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**mitsui** E&P

Australia

**WAITSIA GAS PROJECT STAGE 2:  
WATER MANAGEMENT PLAN**

Issued for Comment

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## Abbreviations and terms

Abbreviation / Terms	Definition
ACAR	Annual Compliance Assessment Report
AHD	Australian Height Datum
ANZG	Australian and New Zealand Guidelines
ARI	Assessment on Referral Information
AWE Perth Pty Limited	AWE Perth Pty Limited is the legal entity, operator of the relevant Production Licences (L1 and L2), the proponent for the Proposal and operates under the Mitsui E&P Australia (MEPAU) brand.
BTEXN	Benzene, toluene, ethylbenzene, xylene and naphthalene
CO <sub>2</sub>	Carbon Dioxide
DBNGP	Dampier to Bunbury Natural Gas Pipeline
Development Envelope	The area of which the Proposal comprises
DO	Dissolved Oxygen
DoW	Department of Water
DWER	Department of Water and Environmental Regulation
EIA	Environmental Impact Assessment
EP Act	<i>Environmental Protection Act 1986</i>
EPA	Environmental Protection Authority
Flowline	Pipes that carry raw oil or gas products from the wells to a processing facility
GDE	Groundwater Dependant Ecosystem
ha	Hectares
kL	Kilolitre
kL yr	Kilolitre per year
km	Kilometres
m	metres
MEPAU	Mitsui E&P Australia Group AWE Perth Pty Limited is the legal entity, operator of the relevant Production Licences (L1 and L2), the proponent for the Proposal and operates under the Mitsui E&P Australia (MEPAU) brand
OCPs	Organochlorine pesticides
P1	Priority 1
PAHs	Polycyclic aromatic hydrocarbons
Pipeline	Pipes that carry processed oil or gas products from a processing facility to market.
SWL	Standing Water Levels
TDS	Total Dissolved Solids
The Proposal	The Waitsia Gas Project Stage 2
The Site	The Proposal location within the existing Waitsia Gas field located approximately 16 km south-east of Dongara, in the Shire of Irwin, Western Australia
TJ	Terajoule
TRH	Total Recoverable Hydrocarbons
WA	Western Australia

Abbreviation / Terms	Definition
Waitsia Gas Field	The known gas field resource subject to the existing and proposed operations
Waitsia Stage 1	The Waitsia Gas Project Stage 1
WGP	Waitsia Gas Plant (proposed)
XPF	Xyris Production Facility
Yaragadee	The Yaragadee Aquifer

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## 1.0 SUMMARY

A summary of this Water Management plan is provided in Table 1-1.

**Table 1-1: Summary of the Proposal**

<b>Proposal Title</b>	<b>Waitsia Gas Project Stage 2 (the Proposal)</b>
Proponent Name	AWE Perth Pty Limited Operating as MEPAU
Proponent Activities	Conventional gas plant, extraction, processing and distribution to the Dampier to Bunbury Natural Gas Pipeline
Short Description	The Proposal is to develop conventional gas production operations (Waitsia Stage 2) located approximately 16 km east of Dongara in Western Australia.
Ministerial Statement	The Proposal is currently being assessed by the EPA (Assessment 2226) and a Ministerial Statement and associated proposal implementation conditions are yet to be issued.
Purpose of this Water Management plan	<p>The purpose of this Plan is to identify the potential direct and indirect impacts on water systems and develop management and monitoring measures that protect existing systems as well as the groundwater-dependent ecosystems adjacent to the Proposal project development envelope.</p> <p>This plan has been written in accordance with the "Instructions on how to prepare Environmental Protection Act 1986 Part IV Environmental Management Plans" (EPA, 2018).</p>
<b>Key Environmental Factors and Objectives</b>	
Inland Waters	<b>EPA Objective:</b> <i>To maintain the hydrological regimes and quality of groundwater and surface water so that environmental values are protected.</i>
<b>Condition Clauses</b>	
Not applicable	Not applicable
<b>Key Provisions in the Plan</b>	
Key provision in the plan	<ul style="list-style-type: none"> <li>• Baseline ground and surface water monitoring</li> <li>• Ongoing ground and surface water monitoring</li> <li>• Trigger and threshold criteria and subsequent response actions</li> <li>• Annual reporting (including results of monitoring).</li> </ul>

## 2.0 CONTEXT, SCOPE AND RATIONALE

This Plan has been prepared by Mitsui E&P Australia (MEPAU)<sup>1</sup>. This Plan is intended to support the assessment, approval and implementation of the Proposal under Part IV of the *Environmental Protection Act, 1986* (EP Act).

MEPAU referred the Proposal to the Environmental Protection Authority (EPA) under Part IV of the EP Act on 22 August 2019 (EPA Assessment 2226). The EPA has decided to assess the Proposal as a significant proposal, through Assessment of Referral Information (ARI). The ARI is to include additional information requested under Section 40(2)(a) of the EP Act, including this Plan, which will be subject to a two-week public review period.

This plan has been written in accordance with the *“Instructions on how to prepare Environmental Protection Act 1986 Part IV Environmental Management Plans”* (EPA, 2018a).

### 2.1 Proposal

The petroleum exploration and production sector has been continually active in the northern Perth Basin since the 1960s. MEPAU is building on this long-standing presence and is progressively developing the Waitsia gas field, a free-flowing, conventional gas reservoir near the Dongara-Port Denison townsites in Western Australia. It is expected this will continue to provide ongoing operator presence in the region for up to 20 years. The Waitsia Gas Project Stage 1 (Waitsia Stage 1) was commissioned in 2016 and has been producing from two existing wells through the Xyris Production Facility (XPF). The Waitsia Gas Project Stage 1 Expansion is now under construction and will connect an additional existing well to XPF.

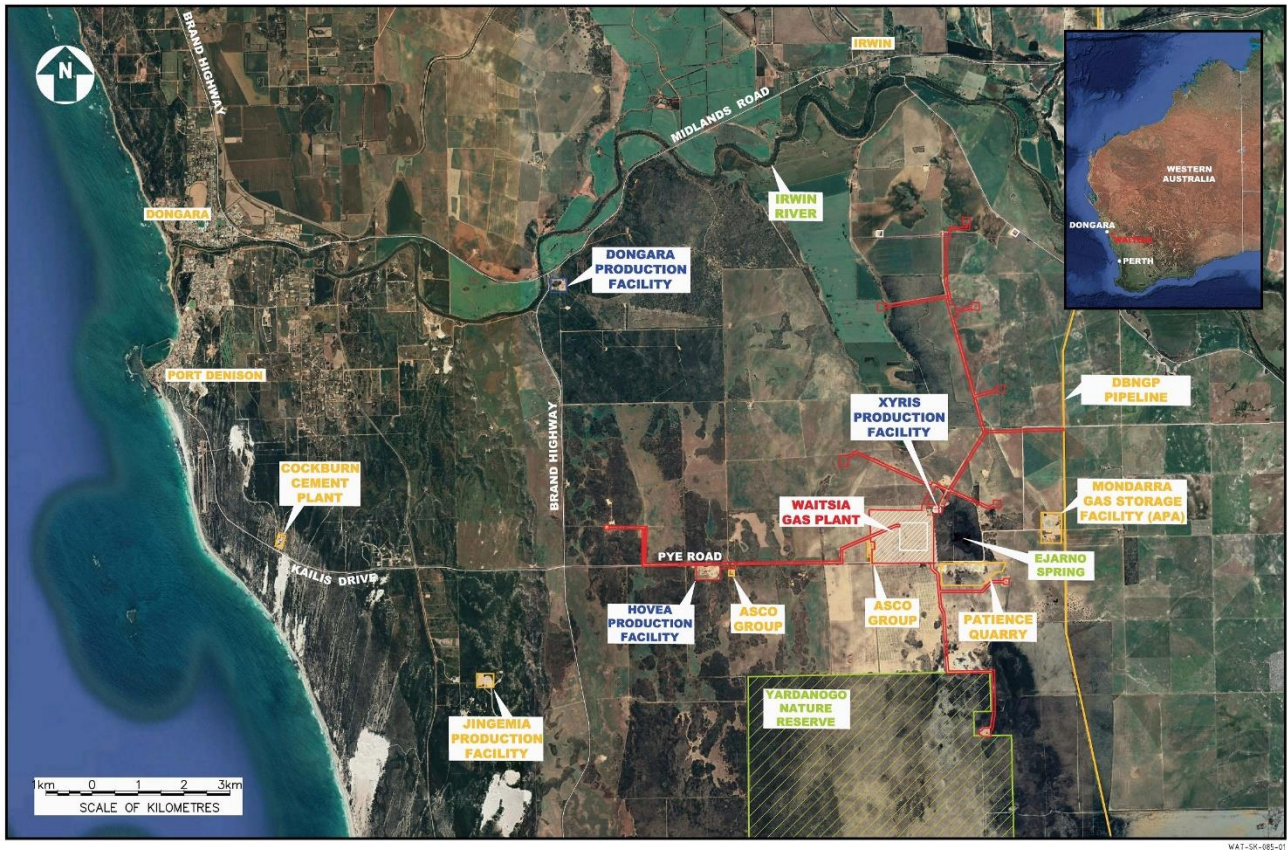
MEPAU is proposing to construct and operate the Waitsia Gas Plant (WGP) and related wells and gathering infrastructure. The Proposal is located in an agricultural area with extensive existing oil and gas field development, approximately 16 km east-south-east of the Dongara-Port Denison townsites (refer Figure 2-1). The Proposal will further develop the Waitsia gas field, a free-flowing conventional gas reservoir<sup>2</sup>.

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<sup>1</sup> AWE Perth Pty Limited is the legal entity, operator of the relevant Production Licences (L1 and L2), the proponent for the Proposal and operates under the Mitsui E&P Australia (MEPAU) brand.

<sup>2</sup> No hydraulic fracture stimulation (i.e. no fracking) is proposed given the free-flowing nature of the Waitsia gas field.





**Figure 2-1: Regional Setting**

The Proposal includes the following components:

- Constructing a new gas plant with a maximum export capacity of 250 terajoules (TJ) per day;
- Drilling up to six<sup>3</sup> new wells, supplementing the existing two (i.e. Waitisia-03 and Waitisia-04) suspended appraisal wells; A gathering system comprising flowlines and hubs to convey the extracted gas from the well sites to the Plant and export the gas;
- Installing a flowline from the WGP for water re-injection to the formation via disused petroleum production well, thus minimising the requirement for and size of evaporation ponds.

### 2.1.1 Waitisia Gas Plant

Gas extracted from the wells will be conveyed to centrally located gas gathering stations, or hubs, then directed via two flowlines to the proposed Plant for processing prior to being exported from the gas plant to the nearby Dampier to Bunbury Natural Gas Pipeline (DBNGP).

The Plant will use the same standard components as those used for processing Waitisia Stage 1 gas from the existing XPF. These would comprise the following processing components:

- Slug catcher and inlet separation as the gas enters the plant
- Mercury removal equipment

<sup>3</sup> Another stage of Waitisia gas field development could include drilling of up to an additional eight (8) wells, resulting in an expected 17 wells in total over the life of the Waitisia gas field. Any additional wells are separate to this Proposal and will be subject to separate approvals.

- Gas refining and treatment to achieve the DBNGP pipeline gas quality specifications, which includes removing carbon dioxide (also known as 'sweetening'),
- Hydrocarbon dew-point control;
- Water content control;
- Export compression;
- Sales gas metering
- Produced water treatment
- Support utilities.

The Plant will be operated 24 hours a day and 365 days a year, except for maintenance shutdowns.

### **2.1.2 Gathering System**

The Gathering System comprises the flowlines that convey the gas from underground wells to the gas hubs and various items of above-ground infrastructure.

### **2.1.3 Wells**

Two existing wells (i.e. Waitsia-03 and Waitsia-04) will be brought on stream as part of the Proposal, with the drilling of up to six additional wells.

Currently, two existing wells (i.e. Waitsia-01 and Senecio-03) are operating, with extracted gas from these wells being transmitted to the existing XPF under the separate Stage 1 project. The Waitsia Stage 1 Expansion will connect a third existing well (Waitsia-02) to XPF.

### **2.1.4 Supporting Utilities**

The following supporting utilities will be required for the Proposal:

- Fuel gas system
- Electrical Power generation facilities
- An instrument air system
- Flare system
- Fire water system
- Utility water system
- Water treatment package
- Diesel system.

### **2.1.5 Development Envelope**

The total area of the development envelope for the Proposal area is ~345 ha (Figure 2-2).

### **2.1.6 Water Extraction**

Groundwater is required to be extracted to support the construction and operation of the WGP. A summary of the activities / systems that will require extracted groundwater include:

- construction
- dust suppression
- amine system (described below)

- ablutions
- lawn irrigation
- workover operations
- fire water ring main.

The amine system is a gas sweetening system that is used to remove carbon dioxide (CO<sub>2</sub>) from the reservoir gas to ensure it meets the specification required to be transported via the DBNGP. This is the key gas processing system where water is required to be used. The amine chemical is diluted with water, and this mixture (lean amine) then is brought in contact with the hydrocarbon gas and the CO<sub>2</sub> is stripped out of the gas. The amine-water-CO<sub>2</sub> mixture (rich amine) is then regenerated and the CO<sub>2</sub> is driven off, resulting in the lean amine which in turn is recirculated back through the process. It is during the amine regeneration stage that water is lost from the system, and so make-up water is required. It is estimated that during peak production, the system may use up to 52 kL /day.

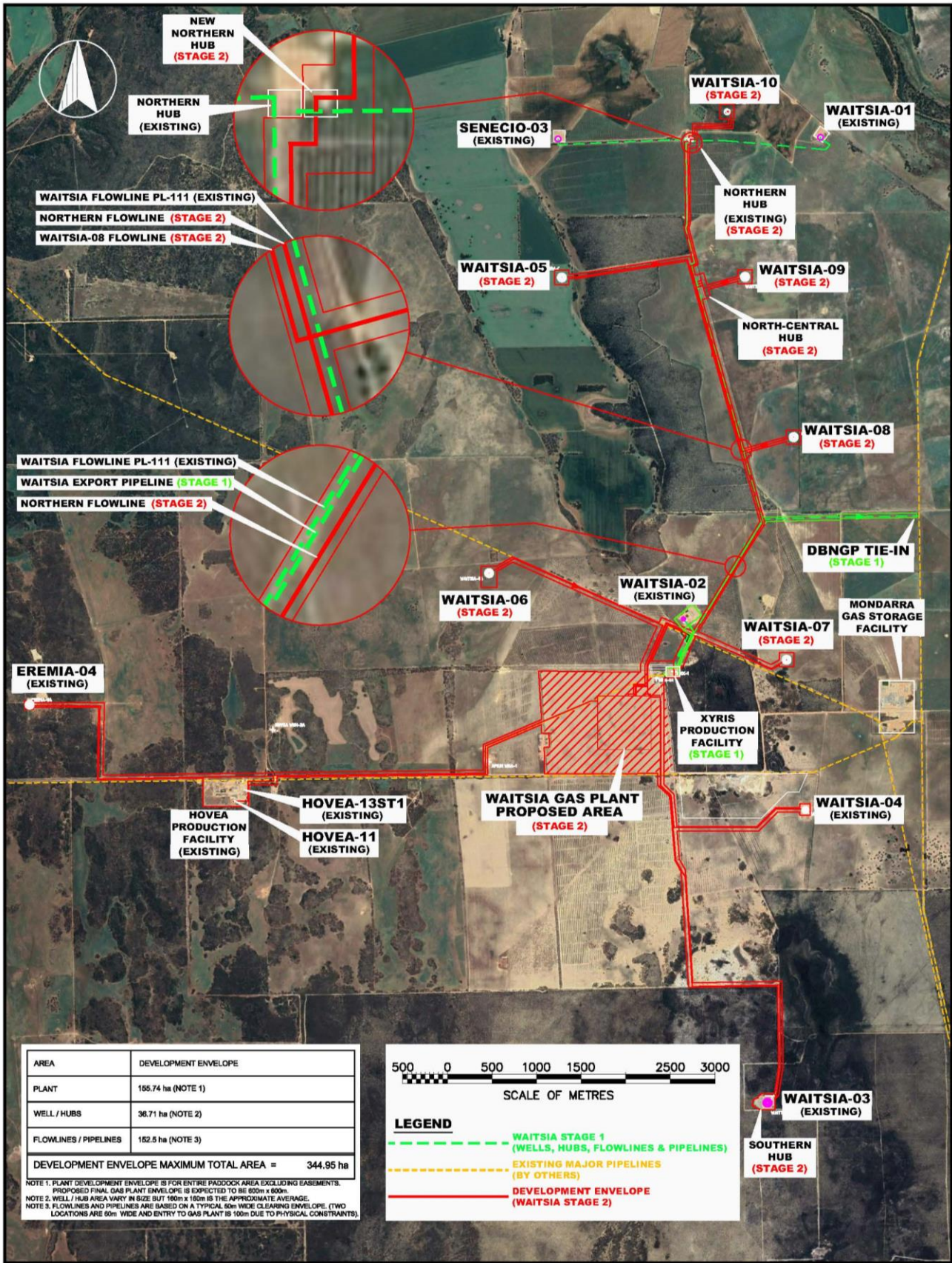
MEPAU estimates that water usage will be higher during the initial construction period, with volumes of groundwater required to support the facility conservatively estimated to be in the order of 60,000 kL /annum for the life of the Proposal (approximately 20 years). This includes water for all aspects of the proposal including gas sweetening, dust suppression, ablutions irrigation and other requirements.

### 2.1.7 Key Proposal Characteristics - Water Management

The Key Proposal characteristics specific to Water Management are summarised in Table 2-1.

**Table 2-1: Key Project Characteristics - Water Management**

Element	Characteristic
Water extraction bore location	Extraction bores will be located within the WGP proposed area (Figure 2-2)
Number of extraction bores	Up to four new extraction bores are estimated to be required to support the Proposal
Volume of water extracted	The estimated volume required to be extracted is conservatively estimated to be in the order of 60,000 kL /annum for the life of the Proposal (approximately 20 years)



WAT-5K-113-01

Figure 2-2: Waitsia Gas Project Stage 2 - Development Envelope

## 2.2 Key Environmental Factors

Water extraction required for the Proposal (Section 2.1.6) has been identified as having the potential to affect the Key Environmental Factor – Inland Waters. A summary of the Inland Waters factor with a specific focus on the extraction of groundwater and the impact relating to this activity is included below in Table 2-2.

**Table 2-2: Summary of key environmental factor – Inland Waters**

Inland Waters	
<b>EPA objective</b>	<i>To maintain the hydrological regimes and quality of groundwater and surface water so that environmental values are protected.</i>
<b>Policy and guidance</b>	<ul style="list-style-type: none"> <li>• Environmental Key Factor Guideline – Inland Waters (EPA, 2018b)</li> <li>• Australian and New Zealand (ANZG) Guidelines for Fresh and Marine Water Quality (2018)</li> <li>• AS/NZS 5667.11:1998 Water Quality – Sampling - Guidance on Sampling of Groundwaters.</li> </ul>
<b>Project activities</b>	Water Extraction for the purpose of construction and operation of the Proposal
<b>Environmental Values</b>	<ul style="list-style-type: none"> <li>• Groundwater Dependent Ecosystems (GDE) – Ejarno Spring</li> <li>• Other groundwater users.</li> </ul>
<b>Potential impacts – Direct impacts</b>	<ul style="list-style-type: none"> <li>• Reduction of SWL associated with the extraction of groundwater volumes conservatively estimated to be in the order of 60,000 kL / annum for the life of the Proposal (approximately 20 years)</li> <li>• Changes to groundwater and surface water quality.</li> </ul>
<b>Potential impacts – indirect impacts</b>	<ul style="list-style-type: none"> <li>• Reduction and/or changes in floristic diversity.</li> </ul>

## 2.3 Condition Requirements

The Proposal is currently being assessed by the EPA (Assessment 2226) and a Ministerial Statement and associated proposal implementation conditions are yet to be issued.

