PROPOSED EAST KERALUP FACILITY

GROUNDWATER LEVEL MANAGEMENT STUDY

C-WISE

REPORT NO. 11375RAL010

7 December 2023

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1. Introduction

This report presents the results of a groundwater level management study undertaken by FSG Geotechnics (FSG) for C-WISE for a new Carbon Recycling Facility (the site) located in East Keralup, Western Australia. The location of the groundwater study area is provided in Figure 1 in Appendix A.

The Carbon Recycling Facility will be built in two stages where Stage 2 will allow for the expansion of the Stage 1 Carbon Recycling Facility.

1.1 Background

C-WISE is proposing to construct a new processing facility in the south-east corner of Keralup (East Keralup Land Development Area). The proposed facility comprises a carbon storage area, liquid waste receival/storage, fuel store/service bay, workshop, office, car park, and an access road and will mainly be constructed on a sand dune ridge which currently exists at the site.

A detailed Keralup District Water Management Strategy (KDWMS) was prepared by Emerson Stewart in 2008/2009. As part of this study three monitoring wells were installed within the site and included in a regional groundwater level monitoring program over the whole KDWMS area. One of the main conclusions from the KDWMS was that coffee rock is present over the whole study area resulting in the presence of a perched aquifer. It is noted that DWER comments provided to the KDWMS disputed this to be the case.

A groundwater level study was undertaken by WSP in May 2023 (WSP 2023), which included installing automated groundwater level loggers within the three wells located within the C-WISE lot boundary and review of publicly available data. The WSP study is presented in Appendix A. In summary, the study concluded:

- A perched groundwater level is not present at the site. The shallow observed groundwater is considered to be part of the regional Superficial Aquifer.
- The historical minimum groundwater level (HMinGWL), the Average Annual Groundwater Level (AAMGL) and the 50 Year Design Groundwater Level (DGWL) for the site were defined based on available site groundwater level data and long-term groundwater level data from a nearby Department of Water and Environmental (DWER) monitoring well (DWER Well 61410079).
- Groundwater level management could be required at the site to maintain the necessary clearance between groundwater level and the site infrastructure. The study provided both potential passive and active drainage control methods.

During the conceptual design undertaken by Talis Consultants (Talis), it has been determined that groundwater level control is required at the site to obtain a minimum clearance of 1.5 m between the estimated highest groundwater level over the design life of the ponds (which is the DGWL) and the base of the lined leachate ponds. Accordingly, the maximum groundwater levels would be required to be controlled as follows:

- Stage 1: To RL 14 m AHD below the Stage 1 leachate ponds (basin base level of RL 15.5 m AHD).
- Stage 2: To RL 15 m AHD below the Stage 2 leachate ponds (basin base level of RL 16.5 m AHD).

The groundwater level drainage system being considered in the design is a passive method with construction of open drains and/or installation of sub-soil drains within and around the site, which would control the maximum level that the groundwater level can rise to beneath the site. The groundwater collected by the drains will then be gravity be discharged off-site into the existing drainage network surrounding the site.

As part of the above process, C-WISE requires a groundwater level management/drainage assessment to be undertaken to assess the required location and depths of the swale/sub-soil drains, as well as potential groundwater drainage rates. This information will then feed into the drainage system design undertaken by Talis.

1.2 Objective

The objective of this study is to undertake a groundwater level management/drainage assessment for the Carbon Recycling Facility to control peak groundwater levels below the set allowable maximum groundwater levels.

1.3 Scope of Work

The following scope of work has been carried out to meet the objective:

- Download the existing groundwater level loggers from the three wells and collate the groundwater level data.
- Review and revise (if required) the DGWL's developed for the site based on the additional collected groundwater level data.
- Develop a numerical 3D Groundwater Model and calibrate the model to the existing groundwater level data.
- Run groundwater model scenarios to estimate the required depths of open drains (or sub-soil drains) to lower the peak groundwater levels to the required target groundwater levels across the site.
- Estimate the maximum flow rates from the drains that would need to be discharged off-site into the existing drainage network.
- Prepare a report with the above results to support the works approval application.

2. Site Setting

The WSP study provides a detailed description of the site conditions including the geological and hydrogeological setting. The study (presented in Appendix A) should therefore be read in conjunction with this report, where the relevant site conditions have only been summarised.

2.1 Site Description

The Carbon Recycling Facility is located approximately 1.9 km north of the existing C-WISE facility and covers an area of around 20 ha within the planned Keralup Industrial Park. The proposed facility area is located in the western part of the site with a total area of approximately 20 ha.

The site is currently considered a greenfield site and used for grazing purposes, consisting of shrubs, trees and open area with several natural and man-made water holes and drainage swales.

2.2 Topography

The topography across the site range between RL 10 m AHD and RL 22 m AHD. The lowest surface elevations occur in the western part of the site. A 3 m to 6 m high sand dune ridge (topographic high) exists along the southern boundary of the site.

The existing surface elevation over the proposed facility area ranges between RL 14 m AHD and RL 20 m AHD, with the proposed Stage 1 process facility having a surface elevation ranging between RL 18 m AHD and RL 19 m AHD and the proposed Stage 2 facility being around 1 m higher than Stage 1.

2.3 Climate

The Bureau of Meteorology (BOM) station (BOM IF 9253) indicates that the average annual rainfall is 704 mm with the wet season occurring from May to September where about 80% of the rainfall occurs.

2.4 Geology

The Geological Survey of Western Australia's (GSWA) Environmental Geology Series 1:50,000 Rockingham sheet (2033 II and III) indicates that the study area is underlain by:

- *Bassendean Sand* – SAND (S8) described as white to pale grey at surface, yellow at depth, fine to medium-grained moderately sorted subangular to subrounded minor heavy minerals of eolian origin, with a high permeability.
- *Thin Bassendean Sand over Guildford Formation* – SAND (S10) over sandy clay to clayey sand of the Guildford Formation of eolian origin.
- *Swamp Deposits* – PEATY CLAY (Cps) described as dark grey and black, soft variable organic content, some quartz sand in places, of lacustrine origin with low permeability.

The S8 material is reported in the area over the site where the sand dune ridge exists, while S10 material is reported over the rest of the site where the elevations are lower. The swamp deposits are present in a small area in the south-eastern corner of the site.

Coffee rock has been reported in a majority of lithological logs across the area including in the three wells installed at the site.

2.4.1 Acid Sulfate Soils (ASS)

The DWER ASS risk map indicates that the Carbon Recycling Facility is located within a low to medium risk area for encountering ASS within 3 m from the surface.

WSP (2023) states that both Bassendean Sand and Guildford Formation are known to contain potential ASS below the groundwater table. In some cases, the Bassendean Sand is referred to as an acidic soil but has similar characteristics in that it can cause acidic groundwater conditions with limited buffering capacity.

2.5 Hydrology

The proposed East Keralup Industrial site is known as a Palusplain area, which is classified by DWER as multiple use geomorphic wetlands due to the shallow groundwater table and occurrence of surface water inundation. These areas are found to have a dense surface drainage network (natural and man-made) to drain the area.

A dense drainage network is present within and around the site, with surface water drains existing at the base of the sand dunes in the lower lying and flatter parts of the area. The drains are expected to drain rainfall runoff while some of the deeper drains also control the groundwater level during the wet season. It is noted that all these surface water drains are ephemeral (i.e. do not flow all year around). During the site visit in October 2023 most of the smaller drains within the site were dry while the larger open drains at the southern and northern lot boundaries contained water in some parts.

Figure 2-1 shows an aerial photograph from 25 August 2017 where several wet areas, ponds and wetlands and surface water drains have water in them. If the open drains were not present it is expected that larger areas could get inundated. This means that the drainage network at the site is currently already controlling the groundwater level over parts of the site.

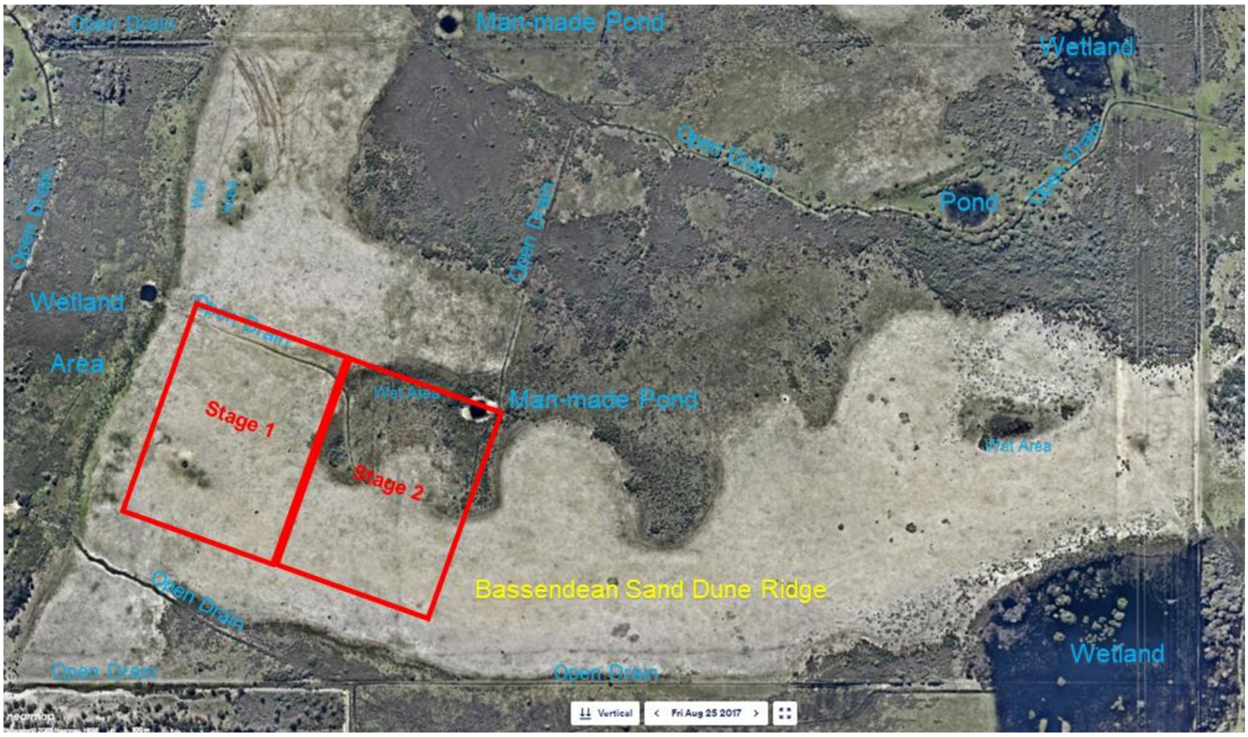


Figure 2-1 Drainage and Surface Water over the Site Area (photo from Nearmap - 25 August 2017).

3. Hydrogeology

The WSP study (Appendix A) presents a detailed description of the hydrogeology and groundwater level data.

Figure 3-1 shows the conceptual hydrogeological model developed by WSP.

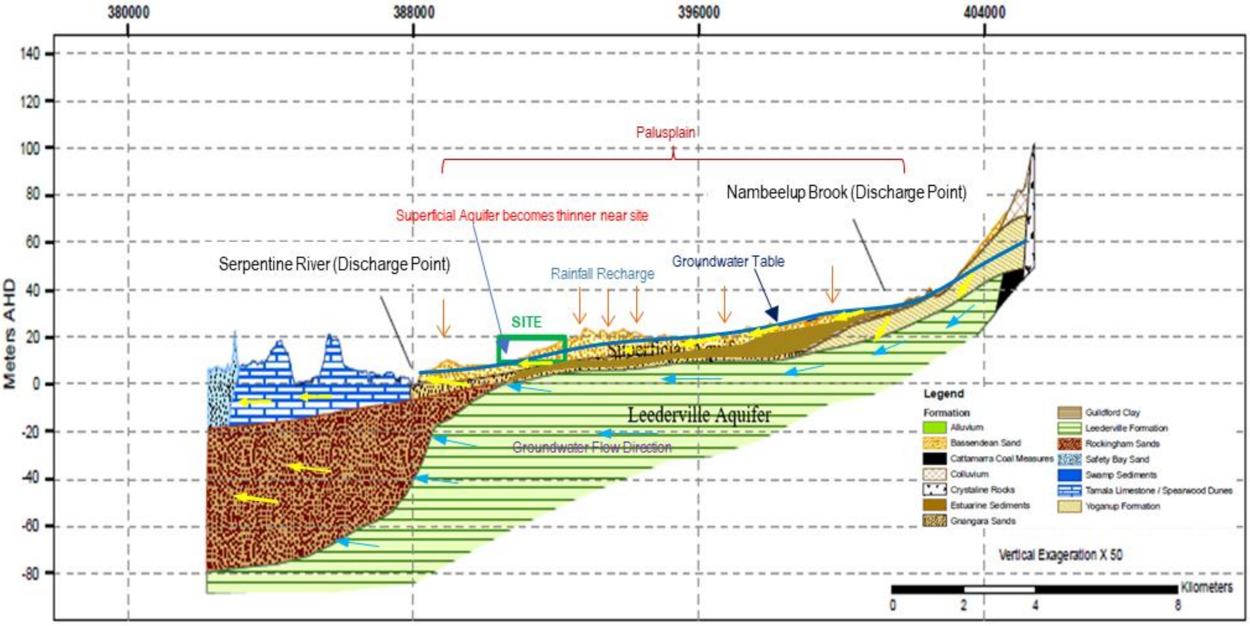


Figure 3-1 Conceptual Hydrogeological Model (WSP 2023).

3.1 Groundwater Level

The groundwater level loggers were downloaded from site monitoring wells EB07, EB08 and EB09 on 11 October 2023. Figure 3-2 shows the hydrographs of these wells and indicates that:

- The groundwater levels behave similarly in all three monitoring wells (one well is screened above, one across and one below the coffee rock), verifying that the wells are not affected by the coffee rock and that no perched aquifer is present at the site.
- The groundwater level starts increasing in June 2023, at the onset of the wet season.
- The groundwater level rise during the 2023 wet season ranged between 0.9 m and 1.2 m.
- During the 2023 wet season there is a clear correlation between rainfall events and groundwater level changes.

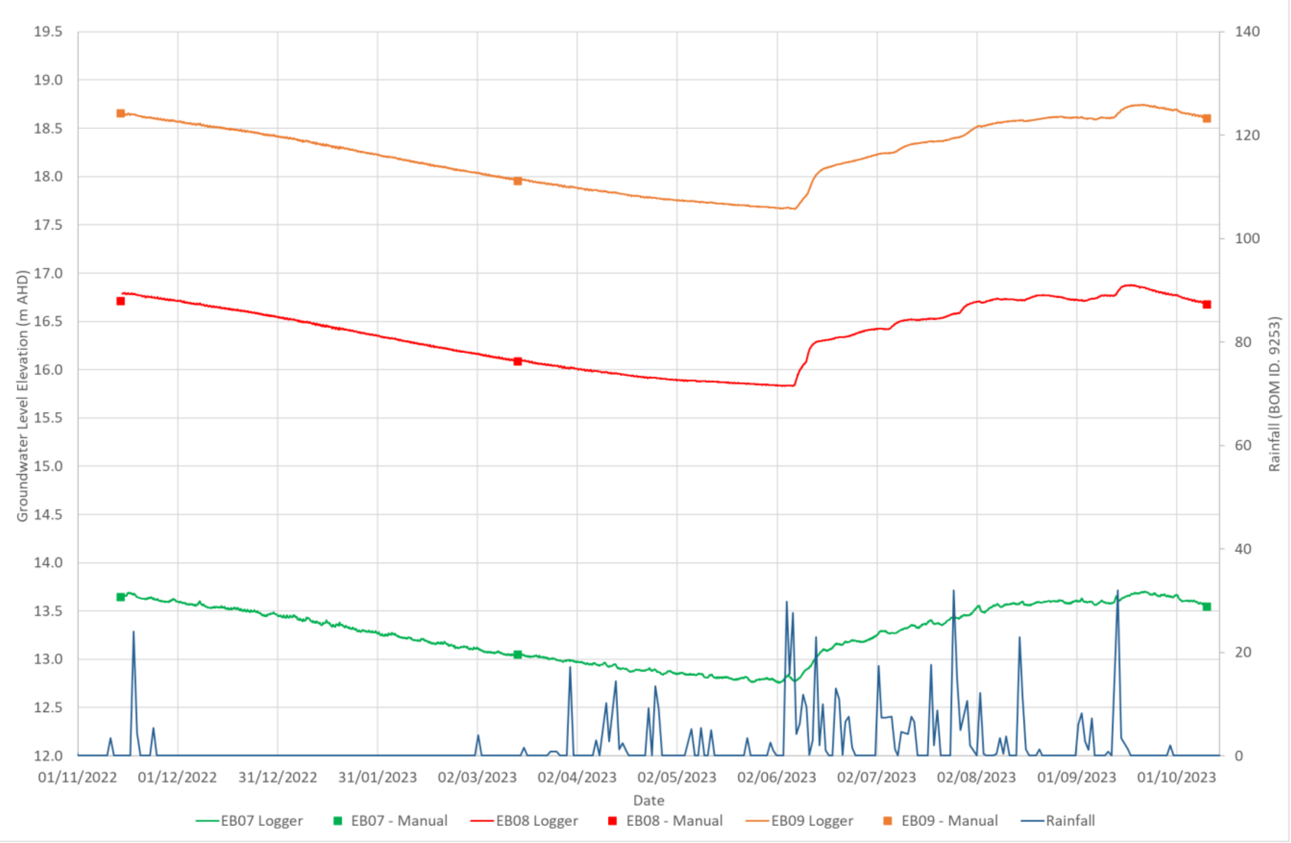


Figure 3-2 Hydrographs of EB07, EB08 and EB09 together with Rainfall from BOM Station 9253.

3.2 Verification of WSP Developed Design Groundwater Levels

The additional groundwater level series from the monitoring wells were plotted against the adjusted hydrograph from DWER Well 61410079, which was used by WSP to estimate the DGWL, AAMGL and HMinGWL.

Figure 3-3 shows the estimated historical groundwater level behaviour at EB07 based on the adjusted hydrograph from DWER Well 61410079 and indicates that the additional 2022/2023 data fits well with the adjusted DWER well hydrograph. This was found to be the same for EB08 and EB09. It is therefore considered that the additional groundwater level data from the three site wells verifies the assessment methodology and resulting estimated DGWL, AAMGL and HMinGWL for EB07, EB08, EB09, and thereby the DGWL and AAMGL contours presented in the WSP study (refer to Figures 5 and 6 in Appendix A).

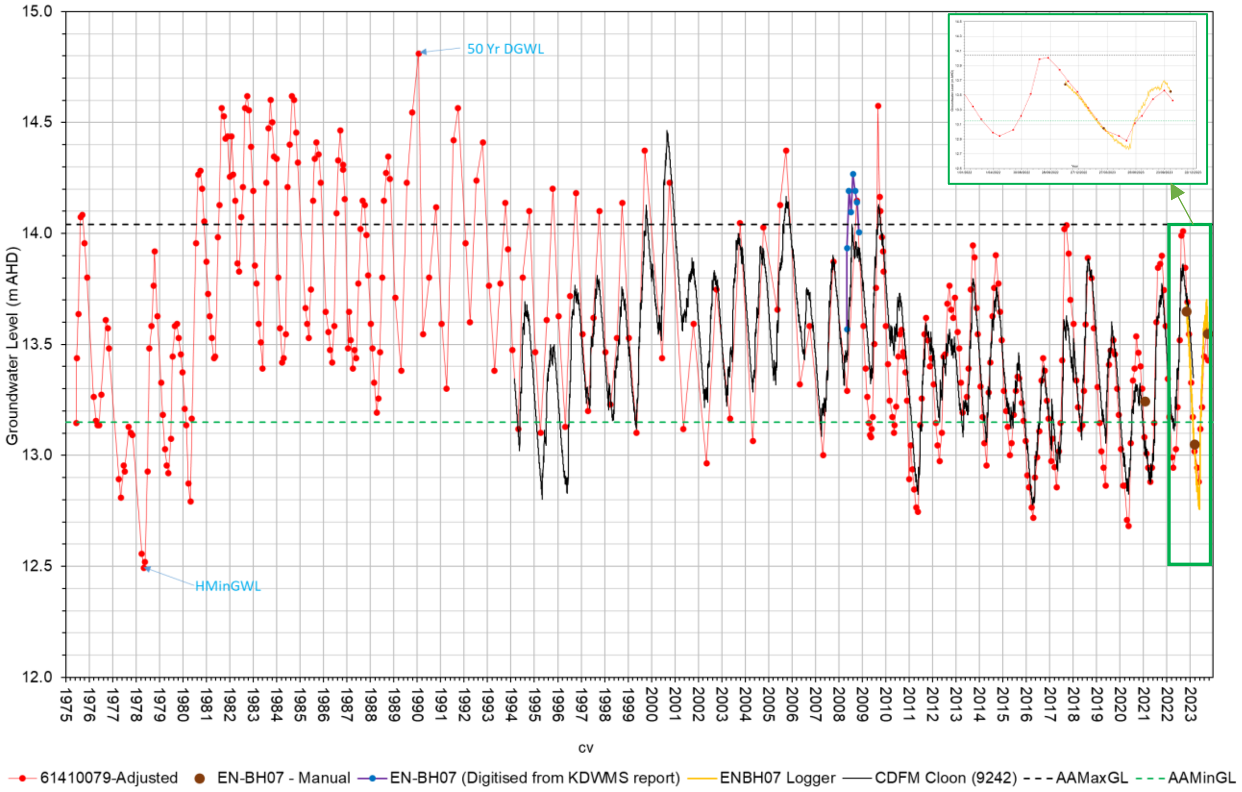


Figure 3-3 Estimated Groundwater Level Behaviour at EB07 based on DWER Well 62410079.

3.3 Groundwater Quality

Western Environmental undertook groundwater quality sampling in February 2021 in two of the project site wells (EB07 and EB09). The review of the groundwater quality results indicates that the results are generally similar across the wider area, but this section only discusses the results from EB07 and EB09. Table 3-1 presents the groundwater quality results for selected parameters for the two wells located within the site.

Table 3-1 Selected Groundwater Quality Results from EB07 and EB09 from February 2021.

Parameters	Units	EB07	EB09
Field pH	pH unit	**4.50**	**3.73**
Field Electrical Conductivity	uS/cm	185	149
Total Acidity	mg/L	37	17
Total Alkalinity	mg/L	<20	<20
Chloride	mg/L	39	17
Sulfate	mg/L	<5	<5
Total Aluminium	mg/L	**0.53**	**0.38**
Total Iron	mg/L	**0.75**	**0.14**
Total Nitrogen	mg/L	**1.1**	**2.4**
Total Phosphorous	mg/L	**0.44**	**0.22**

Note: Bold is when the concentration is outside of Freshwater Guidelines for slightly to moderately disturbed systems.

The groundwater quality results indicate:

- The groundwater is fresh and acidic.
- The chloride and sulfate concentrations are generally low for groundwater.

- The net alkalinity (acidity minus alkalinity) is negative, suggesting that the groundwater has limited to no buffering capacity to maintain a stable pH. This can already be seen with the groundwater being acidic.
- The nutrient concentrations are above typical regulatory guidelines for disposal into the environment.
- Metal concentrations are less than 1 mg/L, but total aluminium is higher than regulatory guidelines.

The groundwater quality results could indicate that the groundwater has or is being affected by ASS or acidic soils.

4. Groundwater Model

A 3D numerical groundwater model was developed using Visual MODFLOW, which is software used worldwide for groundwater modelling. Appendix B provides a description of the model setup while the section below summarises the calibration results from the model.

4.1 Groundwater Model Calibration Results

The steady-state model was first calibrated against the 14 November 2022 observed groundwater levels in the site monitoring wells.

Figure 4-1 shows the modelled groundwater levels vs the WSP inferred groundwater level contours and indicates a good correlation between the groundwater levels.

