









WAGERUP REFINERY & BUNBURY CAUSTIC LOADING FACILITY

GROUNDWATER AND SURFACE WATER MANAGEMENT REVIEW, 2020-2022

REPORT FOR ALCOA OF AUSTRALIA LIMITED

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Rockwater
HYDROGEOLOGICAL AND ENVIRONMENTAL CONSULTANTS

76 Jersey Street Jolimont 6014 Western Australia Postal: PO Box 201 Wembley 6913 Western Australia
Ph: 61 8 9284 0222 Fax: 61 8 9284 1785 Email: consult@rockwater.com.au www.rockwater.com.au ABN: 43 008 804 653

SUMMARY

Groundwater and surface water at Alcoa's Wagerup and Bunbury (alumina refining and ship-loading) operations are managed in accordance with licences issued by the Department of Water and Environmental Regulation (DWER). These licences including operating strategy monitoring and reporting requirements. Monitoring data and assessments pertaining to the DWER licences and operating strategies are reported and assessed in this management review for the period 2020 to 2022 inclusive.

Wagerup Operations

Groundwater and surface water monitoring required by *Environmental Protection Act 1986* Part V Licence L6217/1983/15, Water Pollution Control Conditions, was undertaken during the 2020–2022 review period in accordance with licence conditions. Alcoa's four alkali recovery-bores at the Wagerup Refinery produced a total of 39,700 kL (2020), 40,112 kL (2021) and 60,781 kL (2022) of groundwater, against an annual water entitlement of 146,000 kL. Groundwater licence GWL102669(3) abstraction was 384,368 kL (2020), 373,862 kL (2021) and 406,149 kL (2022), against an annual water entitlement of 550,000 kL. All data required by the Operating Strategy for these licences were collected during 2020–2022 except where monitoring was not possible, as outlined in Section 5.1. Alcoa's three DWER surface-water harvesting licences (SWL151027[4] [Harvey River], SWL99246[5] [Black Tom Brook] and SWL97472[6]) [Yalup Brook]) have a combined Annual Water Entitlement of 8,500 ML. The total volume of water drawn from all surface water sources was 5,672 ML (2020), 4,403 ML (2021) and 4,078 ML (2022). Included in these volumes are 1,491–3,800 ML of water was purchased from Harvey Water each year and not drawn from the licenced sources. All data required by the Operating Strategy for these licences were collected during 2020–2022.

Regarding the Wagerup Refinery:

- No marked drawdown of groundwater levels has been recorded at the refinery or RSAs, or the surrounding properties or the natural water courses.
- The groundwater chemical constituents have shown no changes that adversely affect the water suitability for processing, residue storage operations, or use in the water circuit.
- Surface water harvesting data from the 2020–2022 review period do not suggest downstream flow or water quality impacts as a result of surface water harvesting.
- Alkali fluids plumes are evident in four main areas:
    - Southern area of the refinery in the vicinity of Building 45; alkali fluids in the southern part of the Wagerup refinery area have impacted on the superficial-formation groundwater, and operation of the recovery bores should continue.
    - Northern area of the refinery near Buildings 26, 25A, 30 and 35F; the plume in the shallow groundwater appears to be largely contained by the operation of the two alkali recovery bores, based on the monitoring data trends.
    - Central area of the refinery in the vicinity of Buildings 47, 42A and 40; most of the alkali fluid is apparently contained in the low-permeability upper superficial formations, downward ingress is observed at Building 42A (RF126G) and Building 40 (RF124G and RF125G). There appears to be some migration of alkali-impacted groundwater at these locations. South-western area of the refinery near the Caustic Unloading Area and the

former hydrate stockpile; alkalinity levels have been gradually decreasing since 2009, from maximum values of about 4,500 µS/cm and 1,200 mg/L for EC and alkalinity, respectively, to the current levels of about 240 µS/cm and 100 mg/L.

- There appears to be no significant impact by alkaline waters on the deeper Mesozoic aquifers.

Regarding the RSA areas:

- In the area between RSA/Sand Lake and RSA2, increasing alkalinity has been exhibited during the 2020-2022 period.
- To the north and north-west of the RSAs there is elevated salinity, and variable changes in alkalinity, which may be naturally occurring.
- Monitor bores on the south-western side of ROCP1 exhibited increasing alkalinities during the 2020–2022 review period and require further assessment.
- There are no indications of alkaline waters in the Mesozoic-age formations in the residue area.

Groundwater extraction from superficial formations appears to be sufficient to maintain suitably low aquifer water levels at several water storage ponds. The quality of the extracted groundwater has remained stable.

Regionally, monitoring-bore and stream-flow data indicate that:

- There is no evidence of an adverse impact on groundwater quality beyond Alcoa's property.
- There is no evidence of an adverse impact on stream flow or water quality in surface water bodies and streams.

Bunbury caustic loading facilities

- An alkaline groundwater plume persists in the upper Superficial aquifer to the east of the site, near the caustic containment facilities. The plume appears to be migrating downwards to deeper aquifer intervals, and towards the south-west.
- Plume concentrations appear to be reducing in the deeper aquifer intervals during 2020–22.
- Monitoring bore B-023S/I/D, newly installed to monitor the extent of the plume, recorded low alkalinity levels confirming the above assumption that the plume is migrating downwards (i.e. rather than laterally towards the harbour or Preston River).
- Discharge of alkaline groundwater to the Bunbury inner harbour is likely to be minimal. The effects are likely to be reduced by chemical interactions between the plume groundwater and the saline water interface.
- Concentrations of petroleum hydrocarbons in the monitor bores are below the practical quantification limit (PQL), and does not pose a significant risk to the marine environment in the Bunbury inner harbour.

- There is little to no surface-water runoff from this site to the marine environment. The surface water has shown very little caustic content, and does not pose a significant risk to the marine environment.

Key Recommendations

Alcoa has worked to act upon previous recommendations (Rockwater, 2020). The following additional actions are recommended, based on the assessments contained in this report.

- Continue to implement a program of bore-condition assessments and bore-replacement where required. The redevelopment of B-018B (Bunbury) should be a priority, to help determine the extent of the plume originating nearby.
- Increase the general-hydrochemistry (pH, EC and alkalinity) sampling frequencies for monitor bores RS063S, RS064S, RS065G, RS126G, RS137S/G and RS138S/G.
- Existing bores north of the Sand Lake must be maintained to allow accurate groundwater characteristics beneath the RSA complex.
- If operationally feasible, one or two alternative monitoring sites should be identified, preferably to the west of the eastern dyke at RSA2, and new monitor bores installed and monitored to determine accurate groundwater quality characteristics beneath the RSA complex.
- Monitor water quality trends around ROCP1 as decommissioning is completed. This monitoring will assess if natural monitored attenuation can manage the contamination (due to liner defects when the pond was operated) to the underlying groundwater.
- Increase the extraction from depressurising bores D-010G, D-013G and D-014G, and re-commission bores D-011G and D-012G to lower the underlying groundwater levels at ROCP2.

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REVISION	AUTHOR	REVIEW	AUTHORISED	ISSUED
Draft I	DS	KP, JS, ML (Alcoa)	NE	28 Feb 23
Draft II	DS	KP, JB	NE	28 Mar 23
Final	DS	KP	NE	26 April 23

1 INTRODUCTION

Alcoa of Australia Limited (Alcoa) owns and operates the Wagerup Alumina Refinery and the Bunbury Caustic Loading Facility, located 105 km and 155 km south of Perth, respectively (Figure 1).

The refinery operates under the terms and conditions of a Part V *Environmental Protection Act 1986* (EP Act) licence issued by the Department of Water and Environmental Regulation (DWER), the Water Pollution Control Conditions of which are considered herein. The refinery's water supply comes from local groundwater and surface water sources, which is regulated by licences issued by DWER under the *Rights in Water and Irrigation Act 1914* or is purchased from Harvey Water. These licence conditions stipulate that Alcoa is to present a report on licence-related issues, in accordance with the Groundwater and Surface Water Operating Strategies associated with each. The monitoring period for these licensing requirements is 1 January to 31 December.

This report has been prepared to satisfy Alcoa's triennial water-related reporting commitments listed in the Operating Strategies and supports the information required for the EP Act licence. The report also presents a review of groundwater and surface water monitoring data from the Wagerup Alumina Refinery and Bunbury Caustic Loading Facility for the three years ending 31 December 2022.

All groundwater and surface water monitoring data presented in this report have been provided by Alcoa. Meteorological data presented have been obtained from the Bureau of Meteorology and Alcoa.

1.1 OBJECTIVES OF REPORT

The objectives of this report are to present and review groundwater and surface water data collected during the 2020-2022 water-years from the Wagerup Alumina Refinery and Bunbury Caustic Loading Facility, and to analyse and compare the data with any limits or response levels set in the licence conditions and historical records.

The report assesses the effectiveness and suitability of Alcoa's water management strategies, including the groundwater and surface water monitoring programs for the Wagerup and Bunbury sites.

Alcoa has used a risk assessment approach, consistent with guidelines published as part of the National Water Quality Management Strategy (ANZECC and ARMCANZ 2000, ANZG, 2018), to develop a set of Environmental Objectives (EOs) for its West Australian refinery operations. These objectives have been defined and adopted to minimise any adverse effects relating to Alcoa's operations on the environment. The development of Alcoa's EOs and the associated monitoring objectives has been progressive: the EOs applicable to the data collected in 2020-2022 are from the 2015 Water Monitoring Program Review by Ecotech Environmental Monitoring Solutions (Ecotech). They have been updated from earlier versions (Parsons Brinkerhoff 2006, 2009) to provide a standardised alignment of monitoring objectives and programs across Alcoa's refinery sites. Those relevant to the current triennial review are provided in Table 1, with their applicability to the Wagerup and Bunbury sites noted. This report presents data from the full program and not just that related to the licences and operating strategies.

Table 1: Environmental protection objectives, Wagerup Alumina Refinery and Bunbury Caustic Loading Facility

Environmental Objective	Site applicability	
	Wagerup	Bunbury
1) Abstraction and recovery of groundwater is undertaken in a manner that is sustainable and does not have a long-term detrimental effect on the environment or the beneficial use of groundwater resources.	Yes	No
2) Surface water harvesting is undertaken in a manner that is sustainable and does not have a long-term detrimental effect on the environment or the beneficial use of surface water resources.	Yes	No
3) Adverse effects from Refinery operations and storage areas on groundwater and environmental receptors are identified to determine the effectiveness of current management strategies.	Yes	Yes
4) Alkali recovery systems in the superficial formations reduce the alkali load on groundwater receptors.	Yes	No
5) Adverse effects from residue areas on groundwater and environmental receptors are identified to determine the effectiveness of current management strategies.	Yes	No
6) The integrity of the clay-geomembrane composite liners for process water ponds is maintained.	Yes	No
7) The environmental value of sensitive receptors surrounding Alcoa's operations is sustained.	Yes	Yes

1.2 REPORT FORMAT AND STRUCTURE

The report structure is similar to that provided in 2020 and complies with the requirements outlined in Operational Policy No. 5.12 (DoW 2009).

The 2020-2022 report has been prepared by Rockwater; however, much of the content relating to project setting and site details has been sourced directly from previous reports by Peter Clifton & Associates (for example, Clifton 2014). Rockwater has been completing the Reviews of Groundwater and Surface Water for the Alcoa Wagerup and Bunbury facilities since the 2014 annual report (Rockwater [2020] is the previous review of groundwater and surface water management for the Wagerup and Bunbury facilities).

Sections 2–0 present analyses of the groundwater and surface water monitoring data for the Wagerup Alumina Refinery. The review for the Bunbury Caustic Loading Facility is presented in Section 6. Section 7 presents conclusions and recommendations based on the assessment of the monitoring data in relation to the environmental objectives presented in Table 1.

1.3 REFINERY AND RESIDUE AREA OPERATIONS

The Wagerup Alumina Refinery and early Residue Storage Areas (RSAs) were commissioned in 1984. An aerial photograph superimposed with the layout of the Wagerup Alumina Refinery and RSAs in 2022 is presented in Figure 2.

Alumina is extracted from bauxite ore at the Wagerup Refinery by means of the Bayer process. The Bayer process involves the selective dissolution of the aluminium-containing minerals from the bauxite ore under pressure in a hot solution of concentrated sodium hydroxide (caustic soda) leaving an insoluble residue of mainly oxides. This bauxite residue is settled and removed. The leaching solution has a total alkalinity (expressed as Na_2CO_3) of around 200,000 mg/L. 'Hydrate' (aluminium trihydroxide) is precipitated from the solution and is then calcined (heated to over 1,100°C), driving water from its chemical structure and

converting it to alumina (Al_2O_3). The entire process is carried out under closely controlled conditions to ensure efficiency and quality of product. The bauxite residue is washed to recover sodium hydroxide for re-use in the process. The remaining part of the bauxite residue, including iron-oxides, hydroxides, quartz and clay minerals, comprising mud- and sand-sized particles, is transported in slurry to residue storage areas (RSAs), about 2 km west of the refinery (Figure 2). The slurry containing the finer components is passed through a thickener to further reduce the moisture content and to recover more of the alkaline liquid before final storage. The final thickened residue is deposited in the RSAs.

The RSAs have been constructed progressively since operations at the Wagerup Refinery commenced. At December 2022 there were eight RSAs in use (Figure 2). The RSA complex at Wagerup includes four water storage facilities that are used to contain water from the refinery and RSA operations; ROWS Pond, Cooling Pond, Runoff Collection Pond 2 (ROCP2) and Runoff Collection Pond 3 (ROCP3) (Figure 2). Runoff Collection Pond 1 (ROCP1) is in the process of being decommissioned. No new water has been stored in ROCP1 since decommissioning started in 2017.

Details of the basal liner construction of the RSAs, dates commissioned, and the approximate total alkalinity of the water they contain are summarised in Table 2.

Table 2: Wagerup Residue Storage Area facilities

Facility	Commissioned	Liner	Total Alkalinity (as mg/L Na_2CO_3)[1]
RSA1 / Sand Lake 1	1984	0.5 m compacted clay, and overlying sand drainage layer	23,000
Cooling Pond	1984	0.5 m compacted clay and overlying PVC sheet	20,000
RSA2	1989	0.5 m compacted clay, and overlying sand drainage layer	23,000
RSA3	1992	0.5 m compacted clay, and overlying sand drainage layer	23,000
ROCP1	1992	0.5 m compacted clay	18,000[2]
RSA4	1993	0.5 m compacted clay, and overlying sand drainage layer	23,000
RSA5	1994	0.5 m compacted clay, and overlying sand drainage layer	23,000
ROWS Pond	1996	0.5 m compacted clay and overlying PVC sheet	12,000
RSA6	1998	0.5 m compacted clay, PVC sheet, and overlying sand drainage layer	23,000
ROCP2	1998	0.5 m compacted clay and overlying HDPE sheet	23,000
RSA7	2004 (RSA7)	0.5 m compacted clay, HDPE sheet, and overlying sand drainage layer	23,000
	2010 (RSA7N)		23,000
RSA8	2006	0.5 m compacted clay, HDPE sheet, and overlying sand drainage layer	23,000
RSA9	2014	0.5 compacted clay, HDPE sheet and overlying sand drainage layer	23,000
ROCP3	2015	0.5 m compacted clay and overlying HDPE sheet	23,000

1. Typical mean values of total alkalinity of leachate from RSA underdrains, or water in the storage ponds. Actual values vary seasonally with rainfall and evaporation.
2. Typical mean values when ROCP1 was in operation. Decommissioning of the pond commenced in 2017 by draining and filling it with sand to balance the potential uplift pressure on the liner.