Should this Proposal be approved for implementation, any conditions relating to this Plan will be included in this section.

## 2.4 Rationale and Approach

This section provides a concise description of the rationale and approach for this Plan. Specifically, the following sub-sections summarise:

- The site-specific environmental values, existing and/or potential uses, ecosystem health condition or sensitive component of the key environmental factor which will be affected (Section 2.4.1)
- Study findings (Section 2.4.2)
- Groundwater modelling overview and findings (Section 2.4.3)
- Key assumptions (Section 2.4.4)
- Management approach (Section 2.4.5)
- Rational for choice of provisions (Section 2.4.6).

### 2.4.1 Receiving Environment

In the Development Envelope, the groundwater system comprises predominantly unconfined superficial formations overlying the Yarragadee Aquifer (Yarragadee). Superficial formations overlying the Yarragadee include alluvium, Tamala Limestone, Bassendean Sand and colluvium. These

predominantly drain into the Yarragadee however some perched layers are known to exist in the area (DoW, 2017).

The Proposal is located next to an alluvial depression (situated to the east of the site) which features surface expression of groundwater known as Ejaro Spring, a relic of palaeo-lake system, forming a permanently wetted depression of irregular morphology. Similar features also occur further away to the southeast of the Proposal.

The main regional aquifer beneath the Waitsia Gas Field is the Yarragadee (the top, D unit), which has the following characteristics in the Waitsia Reservoir area:

- composed of shale, siltstone and sandstone (Rockwater, 2015)
- standing water levels (SWLs) vary from 75 m Australian height datum (m AHD) to 15 m AHD, corresponding to 0 to 100 metres below ground surface (m bgs)
- hydraulic gradient is broadly west-southwest toward the Indian Ocean (DoW, 2017)
- salinity is typically fresh to marginal near the surface and increases to brackish with depth.

A review of groundwater levels in existing MEPAU monitoring bores screened in the Yarragadee around the Development Envelope, suggests that the aquifer is likely to be confined or partially confined.

Groundwater recharge into the Yarragadee is by direct rainfall (in outcrops) as well as downward leakage from overlying aquifers i.e. the superficial formations. In the area around the Project site recharge is likely to be affected by:

- concentrated surface water infiltration within the river valleys, for example, the Irwin River system to the north that receives runoff from its catchment
- restricted by clayey lithologies resulting in elevated groundwater salinity in the upper portion of the aquifer (Commander, 1981)
- alluvial depressions such as the one encountered to the east of the Project site.

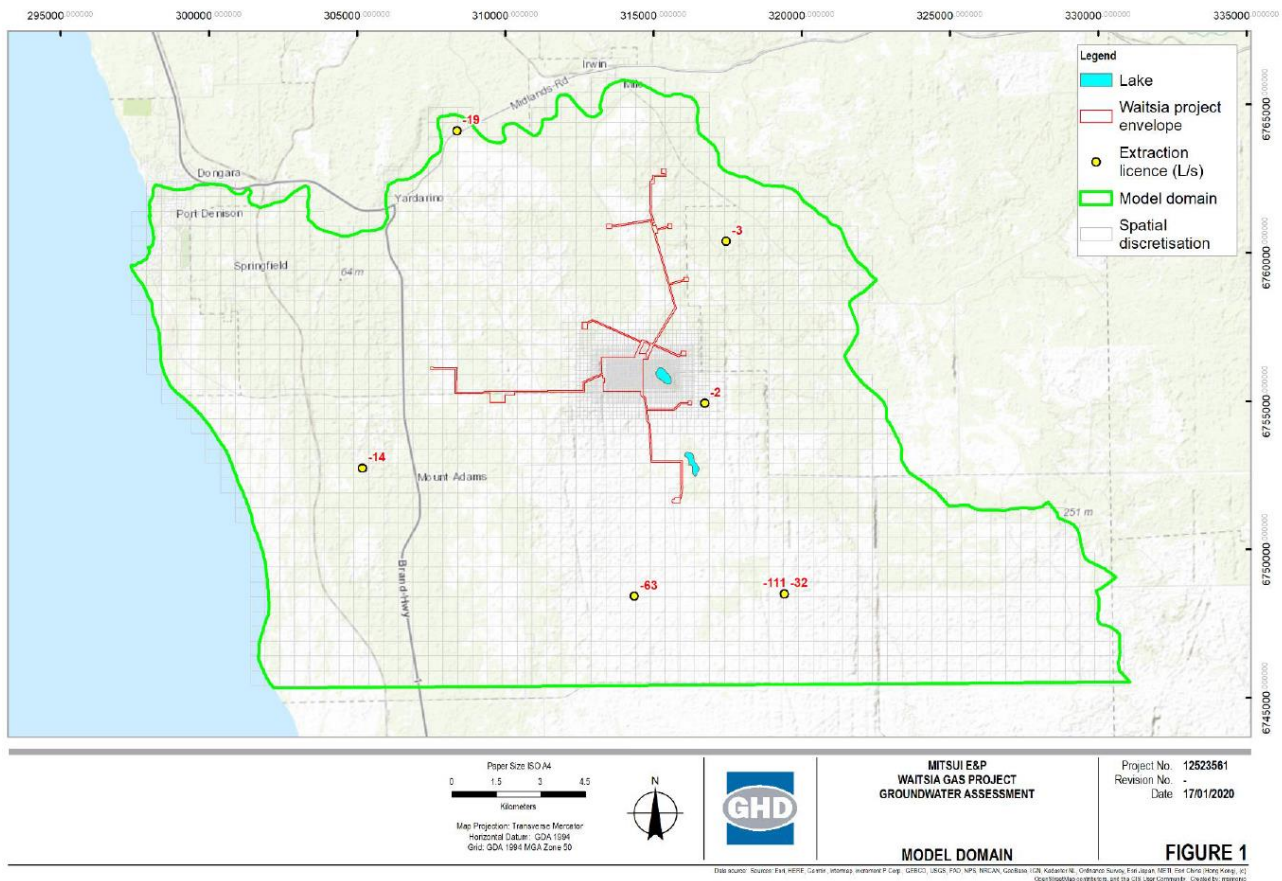
Localised siltstone and shale beds may support perched water table conditions in some areas. Low permeability lacustrine sediments may be present and result in the ponding of water in features such as the Ejaro Spring and the northern end of the Zeus Wetland, located more than 2 km south of the Ejaro Spring.

Groundwater discharges from the Yarragadee via upward groundwater flow into the superficial aquifer and potentially express at the ground surface, as is possibly occurring in the Ejaro Spring area. Other discharge from the Yarragadee enters portions of the Irwin River and offshore into the Indian Ocean (DoW, 2017).

The Allanooka-Dongara Water Reserve is located about 12 km north of the WGP, on the northern side of the Irwin River and more than 3.5 km from the nearest Proposal production well. The reserve is listed as Priority one (P1) Public Drinking Water Source protection area. The Allanooka-Dongara Water Reserve lies up-gradient of the WGP and there is little hydraulic connection between the Allanooka-Dongara Water Reserve and the Proposal.

The Irwin River is a significant hydrological feature located to the north of the Proposal area that meanders towards the west and discharges into the Indian Ocean. The Indian Ocean is situated 16 km west from the Proposal area.

Figure 2-3 shows the development envelope in proximity to sensitive features including surface water features "Lakes" and other groundwater extraction licence users in the region. These are discussed further below.

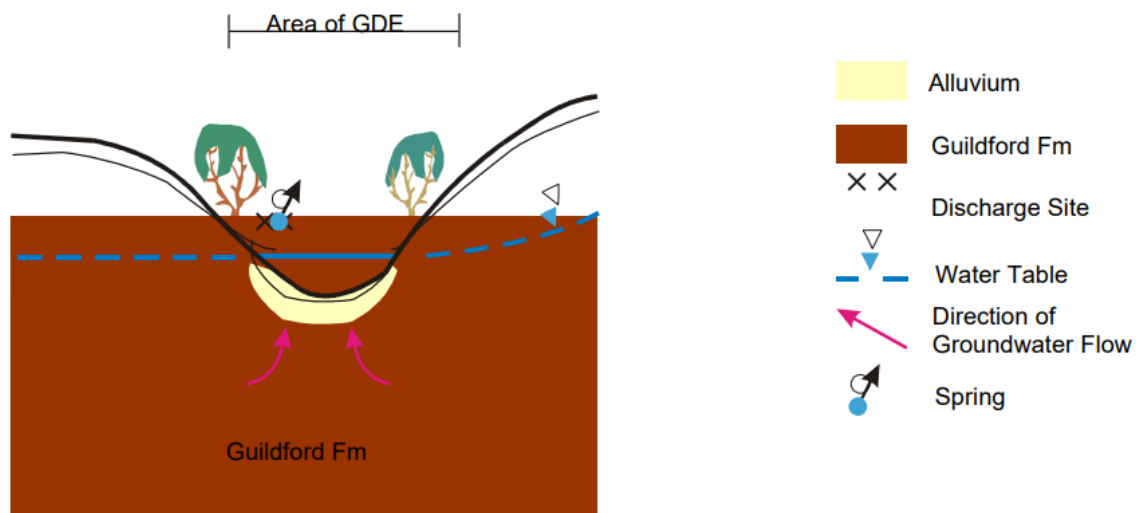


**Figure 2-3: Proximity of the Development Envelop to Environmental Sensitivities**

#### 2.4.1.1 Ejarno Spring

A study of the northern Perth Basin was undertaken by Rutherford *et al.* (2005) to identify sites that are potentially reliant on groundwater – i.e. where depth to groundwater was less than 20 m. These sites were then classified as Groundwater Dependanted Ecosystems (GDEs) as any remnant vegetation in areas of shallow groundwater were considered to be potentially groundwater dependent.

The nearest GDE, Ejarno Spring, is located approximately 500 m to the east of the WGP boundary. Ejarno Spring is associated with a topographic depression. The Ejarno Spring area is mapped as being underlain by the Guildford Formation (Figure 2-4); which with the topographic depression suggests that the spring discharges into a system that may be perched, like those described west of Eneabba (Kern, 1997). Such a perched system would not be significantly impacted by small changes in groundwater levels in the Yarragadee.



Source: Rutherford et al. 2005

Figure 2-4: Potential Perth Basin GDEs

#### 2.4.1.2 Groundwater Users

Licence locations for active Department of Water and Environmental Regulation (DWER) licences to extract groundwater from the Yarragadee Aquifer within proximity of the Proposal are provided in Figure 2-3. With the exception of the extraction licence for Tronox (3.5 M kL/yr) located about 5 km southeast of the Development Envelope, all other extraction licences comprise lower volumes (~60 kL/yr) based upon the DWER databases.

#### 2.4.1.3 Background Water Quality

As part of its overall operations, MEPAU has developed a comprehensive surveillance water quality monitoring program to ensure environmental management measures are effective. It also allows informed responses to regulatory requirements for water quality monitoring. The locations of the water quality sampling points are provided in Figure 2-5.

A summary of the ground and surface water quality studies over the past five years is included in Table 2-3.



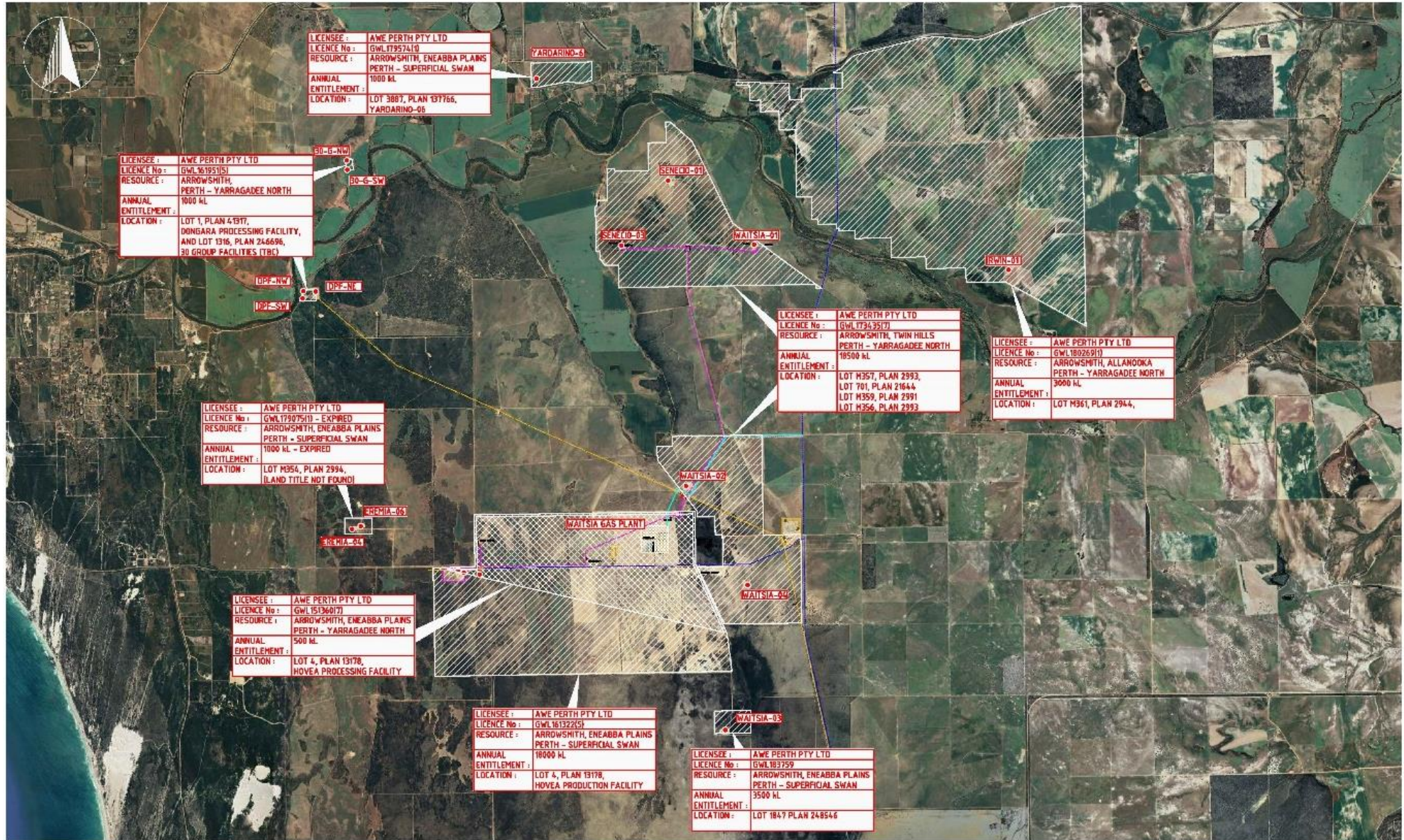


Figure 2-5: Location of existing MEPAU monitoring bores (as at January 2020)

The most relevant groundwater quality monitoring results for the Proposal are provided by the Waitsia-02 groundwater extraction bore (Waitsia-02 AB). Waitsia-02 AB is the monitoring well closest to, and up-gradient from, the WGP and provides a suitable groundwater quality baseline reference. Groundwater and surface water monitoring have been conducted at, and near, the Waitsia-02 site since June 2015 by an experienced third-party subject matter expert (GEMEC, 2018). Monitoring initially consisted of a baseline phase, prior to drilling, and until January 2017 samples were collected six-monthly and tested for a comprehensive analytical suite. Ongoing surveillance monitoring has been conducted on samples collected annually and tested for petroleum hydrocarbons and hydrogeochemical indicators.

In addition to the groundwater samples collected from Waitsia-02 AB, surface water samples have been collected from two locations within the nearby Ejarno Spring (ES1 and ES2). Dissolved sodium and chloride were dominant within both groundwater and surface water, with total dissolved solids ranging from marginal to brackish. Groundwater was of neutral pH and moderate hardness, with surface water very slightly alkaline and hard to very hard. Concentrations of dissolved metals and metalloids were generally consistent between groundwater and surface water samples, with dissolved barium, boron, iron and lithium detected during each event.

Minor concentrations of methane have been detected in surface water samples collected from Ejarno Spring, a result of the decomposition of organic material – a common wetland process. The conclusion of the wetland source of methanogenesis was supported by the absence of formation supplied ethane in the surface water samples. Petroleum hydrocarbons including Total Recoverable Hydrocarbons (TRH), Light fraction organic compounds (e.g. BTEXN compounds), Polyaromatic hydrocarbons (PAH's) nor organochlorine pesticides (OCP's) or phenols have not been detected in any groundwater or surface water samples collected to date.

MEPAU also conducts a broader operational surveillance groundwater monitoring program for its activities throughout the Perth Basin, with the results of Waitsia-02 AB indicating water quality is generally consistent throughout the region.

A summary of the most recent ground and surface water quality studies over the past five years are summarised in Table 2-3.

**Table 2-3: Recent ground and surface water studies**

Document Title	Author and date
Hydrogeological Assessment of the Waitsia Reservoir Drilling Programme	Rockwater Hydrogeological & Environmental Consultants (2015)
Surface Water & Groundwater Monitoring Event Report - Waitsia 02 Location	GEMEC Environmental Consultants (2015)
Waitsia Gas Project Surveillance Monitoring Program - Senecio-03, Waitsia-01 & Waitsia-02 Well Sites	GEMEC Environmental Consultants (2016)
Summary of Baseline Soil & Groundwater Assessments - Waitsia-04 Location	GEMEC Environmental Consultants (2018)
Annual Water Monitoring Report July to June 2018	Mitsui E&P Australia (2018)
Groundwater & Surface Water Monitoring Event Report - September 2019	GEMEC Environmental Consultants (2019)

#### 2.4.2 Study findings

A number of studies were undertaken or reviewed to assess the feasibility and practicability of various design components and aspects of the Proposal. Specifically, the amine system, currently selected to support the removal of acid gas requires significant water use (per Section 2.1.6). A technical scoping

study was conducted to consider various acid gas removal solutions. On the balance of all variables including capital and operational expenditures, flexibility, reliability, efficiency, water use and historic technology use, MEPAU has selected the amine system as the preferred technology of choice for removal of acid gases. Table 2-4 provides a summary of this study.

**Table 2-4: Recent study findings**

Study	Description of findings
<p>A Comparison of Physical Solvents for Acid Gas Removal (Burr and Lyddon, 2008)</p>	<p><i>This study describes the options for acid gas removal, and also compares the ability of four physical solvents to remove acid gas (such as hydrogen sulphide or CO<sub>2</sub>), from product gas streams. More commonly used methods are chemical solvents, physical solvents, membranes, and cryogenic fractionation, summarised as follows:</i></p> <ul style="list-style-type: none"> <li>• <i>Chemical solvent processes which rely on chemical reactions to remove acid gas constituents from sour gas streams and include compounds such as ethanolamines (often abbreviated to “amines”) and hot potassium carbonate. Heat is required to regenerate chemical solvents.</i></li> <li>• <i>Physical solvents rely on the physical interaction between CO<sub>2</sub> and other acid gases. Physical solvents can often be stripped of impurities they remove by reducing the pressure without the application of heat.</i></li> <li>• <i>The membrane process is applicable for high pressure gas containing high acid gas concentrations. Waste streams often require significant recompression and secondary treatment to reduce overall hydrocarbon losses.</i></li> <li>• <i>Cryogenic fractionation has the advantage that the CO<sub>2</sub> can be obtained at relatively high pressure as opposed to the other methods of recovering CO<sub>2</sub>. However, this advantage is offset by significant refrigeration requirements. In addition, special materials are also required for this method.</i></li> </ul> <p><i>Physical solvents are typically preferred over chemical solvents when the gas is at a high pressure or when the concentration of acid gases or other impurities is very high, because the solvents are non-corrosive and thus only require carbon steel constructions. However, physical solvents are impractical for gases at low partial pressures because the compression of the gas for absorption is expensive. A physical solvent may also not be the best option in scenarios where the concentration of heavy hydrocarbons in the feed gas is high, due to higher co-absorption of hydrocarbons (Burr and Lyddon, 2008).</i></p> <p>This study indicates that for the adopted design measures, the amine system is most appropriate as it is capable of managing the concentration of heavy hydrocarbons present within the natural gas.</p>

### 2.4.3 Groundwater Modelling Overview and Findings

MEPAU engaged a specialist consultant to undertake numerical modelling to determine the likely drawdown of the proposed abstraction on groundwater levels in order to assess the potential effect on:

- Ejarno Spring
- Existing groundwater users.