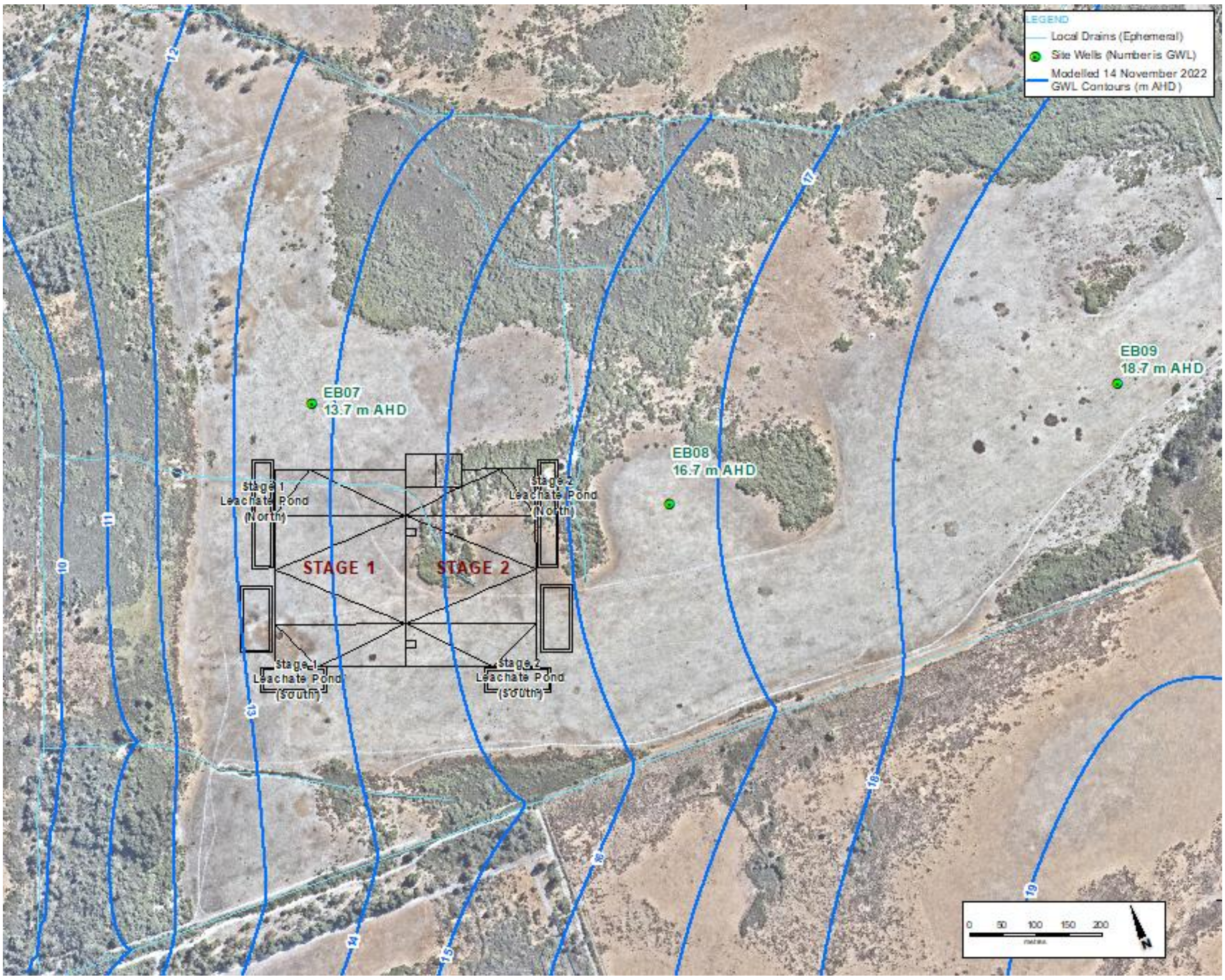


Figure 4-1 Modelled Groundwater Levels vs 11 November 2022 Observed Groundwater Level Contours.

The model was then calibrated in transient conditions from 11 November 2022 to 11 October 2023. Figure 4-2 shows a comparison of the modelled groundwater level behaviour (using monthly rainfall data from BOM Station 9253) against the observed groundwater levels.

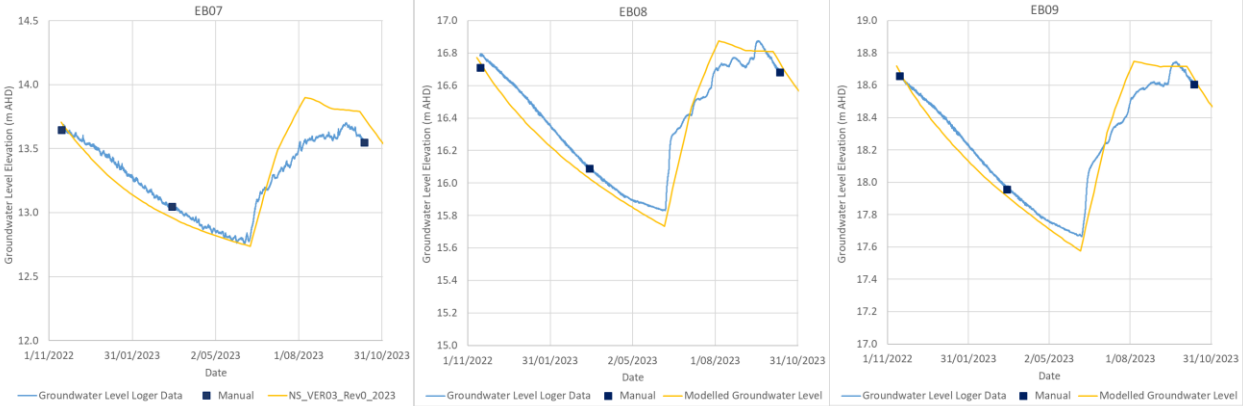


Figure 4-2 Modelled Groundwater Levels vs Observed Groundwater Levels in Site Monitoring Wells.

4.2 Modelled 50 Yr DGWL

Following the model calibration, the groundwater model was run using estimated rainfall recharge rates to create a 50 Yr DGWL event. It is noted that a 50 Yr DGWL event could occur from many different rainfall patterns as the groundwater level has a long-term memory. For example:

- A 50 Yr DGWL event may not occur following a 50 Yr Rainfall event as it would depend on the time of the year of the event and the previous year's rainfall recharge events.
- Three wet rainfall years may result in a higher groundwater level than two dry years followed by an extreme rainfall year.
- In 2018 the peak groundwater levels in the Perth Metro area were found to be the highest in the last 15 years. This was mainly due to two preceding years of above average annual rainfall and a single day rainfall event in January 2018 of 100 mm, resulting in the seasonal low groundwater level being much higher than normal, and leading to the subsequent 2018 wet season groundwater level being very high.

Therefore, to model a 50 Yr DGWL event, a transient model was run using the steady-state model heads as input and then applying an upscaled average monthly rainfall distribution to a very wet year with a similar high rainfall event occurring in the dry season (set in February).

Figure 4-3 shows the modelled 50 Yr DGWL at the project site monitoring wells while Figure 4-4 shows the modelled 50 Yr DGWL contours vs the WSP inferred (manually drawn) DGWL contours (presented in Figure 5 in Appendix A). The modelled 50 Yr DGWL contours are found to fit well with the inferred 50 Yr DGWL contours. At the proposed Carbon Recycling Facility site, the modelled RL 15 m AHD and RL 16 m AHD contours are slightly higher than the WSP inferred DGWL contours, which would only result in slightly more conservative results (e.g. the modelled drainage rates would be on the conservative side).

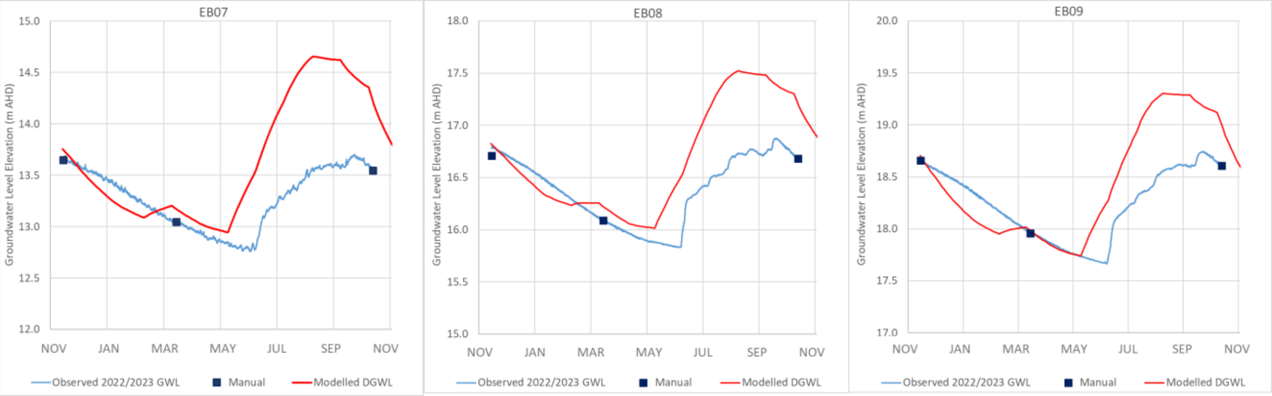


Figure 4-3 Modelled 50 Yr DGWL vs Observed Groundwater Levels in the Project Monitoring Wells.

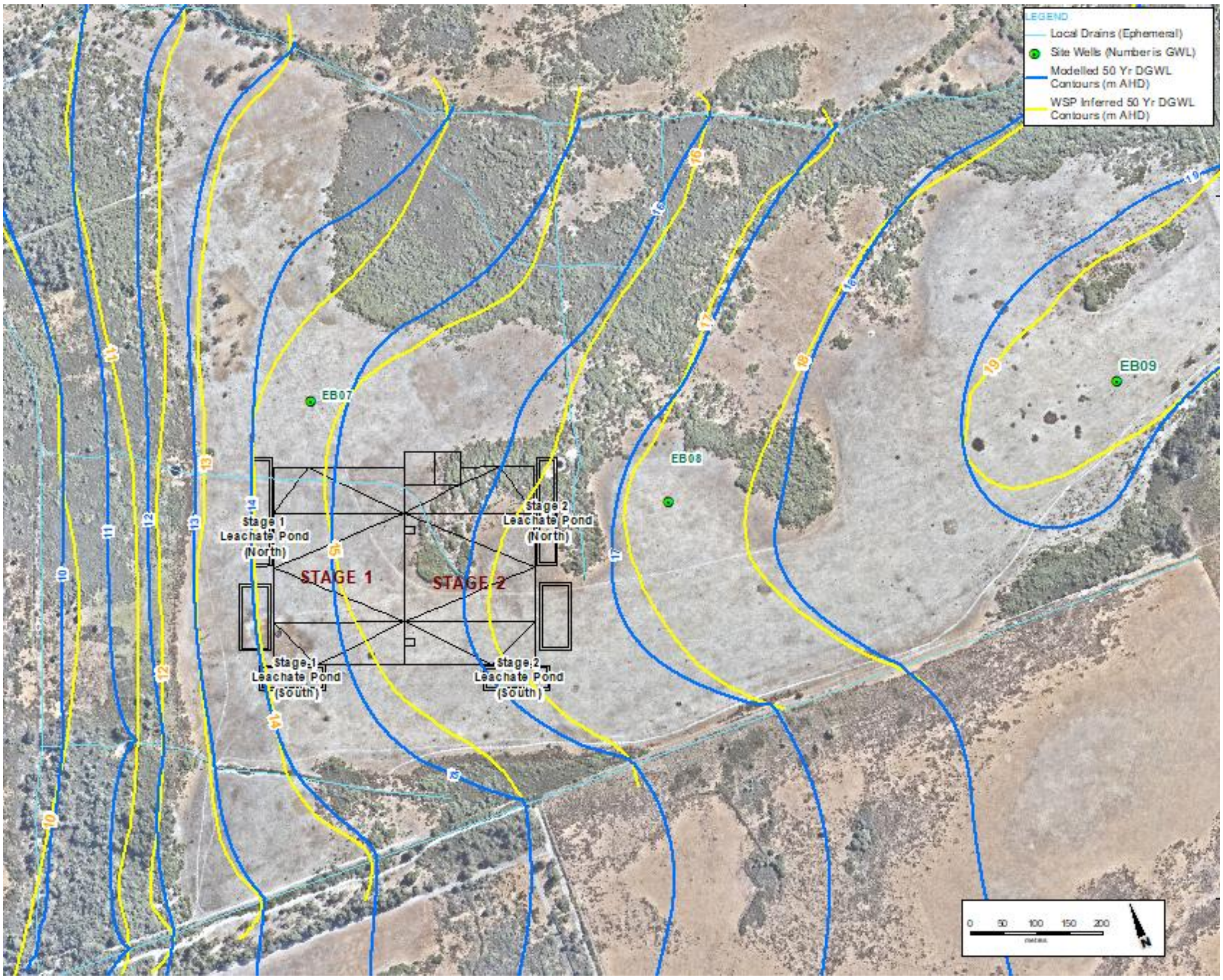


Figure 4-4 **Modelled 50 Yr DGWL Groundwater Levels vs WSP Inferred 50 Yr DGWL Contours.**

5. Groundwater Level Management

5.1 Controlled Peak Groundwater Levels

As outlined in Section 1.1, the required controlled peak groundwater levels are:

- Stage 1: RL 14 m AHD beneath the Stage 1 leachate ponds.
- Stage 2: RL 15 m AHD beneath the Stage 2 leachate ponds.

5.2 Groundwater Level Control Methods and Layout

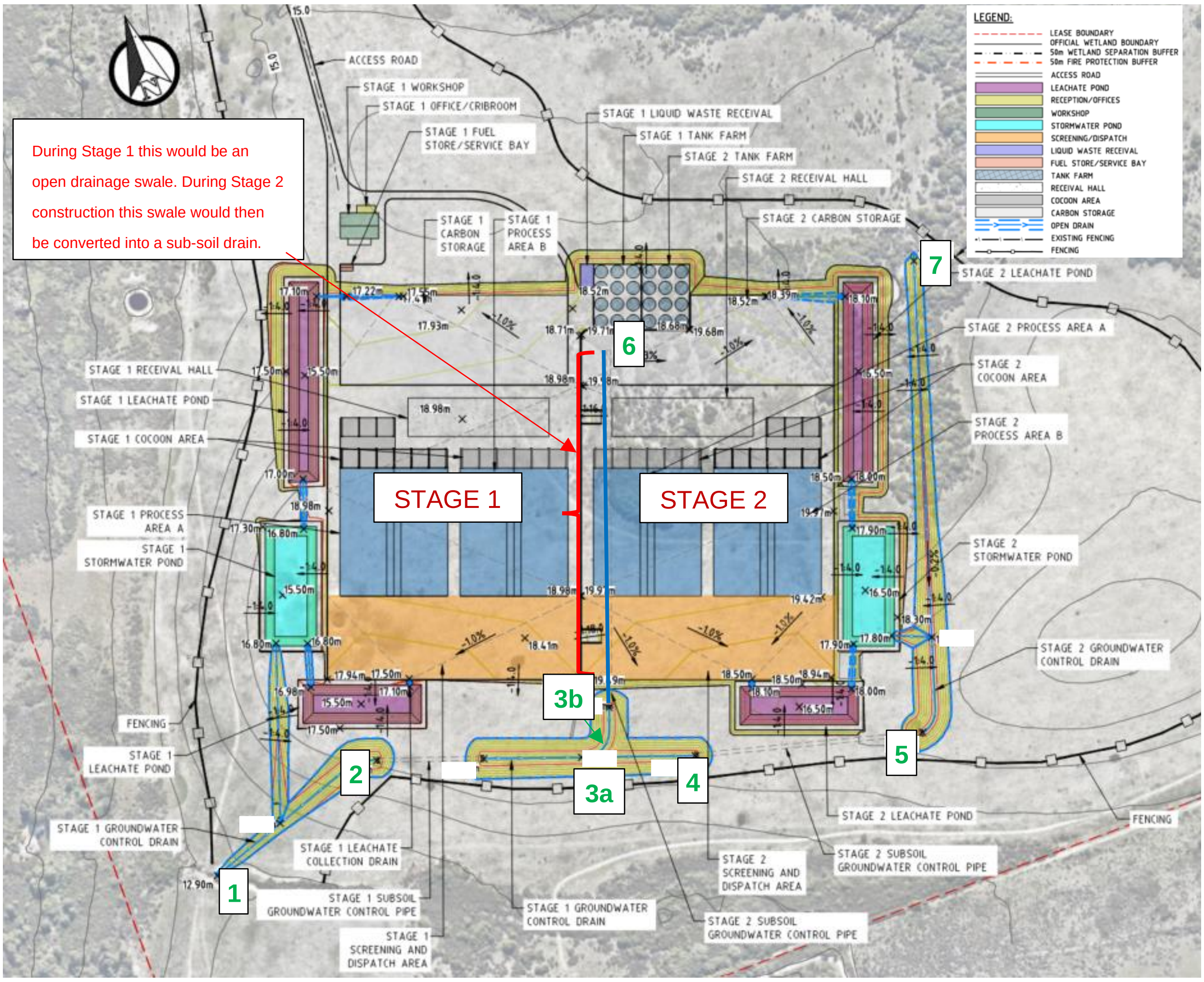
The drain module in Visual Modflow was used to model the proposed drains. The following assumptions were made during the modelling:

- The minimum allowable gradient of the drainage swales and sub-soil drains are 0.2% to ensure that there is sufficient hydraulic gradient to transport/discharge the intersected groundwater.
- Given the flat gradient of drainage swales, it is not uncommon that the groundwater level rises above the drainage swale invert level (i.e. water can be seen in the swales). The water levels in the drains (corresponding to the groundwater level at the drain) was set at 0.3 m above the swale invert levels.
- The majority of the project facility site footprint will be paved/concreted which will reduce the rainfall recharge over the footprint (the rainfall will be mainly becoming runoff water, which will be captured and discharged into lined stormwater ponds. The annual rainfall recharge was modelled to be

15 mm, which is approximately 2% of the annual rainfall (considered conservative).

Figure 5-1 shows the proposed groundwater level control drainage swales layout/concept developed by Talis for both Stage 1 and Stage 2, which consists of:

- An open drainage swale is proposed to be constructed along the southern and eastern boundaries of Stage 1 and Stage 2 (i.e. hydraulic upgradient of the site) to capture part of the groundwater flowing into the Carbon Recycling Facility footprint.
- In a few places an open drain with the required 1:4 batter slopes would result in encroachment into the 50 m wetland separation buffer. In these areas the drainage swale would instead be a sub-soil drain.
- During Stage 1 the drain along the eastern boundary would be an open drainage swale. During Stage 2 construction this swale would then be converted into a sub-soil drain, if required.
- The groundwater control drainage network would be discharged into the existing drainage swale south of the site. The stormwater from the site would also be discharged into this existing drain, making use of the groundwater control drainage system.



During Stage 1 this would be an open drainage swale. During Stage 2 construction this swale would then be converted into a sub-soil drain.

Figure 5-1 Proposed Groundwater Control Drainage Layout Plan.

5.3 Stage 1

For Stage 1 the following two model scenarios were undertaken:

- **Original**: The drainage swales including 1 to 2, 2 to 3a, 3b to 6 (refer to green numbers in Figure 5-1)

- **Optimised**: The drainage swales including 1 to 2, 2 to 3a (refer to green numbers in Figure 5-1)

5.3.1 Groundwater Modelling Results

Table 5-1 provides the required invert levels of the drainage swales for the two different Stage 1 scenarios.

Table 5-1 Modelled Invert Levels of the Drainage Swales for the Stage 1 Scenarios.

Point ID	Original				Optimised			
	Drain Invert Level (m AHD)	Modelled Drain Level (m AHD)	Length (m)	Gradient (%)	Drain Invert Level (m AHD)	Modelled Drain Level (m AHD)	Length (m)	Gradient (%)
D1	13.00	13.30			13.00	13.30		
			145	0.2%			145	0.2%
D2	13.29	13.59			13.29	13.59		
			185	0.2%			185	0.2%
D3a	13.66	13.96			13.66	13.96		
D3b	13.96	14.26			-	-		
			323	0.2%			-	-
D6	14.60	14.90			-	-		

Figure 5-2 and Figure 5-3 show the modelled 50 Yr DGWL contours in plan-view over Stage 1 and the modelled groundwater level change (pre- and post- groundwater level control) at the Stage 1 northern and southern leachate ponds for the optimised layout, respectively. The groundwater modelling indicates **that the open drainage swale along the eastern boundary is not strictly required** to control the groundwater levels to below RL 14 m AHD at the Stage 1 leachate ponds.

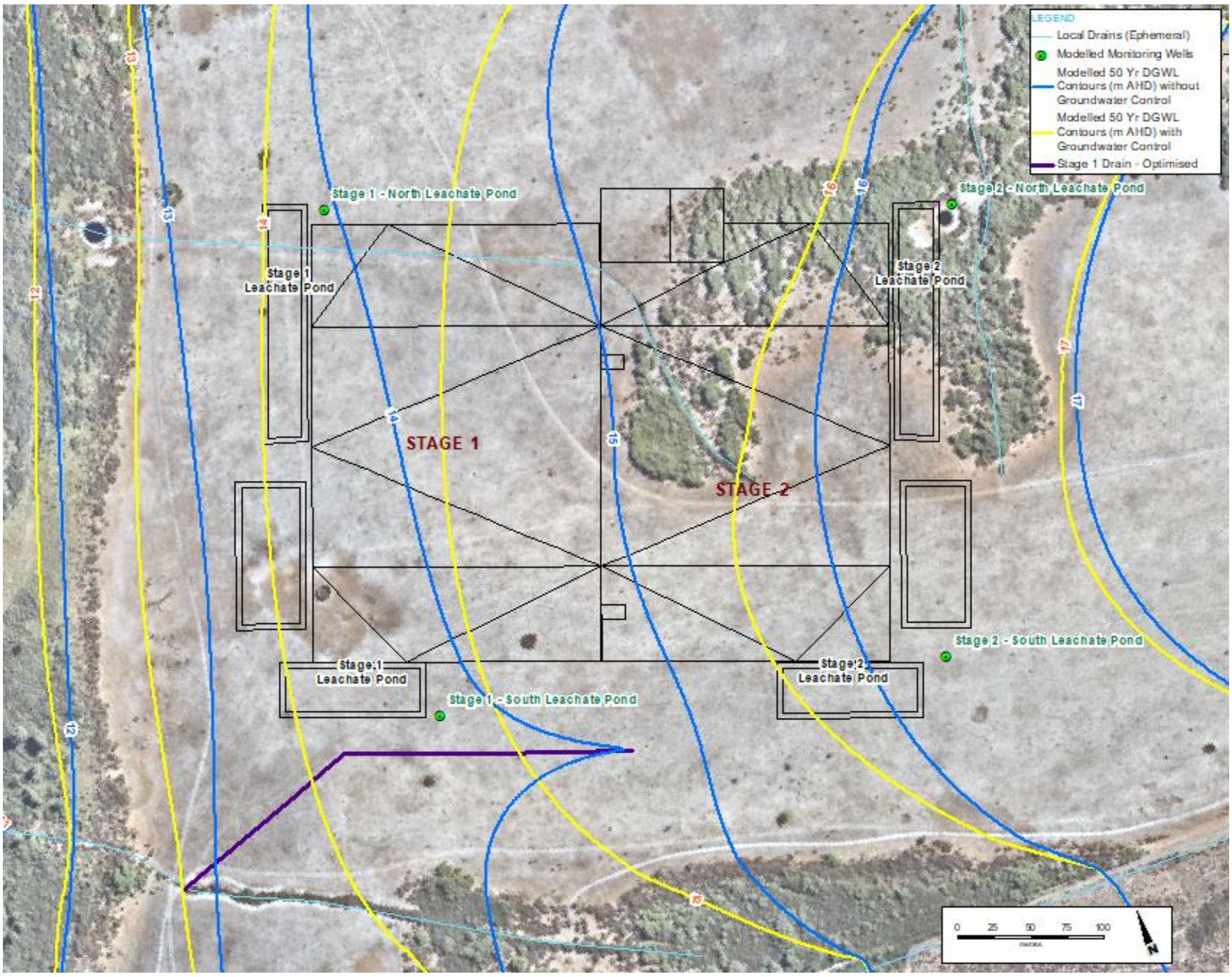


Figure 5-2 The modelled 50 Yr DGWL Pre- and Post-Groundwater Control Drainage for the Stage 1 Optimised Model Scenario.