All the RSAs at Wagerup have basal liners 0.5 m thick that are formed by reworking and compacting locally derived clayey materials, and since 1998 all of the RSAs constructed at Wagerup have included composite liners comprising a continuous sheet of PVC or HDPE above the compacted clayey layer. The floors of the lined RSAs are contoured and covered with a network of drain coils and collector pipes, which in turn are

covered by a layer of fine sand (residue sand) to a depth of up to 0.5 m. The sand layer and drain coils form the underdrainage system that collects alkaline liquids gravitating downwards from the overlying residue deposits. Removal of decant water via these underdrainage systems help reduce the hydraulic head on the basal liners.

All recovered alkaline liquid from the underdrainage systems, along with other runoff from the refinery and RSAs is ultimately stored in the ROWS Pond (Figure 2).

2 WAGERUP SITE INFORMATION

2.1 TOPOGRAPHY, PHYSIOGRAPHIC SETTING AND SURFACE DRAINAGE

The Wagerup Alumina Refinery is located on the eastern edge of the Swan Coastal Plain adjacent to the Darling Scarp. Much of the land on the coastal plain in the vicinity of Alcoa's Wagerup operations has been cleared for agricultural purposes. A map of the topography and surface water drainage in the Wagerup area is presented in Figure 3.

Topographic elevations decrease gradually towards the west from 40−50m AHD near the refinery, to between 15 m AHD and 20 m AHD around the RSAs. The Wagerup Refinery is situated on the Yoganup Shoreline landform, and the RSAs are on the Pinjarra Plain, which is mostly of alluvial origin.

Natural surface water in the Wagerup area flows to the west from the Darling Scarp across the Swan Coastal Plain. Most of the low-lying areas to the west of the Darling Scarp between Waroona and Harvey are prone to water-logging during winter and spring. Groundwater-dependent vegetation such as Melaleuca thickets occurs in isolated remnants across the coastal plain, and these are indicative of locally shallow water tables.

Surface water drainage in the Wagerup area was heavily modified when the region was originally cleared for agricultural purposes. Many shallow drains were cut into the land surface to control water-logging and reduce high groundwater levels during the wetter months. These drains continue to direct water into the Harvey River and ultimately the Peel-Harvey Estuary near Mandurah (Figure 1). Drainage channels are also used for transporting irrigation water-supplies and runoff from catchments in the adjacent Darling Range. Several dams have been constructed in the range to store surface water and service irrigation demands during summer.

The Wagerup Refinery and RSAs are located within the catchments of North Yalup Brook and South Yalup Brook. These streams have relatively small catchments with areas of <10 km^2 each. Surface water is directed around the RSAs by two channels – the Samson Brook South Drain on the north side, and the Diversion Drain on the east and south sides. Samson Brook South Drain is fed mainly by a small catchment to the north of the Wagerup Refinery near Waroona. The Diversion Drain intercepts some of the surface water from the catchments of North Yalup Brook, South Yalup Brook, the small catchment between the refinery and the RSAs, and overflow from Detention Pond 1.

All runoff generated within the Wagerup Refinery and from the RSAs is contained and directed to either the ROWS Pond or the Cooling Pond (Figure 2) for reuse in the ore processing circuit. In 2019, Alcoa received approval from DWER to construct and operate a spillway structure to provide controlled discharge from the ROWS pond. The construction of this structure is a recommendation of the ANCOLD and ICOLD guidelines to manage flow in extreme weather events. The spillway was completed in 2019. It will be activated only if required, for example, during a very wet winter.

2.2 CLIMATE

The Wagerup area generally experiences a Mediterranean-type climate, with hot dry summers and cool wet winters. On average, rainfall occurs during every month of the year with most falling during winter and spring (between May and September) (Table 3; Figure 4).

Alcoa maintains a weather station on the eastern side of the Wagerup Refinery with data provided to the Bureau of Meteorology (Station No. 009894). Rainfall and evaporation records have been collected at this station since 1981. Longer rainfall records are available from Bureau of Meteorology weather stations at Yarloop (Station No. 009624, 4 km south), Waroona (Station No. 009614, 9 km north) and Wokalup (Station No. 009642, 24 km south), although rainfall data post-2015 are not available from Yarloop or Waroona, and these stations appear to have been closed. Evaporation records are available from the Wokalup weather station for 25 years between 1969 and 2000.

Mean annual rainfall at the Wagerup Refinery is 841 mm (based on 39 years of records). Mean annual rainfalls at the Yarloop (981 mm), Waroona (992 mm) and Wokalup (959 mm) weather stations are 13–17% higher than Wagerup Refinery (Table 3). Mean monthly rainfall at the Wagerup Refinery ranges between 13 mm in January and 160 mm in July. Around 80% of annual rainfall generally occurs in the five-month period between May and September. Total annual rainfall recorded at Wagerup Refinery over the past three years has been as follows: 2020 experienced 755 mm of rainfall (90% of average rainfall), 2021 experienced 1042 mm of rainfall (124% of average rainfall) and 2022 experienced 775 mm of rainfall (92% of average rainfall). There is a general trend of decreasing annual rainfall at the Wagerup Refinery station since the mid-1990s.

Table 3: Wagerup area rainfall and evaporation data

Station	Average monthly rainfall/evaporation (mm)												Annual (mm)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Rainfall													
Wagerup Refinery[1,2,A]	13.9	14.1	18.8	42.8	114.2	155.7	160.3	132.2	98.9	46.5	35.4	12.9	841.3
Wokalup[2,3,B]	14.1	15.6	21.1	51.1	132.3	177.4	183.4	131.9	94.6	57.1	35.1	14.5	958.5
Waroona[4,2,A]	12.4	14.2	21.6	53.7	140.1	205.5	187.8	148.9	92.6	56.8	36.7	13.9	992.0
Yarloop[2,5,A]	12.5	14.9	19.6	51.5	131.8	194.1	177.8	142.7	95.5	58.1	35.0	14.0	980.9
Evaporation													
Wagerup Refinery[1,2]	310	268	228	151	109	75	73	79	104	139	217	306	2,059
Wokalup[6,2]	279	242	211	132	84	63	71	78	96	136	177	245	1,825

1. From Alcoa weather monitoring data (site BG002-) – eastern side of refinery. The data from this station is reported on the BoM site (Station No. 009894). Data record from 1981.
2. Records discontinuous.
3. Data record from 1951–Nov 2020.
4. Data record from 1935–Nov 2015.
5. Data record from 1947–Nov 2015.
6. Data record from 1969–2000.
A. Based on a statistical assessment of BoM daily dataset for all available data to March 2023.
B. BoM-compiled statistical values.

Mean annual pan evaporation at the Wagerup Refinery weather station is 2,024 mm, and historically 1,825mm at the Wokalup weather station. Monthly average pan evaporation rates at the Wagerup Refinery range between 63 mm in July and 310 mm in January and December. Pan evaporation exceeds rainfall on average for seven months of each year, between January to April, and October to December.

2.3 WAGERUP AREA GEOLOGY AND HYDROGEOLOGY

The Wagerup Refinery and RSAs overlie sedimentary units of the Perth Basin, and groundwater typically occurs at shallow depths in the area (that is, <5 m). A summary of the shallow stratigraphy in the Wagerup area is listed in Table 4, and a conceptual hydro-stratigraphic cross section illustrating the various hydrological units and directions of groundwater flow is presented in Figure 5.

The stratigraphic sequence in the Wagerup area, relevant to Alcoa's operations, broadly consists of Cenozoic (late-Tertiary and Quaternary) deposits and underlying Mesozoic deposits. The Cenozoic deposits are grouped into the 'superficial formations' (the term 'superficial formations" is an informal name that is used here, in the same sense as Davidson [1995], as a collective term to indicate the late-Tertiary to Quaternary formations of the Perth Basin).

The deposits making up the superficial formations in the Wagerup area are the Guildford Formation, Yoganup Formation, and Ascot Formation. These formations unconformably overlie the Leederville Formation, and at the Wagerup Refinery may overlie the older Cattamarra Coal Measures. While previous reviews of monitoring data and interpretation of borehole samples have inferred the occurrence of the Cattamarra Coal Measures at the Wagerup Refinery, this is being reconsidered within a broader scope of ongoing hydrogeological investigations by Alcoa.

Table 4: Wagerup area shallow hydro-stratigraphy

Formation	Description/characteristics
Superficial formations: Guildford Formation Yoganup Formation Ascot Formation	Late Tertiary to Quaternary sedimentary deposits ranging from dense clay to coarse sands and gravel. Forms a widespread unconfined or semi-confined aquifer where saturated.
Leederville Formation	Cretaceous sedimentary deposits, the upper sections of which in the Wagerup area are mostly dense silt and clay. Occasional thin sand layers or possible channel-lag (shoestring) deposits. Forms a basal aquitard to groundwater in the overlying superficial formations.
Cattamarra Coal Measures	Jurassic sedimentary deposits which may be present at the Wagerup Refinery beneath the Yoganup Formation. At Wagerup this formation, if present, is typically a fine grained and clayey unit that forms a basal aquitard to groundwater in the overlying Yoganup Formation.

The shallow stratigraphic sequence beneath the Wagerup Refinery consists of mainly a discontinuous layer of land fill (sandy clay and small amounts of ironstone gravel) and a thin layer of Guildford Formation (<2–3 m thick) overlying the Yoganup Formation. The Yoganup Formation has a maximum thickness of around 10 m near the refinery, and consists of clayey sand that grades downwards to sand (Wyrwoll 2002). These units are underlain by a mostly fine-grained sequence of silt and clay which has a smaller bulk hydraulic conductivity than the overlying sandy Yoganup sediments. The deeper fine grained units are of Mesozoic age, and form a basal aquitard to groundwater in the overlying Yoganup Formation.

In the vicinity of the Wagerup Refinery, the Yoganup Formation is partly saturated and is a semi-confined to unconfined aquifer. The groundwater flow is predominantly westward towards the RSAs, with some potential for downward flow to the underlying Mesozoic Formations.

The shallow stratigraphic sequence in the vicinity of the RSAs was reviewed as part of an investigation assessing the origin of elevated alkalinity levels to the west of the RSAs (360 Environmental 2016). The shallow stratigraphy in this area is interpreted to comprise Guildford Formation overlying the Ascot

Formation, which is inferred to inter-finger with the Yoganup Formation to the east of the RSAs. The superficial formations unconformably overlie the Leederville Formation at about 15 m AHD.

The Guildford Formation in the Wagerup area is typically a yellow- or grey-coloured clay, clayey sand, or clayey gravel which in some locations includes horizons of well-indurated ferricrete. The Guildford Formation occasionally contains thin layers of sand, which are inferred to be channel lag deposits. Stratigraphic data from drilling at RSA9 and ROCP3 identified thin sheets of relatively permeable sand within the Guildford Formation at this location. The total thickness of Guildford Formation in the vicinity of the RSAs ranges between 5 m and 15 m, pinching out to the east beneath the refinery. Some Guildford Formation appears to have been used as fill around parts of the refinery. Perched water tables are developed in some locations in the Guildford Formation above layers having very low hydraulic conductivities.

Investigations at RSA2 during 2009 identified a distinct layer of dense, grey or occasionally yellow clay which is inferred to be continuous beneath RSA2. This clay layer ranges in thickness between 0.5 m and 2.5 m, and has a relatively small primary hydraulic conductivity. This facies of the Guildford Formation is inferred to effectively form an aquitard within the sequence, at least locally, and has the potential to significantly limit the vertical movement of groundwater. A similar layer of clay was apparent in four shallow, cored boreholes that were drilled during 2010 for monitor bores at the northern end of RSA7, and in several of the boreholes drilled in 2011 and 2012 as part of the RSA9/ROCP3 construction project. This facies of the Guildford Formation may be widespread in the vicinity of the RSAs. Cross sections showing the inferred extent of the clay layer are presented in the 360 Environmental report (2016).

The Guildford Formation in the Wagerup area would generally not be considered as an aquifer, because it does not yield significant amounts of groundwater to bores or seeps. This formation has the characteristics of an aquitard and confines groundwater in the underlying Yoganup and Ascot Formations. The Guildford Formation has a lower bulk hydraulic conductivity than the underlying units, and for this reason the main direction of groundwater movement in the Guildford Formation is vertical. On the eastern side of the RSAs there is the potential for downward flow of groundwater from the Guildford Formation to the Yoganup and/or Ascot Formations. To the south-west of the RSAs the predominant direction of vertical groundwater flow is upward.

The Yoganup Formation crops out along the eastern margin of the Swan Coastal Plain and is overlain by Guildford Formation towards the west. In the general interpretation of Perth Basin stratigraphy, the Yoganup and Ascot Formations inter-finger, and at Wagerup the transition between these formations is inferred to occur west of the refinery. The location of the transition is not known with certainty, but is thought to occur between the refinery and RSAs, that is, between the ancient Yoganup Shoreline and Pinjarra Plain landforms.

Near the RSAs, the Ascot Formation consists of an upper layer of pale grey or white, fine to medium sand, and a lower layer of dark grey, fine to coarse silty sand and sand. In several of the boreholes around the RSAs the Ascot Formation has a characteristic basal layer of sandy gravel with round to sub-round pebbles up to 25 mm diameter. In the central and western parts of the RSAs the basal section of Ascot Formation consists of a fossiliferous sandy and clayey unit. Sample recovery has often been difficult in this basal unit because of the loose nature of the sediments, and it is possible this fossiliferous unit is more widespread than initially thought. The maximum thickness of the Ascot Formation is around 15 m at the RSAs.

The Ascot Formation is saturated in the vicinity of the RSAs and forms a laterally extensive confined aquifer. Groundwater pressure heads in this formation are at or near the natural surface, particularly during the

winter rainy season. Recharge to this aquifer is mainly by rainfall infiltration over outcrops along the eastern margin of the Swan Coastal Plain. In the Wagerup area, groundwater in this aquifer flows in a westerly direction towards the Harvey River Main Drain and the Harvey River.

The upper part of the Leederville Formation in the vicinity of the RSAs consists of a dense, dark grey-green to black clay, silty clay or sandy clay, which occasionally contains fine gravel and is characteristically micaceous. Secondary pyrite and carbonate minerals occasionally occur in the Leederville Formation at this location. This unit has a very low bulk hydraulic conductivity, and forms a basal aquitard to the confined aquifer in the overlying Ascot and Yoganup Formations. The potential for downward flow of groundwater and recharge to the Leederville Formation occurs to the east of the RSAs. Further west the direction of the vertical hydraulic gradient reverses, and here there is potential for groundwater in the Leederville Formation to seep into the overlying Ascot Formation.

Groundwater in the Leederville Formation tends to be naturally alkaline, and some cores obtained during drilling contain well lithified sections, up to 1 m thick, which are cemented with carbonate minerals.