The groundwater modelling report is included as Appendix 1 to this Plan. The modelling study involved a desktop review of key information and available reports to develop an understanding of the hydrogeology and establish the hydrogeological conceptualisation of the site. A numerical model was then developed to simulate groundwater flow at a regional scale, based on the hydrogeological conceptualisation.

Simulations of pumping from a theoretical production bore set in the top section of Yarragadee and located at the eastern boundary of Waitsia processing area (approximately 500 west of the Ejarno Spring) was undertaken to evaluate the potential water level change at Ejarno Spring and the nearby licensed groundwater users.

Due to some uncertainties around the conceptual hydrogeological model, three scenarios were evaluated:

1. ‘Base case’ – the model with locally calibrated parameters

2. 'GARAMS parameterisation case' – as above but with hydraulic parameters taken from the GARAMS model
3. 'Lacustrine low K case' – as (1) with a low hydraulic conductivity unit beneath the Ejarno Spring.

The impact of the abstraction on water levels is evaluated as change in groundwater level and delineation of drawdown for both the Yarragadee and superficial aquifer units. Drawdown contours (reduction in water level) suggest that water level changes attributable to pumping from a theoretical bore at the Waitsia processing area are minor to negligible (Appendix 1; Figure 10 – Figure 15).

The modelled changes in superficial aquifer at the western edge of the lake at Ejarno Spring show a maximum reduction in water levels of 6 cm after five years of pumping (Table 2-5). The modelled changes in Yarragadee water levels show a decrease by up to 19 cm. The anticipated impact on water levels for neighbouring licensed abstractions is predicted to be negligible or very minor due to the distance from the Project site.

**Table 2-5: Predicted drawdown in water levels at western side of Ejarno Spring after 5 years**

Scenario	Superficial Drawdown (m)	Yarragadee Drawdown (m)
Base Case	0.06	0.15
GARAMS parameterisation case	0.00	0.19
Lacustrine low K case	0.05	0.13

#### 2.4.4 Key Assumptions

In accordance with EPA (2018a), key assumptions or parameters, that are used to support any numerical modelling are to be described in the Plan. Specifically, key assumptions and uncertainties used in numerical groundwater modelling to understand the potential for water level drawdown associated with the Proposal are detailed in Table 2-6.

**Table 2-6: Key Assumptions and Uncertainties**

Number	Assumptions and Uncertainties	Comment
1	Number and location of extraction bores	Up to four new extraction bores are estimated to be required to support the Proposal, to be located within the WGP Proposed Area (Figure 2-2).
2	Volume of water required to be extracted for the Proposal	The volume of water required to be extracted is conservatively estimated to be in the order of 60,000 kL/annum. This volume has been used throughout this Plan to enable a worst-case conservative impact assessment to be undertaken.
3	Various Model Assumptions	There are areas where the model calibration was impacted by lack of data and/or gaps in the hydrogeological understanding, specifically in the Ejarno Spring area. There is limited data available on the base elevation of the superficial aquifer and its connectivity with the Yarragadee in the Ejarno Spring area. To address this data gap conservative assumptions were made by discounting the potential presence of perched groundwater or the presence of lower permeability layers preventing the upward flow of groundwater from the Yarragadee into the superficial layers.  In the current numerical model, each hydrogeological unit was assigned a uniform hydraulic conductivity. However, the hydraulic conductivity can vary significantly across individual hydrogeological units. At the local scale the match between observed and simulated water levels in available monitoring bores suggests that the model is sufficiently representative of local conditions.
3a	Model domain set-up	The numerical model domain is based on the two major aquifers and extends to the Irwin River in the north and north east, follows the surface catchment divide in the east and Indian Ocean coast in the west (Appendix 1; Figure 1, with details in Figure 2 and 3). The southern boundary of the model is

Number	Assumptions and Uncertainties	Comment
		arbitrary in absence of any hydrologically relevant features. The model was vertically split into four layers, with two base layers representing the Yarragadee overlain by a thin clay-rich layer observed at the base of the superficial formation and the overlying superficial formation. Layer 1 (top layer) is divided into 'alluvial' unit that also includes the Ejarno Spring and Tamala Limestone of the Superficial Formations. The Yarragadee is assumed to subcrop to the east of the project area (Appendix 1; Figure 5). The base of layer 1 was derived from previous studies (Appendix 1; Figure 6). The bases of layers 2 to 4 were derived by applying uniform thicknesses of 2 m, 50 m and 100 m, respectively. The model does not represent the full thickness of Yarragadee since only the top part of the aquifer is relevant for this assessment.
3b	Boundary conditions	The model domain is bounded in the north and north east by RIV boundary, representing the Irwin River in the top model layer. The eastern boundary in layers representing the Yarragadee are CHD (fixed head or water level) simulating regional groundwater throughflow. Head information taken from GARAMS and Rockwater (2015). The southern boundary is considered 'no flow' as it is aligned in the generally east to west direction of groundwater flow with no additional inputs expected along this boundary. The western boundary is a general head boundary (GHB) with set level of 0.3 m AHD representing the ocean. The locations of the boundary conditions are presented in Appendix 1; Figure 7.
3c	Aquifer parameters	The initial aquifer parameters assigned to the model hydrogeological zones were sourced from GARAMS (2011) and DoW (2017). Some modifications to these parameters were made during the steady state and transient calibration to achieve a good fit between the observed and simulated groundwater levels.
3d	Recharge rates / volumes	The initial aquifer parameters assigned to the model hydrogeological zones were sourced from GARAMS (2011) and DoW (2017). Some modifications to these parameters were made during the steady state and transient calibration to achieve a good fit between the observed and simulated groundwater levels.  The recharge estimate was obtained from regional studies and set at 55 mm/year. This was uniformly applied across the model domain.
3e	Abstraction volumes from other groundwater users	Groundwater abstractions within the model domain (more than 60 kL/yr) were assigned to the current licenced groundwater allocation rate collected from DWER databases, with one exception, the 3.5M kL/yr for Tronox, about 5 km southeast of the Development Envelope which would have caused drawdown that has not being observed in the nearby monitoring bores.

#### 2.4.5 Management Approach.

MEPAU plans to implement outcome-based provisions for **under** this Plan. The reason for this approach is that the outcome can be readily measured with clear thresholds set to enable a level of protection to be achieved.

#### 2.4.6 Rationale for Choice of Provisions

The provisions proposed are based on the following rationale:

- Groundwater modelling indicates that a drawdown of groundwater is not expected to result in a significant impact to sensitive receptors within proximity of the Proposal (i.e. a drawdown of 0.06 m in the superficial aquifer of at the western side of Ejarno Spring over five years)
- Establishment of an outcome-based provision is achievable, and monitoring of groundwater parameters provide a direct insight into any potential environmental impact arising from the Proposal

- Expected changes in rainfall and recharge were accounted for in the model and conservatively set for 55 mm/year which would be expected to fluctuate from year to year
- The adaptive management framework enables for clear decisions regarding water extraction to be made where any impacts may be observed. Where additional mitigation is implemented, the timeframe for mitigation to take effect is expected to be relatively short given the dynamic nature and throughflow of groundwater in the region.

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### **3.0 WATER MANAGEMENT PLAN PROVISIONS**

This section of the Plan identifies the legal provisions that MEPAU will implement to ensure that the environment outcomes are met during the implementation of the Proposal.

It identifies the environmental criteria that will be used to measure performance and the monitoring that will be undertaken in relation to these environmental criteria. Finally, it defines the response actions (trigger level and contingency actions) that will be undertaken if the environmental criteria are exceeded. Table 3-1 details the provisions of this plan.

#### **3.1 Outcomes**

The primary focus of this Plan is groundwater quality and level management as the major environmental values adjacent to the WGP include other groundwater users and Ejarno Spring. Protection of these sensitivities require the depth to groundwater to be maintained so as to not significantly impact the hydrological regime and alter the ecosystem.

#### **3.2 Performance Indicators (Environmental Criteria)**

Key Performance Indicators for the Proposal are documented in Table 3-1.

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**Table 3-1: Key Performance Environmental Criteria (Outcome Based)**

EPA Outcome	Phase	Environmental Criteria	Response Actions	Monitoring	Reporting
<p>To maintain the hydrological regimes and quality of groundwater and surface water so that environmental values are protected</p>	<p>Construction and Operation</p>	<p><b>Trigger Criteria</b> Groundwater level measured at defined monitoring locations (Table 3-4) exceed historical average groundwater level values by 0.7 m<sup>4</sup></p> <p><b>Threshold Criteria</b> Groundwater level measured at defined monitoring locations (Table 3-4) exceed historical average groundwater level values by 0.7 m over two consecutive monitoring events</p>	<p><b>Trigger Contingency Actions</b></p> <ul style="list-style-type: none"> <li>• Determine whether the changes observed in the impact sites are comparable to baseline sampling</li> <li>• Re-examine monitoring results (QA/QC) to validate data. Re-monitor if required</li> <li>• Increase monitoring frequency (and conducting additional monitoring across different seasons)</li> <li>• Identify the reason for the change and determine direct correlation to construction / operational activities or natural variation and review management measures with an adaptive management response.</li> </ul> <p><b>Threshold Contingency Actions</b></p> <ul style="list-style-type: none"> <li>• Initiate vegetation surveys to be undertaken at Ejarno Spring to determine floristic diversity and condition</li> <li>• Initiate implementation of contingency measures including:                             <ul style="list-style-type: none"> <li>○ Re-examine monitoring results (QA/QC) to validate data. Re-monitor if required</li> <li>○ Ground truth the monitoring results to validate findings of the assessment and/or determine/identify what may be causing the exceedance. Where cause is identified during ground truthing and can be rectified, undertake action immediately. For actions which require alternate resources, schedule works to be undertaken as soon as possible.</li> <li>○ Cross reference groundwater monitoring results with most recent vegetation/surface water surveys to determine whether an impact can be identified</li> <li>○ Where the threshold exceedance was not caused by construction or operation, resume standard monitoring frequency.</li> <li>○ Where the threshold exceedance can be attributed to the Proposal activities:</li> </ul> </li> </ul>	<p>Refer to Table 3-4</p>	<p>Annual Reporting</p> <p>Reporting any exceedance of threshold criteria and contingency actions that have been implemented due to the exceedance of threshold criteria within 48 hours</p>
		<p><b>Trigger Criteria</b> Changes to groundwater and surface water quality at defined monitoring locations (Table 3-4) attributable to the proposal exceed historical averages.</p> <p><b>Threshold Criteria</b> Changes to groundwater and surface water quality at defined monitoring locations (Table 3-4) attributable to the proposal exceed historical averages over two consecutive monitoring events</p>			

<sup>4</sup> Water levels in the Superficial aquifer fluctuate seasonally in response to rainfall. Fluctuations typically range from 0.3 to 1.7 m (DoW, 2017). Based upon the incidental drawdown expected to arise from the Proposal (0.06 m) and given the large natural variation a trigger threshold of 0.7 m has been selected, above which will require further investigation to determine if this is attributable to the Proposal or associated with natural variation.



EPA Outcome	Phase	Environmental Criteria	Response Actions	Monitoring	Reporting
			<ul style="list-style-type: none"> <li data-bbox="1111 188 1653 331">▪ Implement adaptive management response (modified abstraction) management guidance within Section 4.0. This may include a reduction in abstraction volumes or sourcing water from other sources.</li> <li data-bbox="1111 341 1653 459">▪ Once management actions have been completed, extend the monitoring program to include an additional recharge event to determine if groundwater quality and level values recover.</li> <li data-bbox="1111 469 1653 555">▪ Continue to implement actions to remediate the exceedance until approval to cease has been given by the relevant regulator.</li> </ul>		

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### 3.3 Monitoring

To clearly understand if the environmental criteria have been met or exceeded, MEPAU has (and will continue) to monitor ground and surface waters adjacent to the WGP. Specifically, the monitoring program will be used to:

- Establish historic groundwater levels and groundwater quality within proximity of Ejarno Spring GDE
- Establish historic surface water quality within Ejarno Spring GDE
- Establish the floristic diversity and vegetation quality of Ejarno Spring
- Verify groundwater level and water quality trends during construction and operations do not significantly affect baseline levels.

#### 3.3.1 Establish Historic Groundwater Level and Groundwater Quality

MEPAU maintains a Perth Basin Surveillance Sampling Program [PB-HSE-PRO-119], developed based on historical field results and legislative sampling requirements. Groundwater sampling is conducted in accordance with the requirements of AS/NZS 5667.11:1998 Water Quality – Sampling - Guidance on Sampling of Groundwaters. Specifically, the Perth Basin Surveillance Sampling Program includes the:

- Location of groundwater sampling bores
- Frequency and monitoring parameters at these locations.

Given new extraction bores are planned to be installed within the WGP Premises, there are currently no monitoring bores that are located between the proposed new extraction points and Ejarno Spring. However, the Waitsia-02 AB provides a suitable historic reference point to support the establishment of groundwater level and quality baseline.

Table 3-2 summarises the monitoring parameters for sites that have been used to inform baseline levels.

**Table 3-2: Groundwater Monitoring**

Infrastructure	Frequency	Number of Years	Monitoring Parameters
Waitsia-02 AB	Annually	<ul style="list-style-type: none"> <li>• 2017</li> <li>• 2018</li> <li>• 2019</li> </ul>	<ul style="list-style-type: none"> <li>• TRH</li> <li>• BTEXN compounds</li> <li>• pH</li> <li>• Standing water level (SWL)</li> <li>• Electrical conductivity</li> <li>• TDS</li> <li>• Dissolved Oxygen (DO).</li> </ul>

#### 3.3.2 Establish Historic Surface Water Quality Within Ejarno Spring GDE

Surface water monitoring is conducted in accordance with the Perth Basin Surveillance Sampling Program [PB-HSE-PRO-119]. The surface water quality of Ejarno Spring is monitored annually. Table 3-3 summarises the monitoring parameters for surface water at Ejarno Spring that have been used to inform baseline levels.

**Table 3-3: Surface water Monitoring (Ejarno Spring)**

Infrastructure	Frequency	Number of Years	Monitoring Parameters
ES1 & ES2	Annually	<ul style="list-style-type: none"> <li>• 2017</li> <li>• 2018</li> <li>• 2019</li> </ul>	<ul style="list-style-type: none"> <li>• TRH</li> <li>• BTEX compounds)</li> <li>• pH</li> <li>• Electrical conductivity</li> <li>• TDS</li> <li>• DO.</li> </ul>

### 3.3.3 Establish the Floristic Diversity and Vegetation Quality of Ejarno Spring

Prior to conducting construction, MEPAU will complete a detailed flora and vegetation survey of Ejarno Spring with the purpose of establishing the floristic diversity and quality of vegetation associated with the GDE. This information will form a baseline level to which future studies, triggered by exceeding threshold criteria, can be compared and analysed. The purpose of this analysis will be to establish if changes in water level or quality, attributable to the Proposal, have impacted on the diversity and quality of Ejarno Spring.

### 3.3.4 Understand Groundwater Level and Water Quality Trends During Construction and Operations

Prior to the construction phase commencing, MEPAU will install a new monitoring bore between the WGP and Ejarno Spring and obtain at least one pre-construction sample. During the construction phase of the proposal, MEPAU will frequently monitor surface and groundwaters to understand trends and inform more frequent review of trigger and threshold criteria. It is expected that following completion of construction, the volume of water extracted will reduce, thus MEPAU plans to reduce the frequency of monitoring events if no significant changes to baseline levels are identified during construction.

The proposed monitoring program during construction and operations is presented in Table 3-4.

**Table 3-4: Monitoring Program**

Type	Sampling location	Phase	Frequency	Monitoring Parameters
Groundwater	Waitsia-02 AB & A new Waitsia MB located between the WGP and Ejarno Spring	Construction	Quarterly	<ul style="list-style-type: none"> <li>• TRH</li> <li>• BTEX compounds;</li> <li>• pH</li> <li>• SWL;</li> </ul>
		Operations / Ongoing	Annually <sup>5</sup>	<ul style="list-style-type: none"> <li>• Electrical conductivity;</li> <li>• TDS</li> <li>• Dissolved Oxygen (DO).</li> </ul>
Surface Water	Ejarno Spring (ES1 and ES2)	Construction	Quarterly	<ul style="list-style-type: none"> <li>• TRH</li> <li>• BTEX compounds;</li> <li>• pH</li> <li>• SWL;</li> </ul>
		Operations	Annually <sup>3</sup>	<ul style="list-style-type: none"> <li>• Electrical conductivity;</li> <li>• TDS</li> </ul>

<sup>5</sup> Following the completion of construction activities and submission of reports to DWER, MEPAU plan to reduce the frequency of the monitoring program to be commensurate with the level of impact and risk and be undertaken annually.

Type	Sampling location	Phase	Frequency	Monitoring Parameters
				<ul style="list-style-type: none"> <li>Dissolved Oxygen (DO).</li> </ul>
Ejarno Spring floristic diversity and vegetation condition	Ejarno Spring	Construction	One-off	<ul style="list-style-type: none"> <li>Baseline vegetation condition report that details vegetation quality and diversity prior to the proposal commencing</li> </ul>
			Ad-hoc	<ul style="list-style-type: none"> <li>As triggered by exceedance of threshold criteria</li> </ul>
		Operations	Ad-hoc	<ul style="list-style-type: none"> <li>As triggered by exceedance of threshold criteria</li> </ul>

### 3.4 Reporting

The environmental outcome will be reported against Trigger and Threshold criteria (Table 3-1) for each calendar year in the Annual Compliance Assessment Report (ACAR) for the Proposal.

The annual report will also include a summary of analysis of monitoring data to facilitate adaptive management.

In the event that trigger and threshold criteria are exceeded during the reporting period, the annual report will include a description of the effectiveness of any management contingency actions that have been implemented to manage the impact.

## **4.0 ADAPTIVE MANAGEMENT AND REVIEW OF THIS PLAN**

### **4.1 Monitoring and Adaptive Management**

A monitoring program is required to measure the effectiveness of the management actions as defined in this Plan. The outcomes of the monitoring program will contribute to ongoing improvements in management actions to ensure an adaptive management approach is adopted.

MEPAU will implement adaptive management to learn from the implementation of mitigation measures, monitoring and evaluation against trigger and threshold criteria, to more effectively meet the conditioned environmental outcome.

The following approaches will apply:

- Monitoring data will be systematically evaluated and compared to baseline
- The effectiveness and relevance of trigger level and threshold contingency actions will be evaluated on an annual basis to determine if any changes to management actions are required
- Increased understanding of the hydrogeological regimes based on additional internal and external studies will be incorporated into the monitoring and management approach when newer relevant information becomes available where applicable.

Adaptive management practices that will be assessed as part of this approach may include:

- Evaluation of the monitoring program, data and comparison to baseline data and reference sites on an annual basis to verify whether responses to project activities are the same or similar to predictions
- Evaluation of assumptions and uncertainties of the management and monitoring program
- Re-evaluation of the risk assessment and revision of risk-based priorities as a result of monitoring outcomes
- Review of data and information gathered over the review period that has increased understanding of site environment in the context of the regional ecosystem
- Assessment of changes which are outside the control of the project and the management measures identified (i.e. a new project within the area or region; regional change affecting management).

