (mBGL)	GROUNDWATER	GRAPHIC LOG	SOIL DESCRIPTION	ORIGIN
18.2			Pale orange yellow (10YR 9/2) silty medium clay ; very few, medium gravelly, subangular calcareous sand fragments; moist; massive structure; very strong consistence; no segregations; borehole terminated at 20mBGL.	NATURAL
18.4				
18.6				
18.8				
19				
19.2				
19.4				
19.6				
19.8				
20				
20.2				
20.4				
20.6				
20.8				
21				
21.2				
21.4				
21.6				
21.8				
22				
22.2				
22.4				

BOREHOLE

MB14a

CLIENT

HANSON CONSTRUCTION MATERIALS

PROJECT No.

12035

TOTAL DEPTH

20mBGL

DRILL DATE

16-Apr-20

PROJECT

TWEED SAND PLANT EXPANSION

SURFACE RL

Not surveyed

DRILLED BY

PACIFIC GEOTECH

EASTING

552711.53

LOCATION

CUDGEN, NSW

DRILL METHOD

AUGER

LOGGED BY

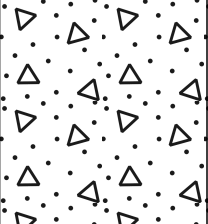
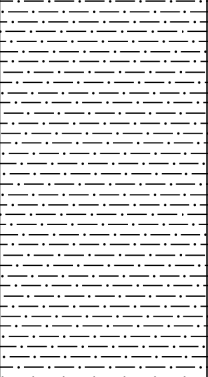
GLH

NORTHING

6872597.36

+GILBERT

SUTHERLAND

DEPTH (mBGL)	GROUNDWATER	GRAPHIC LOG	SOIL DESCRIPTION	ORIGIN
0			Very dark greyish brown (10YR 3/2) silty clay loam ; no coarse fragments; moist; massive structure; weak consistence; no segregations; change to;	NATURAL
0.2				
0.4	▼		Greyish brown (10YR 5/2) sandy loam ; no coarse fragments; wet; massive structure; very weak consistence; no segregations; change to;	NATURAL
0.6				
0.8				
1				
1.2			Greyish brown (10YR 5/2) sandy loam ; very few, medium gravelly, subangular calcareous sand fragments; wet; massive structure; very weak consistence; no segregations; change to;	NATURAL
1.4				
1.6				
1.8				
2				
2.2				
2.4				
2.6				
2.8				
3			Very dark grey (5Y 3/1) clayey sand ; very few, medium gravelly, subangular calcareous sand fragments; wet; massive structure; very weak consistence; no segregations; change to;	NATURAL
3.2				
3.4				
3.6				
3.8				
4				
4.2				
4.4				

BOREHOLE
MB15a

CLIENT	HANSON CONSTRUCTION MATERIALS	PROJECT No.	12035	TOTAL DEPTH	20mBGL	DRILL DATE	17-Apr-20
PROJECT	TWEED SAND PLANT EXPANSION	SURFACE RL	Not surveyed	DRILLED BY	PACIFIC GEOTECH	EASTING	551808.9
LOCATION	CUDGEN, NSW	DRILL METHOD	AUGER	LOGGED BY	GLH	NORTHING	6873422.44

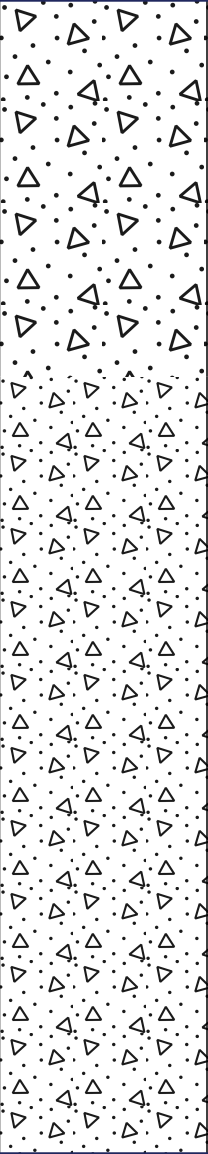


DEPTH (mBGL)	GROUNDWATER	GRAPHIC LOG	SOIL DESCRIPTION	ORIGIN
4.6				
4.8				
5				
5.2				
5.4				
5.6				
5.8				
6				
6.2				
6.4				
6.6				
6.8			grey (5/N) sandy loam ; very few, medium gravelly, subangular calcareous sand fragments; wet; massive structure; loose consistence; no segregations; change to;	NATURAL
7				
7.2				
7.4				
7.6				
7.8				
8				
8.2				
8.4				
8.6				
8.8				
9				

BOREHOLE
MB15a

CLIENT	HANSON CONSTRUCTION MATERIALS	PROJECT No.	12035	TOTAL DEPTH	20mBGL	DRILL DATE	17-Apr-20
PROJECT	TWEED SAND PLANT EXPANSION	SURFACE RL	Not surveyed	DRILLED BY	PACIFIC GEOTECH	EASTING	551808.9
LOCATION	CUDGEN, NSW	DRILL METHOD	AUGER	LOGGED BY	GLH	NORTHING	6873422.44



DEPTH (mBGL)	GROUNDWATER	GRAPHIC LOG	SOIL DESCRIPTION	ORIGIN
9.2 9.4 9.6 9.8 10 10.2 10.4 10.6 10.8 11 11.2 11.4 11.6 11.8 12 12.2 12.4 12.6 12.8 13 13.2 13.4			Dark grey (5Y 4/1) loamy sand; very few, medium gravelly, subangular calcareous sand fragments; wet; massive structure; very weak consistence; no segregations; change to;	NATURAL

BOREHOLE

MB15a

CLIENT	HANSON CONSTRUCTION MATERIALS	PROJECT No.	12035	TOTAL DEPTH	20mBGL	DRILL DATE	17-Apr-20
PROJECT	TWEED SAND PLANT EXPANSION	SURFACE RL	Not surveyed	DRILLED BY	PACIFIC GEOTECH	EASTING	551808.9
LOCATION	CUDGEN, NSW	DRILL METHOD	AUGER	LOGGED BY	GLH	NORTHING	6873422.44

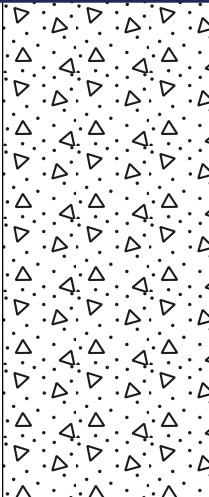


DEPTH (mBGL)	GROUNDWATER	GRAPHIC LOG	SOIL DESCRIPTION	ORIGIN
13.6				
13.8				
14				
14.2				
14.4				
14.6				
14.8				
15			Very dark grey (5Y 3/1) sandy loam ; no coarse fragments; wet; massive structure; very weak consistence; no segregations; change to;	NATURAL
15.2				
15.4				
15.6				
15.8				
16			Dark grey (5Y 4/1) loamy sand ; no coarse fragments; wet; massive structure; very weak consistence; no segregations; change to;	NATURAL
16.2				
16.4				
16.6				
16.8				
17				
17.2				
17.4				
17.6				
17.8				
18				

BOREHOLE
MB15a

CLIENT	HANSON CONSTRUCTION MATERIALS	PROJECT No.	12035	TOTAL DEPTH	20mBGL	DRILL DATE	17-Apr-20
PROJECT	TWEED SAND PLANT EXPANSION	SURFACE RL	Not surveyed	DRILLED BY	PACIFIC GEOTECH	EASTING	551808.9
LOCATION	CUDGEN, NSW	DRILL METHOD	AUGER	LOGGED BY	GLH	NORTHING	6873422.44



DEPTH (mBGL)	GROUNDWATER	GRAPHIC LOG	SOIL DESCRIPTION	ORIGIN
18.2 18.4 18.6 18.8 19 19.2 19.4 19.6 19.8 20 20.2 20.4 20.6 20.8 21 21.2 21.4 21.6 21.8 22 22.2 22.4			Dark grey (5Y 4/1) light loamy fine sand ; very few, medium gravelly, subangular calcareous sand fragments; wet; massive structure; very weak consistence; no segregations; borehole terminated at 20mBGL.	NATURAL

BOREHOLE

MB15a

CLIENT

 HANSON CONSTRUCTION MATERIALS

PROJECT No.

 12035

TOTAL DEPTH

 20mBGL

DRILL DATE

 17-Apr-20

PROJECT

 TWEED SAND PLANT EXPANSION

SURFACE RL

 Not surveyed

DRILLED BY

 PACIFIC GEOTECH

EASTING

 551808.9

LOCATION

 CUDGEN, NSW

DRILL METHOD

 AUGER

LOGGED BY

 GLH

NORTHING

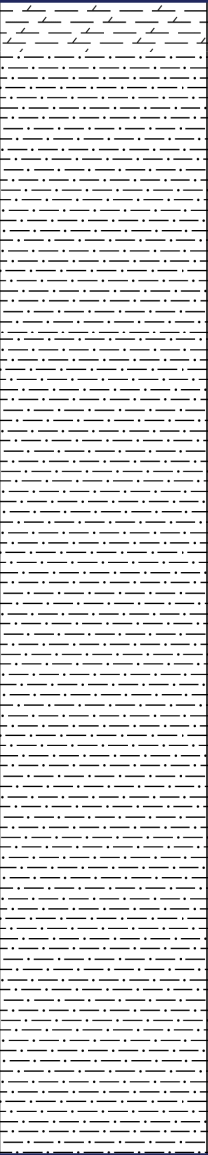
 6873422.44

+GILBERT

SUTHERLAND

+GILBERT

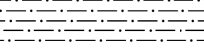
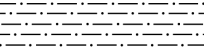
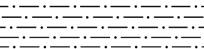
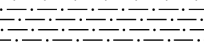
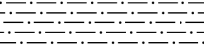
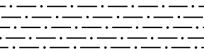
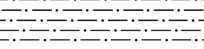
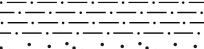
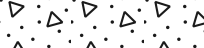
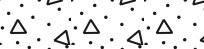
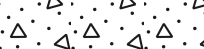
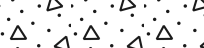
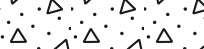
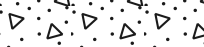
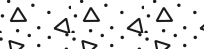
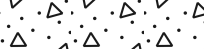
SUTHERLAND

DEPTH (mBGL)	GROUNDWATER	GRAPHIC LOG	SOIL DESCRIPTION	ORIGIN
0			Black (10YR 2/1) silty clay loam ; no coarse fragments; moist; massive structure; very weak consistence; no segregations; change to;	NATURAL
0.2			Greyish brown (2.5Y 5/2) clayey sand ; no coarse fragments; wet; massive structure; very weak consistence; no segregations; change to;	NATURAL
0.4				
0.6				
0.8				
1				
1.2				
1.4			Dark grey (5Y 4/1) clayey sand ; no coarse fragments; wet; massive structure; loose consistence; no segregations; change to;	NATURAL
1.6				
1.8				
2				
2.2				
2.4				
2.6				
2.8				
3				
3.2				
3.4				
3.6				
3.8				
4				
4.2				
4.4				

BOREHOLE
MB16a

CLIENT	HANSON CONSTRUCTION MATERIALS	PROJECT No.	12035	TOTAL DEPTH	20mBGL	DRILL DATE	20-Apr-20
PROJECT	TWEED SAND PLANT EXPANSION	SURFACE RL	Not surveyed	DRILLED BY	PACIFIC GEOTECH	EASTING	552130.24
LOCATION	CUDGEN, NSW	DRILL METHOD	AUGER	LOGGED BY	GLH	NORTHING	6874378.67



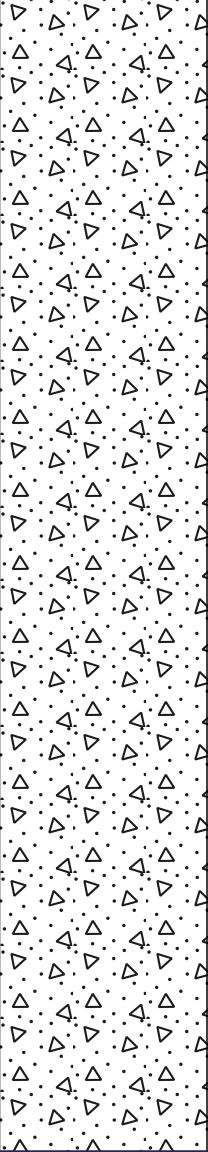
DEPTH (mBGL)	GROUNDWATER	GRAPHIC LOG	SOIL DESCRIPTION	ORIGIN
4.6				
4.8				
5				
5.2				
5.4				
5.6				
5.8				
6			grey (5/N) loamy sand ; very few, medium gravelly, subangular calcareous sand fragments; wet; massive structure; very weak consistence; no segregations; change to;	NATURAL
6.2				
6.4				
6.6				
6.8				
7				
7.2				
7.4				
7.6				
7.8				
8				
8.2				
8.4				
8.6				
8.8				
9				

BOREHOLE

MB16a

CLIENT	HANSON CONSTRUCTION MATERIALS	PROJECT No.	12035	TOTAL DEPTH	20mBGL	DRILL DATE	20-Apr-20
PROJECT	TWEED SAND PLANT EXPANSION	SURFACE RL	Not surveyed	DRILLED BY	PACIFIC GEOTECH	EASTING	552130.24
LOCATION	CUDGEN, NSW	DRILL METHOD	AUGER	LOGGED BY	GLH	NORTHING	6874378.67



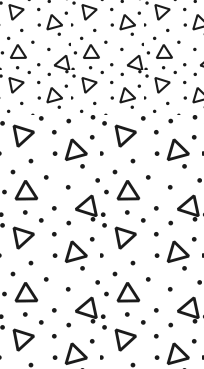
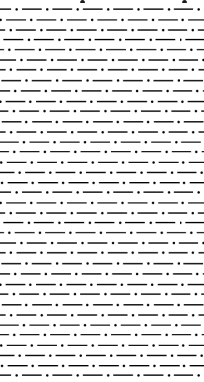
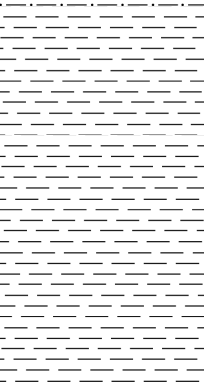
DEPTH (mBGL)	GROUNDWATER	GRAPHIC LOG	SOIL DESCRIPTION	ORIGIN
9.2 9.4 9.6 9.8 10 10.2 10.4 10.6 10.8 11 11.2 11.4 11.6 11.8 12 12.2 12.4 12.6 12.8 13 13.2 13.4				

BOREHOLE

MB16a

CLIENT	HANSON CONSTRUCTION MATERIALS	PROJECT No.	12035	TOTAL DEPTH	20mBGL	DRILL DATE	20-Apr-20
PROJECT	TWEED SAND PLANT EXPANSION	SURFACE RL	Not surveyed	DRILLED BY	PACIFIC GEOTECH	EASTING	552130.24
LOCATION	CUDGEN, NSW	DRILL METHOD	AUGER	LOGGED BY	GLH	NORTHING	6874378.67



DEPTH (mBGL)	GROUNDWATER	GRAPHIC LOG	SOIL DESCRIPTION	ORIGIN
13.6				
13.8				
14			Dark grey (5Y 4/1) sandy loam ; no coarse fragments; wet; massive structure; very weak consistence; no segregations; change to;	NATURAL
14.2				
14.4				
14.6				
14.8				
15			Very dark grey (5Y 3/1) clayey sand ; no coarse fragments; wet; massive structure; loose consistence; no segregations; change to;	NATURAL
15.2				
15.4				
15.6				
15.8				
16				
16.2				
16.4				
16.6			Very dark greenish grey (10Y 3/1) silty medium clay ; no coarse fragments; wet; massive structure; very weak consistence; no segregations; change to;	NATURAL
16.8				
17			Very dark greenish grey (10Y 3/1) silty medium clay ; very few, medium gravelly, subangular calcareous sand fragments; wet; massive structure; very weak consistence; no segregations; borehole terminated at 20mBGL.	NATURAL
17.2				
17.4				
17.6				
17.8				
18				

BOREHOLE

MB16a

CLIENT	HANSON CONSTRUCTION MATERIALS	PROJECT No.	12035	TOTAL DEPTH	20mBGL	DRILL DATE	20-Apr-20
PROJECT	TWEED SAND PLANT EXPANSION	SURFACE RL	Not surveyed	DRILLED BY	PACIFIC GEOTECH	EASTING	552130.24
LOCATION	CUDGEN, NSW	DRILL METHOD	AUGER	LOGGED BY	GLH	NORTHING	6874378.67



DEPTH (mBGL)	GROUNDWATER	GRAPHIC LOG	SOIL DESCRIPTION	ORIGIN
18.2				
18.4				
18.6				
18.8				
19				
19.2				
19.4				
19.6				
19.8				
20				
20.2				
20.4				
20.6				
20.8				
21				
21.2				
21.4				
21.6				
21.8				
22				
22.2				
22.4				

BOREHOLE

MB16a

CLIENT HANSON CONSTRUCTION MATERIALS

PROJECT No. 12035

TOTAL DEPTH 20mBGL

DRILL DATE 20-Apr-20

PROJECT TWEED SAND PLANT EXPANSION

SURFACE RL Not surveyed

DRILLED BY PACIFIC GEOTECH

EASTING 552130.24

LOCATION CUDGEN, NSW

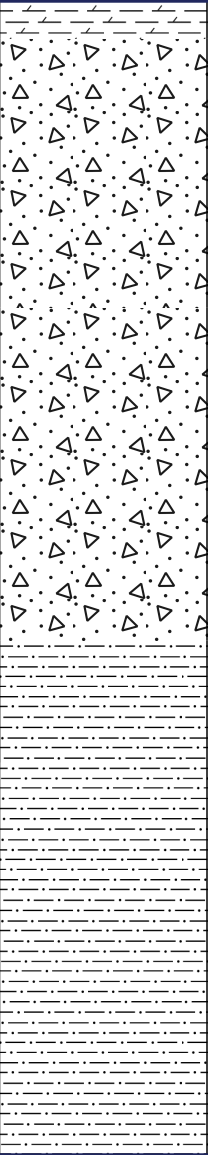
DRILL METHOD AUGER

LOGGED BY GLH

NORTHING 6874378.67

+GILBERT

SUTHERLAND

DEPTH (mBGL)	GROUNDWATER	GRAPHIC LOG	SOIL DESCRIPTION	ORIGIN
0			Very dark grey (10YR 3/1) silty clay loam ; no coarse fragments; moist; massive structure; weak consistence; no segregations; change to;	NATURAL
0.2			Greyish brown (10YR 5/2) heavy loamy sand ; no coarse fragments; moist; massive structure; very weak consistence; no segregations; change to;	NATURAL
0.4				
0.6				
0.8				
1				
1.2			Grey (2.5Y 5/1) heavy loamy sand ; no coarse fragments; wet; massive structure; very weak consistence; no segregations; change to;	NATURAL
1.4	▼			
1.6				
1.8				
2				
2.2				
2.4				
2.6			Dark grey (5Y 4/1) clayey sand ; very few, medium gravelly, subangular calcareous sand fragments; wet; massive structure; very weak consistence; no segregations; change to;	NATURAL
2.8				
3				
3.2				
3.4				
3.6				
3.8				
4				
4.2				
4.4				

BOREHOLE
MB17a

CLIENT	HANSON CONSTRUCTION MATERIALS	PROJECT No.	12035	TOTAL DEPTH	20mBGL	DRILL DATE	21-Apr-20
PROJECT	TWEED SAND PLANT EXPANSION	SURFACE RL	Not surveyed	DRILLED BY	PACIFIC GEOTECH	EASTING	552301.08
LOCATION	CUDGEN, NSW	DRILL METHOD	AUGER	LOGGED BY	GLH	NORTHING	6874902.89