Groundwater salinities in the Wagerup area range between about 500 mg/L and 5,000 mg/L. The most saline groundwater generally occurs within the Guildford Formation, where evapotranspiration and other physical processes, such as salt sieving, lead to the accumulation of salts in the clayey sediments.

2.4 WAGERUP OPERATIONS WATER SUPPLY

Process make-up water for the alumina refining circuit is largely derived from runoff collected at the Wagerup Refinery and the RSAs (Figure 6), runoff from the Yalup Brook catchment, and pumping from the Harvey River Main Drain. The harvesting of surface water from the Yalup Brook catchment and the Harvey River is subject to Department of Water and Environmental Regulation (DWER) licences (Table 5, Appendix C).

Table 5: Wagerup Alumina Refinery water harvesting licences

Location	Source	Licence number	Amount (ML/pa)	Expiry date
Lot 700	Superficial Aquifer	GWL 160881(3)	146.6	12 August 2026
Lot 205	Superficial Aquifer	GWL 102669(3)	550	16 May 2023
Lots 351 and 700	Yalup Brook	SWL 97472(6)	1,600	1 August 2023
Lot 244	Yalup Brook (includes Black Tom Brook)	SWL 99246(5)	2,500	1 August 2023
Lot 358	Harvey River Main Drain	SWL 151027(4)	4,400	1 August 2023

Small supplies of additional process water are obtained from DWER licensed groundwater sources (Table 5, Appendix B), including depressurising bores (some of which may also be utilised as production bores) and an underdrainage sump at the RSAs, alkali recovery bores at the Refinery, and a borrow pit with a groundwater connection to the north of the RSAs. Discharge from the depressurising borefields (ROWS Pond, Cooling Pond, ROCP2, and RSA9/ROCP3) is directed either to the adjacent water storage facility or Detention Pond 2. Groundwater produced by the four alkali recovery bores is directed into the alumina processing circuit.

The abstraction licences listed in Table 5 require compliance with an Operating Strategy. The current Operating Strategy (Appendix B) is combined but for part of the reporting period, up until October 2020,

there were separate Groundwater (Alcoa 2017) and Surface Water (Alcoa 2018) Operating Strategies (Appendix C). More detail on the water sources are available in these strategies.

Alcoa have a contract to purchase 2 GL/year of irrigation water from Harvey Water, which is a privately owned irrigation cooperative. During years when runoff yields have been insufficient to meet process water demands, up to an additional 4 GL can be purchased from Harvey Water.

2.5 SENSITIVE RECEPTORS

A risk assessment process has been used by Alcoa to identify potential sensitive receptors and develop groundwater and surface water monitoring programs for the Wagerup Operations (Section 3). The monitoring programs have been reviewed and updated iteratively on several occasions, the latest review being undertaken by Ecotech in 2015.

The potential sensitive receptors that might be affected by Alcoa's Wagerup Operations can be divided into three main categories: water supply receptors, ecological receptors and land receptors. A targeted monitoring program provides appropriate data to assess any possible adverse impacts at these receptors.

Table 6 lists the potential receptors identified in the original risk assessment (Parsons Brinkerhoff 2009) for the Wagerup operations: the monitoring program is outlined in Section 4.4.

Table 6: Potential sensitive receptors at Alcoa's Wagerup Operations

Type	Receptor	Area	Description
Water supply	Superficial Aquifer	Refinery	Shallow groundwater at the refinery potentially has beneficial use as irrigation and/or stock water; a small amount of groundwater is produced by the alkali recovery borefield at the refinery and subsequently used in the alumina refining circuit.
		RSAs	Groundwater from this aquifer at the RSAs currently supplies a small amount of the water used in the alumina refining circuit; potential beneficial use as irrigation and/or stock water.
		Regional	Groundwater from this aquifer has potential beneficial use as irrigation and stock water.
	Black Tom Brook	North of RSAs	Water used for industrial purposes, with provision for environmental water requirements.
	Yalup Brook	Refinery area	Water used for industrial purposes, with provision for environmental water requirements.
	Harvey River	Harvey River catchment	Water used for industrial and agricultural purposes, with provision for environmental water requirements.
Ecological	North Yalup Brook	Wagerup property	North Yalup Brook supports a moderately disturbed freshwater ecosystem; it is located entirely within Alcoa's Wagerup property.
	Harvey River	Harvey River catchment	Harvey River supports a moderately disturbed freshwater ecosystem.
Land	Neighbouring properties	Beyond Alcoa's Wagerup property	Predominantly agricultural and irrigation land use immediately beyond the property boundary.

3 WAGERUP GROUNDWATER AND SURFACE WATER MONITORING PROGRAMS

Alcoa has developed groundwater and surface water monitoring programs for the Wagerup Operations to satisfy the requirements of the regulatory licences as well as their own environmental operating policies and procedures based on the ANZECC/ARMCANZ guidelines (2000), and more recently the ANZG toxicant guidelines (2018), for water quality monitoring programs. These monitoring programs are reviewed periodically and are modified where necessary and/or recommended in the reports. The most recent comprehensive review of the monitoring program was undertaken by Ecotech in 2015. The monitoring program for the 2020-2022 water years is provided in Appendix D. Additional monitoring is also completed and the data are provided in this report, for stand-alone investigations.

3.1 HYDROCHEMICAL INDICATORS OF CAUSTIC FLUIDS IN WATER SAMPLES

Caustic liquor from the refinery area or caustic residue leachate from the RSAs has the potential to affect both groundwater and surface water quality. Parameters that have been monitored and used to indicate the presence of caustic liquid in water samples are: electrical conductivity (EC), pH, and total alkalinity. Sodium to chloride mass ratio is also referred to in the Bunbury monitoring data. Comments about how these parameters are interpreted follow.

Electrical Conductivity

Electrical conductivity (EC) is a measure of water salinity. The EC of natural groundwater in the superficial formations at the Wagerup site is quite variable, but is generally <1,000 µS/cm near the refinery and <5,000 µS/cm in the vicinity of the RSAs. Residue leachate can have an EC >30,000 µS/cm, and the EC of neat Bayer liquor is higher still. Thus, depending on the setting and the EC of the natural groundwater, changes in EC can provide an indication of the presence of caustic liquid in water samples. It is noted that in highly saline samples the approximately linear relationship between EC and total dissolved solids (TDS) does not apply, and TDS can be greater than inferred from the EC reading alone, due to an increase in non-ionic species present in the water samples. Hence, the magnitude of the increase in salinity at very high EC readings may not be accurately represented, and the value of total alkalinity may be a better indicator.

pH

Natural groundwater and the mineralogy of superficial sediments in the Wagerup area have a natural buffering capacity, which may inhibit changes to groundwater pH resulting from the presence of small amounts of caustic liquor. This, therefore, limits the usefulness of pH as a preliminary indicator for alkali migration. Groundwater pH can, however, be a useful indicator of the presence of significant concentrations of caustic liquor in water samples.

Total Alkalinity

Alkalinity as used in this report indicates total alkalinity at pH 4.5, expressed as mg/L $CaCO_3$.

Of all the water quality parameters that are regularly monitored at the Wagerup Operations, alkalinity tends to be the most reliable and sensitive indicator for the presence of caustic liquor in groundwater samples. However, reactions with the superficial sediments and groundwater can reduce the sensitivity of alkalinity as an indicator of the presence of small amounts of caustic liquor in samples.

Caution is also needed when interpreting the results of alkalinity analyses, as some groundwater samples collected at the Wagerup RSAs, particularly from those bores completed in the Ascot Formation to the west, have relatively high alkalinity. This is likely naturally-occurring, as concluded in an investigation by 360 Environmental (2016).

Sodium to Chloride mass ratio

The mass ratio of sodium to chloride in rainfall is about 0.6 and can be similar in natural groundwater. Caustic residue leachate has a Na/Cl mass ratio of at least 6, and thus the Na/Cl ratio of a groundwater sample is potentially a good indicator of the presence of leachate. However, sodium concentrations in groundwater can be influenced by mineral dissolution and ion exchange processes, and the sensitivity of Na/Cl ratios to increasing alkalinity is strongly dependent on groundwater salinity and aquifer mineralogy. These factors limit the utility of using Na/Cl ratios for determining whether water samples contain caustic liquor (Gerritse and Thomas 2005).

Alcoa presents Na:Cl ratios in annual reports because it is a requirement under licence L6217/1983/15 for the Wagerup Operations.

3.2 MONITORING SITES

An inventory of the groundwater and surface water monitoring sites at the Wagerup Operations is provided in Appendix D. This includes all the sites that have been monitored at the Wagerup Operations, including sites that have been decommissioned, and provides details on monitoring-site nomenclature. Current monitoring programs including monitoring objectives are listed in Appendix D.

3.2.1 GROUNDWATER MONITORING SITES

Monitoring of groundwater levels and hydrochemistry occurs at specified monitor bores, the depressurising bores, a dewatering sump and four alkali-recovery bores. Groundwater levels are also monitored with vibrating wire piezometers installed in the superficial formations beneath the ROWS Pond, ROCP2, ROCP3 and RSA9. Water levels and hydrochemistry are also recorded for the borrow pit, which has the ability to act as a sump. Locations of the above facilities are indicated in the following diagrams:

- Figure 7: Refinery monitor bores and alkali recovery bores;
- Figure 8: RSA monitor bores, vibrating wire piezometers, underdrain and depressurising bores; and
- Figure 9: Regional monitor bores and the borrow pit.

3.2.2 SURFACE WATER MONITORING SITES

Surface water monitoring sites are located on streams, drains, and water storages up slope of the alumina refining operations, within the vicinity of the refinery and RSAs, and down slope of all operational areas. This provides the opportunity to monitor surface water prior to it entering and after leaving the areas potentially affected by activities at the Wagerup Operations.

Locations of the surface water monitoring sites at the Wagerup Operations are indicated in Figure 3.

3.3 GROUNDWATER AND SURFACE WATER MONITORING PROGRAMS

Appendix D2 references the monitoring programs relevant to the current period of review. Minor changes to the program have occurred during the period of review and are documented in the table footnotes. Additional monitoring has occurred for targeted investigations.

3.4 MONITORING PROCEDURES, QUALITY ASSURANCE AND QUALITY CONTROL

The requirements and data quality control procedures for groundwater and surface water monitoring programs currently undertaken at Alcoa's Western Australian Operations have been developed in accordance with AS/NZS 5667. Ecotech Pty Ltd (Ecotech) carried out the monitoring, sampling and partial water analyses under contract to Alcoa. A list of monitoring and quality control procedures is provided in Table 7.

Water samples were analysed for pH, electrical conductivity, oxidation-reduction potential, alkalinity and turbidity by Ecotech. All other water analyses were conducted by the Envirolab MPL Laboratories. Each of the laboratories has NATA accreditation for the particular analyses they perform. Methods used by the laboratories are generally consistent with APHA-AWWA-WEF standards and are NATA accredited through an inter-laboratory quality comparison process with other accredited laboratories.

Ecotech reviews data quality either at the time of collection or prior to entry into Alcoa's database. Further data review is completed by Rockwater during the preparation of this report. These reviews indicate that the data are of sufficient accuracy and precision for use as a basis for interpretation. The data that have been collected for the preparation of this report are mainly consistent with historical data and trends.

Table 7: Monitoring and quality control procedures

ID	Description
EMS_1000	Determination of pH using the WTW Meter and Auto Titrator
EMS_1001	Determination of Electrical Conductivity Using the WTW Meter
EMS_1003	Determination of Alkalinity in Aqueous Solution
EMS_1006	Pipes Valves and Other Discharge Points
EMS_1008	Groundwater Monitor Well Sampling Using A Submersible Electric Pump
EMS_1009	Groundwater Monitor Well Sampling by Bailer
EMS_1010	Surface Water Monitoring and Sampling
EMS_1011	Determination of Static Water Level in Groundwater Wells
EMS_1012	Determination of Nephelometric Turbidity in Aqueous Solutions using a HACH 2100Q or 2100P Turbidity Meter
EMS_1013	Sampling and Analysis Requirements for Hydrocarbon Contamination Assessment
EMS_1014	Balance Calibration and General Requirements
EMS_1019	Calibration and Status Check of WTW Electrical Conductivity
EMS_1020	Calibration and Status Check of WTW pH Meter
EMS_1021	Calibration of Turbidity Hach Meter (2100P & 2100Q)
EMS_1022	Determination of Detection Limits
EMS_1023	Determination of Measurement Uncertainty
EMS_1025	Environmental Laboratory Fortified Matrix Testing
EMS_1031	Water Sample Storage and Preservation
EMS_1039	Auditing the Water Environmental Monitoring Program
EMS_1040	Collection of Field QA Samples
EMS_1041	Determination of ORP using the WTW Meter
EMS_1042	Calibration Check of Air Well Groundwater Flow Rates
EMS_1043	Determination of Dissolved Oxygen in Surface and Ground Waters
EMS_1047	Determination of Alkalinity using Mettler Toledo Auto Titrator
EMS_1049	Groundwater Monitor Well Sampling using a Low Flow Pump
EMS_1050	Determination of Alkalinity in High Alkaline Waters

4 WAGERUP INVESTIGATIONS AND MONITORING PROGRAM MANAGEMENT 2020-2022

4.1 BORE COMMISSIONING

Five new monitor bore pairs were installed at Wagerup Refinery in February 2020 as part of the recommendations from the Stage 2 Detailed Site Investigation completed in 2018 (360 Environmental 2019B). The bores were either replacements for lost/damaged monitor bores or new bores for further plume delineation.

Bore installation logs are provided in Appendix M.

4.2 BORE DECOMMISSIONING

No bores were decommissioned in 2020-2022.

4.3 INVESTIGATIONS

Since 2016 several investigations (360 Environmental 2017A, 2017B, 2017C, 2018B, 2019B, 2019C) have been completed at Wagerup Refinery to track the contamination and groundwater plumes. In 2017, three new bore pairs (monitor bores RF135G/S; RG220G/S; and RG221G/S, 360 Environmental 2018B) were installed to the west of the Former Hydrate Stockpile to further delineate the plume in the south of the refinery. Background soil sampling was completed (360 Environmental 2017A), along with an investigation to derive site-specific Tier 2 soil criteria for vanadium, gallium, magnesium and thorium (360 Environmental 2017B). In order to close some of the medium and low priority gaps (areas around the refinery that required investigation), Stage 1 of a detailed site investigation (comprising 72 soil bores) was completed throughout the refinery (360 Environmental 2017C, 360 Environmental 2018B).

Stage 2 of the detailed site investigation (360 Environmental 2019B [groundwater focussed]) led to the recommendation to install five monitor bore pairs around the central refinery as well as the installation of one recovery bore in the central refinery. During the FEL1 stage of the project this became a pair of recovery bores. Expected completion date for this project is Q1 2024. In 2019, Alcoa elected to commission an accredited Contaminated Sites Auditor to review investigations undertaken to date. The auditor has stated that he is satisfied that the overall quality and completeness of the assessments to date are adequate to form the basis for the current characterisation, and that progression to a Site Management Plan was appropriate once minor outstanding investigations were completed (Senversa 2020). The work completed over the last 7 years was the subject of a workshop to outline the Site Management Plan and ongoing Contaminated Sites strategy for Wagerup Operations in late 2022.

