Hunter Water Corporation

Belmont Drought Response Desalination Plant
Groundwater Assessment Report

November 2019

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1. Introduction

1.1 Overview

The Lower Hunter has sufficient water to meet its needs in average climate conditions in the medium term. However, the region’s reliance on rain-fed dams and groundwater supplies makes it vulnerable to severe drought.

The Lower Hunter Water Plan (LHWP) was developed in 2014 with the aim to ensure that the Lower Hunter is able to withstand a severe drought as well as meeting community needs in the medium term. Within the plan, desalination is proposed in conjunction with other staged drought response measures in the event of an extreme drought. A drought response desalination plant would help make the water supply system more resilient to climate variability, with the primary benefit being that it would provide a drought contingency measure that is not dependent on rainfall.

Following a number of options assessments, a drought response desalination plant (also referred to as the temporary desalination plant) to be located within the existing wastewater treatment works site at Belmont was selected as the preferred option. Hunter Water submitted a State Significant Infrastructure (SSI) application for the Project to the Department of Planning and Environment in November 2017 and received the Secretary’s Environmental Assessment Requirements (SEARs) in December 2017 (SSI 8896). These SEARs outline the requirements for the preparation of an Environmental Impact Statement (EIS) to assess the future construction and operation of the Project, with particular requirements for the assessment of groundwater.

1.2 Purpose and scope of this report

This Groundwater Report has been prepared as a supporting document to the EIS. The purpose of this report is to assess the likely impacts of the future construction and operation of the proposal on groundwater within the coastal sand aquifer at the site, in particular the sensitive groundwater receptors including groundwater dependent ecosystems (GDEs) and registered groundwater supply works that rely on this groundwater. The assessment is based on hydrogeological data obtained from a field investigation program and the predictions of a hydrogeological model. The impact assessment has been undertaken in accordance with the NSW Aquifer Interference Policy.

1.3 Secretary's Environmental Assessment Requirements

Hunter Water submitted an SSI application for the proposal with the Department of Planning and Environment (DPE) in November 2017 and received SEARs in December 2017. A revised SEARs was issued following comment and discussed between Hunter Water and DPE on 24 January, 2018. The SEARs relevant to groundwater issues are reproduced in Table 1-1 below.

Table 1-1 SEARs (SSI 8896) – Groundwater

Key issues	Requirements	Where addressed
Water	An assessment of the impacts of the proposed development on the quantity and/or quality of surface and groundwater resources	Sections 5 and 6
	A description of the measures to minimise surface and groundwater impacts, including how works on steep gradient land or erodible soil types would be managed and any contingency requirements to address residual impacts.	Section 6.2

1.4 Legislation and policy

The following section provides a brief overview of the legislation and policies relevant to this groundwater assessment.

1.4.1 Water Management Act 2000

The *Water Act 1912* has historically been the main legislation for managing water resources in NSW, however is currently being progressively phased out and replaced by water sharing plans (WSPs) under the *Water Management Act 2000* (WM Act). Once a WSP commences, existing licences under the *Water Act 1912* are converted to water access licences (WALs) and to water supply works and use approvals under the WM Act.

The aim of the WM Act is to ensure that water resources are conserved and properly managed for sustainable use benefiting both present and future generations. It is also intended to provide formal means for the protection and enhancement of the environmental qualities of waterways and in-stream uses as well as to provide for protection of catchment conditions.

Water sharing plan

Fresh water sources throughout NSW are managed via WSPs under the WM Act. Provisions within WSPs provide water to support the ecological processes and environmental needs of GDEs and waterways. WSPs also provide how the water available for extraction is shared between the environment, basic landholder rights, town water supplies and commercial uses. Key rules within the WSPs specify when licence holders can access water and how water can be traded.

The WSP relevant to the Project is the North Coast Coastal Sands Water Sharing Plan (NCCS WSP), which commenced in July 2016. The Project is located within the Hawkesbury to Hunter Coastal Sands Groundwater Source, which is managed under this plan.

At the time of plan commencement, total entitlement within the Hawkesbury to Hunter Coastal Sands Groundwater Source was 7,680 ML/year, comprised of 1,325 ML/year town water supply, 25 ML/year basic landholder rights and 6,355 ML/year for other aquifer access. Unassigned water was 12,740 ML/year, based on the Long-Term Average Annual Extraction Limit (LTAAEL).

Relevant rules for water supply works approvals for this groundwater source are as follows:

- No water supply work (bores) to be granted or amended within 200 m of an existing bore that is not used for basic rights, 50 m of an existing bore that is used for basic rights, 50 m of the boundary of the property and 300 m of a local or major water utility bore.
- No water supply work (bores) to be granted or amended within 250 m of a plume associated with a contamination source as identified in the plan.
- No water supply work (bores) to be granted or amended within 800 m of a high priority GDE for bores licensed to extract more than 100 ML/year.

1.4.2 NSW Aquifer Interference Policy

The NSW Aquifer Interference Policy (AIP) was finalised in September 2012 and clarifies the water licensing and approval requirements for aquifer interference activities in NSW, including the taking of water from an aquifer in the course of carrying out mining.

The Policy outlines the water licensing requirements under the *Water Act 1912* and WM Act. A water licence is required whether water is taken for consumptive use or whether it is taken incidentally by the aquifer interference activity (such as groundwater filling a void), even where that water is not being used consumptively as part of the activity's operation. Under the WM Act, a water licence gives its holder a share of the total entitlement available for extraction from the groundwater source. The WAL must hold sufficient share component and water allocation to account for the take of water from the relevant water source at all times.

Sufficient access licences must be held to account for all water taken from a groundwater or surface water source as a result of an aquifer interference activity, both for the life of the activity and after the activity has ceased.

The NSW AIP requires that potential impacts on groundwater sources, including their users and GDEs, be assessed against minimal impact considerations, outlined in Table 1 of the Policy. If the predicted impacts are less than the Level 1 minimal impact considerations, then these impacts will be considered as acceptable.

The Level 1 minimal impact considerations for highly productive coastal sands groundwater sources are as follows:

Water table: less than or equal to 10% cumulative variation in the water table, allowing for typical climatic 'post-water sharing plan' variations, 40 m from any high priority GDE or high priority culturally significant site listed in the schedule of the relevant WSP. A maximum of a 2 m decline cumulatively at any water supply work.

Water pressure: a cumulative pressure head decline of not more than a 2 m decline at any water supply work.

Water quality: any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40 m from the activity.

1.5 Disclaimer

This report has been prepared by GHD for Hunter Water Corporation and may only be used and relied on by Hunter Water Corporation for the purpose agreed between GHD and the Hunter Water Corporation as set out in Section 1.2 of this report.

GHD otherwise disclaims responsibility to any person other than Hunter Water Corporation arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report. GHD disclaims liability arising from any of the assumptions being incorrect.

The opinions, conclusions and any recommendations in this report are based on information obtained from, and testing undertaken at or in connection with, specific sample points. Site conditions at other parts of the site may be different from the site conditions found at the specific sample points.

Investigations undertaken in respect of this report are constrained by the particular site conditions, such as the location of buildings, services and vegetation. As a result, not all relevant site features and conditions may have been identified in this report.

Site conditions may change after the date of this Report. GHD does not accept responsibility arising from, or in connection with, any change to the site conditions. GHD is also not responsible for updating this report if the site conditions change.

2. The Project

2.1 Project location

The Belmont drought response desalination plant is proposed to be located on the southern portion of the current wastewater treatment works (WWTW) site, on the boundary of Belmont and Belmont South, off Ocean Park Road. The proposed plant is just east of the Belmont Lagoon and west of the coastal dunes along Nine Mile Beach (Figure 2-1).

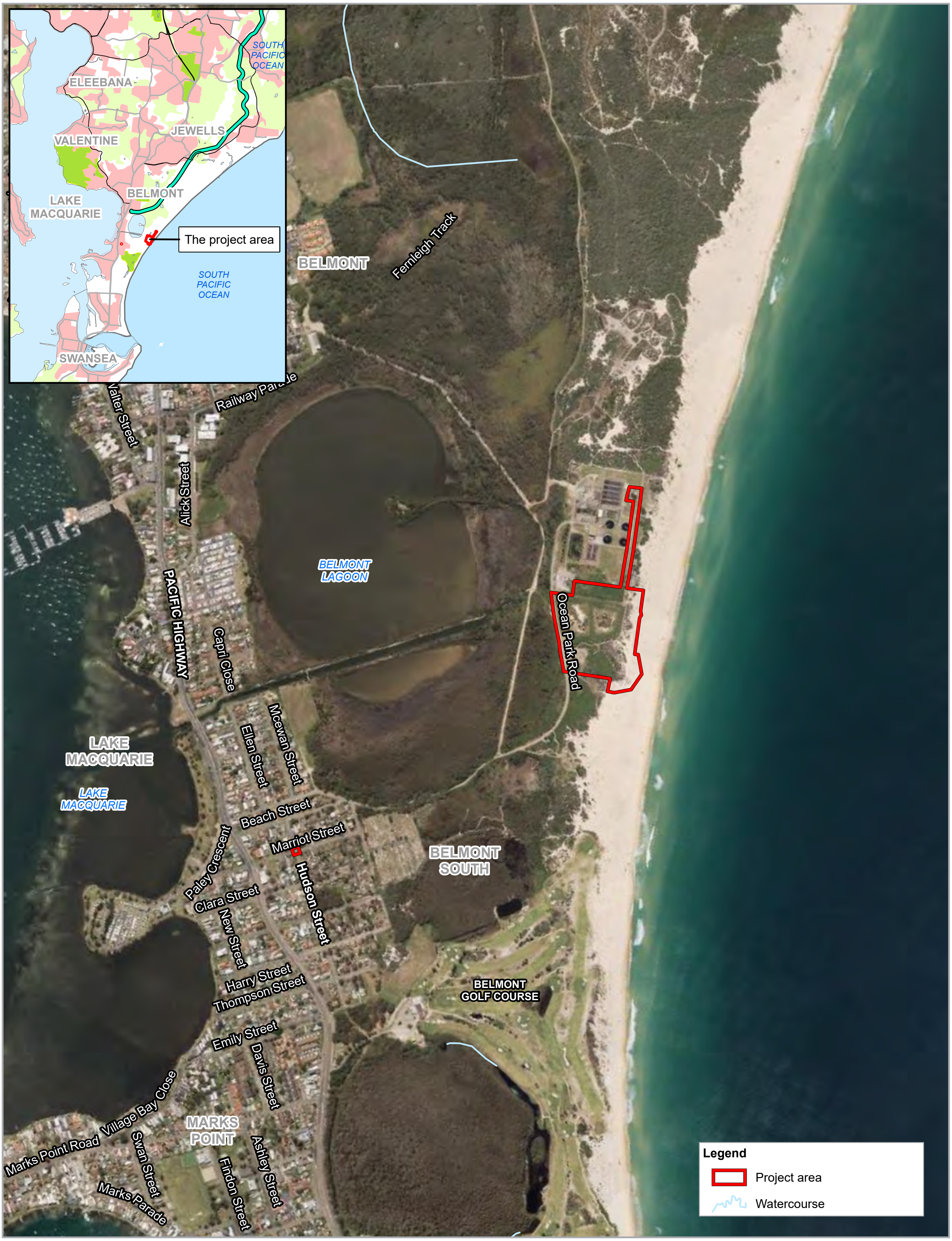
2.2 Land use and ownership

2.2.1 Land zoning

The Project would be located on Hunter Water owned land, zoned primarily SP2 – Infrastructure in the *Lake Macquarie Local Environmental Plan 2014* (Lake Macquarie LEP), within the existing Belmont WWTW site (Lot 1 DP433549). Ocean Park Road is zoned E2 – Environmental Conservation and associated with recreational land uses as well as providing access to the Belmont WWTW.

2.2.2 Land use

The drought response desalination plant would be located entirely within the boundary of the Belmont WWTW (Lot 1 of DP 433549), to the south of the existing WWTW in an area that was previously used for evaporation ponds, the embankments of which are still visible despite being decommissioned as part of previous WWTW upgrades.



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0 110 220 330 440

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

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GHD

Hunter Water Corporation
Belmont Temporary Desalination Plant
Groundwater Assessment Report

Project No. **22-19573**
Revision No. **0**
Date **16/10/2019**

Project location

FIGURE 2-1

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Print date: 16 Oct 2019 - 10:27

Data source: LPI: DTDB / DCDB, 2017; public_NSW_Imagery: . Created by: kpsroba

2.3 Project description

2.3.1 Objectives

The key objectives of the Project are to:

- Provide a rainfall independent water source in the event of an extreme drought
- Slow the depletion of existing water storages in the event of an extreme drought

The Project would address these objectives while considering the environmental, social and economic impacts, with the options assessment process considering these factors.

2.3.2 Key features

The Project is for the construction and operation of a drought response desalination plant, designed to produce up to 15 ML/day of potable water, with key components including:

- **Seawater intake** – The central intake structures would be a concrete structure (referred to as a caisson) of approximately nine to 11 metres diameter, installed to a depth up to 20 m below existing surface levels. The intake structures will be finished above the existing surface (0.5 m to 1 m) to prevent being covered by dune sands over time. The raw feed water (seawater) input is proposed to be extracted from a sub-surface saline aquifer. This would be extracted by intake pipes located approximately eight to 15 m below ground level radiating out from the central structure. Pipelines and pumps are required to transfer the seawater to the desalination plant.
- **Water treatment process plant** – The water treatment process plant would comprise a range of equipment potentially in containerised form. Services to and from the process equipment (e.g. power, communications, and raw feed water (seawater)) would comprise a mix of buried and overhead methods. The general components of the water treatment process would comprise:
  - *Pre-treatment:* a pre-treatment system is required to remove micro-organisms, sediment, and organic material from the seawater.
  - *Desalination:* a reverse osmosis (RO) desalination system made up of pressurising pumps and membranes. These would be comprised of modular components. In addition, a number of tanks and internal pipework would be required.
  - *Post treatment:* desalinated water would be treated to drinking water standards and stored prior to pumping to the potable water supply network.
- **Brine disposal system** – The desalination process would produce around 28 ML/day of wastewater, comprising predominantly brine, as well as a small amount of pre-treatment and RO membrane cleaning waste. The waste brine from the desalination process would be transferred via a pipeline to the existing nearby Belmont WWTW for disposal via the existing ocean outfall pipe.
- **Power supply** – Power requirements of the plant would be met by a minor upgrade to the existing power supply network in the vicinity of Hudson and Marriot Streets. A power line extension from the existing line along Ocean Park Road into a new substation within the proposed drought response desalination plant would also be required.
- **Ancillary facilities** – including a tank farm, chemical storage and dosing, hardstand areas, stormwater and cross drainage, access roads, and fencing, signage and lighting.

The potable water pipelines connecting the Project to the potable water network do not form part of the Project and would be constructed separately. The construction and operation of the potable water pipeline would be part of a separate design and approvals process.