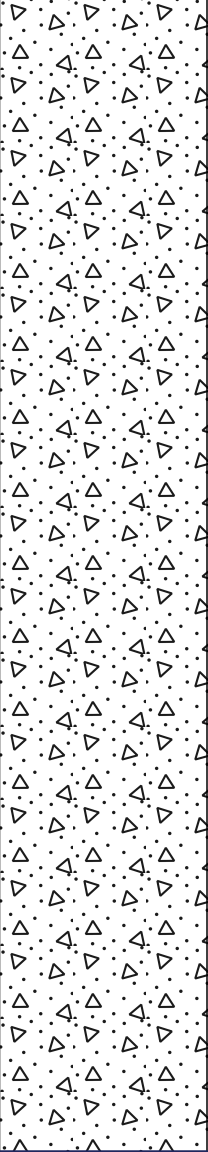


DEPTH (mBGL)	GROUNDWATER	GRAPHIC LOG	SOIL DESCRIPTION	ORIGIN
4.6				
4.8				
5				
5.2				
5.4				
5.6				
5.8				
6				
6.2				
6.4				
6.6				
6.8				
7				
7.2				
7.4				
7.6				
7.8				
8				
8.2			Grey (5Y 5/1) heavy loamy sand ; no coarse fragments; wet; massive structure; loose consistence; no segregations; change to;	NATURAL
8.4				
8.6				
8.8				
9				

BOREHOLE
MB17a

CLIENT	HANSON CONSTRUCTION MATERIALS	PROJECT No.	12035	TOTAL DEPTH	20mBGL	DRILL DATE	21-Apr-20
PROJECT	TWEED SAND PLANT EXPANSION	SURFACE RL	Not surveyed	DRILLED BY	PACIFIC GEOTECH	EASTING	552301.08
LOCATION	CUDGEN, NSW	DRILL METHOD	AUGER	LOGGED BY	GLH	NORTHING	6874902.89



DEPTH (mBGL)	GROUNDWATER	GRAPHIC LOG	SOIL DESCRIPTION	ORIGIN
9.2 9.4 9.6 9.8 10 10.2 10.4 10.6 10.8 11 11.2 11.4 11.6 11.8 12 12.2 12.4 12.6 12.8 13 13.2 13.4				

BOREHOLE

MB17a

CLIENT	HANSON CONSTRUCTION MATERIALS	PROJECT No.	12035	TOTAL DEPTH	20mBGL	DRILL DATE	21-Apr-20
PROJECT	TWEED SAND PLANT EXPANSION	SURFACE RL	Not surveyed	DRILLED BY	PACIFIC GEOTECH	EASTING	552301.08
LOCATION	CUDGEN, NSW	DRILL METHOD	AUGER	LOGGED BY	GLH	NORTHING	6874902.89



DEPTH (mBGL)	GROUNDWATER	GRAPHIC LOG	SOIL DESCRIPTION	ORIGIN
13.6				
13.8				
14				
14.2				
14.4				
14.6				
14.8				
15				
15.2				
15.4				
15.6				
15.8				
16			Grey (5Y 5/1) sandy loam ; no coarse fragments; wet; massive structure; loose consistence; no segregations; change to;	NATURAL
16.2				
16.4				
16.6				
16.8				
17			Very dark grey (5Y 3/1) clayey sand ; no coarse fragments; wet; massive structure; loose consistence; no segregations; change to;	NATURAL
17.2				
17.4				
17.6				
17.8				
18				

BOREHOLE
MB17a

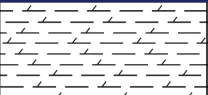
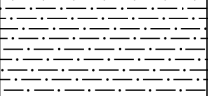
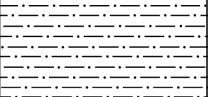
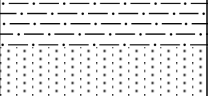
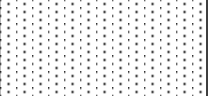
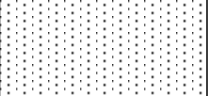
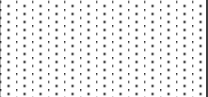
CLIENT	HANSON CONSTRUCTION MATERIALS	PROJECT No.	12035	TOTAL DEPTH	20mBGL	DRILL DATE	21-Apr-20
PROJECT	TWEED SAND PLANT EXPANSION	SURFACE RL	Not surveyed	DRILLED BY	PACIFIC GEOTECH	EASTING	552301.08
LOCATION	CUDGEN, NSW	DRILL METHOD	AUGER	LOGGED BY	GLH	NORTHING	6874902.89



DEPTH (mBGL)	GROUNDWATER	GRAPHIC LOG	SOIL DESCRIPTION	ORIGIN
18.2				
18.4				
18.6				
18.8				
19				
19.2				
19.4			Very dark greenish grey (10Y 3/1) silty medium clay ; no coarse fragments; wet; massive structure; loose consistence; no segregations; borehole terminated at 20mBGL.	NATURAL
19.6				
19.8				
20				
20.2				
20.4				
20.6				
20.8				
21				
21.2				
21.4				
21.6				
21.8				
22				
22.2				
22.4				

BOREHOLE MB17a	CLIENT	HANSON CONSTRUCTION MATERIALS	PROJECT No.	12035	TOTAL DEPTH	20mBGL	DRILL DATE	21-Apr-20
	PROJECT	TWEED SAND PLANT EXPANSION	SURFACE RL	Not surveyed	DRILLED BY	PACIFIC GEOTECH	EASTING	552301.08
	LOCATION	CUDGEN, NSW	DRILL METHOD	AUGER	LOGGED BY	GLH	NORTHING	6874902.89

+GILBERT
SUTHERLAND

DEPTH (mBGL)	GROUNDWATER	GRAPHIC LOG	SOIL DESCRIPTION	ORIGIN
0			Black (10YR 2/1) silty clay loam ; no coarse fragments; moist; massive structure; weak consistence; no segregations; change to;	NATURAL
0.2				
0.4			Grey (10YR 5/1) loamy sand ; no coarse fragments; moist; massive structure; very weak consistence; no segregations; change to;	NATURAL
0.6				
0.8	▼			
1			Grey (7.5YR 5/1) loamy sand ; no coarse fragments; wet; massive structure; very weak consistence; no segregations; change to;	NATURAL
1.2				
1.4			Very dark grey (5Y 3/1) clayey sand ; no coarse fragments; wet; massive structure; very weak consistence; no segregations; change to;	NATURAL
1.6				
1.8				
2				
2.2				
2.4				
2.6				
2.8				
3			Grey (5Y 5/1) sand ; very few, medium gravelly, subangular calcareous sand fragments; wet; massive structure; loose consistence; no segregations; change to;	NATURAL
3.2				
3.4				
3.6				
3.8				
4				
4.2				
4.4				

BOREHOLE

MB18a

CLIENT	HANSON CONSTRUCTION MATERIALS	PROJECT No.	12035	TOTAL DEPTH	21.5mBGL	DRILL DATE	22-Apr-20
PROJECT	TWEED SAND PLANT EXPANSION	SURFACE RL	Not surveyed	DRILLED BY	PACIFIC GEOTECH	EASTING	552979.83
LOCATION	CUDGEN, NSW	DRILL METHOD	AUGER	LOGGED BY	GLH	NORTHING	6874672.57

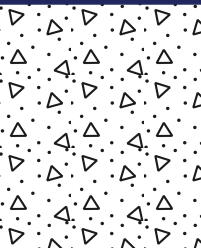
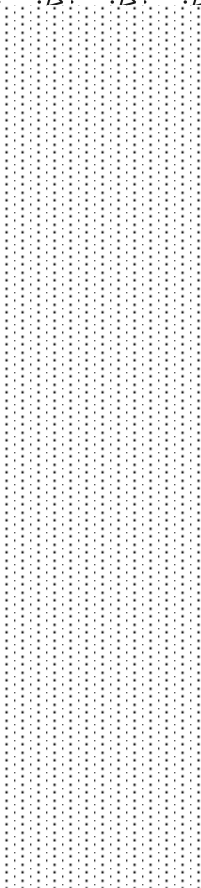


DEPTH (mBGL)	GROUNDWATER	GRAPHIC LOG	SOIL DESCRIPTION	ORIGIN
4.6				
4.8				
5				
5.2				
5.4				
5.6				
5.8				
6			Dark grey (5Y 4/1) loamy sand ; very few, medium gravelly, subangular calcareous sand fragments; wet; massive structure; loose consistence; no segregations; change to;	NATURAL
6.2				
6.4				
6.6				
6.8				
7				
7.2				
7.4				
7.6				
7.8				
8				
8.2				
8.4				
8.6				
8.8				
9				

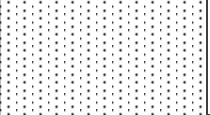
BOREHOLE
MB18a

CLIENT	HANSON CONSTRUCTION MATERIALS	PROJECT No.	12035	TOTAL DEPTH	21.5mBGL	DRILL DATE	22-Apr-20
PROJECT	TWEED SAND PLANT EXPANSION	SURFACE RL	Not surveyed	DRILLED BY	PACIFIC GEOTECH	EASTING	552979.83
LOCATION	CUDGEN, NSW	DRILL METHOD	AUGER	LOGGED BY	GLH	NORTHING	6874672.57



DEPTH (mBGL)	GROUNDWATER	GRAPHIC LOG	SOIL DESCRIPTION	ORIGIN
9.2				
9.4				
9.6				
9.8				
10				
10.2			Grey (5Y 5/1) sand ; very few, medium gravelly, subangular calcareous sand fragments; wet; massive structure; loose consistence; no segregations; change to;	NATURAL
10.4				
10.6				
10.8				
11				
11.2				
11.4				
11.6				
11.8				
12				
12.2				
12.4				
12.6				
12.8				
13				
13.2				
13.4				



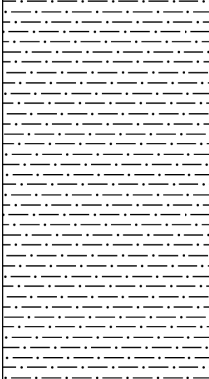
DEPTH (mBGL)	GROUNDWATER	GRAPHIC LOG	SOIL DESCRIPTION	ORIGIN
13.6				
13.8				
14			Dark grey (5Y 4/1) loamy sand ; very few, medium gravelly, subangular calcareous sand fragments; wet; massive structure; loose consistence; no segregations; change to;	NATURAL
14.2				
14.4				
14.6			Dark grey (5Y 4/1) loamy sand ; no coarse fragments; wet; massive structure; loose consistence; no segregations; change to;	NATURAL
14.8				
15				
15.2				
15.4				
15.6				
15.8				
16				
16.2				
16.4				
16.6				
16.8				
17				
17.2				
17.4				
17.6				
17.8				
18				

BOREHOLE

MB18a

CLIENT	HANSON CONSTRUCTION MATERIALS	PROJECT No.	12035	TOTAL DEPTH	21.5mBGL	DRILL DATE	22-Apr-20
PROJECT	TWEED SAND PLANT EXPANSION	SURFACE RL	Not surveyed	DRILLED BY	PACIFIC GEOTECH	EASTING	552979.83
LOCATION	CUDGEN, NSW	DRILL METHOD	AUGER	LOGGED BY	GLH	NORTHING	6874672.57



DEPTH (mBGL)	GROUNDWATER	GRAPHIC LOG	SOIL DESCRIPTION	ORIGIN
18.2				
18.4				
18.6			Very dark grey (5Y 3/1) clayey sand ; no coarse fragments; wet; massive structure; loose consistence; no segregations; change to;	NATURAL
18.8				
19				
19.2				
19.4				
19.6				
19.8				
20				
20.2				
20.4				
20.6				
20.8				
21				
21.2				
21.4				
21.6				
21.8				
22				
22.2				
22.4				

BOREHOLE

MB18a

CLIENT

HANSON CONSTRUCTION MATERIALS

PROJECT

TWEED SAND PLANT EXPANSION

LOCATION

CUDGEN, NSW

PROJECT No.

12035

SURFACE RL

Not surveyed

DRILL METHOD

AUGER

TOTAL DEPTH

21.5mBGL

DRILLED BY

PACIFIC GEOTECH

LOGGED BY

GLH

DRILL DATE

22-Apr-20

EASTING

552979.83

NORTHING

6874672.57

+GILBERT

SUTHERLAND

DEPTH (mBGL)	GROUNDWATER	GRAPHIC LOG	SOIL DESCRIPTION	ORIGIN
0			Black (10YR 2/1) light clay ; no coarse fragments; moderately moist; no segregations; change to;	Natural
0.2				
0.4			Grey (2.5Y 5/1) clayey sand with diffuse transitions to very few, fine sized, distinct, very dark grey (2.5Y 3/1) mottles; no coarse fragments; moist; change to;	Natural
0.6				
0.8				
1			Light grey (2.5Y 7/1) loamy sand with diffuse transitions to many, medium sized, distinct, reddish yellow (7.5YR 6/8) mottles; no coarse fragments; wet; change to;	Natural
1.2				
1.4				
1.6			Grey (2.5Y 5/1) loamy sand with diffuse transitions to few, fine sized, distinct, olive yellow (2.5Y 6/6) mottles; no coarse fragments; wet; change to;	Natural
1.8				
2			Dark grey (4/N) fine-medium sand ; shell fragments @ 4.4, medium shells @ 4.9; wet; change to;	Natural
2.2				
2.4				
2.6				
2.8				
3				
3.2				
3.4				
3.6				
3.8				
4				
4.2				
4.4				

BOREHOLE
AS17

CLIENT HANSON CONSTRUCTION MATERIALS	PROJECT No.	12035	TOTAL DEPTH	19.5mBGL	DRILL DATE	29-Sep-20
PROJECT TWEED SAND PLANT EXPANSION	SURFACE RL	Not surveyed	DRILLED BY	PACIFIC GEOTECH	EASTING	551840
LOCATION CUDGEN, NSW	DRILL METHOD	VIBROCORE	LOGGED BY	SAM	NORTHING	6873610



DEPTH (mBGL)	GROUNDWATER	GRAPHIC LOG	SOIL DESCRIPTION	ORIGIN
4.6				
4.8				
5				
5.2				
5.4				
5.6				
5.8				
6				
6.2				
6.4				
6.6				
6.8				
7				
7.2				
7.4				
7.6			grey (6/N) fine-medium sand ; no coarse fragments; wet; change to;	Natural
7.8				
8				
8.2				
8.4				
8.6				
8.8			Dark grey (4/N) clayey sand ; no coarse fragments; wet; change to;	Natural
9				

BOREHOLE

AS17

CLIENT HANSON CONSTRUCTION MATERIALS	PROJECT No.	12035	TOTAL DEPTH	19.5mBGL	DRILL DATE	29-Sep-20
PROJECT TWEED SAND PLANT EXPANSION	SURFACE RL	Not surveyed	DRILLED BY	PACIFIC GEOTECH	EASTING	551840
LOCATION CUDGEN, NSW	DRILL METHOD	VIBROCORE	LOGGED BY	SAM	NORTHING	6873610



DEPTH (mBGL)	GROUNDWATER	GRAPHIC LOG	SOIL DESCRIPTION	ORIGIN
9.2 9.4 9.6 9.8 10 10.2 10.4 10.6 10.8 11 11.2 11.4 11.6 11.8 12 12.2 12.4 12.6 12.8 13 13.2 13.4			grey (5/N) sand ; shell clusters @ 9.5, 10.1 and 11.3m; wet; no segregations; change to;	Natural
BOREHOLE AS17 CLIENT HANSON CONSTRUCTION MATERIALS PROJECT No. 12035 TOTAL DEPTH 19.5mBGL DRILL DATE 29-Sep-20 PROJECT TWEED SAND PLANT EXPANSION SURFACE RL Not surveyed DRILLED BY PACIFIC GEOTECH EASTING 551840 LOCATION CUDGEN, NSW DRILL METHOD VIBROCORE LOGGED BY SAM NORTHING 6873610 +GILBERT SUTHERLAND				

DEPTH (mBGL)	GROUNDWATER	GRAPHIC LOG	SOIL DESCRIPTION	ORIGIN
13.6 13.8 14 14.2 14.4 14.6 14.8 15 15.2 15.4 15.6 15.8 16 16.2 16.4 16.6 16.8 17 17.2 17.4 17.6 17.8 18				

BOREHOLE

AS17

CLIENT HANSON CONSTRUCTION MATERIALS

PROJECT No. 12035

TOTAL DEPTH 19.5mBGL

DRILL DATE 29-Sep-20

PROJECT TWEED SAND PLANT EXPANSION

SURFACE RL Not surveyed

DRILLED BY PACIFIC GEOTECH

EASTING 551840

LOCATION CUDGEN, NSW

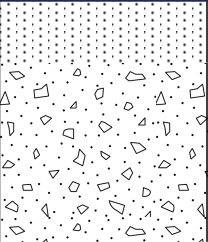
DRILL METHOD VIBROCORE

LOGGED BY SAM

NORTHING 6873610

+GILBERT

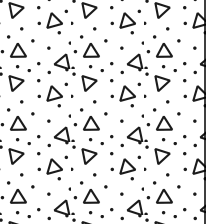
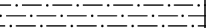
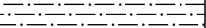
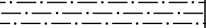
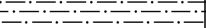
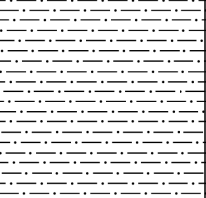
SUTHERLAND

DEPTH (mBGL)	GROUNDWATER	GRAPHIC LOG	SOIL DESCRIPTION	ORIGIN
18.2				
18.4			Very dark greenish grey (5GY 3/1) sandy clay loam ; Bark pieces @18.6m and shell fragments throughout; wet; change to;	Natural
18.6				
18.8			Greenish black (5GY 2.5/1) medium clay ; no coarse fragments; wet; borehole terminated at 19.5mBGL.	Natural
19				
19.2				
19.4				
19.6				
19.8				
20				
20.2				
20.4				
20.6				
20.8				
21				
21.2				
21.4				
21.6				
21.8				
22				
22.2				
22.4				

BOREHOLE
AS17

CLIENT HANSON CONSTRUCTION MATERIALS	PROJECT No.	12035	TOTAL DEPTH	19.5mBGL	DRILL DATE	29-Sep-20
PROJECT TWEED SAND PLANT EXPANSION	SURFACE RL	Not surveyed	DRILLED BY	PACIFIC GEOTECH	EASTING	551840
LOCATION CUDGEN, NSW	DRILL METHOD	VIBROCORE	LOGGED BY	SAM	NORTHING	6873610



DEPTH (mBGL)	GROUNDWATER	GRAPHIC LOG	SOIL DESCRIPTION	ORIGIN
0			Very dark grey (10YR 3/1) light clay ; no coarse fragments; moist; moderate, 2mm angular blocky structure; very weak consistence; no segregations; common, very fine roots; clear change to;	Natural
0.2				
0.4			Light brownish grey (10YR 6/2) loamy sand with diffuse transitions to common, medium sized, distinct, reddish yellow (7.5YR 6/8) mottles; no coarse fragments; moist; weak, 2mm angular blocky structure; very weak consistence; no segregations; cahnge to;	Natural
0.6				
0.8	▼		Grey (10YR 6/1) loamy sand with diffuse transitions to many, coarse sized, prominent, brownish yellow (10YR 6/8) mottles; no coarse fragments; wet; moderate, 3mm angular blocky structure; loose consistence; no segregations; diffuse change to;	Natural
1				
1.2				
1.4				
1.6			Dark greenish grey (5GY 4/1) clayey sand ; no coarse fragments; wet; no segregations; change to;	Natural
1.8				
2				
2.2				
2.4				
2.6				
2.8				
3			grey (5/N) sand ; shell fragments and clay balls @ 10m; wet; no segregations; change to;	Natural
3.2				
3.4				
3.6				
3.8				
4				
4.2				
4.4				