5 WAGERUP GROUNDWATER AND SURFACE WATER MONITORING DATA

5.1 VARIATIONS TO MONITORING PROGRAM

During 2020, 2021 and 2022, monitoring was conducted according to the licence monitoring program except when sampling was not possible as outlined in Table 8. These instances align with the circumstances where the site may be exempt from monitoring. Access, bore condition, and water levels did prevent some

monitoring from the internal program; details on this are available in the comments field of the electronic data files.

Table 8: Monitoring program summary

Site	Monitoring requirements	Status as reported during 2020-2022
D-021G	Annual pH, EC, alkalinity	Bore not working due to power issue – unable to sample 2021
D-033G		
D-034G		
RB002G	Annual comprehensive analysis, 6 monthly calibration	Bore not pumping – unable to calibrate in first half of 2020
RG027S	Quarterly groundwater level, Annual pH, EC and alkalinity	Bore was dry in Q1 2020, Q2 2020, Q1 2021, Q2 2021, Q2 2022 so no sample obtained.
SP006-	Continuous streamflow monitoring	Missing data May – September 2022 due to logger failure and long lead time for replacement.
SP010-	Continuous streamflow monitoring	Missing data July – September 2022 due to logger failure and long lead time for replacement.
SP020-	Continuous streamflow monitoring	Missing data September 2-12 2022 due to new logger positioning.
SP026-	Continuous streamflow monitoring	Missing data September 2 – October 3 2022 due to battery failure.

5.2 GROUNDWATER LEVELS

The groundwater level data from all monitor bores, vibrating wire piezometers and depressurising bores are presented in hydrographs in Appendix F.

Average second-quarter groundwater levels for the refinery and RSAs are shown in Figure 10 to Figure 12. Differences in vertical hydraulic-head at sites with more than one monitor interval are contoured in Figure 13 (2020), Figure 14 (2021) and Figure 15 (2022). Changes in average second-quarter groundwater levels at the Wagerup site are contoured in Figure 16 to Figure 18.

Figure 10 to Figure 12 show groundwater flow is generally in a westward direction across the Wagerup site in both the upper and lower superficial formations and the underlying Mesozoic formations. The horizontal hydraulic gradient on the water table is steep (about 0.01) beneath and immediately west of, the refinery, where the elevation of the water table falls from about 47 m AHD in RF050S to about 20 m AHD in RS116S/G (over approximately 1,750 m). The hydraulic gradient levels are lower beneath the residue storage areas (about 0.003), where the elevation of the water table falls from about 20 m AHD in RS116S/G to about 12 m AHD in RG219S/G (over approximately 3,500 m). Changes in horizontal hydraulic gradient may occur when there is a change in the formation transmissivity, or when vertical components of groundwater flow become significant. The observed change in hydraulic gradient at Wagerup is likely to be related to increased formation transmissivity towards the west, particularly in the lower superficial formations (Figure 5).

Slight cones of depression are evident in the groundwater levels beneath the RSAs likely due to the operation of the depressurising bores, particularly around the ROCP2 bores field. There is also some minor groundwater mounding to the east of the RSAs, possibly resulting from one or more of the following: pressurisation due to loading from the residue storage, restriction of groundwater flow due to construction of ponds with impermeable lining below the water table, seepage from the ponds, the transition between the Yoganup formation and the Ascot formation (Figure 5), and the transition to flatter topography (Figure 3).

The plans of vertical hydraulic-head differences between the upper and lower superficial formations bores (Figure 13 to Figure 15) indicate there is the potential for downward flow of groundwater in this formation over much of the Wagerup area, particularly over the eastern portion of the site. The head-differences tend to be largest in the vicinity of the depressurising borefields and/or in areas where a perched water table appears to have developed. Some upward head gradients also exist in the superficial formations, particularly to the south-west and west of the RSAs. Groundwater levels in the underlying Mesozoic Formations are generally slightly higher or neutral to those in the lower superficial formations, indicating minimal potential for downward flow of groundwater from the superficial formations to these formations.

Groundwater levels in the superficial formations between 2020–2022 have been seasonably-variable, however second-quarter averaged values are stable (Appendix F, Figure 16 and Figure 18). The Mesozoic Formations groundwater levels were largely unchanged (Figure 18).

5.2.1 REFINERY AREA

The monitor bores in the refinery area are generally completed in the Guildford Formation (S Series) and Yoganup Formation (G, I and Y Series), with some deeper bores (W Series) completed in the underlying Mesozoic Formations. Where present, the Guildford Formation tends to be <5 m thick.

The groundwater-level contours indicate westward groundwater flow beneath the refinery. Upper Superficial groundwater levels were generally stable, with local fluctuations of about ± 1.8-2.3 m over the review period.

Changes to groundwater levels with time in the refinery area are plotted as hydrographs in Appendix F (pages 20 – 38). The plots show historical seasonal fluctuations of between about 0.5 and 3 m, with the largest annual variations generally occurring to the south of the site. The magnitude of seasonal variations is generally the same in the upper and lower superficial formations, with the exception of some perched groundwater features where the fluctuation is dampened in the shallow bore. Seasonal variations in the underlying Mesozoic formation at the refinery tend to be less than those observed in the superficial formations, with the exception of bores RF041S/G/W to the south of the site, where the similarity in groundwater levels in the three bores suggests a hydraulic connection between the formations. The magnitude of the seasonal change in groundwater levels appears to be relative to the amount of rainfall in any given year, with trends generally upward in the refinery area since lows in 2016.

Northern Refinery Area

In the northern refinery area (between RF125S/G and RF038S/G) there was a general decline in groundwater levels from around 2000–2012, which appears to have been reversed since about 2012 to 2000 levels. Most bores in this area have seen trends of seasonal lows increasing over the last three years (generally increasing about 0.5 m per year) (Figure 16-Figure 18) with seasonal highs peaking in 2018 and 2021/22 (Appendix F). These trends may be related to climatic factors, with a notable reduction in rainfall in 2010 and 2015 (Figure 4). They could also be a response to local factors such as changes to surface conditions.

With the exception of some of the bores (RF129S/G, RF050S/G, RF051S/G and RF053S/G) where perching of groundwater is evident, most of the bores have the same or very similar groundwater levels in both the upper and lower superficial formations, indicating hydraulic connection within the superficial formation. Where groundwater levels have been measured in the Mesozoic formation (RF050W and RF127W), the potentiometric surface lies above the groundwater levels in the lower Yoganup, indicating upward head

gradients in this area, which will prevent downward flow of groundwater to the underlying formation. This may relate to difference in the hydraulic conductivity of the formations and/or the elevation of the recharge areas to the east of the site.

Any drawdown effects relating to operation of the recovery bores (RB001G and RB002G) are not marked.

Southern Refinery Area

In the southern refinery area (between RF041S/G/W and RF013S/G), the groundwater level trend has generally been relatively stable. There is marked perching of groundwater levels in monitor bore RF011S, located close to the recovery bores RB003G and RB004G; however, in most bores the groundwater level is the same or similar in both the upper and lower Yoganup bores. Where a difference does occur between groundwater levels in the S Series and G Series bores, it is usually in shallow bores that go dry, or where 'insufficient water' is reported, reflecting the possible presence of mud in the base of the bore or temporary perching. Drawdown-head effects relating to operation of the recovery bores (RB003G and RB004G) are not marked.

Bores in the area to the south-west of the refinery (RF022S/G to RF032S/G) have all shown an increase in groundwater level of 2 metres from 2021-22. This may be attributed to the late sampling in 2022 (samples were taken in May 2020 but August 2022), which coincided with a very high rainfall month in 2022, and higher than average winter rainfall in 2021 (Figure 4).

5.2.2 RESIDUE STORAGE AREAS

Monitor bores in the RSAs are mostly completed in the Guildford (S Series), Ascot (I or G Series) and/or Yoganup (Y, I and/or G Series) Formations. A few deeper bores (W Series) are completed in the Leederville Formation. The groundwater level data are supported by data from vibrating wire piezometers (H- or I-prefix).

Cooling Pond / RSA1

Groundwater hydrographs for monitor bores located near the Cooling Pond and RSA1 (Appendix F) show no discernible trends relating to the operation of these facilities, with the exception of higher water levels in the shallow monitor bores at RS043S/G (north-east corner cooling pond) and RS050S/G (south-west corner of cooling pond next to RSA1), which have developed since about 2009. Groundwater levels are generally the same or similar in most of the shallow (S Series) and deeper (G Series) monitor bores suggesting hydraulic connection within the superficial formations. However, downward head gradients do occur naturally in some bores (RS041S/G, RS045S/G) and during periods of minimum groundwater levels, indicating some restriction of vertical groundwater flow. Groundwater levels in 2020–2022 were within the range of historical levels.

RSA1 / RSA2 / Sand Lake

Some minor elevation in groundwater levels in the upper and lower superficial aquifer (S Series and G Series data) appears to have occurred to the immediate north of RSA1/RSA2 in bores RS063S, RS064S and RS065S. Groundwater levels measured in these bores in 2020–2022 have increased on average 1.2 m; however, the levels remain within historical limits (pre 1997).

RSA3 / RSA4 / ROCP1

Historically groundwater levels show no discernible trends relating to the operation of these facilities. Groundwater levels measured in 2020–2022 remain within historical values. Groundwater levels are the same or similar in most of the shallow (S Series) and deeper (G Series) monitor bores suggesting a degree of hydraulic connection within the superficial formations, although small upward head gradients do appear to occur naturally in some bores (RS094S/G and RS100S/I/G), particularly near the south-west corner of the area. Bore RS094S/G showed a period of lower levels (11.2 m AHD) in 2010 to 2015, subsequent monitoring has shown a return to historical levels of 13-14 m AHD. This bore fluctuates seasonally and the apparent variation in water levels in 2021 can be attributed to the month in which they are taken (i.e May levels in 2021 are compared to July 2022 levels in Appendix F).

Monitor bores RS146S/G/W, immediately west of ROCP1, include a bore completed in the Leederville Formation. Groundwater level data from these bores show the potentiometric head in the Leederville Formation generally lies above groundwater levels in the superficial formations indicating potential upward flow of groundwater into the overlying Ascot Formation.

RSA6 / ROCP2

Bores completed to the south of these facilities (RS063S/G, RS064S/G and RS111S/I/G) generally follow the trends noted for RSA1/RSA2. Bores a little to the north (RS137S/G to 142S/G) show a gradual rising trend in minimum groundwater levels in both the shallow and deep monitor bores, rising by approximately 0.05 m/yr and 0.15 m/yr since measurements commenced in 1998.

Groundwater levels monitored in the vibrating wire piezometers in ROCP2 (I-001- to I-003-) are also showing an increasing trend with the highest levels on record during the review period, peaking at 17.8, 16.8, 17.4 m AHD respectively. The levels in ROCP2 ranged from 17 to 19.9 m AHD in the reporting period. As the groundwater levels are nearing pond levels (Figure 57, Plot 2) it is advised to increase the extraction from corresponding depressurising bores D-010G, D-013G and D-014G, and re-connect western depressurising bores D-011G and D-012G.

Groundwater levels are the same or similar in most of the shallow (S Series) and deeper (G Series) monitor bores suggesting a degree of hydraulic connection within the superficial formations. However, downward head gradients do occur naturally in some bores (RS141S/G, RS142S/G) and during periods of minimum groundwater levels indicating some restriction to downward flow.

ROWS Pond

No discernible groundwater-level trends are evident relating to the operation of these facilities. Groundwater levels appear to be naturally higher in most of the shallow (S Series) bores compared with the deeper (G Series) monitor bores, indicating downward head gradients. The area to the east of these bores is likely a region of groundwater recharge and this would contribute to higher groundwater levels in the shallow formation. Prior to about 2007, RS118S/G and RS119S/G on the southern perimeter had very similar water levels in both the S and G series bores, but after about 2007 the S bores have tended to have higher levels, with the difference becoming more pronounced in the last three years. There is an anomalous reversal in groundwater head gradients at RS123S/G, where the data infers an upward head gradient has predominated since 1998, possibly due to a nearby diversion drain lowering shallow groundwater levels slightly. However, seasonal maxima in 2016 to 2022 were higher in the shallow bore (S series). Seasonal maxima in RS123S correlates with peaks-flow periods in the nearby drain (SP016; Figure 62). Groundwater levels measured during 2020–2022 indicate conditions remain stable at the ROWS Pond. Groundwater

levels monitored in the vibrating wire piezometers (H-002- and H-005-) are generally consistent with the above. The exception being vibrating wire piezometer H-005-, which showed several periods of abnormal readings (Figure 53), with recorded peaks of 63.3 m AHD (likely to be an error and clipped from plot in Figure 53). This may indicate the VWP is starting to fail.

RSA7

Groundwater hydrographs for bores on the western flank of RSA7 generally show no discernible trends relating to the operation of these facilities. Bores on the northern perimeter (RS189 S/G to RS191S/G) show a slight increasing trend, and less deviation in seasonal variation than previous reporting periods.

Groundwater levels are the same or similar in most of the shallow (S Series) and deeper (G Series) monitor bores suggesting a degree of hydraulic connection within the superficial formations. A downward head gradient exists between the upper and lower superficial formations in RS168S/G/W, indicating a potential for downward movement of groundwater as well as some restriction of flow between the Guildford and Ascot Formations. Groundwater levels at this site are the same in the Ascot and Leederville Formations, suggesting some hydraulic connection between the two.

RSA8 / Detention Ponds

Groundwater hydrographs show generally stable or declining groundwater-level trends, with notable downward head gradients in the superficial formations occurring at a number of locations (that is, groundwater levels in S Series bores significantly higher than G Series bores) (RS169S/G, RS174S/G, RS175S/G, RS177S/G). This may be due to pumping from the depressurising bores operating at ROCP2, relatively high rainfall recharge rates, and/or possible localised infiltration from the detention ponds or the diversion drain. Water quality results (Section 5.3.3) do not point to a clear source of infiltration.

Groundwater levels were generally within their historical ranges in 2020–2022, with the exception of a defined peak in all upper superficial bores in September 2022, following above average rainfall in July and August 2022. No variation was made to the pumping of nearby depressurising bore D-013G, and levels in lower superficial bores remained stable.

RSA9 / ROCP3

Groundwater hydrographs indicate a relatively steep decline in groundwater levels between 2011 and 2014, reaching minima of between about 8.5–11 m AHD in early 2014 before rebounding approximately 1–3 m in 2015, with minima around 12 m AHD. The decline and rebounding trends are related to dewatering using the depressurising bores during construction of these facilities, which occurred between 2012 and 2014. Groundwater levels are the same or similar in most of the shallow (S Series) and deeper (G Series) monitor bores, suggesting a degree of hydraulic connection within the superficial formations, although downward head gradients are notable in some bores, possibly related to periods of strong pumping. Groundwater levels monitored in the vibrating wire piezometers (H-007S/G to H-018S/G) are consistent with the above. Several vibrating wire piezometers are recording erroneous data (H-009S/G, H-010S/G, H-011S, H-012S/G, H-013G, H-014S, H-015G, H-016S/G, H-018S and potentially H-017G) and it recommended that these are serviced/calibrated when a contractor becomes available.