3. Methodology

The groundwater assessment has been undertaken using the following approach:

- Desktop review to collate relevant climatic, geological and hydrogeological data as well as the identification of groundwater receptors (GDEs and registered groundwater supply works)
- Site investigations, including:
  - Drilling and construction of eight monitoring wells
  - Sample collection during drilling for particle size distribution (PSD) analysis
  - Conductivity profiling during drilling and post well installation
  - Geophysical surveying of the subsurface via electrical resistivity imaging (ERI) and seismic refraction
  - Long term groundwater level monitoring (September 2018 through May 2019)
  - Seven groundwater monitoring events (September 2018 through April 2019)
  - Aquifer testing (slug and pump testing)
- Development of an updated conceptual hydrogeological model based on the desktop review and field investigation
- Construction of a numerical groundwater model to predict groundwater extraction volumes and groundwater drawdown
- Groundwater impact assessment in accordance with the NSW AIP

3.1 Desktop review

Review of the following documents and databases was undertaken:

- Scientific Information for Land Owners (SILO) dataset (rainfall data)
- Geological mapping
- AECOM (2017). Temporary Desalination Project Readiness Activities Stage 1: Belmont, Conceptual Hydrogeological Model
- NSW Water Register, WaterNSW (registered bore search)
- BOM Groundwater Dependent Ecosystem Atlas

Results of the desktop review are outlined in Section 4.1.

3.2 Site investigations

The following site investigations were undertaken. Results are detailed in Section 4.2.

3.2.1 Well installations

Eight (GW101 to GW108) groundwater wells were installed by drilling contractor Total Drilling Pty Ltd using a Hanjin D&B rig and employing a combination of hollow flight auger and wash boring methods. Monitoring well locations were distributed across the site to allow cross-section development in both east-west and north-south orientations. Well locations are shown in Figure 3-1. Spatial coverage allowed:

- Three wells near the proposed intakes (GW105/BH105, GW106, GW107)
- Four wells across the plant area (GW101/BH101 to GW104/BH104)
- One well located up-gradient of the plant area (GW108)

Wells were installed vertically within the unconfined aquifer to depths ranging 20 to 30 m below ground level (BGL), above the underlying clay layer. Wells comprised 50 mm PVC blank and slotted screen casing, packing within the annulus with 5 mm specialised sand and sealing with bentonite above the sand and below the depth to water ensuring a fully saturated screen. Screen lengths ranged 15 to 25 m to allow interpretation of the freshwater/saltwater interface. All monitoring wells were secured with monuments and lockable caps.

Drilling and well installation was supervised by an experienced GHD geologist who recorded logs of each geological profile, gauged electrical conductivity from drill cuttings and took photographs of the sampled sequence. Logs are presented in GHD (2018).

3.2.2 PSD analysis

Sub-samples of drill cuttings were collected at discrete intervals at the discretion of the site geologist. Samples were submitted to a GHD testing laboratory for particle size analysis (method AS 1289.3.6.1). The testing laboratory is National Association of Testing Authorities (NATA) accredited for the method employed.

3.2.3 Conductivity profiling

Electrical conductivity was gauged during drilling to attain indicative freshwater/saltwater interfaces at each well location. These results were confirmed post installation using a downhole electrical conductivity meter and water level gauge. Profiling was conducted post stabilisation of the wells (estimated 7 day period) and prior to purging for groundwater sampling to ensure undisturbed conditions.

3.2.4 Geophysical assessment

Geophysical testing was conducted via seismic refraction and electrical resistivity imaging (ERI) methods to enable interpretation of subsurface lithology between well locations. Two orthogonal seismic refraction lines running from GW101 through GW105 and GW102 through GW104 were measured, along with a 400 m ERI transect parallel the coast (through GW105, GW106 and GW107).

Further details of the methodology are presented in Section 2.1.6 of the Geotechnical Investigation Report (GHD, 2018).

3.2.5 Groundwater level monitoring

Continuous logging down-hole pressure transducers were installed in all eight monitoring wells to capture tidal, storm and seasonal variations in groundwater levels. Transducers were installed in September 2018 and downloaded at each groundwater monitoring event. Pressure readings were calibrated to manually gauged levels taken at each monitoring event.

3.2.6 Groundwater quality monitoring

Groundwater quality sampling was conducted over seven events spanning a period of nine months (14/9/2018, 18/10/2018, 9/11/2018, 30/11/2018, 13/12/2018, 24/1/2019 and 13/5/2019). Sampling was undertaken in accordance with Australian Standard AS/NZS 5667-1998 and the National Environment Protection Council (NEPC) National Environment Protection (Assessment of Site Contamination) Measure, NEPM Amendment 2013 No. 1 (NEPC, 1999).

Paper Size ISO A4

0 20 40 60 80

Meters

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

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Belmont Temporary Desalination Plant
Groundwater Assessment Report

Groundwater monitoring well locations

Project No. 22-19573
Revision No. 0
Date 18/10/2019

FIGURE 3-1

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Data source: LPI: DTDB / DCDB, 2017; NSW DPI: Geology data, 2017. LPI_Imagery_Best: © Department of Finance, Services & Innovation 2017. Created by: TMorton

Sampling was generally conducted using low flow sampling techniques targeting the depth of the well (approximately 20 m) in order to ascertain consistency in saline conditions representative of intake water quality.

The depth of sampling is noted to be atypical for contaminated site assessments that standardly target the water table, particularly for the presence of light non-aqueous phase liquids (LNAPLs). Therefore the interpretation of any absence of these compounds is cautioned.

Each well was purged using dedicated low-density poly-ethylene (LDPE) tubing. Field groundwater quality parameters including pH, dissolved oxygen (DO), redox potential, electrical conductivity (EC) and temperature were gauged during the purging process and recorded on field data sheets. Purging continued until stabilisation was achieved (± 10%) or four (4) well volumes had been removed (whichever the earliest). Purge water was discharged to ground.

Post purging, samples were collected directly into laboratory supplied sampling containers. Samples for dissolved metals were filtered before collection (0.45 µm). Samples were stored in a cool insulated container prior and during transfer to the analysing laboratory. Disposable equipment was replaced at each sampling location. Non-disposable equipment was washed and decontaminated between use at each location.

GHD (and the analysing laboratories) undertook a number of actions, procedures, and checks to ensure the accuracy and reliability of analytical results and ensure the representativeness and integrity of samples taken and analysed. QA involves all of the actions, procedures, checks and decisions, undertaken to ensure the representativeness and integrity of samples and accuracy and reliability of analytical results (NEPC 1999). QC involves protocols to monitor and measure the effectiveness of QA procedures.

All field work was conducted with reference to the relevant standards and appropriate GHD Field Operating Procedures, which ensure collection by a set of uniform and systematic methods.

Quality control samples included the collection of duplicate control samples (inter and intra laboratory samples) at a frequency of 1:20 as per NEPM (2013). Blank samples comprised field and reinstate blanks only.

Samples were submitted to NATA accredited laboratories for the analysis required and accompanied with chain of custody documentation. The analytical suite is outlined in Table 3-1.

Table 3-1 Water quality analytical suite

Location	Analysis
GW101 to GW108	**Physicochemical parameters:** salinity (psu), total alkalinity (mg/L $CaCO_3$), total dissolved solids (mg/L), total hardness (mg/L $CaCO_3$), total suspended solids (mg/L), turbidity (NTU) **Ions** (mg/L): bicarbonate, bromide, calcium, carbonate, chloride, fluoride, magnesium, potassium, sodium, sulfate, sulfide, total cyanide **Nutrients** (µg/L): ammoniacal-nitrogen, nitrate-nitrogen, nitrite-nitrogen, total Kjeldahl nitrogen, total nitrogen, total phosphorus, reactive phosphorus **Dissolved metals** (µg/L): aluminium, iron, manganese, **Total metals** (µg/L): aluminium, arsenic, barium, boron, cadmium, chromium, copper, iron, lead, manganese, mercury, molybdenum, nickel, strontium, tin, zinc **Microbial** (CFU/100 ml): total coliforms, faecal coliforms, *enterococci*, *E.Coli.* **Other parameters** (µg/L): anionic surfactants as MBAS (mg/L), biochemical oxygen demand (day 5, mg/L), chlorophyll-a, dissolved organic carbon (mg/L), dissolved inorganic carbon (mg/L), non-ionic surfactants as CTAS (mg/L), oil and grease (mg/L), phaeophytin, polycyclic aromatic hydrocarbons (total)**,** silica, silt density index (5,10,15; %T), total organic carbon (mg/L), total trihalomethanes µg/L), (UV transmission (254 mm, Abs), total petroleum hydrocarbons (TPH), benzene, toluene, ethyl-benzene, xylenes, polycyclic aromatic hydrocarbons (PAH) suite
Quality Control Samples (inter-lab. intra-lab, field blank, rinsate blank)	**Nutrients** (µg/L): ammoniacal-nitrogen, nitrate-nitrogen, nitrite-nitrogen, total Kjeldahl nitrogen, total nitrogen, total phosphorus, reactive phosphorus **Dissolved metals** (µg/L): aluminium, iron, manganese **Total metals** (µg/L): aluminium, arsenic, barium, boron, cadmium, chromium, copper, iron, lead, manganese, mercury, molybdenum, nickel, strontium, tin, zinc

3.2.7 Aquifer testing

Estimates of sand hydraulic conductivity were obtained by conducting falling head (slug) tests and a pumping test.

Slug tests

Falling head tests were undertaken at three locations across the well network (GW101, GW103 and GW105). Falling head tests involved introducing a 'slug' of water to each well to achieve a positive head displacement. The recording interval of the down-hole pressure transducers were adjusted to produce real-time logs capturing water level displacement.

The slug comprised a known volume of clean water (20L). The process was repeated in triplicate at each location to provide confidence in the results. Water level data were interpreted using the Hvorslev solution.

Pumping test

A single pumping well was installed proximal to existing monitoring well GW105. A 315 mm borehole was drilled by drilling contractor BG Drilling using a Scout drilling rig and mud rotary drilling methods. A 219 mm OD stainless steel well with a wire-wound screen (1 mm apertures) extending the bottom 10 m was installed to a depth of 24.1 m BGL. The annulus was filled with 2 mm graded, well-rounded gravel. The well was set in concrete at surface and developed until the water ran clear. All drilling muds were contained and disposed of offsite.

Following recovery of the well, a four stage step-test was progressed using flow rates of 10 L/s, 15 L/s, 20 L/s and 22.5 L/s. The pump was set in the upper portion of the screen (approximately 14 m BGL).

Flow rates were recorded continuously throughout pumping to monitor for variation. Water levels, temperature and conductivity in the pumping well were monitored in real-time via a vented, down-hole pressure transducer. On completion of the flow rate steps, data logging continued until the water level in the pumping bore recovered by a minimum of 90%.

Drawdown data were reviewed and an optimal pumping rate for the constant rate test was selected. A constant rate test (CRT) was conducted overnight (21 hours and 30 minutes) at a flow rate of 20 L/s. During this time, water levels in the pumping well were again monitored in real-time via a vented, down-hole pressure transducer. On completion of the flow rate steps, data logging continued until the water level in the pumping bore recovered by a minimum of 90%. An additional test at 30 L/s was attempted by lowering the pump to approximately 21 m BGL. This test lasted less than 3 hrs.

The existing monitoring well network was relied upon as observation points. The pressure transducers in each of the eight onsite monitoring wells were set to record drawdown impacts beyond the pumping well.

Water levels in the pumping well and observation wells were assessed using Aqtesolv © software.

3.3 Groundwater model

A conceptual groundwater model was developed from the review and collation of groundwater investigation data. The conceptual model is presented in Section 4.3 and formed the basis for numerical model construction.

The numerical groundwater model was used to predict:

- Inflows into the proposed intake structure and the source (either seawater or groundwater)
- Drawdown in groundwater sources
- Approximate recovery times in groundwater levels

An overview of the construction and results of the numerical modelling is provided in Section 5.

3.4 Impact assessment

The NSW AIP requires that potential impacts on the groundwater sources, including their users and GDEs, be assessed against minimal impact considerations, outlined in Table 1 of the Policy. If the predicted impacts are less than the minimal impact considerations, then these impacts will be considered as acceptable. The Level 1 minimal impact considerations that have been adopted for this groundwater impact assessment and are outlined in Section 1.4.2 and the impact assessment for the Project is detailed in Section 6.

4. Desktop review and site investigations

4.1 Desktop review

4.1.1 Climate

Rainfall data for Belmont was derived from the Scientific Information for Land Owners (SILO) dataset (https://www.longpaddock.qld.gov.au/silo/point-data/), and covers the period of January 1889 to August 2019. The closest weather station to the Project area is the Rathmines Amo weather station (Station number 61063) and is located approximately 10 km west of the Belmont Lagoon.

The region experiences an annual average rainfall of 1,165.6 mm. Figure 4-1 illustrates the annual rainfall anomaly from 1889 to 2018 compared to this average annual rainfall. Over this period, the year of 1944 experienced the lowest annual rainfall total (578.1 mm) while the year of 1980 experienced a low of 671.4 mm. The two highest annual recordings occurred in 1950 (2015.4 mm) and in 1990 (1972.5 mm).

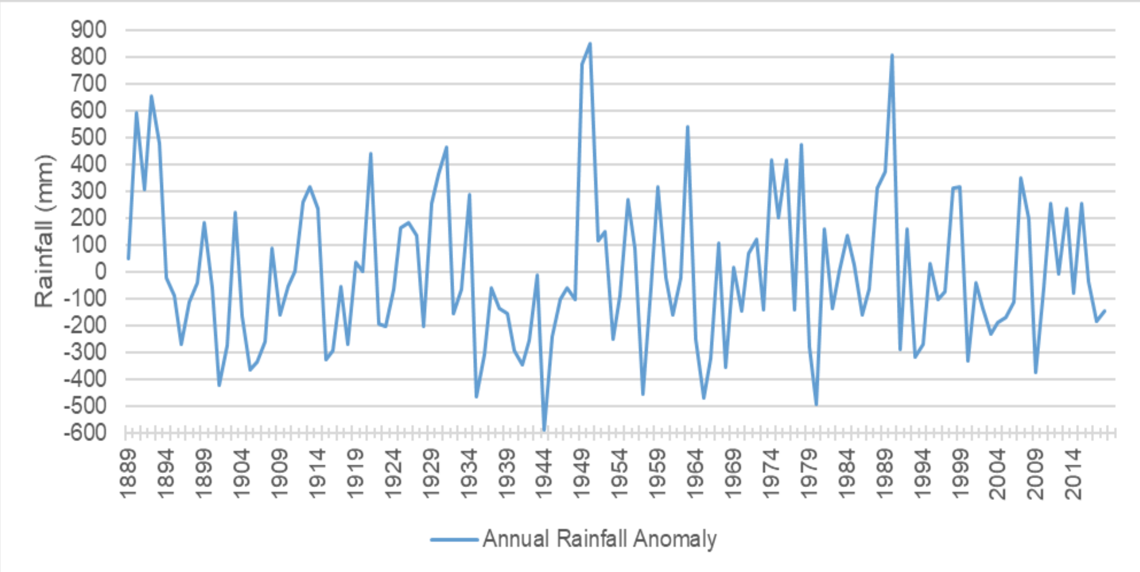


Figure 4-1 Annual rainfall anomaly – 1889 to 2018

The highest monthly average rainfall occurs in March (133.8 mm) while the lowest average monthly rainfall occurs during August (67.7 mm). Based on data from Station 61063, evaporation is highest during December (monthly average 191.7 mm) and lowest during June (monthly average 57.6 mm).