### **4.2 Management Plan review**

This Plan is intended to be dynamic and may be updated to reflect changes in management practices and the natural environment over time. This approach will allow flexibility to adopt new approaches/management measures. The effectiveness and relevance of trigger level and threshold contingency actions will be evaluated on an annual basis, and any amendments to management actions will be completed on an as needs basis. This will include:

- amendment of management actions that are not achieving the desired outcomes
- monitoring that identifies additional impacts requiring additional management actions or changes to existing management actions
- changes to relevant legislation that may affect the implementation of management actions
- improvements to management practices to achieve a greater environmental outcome.

## 5.0 STAKEHOLDER ENGAGEMENT

Consistent with the EPA's expectations for this Plan to align with the principles of EIA, MEPAU consulted with stakeholders, including but not limited to DWER during the development of the EPA referral. For a full summary of stakeholder engagement records refer to MEPAU, 2019.

Any additional consultation regarding this Plan will be captured in subsequent revisions.

Issued for comment

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**APPENDIX 1 : Waitsia Gas Project Groundwater Assessment**

Issued for comment





# **AWE Perth Pty Ltd**

## **Waitsia Gas Project Groundwater Assessment**

February 2020

# Executive summary

GHD Pty Ltd (GHD) was commissioned by Mitsui E&P Australia (MEPAU)<sup>1</sup> to undertake a groundwater impact assessment of the proposed groundwater abstraction for Stage 2 of the Waitsia Gas Project.

The proposed project comprises a conventional gas plant located approximately 16 km east-south-east of Dongara in Western Australia and proposes abstraction of groundwater for use during the construction and operational phases. The water demand for the Project has been estimated by MEPAU to be 60,000 kilolitres (kL) per annum (1.9 litres/second). The water is to be sourced from the underlying Yarragadee aquifer, through the installation of up to four new abstraction bores within the area associated with the proposed Waitsia Gas Plant (refer to as the Project Site).

MEPAU has produced a water management plan (WMP) which aims to identify the potential impacts on water systems and develop management and monitoring measures that protect the existing systems. The WMP identified that the key environmental values were the neighbouring groundwater dependent ecosystem (GDE), referred to as Ejarno Spring, and third party licensed groundwater users.

To assess the potential impact of the proposed Waitsia Gas Plant abstraction on the GDE and licensed groundwater users, GHD developed a groundwater model to assess the reduction in groundwater levels (drawdown). To achieve this the following steps were undertaken: hydrogeological conceptualisation, model construction, calibration and running predictive scenarios, with basic uncertainty analysis.

The model used for this assessment was constructed in MODFLOW-USG software and built on learnings from previous hydrogeological assessments and investigations, including the regional groundwater model (GARAMS). The two-aquifer model (Superficial and Yarragadee aquifers) covers an area of 460 km<sup>2</sup> surrounding the Project Site. Due to the hydrogeological data available, a level of conservatism was applied when constructing the model. The model was calibrated to local groundwater level records over a 10 year period (2011 to 2019) and calibration results suggest that the model adequately represents the local hydrogeological conditions and is considered appropriate for the purpose of the impact assessment.

Groundwater abstraction from the Yarragadee aquifer in the gas plant area was modelled at a rate of 2 L/s for the period of five years. The model results indicate a very minor reduction in groundwater levels which would represent up to 6 cm drawdown in the Ejarno Spring area (GDE) in the Superficial aquifer and 15 cm in the confined Yarragadee aquifer. Third party groundwater users are not considered to be affected by the proposed abstraction at the Waitsia gas plant.

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<sup>1</sup> AWE Perth Pty Limited is the legal entity, operator of the relevant Production Licences (L1 and L2), the proponent for the Proposal and operates under the Mitsui E&P Australia (MEPAU) brand.

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# 1. Introduction

## 1.1 Background

GHD Pty Ltd (GHD) was commissioned by Mitsui E&P Australia (MEPAU)<sup>2</sup> to undertake a groundwater impact assessment of the proposed groundwater abstraction for Stage 2 of the Waitsia Gas Project (referred to as the Project).

The proposed Project comprises a conventional gas plant located approximately 16 km east-south-east of Dongara in Western Australia (Figure 1). The Project proposes abstraction of groundwater for use during the construction and operational phases. The water demand for the Project has been estimated by MEPAU to be 60,000 cubic metres (m<sup>3</sup>) per annum (1.9 L/s) which is proposed to be sourced from the underlying Yarragadee aquifer. The Project proposes the installation of up to four new abstraction bores within the proposed area of the Waitsia Gas Plant.

MEPAU referred the Project to the Environmental Protection Authority (EPA) under Part IV of the Environmental Protection Act 1986 in August 2019. The EPA decided to assess the Project as a significant proposal, through Assessment of Referral Information.

MEPAU has produced a water management plan (WMP) which aims to identify the potential impacts on water systems and develop management and monitoring measures that protect the existing systems. The WMP identified that key environmental values were the neighbouring groundwater dependent ecosystem (GDE), referred to as Ejarno Spring, and other licensed groundwater users. The WMP included a conservative assessment of potential drawdown in groundwater levels using the Theis method (e.g. Fetter, 1994)<sup>3</sup>, which is an analytical solution for calculation of well drawdown for a confined aquifer. That assessment suggested a water level change (drawdown) in the order of 0.22 m at approximately 500 m from the extraction point following 5 years of abstraction.

To assess the potential impact of the proposed groundwater abstraction at Waitsia Gas Plant abstraction, at a nominal rate of 60,000 kL/yr, on the GDE and licensed groundwater users, GHD developed a simple but robust groundwater model for drawdown estimation purposes. This included the following steps: hydrogeological conceptualisation, model construction, calibration, predictive scenarios, and uncertainty analysis.

## 1.2 Objectives

The objective of this scope of work is to carry out numerical groundwater modelling to estimate the likely drawdown of the proposed abstraction on groundwater levels, in order to assess the potential impact of proposed abstraction on:

1. Ejarno Spring
2. Existing groundwater users

## 1.3 Limitations

This report: has been prepared by GHD for AWE Perth Pty Limited and may only be used and relied on by AWE Perth Pty Limited for the purpose agreed between GHD and AWE Perth Pty Limited as set out in section 1.1 of this report.

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<sup>2</sup> AWE Perth Pty Limited is the legal entity, operator of the relevant Production Licences (L1 and L2), the proponent for the Proposal and operates under the Mitsui E&P Australia (MEPAU) brand.

<sup>3</sup> Fetter, CW (1994): Applied Hydrogeology. Prentice-Hall, Inc.

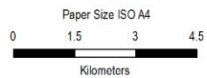
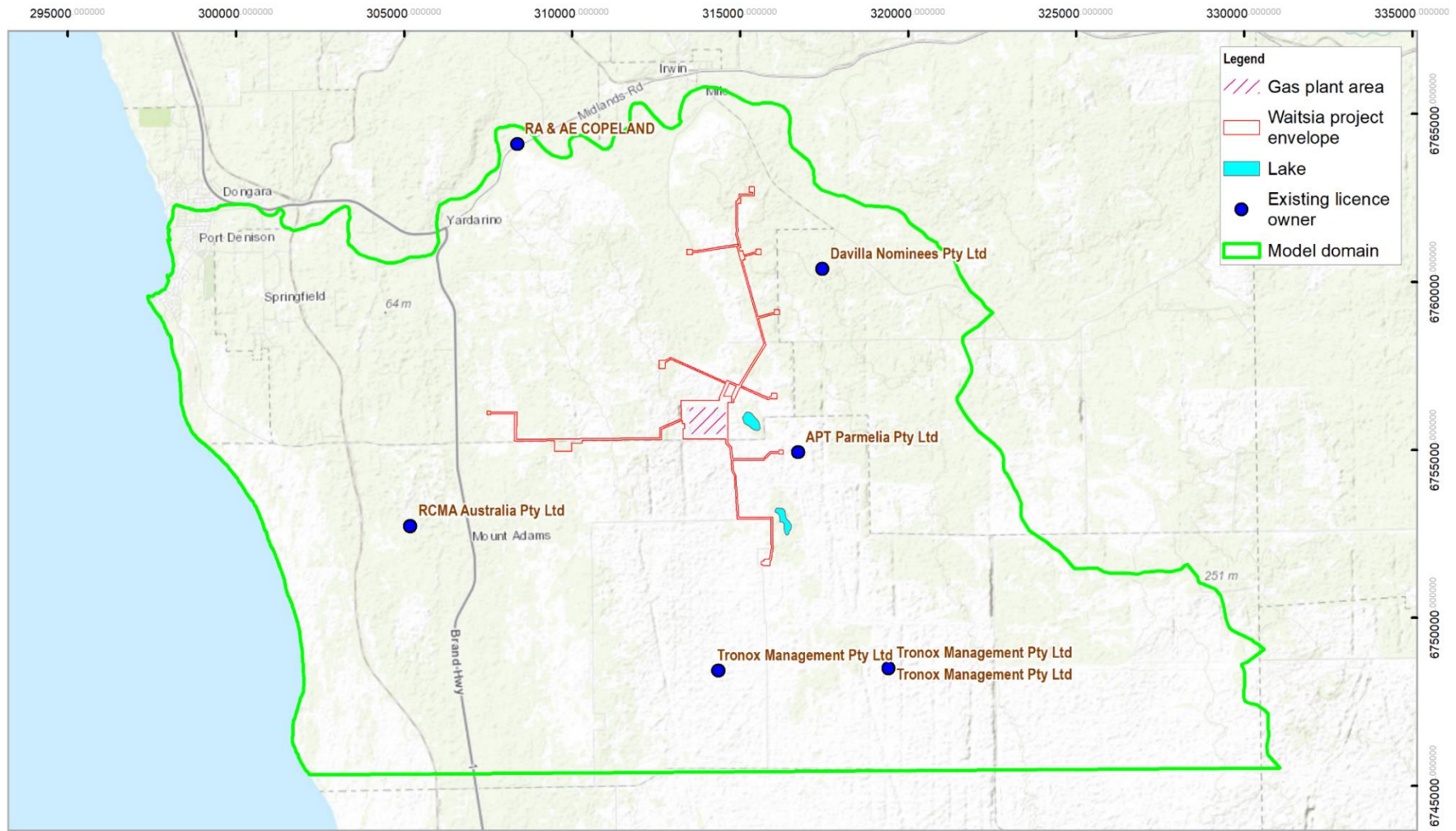
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Map Projection: Transverse Mercator  
 Horizontal Datum: GDA 1994  
 Grid: GDA 1994 MGA Zone 50



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 WAITSIA GAS PROJECT  
 GROUNDWATER ASSESSMENT

PROJECT AREA  
 (REGIONAL SETTING)

Project No. 12523561  
 Revision No. -  
 Date 17/01/2020

**FIGURE 1**

Data source: Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeBCO, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), Swisstopo, Mapbox, OpenStreetMap contributors, and the GIS User Community. Created by: mramos

**Figure 1-1 Project Site (regional setting)**

## 2. Review of Hydrogeological Conceptualisation

### 2.1 Desktop Review

A review of key information and available reports was carried out to formulate an understanding of the hydrogeology and establish the key aspects of the hydrogeological conceptualisation of the site.

The reports reviewed are presented in Table 2-1. They include aquifer reviews conducted for AWE, and regional modelling reports developed for the region, in particular the GARAMS (Gingin Arrowsmith Regional Aquifer Modelling System) model which was developed by GHD (2011) for Department of Water (now Department of Water and Environmental Regulation, the DWER), for the management of groundwater at a regional scale.

DWER also prepared an update of the hydrogeological conceptualisation of the region in 2017, based on new drilling and testing information.

**Table 2-1 Information sources used for review**

Document title	Author and date
Report for Gingin Arrowsmith Regional Aquifer Modelling System (GARAMS)	GHD, 2011
Hydrogeological Assessment of the Waitsia Reservoir Drilling Programme	Rockwater Hydrogeological & Environmental Consultants (2015)
The Hydrogeology of Groundwater Dependent Ecosystems in the Northern Perth Basin	Department of Environment (Now DWER) (2015)
Surface Water & Groundwater Monitoring Event Report - Waitsia 02 Location	GEMEC Environmental Consultants (2015)
Waitsia Gas Project Surveillance Monitoring Program - Senecio-03, Waitsia-01 & Waitsia-02 Well Sites	GEMEC Environmental Consultants (2016)
Northern Perth Basin: Geology, Hydrogeology and Groundwater Resources	DoW (2017)
Summary of Baseline Soil & Groundwater Assessments - Waitsia-04 Location	GEMEC Environmental Consultants (2018)
Annual Water Monitoring Report June 2018	Mitsui E&P Australia (2018)
Groundwater & Surface Water Monitoring Event Report - September 2019	GEMEC Environmental Consultants (2019)
Geology of the Mingenew-Dongara 1:100 000 Sheet. Western Australia Geological Survey, 1:100 000 Geological Series Explanatory Notes	Mory, AJ (1995)

The conceptual hydrogeological model of Waitsia Project Site takes into account rainfall recharge, evaporation, drainage, abstraction and the interaction between the two major aquifers. The conceptual model was developed using regional information, as listed in Table 2-1.

### 2.2 Project Site Description

The **Project Site** refers to a proposed Waitsia conventional gas plant located approximately 16 km east-south-east of Dongara in Western Australia (Figure 1), in a surrounding region of existing agricultural activities and oil and gas development. The region encompassing the site



and used in this assessment is bound to the north and partly east by the Irwin River course, the Indian Ocean to the west, while to the south it is arbitrarily delineated by a line perpendicular to the ocean, 10 km distal to the site (Figure 1).

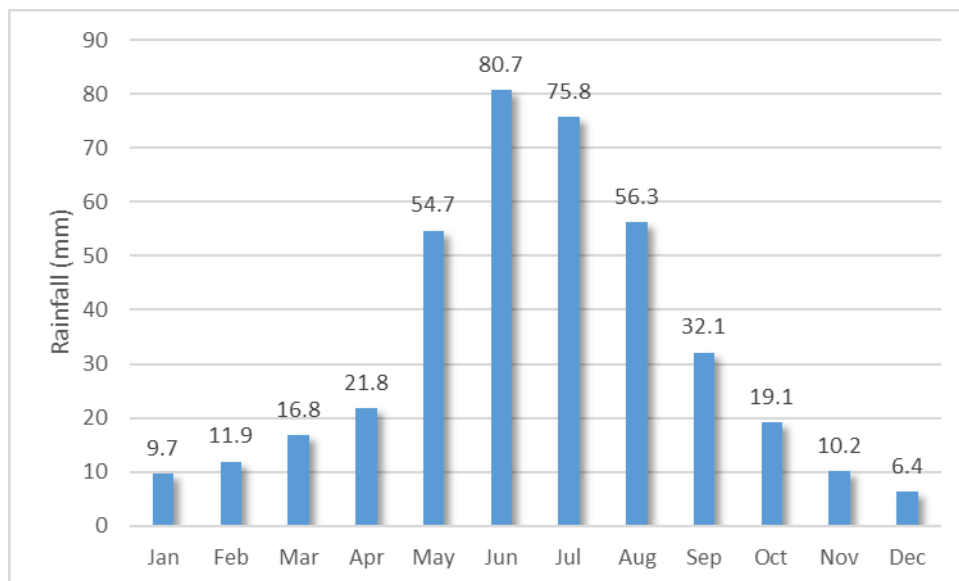
The Project Site is located in a topographic depression or valley, between two ridges running in a north-north-west direction towards the Irwin River (Figure 2-2). The lowest ground elevation in the plant area is approximately 32 m AHD, with adjacent ridges reaching to over 120 m AHD.

The Project Site is situated within the Irwin River catchment. The Irwin River flows at a distance of approximately 8 km to the northeast and north of the proposed gas plant. There are several recognised groundwater dependent ecosystems (GDEs) in the region including the Ejarno Spring (situated 500 m east of the gas plant area) and Yardanogo Nature Reserve (6 km south).

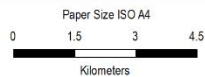
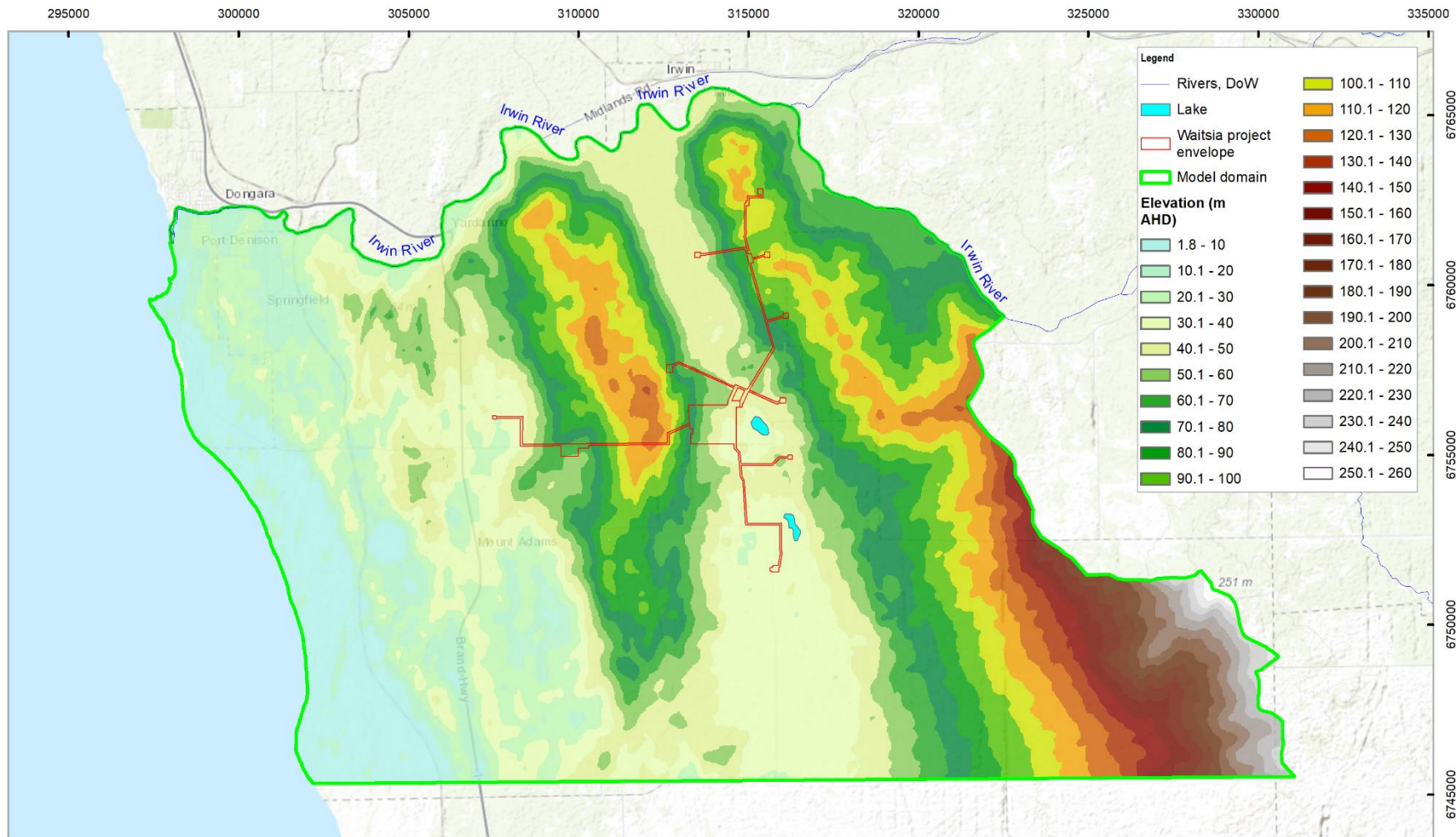
### 2.3 Rainfall and Evapotranspiration

The Project Site has a subtropical Mediterranean type climate with hot dry summers and mild wet winters. The average annual rainfall is approximately 400 mm (data from the closest Bureau of Meteorology station, Mingenew 008088) and occurs mainly between May and September (Figure 2-1). There is a strong rainfall gradient with rainfall decreasing with distance from the coast (DOW, 2017), so it is likely that rainfall at the site might be slightly higher based on its proximity to the coast.