5.2.3 REGIONAL MONITOR BORES

The regional monitor bores are shown in Figure 9 and groundwater hydrographs are presented in Appendix F. The bores are mostly located between the refinery and residue storage areas; around the perimeter of

the RSAs, and; to the south of the Wagerup site. There are a few other bores located to the north and west of the site.

In general, there are no marked water-level trends in the regional monitor bores, with groundwater levels being fairly stable within their annual seasonal fluctuations. Some possible exceptions are monitor bores RF034S/G/W, RF035G/W, RG007G, RG011G, RG014G, RG020G, RG022G, RG034G, RG035G and RG036G, where there may be long-term declining trends. The declining trend stabilised between 2010 and 2016, with a rising trend from about 2017. The water levels have since remained stable at the elevated level, with an increase of up to 3 m (RG034G) and 6 m (RG036G) since 2016.These bores are located around and to the west of the refinery, where similar trends have been noted and attributed to drying climatic conditions (Section 5.2.1). For RG036G, it is likely related to the use of an inaccurate survey level between 1982 and 2015. This bore was resurveyed following headwork repairs after the 2016 Waroona fire and the surveyed level was 2.6 m different to the 1982 surveyed level and closer to the 1981 surveyed level. The reason is unclear for RG034G and RG080G, but they may be artefacts of increased monitoring frequencies, or due to infiltration from nearby drains.

Groundwater levels in the Leederville Formation (W Series bores) are mostly similar to or slightly above those in the lower superficial formations (G Series) indicating neutral or small to moderate upward head-gradients across the Wagerup site, and in general the seasonal variation is the same or dampened in the Leederville bores. At RG027S/G/W the groundwater levels in the Leederville Formation show minimal seasonal variation, with groundwater levels in the superficial formations fluctuating over elevations above and below those in the underlying formation. The disconnect in aquifer response suggests limited connection between the aquifers at this site.

Since 2007, groundwater levels in monitor bore RG025G have peaked well above the groundwater levels in the underlying Leederville Formation, suggesting mounding resulting from restricted flow though the RSA region.

A perched water table is apparent in monitor bore RG156S, to the north of the detention ponds. However, this appears to be natural or related to agricultural activities, as it lies some distance from the RSAs and is located next to a drainage channel, suggesting an area of natural water logging. Similarly, a perched water table exists in RF035S, located on a drainage channel to the west of the refinery. Groundwater levels in RG158S are more variable than those in the deeper monitor bores at that location (north-west corner of the Wagerup site), but these appear to be influenced by conditions off-site, as no similar response is observed in other monitor bores.

Off-site monitor bores

Monitor bores B-001- to B-003- are located off-site to the south-west, and are completed in the Leederville Formation (B-002- and B-003-) and superficial formations (B-001-, though B-001 may also be slotted into the upper Leederville Formation). Groundwater level trends are similar to those at the Wagerup site that are unaffected by operations. Figure 13 to Figure 15 suggest a slight increase in the upward-head areas from 2020–2022. The groundwater level trends are similar in all bores but with dampened seasonal variations in the deeper bores. The April 2020 readings from the deeper bores were notably lower than previous records. These anomalous readings may be a measurement error or a result of local groundwater changes. Groundwater levels returned to historical levels and were stable during 2021-22. The slotted casing in these bores occurs at different levels to the majority of the Wagerup monitor bores, with B-002- and B-003- slotted at greater depths than other Leederville bores on site. Nearby monitor bores RG219S/G/W all have

very similar water levels (and similar to those in B-001-), indicating a degree of connection between the formations at this location.

5.2.4 DEPRESSURISING BORES

Groundwater hydrographs for the depressurising bores are presented in Appendix F. The bores are located in three main areas: on the west and south-west perimeter of the residue storage areas, around ROCP1/RSA9/ROCP3; to the east of RSA6, around ROCP2, and; to the south-east, around the ROWS Pond. They are completed in the lower superficial formations (G Series). The trends in groundwater levels are generally consistent with those reported above. Further details are presented in Section 5.4.1.

5.2.5 SUMMARY AND CONCLUSIONS

- The hydrographs for monitor bores not notably affected by Wagerup operations show seasonal fluctuations, with minima in late autumn, before the onset of the winter rains, and maxima in late spring. Seasonal variations are apparent in monitor bores completed both in the superficial formations and the Mesozoic formations. At sites with two or three monitor bores completed at different depths, the seasonal range of groundwater levels is generally similar for the superficial bores and somewhat less in the deeper formations. The general pattern of seasonal groundwater level variations is similar throughout the Wagerup area with fluctuations in groundwater levels generally ranging between about 0.5–2.5 m.

- Operation of the depressurising borefield at ROCP2 (and RSA9/ROCP3 between 2012 and 2014), where groundwater is pumped from the lower superficial formations, may have created a slight depression of groundwater levels in monitor bores completed in the upper and lower superficial formations near these borefields. The impact was greatest in 2014 when construction and maintenance of RSA9/ROCP3 was undertaken. Groundwater levels had fully recovered by 2015, and data collected from 2019-22 suggests maxima had generally returned to the previous usual levels.

- A perched or elevated water table is inferred by the data from some bores where there may be greater rainfall recharge and/or restricted hydraulic connection between the upper and lower superficial formations. The difference in groundwater levels between the shallow Guildford Formation bores and the deeper Ascot or Yoganup Formations bores may be influenced by production from the lower aquifer or possible infiltration from surface water storage sites such as the detention ponds, ROCP2 or the duck pond. Elevated groundwater levels in the vicinity of the Sand Lake may represent hydraulic connection between the water body in the Sand Lake and the monitor bores, through the dyke; it is noted however, that this interpretation is based on results from an older bore where the data may be compromised by surface water ingress down the bore annulus. Water quality at this site is further discussed in section 5.3.

- Groundwater levels in monitor bore RS123S, immediately east of the ROWS Pond, are generally about 5 m lower than groundwater levels in nearby shallow monitor bores. The depressed groundwater levels at RS123S have been apparent for most of the past decade. RS123S is located close to the Diversion Drain (see Figure 3 and Figure 8), and the groundwater-level depression may be related to the close proximity of the drain, which likely

captures shallow seepage from the upper superficial formations. Seasonal maxima in RS123S correlate with peak-flow periods in the nearby drain (SP016; Figure 62).

- Differences between groundwater levels at sites with shallow and deep monitor bores indicate the potential for downward flow from the upper to the lower superficial formations in the eastern part of the refinery and over the north and eastern of the RSAs. The direction of the vertical hydraulic gradient between these units tends to reverse to the south and west of the RSAs, where there is potential for upward flow of groundwater from the lower superficial formations to the upper superficial formations.

- The average groundwater level in shallow monitor bore RS175S is generally more than 5 m above the groundwater level in the adjacent deep monitor bore RS175G. This pair of monitor bores is located on the east side of Detention Pond 2 and similarly large differences in groundwater levels have prevailed since the bores' installation in 2006. Groundwater levels at a few nearby shallow bores are also significantly higher than those in the adjacent deep bore, indicating a relatively strong potential for downward flow of groundwater from the upper to the lower superficial formations in this area. The cause of the inferred perching is unclear, but it may be related to rainfall recharge on the plain to the east, local geology (that is, transition between lithologies associated with the Yoganup Shoreline and the Pinjarra Plain), infiltration from the detention ponds and/or depressurising of the lower formation. Vertical hydraulic flow is clearly restricted, most likely by low-permeability clays in the area. It is also possible that the clay liners of the RSA facility restrict natural groundwater flow from the east, causing groundwater mounding along the eastern perimeter where the liners extend below the water table. Regional bore RG025G/W is also in this area, where increased spring groundwater levels have been noted previously.

- The vertical head differences between the lower superficial formations and the Mesozoic formations in 2020–2022 suggest that upward flow of groundwater predominates over a large part of the Wagerup area. This is consistent with the historical data and reflects natural conditions in the area.

- The apparent long-term declining trend in some regional bores (RF034S/G/W, RF035G/W, RG007G, RG011G, RG014G, RG020G, RG022G, RG035G and RG036G) stabilised between 2010 and 2016, with a rising trend from about 2017 to present.

There are very few anomalous results that are apparent in the 2020 to 2022 groundwater-level data (Appendix F). The data are generally of a very high quality, other than for the offsite bores B-002- and B-003- in April 2020.

5.3 GROUNDWATER CHEMISTRY

The spatial distributions of groundwater pH, electrical conductivity (EC), and alkalinity during 2020 to 2022, and the changes that have occurred in these parameters since the previous year are presented in Figure 19 to Figure 49. The trends apparent in these data are discussed separately for the refinery, the RSA area and regional bores in the following sections.

Groundwater quality data are discussed in Section 5.4 (alkali recovery bores) and Section 5.5 (depressurising bores). Time-series graphs for key water quality parameters, pH, EC and alkalinity from the monitor and production bores are included in Appendix G.

5.3.1 OVERVIEW

Groundwater pH

Groundwater pH values (Figure 19–Figure 29) range from about 5.0 to 7.0 in the upper superficial formations, indicating slightly- to moderately- acidic conditions. On the northern perimeter of the RSAs, the pH of monitor bores RS168S and RS171S sometimes falls below 5. Slightly-elevated pH (>7.0) occurred in RS098S at RSA9 in 2020 and regionally at RG027S, and significantly-elevated pH (>9) values are measured beneath the refinery itself, particularly to the south. In the lower superficial formations, pH ranges from slightly acidic (about 5) to circum-neutral (up to 7.4), with the higher values generally extending from the RSAs to the west. Significantly elevated pH values are also measured in the lower superficial formations at the refinery, and in near-by regional bores. The pH in the underlying Mesozoic formations is circum-neutral (6–8).

Groundwater Electrical Conductivity

Groundwater salinity in the superficial formations, as measured by electrical conductivity (EC) (Figure 30 to Figure 40), generally ranges from fresh (<1,000 µS/cm) along the scarp to the east, where natural recharge is likely to occur, to brackish (>5,000 µS/cm) on the plains to the west. This salinity distribution likely reflects natural conditions in the Wagerup area; however, elevated salinity values (>10,000 µS/cm) are notable at some locations beneath the refinery and the RSAs, particularly in the upper superficial formations. There is a zone of mixing (EC between 1,000 µS/cm and 2,000 µS/cm) that occurs where the land begins to level out just east of the RSAs, and this zone extends some distance to the west in the lower superficial formations south of the Wagerup site. Given the higher salinity in the upper superficial formations in this location, this likely represents a region of greater hydraulic conductivity in the lower formations. Localised areas of lower salinity in the upper superficial formations on the southern perimeter of the RSAs are coincident with upward groundwater-head gradients and are probably areas of upward discharge from the lower formation. The annual-average salinity in the underlying Mesozoic formations is generally slightly brackish (between about 1,700–4,000 µS/cm): an area of elevated salinity (>7,000 µS/cm, RF050W) is notable beneath the refinery.

Groundwater Alkalinity

The spatial distribution of groundwater alkalinity values (Figure 41 to Figure 51) suggests regional-area alkalinity values range from about 2–400 mg/L in the superficial formations and about 120–280 mg/L in the Mesozoic formations. Areas of elevated alkalinity (generally between 200–500 mg/L but reaching about 850 mg/L) are evident beneath the RSAs and extend to the west in both the upper and lower superficial formations, as well as beneath the refinery (where maximum values exceed 150,000 mg/L). The pattern of elevated alkalinity distribution suggests possible downward migration of leachate from point sources at the refinery and RSAs (ROCP1 and/or RSA1/RSA2), diffusing and migrating to the west in the lower superficial formations, although it is likely that the higher alkalinities to the west of the RSAs are naturally-occurring (360 Environmental, 2016). No significant migration to the underlying Mesozoic formation is apparent (Figure 43).

5.3.2 REFINERY AREA GROUNDWATER CHEMISTRY

Time-series plots of groundwater chemistry data from the refinery area are presented in Appendix G. Contour plans for key parameters in the refinery area are provided in Figure 25 to Figure 27 (pH), Figure 36 to Figure 38 (EC) and Figure 47 to Figure 49 (alkalinity). The detailed contour plots for monitor bores

completed in the superficial formations at the refinery site indicate significantly elevated pH, EC and/or alkalinity in four main areas, in order of apparent impact, in the:

1. Southern area of the refinery in the vicinity of Building 45;
2. Northern area of the refinery near Buildings 26, 25A, 30 and 35F;
3. Central area of the refinery in the vicinity of Buildings 47, 42A and 40; and
4. South-western area of the refinery near the Caustic Unloading Area and the former hydrate stockpile.

These sites broadly coincide with the areas identified in Golder Associates' Desktop Groundwater Assessment, as reported in a technical memorandum (Golder Associates 2015) and more recent contaminated sites investigations (Section 4.3). The concentration and distribution of the key parameters are indicative of likely point-source seepage from leaks and spills of caustic process liquor and/or bauxite slurry. The impact of seepage is significant in both the upper and lower superficial formations, indicating downward flow of the caustic liquor to the deeper groundwater intervals. The impact is less evident in alkalinity concentrations; however, pH remains high (up to 12) in the lower aquifer.

Current trends are summarised below (site locations shown in Figure 7).

Southern Refinery Area
Building 45

Groundwater quality has been most significantly impacted by operations in the western vicinity of Building 45 in monitor bores RF011S/G, RF017Y, RF019Y, RF020S/Y and RF021Y and recovery bores RB003G and RB004G.

The hydrochemistry plots (Appendix G, Pages 14 & 15) show groundwater quality in RF011S was affected by process operations when it was constructed in 1995, and that continual seepage from that time has resulted in an overall increasing trend in EC and alkalinity. pH has remained relatively stable at about 13 pH units over the last 20 years. In the deeper bore at this site, RF011G (Appendix G, page 14), groundwater quality remained relatively unaffected until 2006 when pH, EC and alkalinity rose sharply. This was followed by a general decreasing trend for these parameters, particularly from 2011. In 2014, values returned to near background levels briefly, before EC and alkalinity returned to values slightly higher than those measured in 2013. pH has generally been in the range of 10 – 11.5 pH units since 2006. Recent sampling has noted a continuation of the increasing trend in both EC and alkalinity in these bores. EC and alkalinity values peaked at around 200,000 µS/cm and 160,000 mg/L, respectively in RF011S in 2021, and the same peak was apparent in the following year (2022) in RF011G, with EC and alkalinity around 10,000 µS/cm and 4,500 mg/L, respectively. These are the highest groundwater EC and alkalinity values on record for both the shallow and deep bore at this site (RF011). This may be a result of continued pumping from RB003G/4G, drawing alkaline water from the Building 45 area, as this bore is located in between the recovery bores and Building 45.

During 2020-22, groundwater pH ranged from 9.4 to 13 in the shallow bores and about 9.2 to 13 in the deep bores. Groundwater salinity ranged from about 230–200,000 µS/cm in the shallow bores and from about 300–63,000 µS/cm in the deep bores, also with values generally within historic variation. Groundwater alkalinity ranged from about 60,000–65,000 mg/L in the shallow bores, and from about 3,250–13,000 mg/L in the deep bores. The impact is centred on monitor bores RF011, RF017, RF019 and RF021.