4.1.2 Previous reports

AECOM (2017) describes the hydrogeology at the site as comprising an unconfined aquifer within the Quaternary aged sands overlying Permian aged sandstone (bedrock). The water table is stated to lie within the sand unit at approximately 4 m below ground level (BGL) and groundwater flow is expected to be to the east. Localised westward flow is hypothesised proximal to connected surface waters such as Belmont Lagoon. The thickness of the aquifer is stated to range 15 m to 40 m, and expected to thin significantly at the coast. Hydraulic conductivity is estimated to be high, with yields greater than 20 L/s.

The water quality within the upper portion of the sand aquifer is described by SKM (2012) as ranging from slightly acidic to neutral and fresh to marginal (600 to 1000 µS/cm). Shallow groundwater is also reported to contain elevated levels of nitrogen and phosphorus, as well as the metals copper, nickel and zinc, but not spatially consistent. Water quality throughout the vertical profile had not been assessed. Salinity is expected to increase with depth.

4.1.3 Geological maps

Reference to both the regional geological and coastal Quaternary geology maps indicates that the desalination plant site is underlain by medium to fine grained dune and marine sand, disturbed by fill and excavation works related to the construction of the Belmont WWTW.

The surface geology map in Figure 4-2, sourced from the Newcastle Coalfield Regional Geology 1:100 000 map (Hawley et al, 1995), shows the extensive sand deposit in the vicinity of the Project area.

4.1.4 Registered groundwater bores

An examination of the online WaterNSW register (conducted September 2019) identified 73 registered groundwater bores within 5 km of the Project area (https://realtimedata.waternsw.com.au/). Available bore details are tabulated in Appendix A. Bore locations are shown in Figure 4-3.

The majority of registered bores are located to the southwest of the Project area throughout Belmont South and Swansea. The closest bore to the Project area (GW054897) is located approximately 1 km to the west on the western side of Belmont Lagoon.

Most bores are shallow (less than 7 m depth). Usage data is limited, although it is assumed most are used for domestic and irrigation purposes. Only one bore is listed as ‘abandoned’, although the status of many is ‘unknown’. The existing monitoring wells were not identified in the search.

4.1.5 Groundwater dependent ecosystems

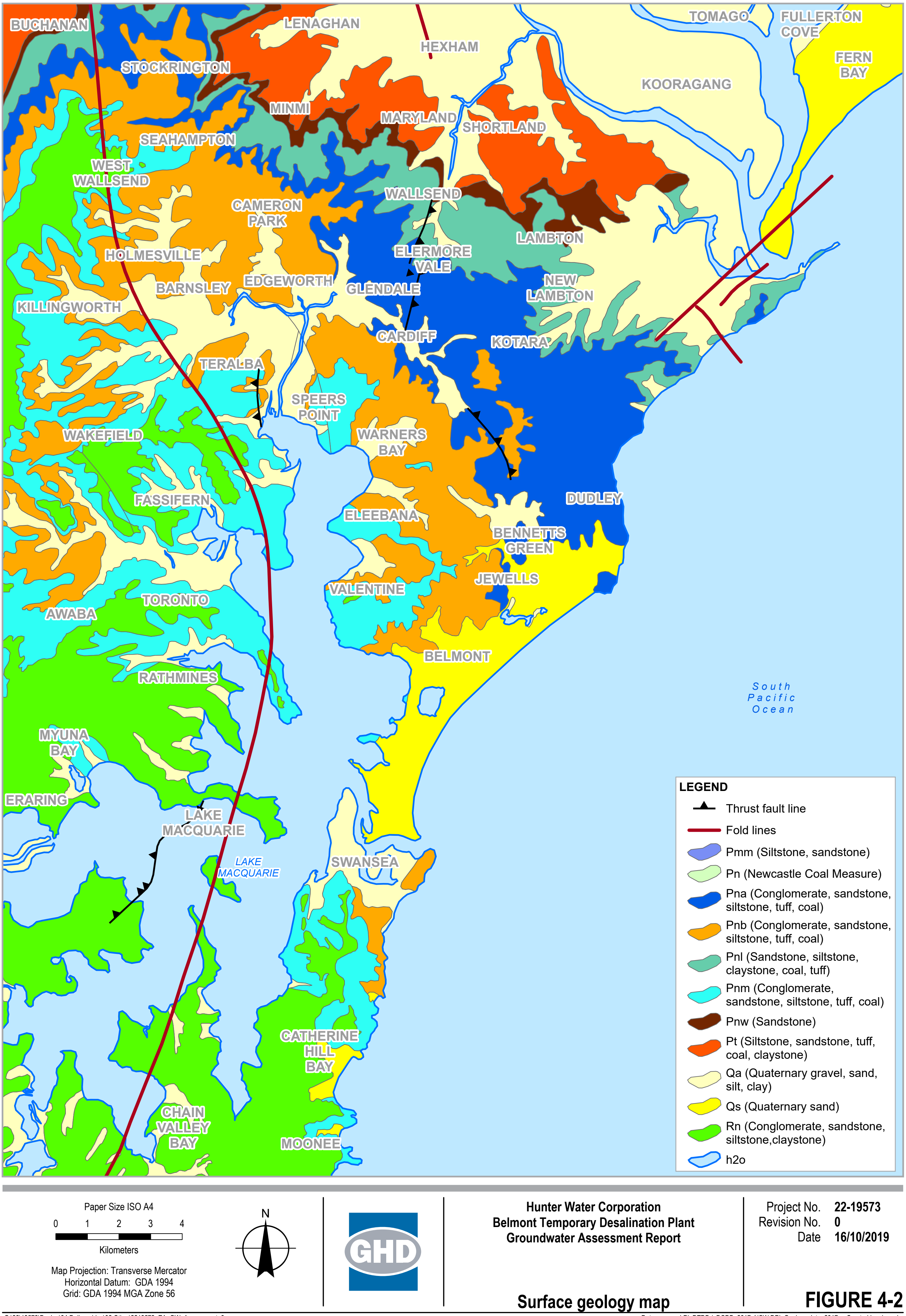
A search of the Groundwater Dependent Ecosystems Atlas (BOM, 2018) was undertaken as part of the Biodiversity Development Assessment Report for the Project (GHD, 2019). Results of the search are presented in Figure 4-4.

An aquatic GDE (known as Belmont Lagoon Swamps) is mapped to the west of the Project area. An aquatic GDE relies on the surface expression of groundwater. It is listed as a High Priority GDE for the Hawkesbury to Hunter Coastal Sands Groundwater Source. The boundary of this High Priority GDE is located less than 400 m from the intake structures at its closest point. It is noted that the High Priority GDE excludes the mangroves, saltmarsh, seagrass and saline waterway components of the Belmont Lagoon Swamps.

In addition, a high potential terrestrial GDE is mapped on the seaward side of the foredunes. A terrestrial GDE interacts with the subsurface presence of groundwater. As outlined in GHD (2019), the associated vegetation that the Atlas identifies as being a high potential terrestrial GDE is PCT 1644 Coast Tea Tree – Old Man Banksia coastal shrubland on foredunes of the Central and lower North Coast.

4.1.6 Acid sulfate soils

GHD (2018) reports that the beach area in the vicinity of the desalination plant site is mapped as low Acid Sulfate Soil (ASS) risk on the Acid Sulfate Soil Risk Map. Higher ASS risk areas are located to the west of the site towards Belmont Lagoon.



Hunter Water Corporation
Belmont Temporary Desalination Plant
Groundwater Assessment Report

Surface geology map

Project No.	22-19573
Revision No.	0
Date	16/10/2019

FIGURE 4-2

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Print date: 16 Oct 2019 - 10:25

Data source: LPI: DTDB / DCDB, 2017; NSW DPI: Geology data, 2017. . Created by: kpsroba

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0 0.4 0.8 1.2 1.6

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

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Groundwater Assessment Report

Registered Groundwater Bores

Project No. 22-19573
Revision No. 0
Date 16/10/2019

FIGURE 4-3

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Data source: LPI: DTDB / DCDB, 2017; NSW DPI: Geology data, 2017. LPI_Imagery_Best: © Department of Finance, Services & Innovation 2017. Created by: kpsroba

Paper Size ISO A4

0 0.1 0.2 0.3 0.4

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

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Groundwater Assessment Report

High potential GDEs mapped by the Groundwater Dependent Ecosystems Atlas

Project No. 22-19573
Revision No. 0
Date 16/10/2019

FIGURE 4-4

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Data source: LPI: DTDB / DCDB, 2017; NSW DPI: Geology data, 2017. sixmaps/LPI_Imagery_Best: © Department of Finance, Services & Innovation 2017. Created by: kpsroba

4.2 Site investigation results

4.2.1 Drilling investigations

Drilling investigations confirmed a geological sequence of sand thinning eastwards overlying an extensive clay unit. No basement rock was encountered. Lithology varied from west to east between the inland and coastal (GW105-GW107) boreholes. Inland boreholes (GW101-GW104 and GW108) indicated the following general sequence:

- Presence of top soil to a maximum of 0.2 m BGL however generally absent
- Spatially inconsistent fill ranging up to 1.3 m BGL
- Aeolian sand and silty sand up to 0.9 m thick.
- Alluvial sand and silty sand to a depth of 31 m BGL
- Clay extending beyond 41 m BGL

Coastal boreholes (GW105-GW107) indicated the following general sequence:

- Aeolian sand and silty sand up to 20.5 m BGL
- Clay extending beyond 20.5 m BGL

4.2.2 PSD analysis

PSD analysis was undertaken using samples from GW105, GW106 and GW107. The analysis confirmed an increasing fines fraction beyond 20 m BGL. Above this depth, particle proportions are dominated by medium grained sand sized fractions. The general size proportions ranging as follows:

- Fine grained (<300 µm) - 5 to 30 %
- Medium grained (300-600 µm) - 50 to 70%
- Coarse grained (>600 µm) – 10 to 45%

Hydraulic conductivity was estimated from the PSD analysis using the Hazen (1892) formula. Results are shown in Table 4-1. Hydraulic conductivity of the sand, based on PSD curves, is approximately 0.00026 m/s (22 m/day).

Table 4-1 K estimates from PSD curves

Borehole	Depth (m)	Description	K (m/s)
GW105/BH105	7.00 - 7.45	SAND: yellow/brown	2.9×10^{-4}
GW105/BH105	16.00 - 16.45	SAND: yellow	1.3×10^{-3}
GW106/BH106	5.50 - 5.95	SAND: with silt yellow with grey	2.6×10^{-4}
GW106/BH106	10.00 - 10.45	SAND: mottled grey/yellow/brown	2.7×10^{-4}
GW107/BH107	7.00 - 7.45	SAND: yellow/brown	2.6×10^{-4}

4.2.3 Conductivity profiling

Electrical conductivity (EC) profiling indicated the presence of a notable fresher (0 – 10,000 µS/cm) body averaging a thickness of approximately 10 m varying spatially and thinning towards the east.

The transition to saline conditions occurs via a mixing zone (10,000 – 50,000 µS/cm) of approximately 5 m thickness. Saline water (> 50,000 µS/cm) extends to the base of the aquifer ranging approximately 30 m BGL in the west and thinning to approximately 10 m BGL at the coast.

Conductivity profiling conducted at monitoring well GW102 identified the freshwater/saltwater interface to occur between -9 and -10 m AHD with a distinct shift from brackish (< 10,000 µS/cm) to saline (>30,000 µS/cm) conditions.

4.2.4 Geophysical investigations

Geophysical investigations confirmed overlying sands to extend approximately 30 m depth thinning to less than 15 m upwards and eastward. The underlying clay was interpreted to be more than 30 m thick (extending beyond 60 m BGL) central to the site while also thinning upwards to the east to less than 5 m thickness. Basement rock is inferred beyond these depths but was not determined.

Groundwater was inferred to lie 1 to 5 m BGL with an upper freshwater region ranging approximately 2 to 15 m thick above a lower saline region ranging approximately 3 to 30 m thickness. The freshwater/saltwater interface is observed to be highly variable occurring between approximately -2 to -10 m AHD. The interface becomes increasingly shallow as the aquifer thins eastwards.

4.2.5 Groundwater level monitoring

Based on continuous groundwater level monitoring of wells GW101 – GW108 between September 2018 and May 2019, the water table is shallow with elevation ranging from approximately 0.3 to 1.2 m AHD across these sites. The average groundwater levels throughout this monitoring period at each well are plotted as groundwater contours in Figure 4-5. It is noted that there is a slight anomaly in the groundwater level at GW103 (groundwater is 0.05 – 0.1 m lower in elevation than would be expected from the contours). This may be attributable to a minor inaccuracy in the survey at this point. Groundwater flow in the vicinity of the Project area is generally from east to west as shown in Figure 4-5. Continuous monitoring data is shown in Figure 4-6.

Temporal variation in levels is relatively small (approximately 0.5 m) due to the close proximity to the ocean, and occur as a result of tidal variation and rainfall recharge. Tidal effects decrease with distance from the coast and have been most notable at GW107 with fluctuations ranging approximately 10 cm. Conversely, rainfall response is most notable for inland wells and decreases towards the coast. Inland wells (GW101, GW102, GW103, GW104 and GW108) respond more rapidly than coastal wells (GW105, GW106 and GW107). Increased groundwater levels dissipate gradually over days.

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

GHD

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Average observed groundwater contours

Project No. 22-19573
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Date 18/10/2019

FIGURE 4-5

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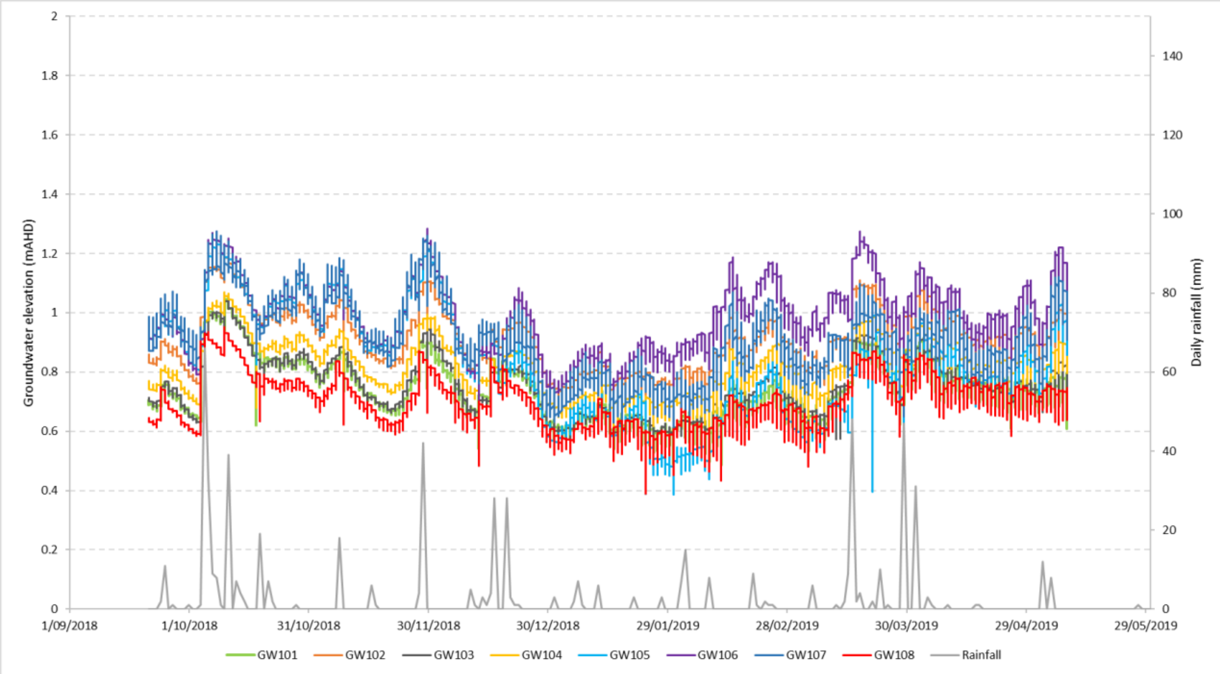


Figure 4-6 Continuous groundwater level data

4.2.6 Groundwater quality monitoring

Based on sampling results from GW101 – GW108, groundwater is near neutral (pH 7 – 8), saline at depth (approximately 50,000 - 60,000 µS/cm) and of Na-Cl type. Dissolved oxygen levels are less than 6.5 mg/L and the redox state is generally oxidative. Metal, organic and pathogen concentrations are low at depth but vary in concentration in the upper part of the aquifer.