Annual evaporation and evapotranspiration sums are approximately 2,200 mm and 550 mm, respectively.



**Figure 2-1 Mean rainfall for Mingenew (station 008088, source: BOM)**



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**SURFACE TOPOGRAPHY**

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Data source: Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community. Created by: mramos

**Figure 2-2 Surface topography**

## 2.4 Hydrogeology

The Project Site is situated in the North Perth Basin region which is geologically and hydrogeologically complex at a regional scale. The Project Site conceptual hydrogeological model, comprises simplified geology and hydrogeology and a representation of major hydraulic processes within the model area.

At the Project Site the groundwater system comprises the predominantly unconfined Superficial formations overlying the Yarragadee Aquifer. Superficial formations overlying the Yarragadee include alluvium, Tamala Limestone, Bassendean Sand, lateritic weathering residues and colluvium (Figure 2-4). These may be in direct hydraulic connection with the Yarragadee aquifer however some perched layers are known to exist in the area (DoW, 2017).

The main regional aquifer beneath the Waitsia Gas Field is the Yarragadee, which has the following characteristics in the Waitsia Reservoir area:

- composed of shale, siltstone and sandstone (Rockwater, 2015)
- standing water levels (SWLs) vary from 75 m Australian height datum (m AHD) to 15 m AHD, corresponding to 0 to 100 metres below ground surface (m bgs), depending on site topography
- hydraulic gradient is broadly west-southwest toward the Indian Ocean (DoW, 2017)
- salinity is typically fresh to marginal near the surface and increases to brackish with depth.

The Yarragadee aquifer is overlain by Superficial formations at the Project Site, 18 to 20 m thick, with a less permeable unit at their base (possibly an equivalent of Becher Unit).

A review of groundwater levels in the MEPAU bores screened in the Yarragadee aquifer around the Project Site, suggests that the Yarragadee aquifer is likely to be confined, with an upward component of groundwater flow in the Yarragadee aquifer.

Monitored groundwater levels in the region surrounding the Project site indicate predominantly stable trends, suggesting that the groundwater system is in dynamic equilibrium. Seasonal variations in recorded water levels are observed within a 2 metre amplitude around a stable trend.

## 2.5 Groundwater Recharge

Groundwater recharge into the Yarragadee aquifers occurs by direct rainfall (in outcrops) as well as downward leakage from overlying aquifers i.e. the Superficial formations. In the region around the Project Site recharge is likely to be affected by:

- concentrated surface water infiltration within the river valleys, for example, the Irwin River system to the north that receives runoff from its catchment,
- restricted by clayey lithologies resulting in elevated groundwater salinity in the upper portion of the aquifer (Commander, 1981)
- alluvial depressions such as the one encountered to the east of the Project Site.

Localised siltstone and shale beds may support perched water table conditions in some areas. Low permeability lacustrine sediments are present in topographic depressions and result in the ponding of water in features such as the Ejarno Spring.

## 2.6 Groundwater Discharge

Groundwater discharges from the Yarragadee aquifer are likely to be via upward groundwater flow into the Superficial aquifer and potentially express at the ground surface, as is possibly

occurring in the Ejarno Spring area. Other discharges from the Yarragadee aquifer enter portions of the Irwin River and offshore into the Indian Ocean (DoW, 2017).

## 2.7 Groundwater Use

Groundwater is also used for licensed and unlicensed abstraction. The latter is likely to include domestic and stock watering which extract relatively minor volumes of groundwater from the Superficial formation.

Abstraction of groundwater from the Yarragadee aquifer is licensed in proximity to the Project Site and groundwater licences have been granted up to 3,500,000 kL/yr (Table 2-2). Abstraction licences with more than 50,000 kL/yr in proximity to the Project Site are shown in Figure 1. The points of abstraction licences represent the centre of the lot that the abstraction licence is associated with and does not represent the actual abstraction location.

**Table 2-2 Summary of groundwater abstraction licences**

Number	Issue date	Expiry date	Allocation (kL)	Owner
109604	30/07/2015	29/07/2025	600,000	RA & AE COPELAND
151360	15/01/2015	15/01/2025	500	AWE Perth Pty Ltd
155141	25/06/2019	17/09/2023	20,600	Lattice Energy Limited
161322	15/01/2015	15/01/2025	18,000	AWE Perth Pty Ltd
161951	31/01/2017	30/01/2027	1,000	AWE Perth Pty Ltd
162324	14/08/2014	14/08/2024	3,500,000	Tronox Management Pty Ltd
162349	14/08/2014	14/08/2024	1,000,000	Tronox Management Pty Ltd
171038	13/08/2013	13/08/2023	55000	APT Parmelia Pty Ltd
173435	8/02/2017	31/03/2024	18,500	AWE Perth Pty Ltd
174989	14/08/2014	14/08/2024	2,000,000	Tronox Management Pty Ltd
180269	15/01/2015	15/01/2025	3,000	AWE Perth Pty Ltd
181277	30/07/2015	29/07/2025	10,000	AWE (WA) Investment Company Pty Ltd
182409	17/12/2018	16/12/2028	99,300	Davilla Nominees Pty Ltd
183759	18/01/2017	18/01/2022	3,500	AWE Perth Pty Ltd
202619	28/03/2019	20/06/2025	12,800	RCMA Australia Pty Ltd
202801	28/05/2019	27/05/2029	450,000	RCMA Australia Pty Ltd

The closest regulated groundwater area, the Allanooka-Dongara Water Reserve, is located 16 km to the north from the Project Site. The reserve is listed as a 'Priority One' Public Drinking Water Source protection area but unlikely within the influence of the proposed Project Site activities.

## 2.8 Groundwater Dependent Ecosystems

The Project Site is situated next to an alluvial depression (to the east of the Project Site) which features surface expression of groundwater known as Ejarno Spring which is classified as a groundwater dependent ecosystem (GDE) also referred to as the 6 Mile Swamp (GMEC, 2019).

Similar features also occur further away to the southeast of the Project Site in southbound continuation of the topographic depression and are known as the Zeus Wetland. They form part of the Beharra Spring consanguineous wetland suite which consists of a relict palaeo-lake system blanketed by Bassendean Sands forming dampland of irregular morphology (Strategen, 2012 in GMEC, 2019).

The hydrological connectivity between the Zeus wetlands and the underlying surficial aquifer varies between unconfined to perched (Strategen, 2012). The vegetation in and surrounding the Zeus wetland transitions from wetland to dryland vegetation and is considered to be partially

dependent on groundwater, either as a perched water table or the surficial aquifer water table (Strategen, 2012). The Zeus Wetland is ephemeral.

Other GDEs in the area include (Figure 2-4):

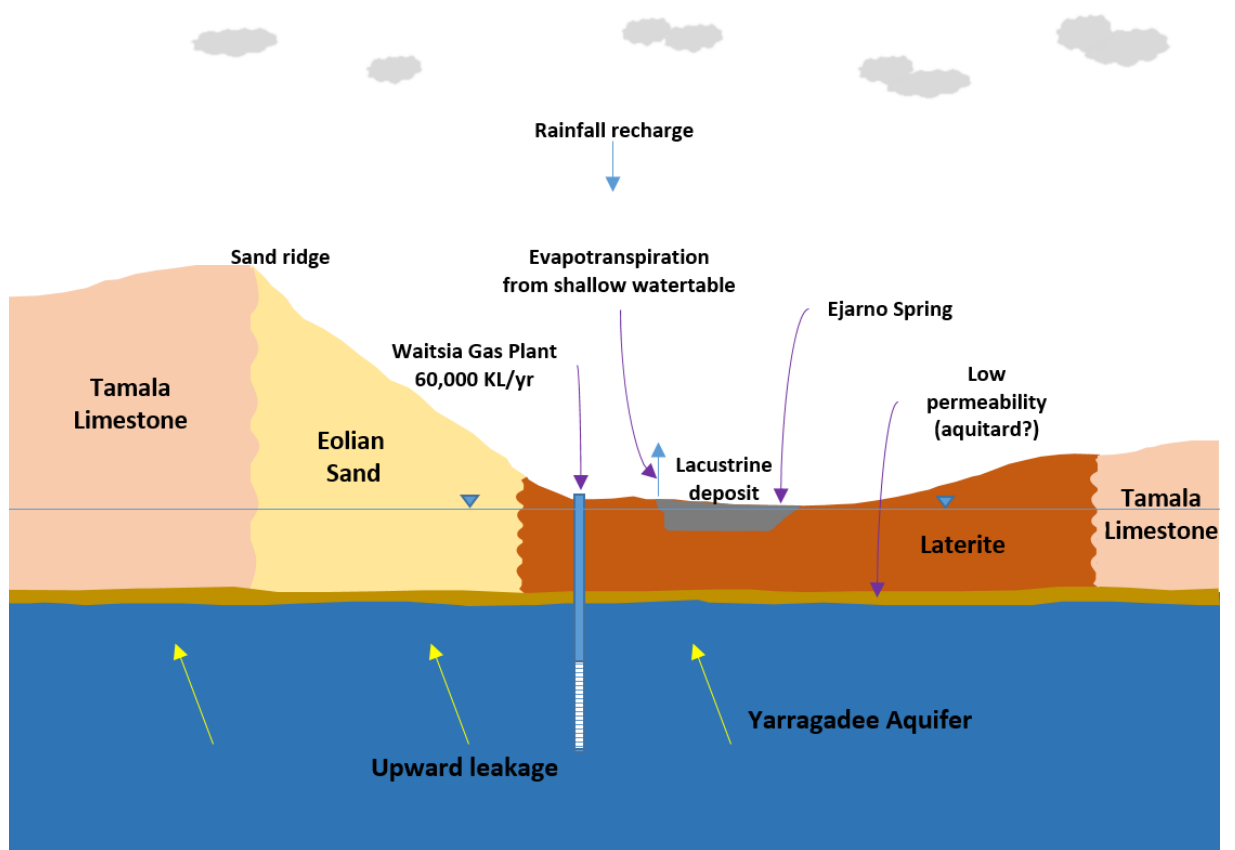
- the Yordanogo Nature Reserve (2.5 km south of the gas plant area)
- Beekeepers Nature Reserve (10 km west of the gas plant area) along the coast
- Crown Reserves 27935 and 43543 (14 to 15 km ENE of the gas plant area) along the Irwin River

## **2.9 Conceptualisation Summary and Limitations**

Groundwater flow at the site and in its immediate vicinity, especially in relation to the Ejarno Spring next to the Project Site, is characterised by the following main features:

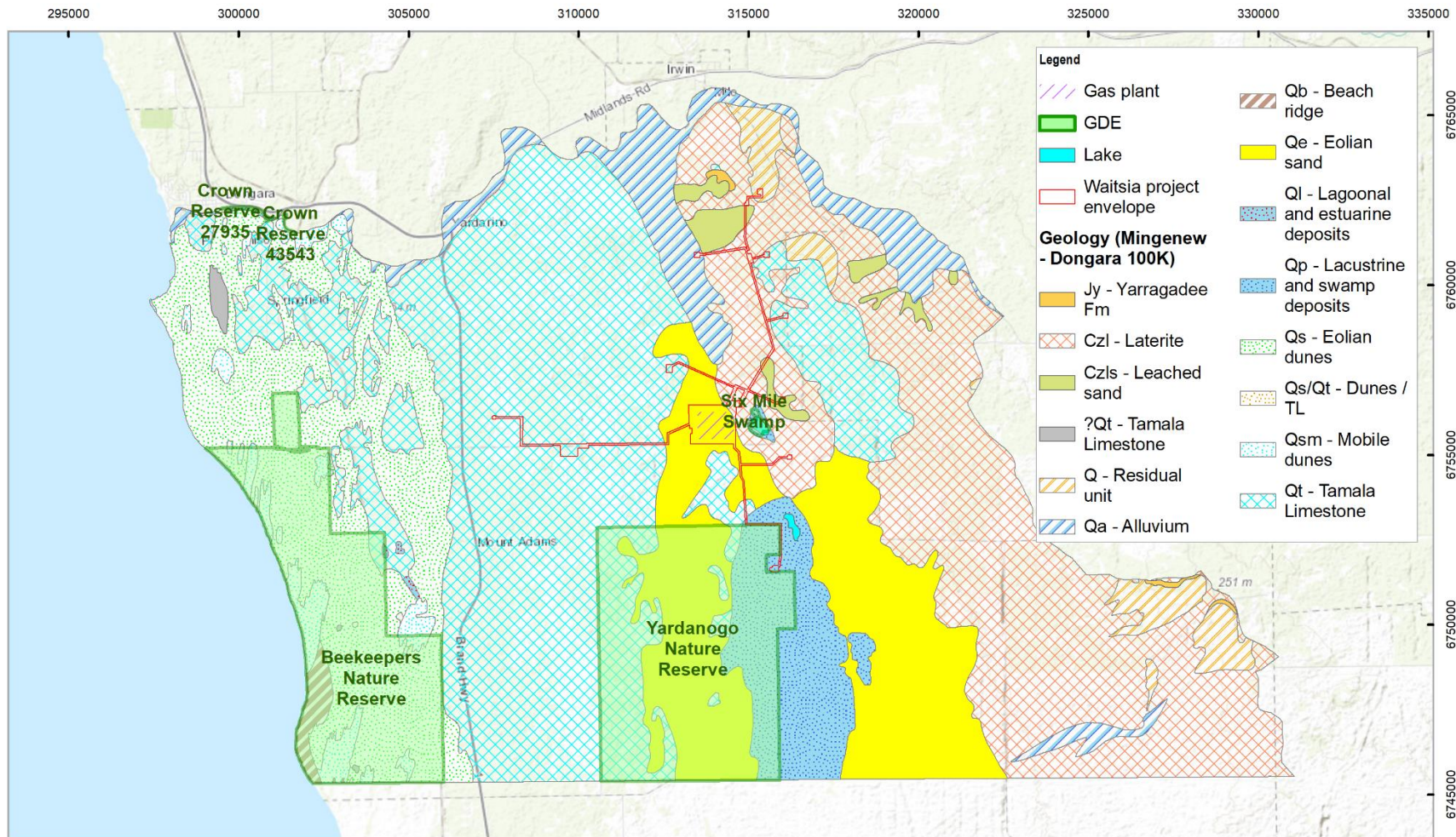
- Two main aquifers form the shallow aquifer system at the site, the shallower and unconfined Superficial aquifer overlying the top of the regionally extensive Yarragadee and largely confined aquifer. Their connectivity may be affected by the presence of a less permeable layer at the base of Superficial aquifer. There is however no drilling data available to explicitly confirm this or provide detailed account of lithology underneath the Ejarno Spring feature.
- Groundwater flow directions are generally towards the ocean, in the westerly to south-westerly direction. Groundwater levels show stable trends with only minor variations related to the seasonal cycle.
- The Ejarno Spring has developed in the area of a topographic low and likely to be a combination of groundwater expression and rainfall/ surface water runoff ponding on the less permeable surface.
- There is a head difference between the Superficial and Yarragadee aquifers suggesting an upward component of groundwater flow at the Project Site and in the area of the Ejarno Spring
- Groundwater recharge consists of two main components, the direct diffuse rainfall recharge and focused (river) recharge replenishing the Superficial aquifer; and the lateral inflow from the regional system (from the east) within the Yarragadee aquifer.
- Groundwater eventually discharges from the aquifer system by outflow to the ocean, evapotranspiration in the topographic depressions or areas with shallow groundwater and potential discharge into the river system (Irwin River).
- Groundwater is extracted from the aquifer system and may include unlicensed extraction from the Superficial aquifer and licensed and regulated abstraction from the Yarragadee aquifer.

The hydrogeological conceptualisation summary for the Project Site and the Ejarno Spring is depicted in Figure 2-3.



**Figure 2-3 Conceptual section across the Project site and Ejarno Spring**

The geological details at the Project Site and Ejarno Spring are interpreted from regional geological information and bore logs around the Project Site as there has been no hydrogeological drilling in the spring area.



**Figure 2-4 Surface geology and GDE mapping**

## 3. Numerical Modelling

### 3.1 Model Construction

The numerical model was developed to simulate groundwater flow at a subregional scale, based on the conceptual hydrogeological model described in Section 2. Data and maps from the previous hydrogeological investigations were reviewed and captured using GIS and modelling tools. Groundwater level and abstraction data was collected from the DoW databases. The numerical model was constructed using MODFLOW-USG software which allows for efficient grid refinement in the area of interest (Figure 3-1).

The model comprises the following components and approaches:

#### 3.1.1 Model Domain and Spatial Discretisation

In alignment with hydrogeological conceptualisation, the numerical model domain comprises the two major aquifers, and extends to the Irwin River in the north and north east, follows the surface catchment divide in the east and Indian Ocean coast to the west. The southern boundary of the model is arbitrary in absence of any hydrologically relevant features.

The model was vertically discretised into four layers:

- two base layers (Layer 3 and 4) representing the **Yarragadee Aquifer**
- Yarragadee aquifer overlain by a thin **clay-rich layer** (Layer 2) observed at the base of Superficial Formation and the overlying Superficial Formation.
- Layer 1 (top layer) representing the **Superficial formations**, divided into an 'alluvial' unit (that includes the Ejarno Spring) and Tamala Limestone. It also includes, to the east of the site, the subcropping Yarragadee aquifer (Figure 3-2) since the Superficial formations may be thin and largely unsaturated.

The layer elevations were implemented as follows:

- The base of layer 1 was derived from previous studies (Figure 3-3).
- The bases of layers 2 to 4 were derived by applying uniform thicknesses of 2 m, 50 m and 100 m, respectively.
- The model does not represent the full thickness of Yarragadee aquifer since only the top section of the formation is required for this assessment.

An example of the model layer setup in a W-E section across the Project site and Ejarno Spring area is presented in Figure 3-4.

#### 3.1.2 Boundary Conditions

The boundary conditions implemented in the numerical model are as follows:

- The model domain is bounded in the north and north east by MODFLOW RIV boundary, representing the Irwin River in the top model layer (Layer 1).
- The eastern boundary in layers representing the Yarragadee aquifer (Layer 3 and 4) are CHD (fixed head or water level) simulating regional groundwater throughflow. Head information for this boundary was taken from GARAMS and Rockwater (2015).
- The southern boundary is considered 'no flow' as is aligned in the generally east to west direction of groundwater flow with no additional flow inputs expected along this boundary.



- The western boundary is a general head boundary (GHB) with set level of 0.3 m AHD representing the ocean. The setup and locations of the boundary conditions are presented in Figure 3-1.

### **3.1.3 Aquifer parameters**

The initial aquifer parameters assigned to the model hydrogeological zones were sourced from GARAMS (2011) and DoW (2017). Some modifications to these parameters were made during the steady state and transient calibration to achieve a better fit between the observed and simulated groundwater levels.