BOREHOLE

AS20

CLIENT HANSON CONSTRUCTION MATERIALS	PROJECT No.	12035	TOTAL DEPTH	19.5mBGL	DRILL DATE	30-Sep-20
PROJECT TWEED SAND PLANT EXPANSION	SURFACE RL	Not surveyed	DRILLED BY	PACIFIC GEOTECH	EASTING	552008
LOCATION CUDGEN, NSW	DRILL METHOD	VIBROCORE	LOGGED BY	SAM	NORTHING	6873564



DEPTH (mBGL)	GROUNDWATER	GRAPHIC LOG	SOIL DESCRIPTION	ORIGIN
4.6				
4.8				
5				
5.2				
5.4				
5.6				
5.8				
6				
6.2				
6.4				
6.6				
6.8				
7				
7.2				
7.4				
7.6				
7.8				
8				
8.2				
8.4				
8.6				
8.8				
9				

BOREHOLE

AS20

CLIENT HANSON CONSTRUCTION MATERIALS

PROJECT No. 12035

TOTAL DEPTH 19.5mBGL

DRILL DATE 30-Sep-20

PROJECT TWEED SAND PLANT EXPANSION

SURFACE RL Not surveyed

DRILLED BY PACIFIC GEOTECH

EASTING 552008

LOCATION CUDGEN, NSW

DRILL METHOD VIBROCORE

LOGGED BY SAM

NORTHING 6873564

+GILBERT

SUTHERLAND

DEPTH (mBGL)	GROUNDWATER	GRAPHIC LOG	SOIL DESCRIPTION	ORIGIN
9.2 9.4 9.6 9.8 10 10.2 10.4 10.6 10.8 11 11.2 11.4 11.6 11.8 12 12.2 12.4 12.6 12.8 13 13.2 13.4				

BOREHOLE

AS20

CLIENT HANSON CONSTRUCTION MATERIALS

PROJECT No. 12035

TOTAL DEPTH 19.5mBGL

DRILL DATE 30-Sep-20

PROJECT TWEED SAND PLANT EXPANSION

SURFACE RL Not surveyed

DRILLED BY PACIFIC GEOTECH

EASTING 552008

LOCATION CUDGEN, NSW

DRILL METHOD VIBROCORE

LOGGED BY SAM

NORTHING 6873564

+GILBERT

SUTHERLAND

DEPTH (mBGL)	GROUNDWATER	GRAPHIC LOG	SOIL DESCRIPTION	ORIGIN	
13.6					
13.8					
14					
14.2					
14.4					
14.6					
14.8					
15					
15.2					
15.4					
15.6					
15.8					
16					
16.2				Light grey (7/N) sand; no coarse fragments; wet; no segregations; change to;	Natural
16.4					
16.6					
16.8					
17					
17.2					
17.4					
17.6					
17.8					
18					

BOREHOLE

AS20

CLIENT HANSON CONSTRUCTION MATERIALS

PROJECT No. 12035

TOTAL DEPTH 19.5mBGL

DRILL DATE 30-Sep-20

PROJECT TWEED SAND PLANT EXPANSION

SURFACE RL Not surveyed

DRILLED BY PACIFIC GEOTECH

EASTING 552008

LOCATION CUDGEN, NSW

DRILL METHOD VIBROCORE

LOGGED BY SAM

NORTHING 6873564

+GILBERT

SUTHERLAND

DEPTH (mBGL)	GROUNDWATER	GRAPHIC LOG	SOIL DESCRIPTION	ORIGIN
18.2			Very dark greenish grey (10Y 3/1) clayey sand ; no coarse fragments; wet; no segregations; change to;	Natural
18.4				
18.6			Greenish black (10Y 2.5/1) medium clay ; no coarse fragments; wet; no segregations; borehole terminated at 19.5mBGL.	Natural
18.8				
19				
19.2				
19.4				
19.6				
19.8				
20				
20.2				
20.4				
20.6				
20.8				
21				
21.2				
21.4				
21.6				
21.8				
22				
22.2				
22.4				

BOREHOLE

AS20

CLIENT HANSON CONSTRUCTION MATERIALS **PROJECT No.** 12035

TOTAL DEPTH 19.5mBGL

DRILL DATE 30-Sep-20

PROJECT	TWEED SAND PLANT EXPANSION	SURFACE RL	Not surveyed
----------------	----------------------------	-------------------	--------------

DRILLED BY PACIFIC GEOTECH **EASTING** 552008

LOCATION CUDGEN, NSW

DRILL METHOD VIBROCORE

LOGGED BY SAM

NORTHING 6873564

+GILBERT SUTHERLAND

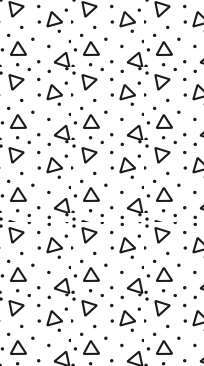
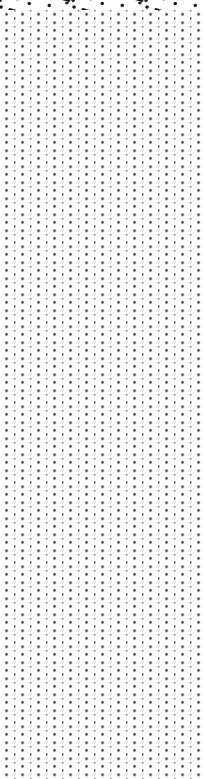
DEPTH (mBGL)	GROUNDWATER	GRAPHIC LOG	SOIL DESCRIPTION	ORIGIN
0			Black (10YR 2/1) light medium clay ; no coarse fragments; moist; change to;	Natural
0.2				
0.4				
0.6	▼		Light yellowish brown (2.5Y 6/3) clayey sand with diffuse transitions to few, fine sized, distinct, very dark grey (2.5Y 3/1) mottles; no coarse fragments; wet; change to;	Natural
0.8				
1				
1.2				
1.4				
1.6				
1.8				
2				
2.2				
2.4			Dark greenish grey (10Y 4/1) loamy sand ; no coarse fragments; wet; segregations of lighter CS (10YR 6/3) throughout; change to;	Natural
2.6				
2.8				
3				
3.2				
3.4				
3.6				
3.8				
4				
4.2				
4.4				

BOREHOLE

AS21

CLIENT HANSON CONSTRUCTION MATERIALS	PROJECT No.	12035	TOTAL DEPTH	14.6mBGL	DRILL DATE	30-Sep-20
PROJECT TWEED SAND PLANT EXPANSION	SURFACE RL	Not surveyed	DRILLED BY	PACIFIC GEOTECH	EASTING	552277
LOCATION CUDGEN, NSW	DRILL METHOD	VIBROCORE	LOGGED BY	SAM	NORTHING	6873669



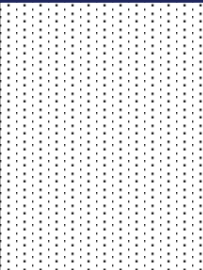
DEPTH (mBGL)	GROUNDWATER	GRAPHIC LOG	SOIL DESCRIPTION	ORIGIN
4.6				
4.8				
5				
5.2				
5.4			Dark grey (4/N) loamy sand ; no coarse fragments; wet; change to;	Natural
5.6				
5.8				
6			Dark grey (4/N) fine-medium sand ; shell fragments throughout; wet; change to;	Natural
6.2				
6.4				
6.6				
6.8				
7				
7.2				
7.4				
7.6				
7.8				
8				
8.2				
8.4				
8.6				
8.8				
9				

BOREHOLE
AS21

CLIENT HANSON CONSTRUCTION MATERIALS	PROJECT No.	12035	TOTAL DEPTH	14.6mBGL	DRILL DATE	30-Sep-20
PROJECT TWEED SAND PLANT EXPANSION	SURFACE RL	Not surveyed	DRILLED BY	PACIFIC GEOTECH	EASTING	552277
LOCATION CUDGEN, NSW	DRILL METHOD	VIBROCORE	LOGGED BY	SAM	NORTHING	6873669



DEPTH (mBGL)	GROUNDWATER	GRAPHIC LOG	SOIL DESCRIPTION	ORIGIN
9.2 9.4 9.6 9.8 10 10.2 10.4 10.6 10.8 11 11.2 11.4 11.6 11.8 12 12.2 12.4 12.6 12.8 13 13.2 13.4			grey (6/N) fine-medium sand ; no coarse fragments; wet; change to;	Natural
BOREHOLE AS21 CLIENT HANSON CONSTRUCTION MATERIALS PROJECT No. 12035 TOTAL DEPTH 14.6mBGL DRILL DATE 30-Sep-20 PROJECT TWEED SAND PLANT EXPANSION SURFACE RL Not surveyed DRILLED BY PACIFIC GEOTECH EASTING 552277 LOCATION CUDGEN, NSW DRILL METHOD VIBROCORE LOGGED BY SAM NORTHING 6873669 +GILBERT SUTHERLAND				

DEPTH (mBGL)	GROUNDWATER	GRAPHIC LOG	SOIL DESCRIPTION	ORIGIN
13.6			Light greenish grey (10Y 7/1) medium sand ; shell fragments; wet; borehole terminated at 15mBGL.	Natural
13.8				
14				
14.2				
14.4				
14.6				
14.8				
15				
15.2				
15.4				
15.6				
15.8				
16				
16.2				
16.4				
16.6				
16.8				
17				
17.2				
17.4				
17.6				
17.8				
18				

BOREHOLE

AS21

CLIENT HANSON CONSTRUCTION MATERIALS

PROJECT No.

12035

TOTAL DEPTH

14.6mBGL

DRILL DATE

30-Sep-20

PROJECT TWEED SAND PLANT EXPANSION

SURFACE RL

Not surveyed

DRILLED BY

PACIFIC GEOTECH

EASTING

552277

LOCATION CUDGEN, NSW

DRILL METHOD

VIBROCORE

LOGGED BY

SAM

NORTHING

6873669

+GILBERT

SUTHERLAND

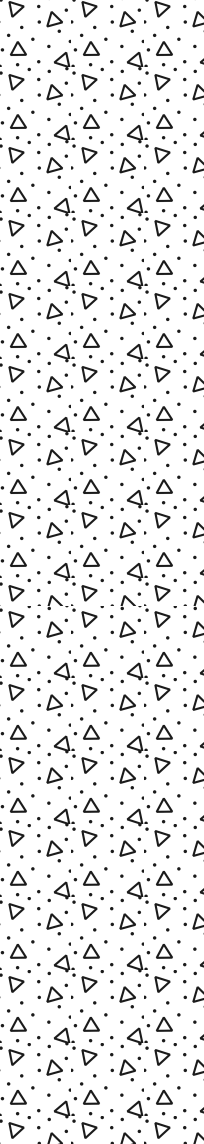
DEPTH (mBGL)	GROUNDWATER	GRAPHIC LOG	SOIL DESCRIPTION	ORIGIN
0			Very dark greyish brown (10YR 3/2) light clay ; no coarse fragments; dry; change to;	Natural
0.2			Grey (10YR 5/1) clayey sand with diffuse transitions to very few, fine sized, distinct, brownish yellow (10YR 6/8) mottles; no coarse fragments; moist; change to;	Natural
0.4				
0.6				
0.8	▼		Dark grey (2.5Y 4/1) clayey sand to sandy loam ; no coarse fragments; wet; change to;	Natural
1				
1.2			Very dark greenish grey (10Y 3/1) clayey sand to sandy loam ; no coarse fragments; wet; change to;	Natural
1.4				
1.6				
1.8				
2			Dark greenish grey (10Y 4/1) loamy sand to clayey sand ; no coarse fragments; wet; change to;	Natural
2.2				
2.4				
2.6				
2.8				
3			Dark greenish grey (10Y 4/1) loamy sand ; no coarse fragments; wet; change to;	Natural
3.2				
3.4				
3.6				
3.8				
4				
4.2				
4.4				

BOREHOLE

AS23

CLIENT HANSON CONSTRUCTION MATERIALS	PROJECT No.	12035	TOTAL DEPTH	17.5mBGL	DRILL DATE	7-Oct-20
PROJECT TWEED SAND PLANT EXPANSION	SURFACE RL	Not surveyed	DRILLED BY	PACIFIC GEOTECH	EASTING	552517.8462
LOCATION CUDGEN, NSW	DRILL METHOD	VIBROCORE	LOGGED BY	MTC	NORTHING	6873589.771



DEPTH (mBGL)	GROUNDWATER	GRAPHIC LOG	SOIL DESCRIPTION	ORIGIN
4.6				
4.8				
5				
5.2				
5.4				
5.6				
5.8				
6				
6.2				
6.4				
6.6				
6.8				
7			Grey (5Y 5/1) loamy sand ; very few, medium shell fragments and bark pieces; wet; change to;	Natural
7.2				
7.4				
7.6				
7.8				
8				
8.2				
8.4				
8.6				
8.8				
9				

BOREHOLE
AS23

CLIENT HANSON CONSTRUCTION MATERIALS	PROJECT No.	12035	TOTAL DEPTH	17.5mBGL	DRILL DATE	7-Oct-20
PROJECT TWEED SAND PLANT EXPANSION	SURFACE RL	Not surveyed	DRILLED BY	PACIFIC GEOTECH	EASTING	552517.8462
LOCATION CUDGEN, NSW	DRILL METHOD	VIBROCORE	LOGGED BY	MTC	NORTHING	6873589.771



DEPTH (mBGL)	GROUNDWATER	GRAPHIC LOG	SOIL DESCRIPTION	ORIGIN
9.2 9.4 9.6 9.8 10 10.2 10.4 10.6 10.8 11 11.2 11.4 11.6 11.8 12 12.2 12.4 12.6 12.8 13 13.2 13.4				

BOREHOLE

AS23

CLIENT HANSON CONSTRUCTION MATERIALS **PROJECT No.** 12035

TOTAL DEPTH 17.5mBGL

DRILL DATE 7-Oct-20

PROJECT	TWEED SAND PLANT EXPANSION	SURFACE RL	Not surveyed
----------------	----------------------------	-------------------	--------------

DRILLED BY PACIFIC GEOTECH **EASTING** 552517.8462

LOCATION CUDGEN, NSW

DRILL METHOD VIBROCORE

LOGGED BY MTC

NORTHING 6873589.771

+GILBERT SUTHERLAND

DEPTH (mBGL)	GROUNDWATER	GRAPHIC LOG	SOIL DESCRIPTION	ORIGIN
13.6				
13.8				
14				
14.2				
14.4				
14.6				
14.8				
15			Grey (5Y 5/1) loamy sand to sand ; no coarse fragments; wet; change to;	Natural
15.2				
15.4				
15.6				
15.8				
16			Dark grey (5Y 4/1) sandy loam ; no coarse fragments; wet; change to;	Natural
16.2				
16.4				
16.6				
16.8			Very dark greenish grey (10Y 3/1) sandy clay loam ; no coarse fragments; wet; change to;	Natural
17			Very dark greenish grey (10Y 3/1) clay loam, sandy ; no coarse fragments; wet; change to;	Natural
17.2				
17.4			Very dark grey (3/N) heavy clay ; no coarse fragments; wet; borehole terminated at 17.5mBGL.	Natural
17.6				
17.8				
18				

BOREHOLE

AS23

CLIENT HANSON CONSTRUCTION MATERIALS	PROJECT No.	12035	TOTAL DEPTH	17.5mBGL	DRILL DATE	7-Oct-20
PROJECT TWEED SAND PLANT EXPANSION	SURFACE RL	Not surveyed	DRILLED BY	PACIFIC GEOTECH	EASTING	552517.8462
LOCATION CUDGEN, NSW	DRILL METHOD	VIBROCORE	LOGGED BY	MTC	NORTHING	6873589.771



DEPTH (mBGL)	GROUNDWATER	GRAPHIC LOG	SOIL DESCRIPTION	ORIGIN
0			Black (10YR 2/1) light clay ; no coarse fragments; dry; change to;	Natural
0.2				
0.4				
0.6			Greyish brown (10YR 5/2) loamy sand with diffuse transitions to very few, fine sized, distinct, brownish yellow (10YR 6/8) mottles; no coarse fragments; moist; change to;	Natural
0.8	▼		Grey (2.5Y 5/1) clayey sand with diffuse transitions to very few, fine sized, distinct, brownish yellow (10YR 6/8) mottles; no coarse fragments; wet; change to;	Natural
1			NR.	Natural
1.2				
1.4				
1.6				
1.8				
2				
2.2			Very dark greenish grey (10Y 3/1) sandy loam ; no coarse fragments; wet; change to;	Natural
2.4				
2.6				
2.8				
3				
3.2				
3.4				
3.6				
3.8				
4			Dark greenish grey (10Y 4/1) loamy sand ; few, fine shell fragments from 5.6-5.9m; wet; change to;	Natural
4.2				
4.4				

BOREHOLE
AS25

CLIENT HANSON CONSTRUCTION MATERIALS	PROJECT No.	12035	TOTAL DEPTH	16mBGL	DRILL DATE	12-Oct-20
PROJECT TWEED SAND PLANT EXPANSION	SURFACE RL	Not surveyed	DRILLED BY	PACIFIC GEOTECH	EASTING	552762.4908
LOCATION CUDGEN, NSW	DRILL METHOD	VIBROCORE	LOGGED BY	MTC	NORTHING	6873536.198



DEPTH (mBGL)	GROUNDWATER	GRAPHIC LOG	SOIL DESCRIPTION	ORIGIN
4.6				
4.8				
5				
5.2				
5.4				
5.6				
5.8				
6			Grey (5Y 5/1) sand to loamy sand ; wet; change to;	Natural
6.2				
6.4				
6.6				
6.8				
7				
7.2				
7.4				
7.6				
7.8				
8				
8.2				
8.4				
8.6				
8.8				
9				

BOREHOLE
AS25

CLIENT HANSON CONSTRUCTION MATERIALS	PROJECT No.	12035	TOTAL DEPTH	16mBGL	DRILL DATE	12-Oct-20
PROJECT TWEED SAND PLANT EXPANSION	SURFACE RL	Not surveyed	DRILLED BY	PACIFIC GEOTECH	EASTING	552762.4908
LOCATION CUDGEN, NSW	DRILL METHOD	VIBROCORE	LOGGED BY	MTC	NORTHING	6873536.198



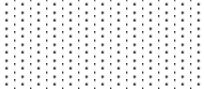
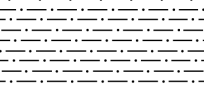
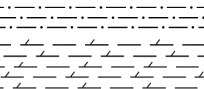
DEPTH (mBGL)	GROUNDWATER	GRAPHIC LOG	SOIL DESCRIPTION	ORIGIN
9.2			Dark greyish brown (10YR 4/2) clayey sand to sandy loam with diffuse transitions to very few, fine sized, distinct, black (10YR 2/1) mottles; no coarse fragments; wet; change to;	Natural
9.4				
9.6				
9.8				
10				
10.2				
10.4			Brown (10YR 5/3) loamy sand ; no coarse fragments; wet; change to;	Natural
10.6			Grey (2.5Y 6/1) sand to loamy sand ; no coarse fragments; wet; change to;	Natural
10.8			Brown (10YR 5/3) loamy sand ; no coarse fragments; wet; change to;	Natural
11				
11.2			Light olive grey (5Y 6/2) loamy sand to sand ; no coarse fragments; wet; change to;	Natural
11.4				
11.6				
11.8				
12				
12.2				
12.4				
12.6				
12.8			Olive yellow (2.5Y 6/6) loamy sand to sand ; no coarse fragments; wet; change to;	Natural
13				
13.2				
13.4			Light brownish grey (2.5Y 6/2) loamy sand to sand with diffuse transitions to common, medium sized, distinct, olive yellow (2.5Y 6/6) mottles; no coarse fragments; wet; change to;	Natural