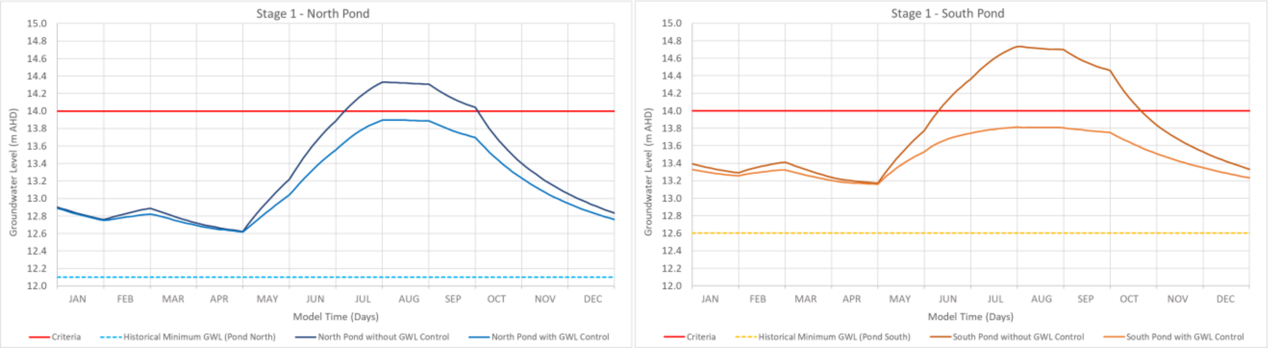


Figure 5-3 The modelled Groundwater Level Pre- and Post-Groundwater Control Drainage at Stage 1 Leachate Ponds during a 50 Yr DGWL event for the Stage 1 Optimised Model Scenario.

5.3.2 Drainage Rates and Duration

The peak modelled drainage rate during the modelled 50 Yr DGWL event is around 4 L/s with the drainage swales controlling groundwater levels between June and October (i.e. over a 5-month period). The total modelled volume for the modelled 50 Yr DGWL event is 36,000 kL at an average rate of 2.3 L/s over the 5-month period.

Based on the historical groundwater level behaviour (using DWER Well ID. 62410079), the Stage 1 groundwater control drain would have resulted in groundwater being discharged during part of the wet season in most years.

5.3.3 Effect of the Stage 1 Drains

The Stage 1 groundwater control drain could result in the following:

- A maximum annual additional discharge of 36,000 kL into the existing drainage system during the 50 Yr DGWL event (it is noted that the existing drainage system already discharges groundwater during these occurrences.
- The groundwater levels would be reduced around the groundwater control drain during the wet season only as the drain will remove the peak groundwater levels (refer to Figure 5-3). This could also reduce the groundwater level in the nearby wetland system, but the groundwater level will not be reduced to below the current seasonal low.
- The groundwater level would not be reduced to below the historical minimum groundwater level. Therefore, the risk of affecting potential ASS by oxidising soils that currently do or have historically already become desaturated naturally, is considered very low. The groundwater control drains are therefore not expected to deteriorate the groundwater quality as it will only drain groundwater during wetter parts of some wet season and therefore this drained water will consist of recently infiltrated rainfall water.

5.4 Stage 2

For Stage 2 the following model scenario was undertaken:

- **Original**: The drainage swales including 1 to 2, 2 to 3a, 4 to 5, 5 to 7 (refer to green numbers in Figure 5-1) using a minimum allowable gradient of 0.2%.

5.4.1 Groundwater Modelling Results

Table 5-2 provides the invert levels of the drainage swales for the original gradient model scenario.

Table 5-2 Modelled Invert Levels of the Drainage Swales for Stage 2 Original Gradient Scenario.

Point ID	Drain Invert Level (m AHD)	Modelled Drain Level (m AHD)	Length (m)	Gradient (%)
D1	13.00	13.30		
			145	0.20%
D2	13.29	13.59		
			185	0.20%
D3a	13.66	13.96		
			79	0.20%
D4	13.82	14.12		
			176	0.20%
D5	14.18	14.48		
			380	0.20%
D6	14.94	15.24		

Figure 5-4 and Figure 5-5 show the modelled 50 Yr DGWL contour in plan-view over Stage 2 and the modelled groundwater level change (pre- and post- groundwater level control) at the Stage 2 northern and southern leachate ponds, respectively. The results indicate that **using the minimum allowable drain gradient of 0.2% results in the drain invert level in the northern end of the eastern drain becoming too high to limit the peak groundwater level to RL 15 m AHD below the northern leachate pond** (the drain is only able to reduce the groundwater level to RL 15.3 m AHD at the northern leachate pond).

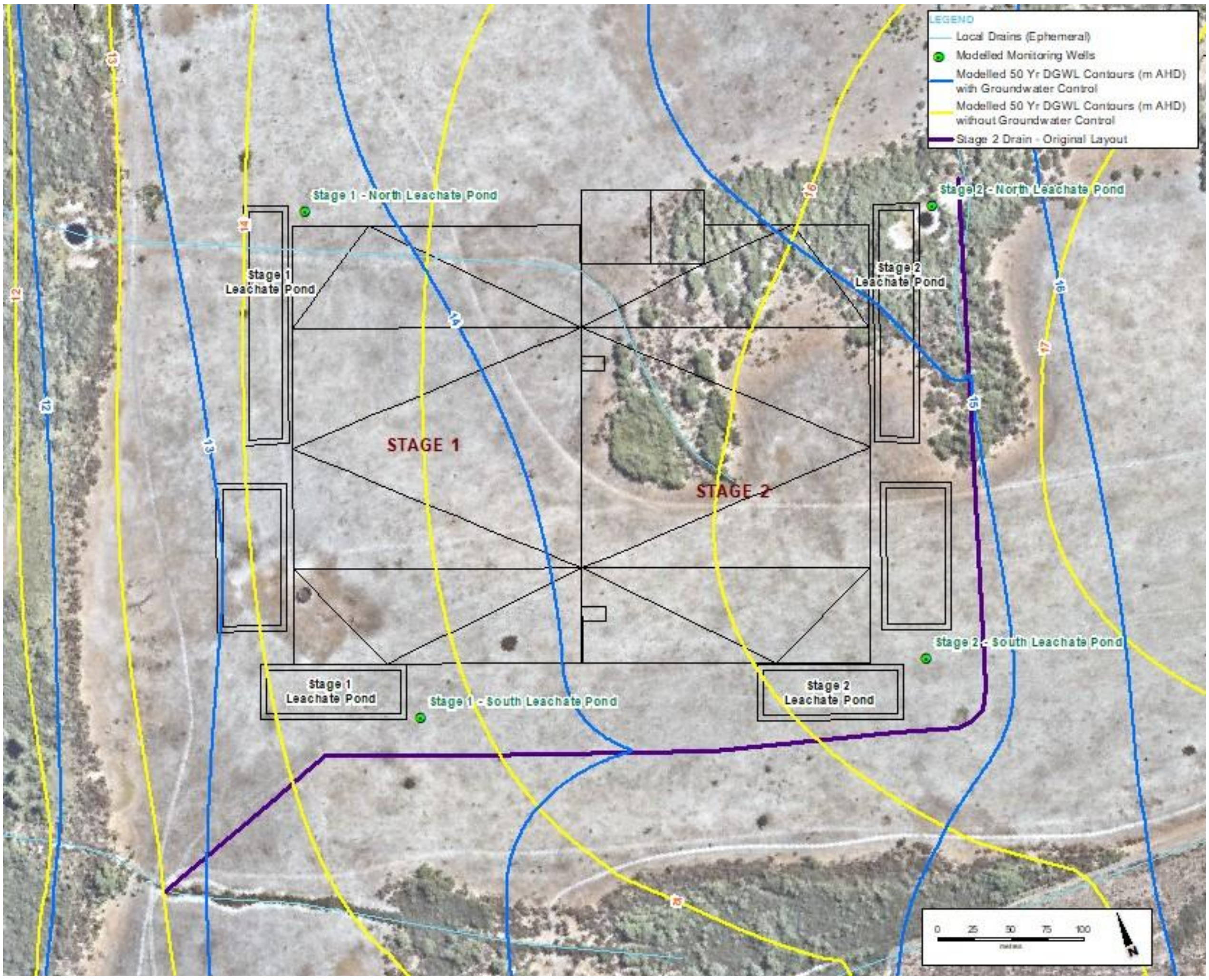


Figure 5-4 The modelled 50 Yr DGWL Pre- and Post-Groundwater Control Drainage for the Stage 2 Original Gradient Model Scenario.

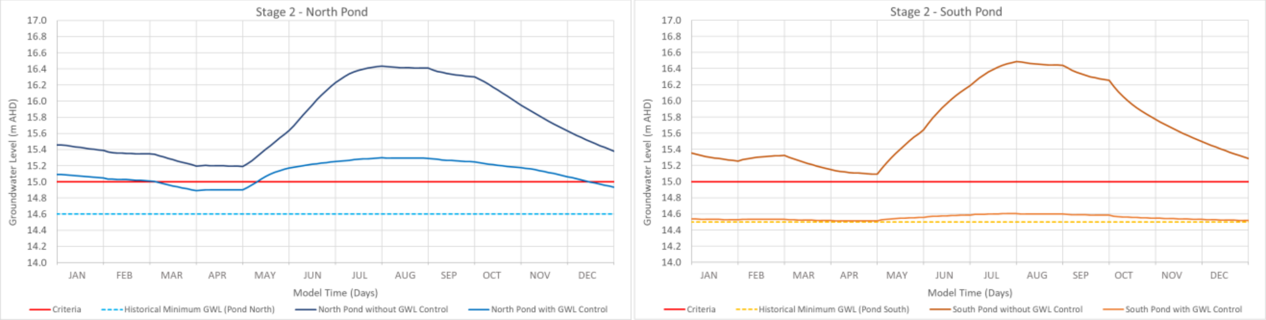


Figure 5-5 The modelled Groundwater Level Pre- and Post-Groundwater Control Drainage at Stage 2 Leachate Ponds during a 50 Yr DGWL event for the Stage 2 Original Model Scenario.

5.4.1.2 Drainage Rates and Duration

The peak modelled drainage rate during the modelled 50 Yr DGWL event is 12 L/s with the drainage swales controlling the groundwater levels all year around in the south-eastern corner of the system. The total modelled volume for the modelled 50 Yr DGWL event is 159,000 kL at an average rate of 5 L/s over that calendar year.

Based on the historical groundwater level behaviour (using DWER Well ID. 62410079), the Stage 2 groundwater control drain would have resulted in groundwater being discharged every year in the last 50 years, and in most years the drain would discharge all year round.

5.4.1.3 Effect of the Stage 2 Drain

The Stage 2 groundwater control drain scenario could result in the following:

- A maximum annual additional discharge of 159,000 kL into the existing drainage system, with groundwater also discharging into the existing drain during the dry season (when the existing drain is currently dry).
- The groundwater level control drains in the southeastern corner of the site would reduce the groundwater levels to just above the estimated HMinGWL in this area. This would result in a reduction in groundwater level in the nearby wetland system to the south, with a potential risk of affecting/changing the ecology of the wetland. It is noted that this assessment has been made on the current data, and as further groundwater data is collected, the design controls for Stage 2 should be reassessed and updated, if required. This update should ensure that the groundwater control level would not result in undue effect on the surrounding wetlands. C-WISE should engage with the regulator to provide additional detail on the Stage 2 groundwater level control system design if/when this stage is constructed.
- The groundwater levels in the southeastern corner of the site would not reduce to below the estimated HMinGWL in this area but would increase the risk of oxidising potential ASS (if it is present in this area) that has only historically once been naturally desaturated. This could affect the groundwater quality in this area (e.g. further reduction in the pH and increase in metal concentrations). As with the above, this assessment has been made on the current data, and as further groundwater data is collected (refer to Section 7.0), the design controls for Stage 2 should be reassessed and updated, if required. This update should ensure that the groundwater control level would not result in undue effect on potential ASS. C-WISE should engage with the regulator to provide additional detail on the Stage 2 groundwater level control design if/when this stage is constructed.

5.5 Required Groundwater Monitoring Network and Program

A groundwater monitoring network will be required as part of the groundwater level control drainage system that allows for collection of groundwater level and quality data at the leachate ponds as well as assessing the groundwater level changes caused by the drainage system.

Figure 5-6 shows the proposed minimum groundwater monitoring network related to the groundwater level control drainage system. Though the Stage 2 monitoring wells could be installed later when Stage 2 will/has been constructed, it is recommended that they are installed during the Stage 1 construction works, because this will assist with verifying/revising the Stage 2 drainage system design when it is required.

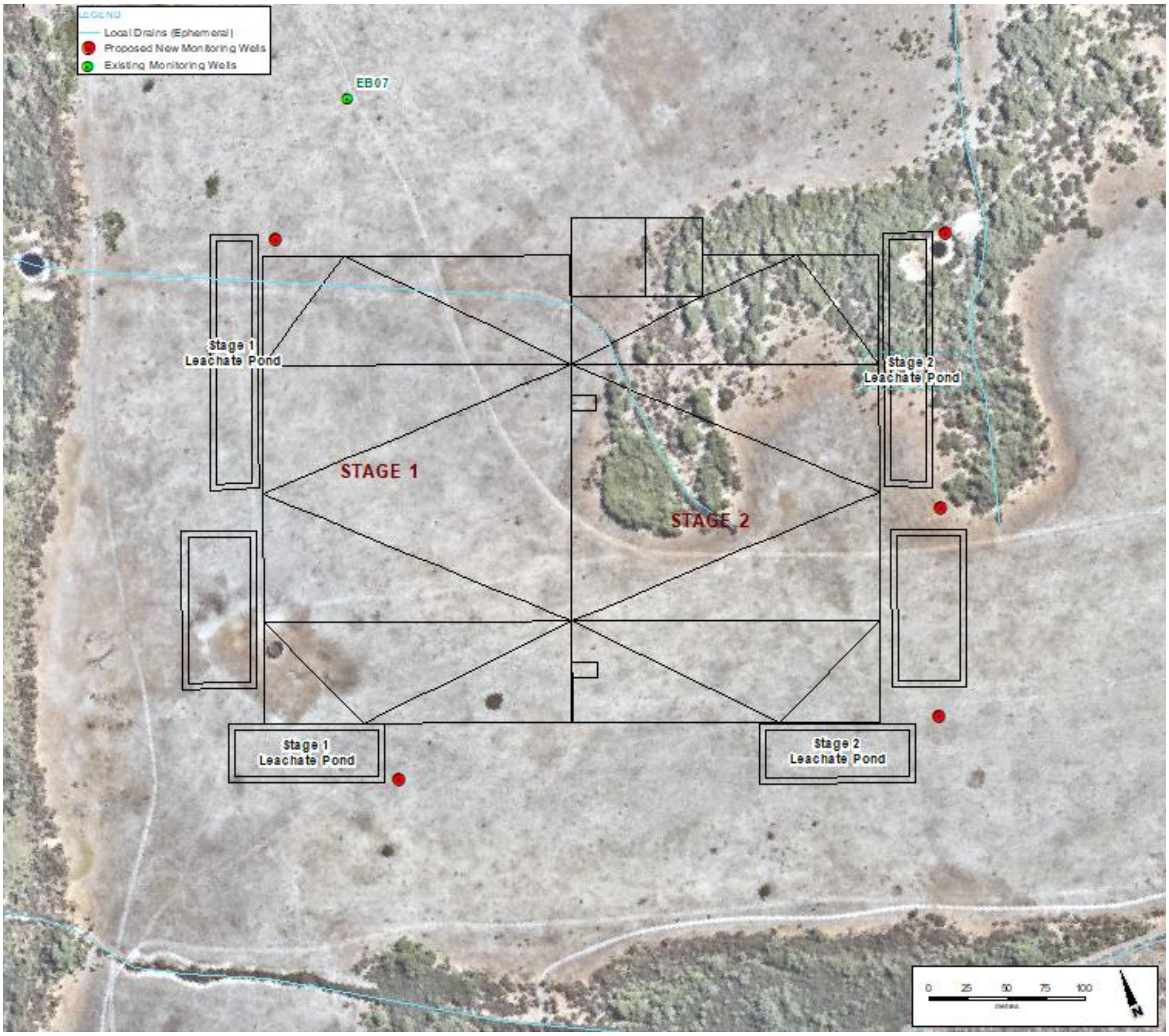


Figure 5-6 The Proposed Minimum Groundwater Monitoring Network related to the Groundwater Level Control Drainage System.

We recommend that automated groundwater level loggers be installed in a minimum of the four wells located hydraulic upgradient of the four leachate ponds with a proposed hourly monitoring frequency (maximum daily frequency). The loggers are recommended to be downloaded and plotted on a quarterly basis (minimum twice per year).

6. Conclusion

The conclusion of this Groundwater Level Management Study is as follows:

- The additional groundwater level monitoring undertaken at the site since the Groundwater Level Study undertaken by WSP in May 2023 verifies the design groundwater levels prepared during that study. The data also continues to indicate that perched groundwater levels (even during the wet season) are not present at the site.
- A groundwater level control network consisting of open drainage swales and sub-soil drains (where space is tight) should be able to successfully lower the peak groundwater levels to the required values of RL 14 m AHD below the Stage 1 leachate ponds and RL 15 m AHD below the Stage 2 leachate ponds. The Stage 1 groundwater level control drainage network is estimated to drain groundwater for a period of 5 months during a 50 Yr DGWL event year. The total modelled volume for the modelled 50 Yr DGWL event is 36,000 kL at an average rate of 2.3 L/s over the 5-month period. Based on the historical groundwater level behaviour (using DWER Well ID. 62410079), the

Stage 1 groundwater control drain would have resulted in groundwater being discharged during part of the wet season in most years, keeping the groundwater within typical seasonal groundwater level variation and thereby the risk of undue detrimental effect on the environment is low.

- For Stage 2 the required groundwater level lowering is higher than for Stage 1. The currently proposed groundwater level control drainage system along the southern and eastern boundaries of the Stage 2 Carbon Recycling Facility could have the following issues:
    - The set minimum drain gradient of 0.2% (typical industry standard) would not be able to lower the peak groundwater level below the northern Stage 2 leachate pond to the required level of RL 15 m AHD (it can only lower it to RL 15.3 m AHD).
    - The drainage network would likely flow almost all year around with a maximum annual groundwater drainage volume of 159,000 kL during a 50 Yr DGWL event (maximum drainage rates would be 12 L/s).
- For Stage 2, though the resulting groundwater level lowering from the groundwater control drainage system is higher compared to Stage 1, the modelling indicates that the resulting groundwater levels can be kept above the estimated historical minimum natural groundwater level, which reduces the risk of detrimental environmental impacts.

7. Recommendations

We provide the following recommendations:

- A groundwater level monitoring network should be installed as part of the groundwater level control drainage system that allows for collection of groundwater level and quality data at the leachate ponds as well as assessing the groundwater level changes caused by the drainage system.
    - The Stage 2 monitoring wells should be installed already during the Stage 1 construction works, because hydrographs from these wells can then be used to verify/revise the Stage 2 drainage system design, when Stage 2 will be constructed.
    - Automated groundwater level loggers should be installed in a minimum of the four wells located hydraulic upgradient of the four leachate ponds with a proposed hourly monitoring frequency (maximum daily frequency). The loggers are recommended to be downloaded and plotted on a quarterly basis (minimum twice per year).
    - The existing groundwater level logger and barotroll should be kept in monitoring well EB07, which is used to provide continuous baseline values throughout construction and operation of Stage 1, which can then be used for verification/revision of the DGWL for Stage 2.
- Update and refine the groundwater model prior and Stage 2 drainage design prior to the construction of the Stage 2, based on the operational experience of the Stage 1 drainage system and the additional groundwater level monitoring data collected during the operation of Stage 1, to achieve the required 1.5 m groundwater level separation beneath the northern leachate pond. This could for example include assessing the possibility of reducing the gradient of the swale in key areas or assess potential alternative drainage layouts to achieve the required 1.5 m groundwater level separation, and to minimise any effects to groundwater quality and adjacent wetlands.
- Consider installing a pumping well adjacent the Stage 2 northern leachate pond. This pumping well could then be used to lower the groundwater level locally at the Stage 2 northern leachate pond during a 50 Yr DGWL event. It is expected that the pumping well would likely only be required less than 5 times during the design life of the facility. The pumping well could be installed with an automated level switch that would turn on the pump if the groundwater level in the well reaches a certain trigger level (proposed to be set at RL 14.7 m AHD).

8. References

Emerson Stewart 2008. Keralup District Water Management Strategy: Working Paper 1 – Study Definition.

Emerson Stewart 2009. Keralup District Water Management Strategy: Working Paper 3 – Groundwater Study.

Talis (2023a). Earth Work Plan Layout. TW211124-C-104 Rev B dated 2 March 2022.

Talis (2023b). Surface Water and Leachate Management Layout – Stage 1. TW211124-C-106 Rev A dated 2 March 2022.

WSP (2023). Groundwater Level Study. Proposed East Keralup Facility, May 2023 (WSP Ref. PS134349-WSP-PER-GEO-REP-00001 Rev A)

9. Closing Remarks

We trust that this supporting Groundwater Level Management provides sufficient information for the feasibility of the proposed groundwater level control management at the proposed new East Keralup Carbon Recycling Facility.

Finally, we draw your attention to the attached Important Information about your FSG report included in Appendix C.

Please contact the undersigned if any further information or clarification is required.

Regards,

Allan Lundorf

Allan Lundorf
Senior Principal Groundwater Engineer

Appendix A

Groundwater Level Study by WSP, May 2023

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May 2023

Confidential

Groundwater Level Study

Proposed East Keralup Facility

Question today
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Groundwater Level Study
Proposed East Keralup Facility

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Rev	Date	Details
A	12 May 2023	Draft report for client review

	Name	date	signature
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Reviewed by:	Allan Lundorf	12 May 2023	
Approved by:	Allan Lundorf	12 May 2023	

WSP acknowledges that every project we work on takes place on First Peoples lands.
We recognise Aboriginal and Torres Strait Islander Peoples as the first scientists and engineers and pay our respects to Elders past and present.

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Table of contents

1 Introduction

This report presents the results of a groundwater level study undertaken by WSP Australia Pty Ltd (WSP) for C-Wise for a new processing plant facility (the site) located in East Keralup, Western Australia. The location of the groundwater study area is provided in Figure 1.

The work was authorised by Greg Watts (C-Wise) on 12 October 2022.

1.1 Project Background

C-Wise is proposing to construct a new processing facility in the south-east corner of Keralup (East Keralup Land Development Area). The proposed facility comprises a carbon storage area, liquid waste receival/storage, fuel store/service bay, workshop, office, car park, and an access road and will mainly be constructed on a dune sand ridge which currently exists at the site.

A detailed Keralup District Water Management Strategy (KDWMS) has been prepared by Emerson Stewart in 2008/2009. As part of this study three monitoring wells were installed within the site as part of a regional groundwater level monitoring program over the whole KDWMS area and a groundwater level assessment (maximum and minimum groundwater levels) was undertaken including development of a regional groundwater model for the area. One of the main conclusions from the KDWMS was that coffee rock is present over the whole study area resulting in the presence of a perched aquifer. It is noted that DWER comments provided to the KDWMS disputes this to be the case.

C-wise has advised that Department of Water and Environmental Regulation (DWER) nominate a required separation between the development and the prevailing water table but not the perched ephemeral water table.

1.2 Objectives

The objectives of this study are:

- Assess the groundwater level behaviour beneath the site (Sections 2 and 3).
- Assess if a perched aquifer (above the coffee rock) is present beneath the site (Section 2.8).
- Prepare Average Annual Maximum Groundwater Levels (AAMGL) and Design Groundwater Levels (DGWL) for the site (Section 4).

1.3 Scope of Work

The following scope of work has been carried out to meet the objectives:

- A desktop review of provided and publicly available information, including:
  - A review of available long-term groundwater level data and lithological data (pertaining to ‘coffee rock’) from the DWER online Water Information Reporting (WIR) database.
  - A review of reports provided by C-Wise including Emerson Stewart (2008, 2009a, and 2009b), Western Environmental (2021), and Coterra Environment (2021).
  - A review of groundwater levels provided by C-Wise for their current site.
- A site visit on 14 November 2022 which included:
  - A site walkover to obtain a better understanding of the site layout and conceptual hydrogeology.

  - Inspection of three historical groundwater monitoring wells installed by Endemic Pty Ltd in 2008 (referred to from hereon as EB07, EB08 and EB09) to determine their operational status.
  - Measure the groundwater level in the three site groundwater monitoring wells.
  - Undertake hydraulic (slug) testing in three site monitoring wells to estimate the hydraulic conductivity of the screened aquifer.
  - Installation of a groundwater level logger in each of the three site groundwater monitoring wells (including a barometric logger at EB07).
  - Undertake a hand auger borehole to the top of the groundwater level at EB07.
- A site visit on 15 March 2023 which included:
  - Manual groundwater level measurements and download of groundwater level loggers.
  - Survey of the three existing wells (EB07, EB08 and EB09) within the site.
  - Survey of an additional 17 locations across the site (refer to Figure 2)
    - Four existing ponds across the site, three of which had water in them during the survey (the water level was surveyed and for the dry pond the pond bed was surveyed).
    - Twelve surface water drain locations across the site (none of the drains had water in them during the survey, so the drain inverts where surveyed where possible).
- Estimation of the Average Annual Maximum Groundwater Level (AAMGL) and 50 Yr Design Groundwater Level (DGWL) for the site using the available data.