Other active monitor bores located near Building 45 include: RF013S/G, RF014S/G, RF016Y, RF018 to 20Y, RF045S/G, RF046S/G, RF131S/G, RF132G, RF133W and RF134G. Of these monitor bores:

- RF045S/G, RF046S/G, RF132G, and RF134G have historically shown water quality parameters at elevated levels (that is, pH >7.5, EC >1,000 µS/cm and alkalinity >150 mg/L). Continued sampling has seen these bores return to low levels, except the pH in RF046G which remains at around 11.
- RF018Y pH historically increased by 2.7 in 2016 and a further 0.4 in 2017 with accompanying increases in EC and alkalinity. The 2018 to 2022 results returned to more typical values for all parameters, with levels now at pH 5.5, EC 208 µS/cm and alkalinity 27 mg/L.
- RF019Y pH values increased from 7.0 in 2017 to 10.2 in 2022, coinciding with steep increases in EC and alkalinity (1,500 to 4,900 µS/cm and 400 to 2,500 mg/L respectively).
- RF020Y pH values increased from 8.0 in 2017 to 11.5 in 2022, with EC and alkalinity continuing an increasing trend.

Elevated readings in RF019Y and RF020Y coincide with the rapid increase in alkali recovery from RB004G (further discussed in section 5.4) which is likely to be in a concentrated form.

Monitoring data in Building 45 region suggests the following trends from 2020 to 2022:

- pH values have generally remained stable in the Upper Superficial formations and have risen slightly (<1 pH unit) in the Lower Superficial formations.
- Alkalinity values have remained fairly stable (±<1000 mg/L) in both the Upper and Lower Superficial formations except for bores RF011S and RF017Y which fluctuated by 130,000 and 8,000 mg/L respectively.
- Electrical conductivities were stable in the Upper Superficial formations, except for RF011S which decreased 57,000 µS/cm after a peak of nearly 200,000 µS/cm in 2020. In the Lower Superficial formations, the EC generally remained stable except for bores RF11G and RF17Y, which increased by 3,820 and 11,700 µS/cm respectively.

These trends suggest that the two alkali recovery bores (RB003G and RB004G (Figure 7), constructed to the west of Building 45 in 2014) are having a positive impact on groundwater chemistry in the Building 45 vicinity. Further information on the operation and water quality of these recovery bores is provided in Section 5.4.

Caustic Unloading Area

Monitor bore RF015S/G is located at the Caustic Unloading Area, 250 m west of Building 45.

In the shallow monitor bore, RF015S, EC and alkalinity levels have been gradually decreasing since 2009, from maximum values of about 4,500 µS/cm and 1,200 mg/L for EC and alkalinity, respectively, to the current levels of about 240 µS/cm and 100 mg/L. Significant containment improvement at the caustic unloading facility was completed in early 2008 including a widened concrete sealed containment area incorporating curbing and a steel lined box drain that transfers spilt caustic to the 06D tank. Groundwater pH followed a similar trend, reaching a maximum value of about 12, and decreasing to the current value of about 8.5.

Results from the deep bore are variable. RF015G pH ranges from about 6–10, with EC ranging from about 6600–2,500 µS/cm and alkalinity up to about 1,200 mg/L (from 150 mg/L) during the 2020–2022 review period. Result variability can be attributed to the sampling method. Samples are typically collected using a high-flow pump (MP1), whereas the April 2016 to October 2017 samples were collected using a low-flow bladder pump, as they were collected for a contaminated sites investigation. These data suggest that alkali fluids have historically reached the lower formation at this location. Monitor bore RF015G was blocked in 2018 and 2019) but has been sampled successfully since 2020.

Monitor bores RF049S/G are located about 180 m west of Building 45 and 125 m east of the Caustic Unloading Area. The groundwater quality results indicate a general increasing trend for key parameters in the shallow bore; however, since about 2017, the EC and alkalinity have decreased to about 2,000 µS/cm and 1,000 mg/L in 2022. Groundwater quality in the deeper bore is consistent with natural conditions. The occurrence of alkaline fluids in the shallow bore but not in the deeper bore suggests groundwater quality at this site is affected by a nearby source. Monitor bores RF135S/G, RG220S/G and RG221S/G were installed in 2017 down-gradient of the caustic unloading area and former hydrate stockpile for plume delineation. The results indicate that the plume may have migrated in the Yoganup Formation as far as RF135G but not to the other bores further west. The early, more-elevated results may be related to incomplete bore development.

Former Hydrate Stockpile

Groundwater quality in this area, to the south-west of the refinery site, is monitored by active monitor bores RF023S/G, RF025S/G, RF026S/G, RF027S/G, RF032S/G, RF033S/G and RF013S/G.

Groundwater parameters in most of these bores are currently at or near background conditions (that is, pH <7.5, EC <1,000 µS/cm and/or alkalinity <150 mg/L) with the exception of elevated pH in monitor bore RF033G (about pH 9) and elevated alkalinity in monitor bores RF025G and RF033G, where historically some impact has occurred. Groundwater quality trends are generally stable or decreasing.

Northern Refinery Area

Buildings 26, 25A, 30 and 35F

Groundwater quality has been most significantly impacted by operations in the vicinity of Building 26 in monitor bores RF122S/G, and a plume apparently extends between Building 35F and 25A. The area is monitored by active monitor bores RF001G, RF003S/G, RF005S/G, RF006S/G, RF036S/G, RF038S/G, RF039S/G, RF043G, RF044S/G, RF086G, RF122S/G and RF123S.

The groundwater quality data for monitor bores RF122S/G indicate that alkali fluids have impacted the upper superficial formations at this location. The results from the 2020–2022 monitoring for RF122S show pH is currently about 12.5, EC is about 25,000 µS/cm and alkalinity is 5,000-10,000 mg/L, with an overall decreasing trend in EC and alkalinity since 2010, despite increases in 2017, 2018 and 2022. Alkali fluids appear to have been largely contained within the upper formation, with the deeper bore being much less impacted. Trends are fairly stable or decreasing in RF122G within seasonal variations, which have dampened in more recent years.

Elevated pH, EC and/or alkalinity values (that is, pH >7.5, EC >1,000 µS/cm and/or alkalinity >150 mg/L) have been measured in monitor bores RF001G, RF003S/G, RF005S, RF006S, RF036S/G, RF039S/G, RF043G, and RF123S. These bores show pH ranges from about 6.5–13, EC ranges from about 700–3,000 µS/cm, and alkalinity ranges from about 150–1,200 mg/L. The trends in these bores are generally stable or declining, or fluctuating within recent seasonal variations, except bore RF003S, which showed a minor increasing trend.

In general, groundwater quality is stable or improving in this area of the refinery (see further discussion in section 5.4.1).

Central Refinery Area
Buildings 47, 42A and 40

Groundwater quality has been impacted by operations in the vicinity of Building 47 at monitor bore RF130S, in the vicinity of Building 42A at monitor bore RF126S/G, and to a lesser extent in the vicinity of Building 40 at monitor bore RF124G. The area is monitored by active monitor bores RF009S/G, RF040S/G, RF047S/G, RF048S/G, RF124G, RF125S/G, RF127S/G/W, RF128S/G, RF129S/G and RG012G.

The groundwater quality data for RF130G/S, near Building 47, show elevated values of the key parameters in the shallow bore, with pH of about 8.5, EC of about 12,000 µS/cm, and alkalinity of about 4,000-7,000 mg/L, with values now stabilising after a previous increasing trend. Groundwater constituents in the deeper bore are within the range of natural groundwater at this location. The presence of elevated salinity and alkalinity in the shallow bore only suggests seepage of caustic fluids from the surface at this site, with restricted downward flow. Nearby monitor bores RF040S/G show a similar pattern, with increasing trends of salinity and alkalinity in the shallow bore; however, there is only a slight increasing trend in the deeper bore.

Monitor bores RF047S, RF048S (now decommissioned and replaced with RF137S/G) and RF129G are located about 125 m east of Building 47, and about 40 m down hydraulic gradient of monitor bores RF040S/G. These bores (Except RF137S/G) also show elevated pH, EC and/or alkalinity values (that is, pH >7.5, EC >1,000 µS/cm and/or alkalinity >150 mg/L). Within these bores, pH ranges from about 6.8–10, EC ranges from about 510–3,500 µS/cm, and alkalinity ranges from about 240–1,700 mg/L. Bore RF047S was dry for the entirety of the reporting period. The EC, pH and alkalinity peaked in bore RF129G in 2020 and has since shown a declining trend, returning to background levels in 2022. Bore RF134G has been sampled using low flow methods (as recharge is very slow), and recorded pH values between 5.5 and 6.3 and alkalinity between 46 and 191 mg/L over the review period.

At Building 42A, groundwater pH, EC and alkalinity values are elevated but generally stable at monitor bores RF126S/G. Groundwater quality parameters in nearby shallow monitor bore RF009S (located 50 m north-west of building 42A), generally remain within the values expected for natural groundwater in this area. In the deeper bore RF009G, slightly elevated levels of EC (900 µS/cm) and alkalinity (260 mg/L) were observed in July 2022. Levels in subsequent samples where lower, but still show a slight increasing trend. RF128G, located about 50 m south-west of building 42A, shows a slight increasing trend.

Near Building 40, groundwater pH, EC and alkalinity have historically been elevated at monitor bore RF124G. Water quality data from these bores have been variable, which may have been the result of the different pumping method used (see Caustic Unloading Area commentary, Section 5.3.2), especially in October 2017. The 2020-22 results were more consistent with general trends, currently with a pH of 11, EC is 1,900 µS/cm, and alkalinity at 782 mg/L. No data are available for the shallow bore as this bore has had insufficient water for sampling since it was installed, indicating that there is not a perched water table (≤12.6 m depth) at this location. Monitor bore RF125S/G is located 50 m south-east of building 40. Key water quality parameters in the shallow bore have shown an increasing trend since 2014; the EC in RF125S has increased from 510 to 2,100 µS/cm, pH from 7 to 9.4 and alkalinity from 167 to 1,100 mg/L. In the deeper bore RF125G, the water quality has been highly variable since 2016, with EC fluctuating between <500 and 9,500 µS/cm, and alkalinity between <100 and 3,600 mg/L. The pH has remained fairly constant at an elevated level, averaging 11.9. Bore RF127G, located just to the north of Building 40, remained stable for the 2020-22 period. Newly

installed monitoring bore RF139S/G, located 60 m south-west of Building 40, was sampled three times over the monitoring period using low-flow methods. The shallow bore had a EC range of 380-443 mS/cm, pH 5.9-6.3 and alkalinity between 62 and 86 mg/L, indicating the plume has not reached this location in the shallow aquifer. The deeper bore RF139G, recorded a EC of 396-429, pH 11.5-11.9 and alkalinities between 2,200 and 3,300 mg/L, indicating the plume persists in the south western margin of the building (i.e. down hydraulic gradient).

Monitor bore RF127W, completed in the Mesozoic formation, has groundwater quality parameters generally within the range of other bores completed in this formation near the refinery (pH of about 6.6, EC of about 5,000 µS/cm and alkalinity of about 350 mg/L).

In summary, three local sites of impact are noted near Buildings 47, 42A and 40. While most of the alkali fluid is apparently contained in the low-permeability upper superficial formations, downward ingress is observed at Building 42A (RF126G) and Building 40 (RF124G,RF125G and RF139G). There appears to be some migration of alkali-impacted groundwater at these locations. There is no evidence of significant impact on groundwater in the Mesozoic formation.

North-Eastern Refinery Area
Near Building 35C

This area is monitored by active monitor bores RF050S/G/W, RF051S/G, RF052S/G, RF053S/G and RF059S.

Key groundwater quality parameters are generally stable and within the range of natural groundwater in the upper aquifer, although some fluctuations are noted in monitor bore RF051S, and a slight increasing trend in all parameters is observed in monitor bore RF053S.

Water quality in the lower superficial aquifer remained stable in all monitor bores.

Key groundwater quality parameters in the Mesozoic monitor bore RF050W are fairly stable at about pH 7, EC 7,000 µS/cm and alkalinity 380 mg/L. As these values are higher than any measurements made for these parameters at any time in the overlying superficial formations, they may represent the background conditions at this location.

5.3.3 RESIDUE STORAGE AREA GROUNDWATER CHEMISTRY

Contour plans for the key geochemical parameters in the RSA are shown in Figure 19 to Figure 21 (pH), Figure 30 to Figure 33 (EC) and Figure 41 to Figure 43 (alkalinity). The changes in these parameters between the 2020–2022 monitoring reviews are shown in Figure 22 to Figure 24 (pH), Figure 34 to 36 (EC) and Figure 44 to Figure 46 (alkalinity). Time-series plots for the RSA monitor bores are presented in Appendix G.

An overview for each key parameter is provided below, along with notable trends in the 2020-2022 data for each of the main storage areas.

Groundwater pH

Groundwater pH (Figure 19 & 20) in the superficial formations at the RSAs tends to be slightly acidic to circum-neutral, ranging from about 5.2–7.5 and generally increases from east to west in the lower superficial formations. The groundwater pH in the underlying Mesozoic formations tends to be circum-neutral to slightly alkaline, ranging from about 7.0–7.6. The values are consistent with the regional variation of groundwater pH in these units in the Wagerup area.

Figure 22 to Figure 24, which show changes to pH between 2020–2022, show variations in the order of ±1, but no clear pattern is discernible. The groundwater pH in the lower Mesozoic formations showed no significant change.

Groundwater Electrical Conductivity

Groundwater salinity in the superficial formations (Figures 30 & 31) in the RSA area generally ranges from fresh (<1,000 µS/cm) along the eastern edge of the facility, to brackish (2,000 µS/cm to 5,000 µS/cm) over most of the area. There are some areas of elevated salinity (>5,000 µS/cm), particularly in the upper superficial formations along the northern perimeter of the RSAs. Another area of elevated salinity occurs immediately west of the RSAs, also in the upper superficial formations, in an area subject to seasonal waterlogging. In the lower superficial formations, an area of mixing between the fresh and brackish groundwater occurs to the south of the RSAs, possibly marking an area of higher hydraulic conductivity. This lower EC groundwater apparently discharges to the upper superficial formations along the south-western perimeter of the RSAs, in areas coinciding with upward hydraulic-head gradients.

Groundwater salinity in the underlying Mesozoic formation tends to be slightly brackish (about 2,000–4,000 µS/cm) in the RSA area.

Changes to EC during the current period of review are shown in Figure 33 to Figure 38. In general, significant changes tend to occur in individual bores, rather than over a specific area. They are discussed further below.

Groundwater Alkalinity

Figure 41 and Figure 42 show that in the vicinity of the RSAs, most of the groundwater in the superficial formations has alkalinity values of 20–250 mg/L, however two distinct areas contain higher alkalinity values (up to about 1,000 mg/L); one to the south-west (near ROCP1) and the other to the north-east. There are some localised areas of significantly-elevated alkalinity (>500 mg/L) in the upper superficial formations in bores around the Sand Lake (including bore RS064S). There are also some individual bores with alkalinity values well above those in neighbouring bores. The higher-alkalinity groundwater immediately west of the RSAs tends to have alkalinity increasing with depth. This is likely due to the presence of older groundwater within the calcareous Ascot Formation (360 Environmental 2016). Monitor bores with elevated salinity on the northern perimeter of the RSAs have low-background, or only moderately-elevated, levels of alkalinity.