BOREHOLE

AS25

CLIENT HANSON CONSTRUCTION MATERIALS	PROJECT No.	12035	TOTAL DEPTH	16mBGL	DRILL DATE	12-Oct-20
PROJECT TWEED SAND PLANT EXPANSION	SURFACE RL	Not surveyed	DRILLED BY	PACIFIC GEOTECH	EASTING	552762.4908
LOCATION CUDGEN, NSW	DRILL METHOD	VIBROCORE	LOGGED BY	MTC	NORTHING	6873536.198



DEPTH (mBGL)	GROUNDWATER	GRAPHIC LOG	SOIL DESCRIPTION	ORIGIN
13.6				
13.8				
14			Light grey (2.5Y 7/1) sand ; no coarse fragments; wet; change to;	Natural
14.2				
14.4			Brownish yellow (10YR 6/6) clayey sand ; no coarse fragments; wet; change to;	Natural
14.6				
14.8				
15				
15.2				
15.4			Dark greenish grey (10Y 4/1) silty clay loam ; no coarse fragments; wet; change to;	Natural
15.6				
15.8			Dark greenish grey (10Y 4/1) heavy clay ; no coarse fragments; wet; borehole terminated at 16mBGL.	Natural
16				
16.2				
16.4				
16.6				
16.8				
17				
17.2				
17.4				
17.6				
17.8				
18				

BOREHOLE

AS25

CLIENT HANSON CONSTRUCTION MATERIALS

PROJECT No. 12035

TOTAL DEPTH 16mBGL

DRILL DATE 12-Oct-20

PROJECT TWEED SAND PLANT EXPANSION

SURFACE RL Not surveyed

DRILLED BY PACIFIC GEOTECH

EASTING 552762.4908

LOCATION CUDGEN, NSW

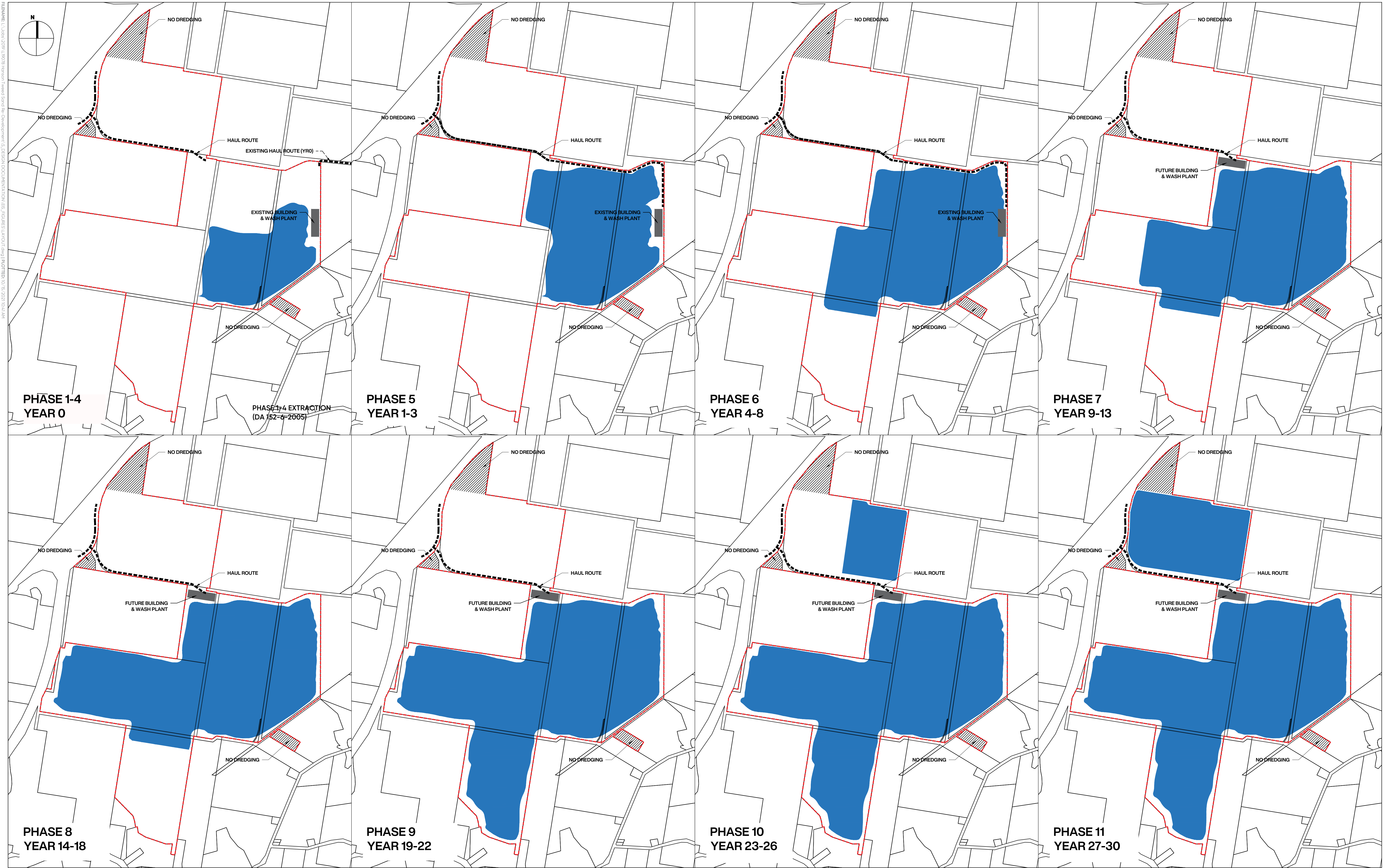
DRILL METHOD VIBROCORE

LOGGED BY MTC

NORTHING 6873536.198



11 Appendix 5 – Reference drawings



FILENAME: L:\Jobs\2019\119078 Hanson Tweed Sand Re-Development\5. DESIGN DOCUMENTATION\ES. FIGURES\Layout\Fig. PLOTTED: 10/15/2021 10:41 AM

PROJECT TITLE
HANSON TWEED SAND PLANT EXPANSION PHASE 5 TO PHASE 11
ENVIRONMENTAL IMPACT STATEMENT

DRAWING TITLE
FIGURE 19: EXTRACTION PHASES

REV	DESCRIPTION	DATE	DRAWN	DESIGN	CHECK	APPROVED
A	PHASING ARRANGEMENT CHANGES - REQ. PLANNER	25/01/2021	ZP	LN	LN	LN
B	PHASING ARRANGEMENT CHANGES - REQ. PLANNER	15/10/2021	MS	LN	LN	LN

ISSUE:	PRELIMINARY	CLIENT:	HANSON CONSTRUCTION MATERIALS PTY LTD
BASE PROVIDED BY:	SIXMAPS DCDB	MANAGER:	LANCE NEWLEY

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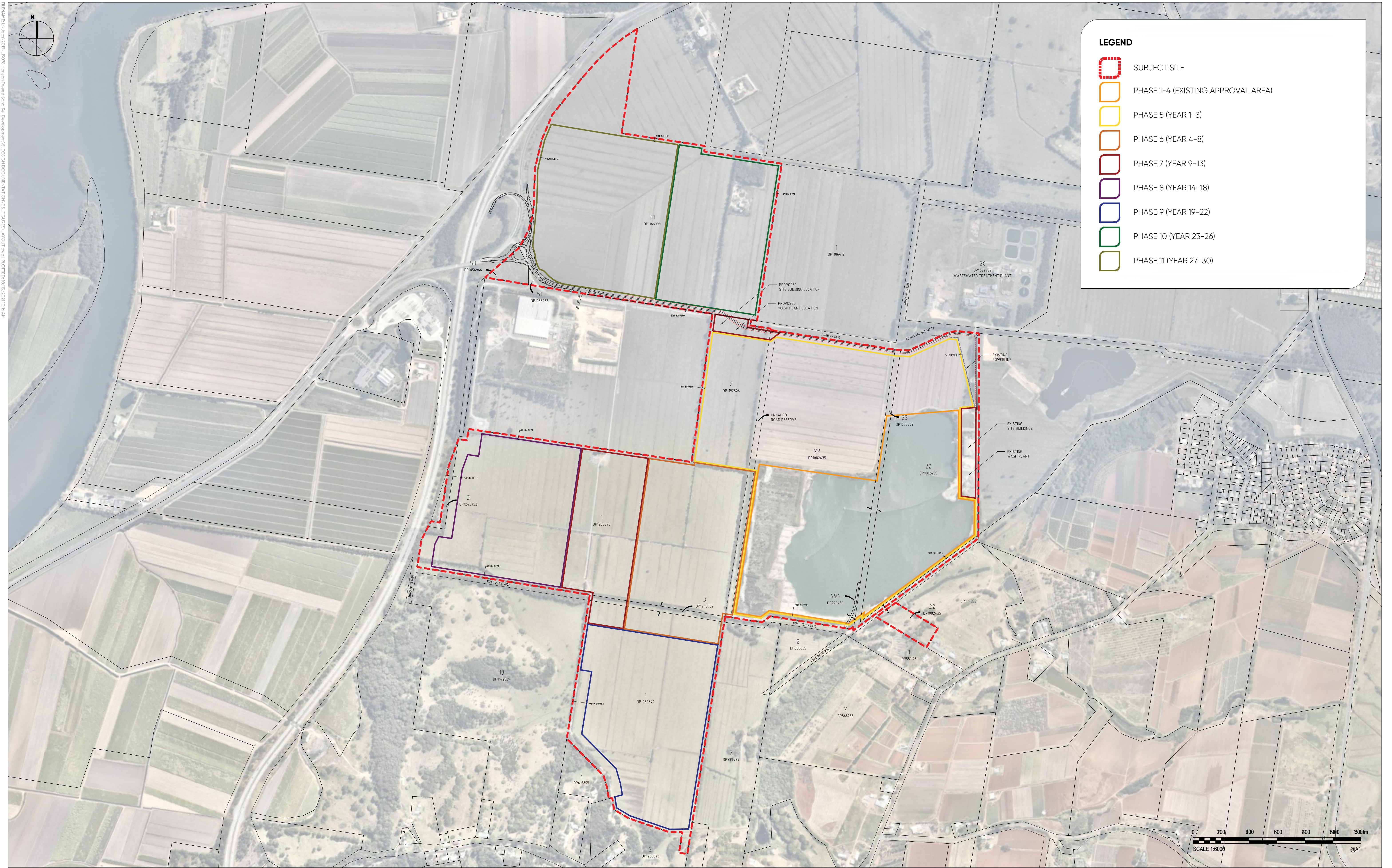
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JOB / DRAWING NO:

Z19163- F119

SHEET NO.

SHEET 17 OF 21



LEGEND

- SUBJECT SITE
- PHASE 1-4 (EXISTING APPROVAL AREA)
- PHASE 5 (YEAR 1-3)
- PHASE 6 (YEAR 4-8)
- PHASE 7 (YEAR 9-13)
- PHASE 8 (YEAR 14-18)
- PHASE 9 (YEAR 19-22)
- PHASE 10 (YEAR 23-26)
- PHASE 11 (YEAR 27-30)

PROJECT TITLE
HANSON TWEED SAND PLANT EXPANSION PHASE 5 TO PHASE 11
ENVIRONMENTAL IMPACT STATEMENT

DRAWING TITLE
FIGURE 20: SITE LAYOUT

REV	DESCRIPTION	DATE	DRAWN	DESIGN	CHECK	APPROVED
A	PRELIMINARY ISSUE	17/03/21	ZP	LN	LN	LN
B	PRELIMINARY ISSUE	15/10/21	MS	LN	LN	LN

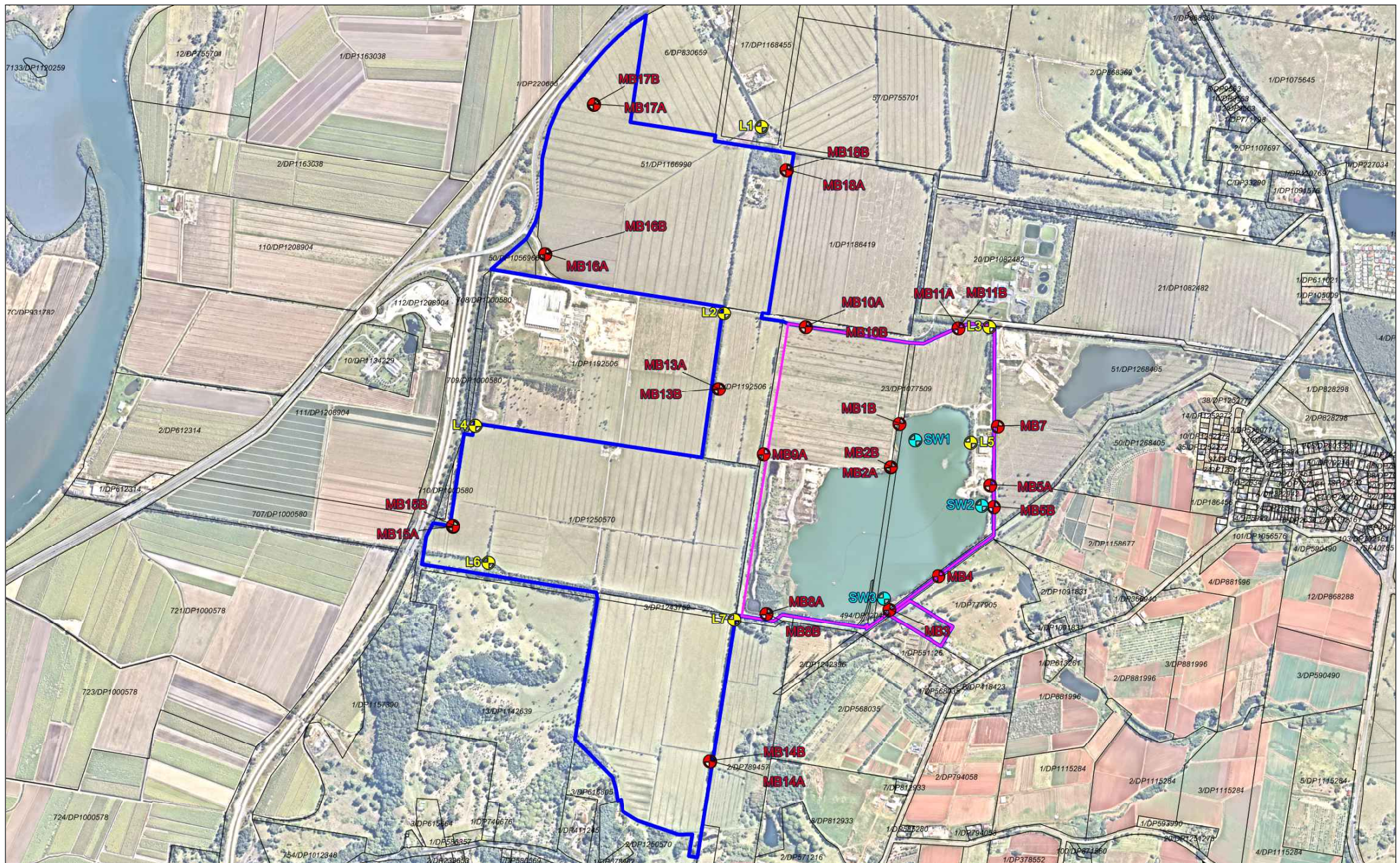
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Z19163- F120

SHEET NO.
SHEET 18 OF 21



ORIENTATION



ROBINA
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07 5578 9944
www.access.gs

LEGEND

- Cadastral boundaries
- Site Boundary - Existing
- Site boundary - Expansion Area
- Groundwater monitoring bores
- Surface water monitoring locations
- Surface water loggers

SOURCES

Image: Nearmap image dated 14 September 2020.
Cadastral: NSW Six Maps, sourced 23/11/2020.