1.4 Provided Information

The following information has been provided by C-Wise:

- Keralup District Water Management Strategy: Working Paper 1 – Study Definition (Emerson Stewart, 2008).
- Keralup District Water Management Strategy: Working Paper 3 – Groundwater Study (Emerson Stewart, 2009).
- Geotechnical Soil Bore Engineering Logs (Endemic Pty Ltd 2008)
- 320 Gull Road, Keralup: Baseline Environmental Report (Western Environmental, 2021).
- Baseline Environmental Report: Keralup Landholdings – Site 4 (Coterra Environment, 2021).
- Proposed project drawings (3314.A2.1 to 3314.A2.5) (C-Wise, 2022).
- General Arrangement Drawing (TW21124-C-100-RevD) (Talis Consultants, 2022)
- Groundwater level Monitoring Data (January 2019 to October 2022) from C-Wise groundwater level monitoring network at the existing plant (email on 27 February 2023).

2 Site Setting

2.1 Site Description

Figure 2 shows the Site Plan for the proposed new site which is located approximately 1.9 km north of the existing C-Wise plant facility and covers an area of around 20 Ha within the planned Keralup Industrial Park. The proposed plant area is located in the western part of the site with a total area of approximately 20 Ha.

The site is currently considered a greenfield site and used for grazing purposes. The site consists of shrubs, trees and open area with several natural and man-made water holes. A new road has recently been constructed to the west and northwest of the site. The rest of site is bordered by greenfield areas with the closest infrastructure being C-Wise’s existing plant to the south.

2.2 Topography

Figure 2 shows the 1m LIDAR data across the site which range between RL 10 m AHD and RL 22 m AHD. The lowest surface elevations occur in the western part of the site. A 3 m to 6 m high sand dine ridge (topographic high) exists along the southern boundary of the site.

The existing surface elevation over the proposed plant area range between RL 14 m AHD and RL 20 m AHD.

2.3 Climate

Figure A shows the average monthly rainfall from 2001 to 2022 (except 2014 where no data is available) for the Hopelands Rainfall Station (BOM ID 9253), which is located approximately 10 km north of the site. The average annual rainfall is 704 mm/year with the wet season occurring from May to September where about 80% of the rainfall occurs.

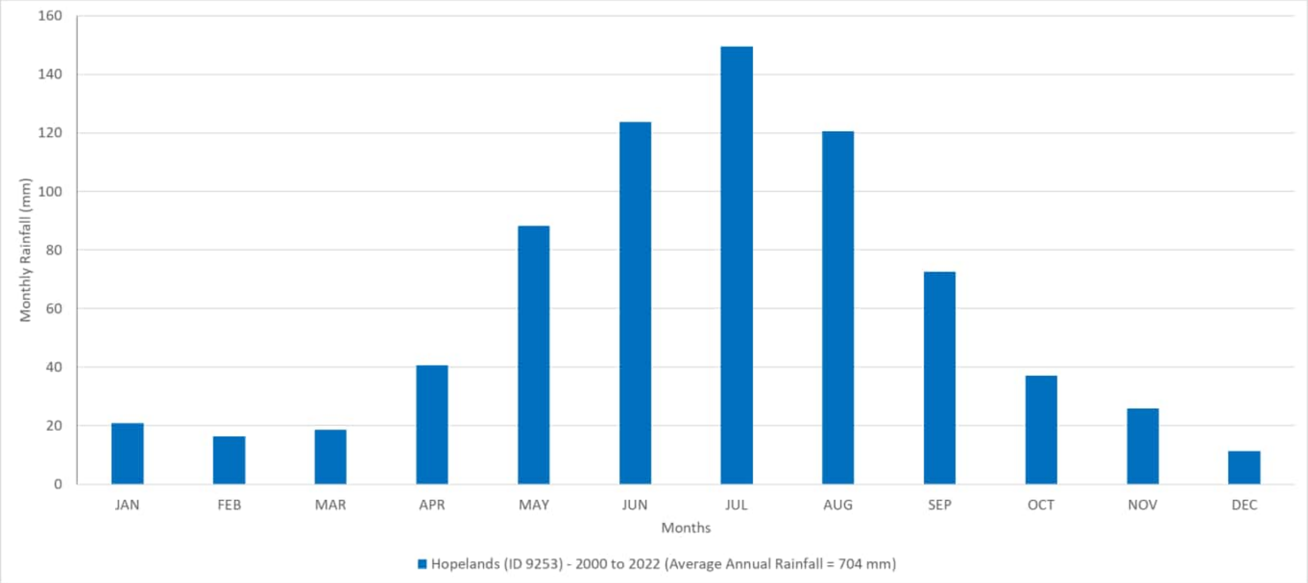


Figure A: Average Monthly Rainfall for Hopelands Rainfall Station (BOM ID 9253) from 2001 to 2022.

The Mandurah Rainfall Station is located 7.5 km southwest of the site (i.e. closer to the site), but given that the Hopelands Station is at a similar distance from the coast as the site, The Hopelands Station is considered more representative.

2.4 Geology

2.4.1 Regional Geology

Figure B presents a geological cross-section (excerpt from DoW 2010). The cross-section traversing west to east is located approximately 2.5 km north of the site, but still provides a good understanding of the general regional geological setting.

The geological cross-section (green square is the approximate site location) indicates that the site is underlain by Bassendean Sand, overlying Gnangara/Rockingham Sand, which is overlying the Leederville Formation. The most important feature of this cross-section is to notice the shallow thickness of the superficial sand over the site.

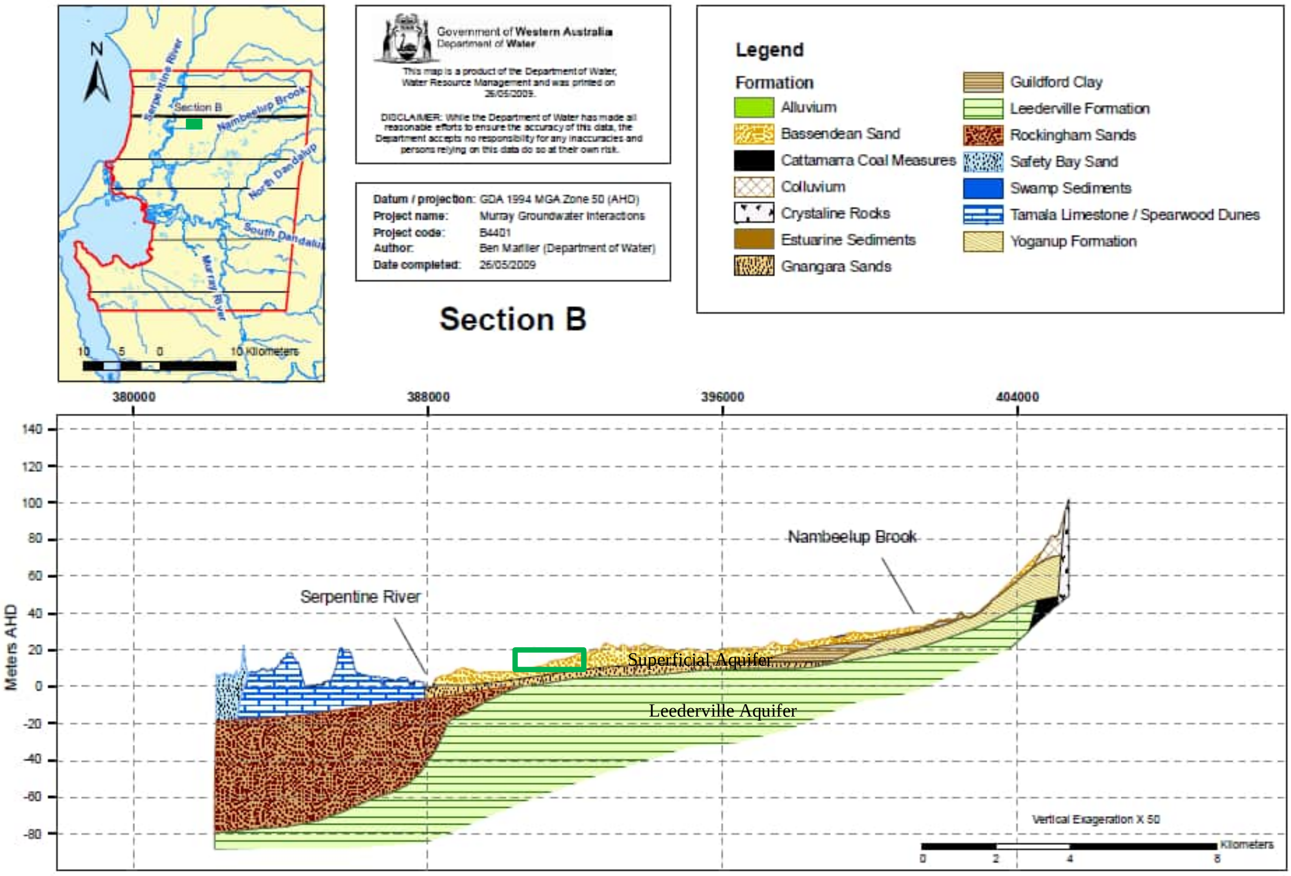


Figure B: Regional Geological Cross-Section near the site (excerpt from DoW 2010).

2.4.2 Local Geology

The Geological Survey of Western Australia's (GSWA) Environmental Geology Series 1:50,000 Rockingham sheet (2033 II and III) indicates that the study area is underlain by:

- *Bassendean Sand* – SAND (S8) described as white to pale grey at surface, yellow at depth, fine to medium-grained moderately sorted subangular to subrounded minor heavy minerals of eolian origin, with a high permeability.
- *Thin Bassendean Sand over Guildford Formation* – SAND (S10) over sandy clay to clayey sand of the Guildford Formation of eolian origin.
- *Swamp Deposits* – PEATY CLAY (Cps) described as dark grey and black, soft variable organic content, some quartz sand in places, of lacustrine origin with low permeability.

The S8 is reported in the area over the site where the sand dune ridge exists, while S10 is reported over the rest of the site where the elevations are lower. The swamp deposits are present in a small area in the south-eastern corner of the site.

It is noted that the described surface geology is different on the geological map than the cross-section presented in Section 2.4.1, with the Guildford Formation shown to be prevalent in the area beneath a thin layer of Bassendean Sand. To our knowledge no drilling to the base of the superficial formations (i.e. to the top of the Leederville Formation) has been undertaken at the site. The presence of low-lying wetlands areas and the drainage pattern would suggest that the Guildford Formation (a lower permeability layer) is present in the area. The geological map is therefore considered to be more representative of the sub-surface geological site conditions than the DoW 2010 cross-section.

2.4.2.1 Coffee Rock

Coffee rock is typically a dark brown to black friable variably cemented iron and/or organic rich sand, which can often be found in Bassendean Sand near the historical groundwater level. The consolidation, thickness and extent of the coffee rock can be highly variable. The coffee rock is known to sometimes create local perched aquifers (i.e. rainfall recharge water will perch on top of the coffee rock) due to its cementation and thereby low permeability.

Coffee rock has been reported in majority of lithological logs across the area.

2.4.3 Acid Sulfate Soils (ASS)

The DWER ASS risk map indicates that the site is located within a low to medium risk area for encountering ASS within 3 m from the surface. The swamp area in the south-eastern corner of the site where the geology is peaty clay is reported as a high risk area.

Coterra undertook a baseline environmental investigation in April 2021 (Coterra 2021) for the wider Keralup Landholdings site. The report also referred to a preliminary ASS investigation undertaken by Coffey in 2009, which indicated that 26% of all analysed samples from 39 locations indicated the presence of ASS within 4 m from the surface (only 1 sample seems to have been taken from within the C-wise site and it is not reported if samples from this location detected the presence of ASS).

From experience, both Bassendean Sand and Guildford Formation are known to contain potential ASS below the groundwater table. In some cases, the Bassendean Sand is referred to as an acidic soil but has similar characteristics in that it can cause acidic groundwater conditions with limited buffering capacity.

2.5 Surface Water

The two largest regional surface water features in the area are the Serpentine River located approximately 4 km west of the proposed plan site centre and Nambeelup Brook located approximately 3 km east of the centre (refer to Figure 3). Both surface water features flow in a south and south-westerly direction where they eventually discharge into the Peel Inlet.

The area between the Serpentine River and the Darling Scarp is known as a Palusplain area, which is classified by DWER as multiple use geomorphic wetlands due to the shallow groundwater table and occurrence of surface water inundation. These areas are found to have a dense surface drainage network (natural and man-made) to drain the area.

2.5.1 Drainage

Figure C shows the drainage network presented in the KDWMS (Emerson Stewart, 2008), and indicates that a dense drainage network is present within and around the site. This indicates that surface water drains exist at the base of the sand dunes in the lower lying and flatter parts of the site. The presence of the drains were confirmed during the site walkover and survey in March 2023. Some of the drains within the site are quite shallow, while the drains along the site boundaries are deeper. The drains are expected to drain rainfall runoff and some of the deeper drains would also control/drain the groundwater during the wet season. It is noted that all these surface water drains are ephemeral (i.e. do not flow all year around). During the site visit in March 2023 all of the drains were dry (as expected).

Figure C: Drainage lines presented in KDWMS (excerpt from Emerson Stewart (2008))

2.5.2 Surface Water Inundation and Drainage

A review of historical aerial photographs from Nearmap and Landgate indicates that parts of the site (lower and flatter areas) are wet and possibly prone to surface water inundation during the wet season. If the open drains were not installed it is expected that larger areas could get inundated. Figure D shows the aerial photograph from 25 August 2017 where several wet areas, ponds and wetlands and the surface drains have water in them (no rainfall occurred the week before the aerial photograph was taken, but prior to that 111 mm of rainfall had occurred over a 9 day period).

Figure D: Example of Drainage and Surface Water over the Site Area (photo from Nearmap - 25 August 2017).

2.6 Groundwater

2.6.1 Aquifers

There are two main regional aquifers underlying the site: the Superficial Aquifer and the Leederville Aquifer. The Superficial Aquifer comprise all the geological units above the Leederville Aquifer. The two aquifers are often separated by an aquitard (low permeability unit), but in some areas they are directly connected. In this area the Guildford Formation may in some areas act as the aquitard.

2.6.1.1 Perched Aquifer

A perched water table or aquifer is an aquifer that occurs above the regional water table or aquifer. The perched aquifer forms when there is an impermeable layer (aquitard) above the regional aquifer but below the land surface, which makes water perch on top of this layer. Typically for perched water there would be an unsaturated zone between the perched aquifer and the regional aquifer.

In the Perth region the seasonal variations in the perched aquifer and regional aquifers typically differs and it is not uncommon that the perched aquifers only exist during the wet season and then dries out during the dry season.

The KDWMS described that the occurrence of coffee rock has resulted in a perched aquifer of groundwater above the coffee rock across the whole Keralup area (i.e. they concluded that near surface groundwater is prevented from freely infiltrating into the lower sands by the low permeability coffee rock and thus acts as an aquitard which separates the surface sand layers from the deeper sand layers). It is noted that DWER does not consider that this conceptual understanding is supported by the existing data (Comment B.1 in Appendix E of Emerson Stewart 2009).

Based on the collated data, we are in agreeance with DWER and do not consider that a large scale perched aquifer exists in the area. It is acknowledged that locally perched conditions may exist in some areas, but it is considered that the observed groundwater levels form part of the regional Superficial Aquifer (refer further to Section 2.7).

2.6.2 Hydraulic Properties

The groundwater modelling report (DoW 2012) uses a horizontal hydraulic conductivity range between 5 and 15 m/day for Bassendean Sand.

Table 2.1 summarises the estimated hydraulic conductivity from the three monitoring wells located within the site boundary based on hydraulic (slug) testing results. It is noted that from experience hydraulic testing can provide the lower range of the actual hydraulic conductivity in permeable material. The results fit well with the DoW 2012 report and publicly available literature on Bassendean Sand.

Table 2.1 Hydraulic (slug) testing results

Well ID	**Screened Interval (m bgl)**	**Screened Geology**	**Screen in Relation to Coffee Rock**	**Hydraulic Conductivity (m/day)**
EB07	5.9 – 8.9	Geology only described to 5 m	Below	4
EB08	2.4 – 5.4	White medium sand	Across	9 - 11
EB09	2.7 – 5.7	White medium sand	Above	7 - 9

2.6.3 Groundwater Quality

Western Environmental undertook groundwater quality sampling in February 2021 in 8 monitoring wells in the Keralup Landholdings area, of which 2 wells (EB07 and EB09) are located within the site (Western Environmental 2021). The review of the groundwater quality results indicates that the results are generally similar across the wider area, but this section only discusses the results from EB07 and EB09. Table 2.2 presents the groundwater quality results for selected parameters for the two wells located within the site.

Table 2.2 Selected Groundwater Quality Results from EB07 and EB09 from February 2021.

Parameters	**Units**	**EB07**	**EB09**
Field pH	pH unit	**4.50**	**3.73**
Field Electrical Conductivity	uS/cm	185	149
Total Acidity	mg/L	37	17
Total Alkalinity	mg/L	<20	<20
Chloride	mg/L	39	17
Sulfate	mg/L	<5	<5
Total Aluminium	mg/L	**0.53**	**0.38**
Total Iron	mg/L	**0.75**	0.14
Total Nitrogen	mg/L	**1.1**	**2.4**
Total Phosphorous	mg/L	**0.44**	**0.22**

Note: Bold is when the concentration is outside of Freshwater Guidelines for slightly to moderate disturbed systems.

The groundwater quality results indicate:

- The groundwater is fresh and acidic.
- The chloride and sulfate concentrations are generally low for groundwater.
- The net alkalinity (acidity minus alkalinity) is negative, suggesting that the groundwater has limited to no buffering capacity to maintain a stable pH. This can already be seen with the groundwater being acidic.
- The nutrient concentrations are above typical regulatory guidelines for disposal into the environment.
- Metal concentrations are less than 1 mg/L, but total aluminium is higher than regulatory guidelines.

The groundwater quality results could indicate that the groundwater has or is being affected by ASS or acidic soils.

2.7 Groundwater Level Data

2.7.1 Regional Publicly Available Groundwater Level

The 1997 Perth Groundwater Atlas, which presents inferred historical maximum groundwater level contours, does not cover this area.

The 2004 Perth Groundwater Atlas, which presents the inferred May 2003 (dry season) groundwater level contours indicates that the groundwater levels range between about RL 9 m AHD at the western site boundary and RL 13 m AHD at the eastern site boundary. The groundwater flow direction is depicted to be in a westerly direction toward the Serpentine River.

Figure E shows the groundwater level contours for the Superficial Aquifer together with flow-net flow lines (DoW 2010) and indicates that the groundwater level range between about RL 8 m AHD and RL 15 m AHD with westerly flow direction. It is noted that the year or season of the groundwater level contours are not provided. The figure also shows that Nambeelup Brook drains groundwater, creating a groundwater divide just southeast of the site.

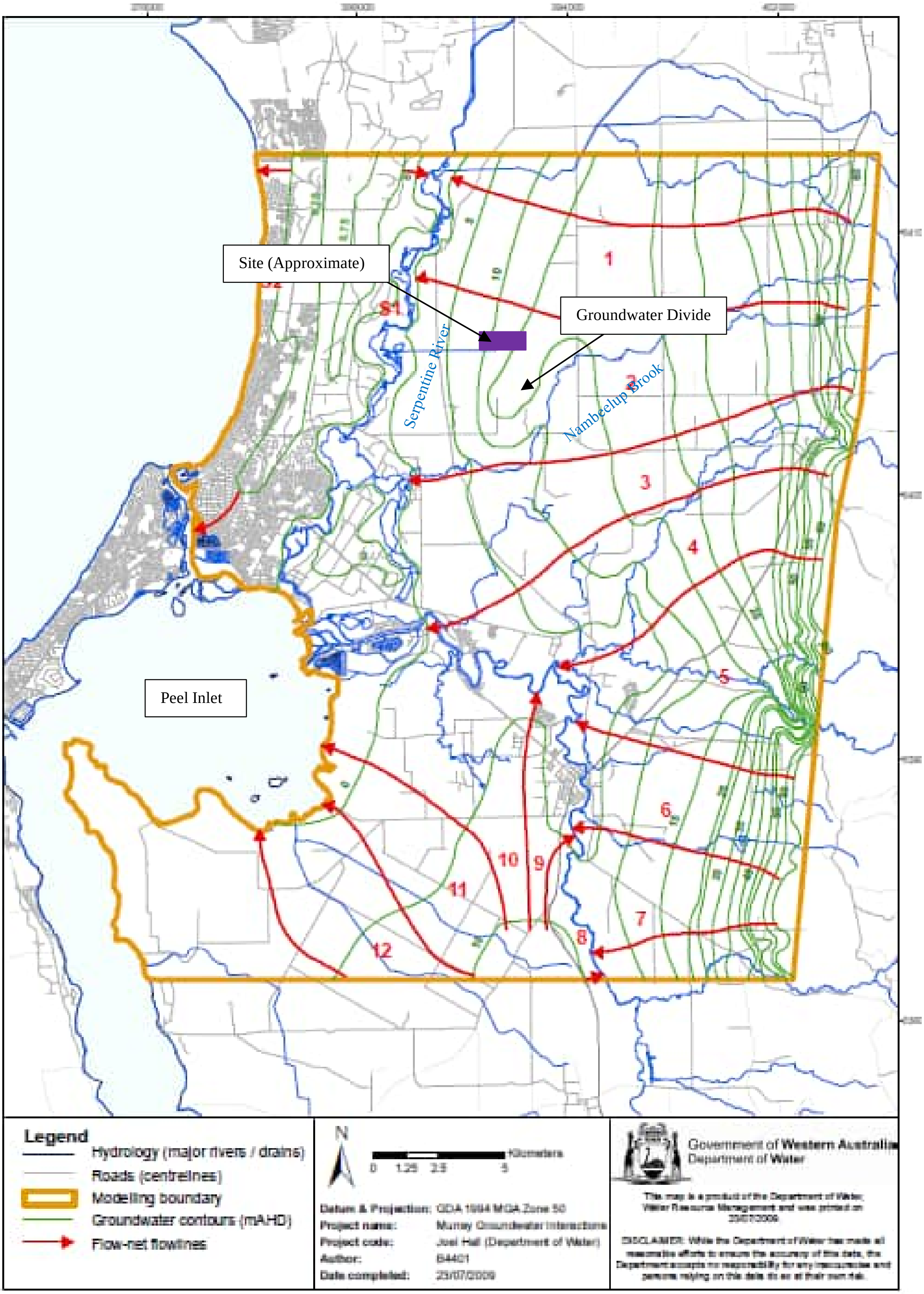


Figure E: Groundwater Level Contours and Flow-Net Lines (excerpt from DoW 2012)

2.7.2 DWER Database

A search of the DWER Water Information Reporting (WIR) database was undertaken around the site. Figure 3 shows selected monitoring wells with historical groundwater level data from the Superficial Aquifer. Figure F presents the hydrographs from selected monitoring wells installed in Superficial Aquifer and indicate:

- Historical groundwater level data range from around 1975 to 2023 (i.e. almost 50 years).
- When compared to the annual rainfall from 2001 onwards, the groundwater levels generally seem to follow the rainfall, suggesting that the rainfall recharge is one of the main mechanisms in groundwater level changes.
- The groundwater levels show a rising trend in the 1980s and are then steady to around 2010. The 2010 rainfall was particularly dry, which in some wells resulted in a decline of groundwater level by more than 1 m. Since 2010 the groundwater levels have generally been steady or slightly increasing.

Appendix A present a summary table of well construction details of the selected wells.