Groundwater alkalinity in the underlying Mesozoic Formation tends to range from about 180–250 mg/L in this area. Changes in alkalinity during the current period of review are shown in Figure 44 to Figure 46. In general, significant changes tend to occur in individual bores rather than over a specific area and were generally in opposite directions in 2020 compared to 2021 and 2022, suggesting annual-scale fluctuations.

Cooling Pond / RSA1

This area is monitored by monitor bores RS039S/G to RS050S/G, RS122S/G and RS125S (blocked). Alkalinities in this area are generally high (about 20–600 mg/L) and shallow bores show an increasing trend in 2020–2022 (including RS039S, RS040S, RS041S, RS042S, RS044S and RS050S (see Appendix G). However, EC has generally been decreasing or stable over the same period. Alkalinity is low (about 25 mg/L) in the lower superficial formation bores (G series).

RSA1 / RSA2 / Sand Lake

This area contains monitor bores RS046S/G to RS050S/G and RS063S/G to RS066S/G. There are increasing alkalinity levels to the north of the Sand Lake in RS063S, RS064S and RS065G. Rockwater (2017) noted that

bores RS063S and RS064S may be compromised and subject to surface water ingress. Monitor bores RS126G and RS138S/G, located just north of RS063S/G and RS064G, also show signs of impact with alkali fluids (increasing alkalinity). It is possible that the increased extraction from depressurising bore D-014G is drawing alkali contaminated groundwater from neighbouring RSA6 and Sand Lake and may represent hydraulic connection between the water body in the Sand Lake and the monitor bores.

Infiltration of alkali fluids to the lower superficial formations generally appears to be restricted, with bores completed in this formation showing generally stable trends within historic variations and close to values that occur naturally in the area. Except where noted above, and in RS063G, EC remains below background values.

Monitor bores RS058S/G, RS059S/G and RS060S/G were decommissioned in 2015 and RS061S/G were decommissioned in 2017. In recent years, Alcoa has had a policy of not installing bores through RSA liners, as the bores themselves can create pathways for contamination of groundwater (Gerritse and Thomas 2009). When walls are lifted on the RSAs, the new crest overlies previously-deposited residue mud and the walls are constructed using residue sand. Therefore, to install bores in lifted walls they would have to penetrate the liner as well as a source of contamination (residue mud and sand). Alcoa has agreed to assess the risks related to through seal bore installation when new bores are required in the central residue area at Wagerup. If operationally feasible, one or two alternative monitoring sites should be identified, preferably to the west of the eastern dyke at RSA2, and new monitor bores installed and monitored to determine accurate groundwater quality characteristics beneath the RSA complex.

RSA3 /RSA4/ ROCP1

This area contains monitor bores RS090S/G to RS094S/G, RS095S/I/G to RS102S/I/G, RS145S, RS146S/G/W, RS147S/I/G and RS149G. Key groundwater quality parameters are generally stable and within the ranges of historical values in this area.

Slightly elevated EC occurs in several shallow bores located in the south-west corner of the RSAs, namely RS096S, RS097S and RS100S with EC ranging between about 5,000–10,000 µS/cm. Alkalinity is also elevated (about 200–1, 500 mg/L), particularly in an area to the north of ROCP1.

Groundwater parameters can be somewhat variable in a number of monitor bores, although often there is an inverse correlation between salinity and alkalinity, with alkalinity decreasing as salinity increases, and vice versa (for example, RS090S, RS091G, RS094S, RS098S/I and RS102S/I). While the reason for the variability is unclear, it is possible the changes relate to mixing of different groundwater types (upward head gradients occur in the area) and/or some infiltration of a surface water source other than the alkali fluids.

Alkalinities on the northern and western edges of ROCP1 (monitored by RS097S & RS100S, Figure 41), have increased since 2011 and are now about 1,000 and 1,500 mg/L respectively. A number of other upper superficial formation bores around ROCP1 (including RS098S and RS102S) also had alkalinity increases in 2020 to 2022, however this does not appear to extend to RS103S. This could be related to the decommissioning of the pond that commenced in 2017 (Section 1.3). However, RS090S and RS091S, to the south of RSA3, also saw smaller increases in alkalinity so it could be part of a broader trend. Prior to the decommissioning, Alcoa aimed to manage pond water levels below the ground water levels to prevent a downward head inducing flow through liner defects into the underlying groundwater (Section 5.5.2). The decommissioning work is now 90% complete, and residual liquor/fines continue to be pumped out as required. A detailed site investigation is currently being completed to assess if recovery is required or the contamination can be managed by natural monitored attenuation.

There were no appreciable changes to pH, EC or alkalinity for groundwater samples collected from the monitor bore completed in the Mesozoic formations to the west of ROCP1 (RS146W).

RSA6 / ROCP2

This area is monitored by monitor bores RS111S/I/G, RS126G, RS127G and RS137S/G to RS142S/G. Alkalinity and EC and to a lesser extent pH, are trending upward in RS126G; however, levels are still low compared to other areas but above the levels in this bore in 2014 when the ROCP2 liner required repair. Likewise, alkalinity has been elevated in RS137S and RS138S on the southern perimeter of ROCP2. Key groundwater quality parameters are generally stable and within the range of historical values in this area for the other bores.

EC and alkalinity remain elevated in the shallow superficial formations in monitor bores RS111S (EC of about 3,000 µS/cm and alkalinity of about 700 mg/L) and RS138S (see 'RSA1 / RSA2 / Sand Lake' comments above) located on the eastern perimeter of RSA6 between ROCP2 and the Sand Lake.

ROWS Pond

This area is monitored by monitor bores RS115G, RS116S/G to RS123G, RS130S/G, RS145S and RS149G. There are no clear trends of changing pH and/or alkalinity in this area. There is an area in the south-west corner that has slightly elevated EC in the upper superficial formations (up to 5,540 µS/cm in RS130S), however this has remained stable since 2001. All values for the key chemical parameters (pH, EC and alkalinity) are within historical limits in 2020–2022.

RSA7 / RSA8

This area contains monitor bores RS160S/G to RS163S/G, RS168S/G/W, RS169S/G to RS172S/G, and RS189S/G to RS192S/G. Groundwater quality has historically been highly variable in RS160S, although it returned to values similar to background levels in 2019 and has remained stable since.

Readings from upper superficial bores north of RSA8 (RS168S and RS169S) have fluctuated over the reporting period. In RS168S, EC ranged from 9,520 µS/cm in 2020, to about 1,100 µS/cm in 2022, alkalinity ranged from 9 mg/L in 2020 to 295 mg/L in 2022 and pH ranged from 5 in 2020 to 7.2 in 2022. Lower superficial bores did not show the same trend indicating the possible contamination is confined.

Groundwater alkalinity in these bores tends to be low, and any changes tend to be inversely correlated to salinity (that is, when salinity increases, alkalinity decreases and vice versa). This anomalous trend is particularly marked in shallow monitor bores RS160S, RS168S, RS169S and RS170S. The cause is unknown and may be due to regional-scale land-clearing impacts beyond the RSAs (Section 5.3.4). Values of EC and alkalinity are generally within historical values in both the shallow and deep bores.

There were no appreciable changes to pH, EC or alkalinity for groundwater samples collected from the monitor bore completed in the Mesozoic formations (RS168W).

Detention Ponds

This area contains monitor bores RS173S/G to RS178S/G. Historically, monitor bore RS173S tends to have similar attributes to those located north of RSA8, and groundwater quality is probably influenced by the same processes predominating at that location.

As noted in 'RSA7 / RSA8' comments, bores on the northern end of RSA 8 and Detention Pond 2 show highly variable water quality results in the upper superficial formations. Monitor bores RS173S and RS174S, located to the east of Detention Pond 2, are stable.

Key groundwater quality parameters in monitor bores RS175S/G, RS176S/G, located on the south-eastern boundary are within the range of natural groundwater at this location and within historical variations during the period of review.

An inverse correlation between EC and alkalinity, noted for bores near RSA7/RSA8, is evident in several bores, including RS173S, RS174S and RS175S. Groundwater quality tends to be variable in the shallow bores (S series) and more stable in the deeper bores (G Series).

RSA9 / ROCP3

This area contains monitor bores RS193S/G to RS205S/G. Key groundwater quality parameters are within the range of natural groundwater at this location and within historical variation in 2020-22. In general, groundwater quality trends are fairly stable. As for other bores in the northern sector of the RSAs, elevated salinity is not associated with elevated alkalinity, and in some instances an inverse correlation applies (that is, an increase in salinity corresponds to a decrease in alkalinity and vice versa), therefore processes other than infiltration of alkaline fluids are assumed to apply. There were no appreciable changes to pH, EC or alkalinity in groundwater samples collected from the monitor bore completed in the Mesozoic formations (RS198W).

5.3.4 REGIONAL GROUNDWATER CHEMISTRY

Groundwater quality contours for regional monitor bores in the Wagerup area are presented in Figure 19 to 21 (pH), Figure 30 to Figure 32 (EC) and Figure 41 to Figure 43 (alkalinity). Changes to these parameters over the period of review are presented in Figure 22 to Figure 24 (pH), Figure 33 to Figure 35 (EC) and Figure 44 to Figure 46 (alkalinity). Time-series plots are presented in Appendix G.

Groundwater pH

Groundwater from regional monitor bores completed in the superficial formations is generally slightly to moderately acidic to circum-neutral, with pH ranging from 4.6 at some locations near the refinery and to the north, to 7.2 in the lower superficial formations to the west of the RSAs, and up to 10.7 at sites in close proximity and directly west of the refinery. The groundwater at some sites may be more acidic than would occur naturally, possibly due to elevated groundwater levels and subsequent geochemical reactions. Groundwater with elevated pH occurs in the refinery area. Groundwater from the Mesozoic formations ranges from circum-neutral to slightly alkaline.

No significant changes in pH were recorded in regional monitor bores in the 2020–2022 monitoring period (Figure 22 to Figure 23), with all changes generally within the range of ±0.3 pH units, with the exception of monitor bore RG012G, where pH is highly variable, ranging from about 9.4–10.7 during the review period. The overall trend in this bore is increasing and a recovery system is planned for this plume, due for completion in Q1 2024.

Groundwater Electrical Conductivity

The electrical conductivity of groundwater in the upper superficial formations (Figure 30) generally ranges from fresh (<1,000 µS/cm) to brackish (>5,000 µS/cm). The lowest EC values in this unit occur to the east of the RSAs where land elevations are slightly higher than surrounding areas and there is more potential for groundwater recharge. In the lower lying region to the west, which includes most of the area covered by the RSAs, groundwater EC is slightly to moderately brackish due largely to physical and chemical processes occurring in the shallow soil profile, including weathering and evapotranspiration. Some elevated EC values

(>5,000 µS/cm) in the upper superficial formations at the refinery site, and in close proximity to the RSAs, are likely due to impacts from the Wagerup operations.

Shallow regional monitor bores RG016S, RG027S, RG150S to RG158S and RG219S were generally within the range of natural groundwater for this area, with trends that were stable, or fluctuated within historic variations. After a peak in 2015, shallow monitor bore RG158S EC returned to baseline conditions of about 500 µS/cm. This trend is likely to be related to regional-scale land-clearing impacts beyond the RSAs.

There are 32 lower superficial regional monitor bores: RG001G to RG003G, RG007G to RG009G, RG011G, RG012G (discussed in Section 5.3.2), RG016G, RG020G, RG022G, RG024G to RG026G, RG034G to RG036G, RG079G, RG080G, RG150G to RG158G, RG166G and RG219G to RG221G. The EC of groundwater from the lower superficial formations (Figure 31) generally increases in a westerly direction from <500 µS/cm in likely rainfall recharge areas, to >3,500 µS/cm in low-lying areas with seasonal water logging. This distribution is consistent with groundwater salinity increasing along the flow-path due to natural chemical reactions with formation minerals in a low-flow environment. Groundwater salinity in the lower superficial formations generally remained stable or within historical variations, and EC values are generally in the range of natural groundwater in the area. There is a very slight increasing trend in RG155G (increasing EC trend to about 2,400 µS/cm in 2022); however, the EC continues to be lower than RG156G to the north and within the range of naturally occurring groundwater.

Groundwater from the Mesozoic formations tends to be slightly to moderately brackish, with EC generally in the range 1,900–4,000 µS/cm (Figure 32). Groundwater EC in these units also tends to increase in a westerly direction, and this is consistent with groundwater salinity increasing along the groundwater flow path.

Mesozoic formation regional monitor bores RG001W, RG002W, RG025W, RG027W, RG150W to RG158G, RG166W and RG219W's groundwater salinities are within values expected for the Mesozoic Formation at these locations. Their salinity trends are generally very stable.

Groundwater Alkalinity

Groundwater alkalinities are highest in the Mesozoic formations and in the lower superficial formations to the west of the RSAs, with values generally >150 mg/L (Figure 42 and 43). In contrast, groundwater elsewhere in the superficial formations generally has alkalinity <150 mg/L. 360 Environmental (2016) suggests that the relatively high alkalinity of groundwater in the lower superficial formations to the west of the RSAs is likely due to 'aged' groundwater being in contact with the Ascot Formation, which naturally contains calcareous material.

Elevated alkalinity is notable beneath the refinery where downward leakage of caustic fluids occurs. The extent of migration of alkali fluids to the west of the refinery is unclear, but elevated alkalinity is apparent in monitor bore RG012G, located just west of the refinery area and monitor bore RG036G, located approximately 350 m west of the refinery area, is showing a slight increasing trend.

With the exception of a few monitor bores, the average alkalinity of regional-bore groundwater samples did not change appreciably in either the superficial or Mesozoic formations between 2020–2022 (Figures 44 to 46). Slight variations within the upper superficial formations do not exceed historical limits. Alkalinity concentrations were generally stable or within historic variations in the regional monitor bores during the period of review.

5.3.5 GENERAL CONCLUSIONS ON GROUNDWATER QUALITY

Refinery

- The quality of the groundwater beneath the Wagerup refinery site has been locally impacted by alkali fluids, particularly at Building 45 in the southern area, and to a lesser extent at Buildings 26 and 42A in the northern and mid-northern areas. The extent of the alkali plumes evident in the contour plots appear to represent multiple, localised point-sources, rather than significant migration within the groundwater system.
- In the vicinity of Building 45, no notable trends in salinity and alkalinity were noted during 2020–2022, suggesting that the recovery bores are having a positive influence and conditions may be stabilising in this area.
- Generally-declining salinity and alkalinity in the northern area suggests increasing efficacy in the alkali recovery bore operation at Building 26.
- Downward leakage to the lower superficial formations appears to be significantly retarded, but does occur at some locations. Once in the lower superficial formations, there may be greater migration of the alkali fluids due to the higher hydraulic conductivity in this formation.