PROJECT

TWEED SAND
PLANT
EXPANSION

SCALE
1:12 500@A3

DATE
19/01/2021

CLIENT

HANSON
CONSTRUCTION
MATERIALS

DRAWN
AJF

CHECKED
CMA

DRAWING

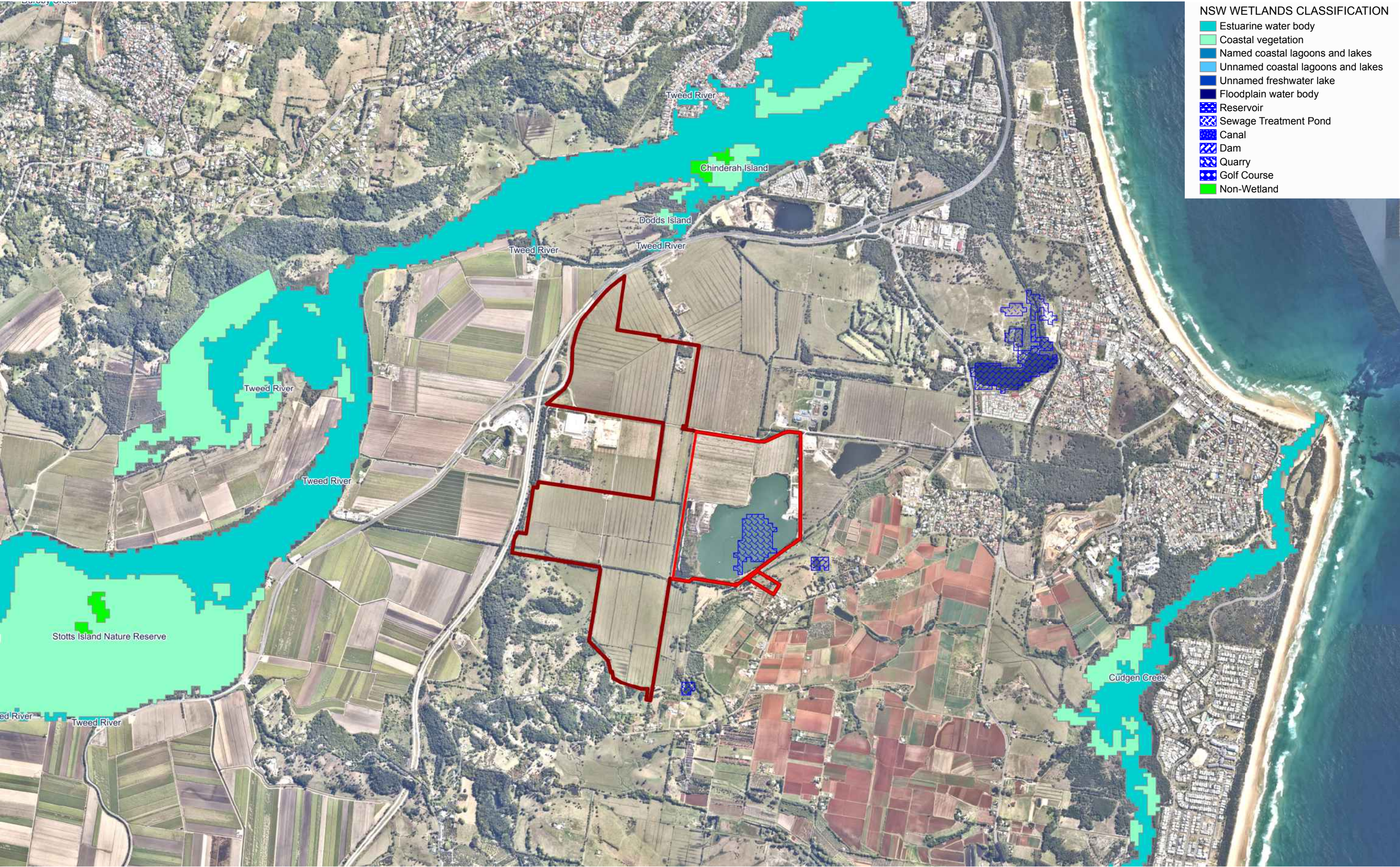
MONITORING
LOCATIONS

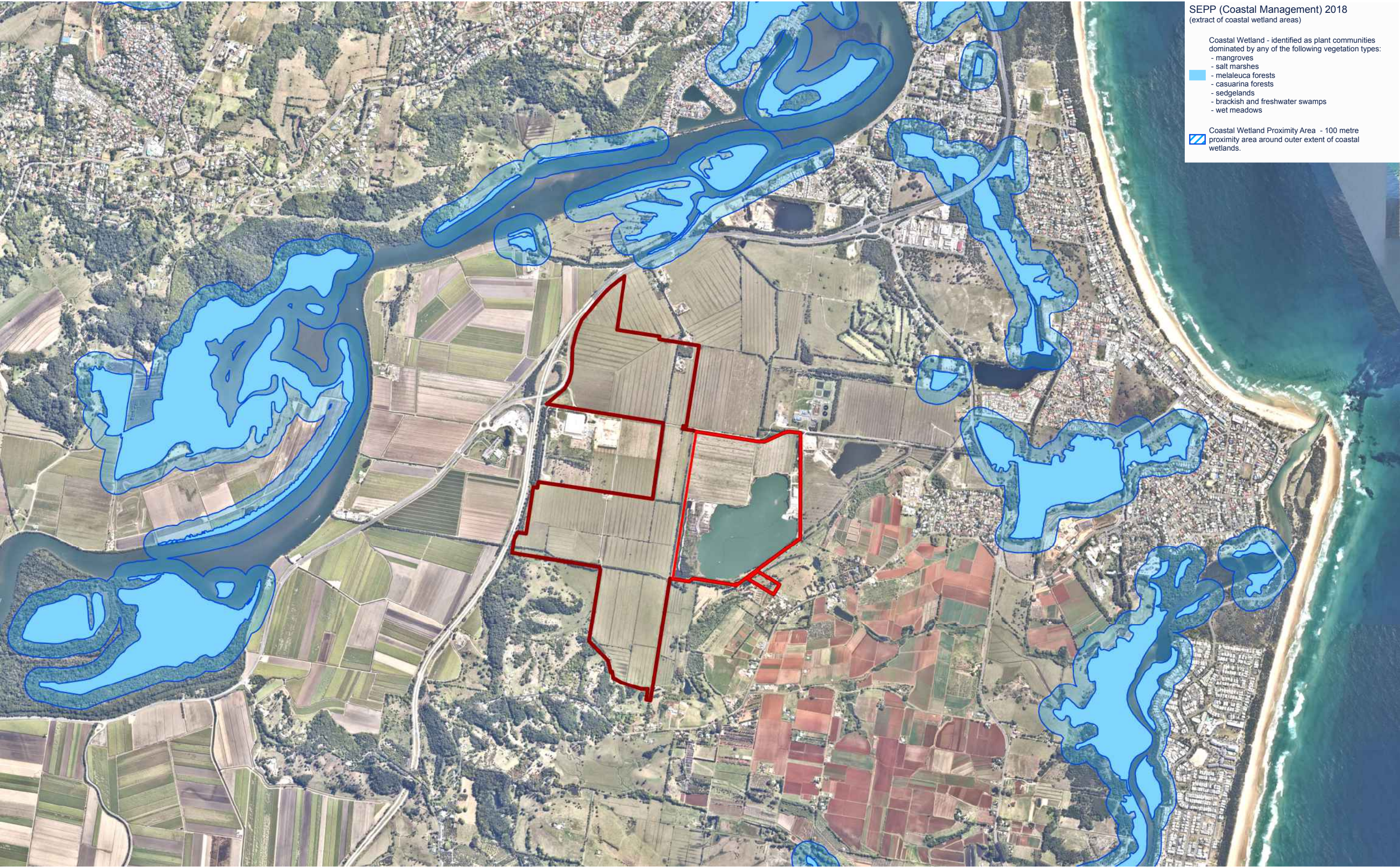
PROJECT
12035

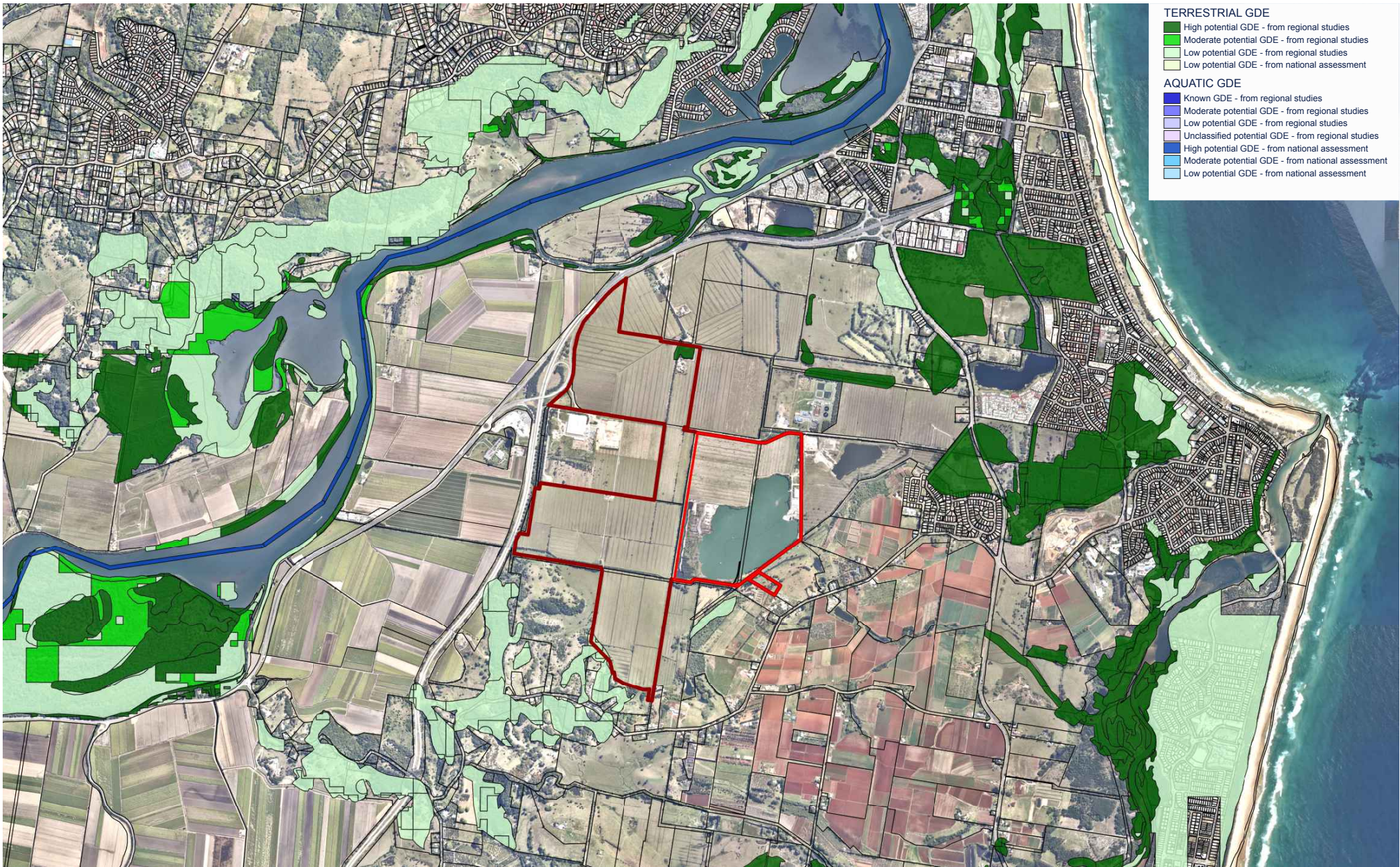
DRAWING
003

REVISION
-

**+GILBERT
SUTHERLAND**







ORIENTATION

SCALE

250 500 750 1000 1250 metres

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www.access.gs

LEGEND

- Cadastral boundaries
- Site Boundary - Existing
- Site Boundary - Expansion Area

SOURCES

Image: Nearmap Image dated 14 September 2020.

Cadastral: NSW Six Maps, sourced 23 November 2020.

GDE: Groundwater Dependent Ecosystem Atlas, Bureau of Meteorology

PROJECT

TWEED SAND PLANT EXPANSION

CLIENT

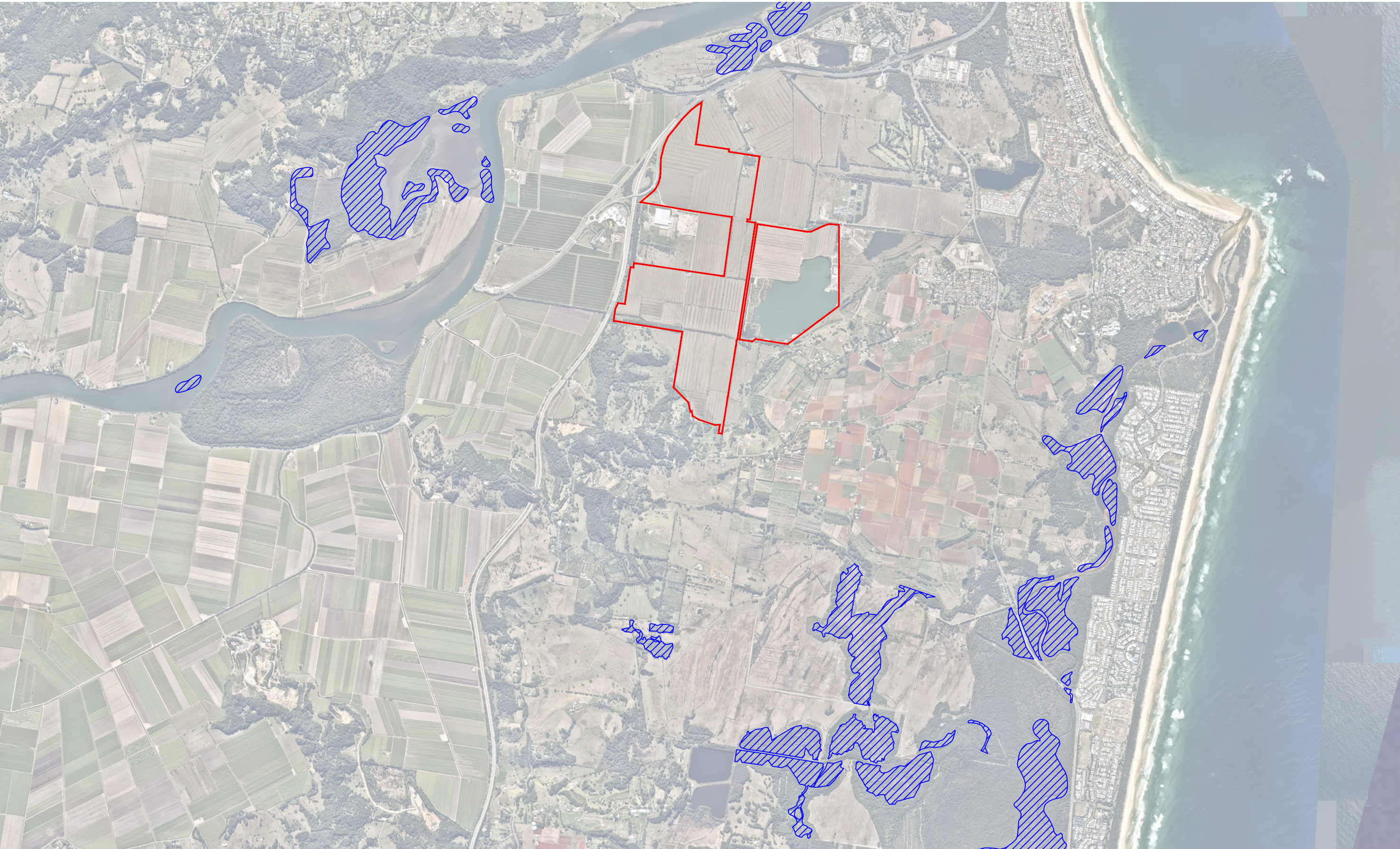
HANSON CONSTRUCTION MATERIALS

DRAWING

GROUNDWATER DEPENDENT ECOSYSTEMS

SCALE 1:25 000@A3 **DATE** 19/01/2021 **DRAWN** AJF **CHECKED** ELH **PROJECT** 12035 **DRAWING** 103 **REVISION** -

+GILBERT SUTHERLAND



ORIENTATION

SCALE 1:32000

400 800 1200 1600 metres

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LEGEND

Site Boundary

'High Priority' Groundwater Dependent Ecosystems

SOURCES

Image: Nearmap 2020. Image date: 5/08/2021

GDE's: Water Sharing Plan for the North Coast Coastal Sands Groundwater Sources 2016

PROJECT

TWEED SAND PLANT EXPANSION

CLIENT

HANSON CONSTRUCTION MATERIALS

DRAWING

'HIGH PRIORITY' GROUNDWATER DEPENDENT ECOSYSTEMS

SCALE	DATE	DRAWN	CHECKED	PROJECT	DRAWING	REVISION
1:32 000@A3	22/09/2021	SWP	ELH	12035	104	-



12 Appendix 6 – Potentiometric surface drawings (m AHD)



ORIENTATION

SCALE

0

125

250

375

500

625

metres

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- LEGEND
- Groundwater bores

Groundwater flow direction

Groundwater level major contour (0.1 m interval) (mAHd)

Groundwater level minor contour (0.025 m interval) (mAHd)

SOURCES

Image: Nearmap image dated 1 June 2020.

PROJECT

TWEED SAND PLANT
EXPANSION

CLIENT

HANSON
CONSTRUCTION
MATERIALS PTY LTD

DRAWING

GROUNDWATER CONTOURS & FLOW
DIRECTIONS 6 MAY 2020

SCALE

1:12,500 @A3

DATE

3/12/2020

DRAWN

AJF

CHECKED

ELH

PROJECT

12035

DRAWING

502

REVISION

-

GILBERT
SUTHERLAND



ORIENTATION

SCALE

0

125

250

375

500

625

metres

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07 5578 9944

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LEGEND

Groundwater bores

Groundwater flow direction

Groundwater level major contour (0.1 m interval) (mAHD)

Groundwater level minor contour (0.025 m interval) (mAHD)

SOURCES

Image: Nearmap image dated 1 June 2020.

PROJECT

TWEED SAND PLANT
EXPANSION

CLIENT

HANSON
CONSTRUCTION
MATERIALS PTY LTD

DRAWING

GROUNDWATER CONTOURS & FLOW
DIRECTIONS 17 JUNE 2020

SCALE

1:12,500 @A3

DATE

3/12/2020

DRAWN

AJF

CHECKED

ELH

PROJECT

12035

DRAWING

503

REVISION





ORIENTATION

SCALE

0

125

250

375

500

625

metres

ROBINA

P O Box 4115 Robina QLD4230

07 5578 9944

Email robina@access.gs

www.access.gs

LEGEND

Groundwater bores

Groundwater flow direction

Groundwater level major contour (0.1 m interval) (mAHd)

Groundwater level minor contour (0.025 m interval) (mAHd)

SOURCES

Image: Nearmap image dated 1 June 2020.

PROJECT

TWEED SAND PLANT
EXPANSION

CLIENT

HANSON
CONSTRUCTION
MATERIALS PTY LTD

DRAWING

GROUNDWATER CONTOURS & FLOW
DIRECTIONS 16 JULY 2020

SCALE

1:12,500 @A3

DATE

3/12/2020

DRAWN

AJF

CHECKED

ELH

PROJECT

12035

DRAWING

504

REVISION





ORIENTATION
▲

SCALE
0 125 250 375 500 625 metres

ROBINA
PO Box 4115 Robina QLD4230 07 5578 9944
Email robina@access.gs www.access.gs

- LEGEND**
- Groundwater bores
 - Groundwater flow direction
 - Groundwater level major contour (0.1 m interval) (mAHD)
 - Groundwater level minor contour (0.025 m interval) (mAHD)

SOURCES
Image: Nearmap image dated 1 June 2020.

PROJECT
TWEED SAND PLANT
EXPANSION

CLIENT
HANSON
CONSTRUCTION
MATERIALS PTY LTD

DRAWING
GROUNDWATER CONTOURS & FLOW
DIRECTIONS 11 AUGUST 2020

SCALE
1:12,500 @A3

DATE
3/12/2020

DRAWN
AJF

CHECKED
ELH

PROJECT
12035

DRAWING
505

REVISION
-

**+GILBERT
SUTHERLAND**



ORIENTATION

SCALE

0

125

250

375

500

625

metres

ROBINA

P O Box 4115 Robina QLD4230

07 5578 9944

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www.access.gs

LEGEND

Groundwater bores

Groundwater flow direction

Groundwater level major contour (0.1 m interval) (mAHD)

Groundwater level minor contour (0.025 m interval) (mAHD)

SOURCES

Image: Nearmap image dated 1 June 2020.

PROJECT

TWEED SAND PLANT
EXPANSION

CLIENT

HANSON
CONSTRUCTION
MATERIALS PTY LTD

DRAWING

GROUNDWATER CONTOURS & FLOW
DIRECTIONS 26 AUGUST 2020

SCALE

1:12,500 @A3

DATE

3/12/2020

DRAWN

AJF

CHECKED

ELH

PROJECT

12035

DRAWING

506

REVISION





ORIENTATION

SCALE

0

125

250

375

500

625

metres

ROBINA

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07 5578 9944

Email robina@access.gs

www.access.gs

- LEGEND
- Groundwater bores

Groundwater flow direction

Groundwater level major contour (0.1 m interval) (mAHD)

Groundwater level minor contour (0.025 m interval) (mAHD)

SOURCES

Image: Nearmap image dated 1 June 2020.

PROJECT

TWEED SAND PLANT
EXPANSION

CLIENT

HANSON
CONSTRUCTION
MATERIALS PTY LTD

DRAWING

GROUNDWATER CONTOURS & FLOW
DIRECTIONS 9 SEPTEMBER 2020

SCALE

1:12,500 @A3

DATE

3/12/2020

DRAWN

AJF

CHECKED

ELH

PROJECT

12035

DRAWING

507

REVISION

-





ORIENTATION

SCALE

0

125

250

375

500

625

metres

ROBINA

P O Box 4115 Robina QLD4230

07 5578 9944

Email robina@access.gs

www.access.gs

LEGEND

Groundwater bores

Groundwater flow direction

Groundwater level major contour (0.1 m interval) (mAHd)

Groundwater level minor contour (0.025 m interval) (mAHd)

SOURCES

Image: Nearmap image dated 1 June 2020.

PROJECT

TWEED SAND PLANT
EXPANSION

CLIENT

HANSON
CONSTRUCTION
MATERIALS PTY LTD

DRAWING

GROUNDWATER CONTOURS & FLOW
DIRECTIONS 22 SEPTEMBER 2020

SCALE

1:12,500 @A3

DATE

3/12/2020

DRAWN

AJF

CHECKED

ELH

PROJECT

12035

DRAWING

508

REVISION





ORIENTATION

SCALE

0125250375500625

metres

ROBINA

P O Box 4115 Robina QLD4230
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07 5578 9944
www.access.gs

- LEGEND
- Groundwater bores

Groundwater flow direction

Groundwater level major contour (0.1 m interval) (mAHD)

Groundwater level minor contour (0.025 m interval) (mAHD)

SOURCES

Image: Nearmap image dated 1 June 2020.

PROJECT

TWEED SAND PLANT
EXPANSION

CLIENT

HANSON
CONSTRUCTION
MATERIALS PTY LTD

DRAWING

GROUNDWATER CONTOURS & FLOW
DIRECTIONS 7 OCTOBER 2020

SCALE

1:12,500 @A3

DATE

3/12/2020

DRAWN

AJF

CHECKED

ELH

PROJECT

12035

DRAWING

509

REVISION



13 Appendix 7 – Recharge

13.1 Recharge determination via Cook's Method

Cook's Method¹⁴ is based on the chloride balance between the rainfall and the groundwater. The proportion of groundwater recharge in excess of the landscape environmental requirements is reflected by the ratio between the rainfall chloride concentration and the ground water chloride concentration. The general formula is:

$$G = (P \cdot C_p) - (R \cdot C_p) \quad C_g$$

Where:

G = ground water recharge (mm)

P = precipitation (mm)

R = run-off (mm)

C_p = Chloride conc. of rainfall (mg L⁻¹)

C_g = Chloride conc. of groundwater (mg L⁻¹)

Within the site, spatial variability of the Chloride concentrations may have impact on the distribution of recharge on the site (Cook 1989 and de Silva 2004).