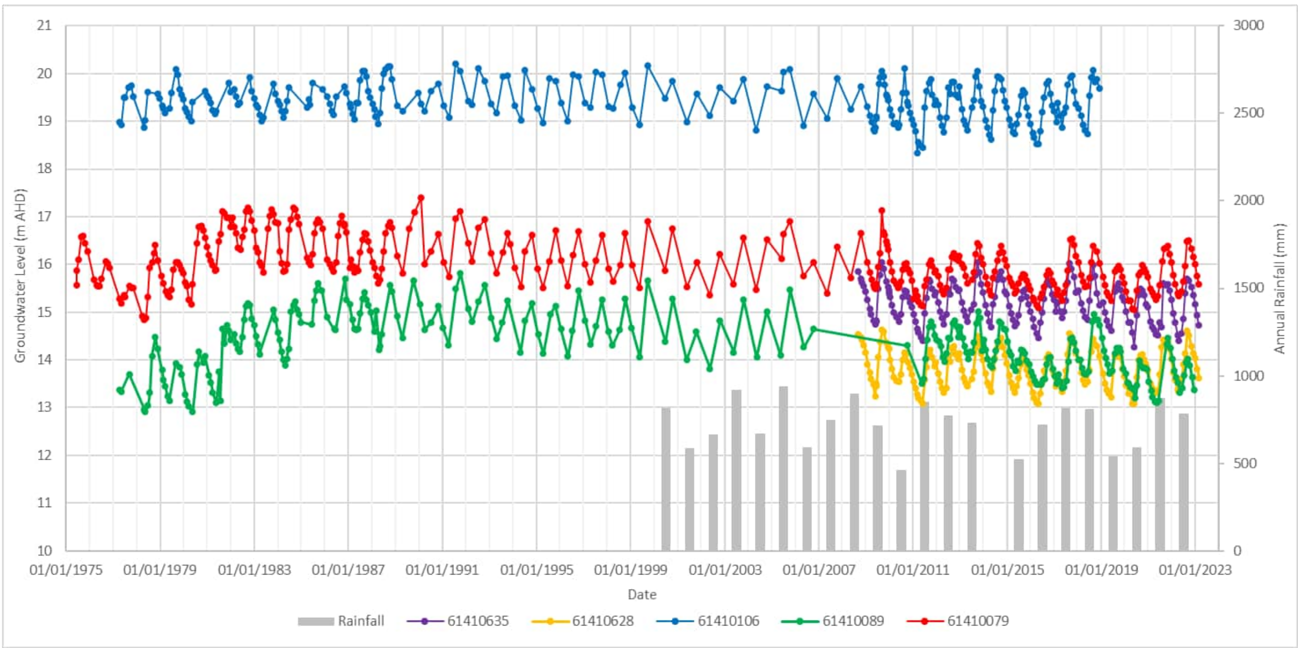


Figure F: Selected Hydrographs from DWER Database.

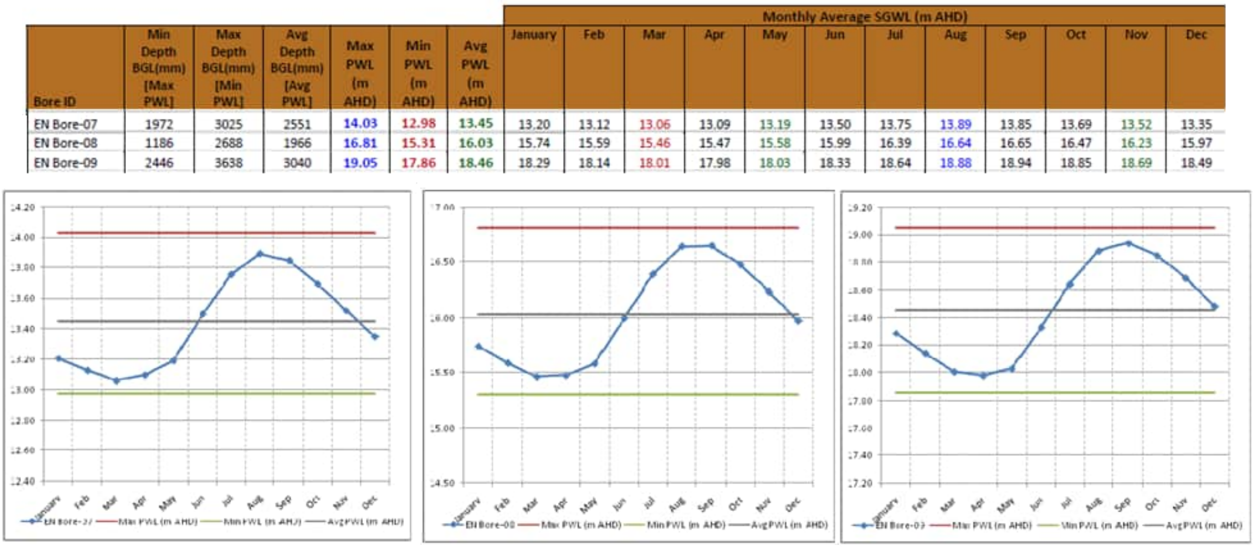
Following a review of all the hydrographs in the area, it is considered that the hydrograph from monitoring well 61410079, which is located approximately 2.3 km south of the centre of the proposed plant area, best represents the groundwater levels at the site (refer to Section 4).

2.7.3 KDWMS Groundwater Level

As part of the KDWMS, Emerson Stewart developed a groundwater model and undertook some groundwater modelling to estimate the average annual maximum groundwater level, however it is not clear what period the average groundwater level covers. Figure G presents the groundwater modelling results for the three monitoring wells (EB07, EB08, EB09) within the site (excerpt from Emerson Stewart 2009).

The results from the KDWMS indicate:

- The maximum groundwater level elevations were estimated to be RL 14.0 m AHD, RL 16.8 m AHD and RL 19.0 m AHD in monitoring wells EB07, EB08 and EB09, respectively.
- The average seasonal groundwater level variations were estimated range between 0.83 m and 1.18 m in the three monitoring wells.



Bore ID	Min Depth BGL(mm) [Max PWL]	Max Depth BGL(mm) [Min PWL]	Avg Depth BGL(mm) [Avg PWL]	Max PWL (m AHD)	Min PWL (m AHD)	Avg PWL (m AHD)	Monthly Average SGWL (m AHD) January	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
EN Bore-07	1972	3025	2551	14.03	12.98	13.45	13.20	13.12	13.06	13.09	13.19	13.50	13.75	13.89	13.85	13.69	13.52	13.35
EN Bore-08	1186	2688	1966	16.81	15.31	16.03	15.74	15.59	15.46	15.47	15.58	15.99	16.39	16.64	16.65	16.47	16.23	15.97
EN Bore-09	2446	3638	3040	19.05	17.86	18.46	18.29	18.14	18.01	17.98	18.03	18.33	18.64	18.88	18.94	18.85	18.69	18.49

Figure G: Groundwater Modelling Results from KDWMS Report (excerpts from Emerson Stewart (2009))

2.7.4 C-WISE Groundwater Level Data

Table 2.3 summarises the measured groundwater levels in the 3 monitoring wells within the site from the date of installation, during a groundwater quality sampling round in February 2021 and during installation and download of the automated groundwater level loggers on 14 November 2022 and 15 March 2023, respectively. Monthly groundwater level monitoring was also undertaken in EB07 from June to November 2008. The data was not available in tabular format, but was instead digitised from a figure in the KDWMS report (i.e. the accuracy of these levels is considered +/- 10 cm only).

Table 2.3 Manual Groundwater Level Measurements within the Site

Bore ID	**Surveyed Ground Elevation (m AHD)**	**Screened Interval (m bgl)**	**Top of Coffee Rock (m bgl) [m AHD]**	**Screen in Relation to Coffee Rock**	**Groundwater Levels m bgl [m AHD]** 13 May 2008 *	Jun 2008 to Nov 2008 *	1 Feb 2021	14 Nov 2022	15 Mar 2023
EB07	16.59	5.9 – 8.9	3.8 [12.8]	Below	3.02 [13.57]	2.4 to 2.7 [13.6 to 13.9]	3.35 [13.24]	2.94 [13.65]	3.54 [13.05]
EB08	19.00	2.4 – 5.4	4.8 [14.2]	Across	2.34 [16.66]	-	-	2.29 [16.71]	2.91 [16.09]
EB09	21.91	2.7 – 5.7	6.1 [15.8]	Above	3.70 [18.21]	-	3.73 [18.18]	3.25 [18.66]	3.95 [17.96]

* Digitised from KDWMS report.

Automated groundwater level loggers were installed in the three monitoring wells on 14 November 2022. The loggers are monitoring at an hourly frequency. The groundwater level loggers were downloaded on 15 March 2023. Following the download, the loggers were setup to run for an additional year and put back in the monitoring wells. The loggers would therefore still be measuring the groundwater level, which is considered important for understanding the groundwater level behaviour at the site and verify the design groundwater levels.

Figure H shows the groundwater level data from the loggers together with the manual readings.

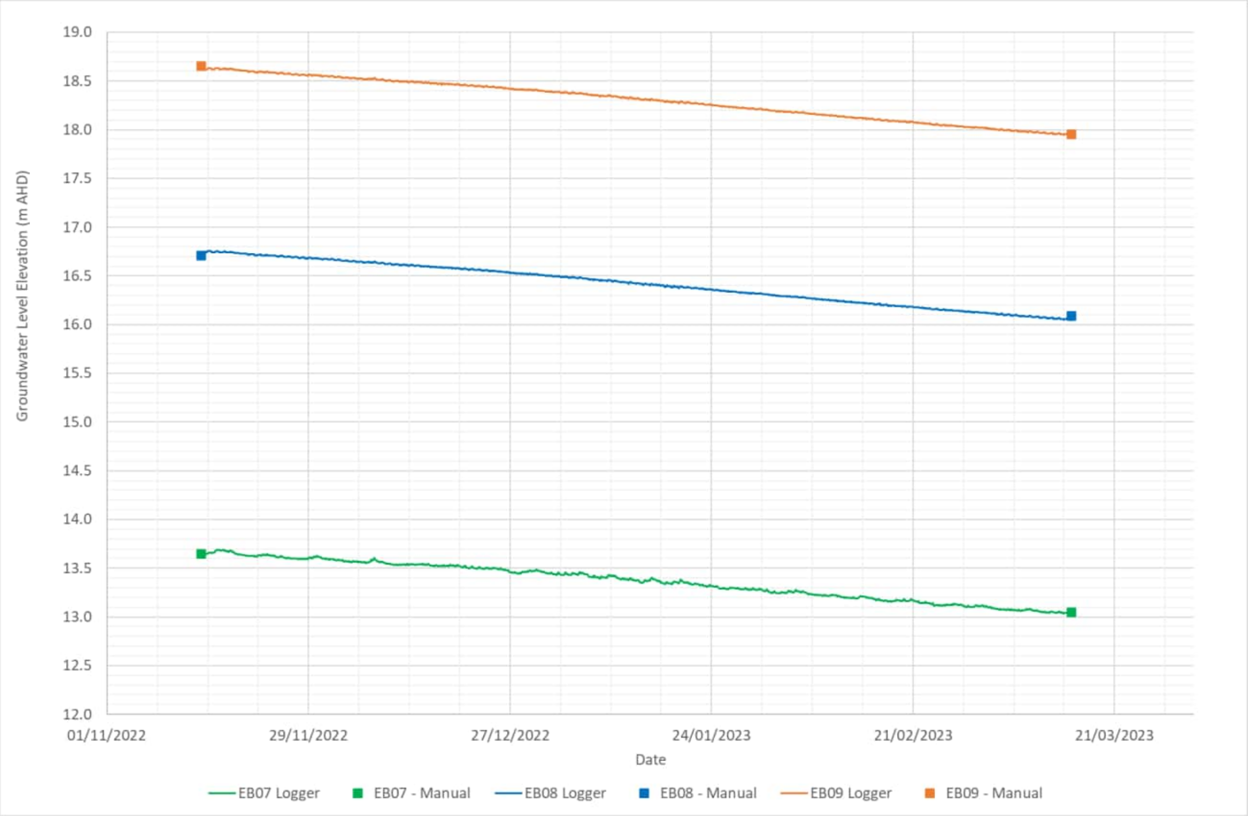


Figure H: Groundwater Level Data from EB07, EB08 and EB09

The groundwater level monitoring data from the existing C-Wise site was also received for the period from January 2019 to October 2022. Though the existing C-Wise site is located 1 km south of the proposed plant area, these groundwater levels were used in the groundwater level contouring and assessing seasonal fluctuations in generally similar geological settings.

In addition to the groundwater level monitoring data from the three wells, the water levels were measured in 3 on site ponds on 15 March, which were used to estimate the current and design groundwater level contours.

Figure 4 shows the inferred March 2023 groundwater level contours based on the measured groundwater level and the survey of the surface water features across the site and indicates:

- The groundwater level range between RL 9 m AHD at the western boundary to around RL 18 m AHD in the eastern part of the site.
- The groundwater levels over the Proposed Plant Area range between:
  - Stage 1: RL 12 m AHD to RL 13.2 m AHD
  - Stage 2: RL 13.2 m AHD to RL 11.5 m AHD
- The straightness of the contours below the drains indicates that the drains are dry and the dry season groundwater levels are not directly affected by the drains during this time.

2.8 Discussion - Perched Aquifer Caused by Coffee Rock?

A perched water table or aquifer is an aquifer that occurs above the regional water table or aquifer. The perched aquifer forms when there is an impermeable layer (aquitard) above the regional aquifer but below the land surface, which makes water perch on top of this layer. Typically for perched water there would be an unsaturated zone between the perched aquifer and the regional aquifer. In the Perth region the seasonal variations in the perched aquifer and regional aquifers typically differs and it is not uncommon that the perched aquifers only exist during the wet season and then dries out during the dry season.

Coffee rock is typically a dark brown to black friable variably cemented iron and/or organic rich sand, which can often be found in Bassendean Sand near the historical groundwater level. The consolidation, thickness and extent of the coffee rock can be highly variable. The coffee rock is known to sometimes create local perched aquifers (i.e. rainfall recharge water will perch on top of the coffee rock) due to its cementation and thereby low permeability.

The Endemic 2008 bore logs (Appendix B) indicates that coffee rock was encountered in two of the boreholes drilled within the site and possibly also in the third (EB09 which is reported to refuse on a dense layer). The lithological logs available from the DWER database search indicates that coffee rock is described to be present in majority (65%) of the of the boreholes, with the top of coffee rock ranging from 0.6 m to 5.0 m below ground level and with an average thickness of around 0.5 m. This is not unexpected given the coffee rock is known to occur in Bassendean Sand.

Table 2.4 summarises the geology and well construction details. The information suggests that the top of the coffee rock is encountered between 3.8 m and 6.1 m below ground, corresponding to around RL 12.8 m AHD to RL 15.8 m AHD. It is noted that one well is screened above the coffee rock (EB09), one across (EB08) and one below (EB07).

Table 2.4 Geology and Well Construction Details

Well ID	**Ground Elevation (m AHD)**	**Bore Hole Depth (m)**	**Screened Interval (m bgl)**	**Screened Geology**	**Coffee Rock m bgl [m AHD]**	**Screen in Relation to Coffee Rock**	**Groundwater Level Range m bgl [m AHD]**
EB07	16.59	8.9	5.9 to 8.9	Geology only described to 5 m	3.8 [12.8]	Below	2.4 to 3.5 [13.0 to 13.9]
EB08	19.00	5.4	2.4 to 5.4	White medium sand (Bassendean Sand)	4.8 [14.2]	Across	2.3 to 2.9 [16.1 to 16.7]
EB09	21.91	6.1	2.7 to 5.7	White medium sand (Bassendean Sand)	Possibly at 6.1 [15.8]	Above	3.3 to 4.0 [18.0 to 18.7]

Table 2.4 indicates that EB07 is screened below the coffee rock, but the measured groundwater levels are above the coffee rock. During the November 2022 visit a hand auger borehole was drilled next to EB07 with the intend to install a shallow piezometer above the coffee rock. This would allow measurement of the groundwater levels in wells installed above and below the coffee rock at the same location within the site. During the hand auger drilling the groundwater was encountered at the same depth as what was measured in EB07. Unfortunately the whole kept collapsing at the groundwater table and it was not possible to further advance the drill hole and install the piezometer. Nevertheless, given that the groundwater levels in the hand auger hole and EB07 was at similar depths and the groundwater level in EB07 is above the coffee rock, <u>this would suggest that perched groundwater is not present above the coffee rock at EB07.</u>

The DWER database included a pair of monitoring wells at the same location, with Well 61410678 installed to a depth of 3.5 m and screened above the coffee rock while Well 61410677 was installed to a depth of 8.3 m and screened below the coffee rock. The wells are located approximately 2 km south of the site. Well.

Figure I shows two groundwater level hydrographs of two monitoring wells and indicate:

- The groundwater levels in both wells are above the coffee rock, which means that there is no unsaturated zone below the coffee rock.

- The hydrographs in the two monitoring wells are generally found to be similar (up to 0.1 m difference) with similar seasonal fluctuations. The higher groundwater level is observed in the deeper well screened below the coffee rock, suggesting there is actually slight upward gradient.

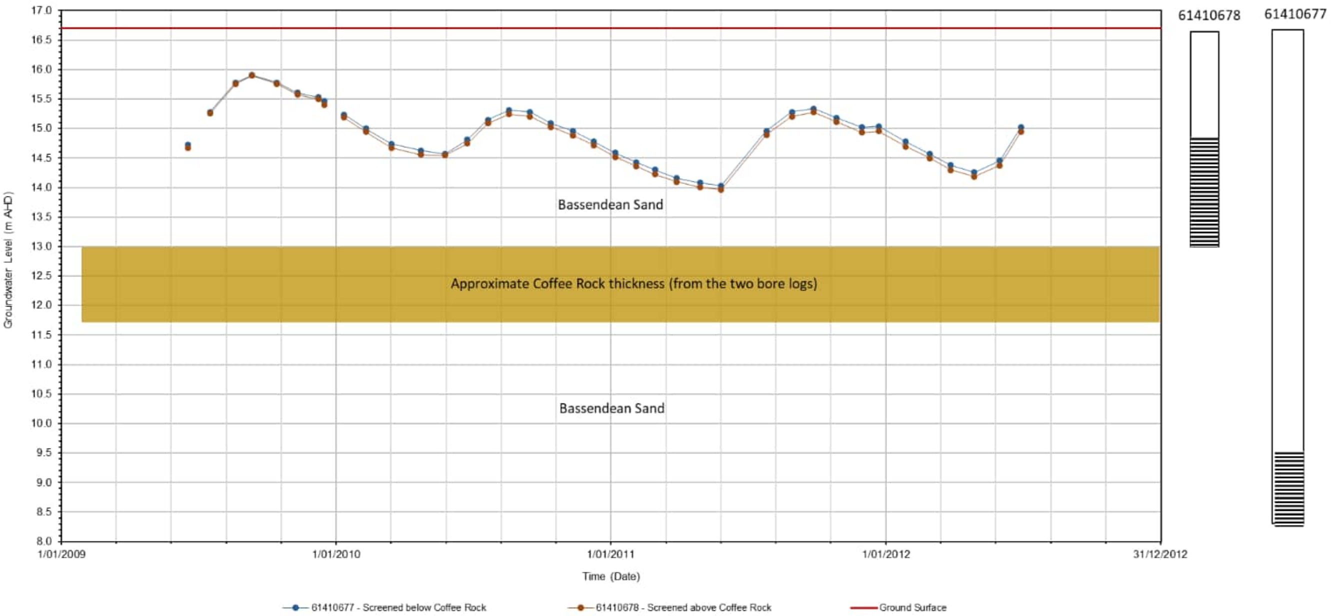


Figure I: Groundwater Level in 2 Wells at the Same Location, but Screened above and Below Coffee Rock.

<u>This would suggest that perched groundwater is not present above the coffee rock at the 61410677/78 location.</u>

Figure H shows that the groundwater level behaviour/change is similar in EB07, EB08 and EB09, irrespective if the well is screened above, across or below the coffee rock, <u>which would suggest that perched groundwater is not present above the coffee rock at these locations.</u>

Based on the collated data, we are currently in agreeance with DWER and do not consider that a large scale perched aquifer exists in the area. It is acknowledged that locally perched conditions may exist in some areas, but it is considered that the observed groundwater levels form part of the regional Superficial Aquifer.

3 Conceptual Hydrogeological Model

Figure J show the conceptual hydrogeological model based on the available data and our experience.

The site is located in a Palusplain wetland area underlain by a thin layer of permeable Bassendean Sand (varying thicknesses) which is overlying the lower permeability Guildford Formation. These units form the Superficial Aquifer. The rainfall recharge is generally sufficient to “fill” the thin Superficial Aquifer, resulting in a shallow depth to the groundwater table due and in some areas causes inundation (i.e. the groundwater level rises to the surface). The net rainfall recharge will be greater in areas where the unsaturated zone of the Bassendean Sand is thicker (e.g. in the Bassendean sand dunes on site), compared to areas where the unsaturated zone is thin where infiltration will be impeded.

Figure J shows that the Superficial Aquifer becomes thinner at the site, which results in a rise in groundwater level and steeper hydraulic gradients in this area. The Superficial Aquifer is estimated to be as thin as 10 m to 15 m in lower lying areas of the site.

Coffee rock has been encountered during drilling at shallow depth in the area. However, there is no data available that suggests that the shallow groundwater table is the result of a perched aquifer overlying the Superficial Aquifer.

The seasonal groundwater level fluctuation of the Superficial Aquifer is estimated to be around 0.8 m to 1.2 m.

A vast open drainage network (natural and man-made) exists in the area, which manages surface water runoff as well as controls groundwater levels during the wet season. The drainage network drains into wetland areas (lower-lying areas) or into main surface water features in the area (Serpentine River and Nambeelup Brook).

The Leederville Aquifer is underlying the Superficial Aquifer and is quite close to the ground surface in this area (compared to other areas in the Perth Metro Area). Both aquifers generally flow in a westward direction from Darling Scarp toward the coast, but surface water features also intercept groundwater from the Superficial Aquifer.

The Leederville Aquifer is likely in direct connection with the Superficial Aquifer near the Darling Scarp where it receives groundwater from the Superficial Aquifer (recharge zone). Near Serpentine River the groundwater head in the Leederville Aquifer is higher than in the Superficial Aquifer, and the Leederville Aquifer therefore discharges groundwater into the Superficial Aquifer (discharge zone).

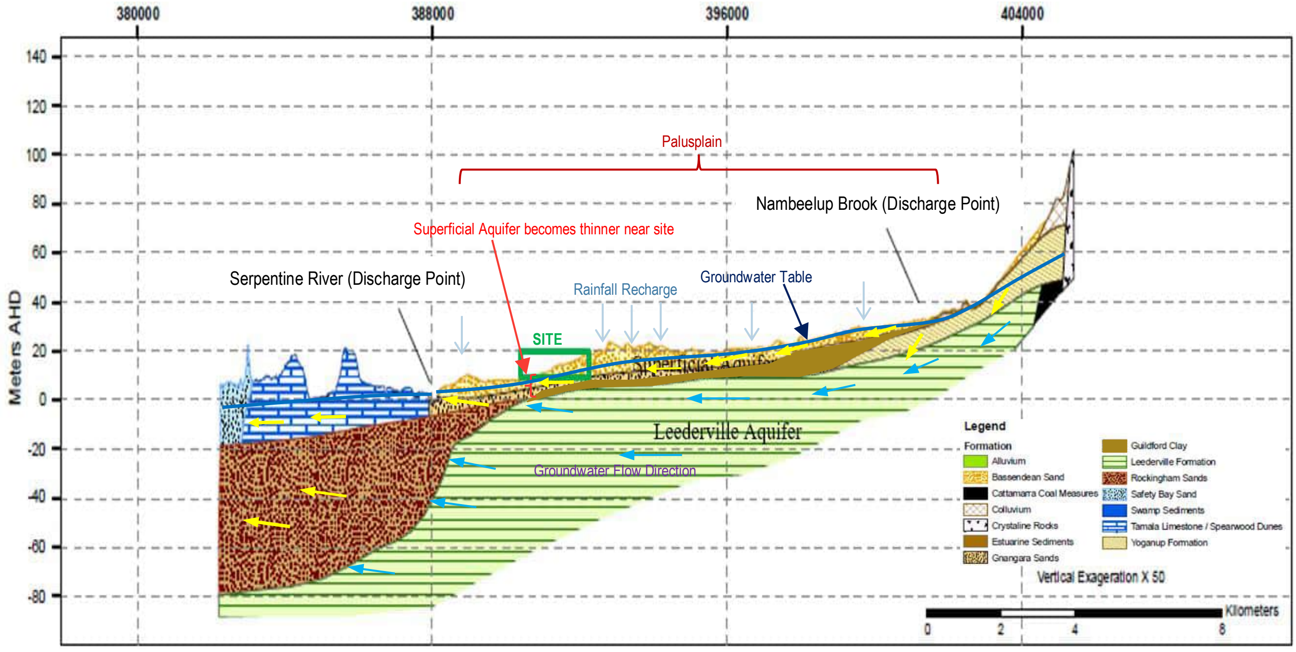


Figure J: Conceptual Hydrogeological Model (background image taken from DoW 2012)

4 Design Groundwater Levels

There are different types of Design Groundwater Levels (DGWL) definitions, which is normally based on risk and consequence. For example, for structures (e.g. a bridge or buildings) the DGWL may need to be higher for structural integrity (e.g. the DGWL may need to reflect a 1 in 100 Year groundwater level (1% Annual Exceedance Probability (AEP)), while for a road or a basin the consequential risk is lower and a DGWL may need to reflect a 1 in 50 Year (2% AEP) or a 1 in a 10 Year (10% AEP) groundwater level.