Groundwater contained low levels of ammonia (<1 mg/L), nitrate (<2 mg/L), phosphorus (<2 mg/L) and dissolved organic carbon (DOC), ranging below limit of reporting (LOR) to 4 mg/L. Dissolved metals concentrations were generally below LOR however it is noted reporting limits for cadmium, copper, lead, nickel and zinc exceed marine water assessment criteria. Total recoverable hydrocarbon (TRH) and polycyclic aromatic hydrocarbon (PAH) concentrations were all below LOR. Volatile hydrocarbon concentrations (benzene, toluene, ethylbenzene and xylenes) were generally below LOR with exception of minor detections attributable to the sampling apparatus used to enable sampling from depth.

Biological population counts are highly dependent on sampling depth and methods, generally being lower (even below detection) at depth and when sampled with low flow techniques.

Faecal coliform and *Escherichia coli* (*E. coli*) bacteria counts generally approximated 1 CFU/100 ml with occasional exceptions. Total coliform counts ranged below detection to 250,000 CFU/100 ml, being highest in the first groundwater monitoring event. *Enterococci* bacteria counts were generally low in all wells with the exception of GW104 with populations consistently above LOR ranging 10 to 9000 CFU/100 ml.

4.2.7 Aquifer testing

Slug tests

Analysis of falling head tests undertaken at GW101, GW103 and GW105 (three tests at each site) using the Hvorslev method indicates a sand hydraulic conductivity ranging from 1.3×10^{-4} to 3.9×10^{-4} m/s (approximately 11 to 34 m/day). Interpretation of results was difficult due to small displacements and rapidly falling water levels.

Pumping test

Analysis of the four stage step-test (flow rates of 10 L/s, 15 L/s, 20 L/s and 22.5 L/s) using the Theis solution indicates a transmissivity of 380 m^2/day. Based on an aquifer thickness of 30 m, this equates to a hydraulic conductivity of approximately 13 m/day. It should be noted that this solution assumes confined conditions which does not match the conceptualisation of the system.

Analysis of the response in monitoring bore GW105 during the constant rate test using the Neuman solution provided a reasonable match to observation data but only during the first 5 hours of the test. This analysis indicates a much higher transmissivity of 1,364 m^2/day and lower than expected specific yield of 0.06 – 0.07.

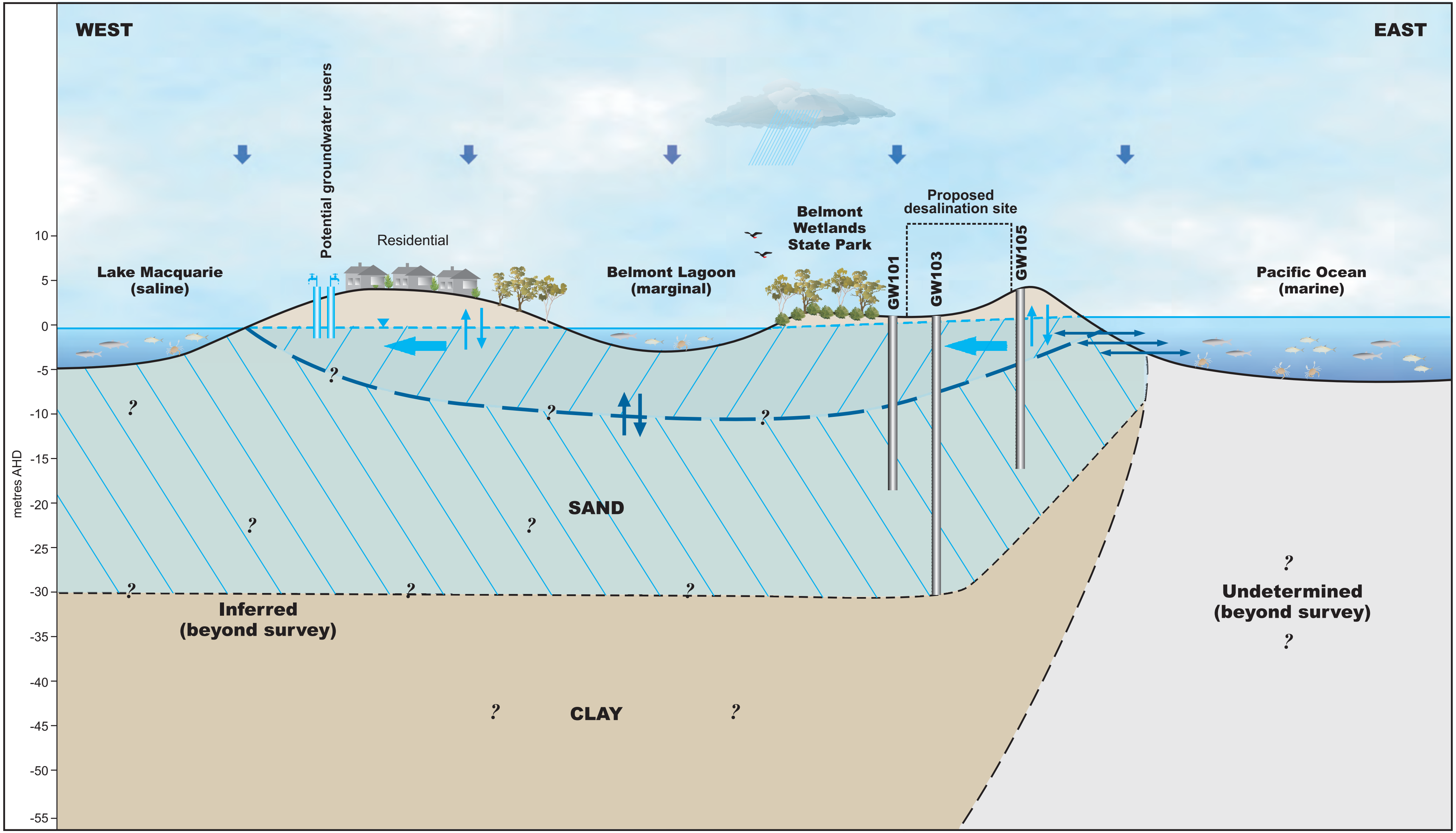
4.3 Updated conceptual hydrogeological model

The conceptualisation presented in AECOM (2017) has been further developed and updated as part of this groundwater assessment, using findings from the desktop study and site investigations. The updated conceptual hydrogeological model is presented in Figure 4-7. The sand unit forms an unconfined aquifer with recharge from rainfall and connection (flow in and flow out) with the Pacific Ocean to the east and Belmont Lagoon to the west. The aquifer is density stratified with significant freshwater storage within the upper 10 m of the aquifer. Saline conditions extend to a maximum of 20 m thickness and thin to the east.

Based on groundwater level observations, the groundwater flow direction is east to west. This is consistent with the head difference between the ocean (recorded ocean tidal levels are outlined in Section 5.2.3) and levels recorded in Lake Macquarie at Belmont (MHL, 2019) which indicate a gradient of approximately 0.9 m on average between the Ocean and the Lake. Recorded groundwater elevations in coastal wells (GW105, GW106 and GW107) generally reflect ocean tidal levels. During wet periods, there may be some minor freshwater mounding in the vicinity of the site and a small hydraulic gradient from the coastal wells to the ocean.

Groundwater level monitoring undertaken by SKM (2012) at the Belmont Waste Water Treatment Works also suggests east to west groundwater flow in this area.

Belmont Lagoon is connected to Lake Macquarie via Cold Tea Creek, which was constructed in the 1940s, and altered the hydrology and water quality of the Lagoon. (Andrews Neil Pty Ltd, 2010). As such, it is assumed that the water level in Belmont Lagoon equals the water level in Lake Macquarie at Belmont.



Conceptual diagram only - scale is approximate

LEGEND

- Groundwater level
- Fresh water
- Saline water
- Groundwater flow direction
- Rainfall recharge
- Direct tidal connection
- Recharge
- Screened well
- Potential abstraction bore
- FW/SW interface
- ? Inferred data

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Job Number | 22-19573
Revision | A
Date | 1 Oct 2019

Conceptual Hydrogeological Model

Figure 4-7

Level 3, 24 Honeysuckle Drive Newcastle NSW 2300 T 61 2 4979 9999 F 61 2 4979 9988 E ntlmail@ghd.com.au W www.ghd.com

AU\Launceston\Projects\22\19573\2219573_LTN_02.cdr

5. Numerical groundwater model

The numerical groundwater flow model has been developed based on the updated conceptual model presented in Section 4.3 and with reference to the Australian Groundwater Modelling Guidelines (Barnett et al, 2012). The model is considered to generally have the characteristics of class 2 confidence level (i.e. moderate confidence), in accordance with the confidence level classification within the Guidelines.

Numerical modelling was undertaken using the MODFLOW-NWT solver with the Upstream Weighting flow package. MODFLOW-NWT is a version of MODFLOW 2005 that provides a different formulation of the groundwater flow equation (Newton formulation) designed to solve models that are non-linear due to unconfined cells or non-linear boundary conditions. MODFLOW 2005 is a three-dimensional finite-difference groundwater flow model from the United States Geological Survey and is one of the industry-standard codes for numerical groundwater modelling. The Groundwater Modelling System (GMS) graphical user interface (version 10.4) was used to construct and run the model.

Variable density groundwater flow modelling using SEAWAT coupled with MODFLOW and MT3DMS was also considered for this groundwater assessment. After undertaking preliminary modelling runs using this software, it was considered that the modelling effort required was excessive and not necessary in order to meet the model objectives (Section 3.3). It was considered adequate to use the MODFLOW flow budget to estimate the proportion of seawater take by calculating the inflow from the ocean as a proportion to total inflow to the system.

A numerical groundwater model is a mathematical representation of a complex natural environment where parameters and processes can only be inferred from a finite number of measurements. Simplifications and assumptions are necessary in modelling. Efforts have been made to provide clarity on the data used to support the modelling and associated limitations. Findings presented in this report should be considered in this context.

5.1 Model construction

This section describes the geometry of the model grid, the geological structure and boundary conditions.

5.1.1 Grid and model dimensions

A model grid of dimensions 1,400 × 1,100 × 50 m (Length × Width × Height) was created with the intake structure offset from the centre, as shown in

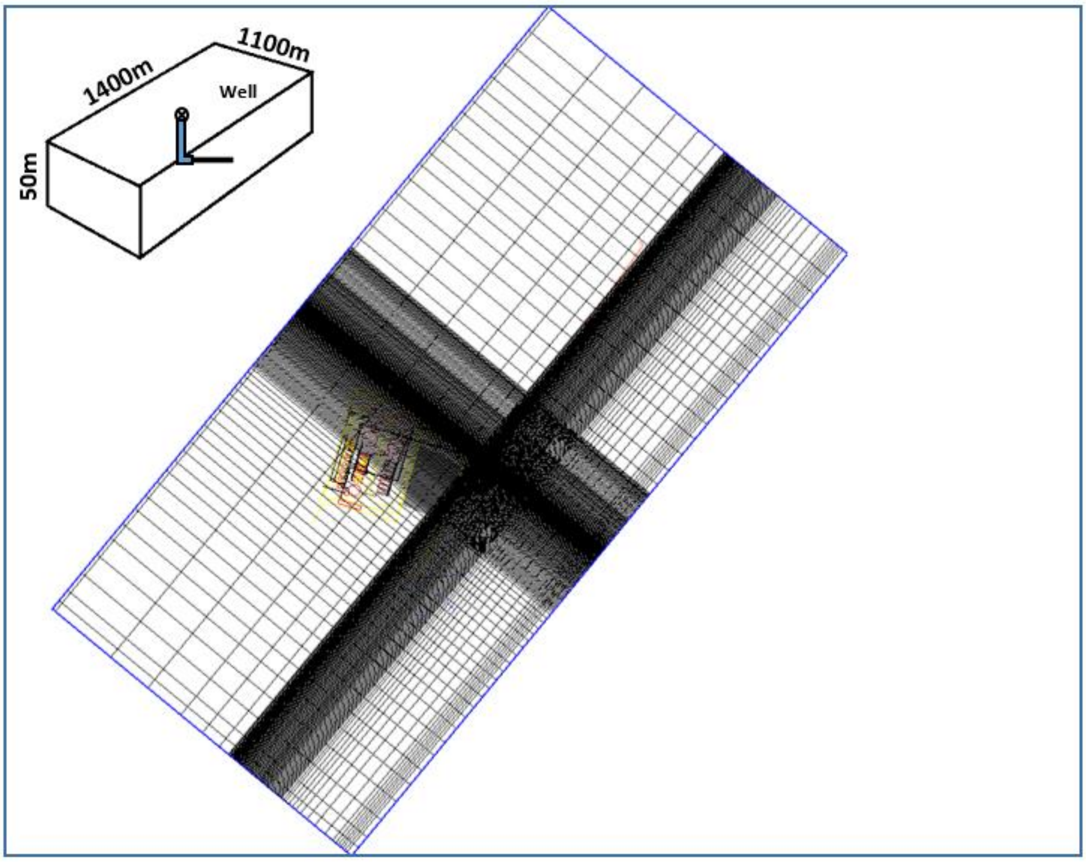

Figure 5-1. To design the multiple angular arrangement of horizontal pipes (arms) of the intake structure and provide more detailed adjustment of element properties around the intake, a non-uniform grid cell size was produced with cell size refined close to the intake to 0.6 m to represent the horizontal well dimensions.

The model domain is defined by hydrogeological and geological boundaries in the area. The model covers a total area of 154 hectares with Belmont Wetlands State Park to the northwest and Pacific Ocean to the southeast as shown in Figure 5-2. These dimensions for the domain were defined to be large enough to show the area of influence around the intake structure while preventing any boundary effects on model predictions.