The associations between the Chloride concentration of the groundwater was assessed by paired comparisons of the bore data using Mann-Whiney U-test¹⁵ for small sample populations. The degree of association between the bore data was identified and the recharge calculated separately for each spatial association.

The estimate of rainfall Cl⁻ concentration was determined from three sources. First was data from sampling of a rainfall event at Robina. The sample site was within 5km of the ocean and 25km from the site. The rain was collected and sent to a laboratory for analysis of major anions and cations.

The second estimate was based on the work by Biggs 2004¹⁶ who measured the chloride concentrations in rainfall at various locations throughout southern Queensland. Biggs developed a mathematical description based on a Power function ($y = ax^b$) of the relationship between rainfall chloride load and distance from the sea. Whilst noting that these types of equations are extremely unreliable, a quadratic equation¹⁷ was developed to describe expected rainfall Cl⁻ concentration using the inputs of mean data from Biggs work and distance from the sea. The intercept of this equation was 5.28 mg Cl⁻ L⁻¹ (95% confidence interval + 0.95 mg Cl⁻ L⁻¹).

Although the derivation of the quadratic mathematical description from this data set was not the intent of the original researcher, in the absence of any other data it is reasonable to use this information to inform the estimate of the expected rainfall Chloride concentration.

The final source of the rainfall Chloride concentration estimate was derived from laboratory analysis of water quality from a freshwater spear pump bore in the frontal dune at Burleigh Heads, Queensland.

The water analysis indicated the Cl⁻ concentration of the freshwater lens (above the salt water table) was 7.1 mg Cl⁻ L⁻¹. The only source of recharge is rainfall and this chloride concentration suggests that the rainfall concentration is some number less than 7.1.

¹⁴ Cook P. G., Walker, G. R. and Jolly, I. D., (1989). Spatial Variability of Groundwater Recharge in a Semi-Arid Region. *Journal of Hydrology*, 111: 195-212, de Silva R.P. 2004 Spatial Variability of Groundwater Recharge - I. Is it really variable? *Journal of Spatial Hydrology* Vol.4, No.1 Fall 2004.

¹⁵ Runyon R.P. and Haber A 1984 Fundamentals of behavioural statistics. Newbery Awards Records, inc. New York USA. pp376-380 Table I4 page 434.

¹⁶ Biggs A.J.W. 2004 Rainfall salt loads in southern Queensland, Australia Proceedings ISCO 2004 - 13th International Soil Conservation Organisation Conference – Brisbane, July 2004. Conserving Soil and Water for Society: Sharing Solutions Paper No. 680.

¹⁷ $Y = 2 \times 10^{-5} \cdot X^2 - 0.0171X + 5.28$ ($R^2 = 0.5666$, standard error of the estimate = 0.8) where Y = expected rainfall Cl⁻ concentration mg L⁻¹ and X = distance from mean high water in kilometres.

Based on these data the boundaries for analysis of potential recharge may be derived, in this case¹⁸ 3.01 to 6.0mg Cl⁻ L⁻¹.

The run-off component of the recharge estimate equation was estimated at 0.1 based on the runoff yield estimates by Nelson (2000)¹⁹ and Burton and Freitz (1969).²⁰

¹⁸ This upper value corresponds to the estimate using Briggs data for a site 3 km from the sea (5.2) plus the standard error of 0.8 to give a maximum of 6.0 mg Cl⁻ L⁻¹.

¹⁹ Nelson, K.D., 1985, *Design and Construction of Small Earth Dams*, Inkata Press, Melb, Vic, pp8-10.

²⁰ Burton, John R and Fietz, T. R. 1969 Water storage on the farm : a manual of design, construction and operation for Australian conditions. Bulletin (Water Research Foundation of Australia), no.9, Table 7.2.

13.2 Cumulative rainfall departure graphs

Figure 1 - SWL of Shallow Bores vs. Cumulative Rainfall Departure

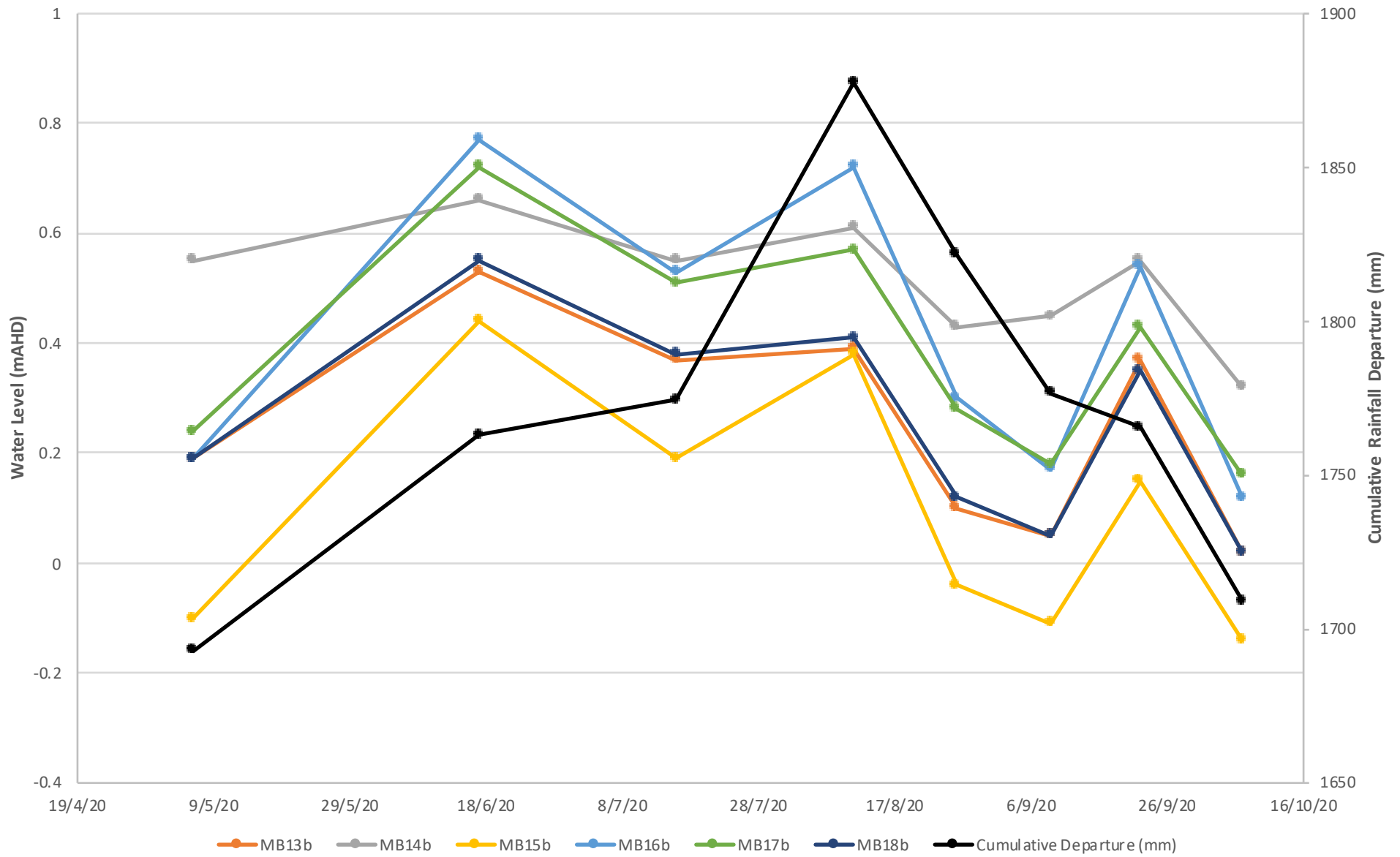


Figure 2 - SWL of Deep Bores vs. Cumulative Rainfall Departure

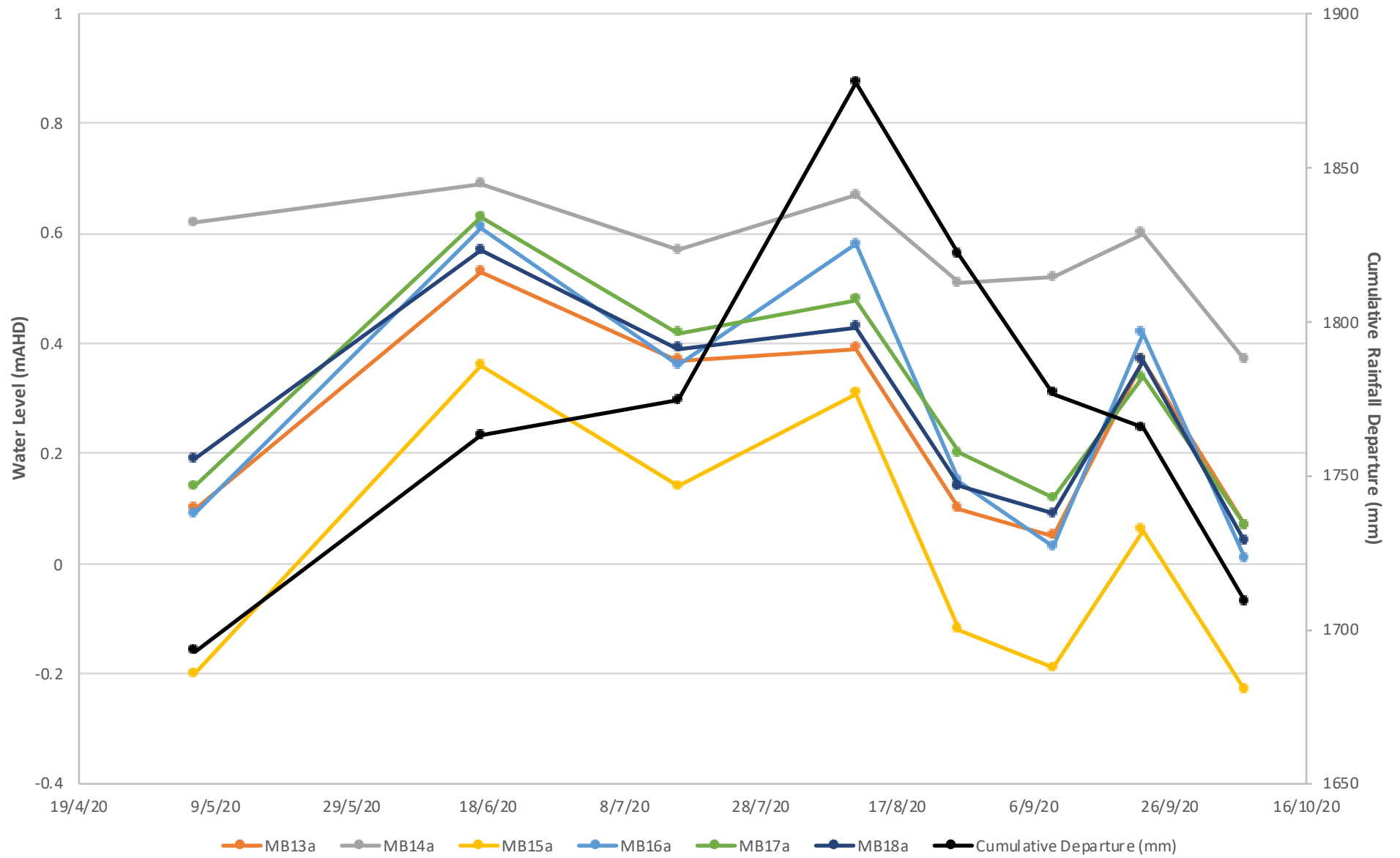
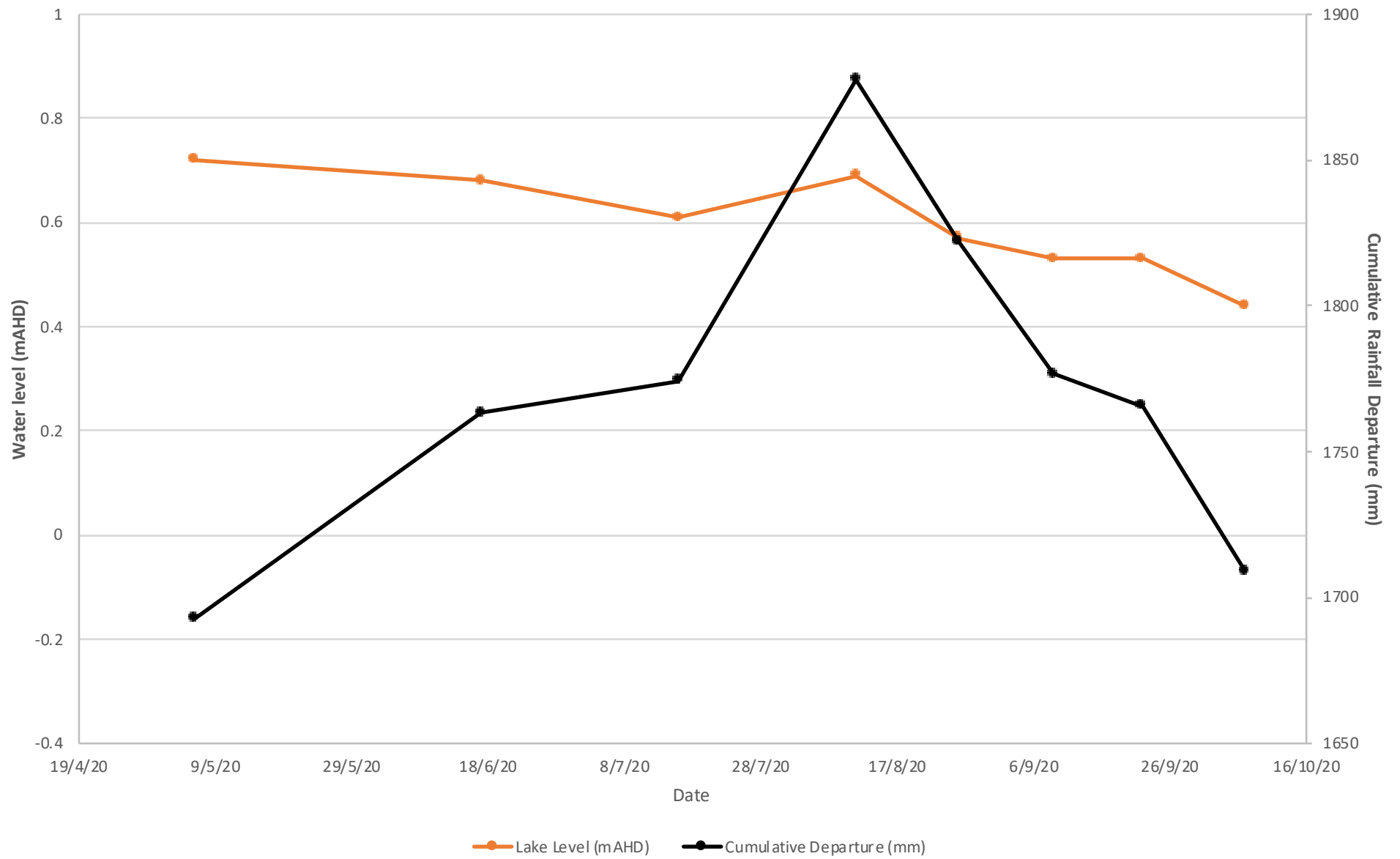
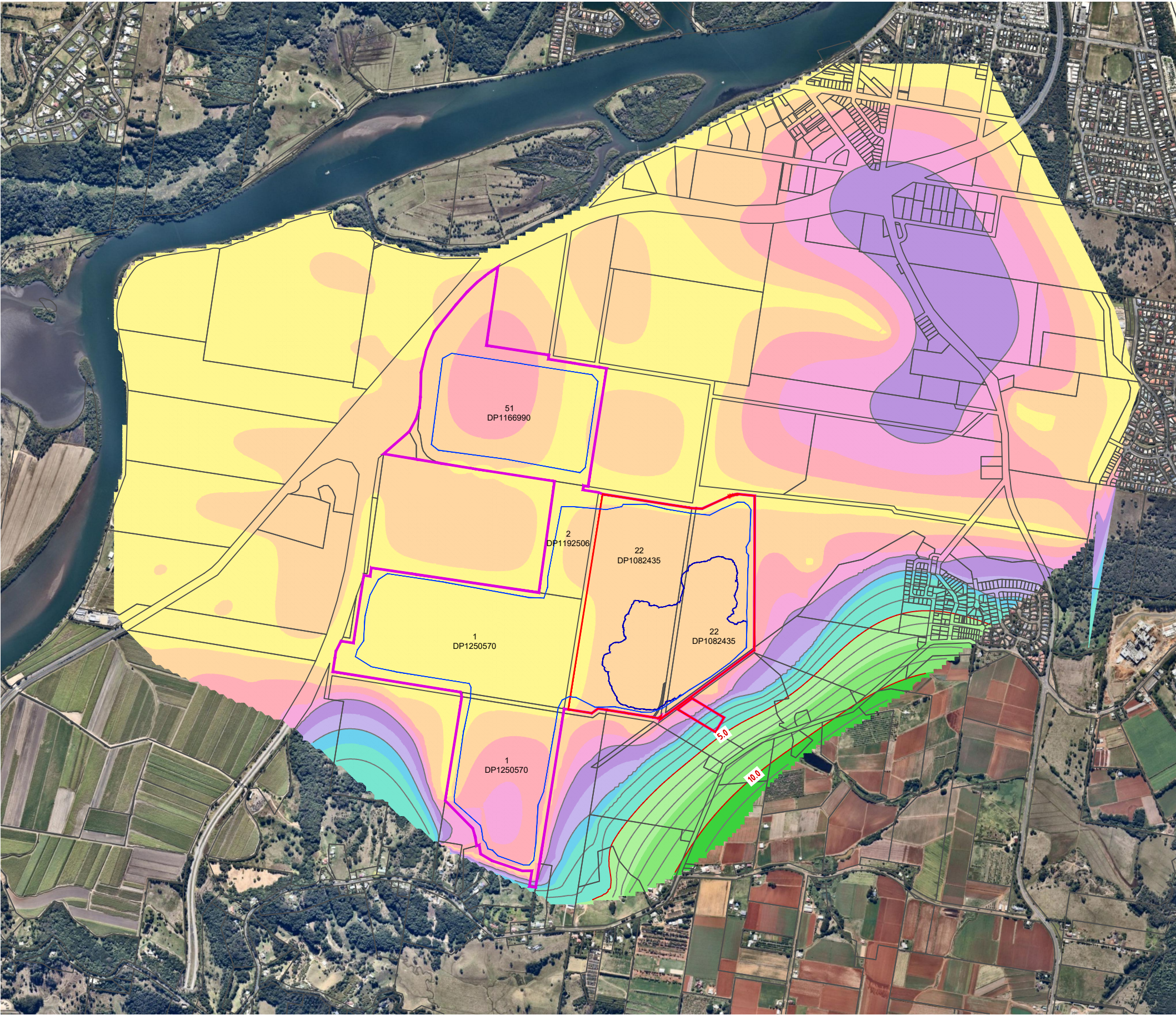


Figure 3 - Lake Levels vs CRD



14 Appendix 8 – Groundwater modelling results



Groundwater elevation		
Minimum Elevation (mAHD)	Maximum Elevation (mAHD)	Color
-1.000	0.000	
0.000	0.250	
0.250	0.500	
0.500	0.750	
0.750	1.000	
1.000	1.500	
1.500	2.000	
2.000	2.500	
2.500	5.000	
5.000	7.500	
7.500	10.000	
10.000	24.500	



ORIENTATION

SCALE

200 400 600 800 1000 metres

ROBINA

PO Box 4115 Robina QLD4230 07 5578 9944
Email robina@access.gs www.access.gs

LEGEND

Cadastral boundaries

Site boundary - Existing

Site boundary - Expansion area

Lake boundary - Existing

Lake boundary - Ultimate expansion area

SOURCES

Image: Nearmap image dated 5 August 2021.
Cadastral: NSW Six Maps, sourced 23 November 2020.