For land developments, we have previously seen reference to the Average Annual Maximum Groundwater Level (AAMGL) as the DGWL. This is estimated by determining the maximum groundwater level for each year over a time period and then take the average of these maximum values. An AMMGL would therefore correspond to a 50% AEP.

Typically a certain clearance between the DGWL and the development is stipulated by the regulatory agencies to account for capillary rise, uncertainties, etc.. We find that for different land developments different clearances are adopted. For example based on our previous experience, for basins a clearance of 0.3 m is typically required from the base of the basin to the DGWL, while for a road a clearance of 0.8 m from the DGWL to the pavement level is typical to account for capillary rise etc.. For housing development projects that we have previously worked on a typical clearance would be up to 1.5 m. Therefore, there could be several different DGWLs within a project development.

For this project we understand that DWER has indicated at that a 2 m clearance may be required to the DGWL. However, what is currently not clear is what the recurrence period of the DGWL is (i.e. is it 2 m clearance to the AAMGL or 2 m clearance to the maximum estimated groundwater level over the design life).

It is important to note that the developed DGWLs are pre-construction groundwater levels, which are used to design the development (e.g. to set levels). However, the construction may affect the future DGWLs at the site. For example, if a stormwater infiltration basin is installed, this could result in an increase in groundwater level around the basin (i.e. the future DGWL would be higher) or if drains are installed they may control how high the groundwater level can rise (i.e. the future DGWL would be lower, as long as the drains remain in operation). The potential impact from the development on the groundwater levels should be considered during the design.

The DGWL over a development area is most like not a single value, but rather a range due to groundwater flow. Therefore, DGWL contours (or a DGWL surface) is prepared for a development area. The DGWL surface is based on assumptions and available data and therefore there are approximations and uncertainties to the surface. The more spatially available data (i.e. the monitoring points) and longer groundwater level series, the more accurate the developed DGWL surface would be. It is noted that there is limited spatial and short groundwater level series for this site, which does affect the accuracy of the DGWL surfaces.

4.1 Definitions

The following definitions apply to this groundwater level assessment:

- Groundwater is water below the ground surface.
- Water standing above the ground is surface water. The standing surface water may or may not be sustained by groundwater.

It is important to note that the DGWL surface is a water surface that has been prepared for design purposes and does not necessarily reflect the current or seasonal groundwater level elevations. There will be some areas (e.g. where inundation is currently occurring seasonally) where the DGWL elevation is controlled (man-made or naturally) and thereby is similar (or very close to) to the current seasonal maximum groundwater level, while in other areas the estimated DGWL may only be reached once or twice over the design life.

4.2 DGWL Approach

The DGWL was estimated using a pragmatic approach, where the historic groundwater levels, hydrogeological features and key parameters (climate, surface water, drains, groundwater abstraction and land use) that would affect the groundwater levels are closely considered for each point with groundwater information. Hydrographs with historical groundwater levels were examined and then grouped based on trends, geology and spatial distribution to assess the local groundwater level behaviour over the site. Given the paucity of available groundwater level data, it has been necessary to adopt engineering judgement during the derivation of the DGWL values. These DGWL may require to be revised in the future as additional data becomes available (e.g. from the currently ongoing groundwater level monitoring).

Given that it is hard to predict changes in the future, a regulatory approved approach is to assume that the future groundwater levels (e.g. 50 Yr DGWL) can be represented by the past 50 years of groundwater level behaviour (i.e. the maximum groundwater level estimated for the past 50 years). This method is currently adopted on all major projects when determining the DGWL surface.

DGWL points were estimated for monitoring wells (only three on site), surrounding monitoring wells and surface water features (e.g. ponds, lakes, open drains, etc.) that would represent or impact the groundwater levels. Following this, the DGWL contours were then manually contoured (1 m interval) using the estimated DGWL points and then compared to the available topographic survey data for the site. Where the DGWL contours indicated that the DGWL was higher than the ground surface the DGWL contours were trimmed to the ground surface.

For this project the following groundwater DGWL contours were developed:

- The AAMGL (50% AEP) contours.
- The 50 Year (2% AEP) DGWL contours.

The 50 Yr DGWL contours are based on almost 50 years of groundwater level data from historical hydrographs near the site.

4.2.1 Historical Long-term Hydrographs

The period over which available groundwater level data exist within the site is too limited to develop DGWL's based on that data alone. Therefore, a typical approach is to collate long-term historical groundwater level data from areas around the site. The assumption is that given that the wells are located in a similar environment, these long-term groundwater level hydrographs would reflect the historical groundwater level behaviour at the site. The groundwater levels from the long-term hydrograph are then adjusted (level and amplitude) to the site groundwater level data.

Following a review of all the hydrographs in the area, it is considered that the hydrograph from DWER monitoring well 61410079 best represents the historical groundwater level behaviour at the East Keralup site (i.e. it can be assumed that the observed groundwater level changes and trends from this site is also what would occur at the East Keralup site). The well is located approximately 2.3 km south of the centre of the proposed plant area and 1 km south of the existing C-Wise plant site, just north of an airport runway (refer to Figure 3 for location).

4.2.2 Cumulative Departure from the Mean

Another approach called the Cumulative Departure from Mean (CDFM) rainfall analysis was also used to assess the groundwater level data. The CDFM approach is based on the premise that rainfall, or the cumulative departure from mean rainfall, over a groundwater monitoring site explains the variations in the groundwater levels. This might not be entirely correct, because other contributing factors might have affected the area (e.g. drains, groundwater abstraction, etc.). In addition to this, other physical aspects of groundwater behaviour are not considered by this method (e.g. heterogeneous aquifer properties over the soil profile and change in evaporation as groundwater level approaches the ground surface). The CDFM is therefore a statistical analysis tool that has some limitations and should be used with caution. Nevertheless, if the CDFM method is found to give a reasonable trend compared to observed groundwater levels, this method could be used to fill in gaps within groundwater level data. The CDFM method was used as an additional method to verify the DGWL.

4.2.3 Design Groundwater Level Estimation

Figure K shows the estimated historical groundwater level behaviour at EB07 (centre of the proposed plant site) based the adjusted hydrograph from DWER Well 61410079.

- The 3 brown points shows the three manual measurements in EB07 in 2021, 2022 and 2023.
- The orange line shows the groundwater level logger data from November 2022 to March 2023.
- The purple line in 2008 show groundwater levels measured by PB in EB07 (the raw data is not available so the elevations were digitised of a graph – i.e. they may not be fully accurate).
- The red hydrograph shows the adjusted 61410079 historical groundwater levels measurements (elevation and amplitude scaled to fit the observed EB07 measurements)
- The black line shows the estimated groundwater level hydrograph using the CDFM method.

The figure shows that there is a good correlation between the site collected groundwater levels and historical groundwater level data from 61410079. The CDFM also provides a reasonable fit, suggesting that the groundwater level around EB07 is mainly governed by rainfall recharge (as expected).

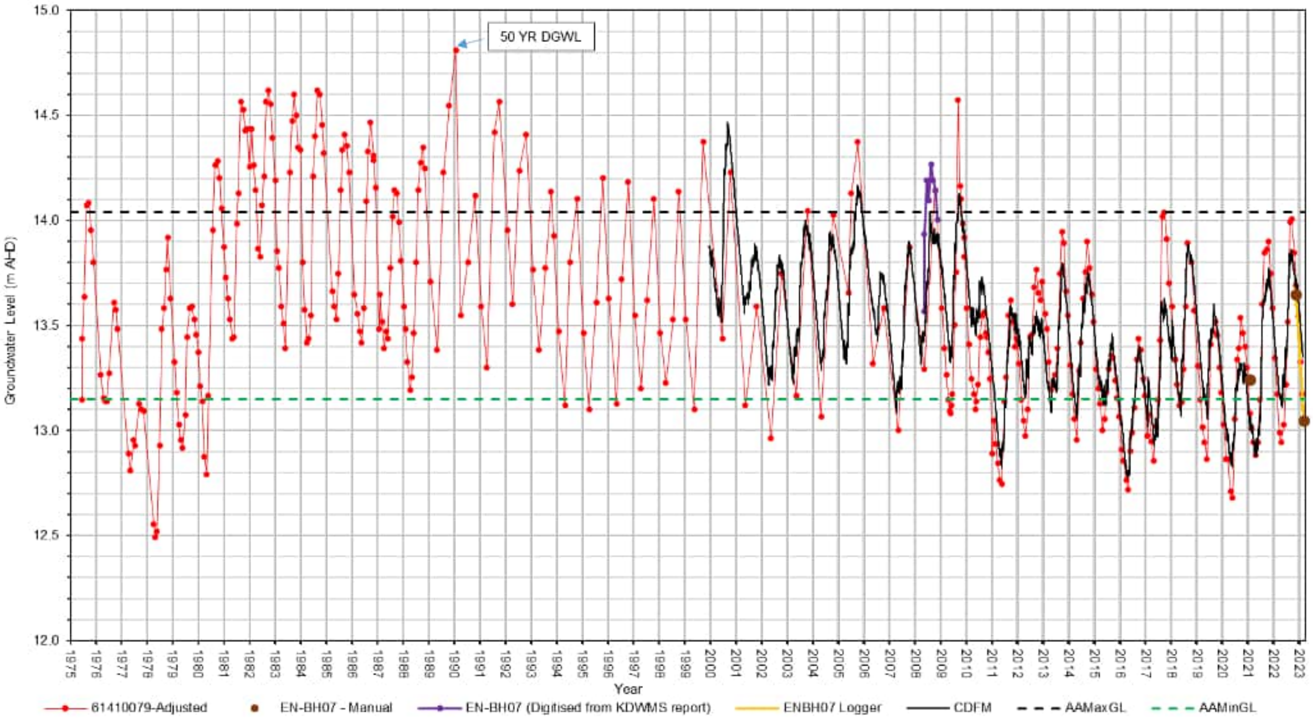


Figure K: Estimated Historical Groundwater Level Behaviour at EB07 based on DWER Well 61410079)

The results indicate that at the location of EB07:

- The maximum observed groundwater level over the almost 50 year monitoring period is RL 14.8 m AHD (i.e. this can be considered the 50 Yr DGWL for EB07), which would have occurred in 1990.
- The AAMGL is RL 14.04 m AHD. It can be seen that the 2022 seasonal maximum groundwater level is found to be similar to the AAMGL.
- The Average Annual Minimum Groundwater Level (AAMinGL) is RL 13.15 m AHD.

- The minimum observed groundwater level over the monitoring period is RL 12.5 m AHD.

The last two bullets could be useful information for discussion with regulators when it comes to potentially controlling the groundwater level at the site (i.e. anything between AAMGL and AAMinGL could be considered average seasonal fluctuation).

The AAMGL for EB07 of RL 14.04 m AHD fits reasonably well with the AAMGL estimated in the KDWMS of RL 13.89 m AHD. However, the maximum estimated groundwater level of RL 14.8 m AHD is significantly higher than what was estimated in the KDWMS of RL 14.0 m AHD, though it is noted that it is unknown what time period was used in the KDWMS.

This approach is then also carried out for the EB08 and EB09.

4.3 Average Annual Maximum Groundwater Level (AAMGL)

Figure 5 shows the inferred AAMGL contours across the site and indicates that:

- The AAMGL range between RL 9.0 m AHD at the north-western site boundary to about RL 19 m AHD at the eastern boundary.
- The AAMGL over the Proposed Plant Area range between:
  - Stage 1: RL 13.0 m AHD and RL 14.5 m AHD.
  - Stage 2: RL 14.5 m AHD and RL 16.0 m AHD.

4.4 50 Year Design Groundwater Levels

Figure 6 shows the inferred 50 Yr DGWL contours across the site and indicates:

- The 50 Yr DGWL range between RL 9.5 m AHD at the north-western site boundary to about RL 19.5 m AHD at the eastern boundary.
- The 50 Yr DGWL over the Proposed Plant Area range between:
  - Stage 1: RL 13.9 m AHD and RL 15.2 m AHD
  - Stage 2: RL 15.1 m AHD and RL 16.5 m AHD

4.5 Controlled Groundwater Levels

The DGWL or AAMGL contours can be used for designing site design levels or if they are set they can be used to assess if groundwater control is required at the site, if possible.

It is understood that the current plant design level may result in requiring to control the groundwater levels. There are different types of groundwater control measures:

- **Passive methods:** If sufficient hydraulic gradient can be established from the groundwater control system that allows for gravity drainage to the existing drainage network, then the groundwater control method could be to install open drains around the plant area or sub-soil drains beneath the plant area in key areas (or possibly a combination of the two).
- **Active methods:**
  - Similar to the passive method, but a pump may be required to pump the groundwater to a drainage point, from which it can flow by gravity to the existing drainage network.

  - Installation of dewatering wells that require active pumping to the end location (e.g. for site groundwater supply or the existing drainage network).

The feasibility and methodology of the groundwater control system will depend on:

- The required groundwater control level.
- The hydrogeological properties of the soil where the groundwater level needs to be lowered. At this site the Bassendean Sand has moderate to high permeability, which could result in moderate to high groundwater control rates, depending on the groundwater control level.
- The capacity of the existing drainage network (i.e. will it be able to take the additional amount of groundwater without overflowing).
- The water quality of the groundwater and the receiving environment and thereby the requirements for obtaining regulatory approval for discharge of the groundwater into the environment. It could be argued that this is currently naturally occurring during the wet season, but depending on the required control groundwater level, groundwater level control may also be required during the drier part of the season where the current drains are not discharging groundwater.

To design a groundwater level control system, a numerical 3D groundwater model should be developed and used as a tool to assist with determining the minimum feasible/practical controlled groundwater level across the site:

- This will allow modelling of numbers, locations, depths, lengths, and spacing of the groundwater control system (e.g. open drains, sub-soil drains, wells, etc.).
- Estimate dewatering rates and volumes – important for the design of the stormwater system if the water is planned to be discharge into the stormwater system.
- Estimate the duration and frequency during which the groundwater control system will control the groundwater (e.g. the control system may only need to control groundwater during 3 months of the wet season).
- Estimate off-site groundwater level drawdown to assess potential environmental impacts, which may be required by the regulators during the approval process.

All of this information may be required to be reported in a groundwater management plan (similar to a dewatering management plan).

5 Conclusion

Based on this groundwater level assessment we conclude:

- Based on the available data, a perched large-scale groundwater table does not seem to exist across the site. The shallow observed groundwater is considered to be part of the regional Superficial Aquifer.
- The groundwater level is currently considered to:
  - Be controlled by natural and man-made drains over parts of the site during part of the wet season.
  - Locally rise in the sand dunes at the site as a result of higher rainfall recharge (i.e. a local groundwater level mound occurs between drains).
- The Average Annual Maximum Groundwater Level (AAMGL) with a 50% Annual Exceedance Probability (AEP) across the plant site is estimated to range between:
  - Stage 1: RL 13.0 m AHD to RL 14.5 m AHD
  - Stage 2 (future development): RL 14.5 m AHD to RL 16.0 m AHD
- The 50 Year groundwater level with a 2% AEP across the plant site is estimated to range between:
  - Stage 1: RL 13.9 m AHD to RL 15.2 m AHD
  - Stage 2 (future development): RL 15.1 m AHD to RL 16.5 m AHD
- The feasibility of a controlled groundwater level across the site (or part thereof) depends on several factors including the required controlled level, discharge options (passive or active), capacity of receiving environment, potential treatment requirements (if any) and regulatory approvals. Further assessment is considered to be required to develop a feasible control groundwater level across the site.

6 Recommendations

We provide the following recommendations:

- A meeting be established with the relevant regulators for them to provide guidance on:
    - What is the groundwater surface (DGWL) that the stipulated clearance is required above (i.e. is it above the AAMGL (50% AEP) or 50 Yr DGWL (2% AEP), or something else). This could have a significant impact on the allowed final plant level and groundwater control level allowance.
    - What is the minimum groundwater level that the site can be controlled at (e.g. can it be lowered to the estimated AAMinGL or to the estimated historical minimum groundwater level).
    - Discharge requirements and criteria for abstracted groundwater from a groundwater control system.
- Continue the groundwater level monitoring in EB07, EB08 and EB09 using the already installed groundwater level loggers. It is recommended that the groundwater level loggers be downloaded minimum every 3 months to reduce this risk of losing data due to potential logger failure.
- Install additional groundwater level monitoring wells in key groundwater control areas (if any) to verify the groundwater level contours presented in this report.
- Depending on the outcome of the meeting with the regulators, undertake additional water quality sampling of selected parameters in both the groundwater and receiving environment (i.e. wetland or drains).
- Develop a numerical 3D groundwater model for the site to assist in the design of the groundwater control and obtain regulatory approval.
- A surface water drainage designer would need to design the discharge network from the groundwater control system.

7 Limitations

Your attention is drawn to the document titled – “Limitation Statement”, which is included in Appendix C of this report. The statements presented in that document are intended to inform a reader of the report about its proper use. There are important limitations as to who can use the report and how it can be used. It is important that a reader of the report understands and has realistic expectations about those matters. The Limitation statement does not alter the obligations WSP has under the contract between it and its client.

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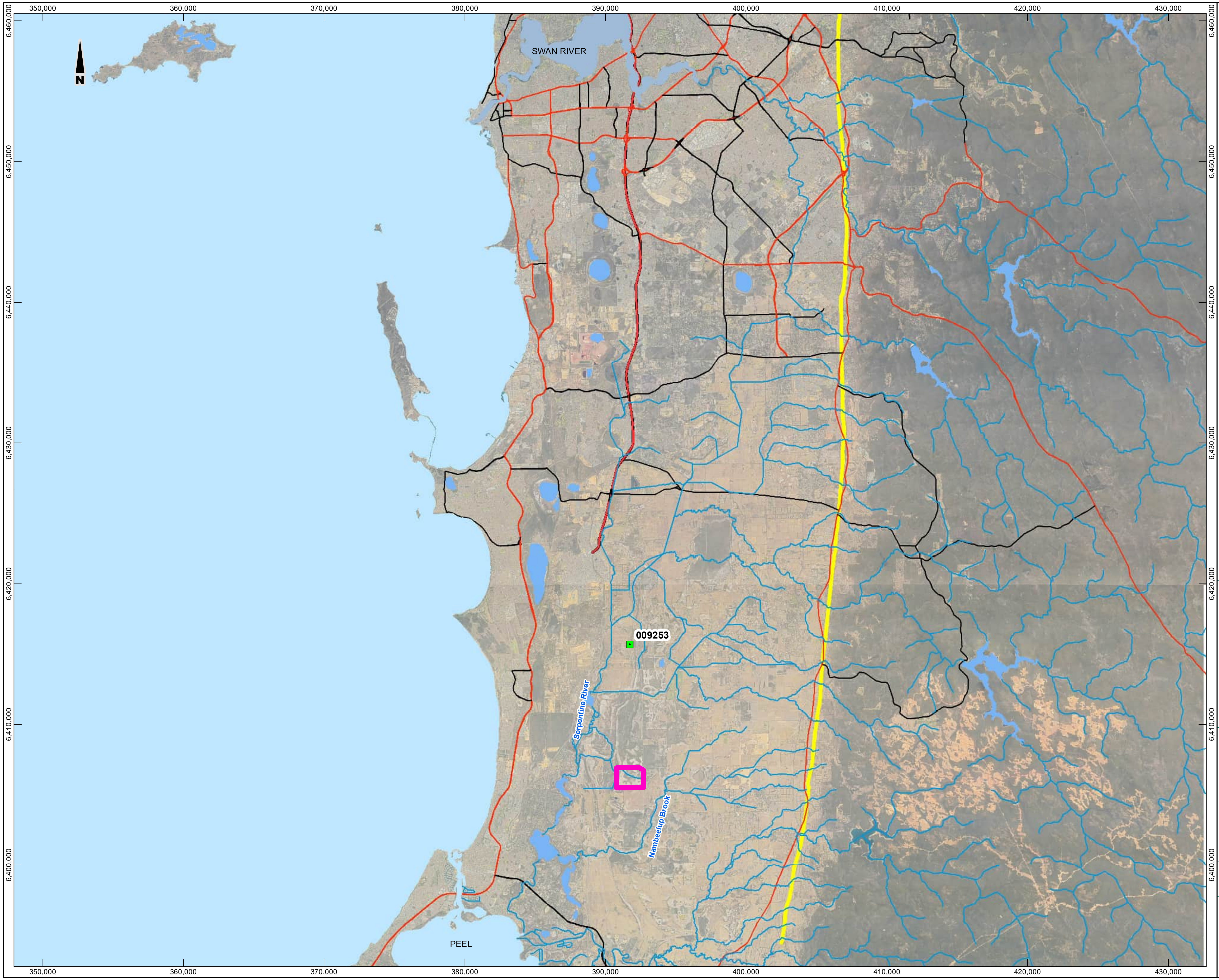

LEGEND

▭ Site Boundary
— Darling Scarp
■ BOM Rainfall Station

Main Roads

— Freeway
— Highway
— Main Road

Main Water Features

▨ Lake/Pond
▨ River/Stream
▨ Ocean

NOTES

Coordinate System: GDA 1994 MGA Zone 50

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Aerial imagery sourced from Nearmap 2021
Site plan provided by Client.

0 2,500 5,000 7,500 10,000
metres
SCALE (at A3) 1:250,000

CLIENT	C-WISE
DOCUMENT	PS134349-WSP-PER-GEO-REP-00001
DATE	12 May 2023
COMPILED	AL
APPROVED	DRAFT

C-WISE
EAST KERALUP SITE

LOCATION PLAN

FIGURE 1

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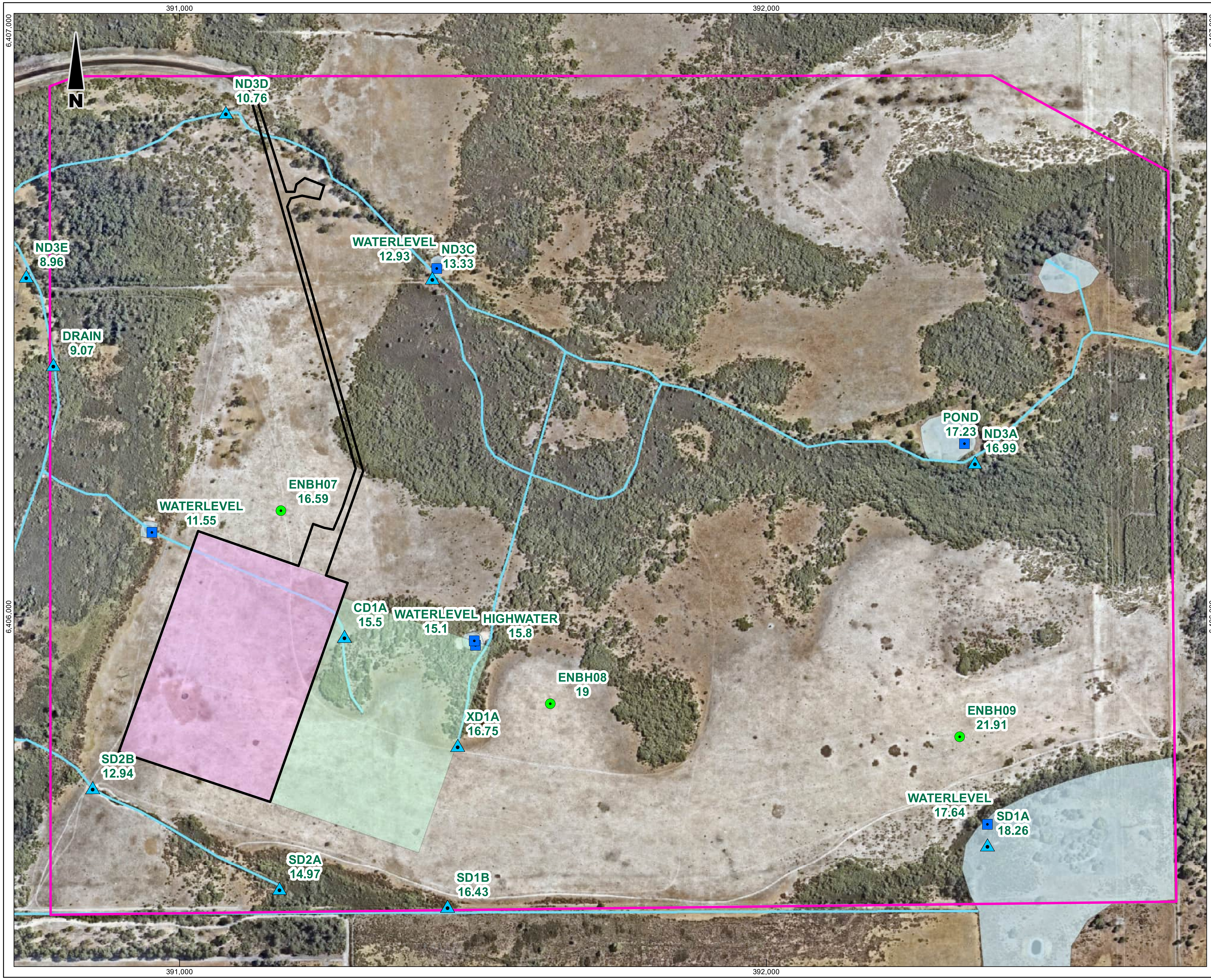

LEGEND

▭ Site Boundary
▭ Stage 1 Development Area

Proposed Plant Area

🟪 Stage 1
🟩 Stage 2 (Future Development)
— Local Drains
▨ Identified Ponds & Wetlands

Survey Locations (Mar 2023)

● Monitoring Well
▲ Drain
■ Pond

NOTES

Coordinate System: GDA 1994 MGA Zone 50

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Aerial imagery sourced from Nearmap 26 February 2023
Site plan provided by Client.