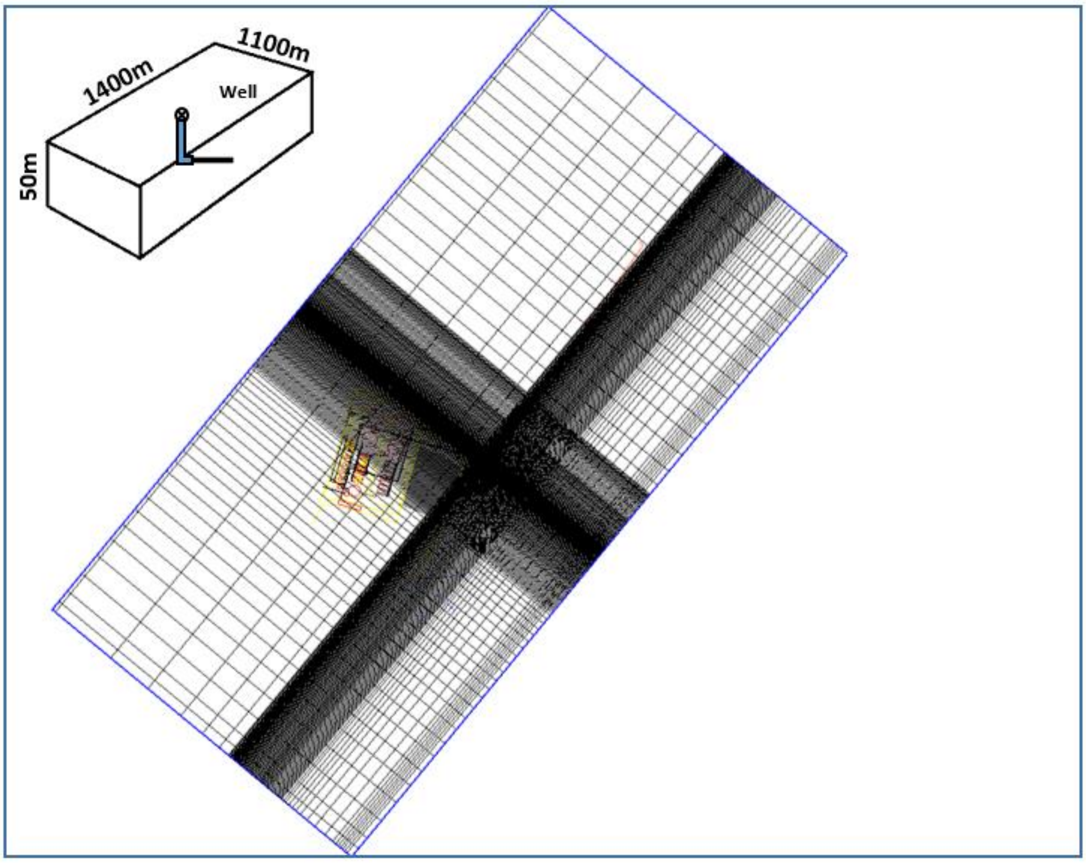

Figure 5-1 Model grid and dimensions

5.1.2 Geological structure

As outlined in Section 4, the underlying geology consists of unconsolidated sediments consisting mainly of sand and clays. Geotechnical reports and available bore logs were used to build the geological structure of the model in GMS. Based on this available data, two materials (sand and clay) were defined throughout the model layers. Clay is located at depths generally greater than 25 m, although this reduces towards the ocean as shown in Figure 5-3.

5.1.3 Boundary conditions

A time-variable specified head (CHD) boundary was set along the north-western boundary of the model to represent flow between the Project area and Belmont Lagoon to the west. This boundary is generally an outflow boundary under existing conditions (due to the east to west groundwater flow gradient), however becomes a potential inflow boundary as a result of groundwater extraction. The head elevation along this boundary was set at 0.1 m, which represents a typical water level in Lake Macquarie at Belmont based on data from MHL (2019).

A time-variable specified head (CHD) boundary was set along the ocean side of the model to define the tidal boundary condition. The north and south boundaries of the model were defined as no-flow boundaries as they are located in parallel to the groundwater flow direction. The top surface boundary was defined as a specified flux condition from infiltration of precipitation and the bottom of the model was treated as a no-flow boundary condition.

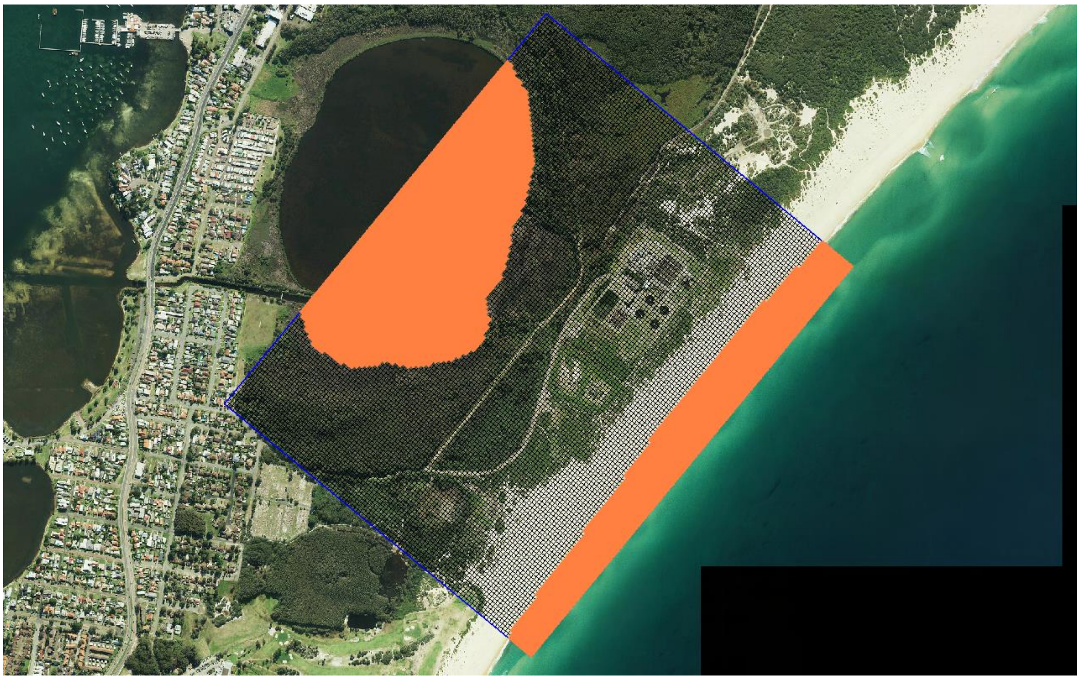

Figure 5-2 Model area

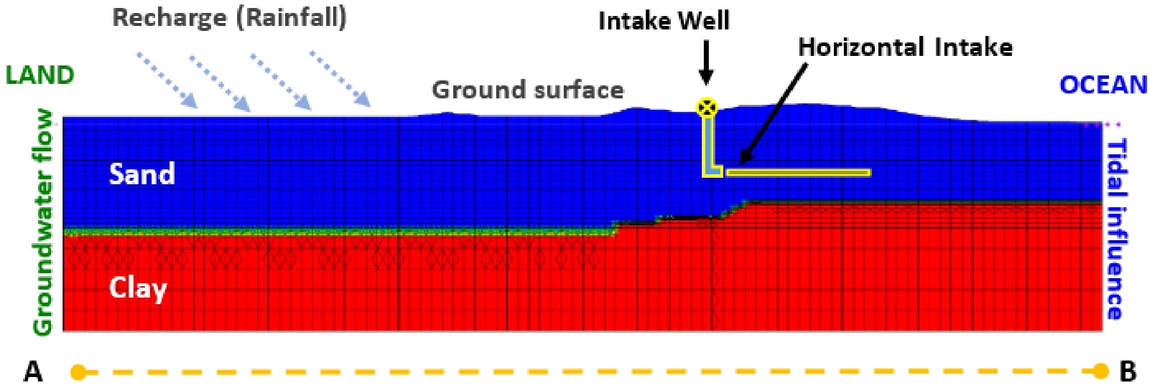

Figure 5-3 Geological structure

5.1.4 Intake well design

The intake was designed in the model using three horizontal subsurface arm arrangements as shown in Figure 5-4. The arms were designed horizontally and extending 80 m in the direction of the ocean boundary with the objective of maximising the seawater inflow compared to fresher groundwater. The first arrangement of three perpendicular arms was implemented as a preliminary model run for the purpose of analysing parameter sensitivity and is not a focus of the modelling assessment.

As shown in Figure 5-4 the concept design includes two intake structures, however only one was modelled in MODFLOW. Due to the grid refinement required around the intake structures, it was more practical to only model one intake to allow for a more timely assessment of arrangement options. It was considered adequate to assess the groundwater impacts from two intakes conceptually rather than numerically, as detailed in Section 5.4.3.

The horizontal arms were represented in the model by defining a series of drain cells along each arm at the proposed elevation. It was found that drain cells provided better model stability in this case compared to well cells.

(a) (b) (c)

Figure 5-4 Intake design: a) three perpendicular; b) three diagonal; c) five diagonal and perpendicular

5.2 Model input parameters

5.2.1 Material properties

Hydraulic conductivity estimates for the sand aquifer are presented in Section 4.2 and are based on PSD analysis, slug (falling head) tests and a pumping test. Estimates range from 11 m/day to over 30 m/day. This range of hydraulic conductivity values was tested during the model calibration and sensitivity analysis phase. Due to the lack of information regarding the clay material, a larger range of hydraulic conductivity was adopted (0.00001 to 0.01 m/day).

A much higher hydraulic conductivity was selected to represent the horizontal intake arms (864 m/day) in order to ensure flow towards the horizontal intake arms during extraction. The hydraulic value ranges for the degree of anisotropy, Kh/Kv (less than 10), specific yield (0.05 to 0.2) and porosity (0.25 to 0.4) were selected from typical ranges in literature (Morris and Johnson, 1967; Domenico and Mifflin, 1965; Batu, 1998).

5.2.2 Rainfall recharge

A uniform net recharge rate was assigned across the model domain to represent the combined effects of rainfall and evaporation. A recharge rate of 1×10^{-8} m/s, equivalent to approximately 25% average annual rainfall of 1166 mm (Section 4.1.1), was applied to represent normal (non-drought) conditions. For the drought condition, a recharge rate of 4×10^{-9} m/s was applied, equivalent to approximately 25% of the average rainfall recorded in the year 1980.

5.2.3 Tidal influence

A time-variant boundary condition was applied along the ocean side to simulate the tidal influence. For the transient condition, six hourly tidal data from the Swansea station located in the south-west of the model domain was obtained from WWW Tide/Current Predictor (http://tbone.biol.sc.edu/tide) and applied to each CHD cell in the model. It is important to note that adding only a vertical boundary condition along the ocean will result in a sloping sea surface and would not represent the flat surface of the sea (Brovelli et al., 2007). As such, the shape of the tidal boundary was defined as an inverted **L** to represent the free surface water at the ocean. A high conductance was applied to the boundary condition (approximately 50 times higher than the sand hydraulic conductivity) to prevent restriction of flow into and out of the model.

5.2.4 Drains

Drain cells were defined with an elevation of -14 m AHD. When the groundwater level is above the drain elevation there is flow into the drains whereas there is no flow into drains when the groundwater level is below the drain elevation. A conductance value relative to the hydraulic conductivity of the aquifer material and dimensions of the horizontal arms was applied to each drain cell.

5.2.5 Starting head (Initial condition)

The starting head for each cell for the steady state run was estimated from groundwater level monitoring data (Section 4.2.5).

5.3 Model sensitivity analysis

Minimal calibration effort was considered appropriate due to the limited observation data available, the minimal spatial and temporal variation in observed groundwater levels and limited stress (groundwater extraction) data. It was considered to be more appropriate to focus effort on a sensitivity analysis of input parameters.

The model was first run under steady-state conditions (with no groundwater extraction from the intake structure) to determine the starting head for the transient runs. Some manual calibration of the model parameters (primarily hydraulic conductivities, recharge and boundary conditions heads) was conducted under steady-state flow conditions to achieve a reasonable fit with the observed groundwater levels.

A comparison between observed and modelled groundwater levels under existing flow conditions (i.e. no groundwater extraction) is shown in Figure 5-5. Both modelled and observed contours show an east to west groundwater flow direction across the site.

For the transient condition, the model was run for 20 years with yearly time steps and comprised of 10 years average rainfall (non-drought) conditions followed by 4 years of drought conditions (which comprised of 2 years with no groundwater extraction then two continuous years of extraction via the horizontal wells) and six years of recovery under average rainfall conditions and no groundwater extraction. The last year of the transient model run was defined as recovery time.

A sensitivity analysis was carried out to determine the degree of sensitivity of model output to changes in certain parameters. The sensitivity analysis demonstrated that the model is very sensitive to changes in hydraulic conductivity of the sand as well as the degree of anisotropy of the sand (Kh/Kv).

Paper Size ISO A4

0 10 20 30 40

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

GHD

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Groundwater Assessment Report

Observed and modelled groundwater contours (metres AHD)

Project No. 22-19573
Revision No. 0
Date 18/10/2019

FIGURE 5-5

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Print date: 18 Oct 2019 - 16:38

Data source: LPI: DTDB / DCDB, 2017; public_NSW_Imagery: . Created by: TMorton

5.4 Model predictions

5.4.1 Scenarios

Following steady state calibration and sensitivity analysis, the 15 year transient model was run under two predictive scenarios:

- One five arm diagonal and perpendicular intake operating for two years under drought conditions (Scenario 1)
- One three arm diagonal intake operating for two years under drought conditions (Scenario 2)

5.4.2 Uncertainty analysis

The uncertainty analysis for each scenario involved four model runs with changes made to the most sensitive parameters. Values set for sensitive parameters for each uncertainty analysis run are shown in Table 5-1 and are based on a range of values that represent typical values as well as values obtained from site investigations (Section 4.2).

Table 5-1 Input parameters for uncertainty analysis runs

Uncertainty analysis	Aquifer hydraulic parameters
Run 1	Sand HC= 20 m/day (0.00023 m/sec)
	Vertical anisotropy (Kh/Kv) = 1
Run 2	Sand HC = 20 m/day (0.00023 m/sec)
	Vertical anisotropy (Kh/Kv) = 5
Run 3	Sand HC = 10 m/day (0.00012 m/sec)
	Vertical anisotropy (Kh/Kv) = 5
Run 4	Sand HC = 10 m/day (0.00012 m/sec)
	Vertical anisotropy (Kh/Kv) = 1

The key input parameters that remained unchanged for each uncertainty analysis run are as follows:

- Clay hydraulic conductivity (1 x 10^{-7} m/s)
- Hydraulic conductivity of the horizontal arms (0.01 m/s)
- Sand specific yield (0.2)
- Sand porosity (0.3)
- Rainfall recharge as defined in Section 5.2.2

5.4.3 Results

The predicted yields for each scenario and uncertainty analysis run are outlined in Table 5-2. The model indicates that yields from one three arm intake are predicted to range from approximately 5.0 to 10.5 ML/day. One five arm intake is predicted to yield 6.3 to 13.0 ML/day.