### **3.1.4 Recharge**

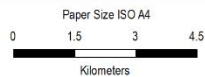
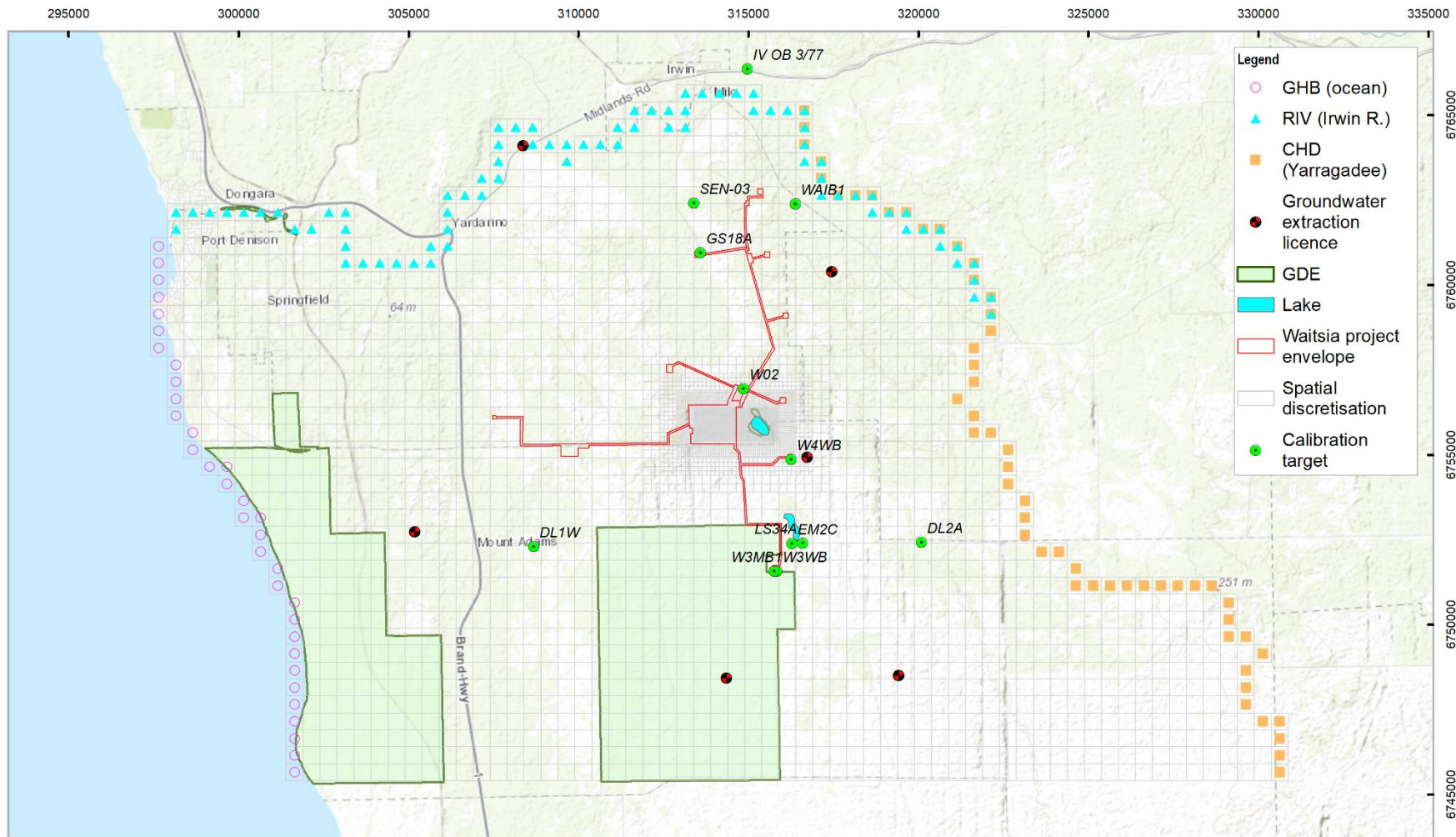
The recharge rate estimate implemented in the model was obtained from regional studies (and set at 55 mm/year (e.g. DOW, 2017). For the purposes of this assessment this estimate was uniformly applied across the model domain.

Since the groundwater level observations in the area show a consistently stable trend (accounting for seasonal variation), representation of temporal variations in the recharge rate were not considered necessary for the purposes of this assessment.

### **3.1.5 Abstraction**

Groundwater abstractions were represented within the model domain (in locations shown in Figure 1) for annual rates greater than 50,000 kL/yr, based on the current licenced groundwater allocation rate specified in the DWER databases.

A review of groundwater levels in the area suggested that there has been no substantial abstraction associated with the Tronox abstraction licence (3,500,000 kL/yr), as there is no evidence of drawdown that would be expected with this abstraction volume. Therefore, the Tronox licenced abstraction was not represented in the model.



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Horizontal Datum: GDA 1994  
Grid: GDA 1994 MGA Zone 50

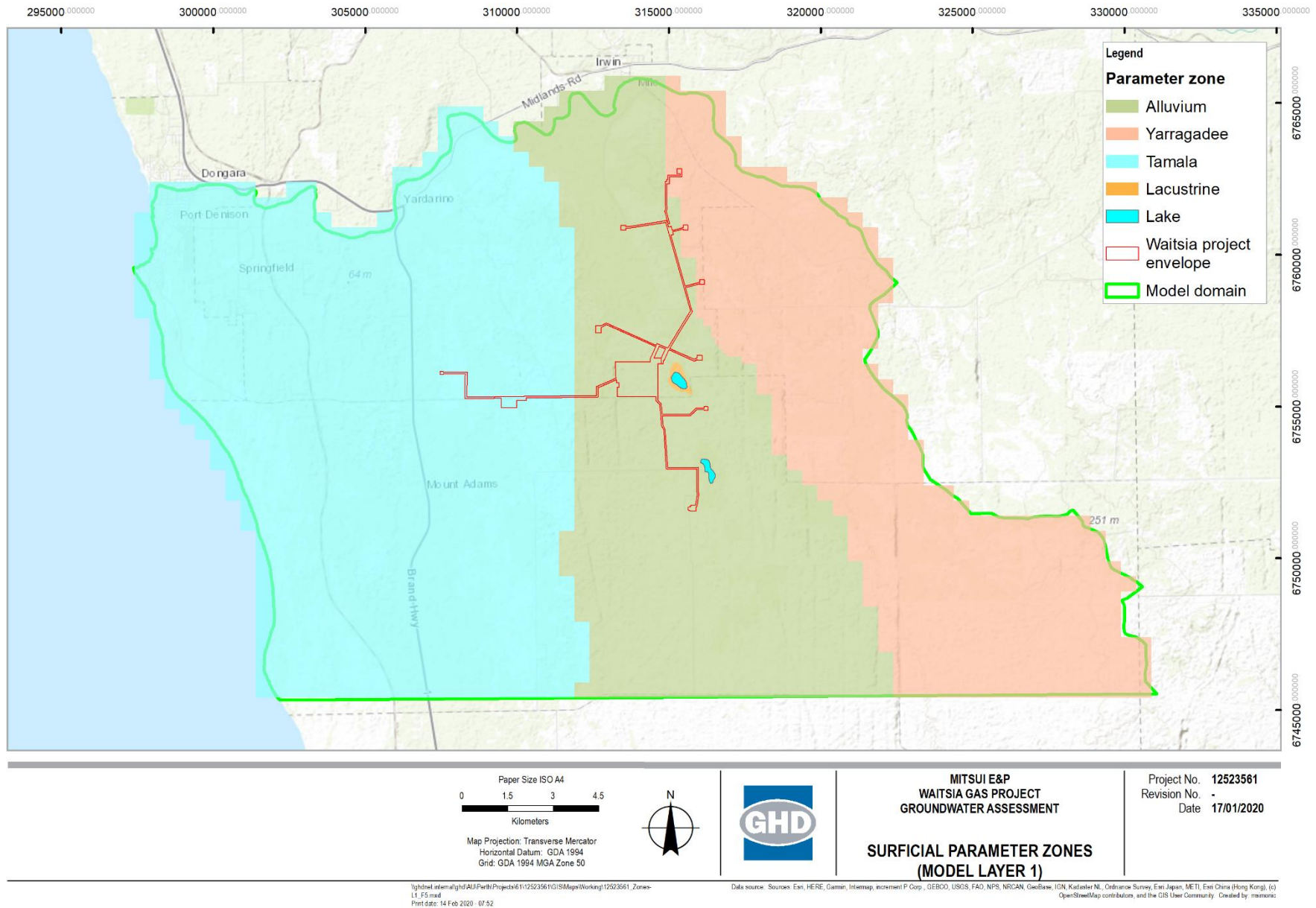


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COMPUTATIONAL GRID AND  
BOUNDARY CONDITIONS

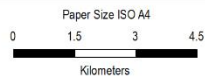
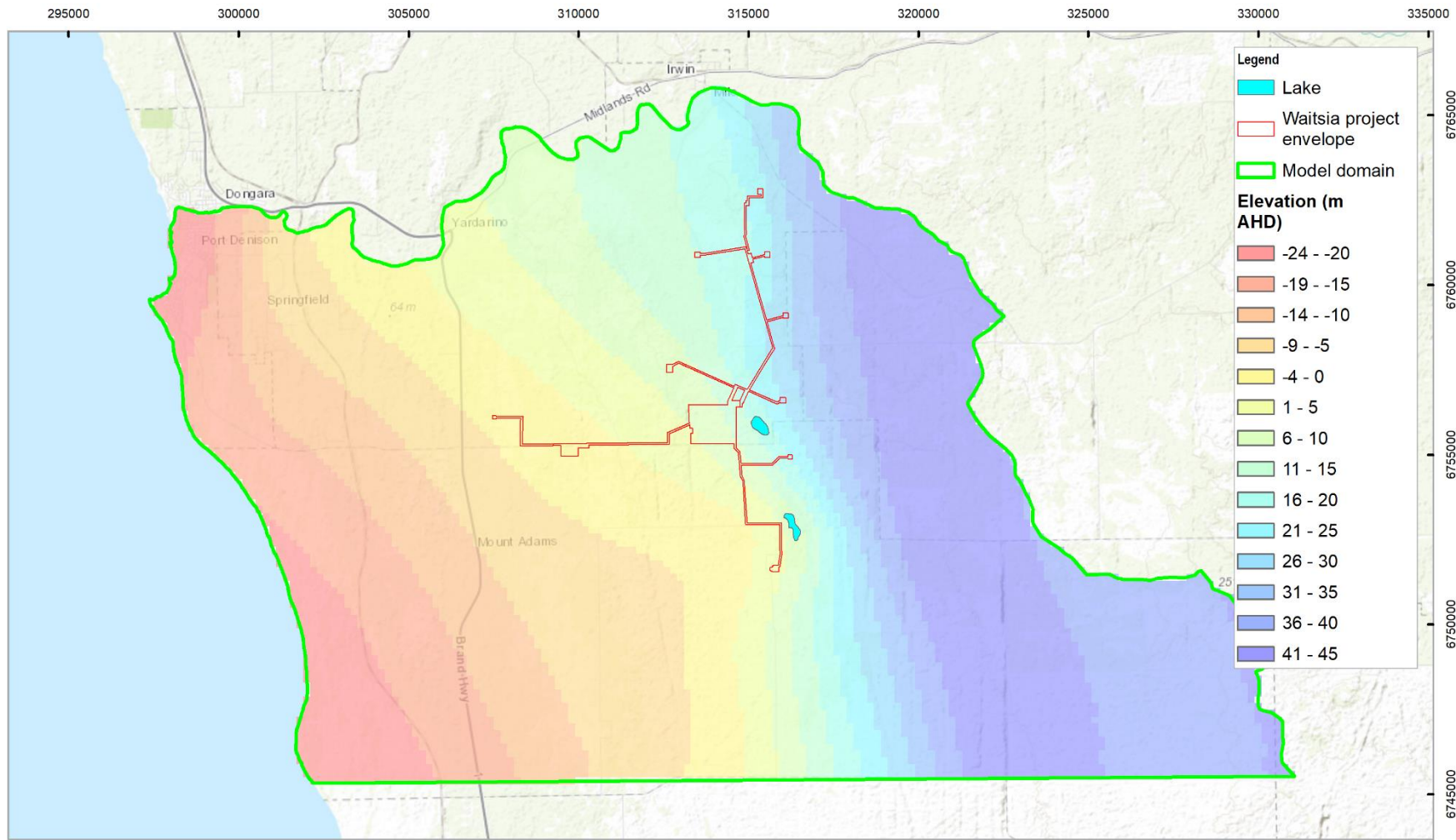
Project No. 12523561  
Revision No. -  
Date 17/01/2020

Data source: Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community. Created by: mramos

**Figure 3-1 Model computational grid and boundary conditions**



**Figure 3-2 Model parameter zones, layer 1 (Surficial formations)**



Map Projection: Transverse Mercator  
Horizontal Datum: GDA 1994  
Grid: GDA 1994 MGA Zone 50



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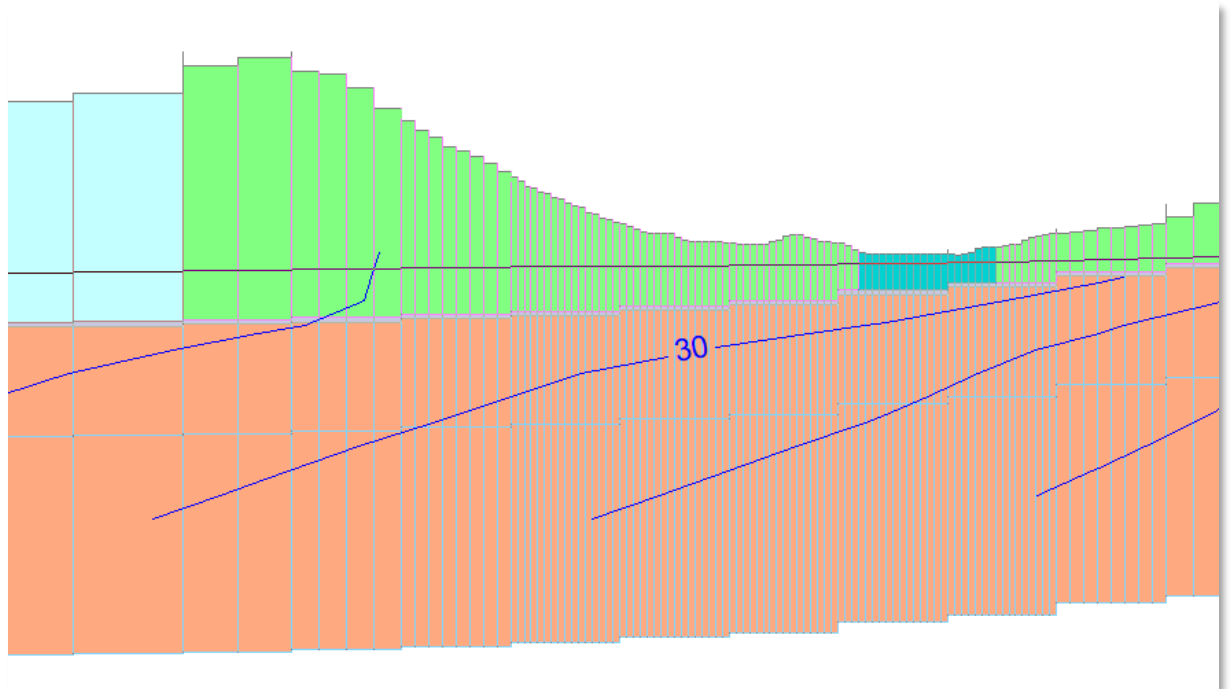
LAYER BASE ELEVATION  
(MODEL LAYER 1)

Project No. 12523561  
Revision No. -  
Date 17/01/2020

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Data source: Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community. Created by: mramos

Figure 3-3 Model layer 1, base elevation



**Figure 3-4 Example model section (W-E) across the Project Site and Ejarno Spring**

## 3.2 Model Calibration

### 3.2.1 Approach

The approach to undertaking model calibration was by performing an iterative adjustment of selected aquifer parameters (hydraulic conductivities) to minimise the difference between observed and modelled groundwater levels at monitoring bore locations. Locations of groundwater targets for which water levels were computed are shown in Figure 3-1.

SMS solver was used to obtain the simulation results from the MODFLOW-USG numerical model, with head and residual convergence criteria of 0.001. Since the available water level data is not detailed enough to show seasonal variation in groundwater levels (Figure 3-6 and Figure 3-7), the model was calibrated in the transient state using time-averaged variables (recharge, evapotranspiration, pumping, throughflow) for the period 2014 to 2019. Seasonal variations are assumed to be in order of 0.3-1.7 metres so this approximation is considered appropriate.

For comparison the model constructed for the purposes of this assessment was also run with GARAMS-derived hydraulic parameters for the regional DWER model.

### 3.2.2 Calibration Results

Hydrographs from ten selected representative bore locations were compared to computed water levels hydrographs and are presented in Figure 3-6. The location of the bores used for calibration is presented in Figure 3-1.

The comparison of real versus simulated levels suggests an acceptable calibration, with matches particular valid around the Project site (bore W02), but also in locations further from the site, with one exception for WAIB1 which is over 6 km NNW of the Project Site. The WAIB1 location is not far from the Irwin River (Figure 3-1) and may be affected by recharge from the river via infiltration in this area, or different (less permeable) hydraulic conditions. Due to the

distance from the Project Site, the difference in actual and simulated water levels at WAIB1 is not considered to impact the representativeness of the 'local' model in the area of interest (Project Site).

A scaled mean square error (SRMS) of 7.4% was achieved for the calibration period. When comparing the modelled and observed heads, the majority of the wells were within the 95% confidence interval. Existing differences between observed and modelled values may have been caused by the parameters and predictions adopted to represent average conditions within the 0.5 km<sup>2</sup> model grid cells; or by the assumed uniform aquifer parameters for the hydrogeological formations. The SRMS value is also affected by the lack of calibration for bore location WAIB1, if this was not considered the SRMS value would be 4.3%.

The match between observed and computed hydrographs for the case with GARAMS regional model derived parameters is shown in Figure 3-7. This suggests a generally less acceptable fit when compared with the results of the 'local' model. It is therefore concluded that local model is a more adequate representation of the Project site conditions.

Storage parameters adopted are consistent with the GARAMS regional model (GHD 2011), as they have been found less sensitive to changes. The GARAMS regional model and this local model calibration confirmed that modelled water levels are more sensitive to lateral hydraulic conductivity values, in this case of the Superficial aquifer and to a smaller degree to hydraulic conductivity of the Yarragadee aquifer. Hydraulic conductivity values were optimised for site-specific conditions and compared to the GARAMS regional model parameterisation.