0 50 100 150 200 250 300
metres

SCALE (at A3) 1:6,000

CLIENT	C-WISE
DOCUMENT	
DATE	12 May 2023
COMPILED	AL
APPROVED	DRAFT

C-WISE
EAST KERALUP SITE

SITE PLAN

FIGURE 2

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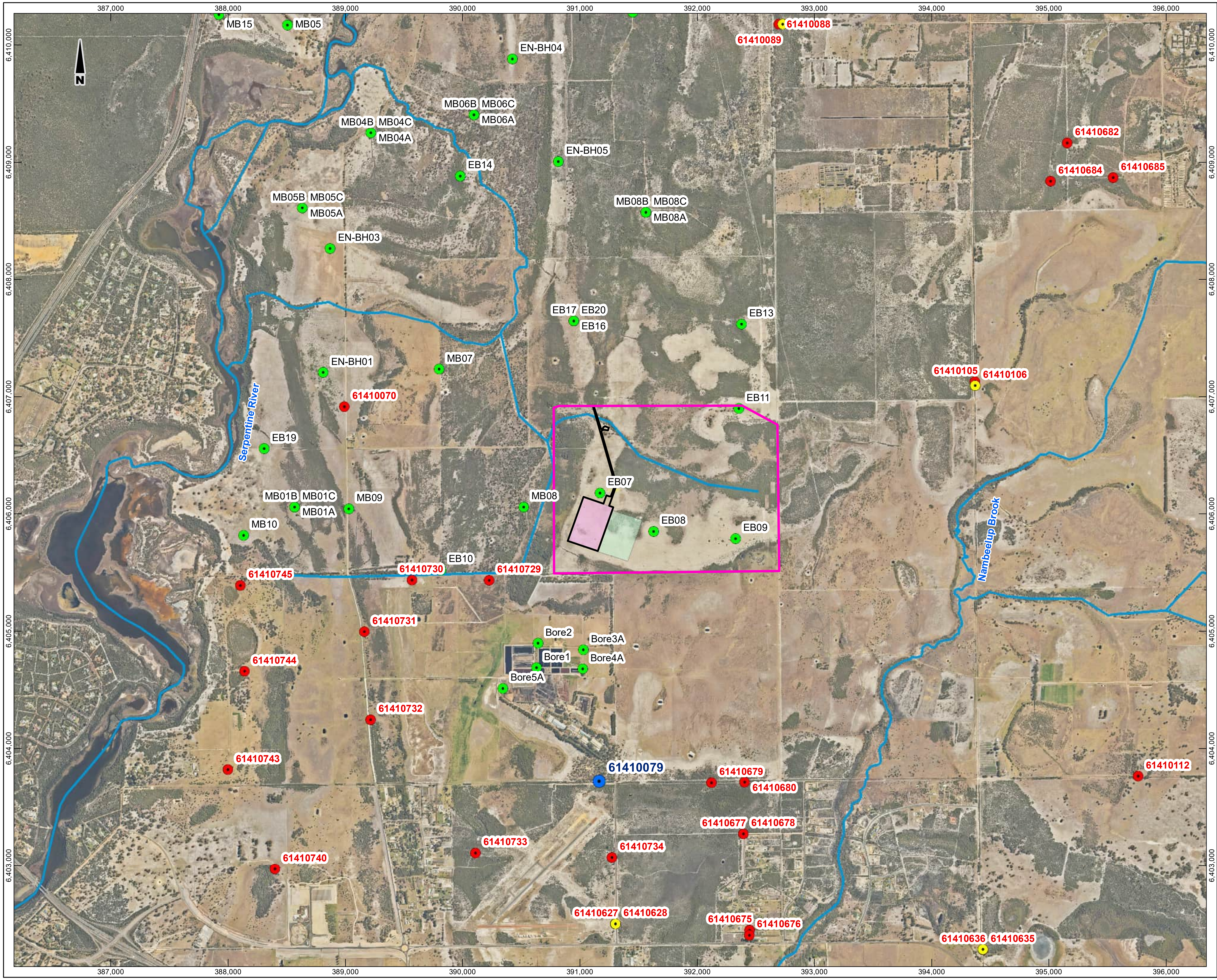

LEGEND

- ▭ Site Boundary
- ▭ Stage 1 Development Area

Proposed Plant Area

- ▨ Stage 1
- ▨ Stage 2 (Future Development)
- ● KDWMS Wells
- ● Selected DWER WIR Bores - Hydrographs
- ● DWER WIR Bores with GWL information
- ● DWER WIR Bore used for DGWL Analysis

NOTES

Coordinate System: GDA 1994 MGA Zone 50

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Site plan provided by Client.

0 500 1,000 1,500
metres

SCALE (at A3) 1:30,000

CLIENT	C-WISE
DOCUMENT	PS134349-WSP-PER-GEO-REP-00001
DATE	12 May 2023
COMPILED	AL
APPROVED	DRAFT

C-WISE
EAST KERALUP SITE

SURFACE WATER & GROUNDWATER

FIGURE 3

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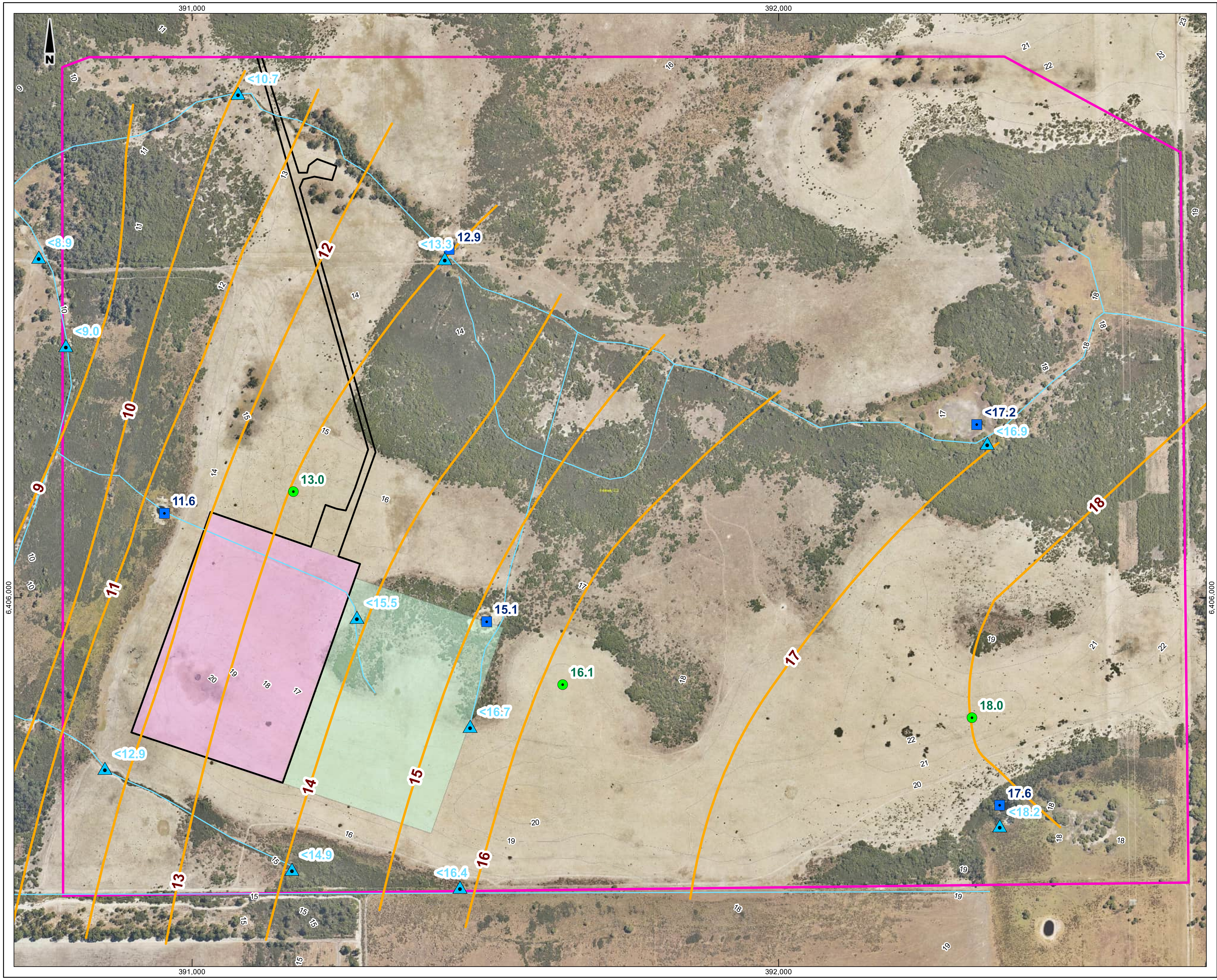

LEGEND

▭ Site Boundary

▭ Stage 1 Development Area

Proposed Plant Area

🟪 Stage 1

🟩 Stage 2 (Future Development)

— Local Drains (Ephemeral)

Surveyed Site Locations

● Monitoring Wells

▲ Surface Drain (dry)

■ Ponds (water level)

— Groundwater Level Contours - 17 March 2023 (m AHD)

— LiDAR Contours Swan Coastal Plain - 1m

NOTES

Coordinate System: GDA 1994 MGA Zone 50

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Aerial imagery sourced from Nearmap 2021
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0 70 140 210 280
metres

SCALE (at A3) 1:6,000

CLIENT	C-WISE
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DATE	12 May 2023
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APPROVED	DRAFT

C-WISE
EAST KERALUP SITE

INFERRED GROUNDWATER LEVEL CONTOURS - 17 MARCH 2023

FIGURE 4

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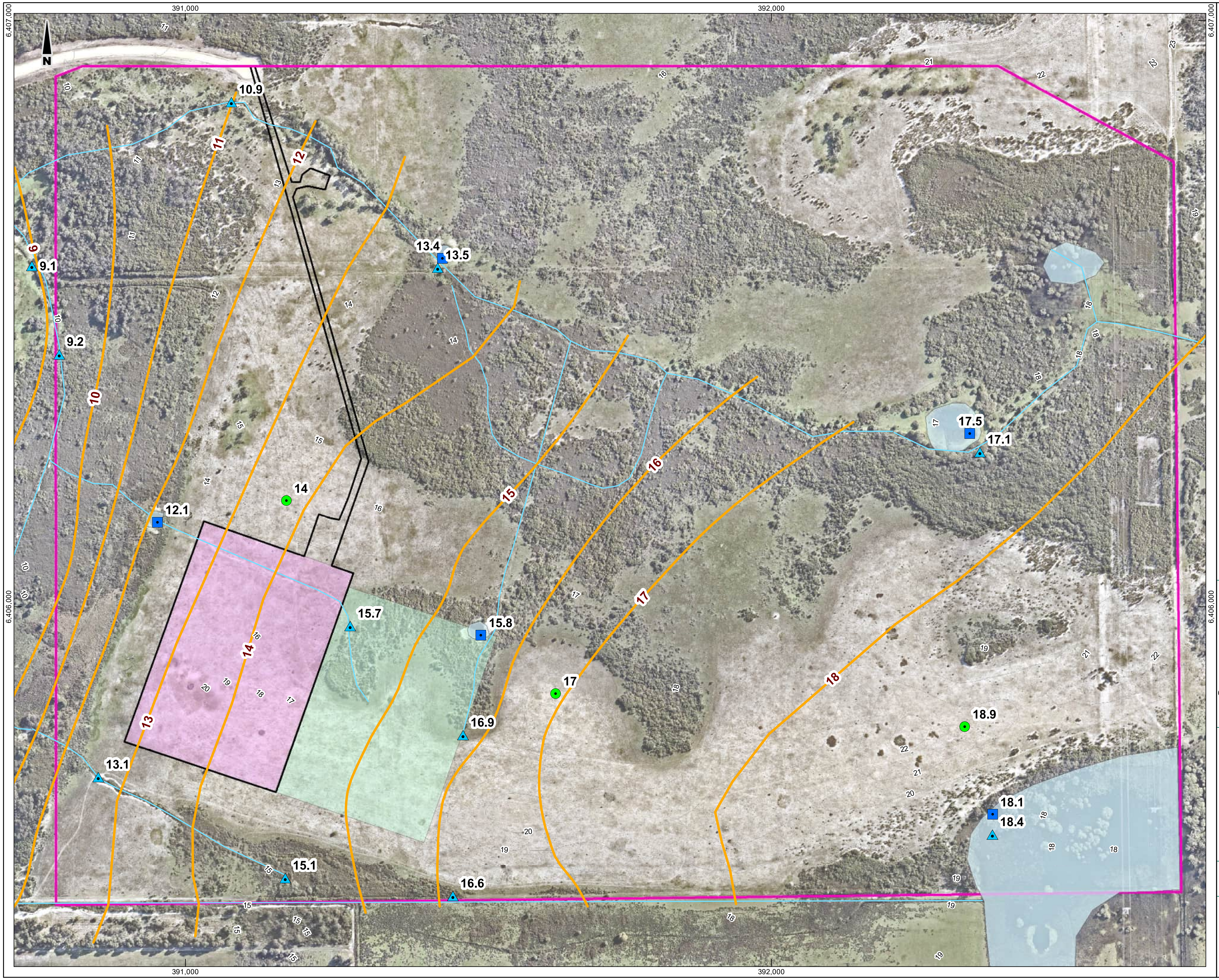

LEGEND

- 🟪 Site Boundary
- ▭ Stage 1 Development Area

Proposed Plant Area

- 🟪 Stage 1
- 🟩 Stage 2 (Future Development)
- — Local Drains (Ephemeral)
- 🟦 Maximum Outline of Ponds & Wetlands
- ● Monitoring Wells (estimated AAMGL)
- ▲ Surface Drain (Estimated WL - could drain groundwater)
- ■ Ponds (Estimated water level)
- — LiDAR topographic contours (m AHD)

NOTES

Coordinate System: GDA 1994 MGA Zone 50

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0 50 100 150 200 250 300
metres

SCALE (at A3) 1:6,000

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APPROVED DRAFT

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INFERRED GROUNDWATER LEVEL CONTOURS - AAMGL

FIGURE 5

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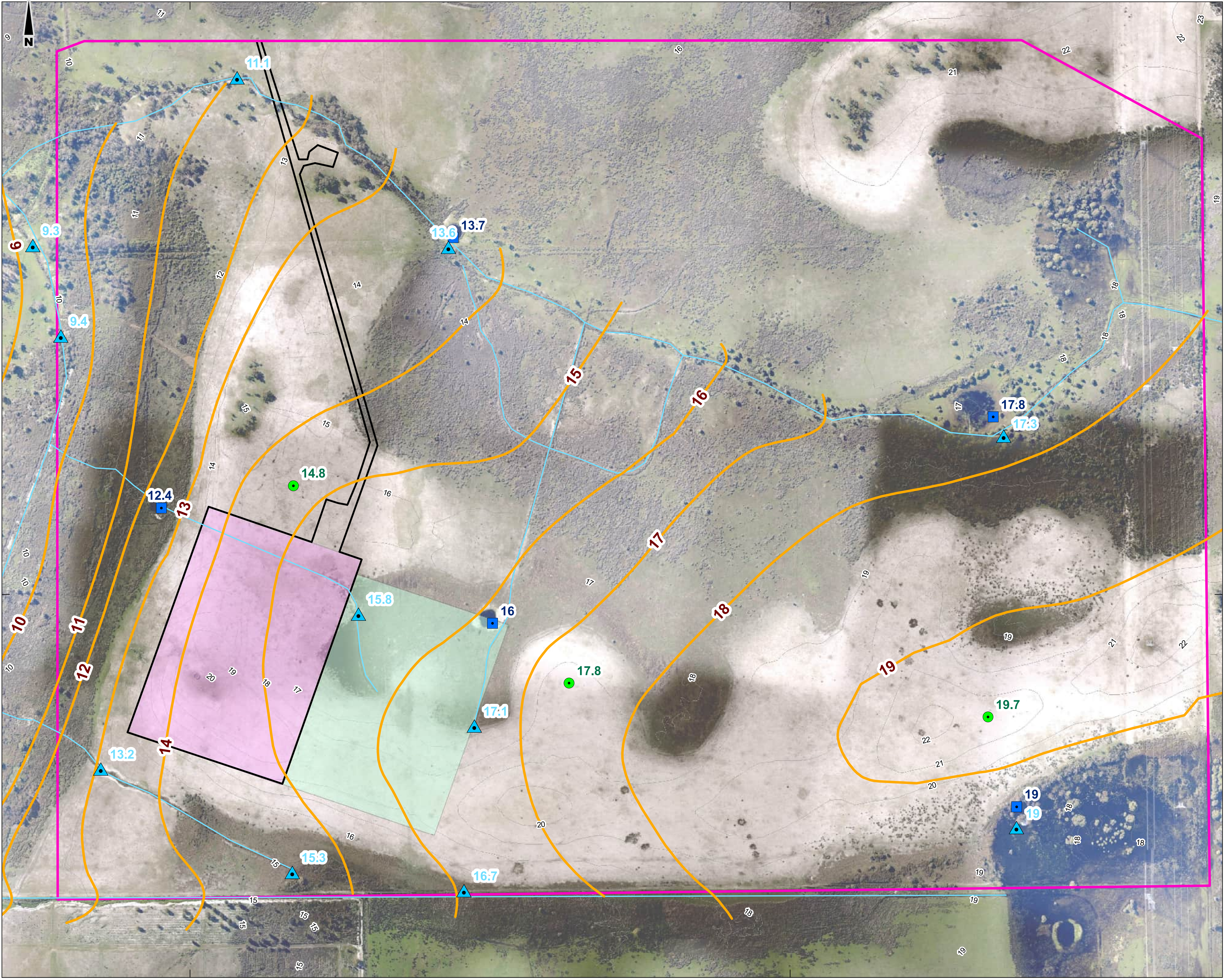
File Location: C:\Users\AUAL504625\OneDrive - WSP O365\C-Wise\4_WIP\02 GIS\Figure 5 - AAMGL Contours.mxd



LEGEND

- ▭ Site Boundary
- ▭ Stage 1 Development Area

Proposed Plant Area

- 🟪 Stage 1
- 🟩 Stage 2 (Future Development)
- — Local Drains (Ephemeral)
- ● Monitoring Wells (estimated GWL)
- ▲ Surface Drain (Max Estimated WL - will drain groundwater)
- ■ Ponds (Estimated water level)
- — Groundwater Level Contours - 50 Yr DGWL (m AHD)
- — LiDAR topographic contours (m AHD)
- — LiDAR topographic contours (m AHD)

NOTES

Coordinate System: GDA 1994 MGA Zone 50

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0 70 140 210 280
metres

SCALE (at A3) 1:6,000

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DATE	12 May 2023
COMPILED	AL
APPROVED	DRAFT

C-WISE
EAST KERALUP SITE

INFERRED GROUNDWATER LEVEL CONTOURS - 50 YR DGWL

FIGURE 6

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File Location: C:\Users\AUAL504625\OneDrive - WSP O365\C-Wise\4_WIP\02 GIS\Figure 6 - 50 Yr DGWL Contours.mxd

Appendix A

Bore Information

A1 Groundwater Bore Information

Table A.1 Information for groundwater bores identified during desktop study from the DWER online Water Information Reporting database (indicated by WIR ID) and

Bore ID	Other ID	Ground Level (m AHD)	Screen (m bgl)	Depth to Coffee Rock (m bgl)	Top to Coffee Rock (m AHD)	Coffee Rock Thickness (m)	Screen Above/Below Coffee Rock	Groundwater Level Information	Groundwater Quality Information
61405266	Murray River Catchment 614 - Bore	13^	14.63 – 18.29	0.6 – 3.6	~12.4	3	Below	No information	
61410070	Lake Thompson – T590	8.338	1.6 – 22.0	Not mentioned	Not mentioned	Not mentioned	Not mentioned	1975 – 2022	
61410079	Lake Thompson – T650	18.195	2.1 – 18.0	4.5 – 10.0	13.7	5.5	Within	1975 – 2022	
61410105	Lake Thompson – T600 (O)	20.860	1.0 – 18.0	1.5 – 3.0	19.3	1.5	Within	1975 – 1983	
61410106	Lake Thompson – T600 (I)	20.91	10.0 – 14.0	No lithological information	No lithological information	No lithological information	Unknown	1977 – 2018	
61410677	Murray Superficial – HS108_2A	16.709	6.25 – 8.25	5.1 – 5.6	11.6	0.5	Below	2009 – 2018	
61410678	Murray Superficial – HS108_2B	16.709	1.0 – 3.5	3.7 – 4.1	13.0	0.4	Above	2009 – 2012	
61410679	Murray Superficial – HS109_1	19.794	2.5 – 5.5	5.8 – 6.0 (Refusal)	14.0	~0.2	Above	2009 – 2012	
61410680	Murray Superficial – HS109_2	20.076	2.6 – 5.6	4.2 – 4.6 and 5.9 – 6.1	15.9	~0.2	Within	2009 – 2012	
61410730	Nambeelup Bores - Wf7S	-	No information	No lithological information	No lithological information	No lithological information	Unknown	2004 – 2005	
Bore 7	N/A	16^	5.86 – 8.86	3.8 – Unknown	~13.2	Unknown	Below	2008, 2021, 2022-2023	
Bore 8	N/A	18^	2.38 – 5.38	4.8 – Unknown	~16.2	Unknown	Across	2008, 2022-2023	
Bore 9	N/A	21.5^	2.72 – 5.72	Possibly ay 6.1	Possibly at 15.8	Unknown	Above	2008, 2021, 2022-2023	

^ - Groundwater level inferred from topographical maps, ‘m bgl’ – metres below ground level’, ‘m AHD’ – metres Australian Height Datum.