Two identical intake structures operating simultaneously was not modelled in MODFLOW as discussed in Section 5.1.4, however an estimate of the yield and drawdown from two intakes was made based on the predictions from the numerical model and the conceptual understanding of the system. Under a two intake design, the structures are located only about 200 m apart (between caissons). Based on the radius of drawdown predicted for one intake, it is considered that the intakes should be at least twice this distance apart to minimise interference during extraction. Assuming a simple linear relationship between combined yield from two intakes and distance between two intakes, it is considered that a reasonable estimate of the combined yield from two intakes is 1.5 times the yield of one intake. In this way, the expected combined yield from two five arm seawater intakes located at the proposed sites is up to 19.5 ML/day, while the combined yield from two three arm intakes is predicted to be up to 16 ML/day.

Table 5-2 Predicted yields for each model scenario

Model run	Aquifer hydraulic parameters	Scenario 1 - 5 arms	Scenario 2 - 3 arms
		ML/day	ML/day
Run 1	Sand HC= 20 m/day Vertical anisotropy (Kh/Kv) = 1	13.0	10.5
Run 2	Sand HC = 20 m/day Vertical anisotropy (Kh/Kv) = 5	12.5	9.9
Run 3	Sand HC = 10 m/day Vertical anisotropy (Kh/Kv) = 5	6.3	5.0
Run 4	Sand HC = 10 m/day Vertical anisotropy (Kh/Kv) = 1	6.5	5.3

The flow budget for Scenario 1 Run 1 is presented in Table 5-3. Analysis of the model flow budget indicates that approximately 80% of the water yielded by the intake is from seawater while the remainder is from Belmont Lagoon, rainfall and groundwater in storage.

Table 5-3 Flow budget

Input/Output	No intake, average rainfall (ML/yr)	No intake, drought condition (ML/yr)	Intake, scenario 1 run 1 (ML/yr)
IN			
Ocean	113	208	3835
Lagoon			757
Rainfall	350	142	142
Storage			12
OUT			
Lagoon	464	351	
Intake			4745

Figure 5-6 shows the change in groundwater baseflow to Belmont Lagoon within the model domain over the 20 year modelling period for Scenario 1 Run 1. There is net flow away from Belmont Lagoon during the period of groundwater extraction. Recovery is rapid following the cessation of pumping and net flow to Belmont Lagoon returns in less than one year. Note that the flows in Figure 5-6 do not represent total groundwater baseflow to Belmont Lagoon, since the site is also fed by a large groundwater catchment to the north outside of the model domain.

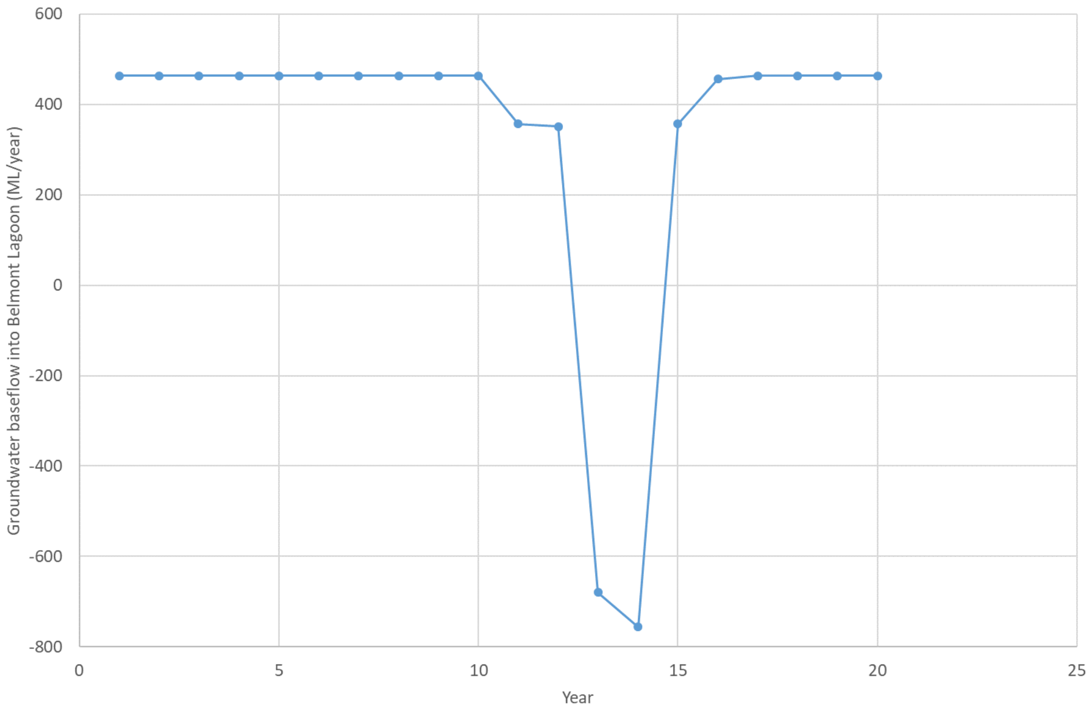

Figure 5-6 Groundwater baseflow to Belmont Lagoon (in model domain)

Predicted groundwater drawdown for each scenario and uncertainty analysis run (one intake only) is shown in Figure 5-8 to Figure 5-15. Drawdown is calculated as the difference between the modelled groundwater elevation with no groundwater extraction (existing condition) and the modelled groundwater elevation after two years of continuous groundwater extraction. In each case, the 3 m drawdown contour does not extend further than 200 m from the intake. The radius of drawdown for the 3 arm arrangement is slightly less than for the 5 arm arrangement as would be expected.

In each case, recovery following the cessation of pumping is relatively rapid, with the majority of recovery predicted over the year following the two years of continuous pumping as reflected in the recovery in groundwater flow to Belmont Lagoon in Figure 5-6. Predicted groundwater drawdown and recovery at the site boundary and at the aquatic GDE between the site and Belmont Lagoon for Scenario 1 Run 1 is shown in Figure 5-7.

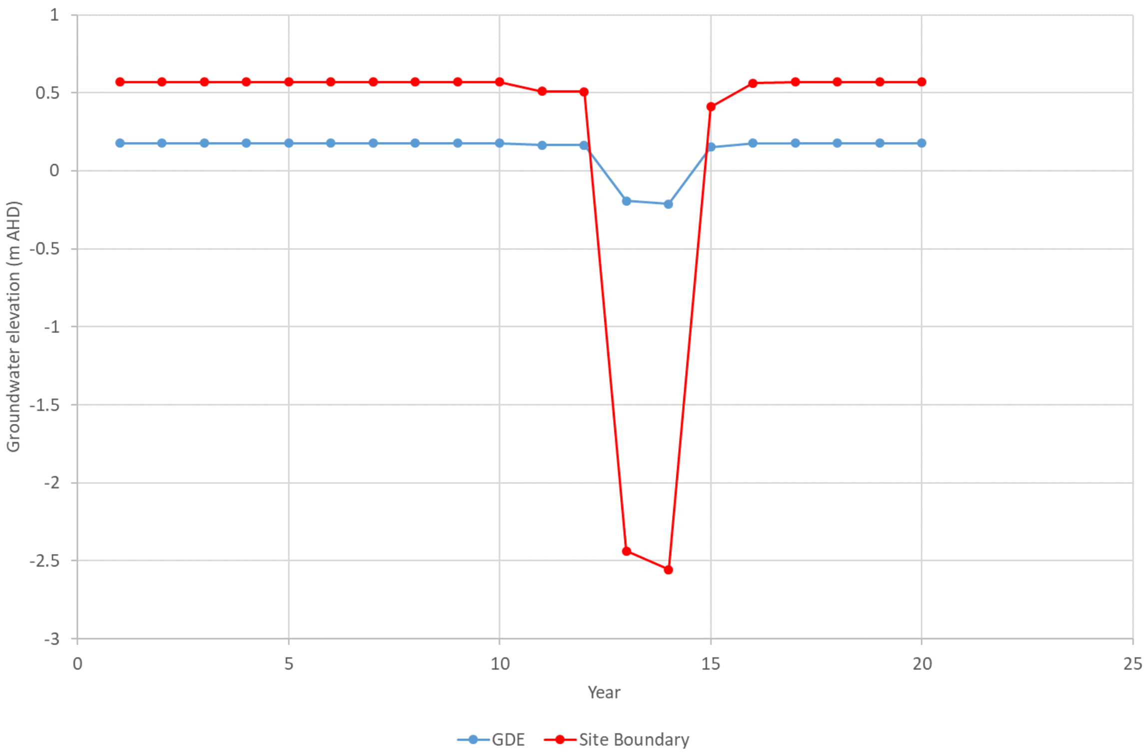

Figure 5-7 Groundwater drawdown and recovery (Scenario 1, Run 1)

In the case of two intakes operating simultaneously, there would be an overlapping of the drawdown zone from each intake which would limit the combined yield that can be obtained as discussed above. The overlapping would occur in the area between the intakes. However, the drawdown zone from the second intake would not extend any further distance inland (i.e. would not come any closer to Belmont Lagoon) than the drawdown zone of a single intake. This is because adding a second intake with the same constraint on intake arm elevations at approximately the same distance away from Belmont Lagoon will not change the hydraulic gradient between the Lagoon and the intake wells. The second intake is actually proposed to be slightly further from the Lagoon than the first.

Paper Size ISO A4

0 25 50 75 100

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

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Groundwater Assessment Report

Predicted Groundwater Drawdown – Scenario 1 Run 1

Project No. 22-19573
Revision No. 0
Date 18/10/2019

FIGURE 5-8

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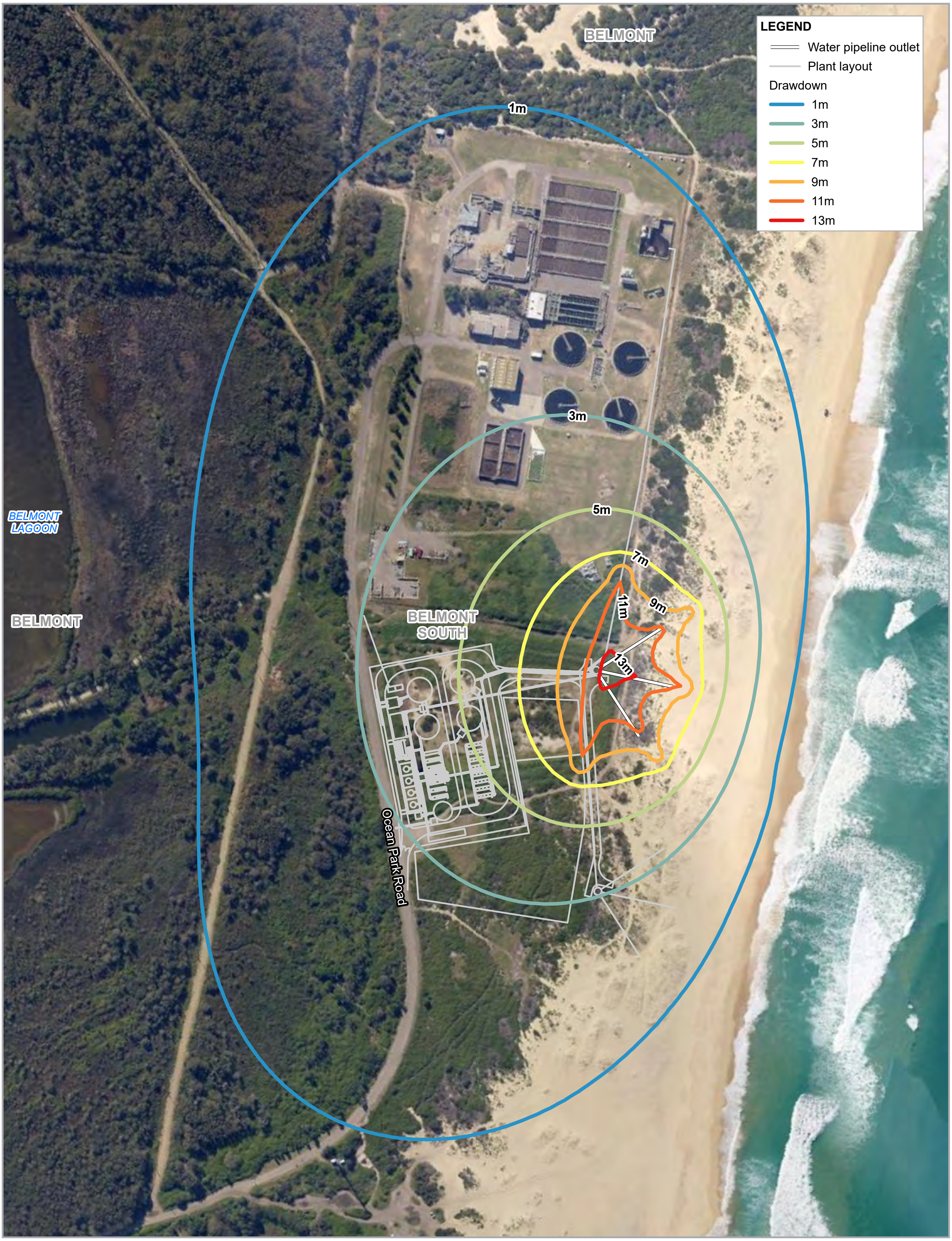
Print date: 18 Oct 2019 - 11:20

Data source: LPI: DTDB / DCDB, 2017; public_NSW_Imagery: . Created by: TMorton



Paper Size ISO A4

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Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