PROJECT

TWEED SAND PLANT EXPANSION

CLIENT

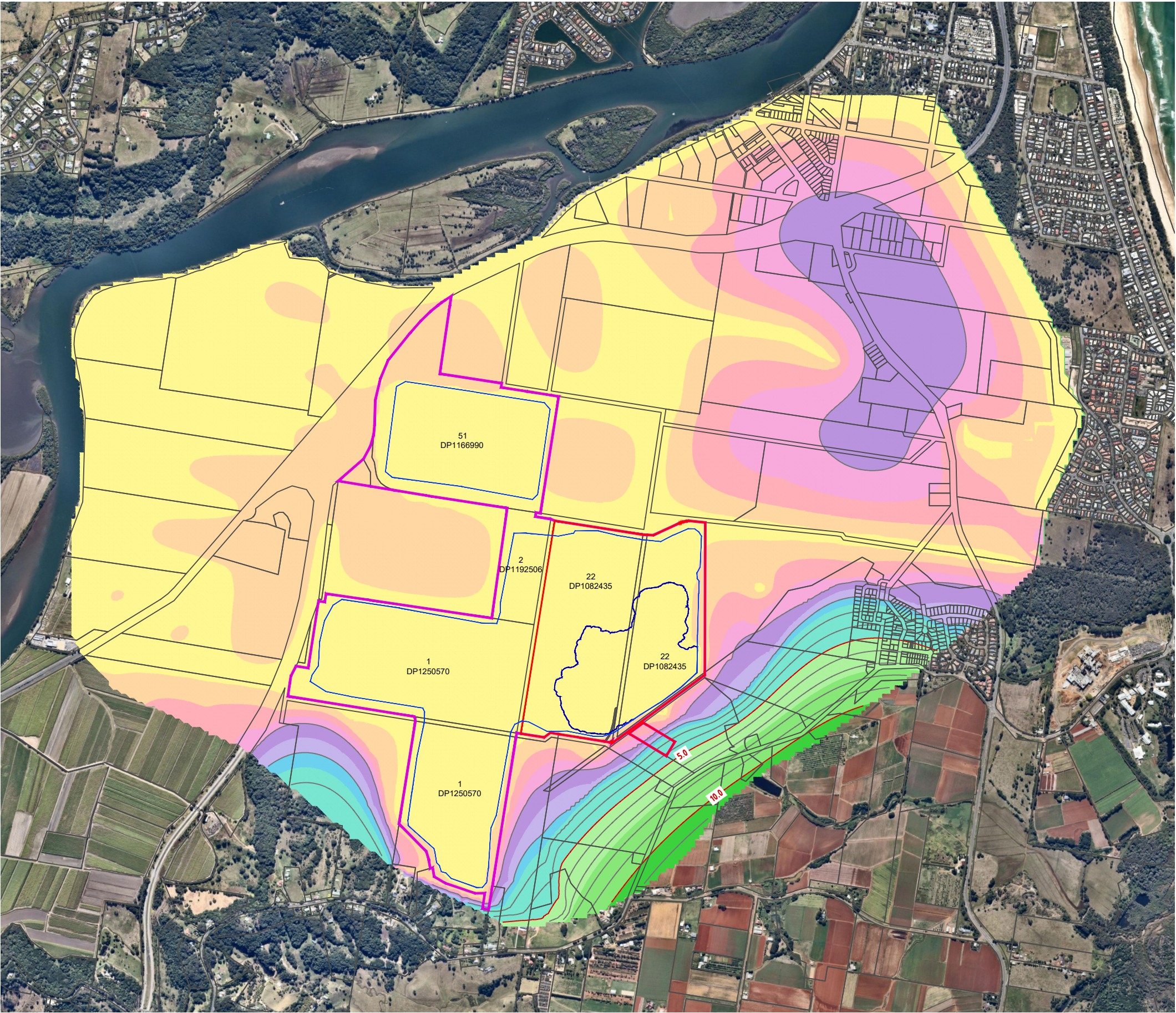
HANSON CONSTRUCTION MATERIALS

DRAWING

MODELLED EXISTING GROUNDWATER CONDITIONS

SCALE	DATE	DRAWN	CHECKED	PROJECT	DRAWING	REVISION
1:20 000@A3	27/09/2021	AJF/SWP	ELH	12035	SUPP_GWM_003	-





Groundwater elevation		
Minimum Elevation (mAHD)	Maximum Elevation (mAHD)	Color
-1.000	0.000	
0.000	0.250	
0.250	0.500	
0.500	0.750	
0.750	1.000	
1.000	1.500	
1.500	2.000	
2.000	2.500	
2.500	5.000	
5.000	7.500	
7.500	10.000	
10.000	24.500	



ORIENTATION

SCALE

200 400 600 800 1000 metres

ROBINA

PO Box 4115 Robina QLD4230 07 5578 9944
Email robina@access.gs www.access.gs

LEGEND

Cadastral boundaries

Site boundary - Existing

Site boundary - Expansion area

Lake boundary - Existing

Lake boundary - Ultimate expansion area

SOURCES

Image: Nearmap image dated 5 August 2021.
Cadastral: NSW Six Maps, sourced 23 November 2020.

PROJECT

TWEED SAND PLANT EXPANSION

CLIENT

HANSON CONSTRUCTION MATERIALS

SCALE

1:20 000@A3

DATE

27/09/2021

DRAWN

AJF/SWP

CHECKED

ELH

DRAWING

MODELLED POST EXTRACTION GROUNDWATER CONDITIONS TWEED SAND PLANT ONLY

PROJECT

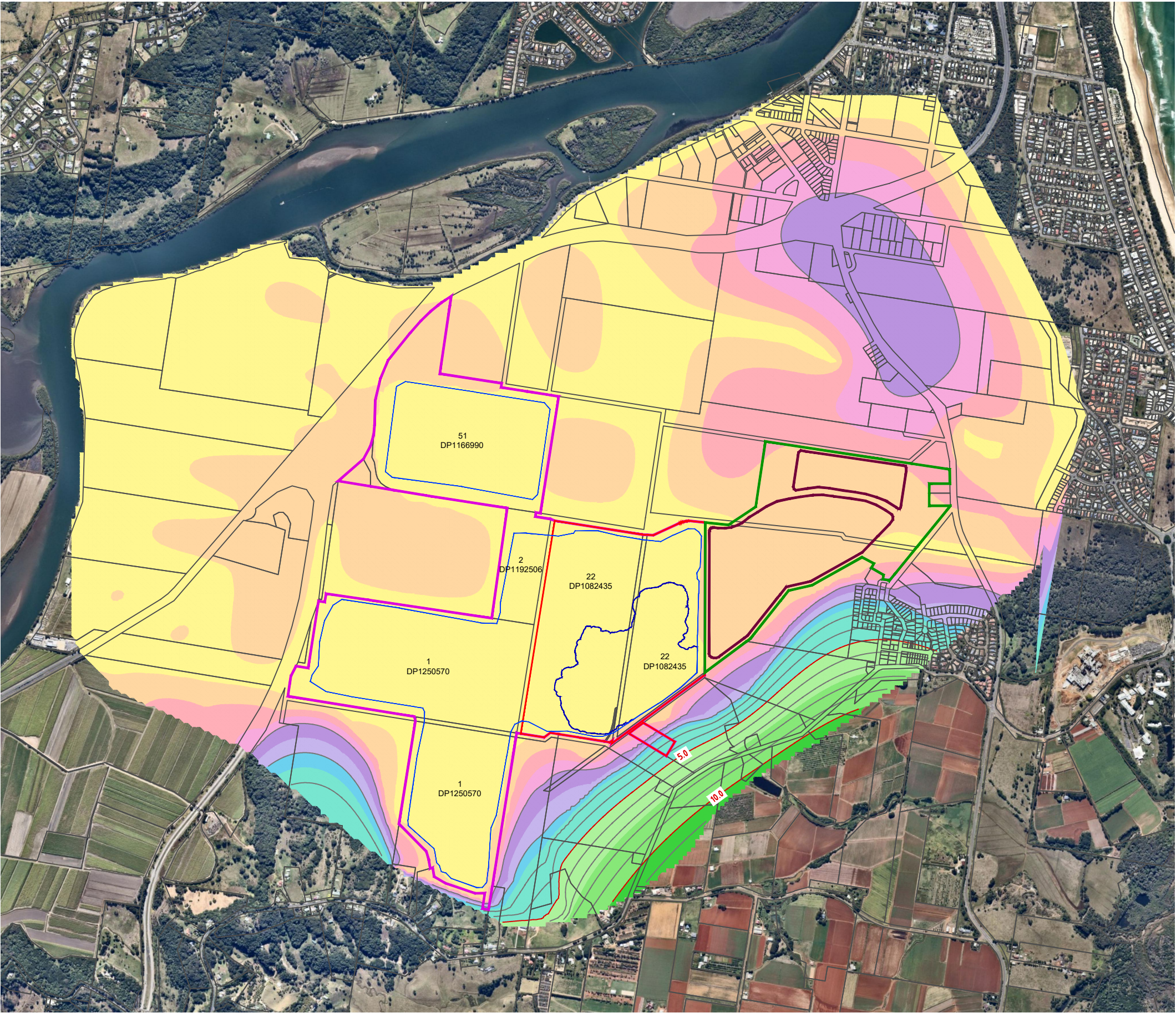
12035

DRAWING

SUPP_GWM_004

REVISION





Groundwater elevation		
Minimum Elevation (mAHD)	Maximum Elevation (mAHD)	Color
-1.000	0.000	
0.000	0.250	
0.250	0.500	
0.500	0.750	
0.750	1.000	
1.000	1.500	
1.500	2.000	
2.000	2.500	
2.500	5.000	
5.000	7.500	
7.500	10.000	
10.000	24.500	



ORIENTATION

SCALE

200 400 600 800 1000 metres

ROBINA

PO Box 4115 Robina QLD4230 07 5578 9944
Email robina@access.gs www.access.gs

LEGEND

Cadastral boundaries

Site boundary - Existing

Site boundary - Expansion area

Lake boundary - Existing

Lake boundary - Ultimate expansion area

Cudgen Lake Boundary

Cudgen Lake Sand Extraction Project Boundary

SOURCES

Image: Nearmap image dated 5 August 2021.
Cadastral: NSW Six Maps, sourced 23 November 2020.

PROJECT

TWEED SAND PLANT EXPANSION

CLIENT

HANSON CONSTRUCTION MATERIALS

SCALE

1:20 000@A3

DATE

27/09/2021

DRAWN

AJF/SWP

CHECKED

ELH

DRAWING

MODELLED CUMULATIVE POST EXTRACTION GROUNDWATER TSP EXPANSION AND CUDGEN LAKES CONDITIONS

PROJECT

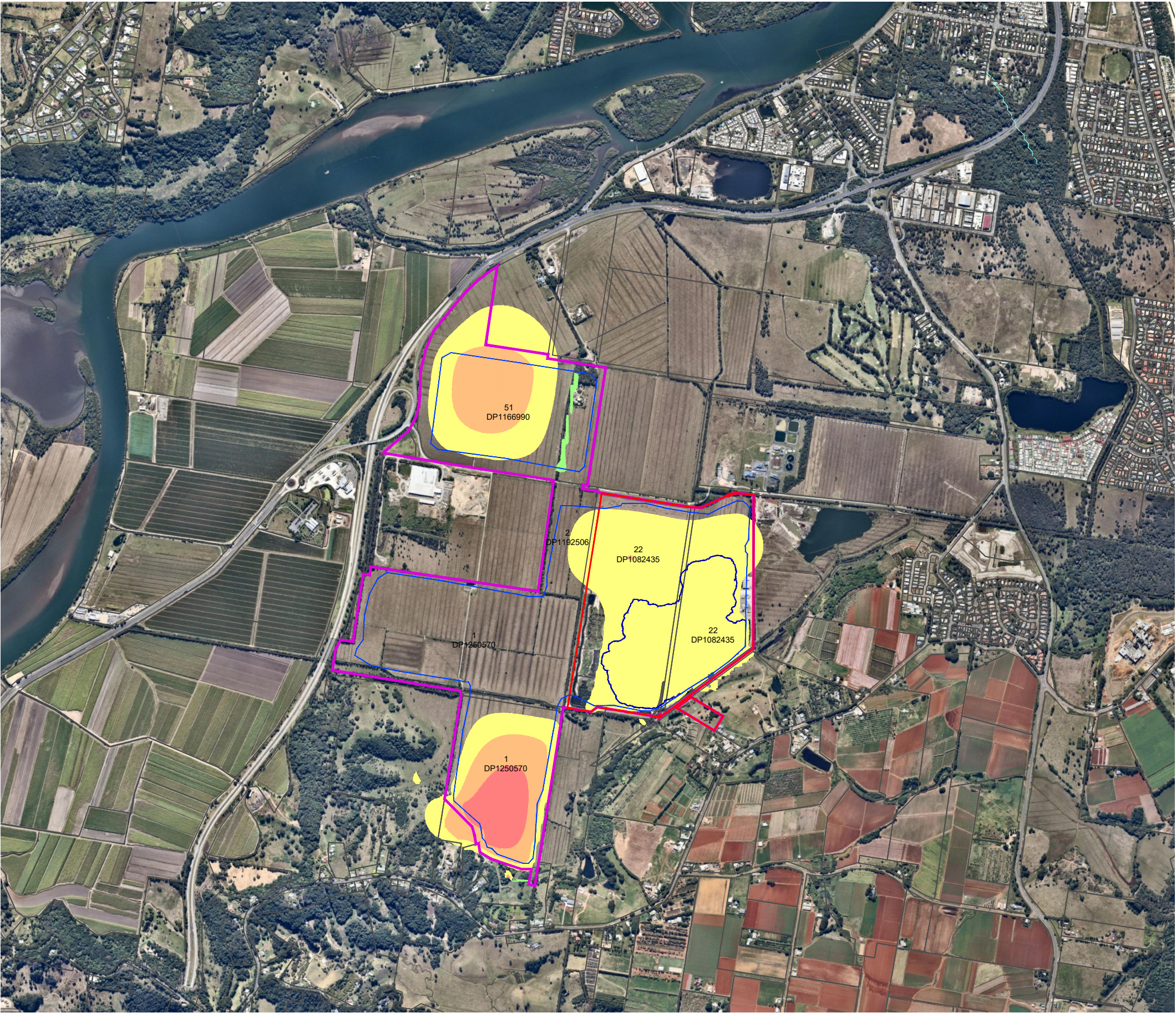
12035

DRAWING

SUPP_GWM_005-

REVISION





Change in groundwater elevation		
Minimum change (m)	Maximum change (m)	Color
-0.500	-1.000	
-0.300	-0.500	
-0.100	-0.300	
0.100	0.500	
0.500	1.000	


ORIENTATION

SCALE

200

400

600

800

1000

metres

ROBINA

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Email robina@access.gs

07 5578 9944
www.access.gs

LEGEND

Cadastral boundaries

Site boundary - Existing

Site boundary - Expansion area

Lake boundary - Existing

Lake boundary - Ultimate expansion area

SOURCES

Image: Nearmap image dated 5 August 2021.

Cadastral: NSW Six Maps, sourced 23 November 2020.

PROJECT

TWEED SAND PLANT EXPANSION

CLIENT

HANSON CONSTRUCTION MATERIALS

DRAWING

CHANGE IN MODELLED GROUNDWATER CONDITIONS ELEVATION (EXISTING TO DEVELOPED SITE) TWEED SAND PLANT ONLY

SCALE

1:20 000@A3

DATE

30/09/2021

DRAWN

AJF/SWP

CHECKED

ELH

PROJECT

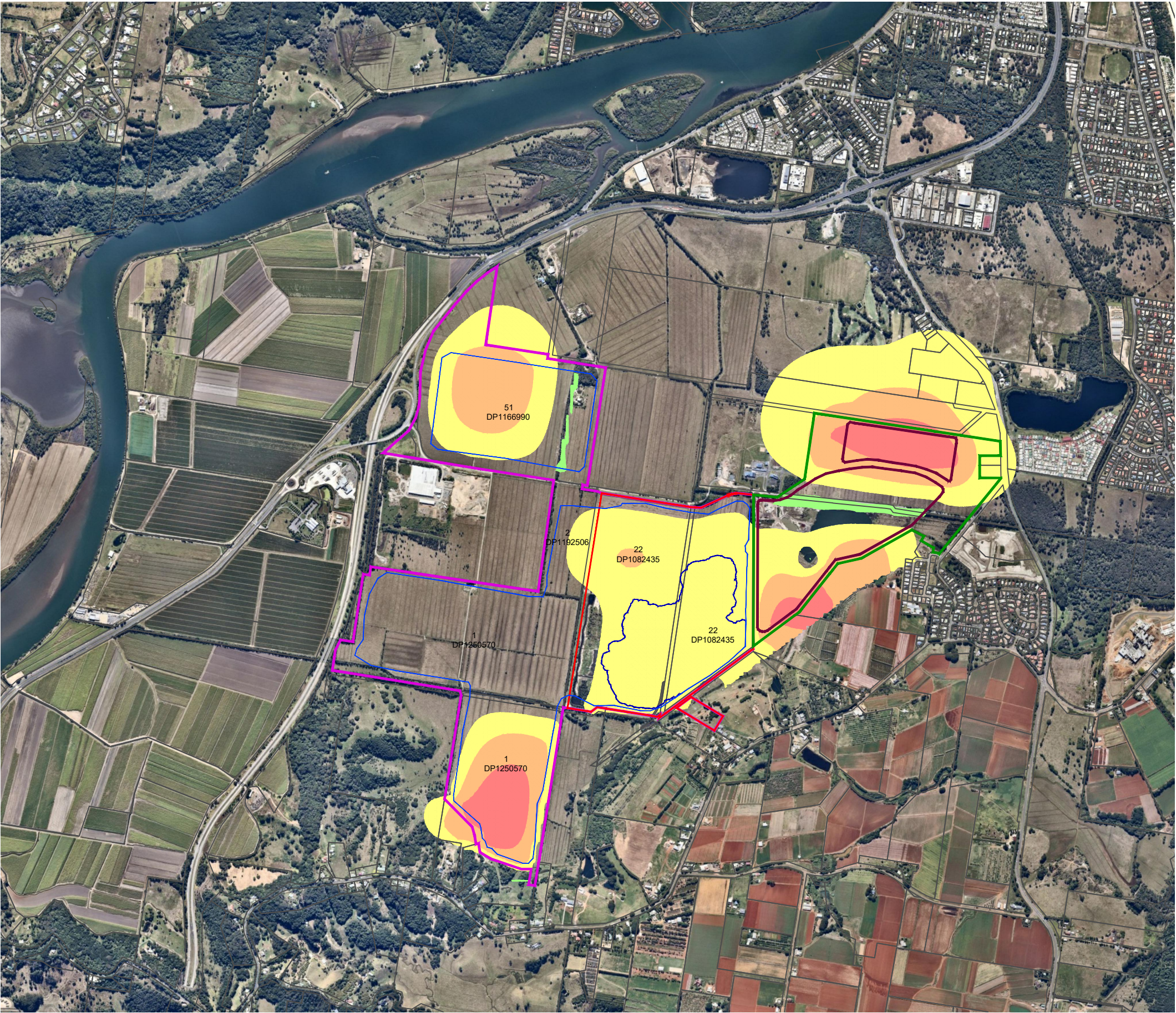
12035

DRAWING

SUPP_GWM_006-

REVISION





Change in groundwater elevation		
Minimum change (m)	Maximum change (m)	Color
-0.500	-1.000	
-0.300	-0.500	
-0.100	-0.300	
0.100	0.500	
0.500	1.000	



ORIENTATION

SCALE

200 400 600 800 1000 metres

ROBINA

PO Box 4115 Robina QLD4230 07 5578 9944
Email robina@access.gs www.access.gs

LEGEND

Cadastral boundaries

Site boundary - Existing

Site boundary - Expansion area

Lake boundary - Existing

Lake boundary - Ultimate expansion area

Cudgen Lake Boundary

Cudgen Lake Sand Extraction Project Boundary

SOURCES

Image: Nearmap image dated 5 August 2021.
Cadastral: NSW Six Maps, sourced 23 November 2020.