Appendix B

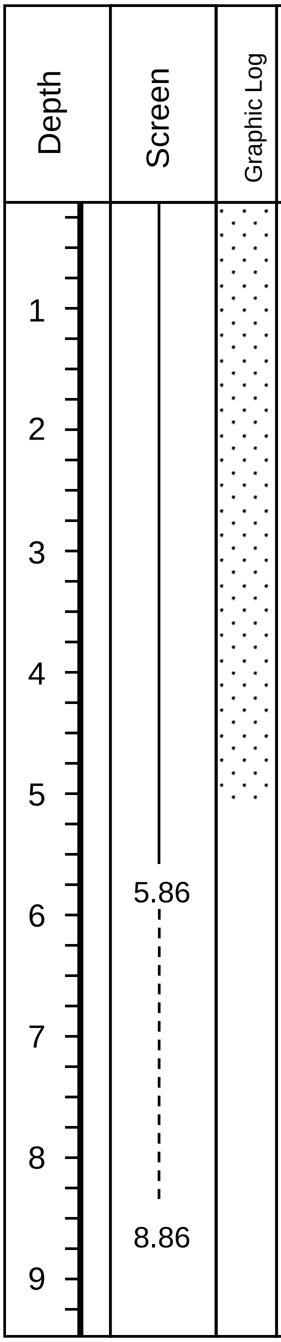
Site Borelogs

Endemic Pty Ltd
17 Railway Road
Subiaco WA 6008

office: + 8 9381 7900
mobile: +0418 111 236
email: endemic@iinet.net.au
ABN: 73692395972

Geotechnical Soil Bore Engineering Log

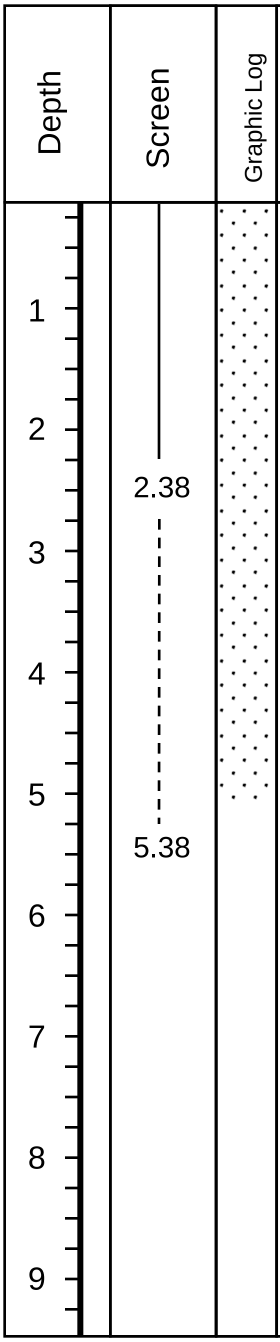
Client:	Emerson Stewart	**Date Sampled:**	13/05/08
Project:	Keralup	**Recorded by:**	Hayden Ajduk
Bore Identification:	B07	**Checked by:**	
GPS Coordinates:	50 391 173 E	**Bore Depth:**	9.0m
	64 06182 N		



m	Soil and Rock Field Description	Moisture	Additional observations
0.5	Grey medium sand	D	
1.0	White medium sand	D	
1.5	White medium sand	D	
2.0	White medium sand	D	
2.5	White medium sand	D	
3.0	White medium sand	W	Water at 2.8m
3.5	White medium sand	W	
4.0	Unable to retrieve sample	W	Coffee rock at 3.8m
4.5	Unable to retrieve sample	W	
5.0	Black brown compact sand (sample taken off auger)	W	

Geotechnical Soil Bore Engineering Log

Client:	Emerson Stewart	**Date Sampled:**	14/05/08
Project:	Keralup	**Recorded by:**	Hayden Ajduk
Bore Identification:	B08	**Checked by:**	
GPS Coordinates:	50 391 630 E	**Bore Depth:**	5.0m
	64 05854 N		



m	Soil and Rock Field Description	Moisture	Additional observations
0.5	Grey medium sand	D	
1.0	White medium sand	D	
1.5	White medium sand	D	Water at 1.9m
2.0	White medium sand	W	
2.5	White medium sand	W	
3.0	White medium sand	W	
3.5	White medium sand	W	
4.0	White medium sand	W	
4.5	White medium sand	W	Coffee rock at 4.8m

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mobile: +0418 111 236
email: endemic@iinet.net.au
ABN: 73692395972

Geotechnical Soil Bore Engineering Log

Client:	Emerson Stewart	**Date Sampled:**	14/05/08
Project:	Keralup	**Recorded by:**	Hayden Ajduk
Bore Identification:	B09	**Checked by:**	
GPS Coordinates:	50 392 330 E	**Bore Depth:**	5 6.0m
	64 057 93 N		

Depth	Screen	Graphic Log	m	Soil and Rock Field Description	Moisture	Additional observations
			0.5	Grey medium sand	D	
1			1.0	White medium sand	D	
			1.5	White medium sand	D	
2			2.0	White medium sand	D	
	2.72		2.5	White medium sand	D	
3			3.0	White medium sand	D	
			3.5	White medium sand	W	Water at 3.3m
4			4.0	White medium sand	W	
			4.5	White medium sand	W	
5			5.0	White medium sand	W	
	5.72		5.5	White medium sand	W	
6			6.0	White medium sand	W	Resistance at 6.1m
7						
8						
9						

Appendix C

Limitation Statement

Limitation Statement

This Report is provided by WSP Australia Pty Limited (*WSP*) for (*Client*) in response to specific instructions from the Client and in accordance with WSP's proposal dated and agreement with the Client dated (*Agreement*).

PERMITTED PURPOSE

This Report is provided by WSP for the purpose described in the Agreement and no responsibility is accepted by WSP for the use of the Report in whole or in part, for any other purpose (*Permitted Purpose*).

QUALIFICATIONS AND ASSUMPTIONS

The services undertaken by WSP in preparing this Report were limited to those specifically detailed in the Report and are subject to the scope, qualifications, assumptions and limitations set out in the Report or otherwise communicated to the Client.

Except as otherwise stated in the Report and to the extent that statements, opinions, facts, conclusion and / or recommendations in the Report (*Conclusions*) are based in whole or in part on information provided by the Client and other parties identified in the report (*Information*), those Conclusions are based on assumptions by WSP of the reliability, adequacy, accuracy and completeness of the Information and have not been verified. WSP accepts no responsibility for the Information.

WSP has prepared the Report without regard to any special interest of any person other than the Client when undertaking the services described in the Agreement or in preparing the Report.

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Appendix B

Groundwater Model Description

1.0 GROUNDWATER MODEL DESCRIPTION

The numerical groundwater model was developed using the software Visual MODFLOW, which is a 3D finite difference groundwater flow model used extensively throughout the world.

1.1 Model Setup

The model setup and main input parameters are outlined below.

1.1.1 Extent and Grid Sizing

Figure A shows the extent of the model, which is 2200 m long and 2200 km wide, which was selected so that:

- Natural boundaries (surface water drains) could be applied where possible, and
- Boundaries were set at distances judged to be far outside the anticipated influence of the groundwater level control drainage system.

The grid sizing within the model 2 m by 2 m and thereby consists of a total of 1100 rows and 1100 columns.

The model has been rotated 20 degrees counterclockwise from the GDA20-PCG20 coordinate system, so that the proposed drains are parallel to the grid, as this allows for a better presentation of these features and will minimise numerical effects related to simulating groundwater at an angle of the cells.

Figure A: Model Extent

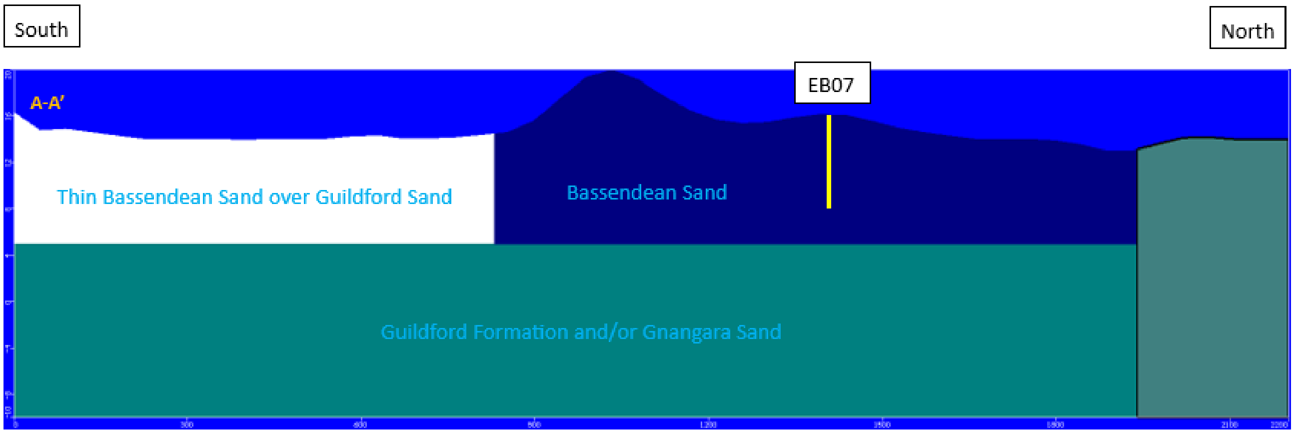
1.1.2 Layers

Figure B shows two schematic cross sections in the model across the site (refer to Figure A for location of sections). The model is divided into two layers:

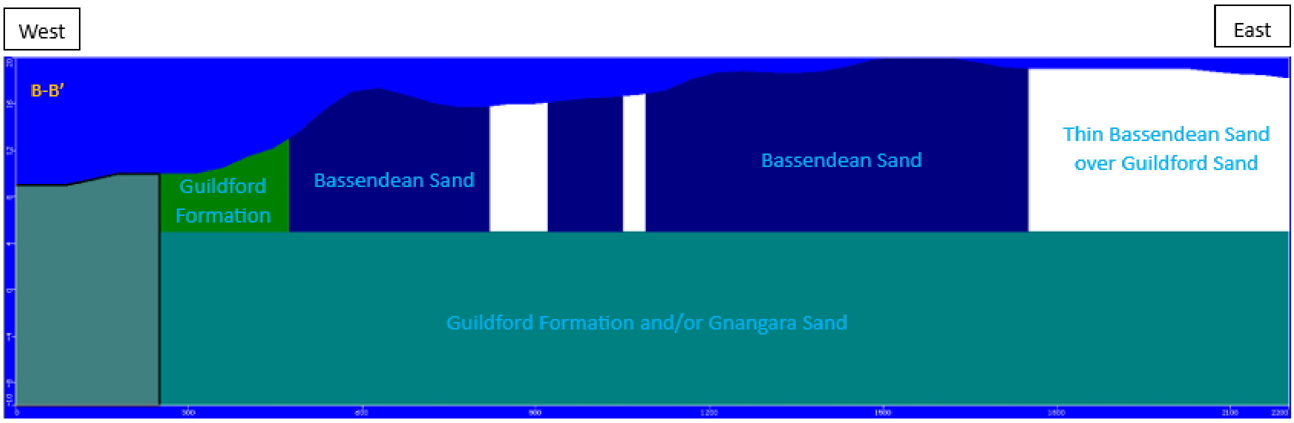
- Layer 1 - representing the Bassendean Sand and Guilford Formation (where Bassendean Sand is not present).
- Layer 2 - representing the Guildford Formation (mainly sand) and/or Gnangara Sand

The geology in the model was based on the WSP conceptual hydrogeological model (presented in Figure J in Appendix A). A Guildford Formation clay was shown to be present at the base of the Superficial Aquifer separating the

The surface elevation is based on the publicly available 1m LIDAR topographic data for the Perth Metro area, while the base Layer 2 (representing the base of the Bassendean Sand where present) is set at constant elevation of RL 5 m AHD, respectively. The bottom of the model has been set at RL -10 m AHD.



Column 332



Row 524

Figure B: Groundwater Model Cross Sections

1.1.3 Boundary Conditions

Boundary conditions are assigned in the model to control how water will flow into and out of the model. It is preferable that natural boundaries are used where they exist, otherwise boundaries should be set far enough away that they do not influence what is occurring within the model.

Figure C shows the boundary conditions used in the model.

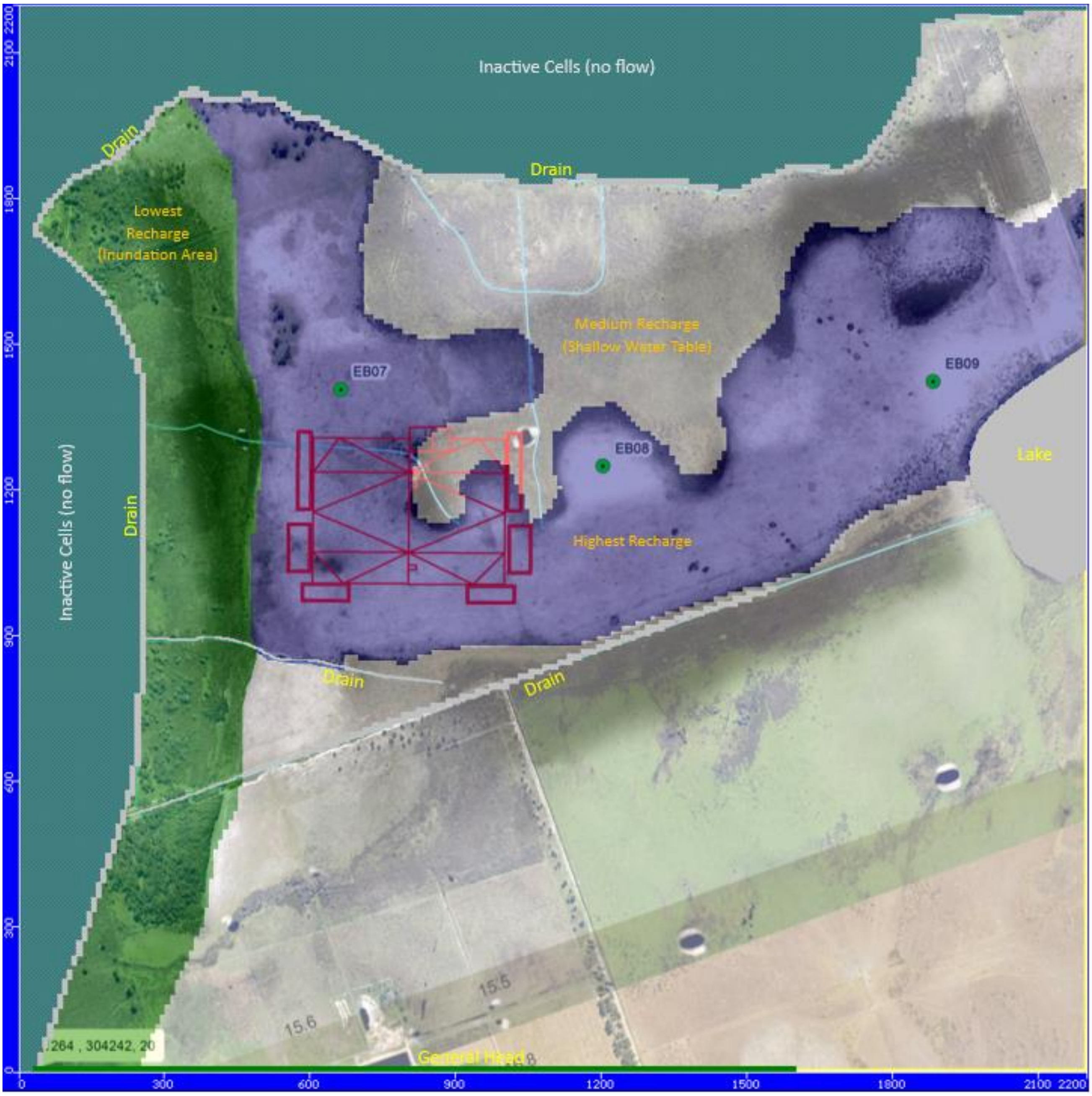


Figure C: Model Boundary Conditions

1.1.3.1 Drain Boundaries

A lake function was applied to represent the wetland feature in the eastern part of the model

Drain functions were applied to represent the surface water drainage features across the site as these drains are ephemeral and will therefore not provide water to the aquifer but rather control/drain the groundwater during the wet season.

The drain module in Visual Modflow was also used to model the proposed drains.

1.1.3.2 General Head Boundaries

General head boundaries (GHB) were assigned at the southern of the model in all layers where no natural boundary is present. The boundaries were set using off-set groundwater level contours and observed groundwater levels in the area.

1.1.3.3 Recharge

Spatially and temporally recharge values of 200 mm/yr to 300 mm /yr (approximately 30% to 40% of Mean Annual Rainfall) had to be applied across the whole model during the steady state model calibration. These recharge rates are considered realistic given the sandy site conditions and generally flat terrain. The higher recharge was applied over the Bassendean Sand dunes where the depth to groundwater is greatest.

For the transient model calibration from November 2022 to October 2023, the respective monthly rainfall data was used with a similar rainfall recharge percentage of the monthly rainfall. Where the monthly rainfall was less than 20 mm, a recharge value of 0 mm was applied based on the assumption that such combined small rainfall events would either evaporate or form part of soil moisture rather than recharging the aquifer.

For the DGWL and drainage scenarios model events the same rainfall recharge percentage was applied, but for a larger rainfall year that would result in a 50 yr DGWL event.

Since most of the project facility site footprint will be paved/concreted which will reduce the rainfall recharge over the footprint (the rainfall will mainly become runoff water, which will be captured and discharged into lined stormwater ponds, the annual rainfall recharge was modelled to be 15 mm during the drainage modelling scenarios, which is approximately 2% of the annual rainfall (considered conservative).

1.1.3.4 Evapotranspiration

An evapotranspiration rate of 1500 mm/yr was applied to the model with an extinction depth of 0.2 m, which means that where the groundwater level reaches the model surface, evapotranspiration would take place. The shallow extinction depth means that the evaporation function would mainly occur in the observed inundation areas.

1.2 Model Assumptions

The following is a list of assumptions used in the design of the model:

- Each hydrogeological unit is homogenous.
- Off-site impacts which could influence the model area such as other pumping/dewatering from other areas has not been considered in the model.
- The drain module was used to model the proposed drains:
    - The minimum allowable gradient of the drainage swales and sub-soil drains are 0.2% to ensure that there is sufficient hydraulic gradient to transport/discharge the intersected groundwater.
    - Given the flat gradient of drainage swales, it is not uncommon that the groundwater level rises above the drainage swale invert level (i.e. water can be seen in the swales). The water levels in the drains (corresponding to the groundwater level at the drain) was set at 0.3 m above the swale invert levels.

2.0 MODEL CALIBRATION

The Steady State model is the calibration phase in the design of the numerical groundwater model. Two steady state models were run to assess the hydraulic properties in the model:

- Dry Season steady state model run where the modelled groundwater level was compared to the measured May 2018 groundwater level.
- “Wet Season” steady state model run where the modelled groundwater level was compared to the higher 2011 groundwater level and transposed groundwater levels in the new monitoring wells based on expected seasonal variation. As described in the report the 2011 groundwater levels do not strictly represent the wet season as the groundwater levels were measured in July 2011, which is during the dry season. However, 2011 was a very wet year and Lagoon 1 was full of water in July 2011, which in an average year would only occur during the wet season. We therefore consider that the 2011 groundwater levels are representative for a normal wet season groundwater levels.

The models were run to simulate the overall average groundwater level contours and groundwater flow direction, by changing hydraulic conductivity and recharge.

A transient calibration model runs was undertaken using the Wet Season steady model results as initial heads in the model. The FWRP Drain was then removed, and the model run for 1 year to simulate the groundwater level decline in the area around the FWRP Drain.

2.1 Calibration Results

The groundwater model calibration results are presented in Section 4 of the main report.

2.2 Adopted Hydraulic Properties

Table 1 presents the hydraulic input parameters that provides the best overall calibration. The hydraulic conductivities used in the model were found to be similar to the estimated hydraulic conductivities and our experience in the area.

Table 2-1 Hydrogeological Parameters used in the Groundwater Model

Model Unit	Horizontal Hydraulic Conductivity (m/d)	Vertical Hydraulic Conductivity (m/d)	Specific Yield	Specific Storage (1/m)
Bassendean Sand	10	3	0.15	-
Thin Bassendean Sand and Guildford Formation	5	2	0.10	$1\text{x}10^{-4}$
Guildford Formation	3	1	0.10	$1\text{x}10^{-4}$

Appendix C
Important Information About Your FSG Report

Important Information About Your FSG Report

Deep foundation and geotechnical engineering problems are a principal cause of construction delays, cost overruns, claims and disputes. The following information is provided to help you to understand this report and its limitations and manage your risks.

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This report has been based on project details as provided to us at the time of the commission. We have assumed that the information supplied to FSG by the client or other external sources on behalf of the client, is correct unless explicitly stated so. FSG does not accept any responsibility for incomplete or inaccurate data provided by others.

If any project details change during the course of the project or observed conditions are considered to differ from those expected or assumed, FSG should be notified in order to investigate if and how changes in project details affect the conclusions and recommendations in our report. If FSG is not consulted when changes are made to the initial project details, we cannot accept any responsibility for problems arising from these changes.

Geotechnical Information and Interpretation

Site investigations only sample discrete parts of the ground, and that extrapolation and interpolation of collected information can be used with varying degrees of risk and uncertainty depending on the extent and quality of the site investigation, the variability of the subsurface conditions and the consequences to the proposed works.

The analyses and recommendations in this report rely on the results of site investigation information, and other reported geotechnical information that is relevant to the works. This may include the results of pile load testing, other geotechnical testing, and inspections and observations from studies that have been performed as part of the works or in the vicinity of the works previously.

We have endeavoured to incorporate the available information into an appropriate geotechnical model based on our interpretation of the likely subsurface conditions. This process, and the geotechnical analysis and interpretation based on that model, is an inexact science, as a model is but a simplification of reality to derive a geotechnical solution. While we endeavour to incorporate realistic model parameters, our models, interpretations and the outcomes or our work generally may differ from reality for a range of reasons including:

- Spatial Variability: Geotechnical and geological variability across the site which may not have been captured in the site investigation works that have been used in our works. Geotechnical site investigations are very limited in the extent of physical investigation compared to the size of the entire site. No site investigation, no matter how comprehensive, can reveal all subsurface details and anomalies and conditions that differ from those observed in the site investigation will occur;
- Temporal Variability: Subsurface conditions can change with time due to man-made events such as cutting or filling or any construction works on or adjacent to the site which can also affect the site drainage and hence underlying properties; or by natural events such as floods or groundwater fluctuations.
- Variability in Mechanical Properties: Normal geotechnical variability in the inferred properties of materials represented in the boreholes, the performance of foundations or other elements that are tested or observed, and the performance of structures that are in contact with the ground in general. The data collected is only directly relevant to the exact location where the investigation was undertaken. The subsurface conditions between test locations have been inferred based on judgement and experience with the facts available at that time and related to the relative position of the proposed works;
- Testing Limitations: Uncertainty associated with geotechnical testing, design correlations associated with those tests or material descriptions, and case histories from which geotechnical parameters may have been inferred or in design and/or analysis methods that have been adopted;

- Construction Effects: Variability in the performance of construction equipment, such as hammers, cushions, guides and associated equipment for piling, construction effects that may influence the way structures interact with the ground, as well as inaccuracies in data measurement and testing methods that may have been used to record construction processes.

The results provided should be considered as indicative of the best estimate of likely outcomes (or range thereof), and should not be considered to be definitive or absolute, or represent the full range of possible outcomes at this site. Caution and prudence should be exercised when making decisions with significant implications for your project. The limitations of this report as outlined herein should be incorporated in decision making, and appropriate contingencies should be put in place to accommodate unexpected variability in relation to the works

Geotechnical Modelling

Model parameters that are used may vary in nature depending on the purpose of the analysis. Where it is necessary to make a realistic evaluation of the soil model, we would normally describe this as a ‘best estimate’ (BE). Depending on the particular application, it may be important to understand the sensitivity of the solution to soil model changes. We may then also define an ‘upper-bound’ (UB) soil model and a ‘lower-bound’ soil model, being estimates of the likely, strongest and weakest soil conditions which are anticipated based on the available geotechnical information and inferred geotechnical parameters. In certain circumstances, such as cases where the ground conditions appear to extremely uncertain or variable, we may also define ‘extreme upper bound’ (XUB) and ‘extreme lower bound’ (XLB) parameters which are intended to represent the likely extremes of the site conditions. In all cases, these models are inferred using engineering judgement from the available information and actual conditions and associated outcomes may differ from those assumed or given in our report, due to the inherent unpredictability of the ground, as outlined in the preceding section.

It should be noted that depending on the particular application either upper-bound or lower-bound analyses could be deemed conservative.

Disclaimer

The results, opinions, conclusions and any recommendations in this report are based on assumptions made by FSG in order to carry out the work. FSG specifically disclaims responsibility: arising from, or in connection with, any change to the site conditions or the nature of the proposed works including change in position of the structure or proposed works relative to the available data; to update this report if the site conditions or project details change or if the report is used after a protracted delay; and for liability arising from any of the assumptions that have been made or information provided being incorrect, incomplete or inaccurate.

Subject to the terms of an Agreement for Professional Services between FSG and the client, and to the maximum extent permitted by law, all implied warranties and conditions in relation to the services provided by FSG and this report are excluded.

Closure

Unless otherwise documented by way of a signed agreement for the services provided, all services in preparing this report have been provided under FSG’s standard Terms and Conditions which are referenced in our fee proposal. The report is specific to the brief provided with its associated time and cost constraints.

Should you require any further information or clarification in relation to this report, please contact FSG.