Calibrated parameters for locally calibrated model are tabulated in Figure 3-5:

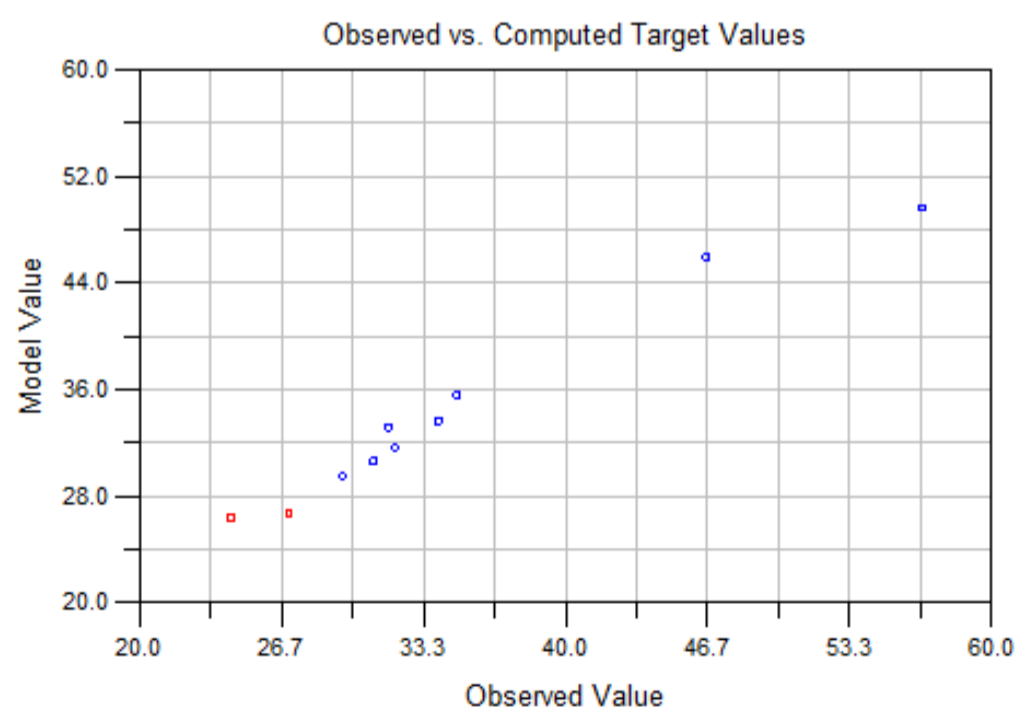
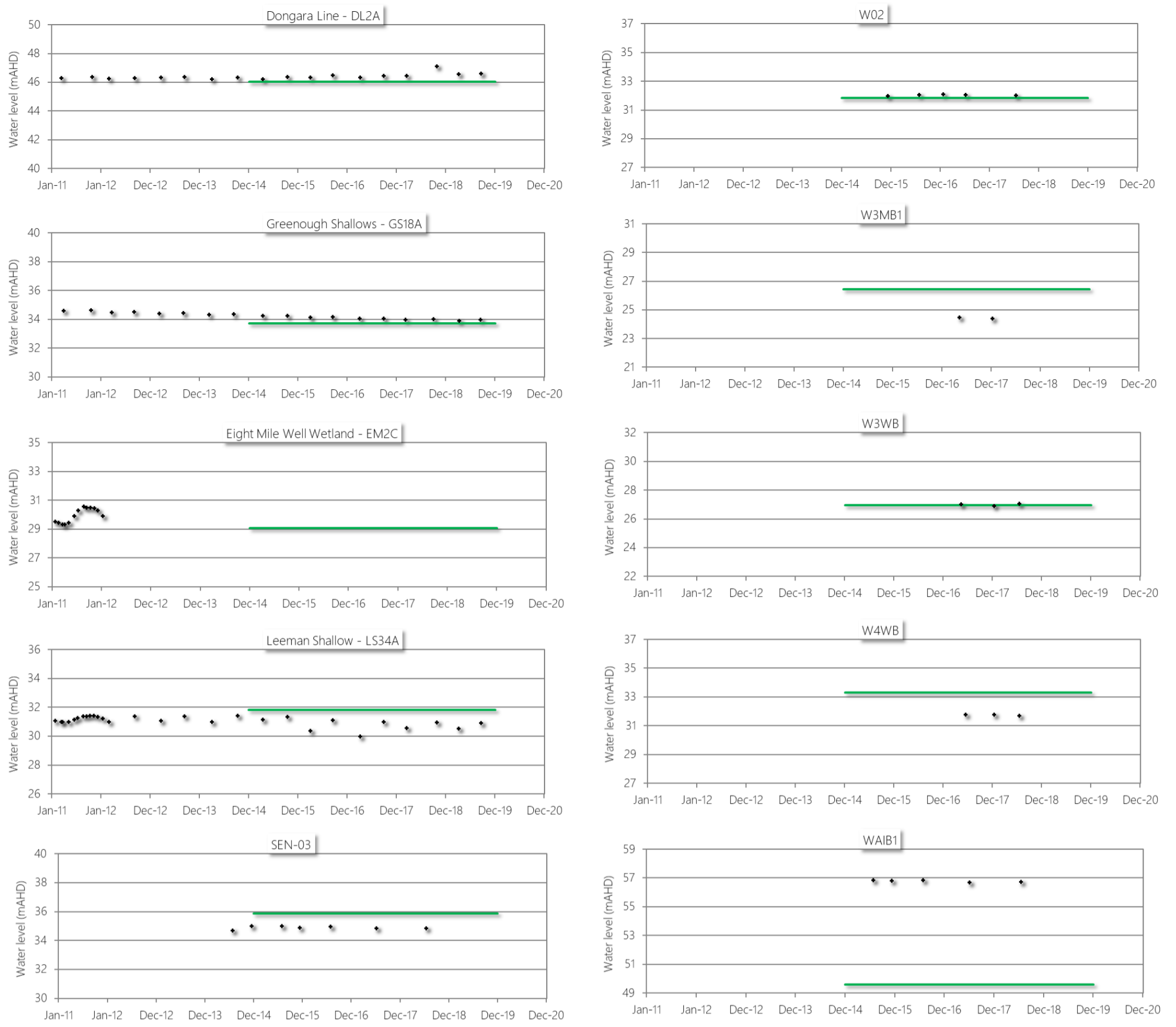
**Figure 3-5 Summary of calibrated parameters**

Zone	Hydraulic conductivity Kh/Kv (m/d)	Specific storage / specific yield (Ss/Sy)
Alluvium (L1)	15/1.5	0.0001/0.2
Yarragadee subcrop (L1)	6/0.6	0.00001/0.1
Tamala Limestone (L1)	200/100	0.00001/0.2
Base of Superficials (L2)	3/0.01	0.00001/0.1
Yarragadee (L3, L4)	3/0.01	0.00001/0.1

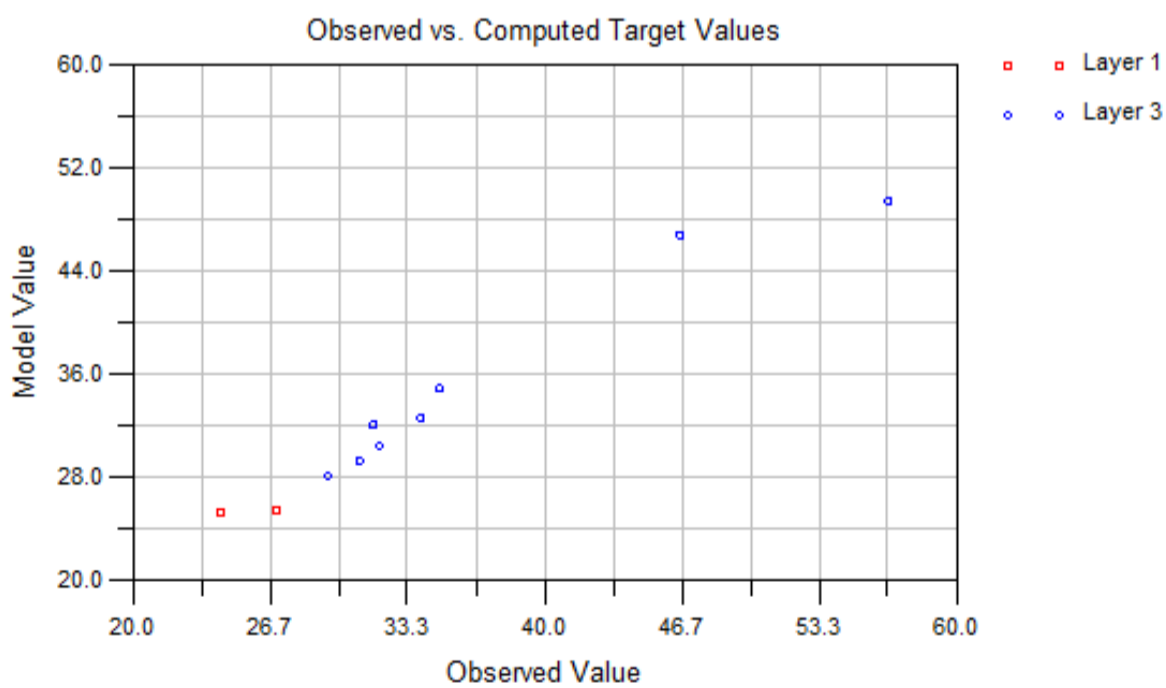
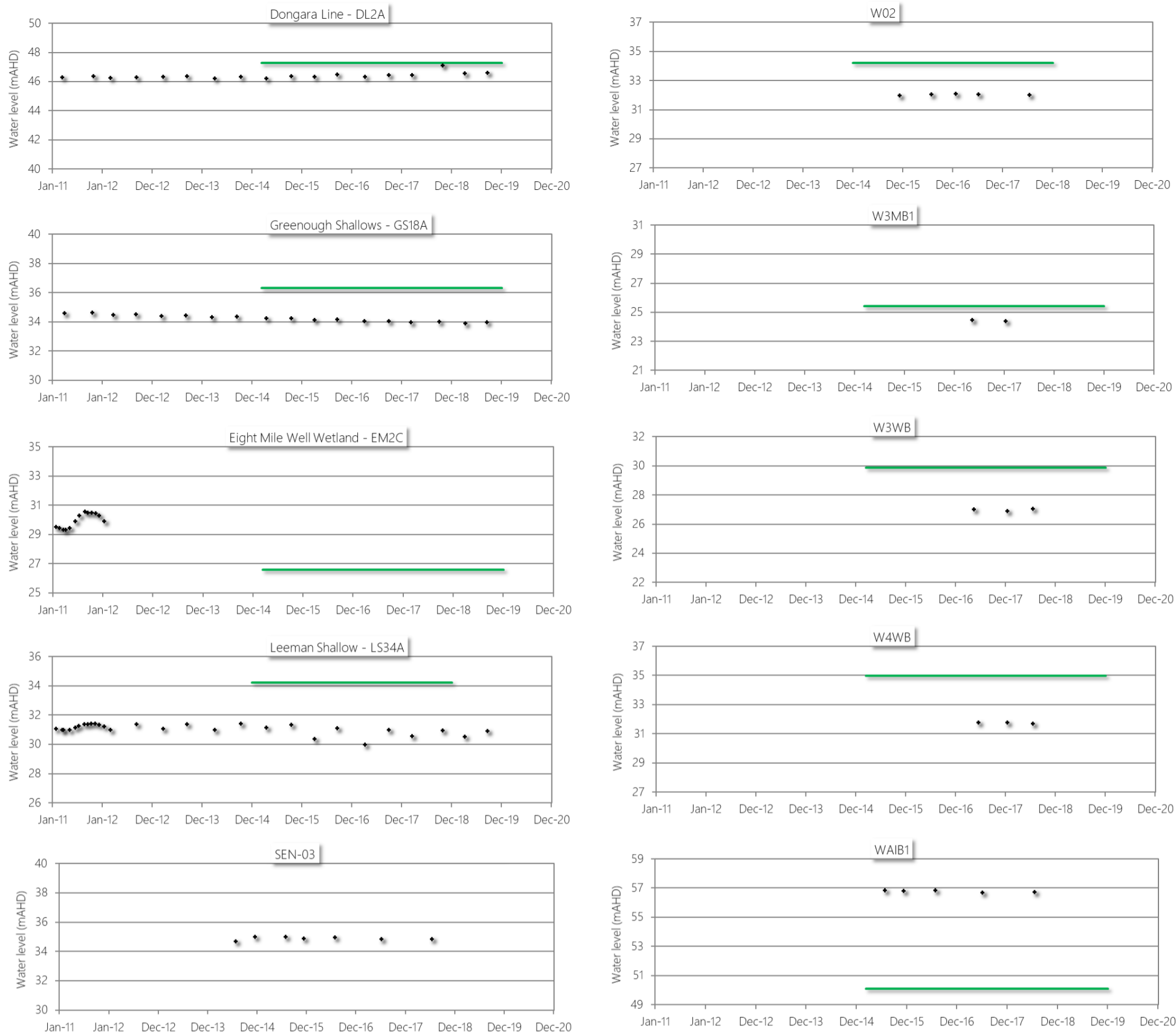
### 3.2.3 Parameter Sensitivity

Sensitivity of the model results was also tested to assess the assumption regarding the presumed low permeability of the surficial sediments potentially present beneath the Ejarno Spring. The overall local model calibration was not affected by perturbations of the permeability of the surficial sediments (within layer 1).

A conservative approach was taken in the base case model, with permeability of these sediments assumed to be equal to the rest of alluvial sediments.



**Figure 3-6 Comparison between observed (black dots) and computed hydrographs (green) of the calibration targets, base case**



**Figure 3-7 Comparison between observed (black dots) and computed hydrographs (green) of the calibration targets, using GARAMS parameters**



### 3.3 Predictive Modelling of Proposed Abstraction

#### 3.3.1 Evaluated Cases

The potential impact of the proposed abstraction at 60,000 kL/yr from the Project Site was assessed by examining the water level change induced by pumping, specifically on the Ejarno Spring (GDE) and third party licensed users in the area.

The water level change (referred to as drawdown) is defined as the difference between the water level before abstraction commences and five years after continuous abstraction.

Simulations of abstraction were undertaken from a proposed production bore set in the top section of Yarragadee aquifer and located along the eastern boundary of the Waitsia processing area. While MEPAU considers up to four abstraction bores, the predictive simulations were done for one location at a closest distance to the Ejarno Spring (approximately 500 m). This is due to a relatively small pumping rate (1.9 L/s) that can be secured by a single pumping bore (location shown in Figure 3-8) and to maintain conservatism of this impact assessment.

This represents a conservative approach to assessing the impact on groundwater levels by simulating abstraction of groundwater as close as possible to the Ejarno Spring - location of the pumping bore further away from the Ejarno Spring (to the west) may reduce groundwater level change at the Ejarno Spring.

Three conceptual scenarios were evaluated:

1. **'Base case (BC)'** – the model with locally calibrated parameters
2. **'GARAMS parameterisation case (GPC)'** – as above but with hydraulic parameters taken from the GARAMS regional model
3. **'Lacustrine low K case (LLKC)'** – as BC but with a low hydraulic conductivity unit beneath the Ejarno Spring.

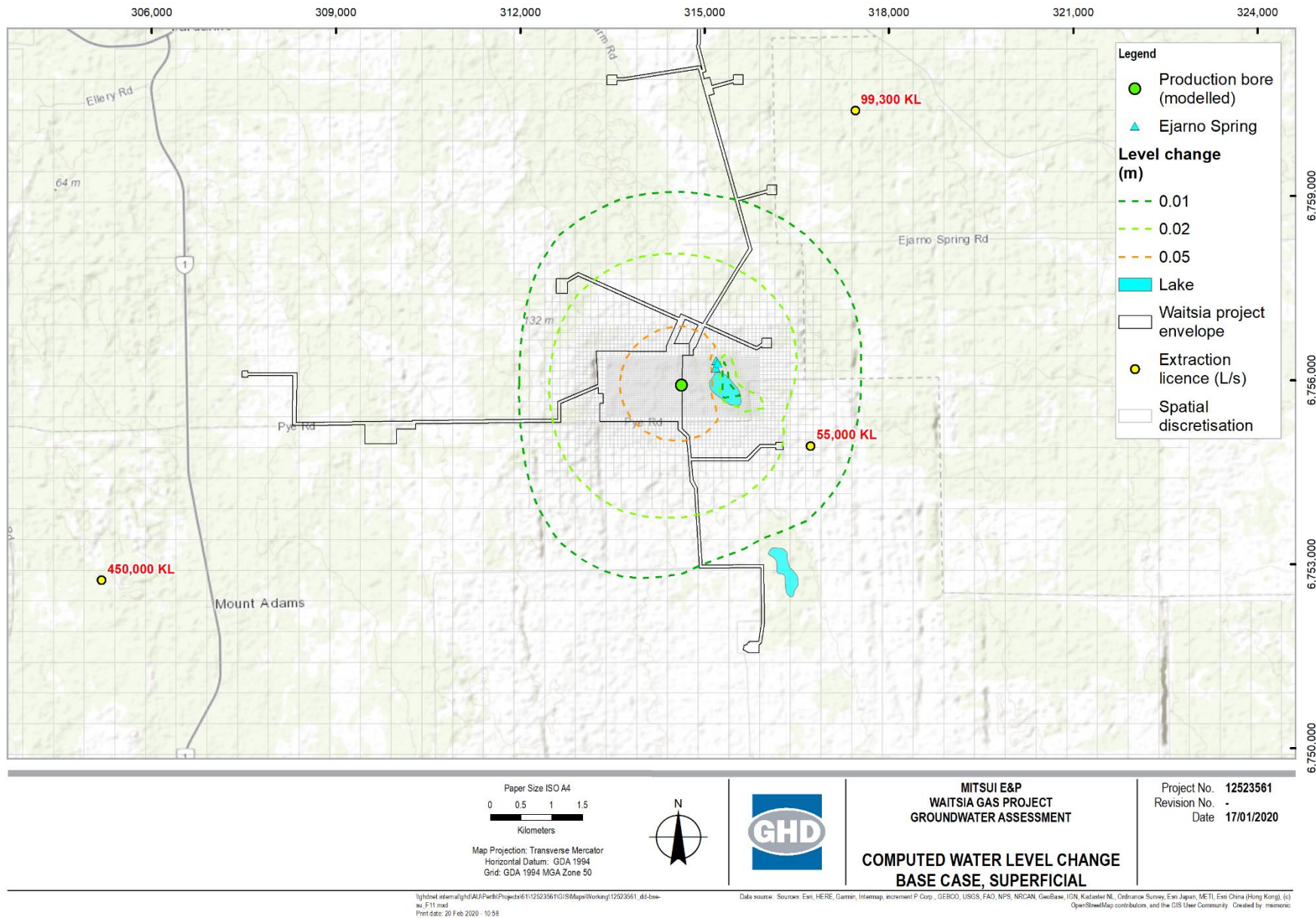
The impact of the abstraction on water levels was evaluated using delineation of drawdown for both the Yarragadee and Superficial aquifers.

#### 3.3.2 Results

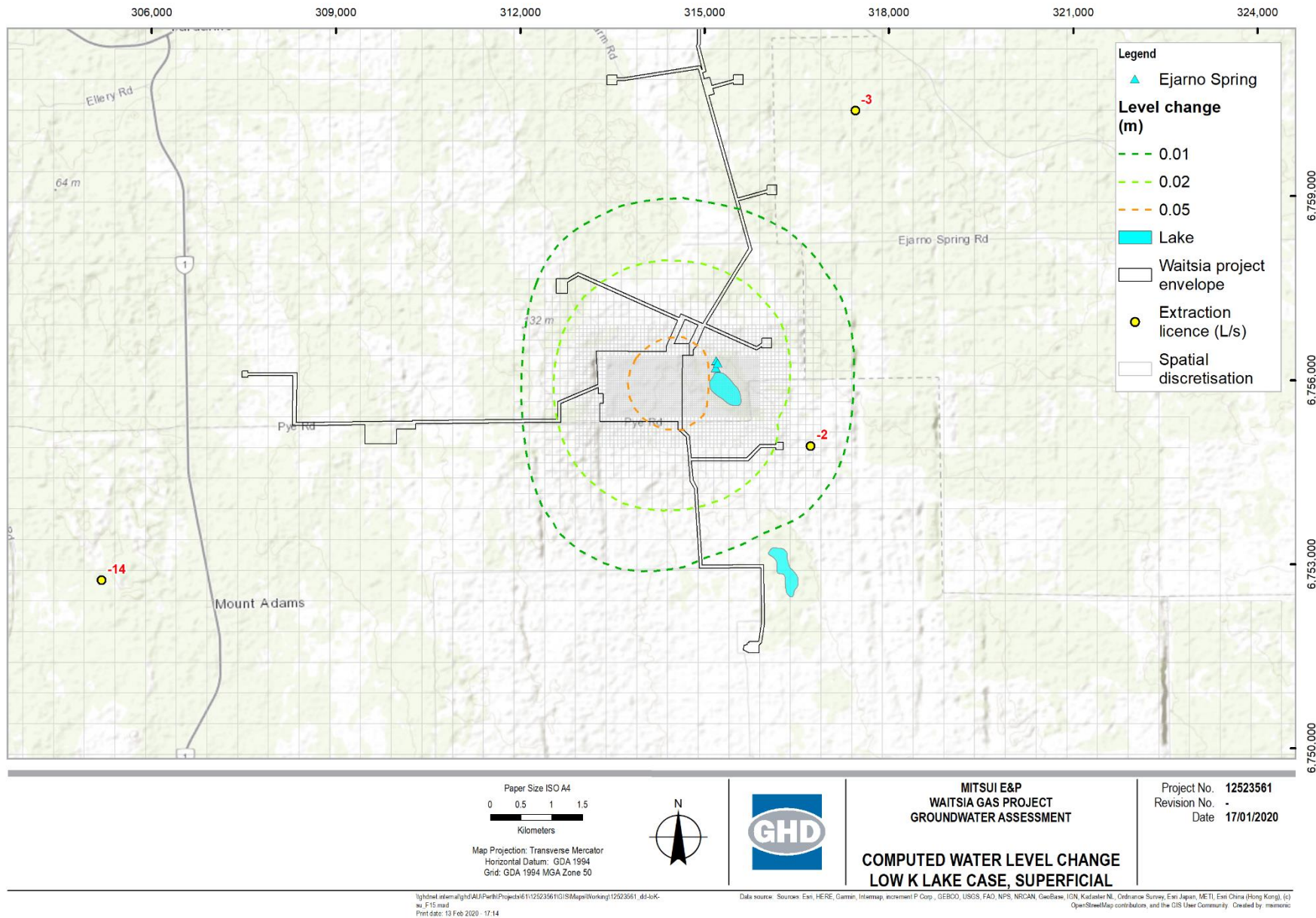
Drawdown contours (representing reduction in water level) presented in Figure 3-8 to Figure 3-13 suggest small water level changes attributable to abstraction from a proposed conceptual bore at the Project Site.