PROJECT

TWEED SAND PLANT EXPANSION

CLIENT

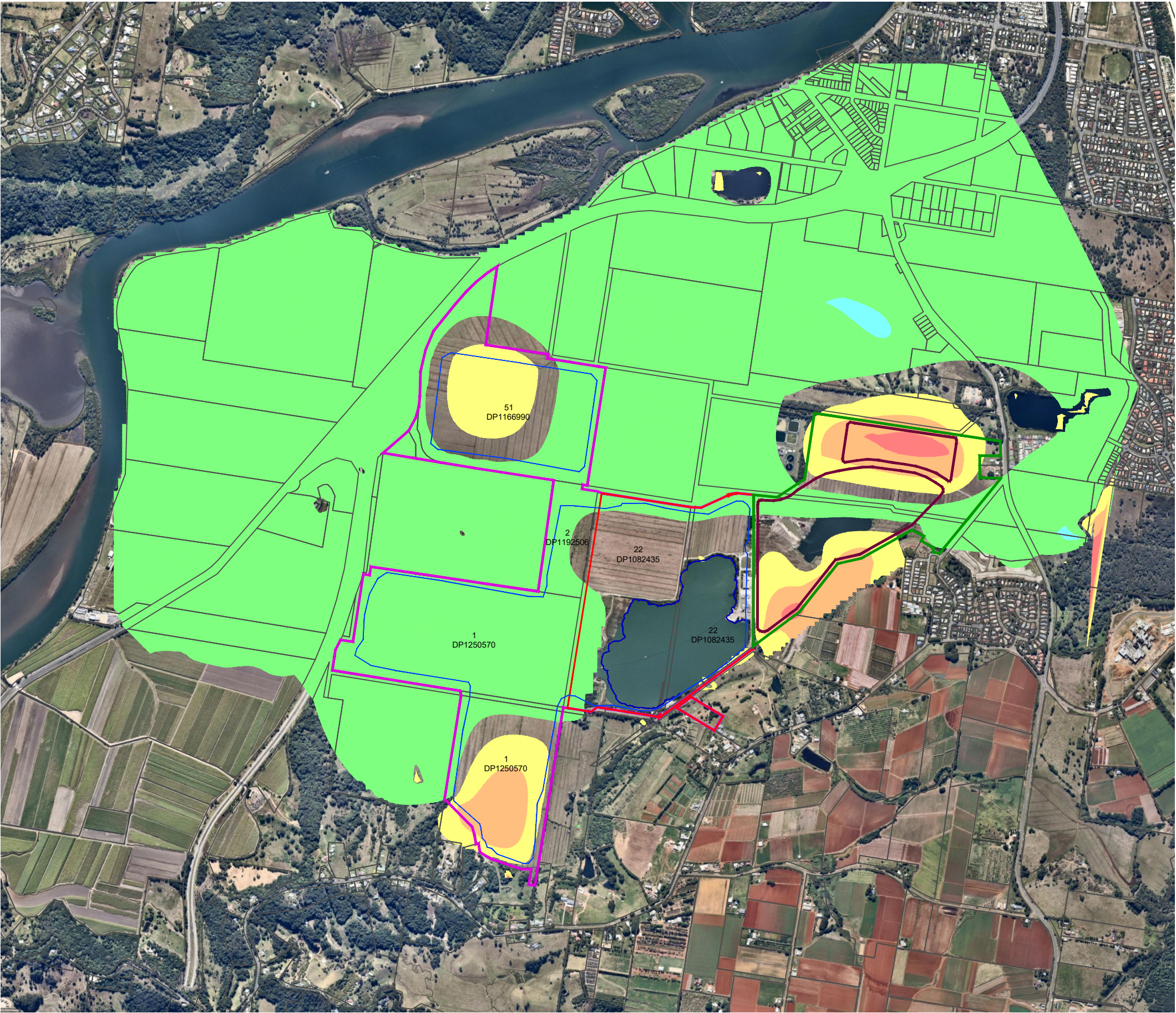
HANSON CONSTRUCTION MATERIALS

DRAWING

CHANGE IN MODELLED CUMULATIVE GROUNDWATER ELEVATION (EXISTING TO DEVELOPED SITE CONDITIONS) TSP EXPANSION AND CUDGEN LAKE

SCALE	DATE	DRAWN	CHECKED	PROJECT	DRAWING	REVISION
1:20 000@A3	30/09/2021	AJF/SWP	ELH	12035	SUPP_GWM_007 -	





Change in groundwater elevation		
Minimum change (m)	Maximum change (m)	Color
-0.500	-1.000	
-0.300	-0.500	
-0.100	-0.300	
0.100	0.500	
0.500	1.000	



ORIENTATION

SCALE

200 400 600 800 1000 metres

ROBINA

PO Box 4115 Robina QLD4230 07 5578 9944
Email robina@access.gs www.access.gs

LEGEND

Cadastral boundaries

Site boundary - Existing

Site boundary - Expansion area

Lake boundary - Existing

Lake boundary - Ultimate expansion area

Cudgen Lake Boundary

Cudgen Lake Sand Extraction Project Boundary

SOURCES

Image: Nearmap image dated 5 August 2021.

Cadastral: NSW Six Maps, sourced 23 November 2020.

PROJECT

TWEED SAND PLANT EXPANSION

CLIENT

HANSON CONSTRUCTION MATERIALS

SCALE

1:20 000@A3

DATE

30/09/2021

DRAWN

AJF/SWP

CHECKED

ELH

DRAWING

CHANGE IN GROUNDWATER ELEVATION WITH 0.4m SEA LEVEL RISE

PROJECT

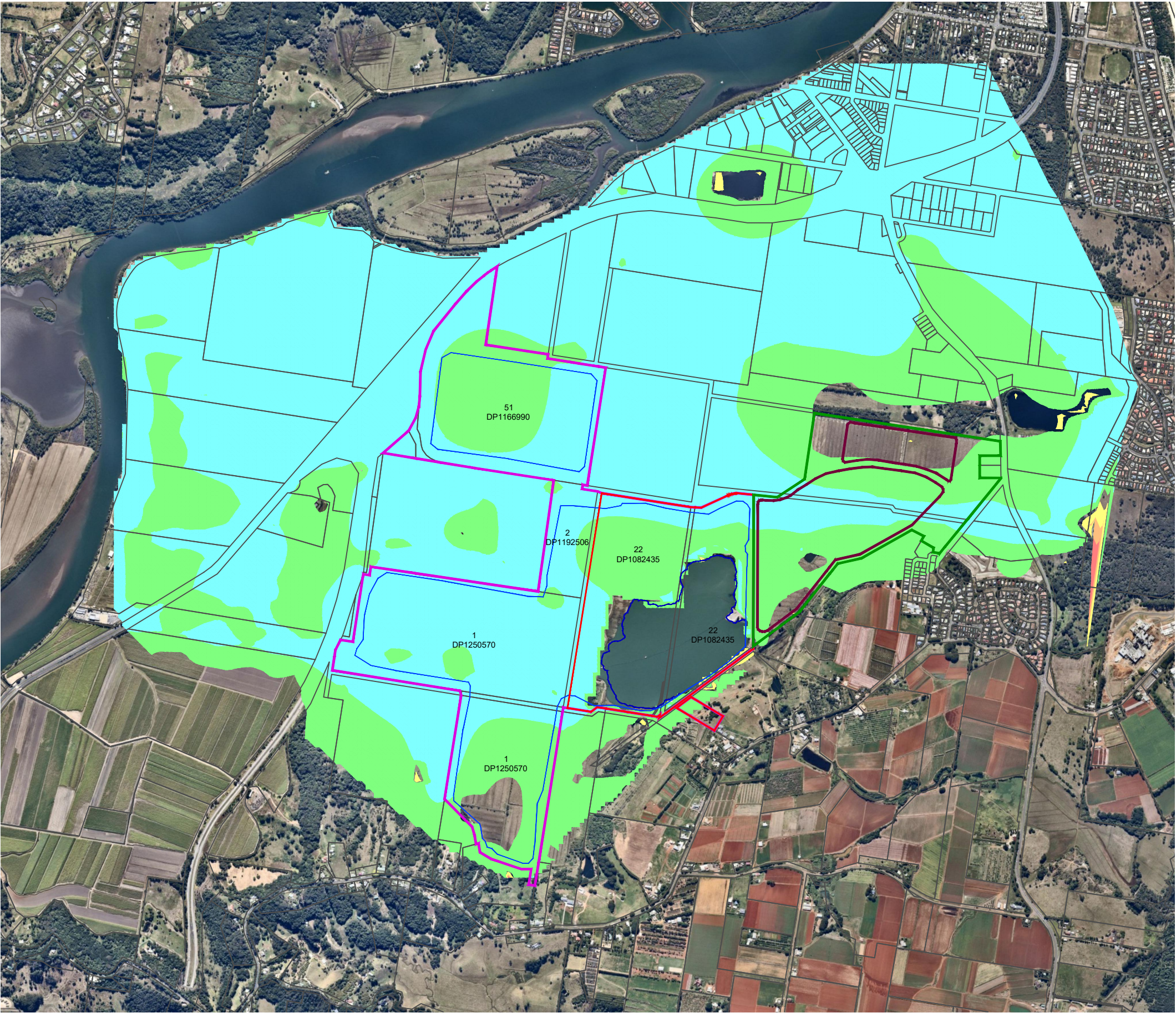
12035

DRAWING

SUPP_GWM_008-

REVISION





Change in groundwater elevation		
Minimum change (m)	Maximum change (m)	Color
-0.500	-1.000	
-0.300	-0.500	
-0.100	-0.300	
0.100	0.500	
0.500	1.000	



ORIENTATION

SCALE

200 400 600 800 1000 metres

ROBINA

PO Box 4115 Robina QLD4230 07 5578 9944
Email robina@access.gs www.access.gs

LEGEND

Cadastral boundaries

Site boundary - Existing

Site boundary - Expansion area

Lake boundary - Existing

Lake boundary - Ultimate expansion area

Cudgen Lake Boundary

Cudgen Lake Sand Extraction Project Boundary

SOURCES

Image: Nearmap image dated 5 August 2021.
Cadastral: NSW Six Maps, sourced 23 November 2020.

PROJECT

TWEED SAND PLANT EXPANSION

CLIENT

HANSON CONSTRUCTION MATERIALS

SCALE

1:20 000@A3

DATE

30/09/2021

DRAWN

AJF/SWP

CHECKED

ELH

DRAWING

CHANGE IN GROUNDWATER ELEVATION WITH 0.9m SEA LEVEL RISE

PROJECT

12035

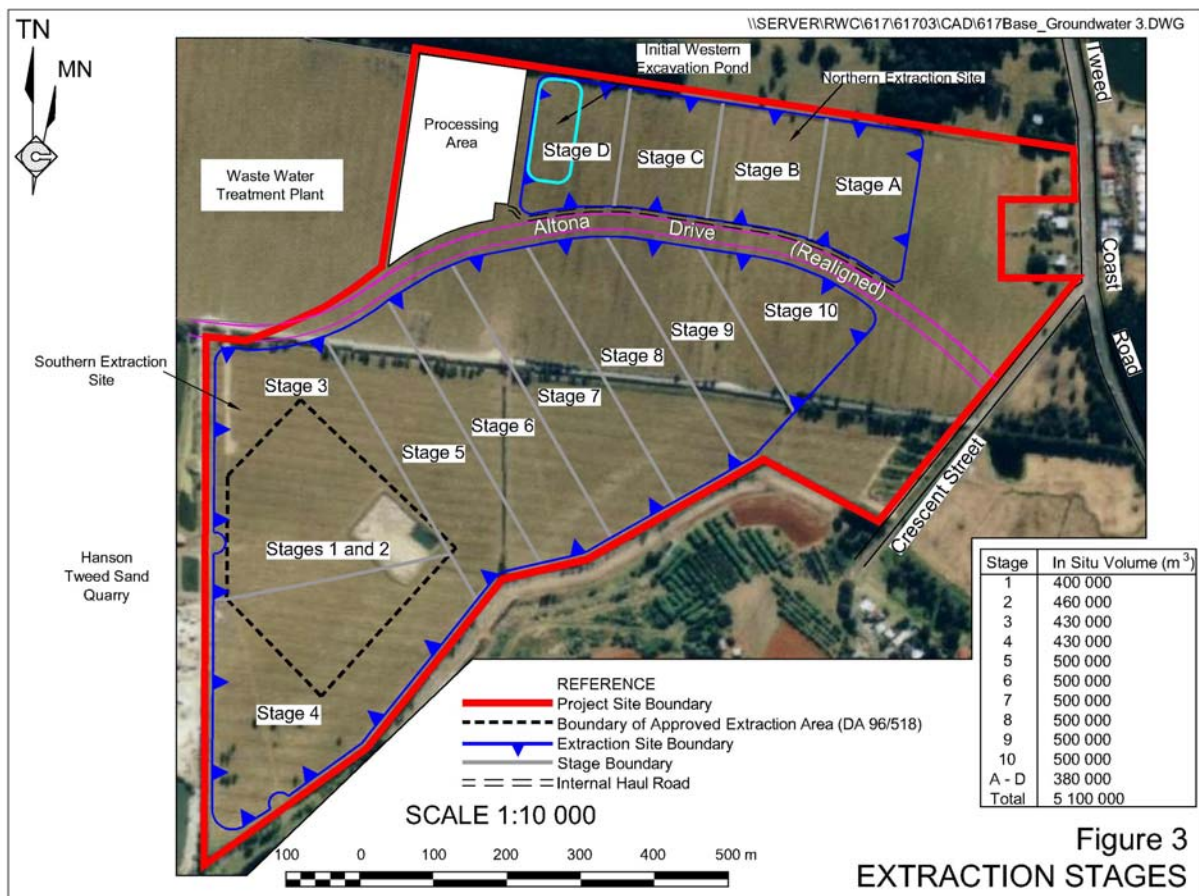
DRAWING

SUPP_GWM_009 -

REVISION



15 Appendix 9 – Cudgen Lakes Sand Extraction Project references



Note: A colour version of this figure is available on the Project CD.

During this ramp up period (and throughout the life of the operation), the rate of extraction would be adjusted to ensure that groundwater drawdown levels remain within acceptable limits. It is noted that Development Consent DA 96/518, which requires the removal of 400 000m³ of sand over a 7ha area (see **Figure 3**) within 6 months (equivalent to a rate of 800 000m³ per year) would be surrendered following the issue of project approval. Hence the likely drawdowns associated with this approved operation would not occur.

Both non-acid generating VENM - VENM(a) and acid producing VENM – VENM(b) would be received at the Project Site via road trucks, appropriate details recorded and the material classification verified. VENM(a) would either be processed to produce saleable products or used to backfill the northern extraction pond or finalised edges of the southern extraction pond. VENM(b) which is suitable for processing would be placed adjacent to the southern extraction pond for treatment, as for the loamy sand material, prior to processing. VENM(b) not suitable for processing would be either used to backfill the northern extraction pond or interned at or near the base of finalised sections of the southern extraction pond.

All VENM delivered to the Project Site and processed materials despatched from the processing area would be transported via Altona Drive and Tweed Coast Road. Access to the Project Site would be provided via three entrances off Altona Drive, one to the processing area and northern extraction site and two to the southern extraction site.

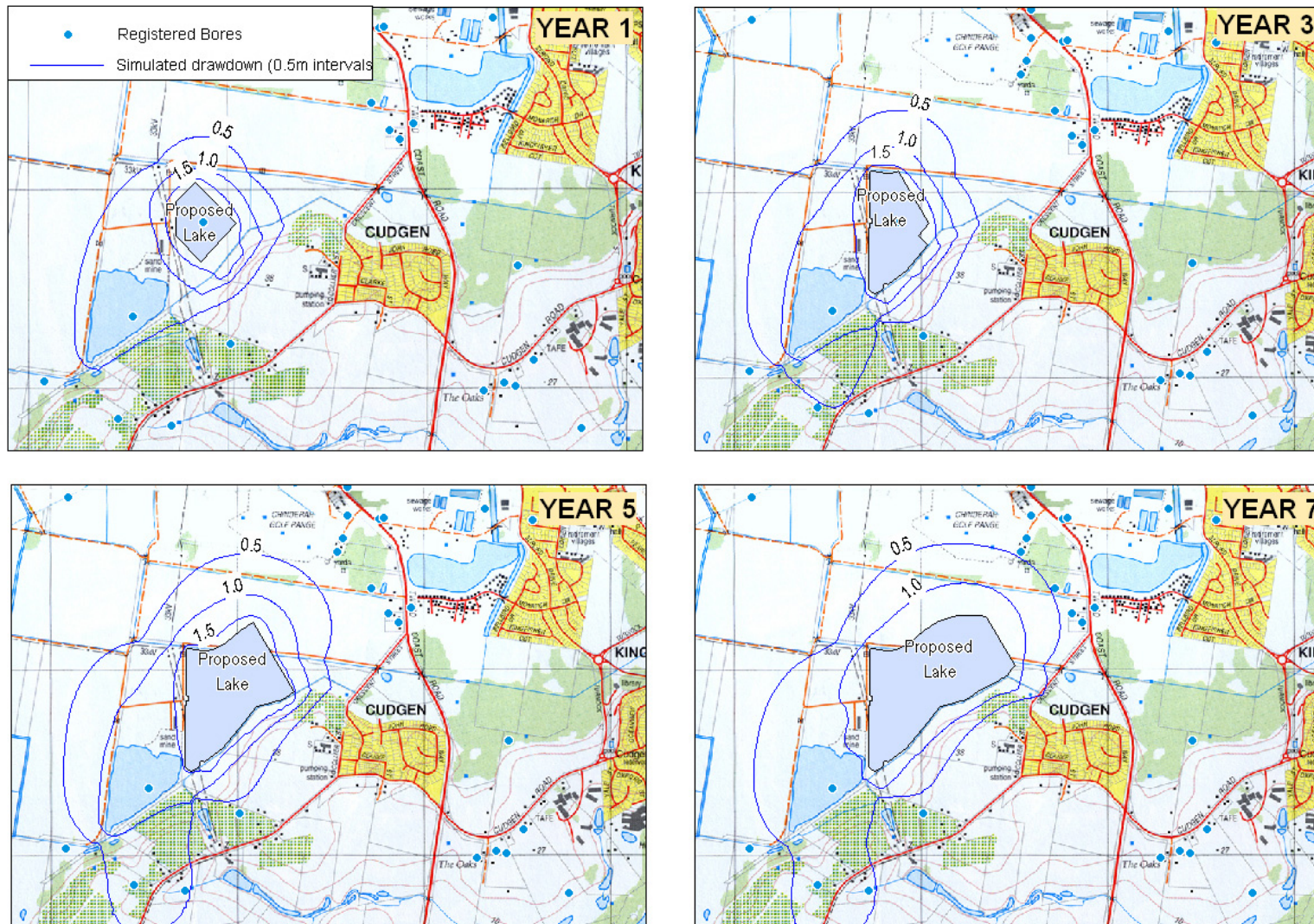


Figure 21 Simulated Water Table Drawdown