N

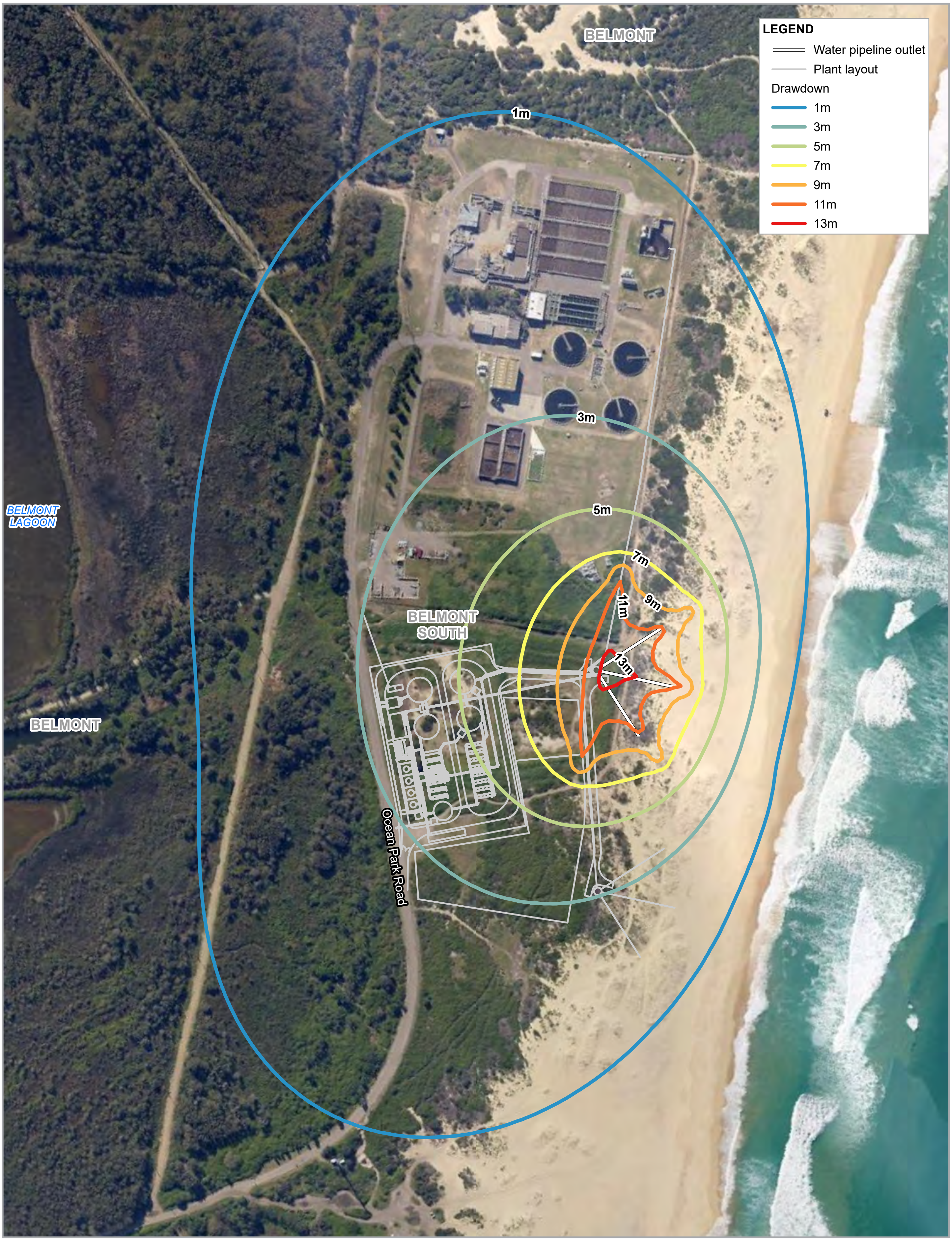
GHD

Hunter Water Corporation
Belmont Temporary Desalination Plant
Groundwater Assessment Report

Predicted Groundwater Drawdown – Scenario 1 Run 2

Project No. 22-19573
Revision No. 0
Date 18/10/2019

FIGURE 5-9



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Hunter Water Corporation
Belmont Temporary Desalination Plant
Groundwater Assessment Report

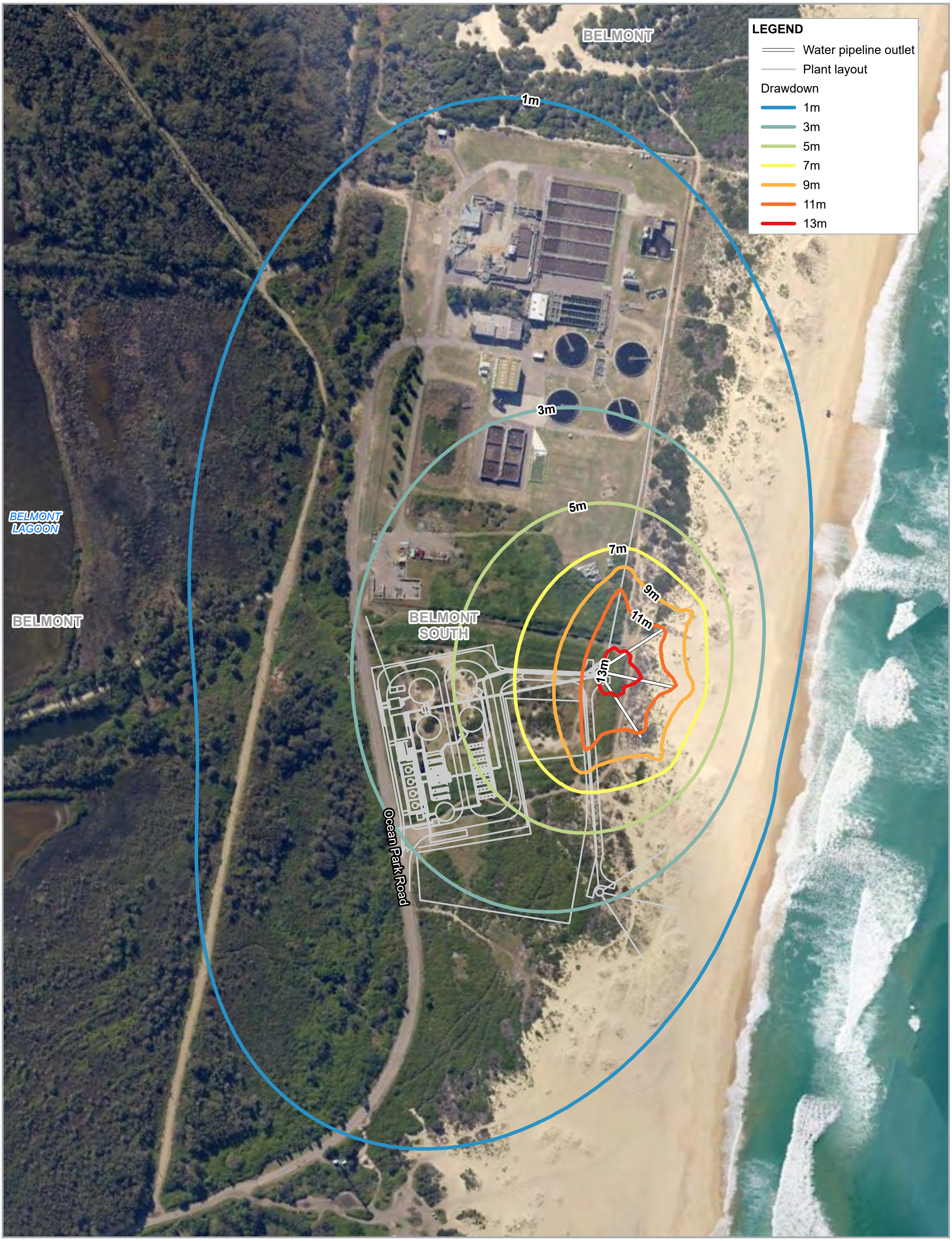
Predicted Groundwater Drawdown – Scenario 1 Run 3

Project No. 22-19573
Revision No. 0
Date 18/10/2019

FIGURE 5-10

G:\22\19573\Design\04 Deliverables\02 Other\2219573_EA_GW_Assessment_0.aprx
Print date: 18 Oct 2019 - 10:38

Data source: LPI: DTDB / DCDB, 2017; public_NSW_Imagery: . Created by: TMorton



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Grid: GDA 1994 MGA Zone 56

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Hunter Water Corporation
Belmont Temporary Desalination Plant
Groundwater Assessment Report

Predicted Groundwater Drawdown – Scenario 1 Run 4

Project No. 22-19573
Revision No. 0
Date 18/10/2019

FIGURE 5-11

Paper Size ISO A4

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Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

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Belmont Temporary Desalination Plant
Groundwater Assessment Report

Predicted Groundwater Drawdown – Scenario 2 Run 1

Project No. 22-19573
Revision No. 0
Date 18/10/2019

FIGURE 5-12

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Print date: 18 Oct 2019 - 10:38

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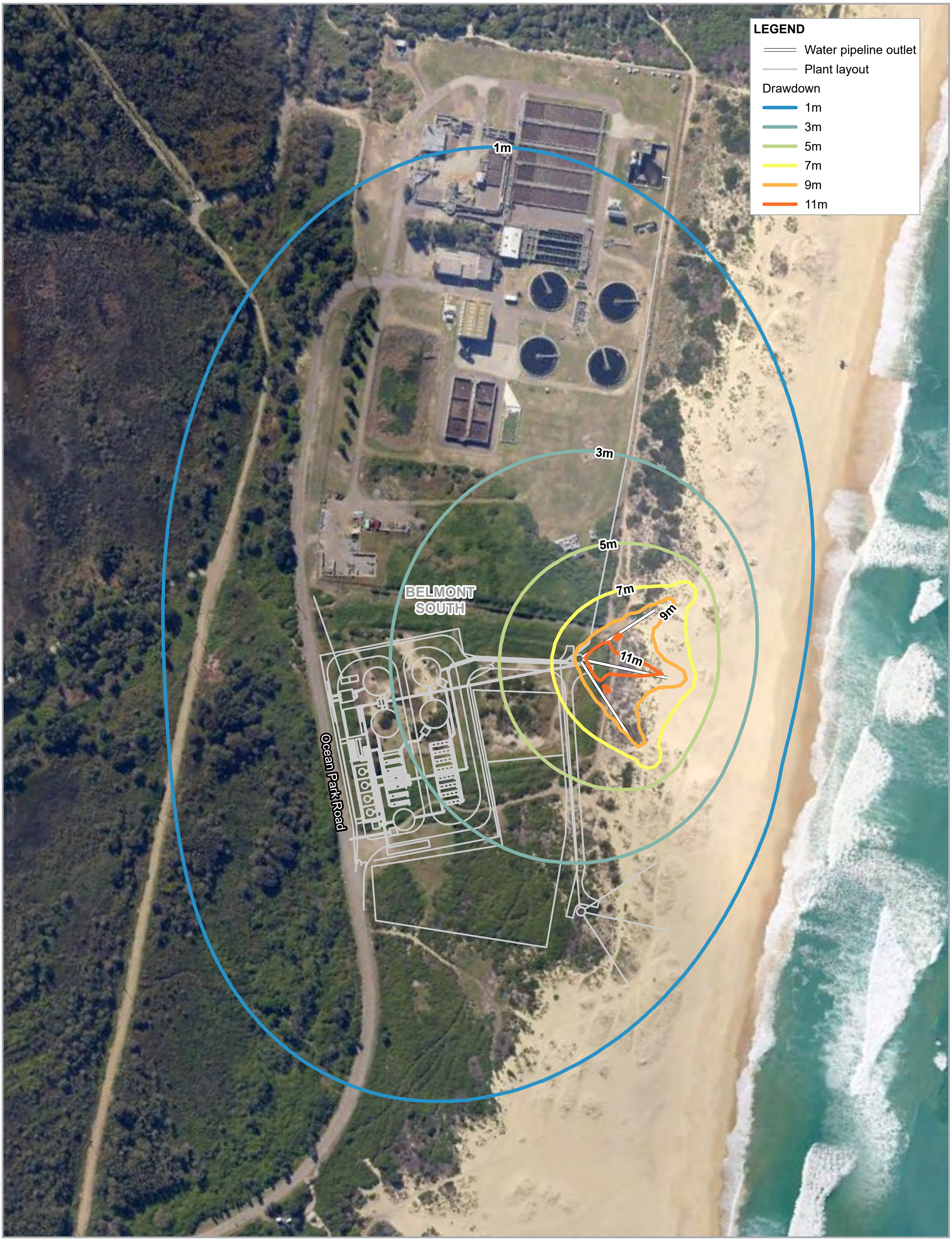

Paper Size ISO A4

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Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

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GHD

Hunter Water Corporation
Belmont Temporary Desalination Plant
Groundwater Assessment Report

Predicted Groundwater Drawdown – Scenario 2 Run 2

Project No. 22-19573
Revision No. 0
Date 18/10/2019

FIGURE 5-13

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Paper Size ISO A4

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Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

Hunter Water Corporation
Belmont Temporary Desalination Plant
Groundwater Assessment Report

Predicted Groundwater Drawdown – Scenario 2 Run 3

Project No. 22-19573
Revision No. 0
Date 18/10/2019

FIGURE 5-14

G:\22\19573\Design\04 Deliverables\02 Other\2219573_EA_GW_Assessment_0.aprx
Print date: 18 Oct 2019 - 10:39

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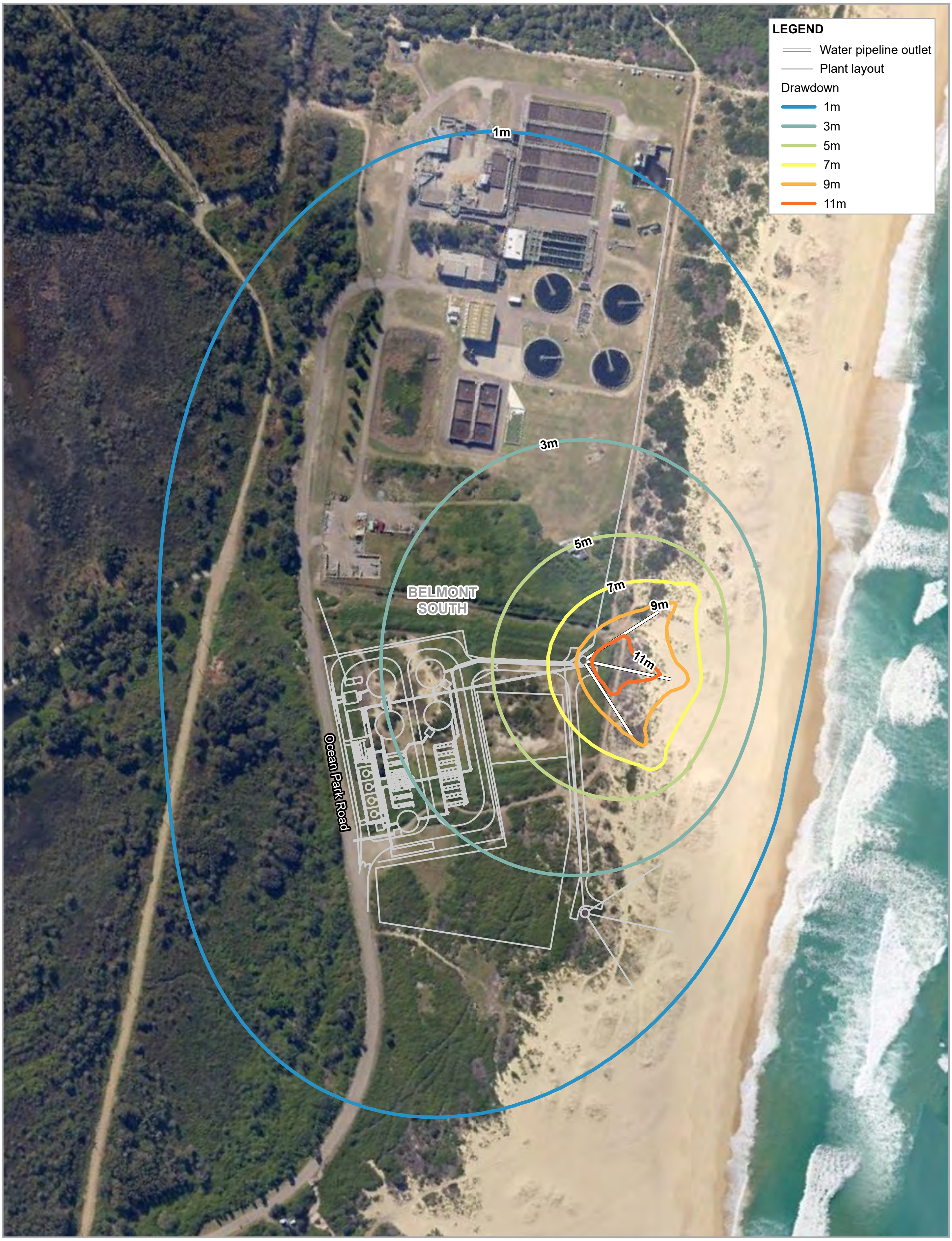

Paper Size ISO A4

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Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 56

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GHD

Hunter Water Corporation
Belmont Temporary Desalination Plant
Groundwater Assessment Report

Predicted Groundwater Drawdown – Scenario 2 Run 4

Project No.	22-19573
Revision No.	0
Date	18/10/2019

FIGURE 5-15

G:\22\19573\Design\04 Deliverables\02 Other\2219573_EA_GW_Assessment_0.aprx
Print date: 18 Oct 2019 - 10:39

Data source: LPI: DTDB / DCDB, 2017; public_NSW_Imagery: . Created by: TMorton

6. Impact assessment

6.1 Construction

Installation of the seawater intakes will involve groundwater interception and dewatering. Most of the requirement for dewatering will be for the installation of the caissons. However, the extent and duration of dewatering during construction is expected to be less than the dewatering and drawdown during operation. Therefore groundwater level (and quantity) impacts during construction are expected to be less than during operation (assessed below).