The modelled changes in Superficial aquifer at the western edge of the lake at Ejarno Spring represent show a maximum reduction in water levels of 6, 0 and 5 cm after five years of pumping for scenarios (1) to (3) respectively.

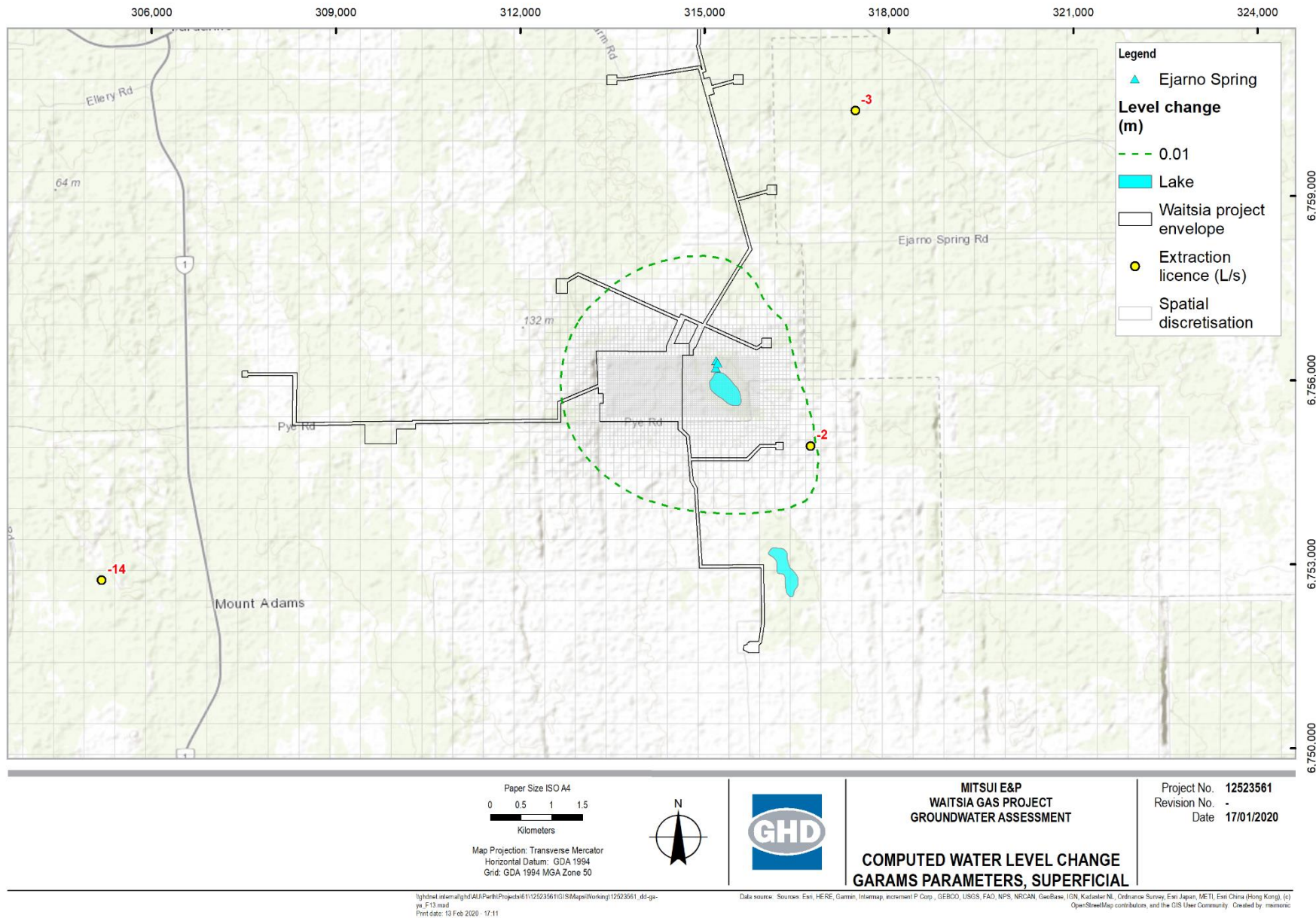
The modelled changes in Yarragadee aquifer water levels are predicted to show a decrease by up to 19 cm at the Ejarno Spring after five years of continuous pumping.



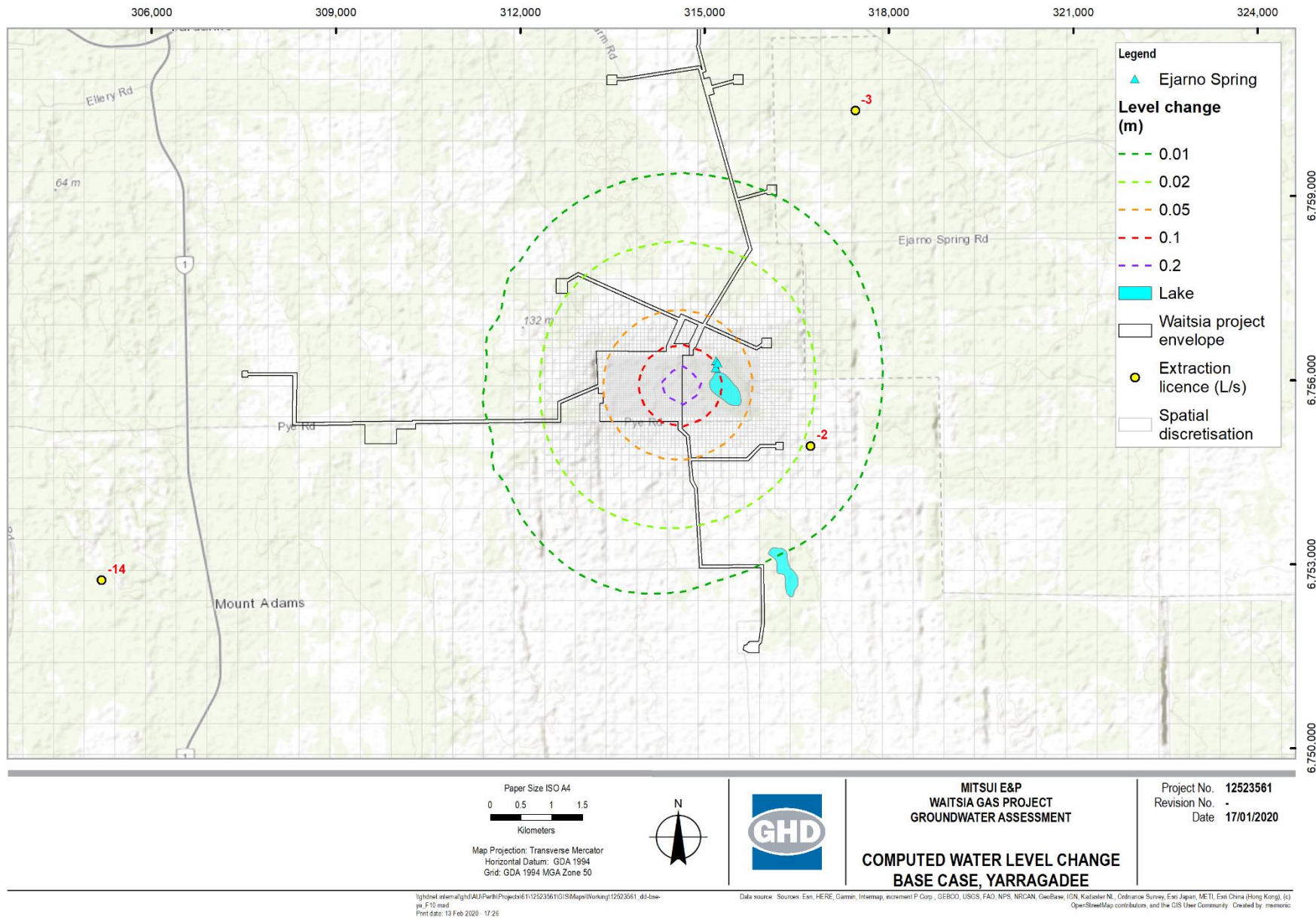
**Figure 3-8 Computed water level change, base case, Superficial aquifer**



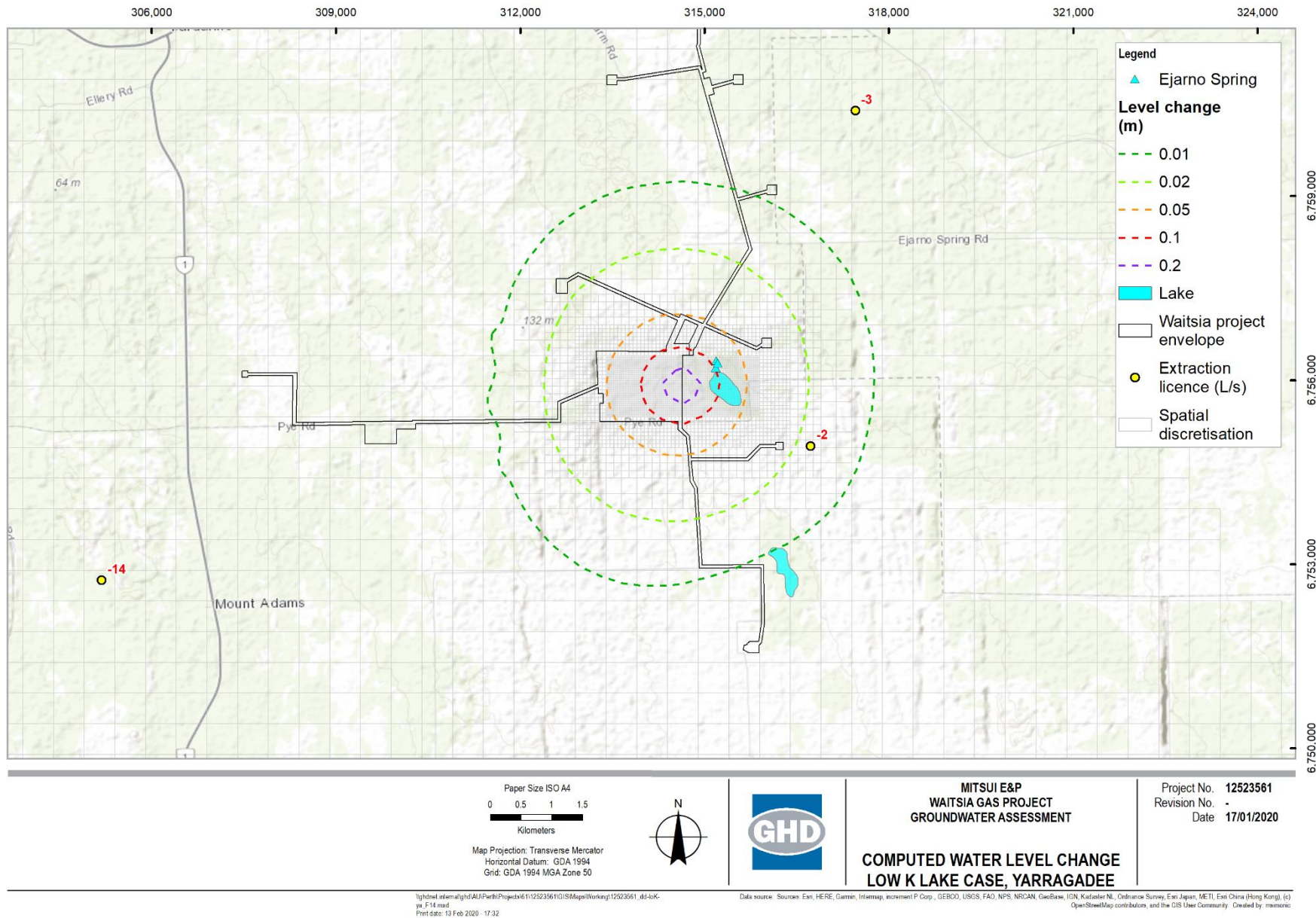
**Figure 3-9 Computed water level change, lacustrine low K case, Superficial aquifer**



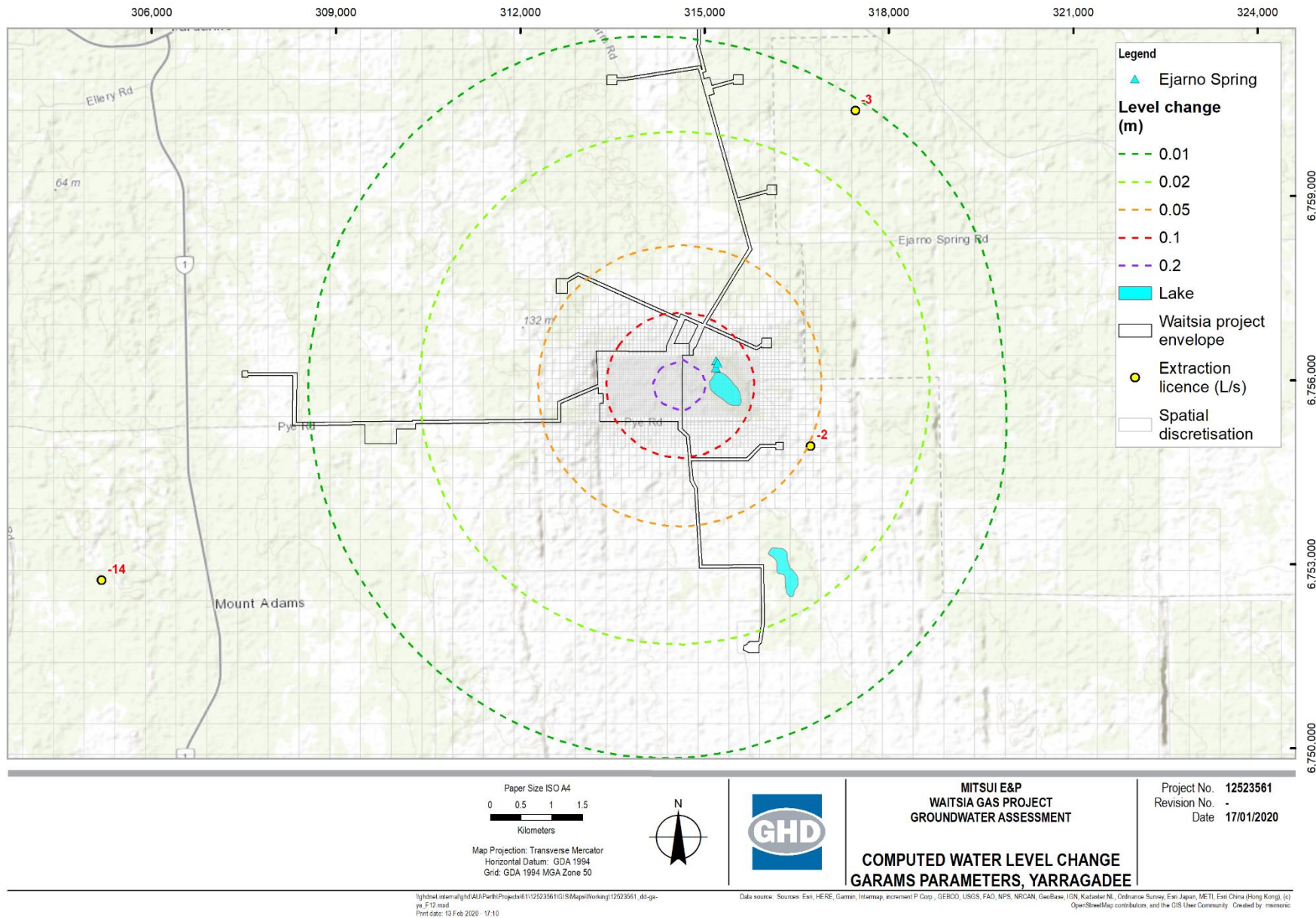
**Figure 3-10 Computed water level change, GARAMS parameter case, Superficial aquifer**



**Figure 3-11 Computed water level change, base case, Yarragadee aquifer**



**Figure 3-12 Computed water level change, lacustrine low K case, Superficial aquifer**



**Figure 3-13 Computed water level change, GARAMS parameter case, Yarragadee aquifer**

### 3.4 Impact Assessment

Simulated results of water level change attributable to pumping from the gas plant area are summarised in Table 3-1. These suggest that there would be a small change of groundwater levels at the Ejaro Spring as a result of the proposed Project abstraction. This predicted reduction in water levels would be practically undistinguishable from the natural (seasonal variations) of water levels in the area, which are in the order of 0.3-1.7 m within a year.

The model results need to be considered in light of the high degree of conservatism adopted. For example, conservative assumptions were made by discounting the potential presence of perched groundwater or the presence of lower permeability layers which would reduce the hydraulic connectivity between the two aquifers and with the Ejaro Spring, by preventing or reducing the upward flow of groundwater from the Yarragadee aquifer into the Superficial layers.

**Table 3-1 Predicted drawdown in water levels at western side of Ejaro Spring after 5 years**

Scenario	Superficial Drawdown (m)	Yarragadee Drawdown (m)
1 Base case	0.06	0.15
2 GARAMS parameterisation case	0.00	0.19
3 Lacustrine low K case	0.05	0.13

The water level change at the GDE (Yardanogo Nature Reserve) to the south of the Project Site is predicted in the order of 1 to 2 cm after five years of pumping, practically undistinguishable from natural variations.

The only licensed site within the predicted drawdown (of 2 cm) from abstraction at the Project Site is APT Parmelia. Therefore the anticipated impact on water levels for neighbouring licensed abstractions is predicted to be negligible due to the limited drawdown impact and distance from the Project Site.

### 3.5 Assessment and Model Limitations

Modelling outcomes described in this report are based on desktop review from information sources in Section 2.1 and relies on validity of that information. There has been no field visit or field testing of aquifer properties as part of this project.

The numerical model is a simplified representation of the hydrogeological system and assumptions have been applied to the model which can present limitations and impact confidence in the model results. These limitations have to be carefully considered when assessing model outputs and impact assessments. The model is considered appropriate based on the information available and within the context of the purpose of the modelling.

To improve the predictive capacity of the numerical model, additional improvement on conceptual understanding could be considered. There are areas with gaps in the hydrogeological understanding, specifically in the Ejaro Spring area. There is limited data available on the base elevation of the Superficial aquifer and its connectivity with the Yarragadee aquifer in the Ejaro Spring area. To address this data gap conservative assumptions were made by discounting the potential presence of perched groundwater or the presence of lower permeability layers, which would have otherwise restricted or prevented the upward flow of groundwater from the Yarragadee aquifer into the Superficial layers.

In the current numerical model, each hydrogeological unit was assigned a uniform hydraulic conductivity. However, hydraulic conductivity can vary significantly across individual hydrogeological units. At the local scale the match between observed and simulated water



levels in available monitoring bores suggests that the model is sufficiently representative of local conditions and appropriate to assess the level of drawdown associated with the proposed Project abstraction rate.

There is limited information on the pumping abstraction records from the DWER – Water Resource Licensing allocation database for licensed abstractions. Any subsequent data update would improve future model revisions and the associated predictions.



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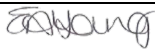
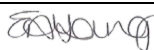
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