Construction activities have the potential to introduce contaminants into the groundwater source, particularly hydrocarbons. This may occur as a result of the operation of the drilling equipment as well as leakage or spillage of hydrocarbon products from vehicles, wash down areas, workshops and refuelling bays and fuel, oil and grease storages. While this has the potential to impact on local groundwater quality, the volumes of potential spillages would be relatively minor and are not anticipated to result in a significant impact.

6.2 Operation

6.2.1 Groundwater receptors

Sensitive groundwater receptors are identified in Sections 4.1.4 and 4.1.5.

Registered groundwater users are located within 5 km of the Project area, however the closest bore to the Project area (GW054897) is located approximately 1 km to the west on the western side of Belmont Lagoon.

Belmont Lagoon Swamps is an aquatic GDE listed as a High Priority GDE for the Hawkesbury to Hunter Coastal Sands Groundwater Source. The boundary of this High Priority GDE is located less than 400 m from the seawater intakes at its closest point.

The beneficial use of the deeper groundwater would be limited due to its high salinity. There is also limited use of the fresher shallow groundwater in the vicinity of the Project area as demonstrated by the absence of registered bores. However there is interaction between the shallow groundwater and aquatic ecosystems and therefore it is considered that the beneficial use category of the groundwater in the vicinity of the Project area would be ecosystem support.

6.2.2 Groundwater model predictions

The numerical groundwater model was used to predict:

- Inflows into the proposed intake structure during Project operation and the source of the water (i.e. seawater, groundwater or water from Belmont Lagoon)
- Drawdown in groundwater sources during operation
- Approximate recovery times in groundwater levels

Two scenarios were modelled:

- One five arm diagonal and perpendicular intake operating for two years under drought conditions (Scenario 1)
- One three arm diagonal intake operating for two years under drought conditions (Scenario 2)

For each scenario, four uncertainty analysis model runs were performed by varying the most sensitive model parameters.

As outlined in Section 5.4.3, yields from one three arm seawater intake are predicted to range from approximately 5.0 to 10.5 ML/day. One five arm intake is predicted to yield 6.3 to 13.0 ML/day.

Two identical intake structures operating simultaneously was not modelled in MODFLOW, however an estimate of the combined yield from two five arm seawater intakes located at the proposed sites is up to 19.5 ML/day, while the combined yield from two three arm intakes is predicted to be up to 16 ML/day.

Groundwater drawdown for each scenario and uncertainty analysis run is predicted to be within a relatively small area primarily within the Project boundary. Some groundwater drawdown will extend beyond the Project area, however in each case the 3 m drawdown contour does not extend further than 200 m from the intake caisson. The zone of groundwater drawdown from two identical intake structures operating simultaneously is not expected to extend any closer inland towards Belmont Lagoon than a single intake operating alone as discussed in Section 5.4.3.

In each case, recovery following the cessation of pumping is relatively rapid, with the majority of recovery predicted over the year following the two years of continuous pumping.

6.2.3 Groundwater impact assessment

As discussed in Section 1.4.2, the NSW AIP Level 1 minimal impact considerations for highly productive coastal sands groundwater sources have been adopted for this assessment and are as follows:

Water table: less than or equal to 10% cumulative variation in the water table, allowing for typical climatic 'post-water sharing plan' variations, 40 m from any high priority GDE or high priority culturally significant site listed in the schedule of the relevant WSP. A maximum of a 2 m decline cumulatively at any water supply work.

Water pressure: a cumulative pressure head decline of not more than a 2 m decline at any water supply work.

Water quality: any change in the groundwater quality should not lower the beneficial use category of the groundwater source beyond 40 m from the activity.

Based on groundwater model predictions, no groundwater drawdown is expected at any registered groundwater bore (the closest being approximately 1 km from the seawater intakes) or at a high priority GDE (Belmont Lagoon), noting that the aquatic GDE between the site and Belmont Lagoon is not considered high priority since it is predominantly saltmarsh. Therefore, the predicted groundwater impacts are less than the Level 1 water table and water pressure criteria from the AIP and are therefore considered to be acceptable.

The reason that the water level in Belmont Lagoon will not drop is that it is connected by Cold Tea Creek to Lake Macquarie. Based on the groundwater model, it is predicted that the usual flow of largely fresh groundwater into Belmont Lagoon will cease (in the vicinity of the project site) and that Belmont Lagoon will become a source of inflow to the aquifer when the scheme is operating.

The zone of predicted groundwater drawdown is centred within the beach and low risk zones on the Acid Sulphate Soil Risk Map but extends westward to the high risk 1-2 m and 2-4 m depth zones. For the three arm scheme, groundwater level drawdown is predicted to be from approximately zero to 2 m in the ASS high risk 1-2 m zone and from 2 m to 3 m in the ASS high risk 3-4 m zone. Since these drawdown predictions are based on continuous extraction for two years, the exposure and oxidation of pyritic material depends on how long the scheme is actually operating for and the existence of PASS in the drawdown zone. It is considered unlikely that the operation of the Project will result in the oxidation of PASS and deterioration of groundwater quality, however it will be necessary to implement the mitigation measures outlined in Section 7.2, including additional ASS investigation in the area during the detailed design phase. Overall, the beneficial use category of the groundwater source is not expected to be lowered and therefore the predicted groundwater quality impact is less than the Level 1 criterion from the AIP and therefore considered to be acceptable.

6.2.4 Licensing

Modelling indicates that approximately 80% of the yield is from seawater and the remainder from Belmont Lagoon and groundwater (including rainfall). Therefore considerably less than 3.2 ML/day (1,168 ML/year) of groundwater is expected to be extracted from two three arm seawater intakes (based on the yield estimate of 16 ML/day). The unassigned water within the Hawkesbury to Hunter Coastal Sands Groundwater Source of the North Coast Coastal Sands Water Sharing Plan is 12,740 ML/year (at commencement of the plan in 2016). Since this exceeds the predicted groundwater take for the Project (both three and five arm scenarios), it is considered that there is sufficient groundwater available within the water source to enable Hunter Water to obtain a Water Access Licence for the Project.

6.2.5 Water sharing plan rules

Relevant rules for water supply works approvals for the Hawkesbury to Hunter Coastal Sands Groundwater Source are listed in Section 1.4.1. The proposed locations of the seawater intakes comply with all rules with the exception of the requirement to be at least 800 m of the high priority GDE for bores licensed to extract more than 100 ML/year. However, since there is no drawdown predicted at the high priority GDE, it is considered that the Water Sharing Plan requirement that the water supply works be located at least 800 m away does not apply.

7. Mitigation measures and monitoring

Groundwater impacts from the Project have been assessed as being less than the Level 1 minimal impact considerations from the NSW AIP and are therefore considered to be acceptable. However, predicted impacts are based on the numerical groundwater model developed for the Project and therefore need to be verified by ongoing monitoring. Groundwater monitoring and mitigation measures are outlined in this Section.

7.1 Monitoring program

A comprehensive groundwater monitoring program will be developed and implemented during both the construction and operation phases. Existing monitoring wells GW101 – GW108 will be considered for inclusion in the program and additional monitoring sites will be identified (if necessary). The groundwater monitoring program will include continuous monitoring of groundwater levels and routine groundwater quality monitoring.

Groundwater level and quality triggers will be established based on baseline monitoring data and groundwater model predictions. A trigger, action, response plan will be developed that defines investigations and actions required if trigger levels are exceeded.

7.2 Mitigation measures

Proposed mitigation measures for groundwater drawdown are as follows:

- Develop an ongoing groundwater monitoring program, including groundwater level triggers and an appropriate trigger, action, response plan.
- Update the groundwater model to revise groundwater drawdown predictions if necessary.
- Reduce groundwater drawdown (if necessary) by modifying the intake pumping schedule (i.e. allow periodic recovery by shutting off pumps) or by shutting off one of more horizontal arms.

Proposed mitigation measures for groundwater quality are as follows:

- Develop an ongoing groundwater monitoring program, including groundwater quality triggers and an appropriate trigger, action, response plan.
- Undertake additional Acid Sulphate Soil (ASS) sampling within the zone of groundwater drawdown during the detailed design phase to confirm the risk of exposure of ASS due to drawdown. Reduce groundwater drawdown (if necessary) as outlined above.

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Appendices

Appendix A – Registered bore search

Bore ID	Type	Status	Total depth	Easting	Northing	Date of completion
GW017372	Well	Supply Obtained	3.6	374356	6339614	1/01/1959
GW051411	Spear	Supply Obtained	4.6	373997	6339271	1/11/1980
GW051737	Spear	Supply Obtained	5.1	374133	6338811	1/10/1980
GW052084	Spear	Unknown	4	372215	6338755	1/11/1980
GW052085	Spear	Unknown	4	374253	6341584	
GW052086	Spear	Unknown	1	373700	6340222	
GW052267	Spear	Supply Obtained	6	374052	6341058	
GW052358	Spear	Supply Obtained	4	374206	6339212	1/02/1981
GW052448	Spear	Supply Obtained	3.9	373971	6339301	1/11/1980
GW052455	Spear	Unknown	3	374199	6341769	1/02/1981
GW052472	Spear	Supply Obtained	3.6	373816	6339269	1/02/1981
GW052541	Spear	Supply Obtained	3.7	372426	6338480	
GW052652	Spear	Unknown	5	372362	6339404	1/10/1980
GW052677	Spear	Supply Obtained	4	374003	6340873	1/10/1980
GW053172	Bore	Unknown	17.4	375422	6347575	1/01/1981
GW053564	Spear	Unknown	4	373890	6341549	
GW053565	Spear	Unknown	4	373865	6341518	
GW054643	Spear	Supply Obtained	6.6	374457	6339800	
GW054659	Spear	Unknown	5.5	374029	6340873	
GW054660	Spear	Unknown	6	374459	6339708	1/08/1981
GW054666	Spear	Unknown	7	374130	6341059	1/01/1981
GW054681	Bore	Unknown	6.7	374227	6341584	1/09/1980
GW054689	Spear	Supply Obtained	6.7	374457	6339800	
GW054829	Spear	Supply Obtained	5.7	373469	6340034	1/12/1981
GW054840	Bore	Unknown	4.3	374490	6339277	
GW054848	Spear	Unknown	5	374489	6339339	1/09/1981
GW054886	Spear	Supply Obtained	4	374706	6342638	1/01/1981
GW054897	Bore	Supply Obtained	5	374735	6342392	1/12/1980
GW055047	Spear	Unknown	5	373952	6340810	1/12/1981
GW055049	Spear	Supply Obtained	6	379330	6346361	1/03/1981
GW055054	Spear	Supply Obtained	3.5	374498	6342696	
GW055065	Spear	Unknown	5	374454	6340078	1/03/1981
GW055847	Spear	Supply Obtained	5	374606	6342359	1/01/1981
GW055959	Spear	Unknown	5.5	374253	6341615	1/09/1981
GW056248	Spear	Supply Obtained	2	372478	6338481	
GW056251	Spear	Unknown	4.5	373816	6339238	1/01/1983
GW056252	Spear	Unknown	4.5	373764	6339299	1/01/1983
GW056253	Spear	Supply Obtained	5	373131	6338089	
GW056255	Spear	Supply Obtained	4	372713	6338299	1/02/1981
GW056256	Spear	Unknown	2.6	372110	6338815	1/09/1980
GW056257	Spear	Unknown	6	374464	6339308	1/10/1981
GW056258	Spear	Supply Obtained	4	372425	6338511	
GW057211	Spear	Unknown	7	374452	6342203	1/03/1981
GW057422	Spear	Unknown	6	374051	6341151	1/12/1982
GW058241	Spear	Supply Obtained	5	375077	6337991	
GW058426	Spear	Supply Obtained	3	372211	6339032	1/02/1983
GW058886	Spear	Supply Obtained	3	374003	6340842	1/01/1983

Bore ID	Type	Status	Total depth	Easting	Northing	Date of completion
GW059577	Spear	Supply Obtained	6.4	373920	6341241	1/05/1983
GW060409	Bore	Unknown	36.3	378376	6345887	1/10/1985
GW060529	Bore open thru rock	Unknown	36.3	378298	6345886	1/10/1985
GW080233	Bore	Unknown	41	377546	6347262	1/04/2000
GW080340	Bore	Unknown		374283	6338925	7/11/2002
GW080381	Spear	Unknown		372596	6339821	14/05/2003
GW080382	Spear	Unknown		372527	6339583	14/05/2003
GW200021	Bore	Unknown		372685	6338751	
GW200142	Bore	Unknown		374199	6341486	15/12/2004
GW200143	Bore	Unknown		374202	6341485	15/12/2004
GW200151	Bore	Unknown		374196	6341481	15/12/2004
GW201530	Battery Spears	Abandoned	7	374453	6342259	17/06/2011
GW201897	Bore	Equipped	3.5	374270	6341616	7/06/2001
GW201898	Bore	Equipped	4	374261	6341643	7/06/2001
GW201899	Bore	Equipped	4	374269	6341642	19/06/2001
GW201900	Bore	Equipped	4	374258	6341629	18/07/2001
GW201901	Bore	Equipped	4	374249	6341630	18/07/2001
GW201902	Bore	Equipped	3.5	374250	6341653	18/07/2001
GW201903	Bore	Equipped	3.5	374270	6341655	18/07/2001
GW201904	Bore	Equipped	3.5	374289	6341654	18/07/2001
GW202688	Bore	Equipped	3	373357	6341904	4/04/2012
GW202689	Bore	Equipped	3	373361	6341922	4/04/2012
GW202690	Bore	Equipped	3	373348	6341921	4/04/2012
GW203217	Bore	Supply Obtained		376188	6345040	14/05/2015
GW203440	Bore	Equipped	3.5	374896	6344200	8/10/2014
GW203441	Bore	Equipped	3.5	374829	6344214	8/10/2014

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1	SA, AB	S Gray		N Malcolm		01/11/2019

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