Residue Storage Areas

- Groundwater quality appears to be impacted in the area between RSA1/Sand Lake and RSA2, particularly in the upper superficial formations. Previous assessments (Rockwater 2017) have suggested that poor-condition monitor bores may be contaminant pathways, and that a program of bore-decommissioning be implemented (Alcoa has decommissioned some bores in this area). Monitor bores RS064S, RS126G and RS138S/G exhibited increasing alkalinities during the 2020–2022 review period and require further assessment.
- Monitor bores RS097S and RS100S on the western margin of ROCP1 exhibited increasing alkalinities during the 2020–2022 review period. Further assessments are required as decommissioning of this pond is completed.
- Bores along the northern edge of RSA8 and Detention Pond 2 show highly variable water quality results in the Upper Superficial Formations.
- Elevated salinity occurs to the north and north-west of the RSAs; however, there is no corresponding increase in alkalinity, and even decreasing alkalinity at a number of sites, suggesting a different source of salinity. Localised areas of elevated salinity and possibly alkalinity occur to the south-west and west of the RSAs. The alkalinity is not proportionally elevated and therefore the elevated salinity is unlikely to be related to Wagerup Operations.
- Localised areas of elevated groundwater pH, salinity and alkalinity occur along the eastern perimeter of the RSAs; however, no consistent trend is evident.
- Slightly higher alkalinity concentrations in the deep bores to the south-west and west of the RSAs likely represents natural groundwater conditions in the calcareous Ascot Formation.
- If operationally feasible, one or two alternative monitoring sites should be identified, preferably to the west of the eastern dyke at RSA2, and new monitor bores installed and monitored to determine accurate groundwater quality characteristics beneath the RSA complex.

5.4 ALKALI RECOVERY SYSTEMS

Two alkali recovery systems (borefields) are operated to enable recovery of alkali-affected groundwater in the Wagerup Refinery area. The recovery systems pump contaminated groundwater from the aquifer into nearby process tanks and it is re-utilised in the refinery process. DWER has issued Alcoa with a licence to take water (GWL160881[3]) for the operation of these bores (Table 5).

The first borefield, adjacent to Building 26 in the north (Figure 7), was commissioned in 2007. Alkali recovery bores RB001G and RB002G have screens in the lower Yoganup Formation and are equipped with air-displacement (Airwell) pumps. A second alkali recovery system, adjacent to Building 45 in the south, was commissioned in October 2014. The two recovery-bores, RB003G and RB004G, were installed to capture groundwater from the alkali plume present in the superficial formations at this location. The bores are also screened within the lower Yoganup Formation.

Table 9 presents graphs of average annual groundwater production, cumulative volume abstracted, monthly alkali recovery and cumulative alkali recovery. Graphs of monthly production rates and alkali recovery from each recovery bore are presented in Appendix H. Table 11 lists the monthly and annual volumes of groundwater produced by each of the four recovery bores during 2020–2022, and the estimated mass of alkali recovered by each bore (expressed as Na2CO3). Estimates of groundwater production from 2015 onwards are derived from the Airwell's pulse-counters and calibrated discharge volumes from the pumps to capture more accurate monthly flow for these bores, Magflow meters are also fitted to the bores for troubleshooting and comparison purposes (Alcoa 2017).

The borefields produced annual totals of 39,700 kL in 2020, 40,112 kL in 2021 and 60,781 kL of groundwater, against an annual water entitlement of 146,000 kL. An estimated total of 57.7 (2020), 54.4 (2021) and 66.7 (2022) tonnes of alkali (Na2CO3 equivalent) was recovered. The cumulative volume of groundwater produced by the borefields to December 2022 is 471 ML, and the estimated cumulative mass of alkali recovered is 421 tonnes (Na2CO3 equivalent) (Table 9).

Table 9: Groundwater and alkali production from recovery bores

Year	Production	Average rate	Cumulative volume	Alkali recovery	Cumulative alkali recovery
	(kL)	(kL/day)	(ML)	(tonnes Na_2CO_3)	(tonnes Na_2CO_3)
2007	1,425	15.5	1.4	0.7	0.7
2008	17,399	47.5	18.8	9.3	10.0
2009	17,324	47.5	36.2	10.7	20.8
2010	23,657	64.8	59.8	11.3	32.0
2011	21,098	57.8	80.9	10.6	42.6
2012	19,415	53.0	100.3	7.9	50.5
2013	14,046	38.5	114.4	6.7	57.2
2014	29,994	82.2	144.4	11.1	68.3
2015	31,975	87.6	176.3	8.7	77.0
2016	27,561	75.3	203.9	9.1	86.1
2017	38,333	105.0	266.3	31.7	117.8
2018	50,232	137.6	324.2	72.9	190.7
2019	37,957	104.0	377.3	53.0	197.9
2020	39,700	108.8	370.1	57.7	300
2021	40,112	109.9	410.2	54.4	355
2022	60,781	166.5	471.0	66.7	421

5.4.1 NORTHERN BOREFIELD – BUILDING 26

The total volumes of groundwater pumped from recovery bores RB001G and RB002G were (816 kL [2020], 3,266 kL [2021] and 5,216 kL [2022]) and (4,857 kL [2020], 14,078 kL [2021] and 22,855 kL [2022]) respectively. RB002G was under maintenance from April 2019 to October 2020. The estimated masses of alkali recovered (Na_2CO_3 equivalent) are 0.71 tonnes (2020), 2.27 tonnes (2021) and 2.45 tonnes (2022) from RB001G and 2.01 tonnes (2020), 4.60 tonnes (2021) and 4.86 tonnes (2022) from RB002G (Table 10).

Groundwater produced by RB001G is more alkaline than the groundwater produced by RB002G. RB001G alkalinity increased early in the review period, peaking at 830 mg/L in November 2020, before falling to background levels for the remainder of the review period. This increase was possibly due to the decreased use of RB002G. RB002G alkalinity was fairly stable around 300 mg/L for the 2020-22 period. The recovered groundwater quality (Table 11) is slightly alkaline to alkaline (pH of 7.2–10.7), fresh (TDS 690–1,200 mg/L) and moderately reducing to moderately oxidising (ORP -159 to 108 mV).

Monitor bore RF043G, located down hydraulic gradient, 94 m west of RB001G and 107 m west-north-west of RB002G, is used to monitor the influence of the recovery system on groundwater quality in this area. This monitor bore is screened in the lower Yoganup Formation and is monitored six-monthly for water levels, pH, EC, alkalinity and comprehensive laboratory analytes (the Operating Strategy only requires annual comprehensive monitoring (Table 12). Groundwater levels in this bore fluctuate seasonally with an increasing trend since 2012 (Appendix F); therefore, recovery bore abstraction does not appear to have a significant impact on down-gradient groundwater levels. Groundwater-quality sampling results (Appendix G) show a gradual decline in EC (from about 2,500 µS/cm to about 1,000 µS/cm) and alkalinity (from about 1,000 mg/L to about 350 mg/L) from the start of recovery in 2007 to 2020. Monitor bore RF036G (proximal to RB002G) shows a decline in alkalinity since 2011 (from about 1000 mg/L to about 410 mg/L in 2022).

Table 10: Alkali recovery bores: groundwater production and estimated alkali recovery, 2020–22

Month	Recovery bore: RB001G		Recovery Bore: RB002G		Recovery bore: RB003G		Recovery bore: RB004G	
	Production (kL)	Alkali recovery (tonnes Na_2CO_3)	Production (kL)	Alkali recovery (tonnes Na_2CO_3)	Production (kL)	Alkali recovery (tonnes Na_2CO_3)	Production (kL)	Alkali recovery (tonnes Na_2CO_3)
Jan-20	0	0.00	0	0.00	948	0.87	1,099	2.27
Feb-20	0	0.00	0	0.00	738	0.67	567	1.21
Mar-20	0	0.00	0	0.00	962	0.94	839	1.74
Apr-20	0	0.00	0	0.00	2,124	2.07	1,173	2.94
May-20	0	0.00	0	0.00	2,121	1.92	1,171	3.27
Jun-20	0	0.00	0	0.00	2,146	1.83	1,173	3.44
Jul-20	0	0.00	0	0.00	2,229	1.90	1,212	3.79
Aug-20	0	0.00	0	0.00	2,229	1.89	1,212	3.84
Sep-20	0	0.00	0	0.00	2,153	1.89	1,160	3.79
Oct-20	116	0.10	319	0.14	2,232	2.07	942	3.56
Nov-20	464	0.41	2,291	0.99	2,294	2.26	738	2.89
Dec-20	236	0.20	2,247	0.88	2,137	2.18	430	1.74
2020	**816**	**0.71**	**4,857**	**2.01**	**22,311**	**20.49**	**11,716**	**34.5**
Jan-21	191	0.16	1,685	0.63	1,852	1.97	400	1.57
Feb-21	157	0.12	718	0.26	1,480	1.58	495	1.82
Mar-21	160	0.12	1,636	0.55	950	0.94	924	3.09
Apr-21	140	0.10	2,136	0.66	532	0.47	1,196	3.41
May-21	106	0.08	1,935	0.62	426	0.37	1,235	3.01
Jun-21	0	0.00	610	0.20	372	0.32	1,150	2.64
Jul-21	0	0.00	474	0.15	402	0.35	1,235	2.95
Aug-21	0	0.00	411	0.13	411	0.36	1,235	3.20
Sep-21	0	0.00	646	0.20	387	0.35	1,184	3.83
Oct-21	438	0.37	828	0.25	339	0.41	1,205	4.08
Nov-21	1,143	0.80	1,918	0.60	932	0.75	1,142	3.71
Dec-21	930	0.51	1,081	0.35	2,089	1.90	1,196	4.39
2021	**3,266**	**2.27**	**14,078**	**4.60**	**10,171**	**9.78**	**12,598**	**37.7**
Jan-22	600	0.28	1,534	0.48	1,954	1.80	1,081	4.28
Feb-22	409	0.17	2,004	0.61	1,678	1.53	914	3.48
Mar-22	382	0.14	2,049	0.61	1,883	1.68	837	3.21
Apr-22	347	0.12	1,713	0.52	1,912	1.73	672	2.75
May-22	376	0.16	804	0.25	1,854	1.62	708	2.81
Jun-22	364	0.18	1,213	0.39	1,184	1.03	1,176	4.01
Jul-22	346	0.17	2,004	0.66	387	0.36	1,197	3.58
Aug-22	421	0.22	1,972	0.69	1,818	1.89	1,197	4.11
Sep-22	479	0.30	1,719	0.64	1,981	1.94	1,082	4.90
Oct-22	510	0.36	1,765	0.74	2,118	2.08	1,030	4.93
Nov-22	498	0.36	1,744	0.67	2,007	1.79	912	3.90
Dec-22	484	0.36	4,334	1.48	2,072	1.82	1,056	3.97
2022	**5,216**	**2.82**	**22,855**	**7.75**	**20,848**	**19.29**	**11,862**	**45.9**

5.4.2 SOUTHERN BOREFIELD – BUILDING 45

The total volume of groundwater produced by RB003G was 22,311 kL (2020), 10,171 kL (2021) and 20,848 kL (2022); the total volume produced by RB004G was 11,716 kL (2020), 12,598 kL (2021) and 11,862 kL (2022). The estimated mass of alkali recovered (Na_2CO_3 equivalent) by RB003G was 20.49 tonnes (2020), 9.78 tonnes (2021) and 17.46 tonnes (2022); the total alkali recovered by RB004G was 34.5 tonnes (2020), 37.7 tonnes (2021) and 41.9 tonnes (2022)) (Table 10). The groundwater produced by RB003G has remained stable at a relatively high alkalinity (about 1000 mg/L), however the alkalinity in RB004G has been rising since 2016, and continued this trend in the 2020-22 period, rising from 1,920 mg/L in 2020 to 4,760 mg/L in 2022.

The recovered groundwater quality (Table 11) is alkaline (pH of 9.5–11.7), brackish (TDS 1,400–7,000 mg/L) and reducing (ORP -350 mV to -77 mV). The increase in these parameters for RB004G indicate the sustained pumping since late 2017 (Table 9) has successfully drawn the plume towards the recovery bore.

Aluminium was significantly elevated in the water from RB004G (about 240 mg/L in 2022). The recovered water is utilised in the process water circuit and not for other non-potable uses such as irrigation; therefore, the elevated pH, EC, alkalinity and metals do not impact the beneficial usage.

Proximal monitor bores RF019Y and RF021Y, located 15 m east and west of RB004G have shown an increasing trend in pH, EC and alkalinity since RB004G was commissioned in 2007. The elevated levels are likely to remain localised around RB004G due to the continued pumping of this bore and will likely remain elevated until the plume dissipates.

Monitor bore RF046G, located down hydraulic gradient, 70 m west of RB004G and 75 m west-south-west of RB003G, is used to monitor the influence of the recovery system on groundwater quality in this area. This monitor bore is screened in the lower Yoganup Formation and is monitored six-monthly (Table 12) for water levels, pH, EC, alkalinity and comprehensive laboratory analyses (the Operating Strategy only requires annual comprehensive monitoring). The groundwater quality sampling results (Appendix G) show a continued decreasing trend for EC and alkalinity at this location, with EC (about 970 µS/cm) and alkalinity (about 410 mg/L) significantly lower than maximum values in about 2014. However, pH remains high, possibly due to a loss of natural buffering capacity at this location. Aluminium concentrations are lower than for the recovery bores but there has been a significant increase since mid-2018 (up to 61 mg/L) (Table 12), likely related to the increasing pH allowing dissolved aluminium to migrate to this bore. Similar groundwater quality improvements are evident in proximal monitor bores RF016G and RF132G, suggesting that the southern borefield is actively recovering alkali groundwater from the Building 45 vicinity. Historical data from proximal monitor bores RF018S, RF019S and RF020S show increasing trends in alkalinity since about 2007, suggesting that active sources continue in the area and that the recovery bores' efficacy may be reduced for the superficial aquifer. The shallow monitor bores were dry during the period of review, so it is unclear if the recovery bores are having an effect on the plume in the superficial aquifer.

Table 11: 2020-22 major component and trace element analyses of recovery bores

Analyte	RB001G			RB002G			RB003G			RB004G		
Sampling date	Nov-20	Oct-21	Oct-22	Nov-20	Oct-21	Oct-22	Oct-20	Aug-21	Oct-22	Oct-20	Aug-21	Oct-22
pH (field measurement)	10.7	9.4	10.2	8	7.2	8.2	9.7	9.5	9.5	10.9	10.6	11.7
Electrical Conductivity (µS/cm)	2010	1950	1600	1180	1180	1100	2000	1880	2000	6440	5470	9600
Oxidation-Reduction Potential (mV) (field measurement)	-159	-54	-57	-147	108	-31	-77	-118	-160	-186	-203	-350
Total Dissolved Salts (mg/L)	1200	1200	990	700	690	690	1400	1300	1400	5000	3500	7000
Sodium (mg/L)	400	410	320	240	220	220	510	410	440	1800	1300	2200
Potassium (mg/L	3.2	3.5	2.2	2.7	3.3	2.4	1.7	1.1	1	4.2	2.6	3.9
Calcium (mg/L)	0.3	0.8	<0.5	0.9	1.5	0.85	0.7	0.6	<0.5	0.8	0.7	0.65
Magnesium (mg/L)	0.6	1.7	2.1	6.1	6.6	5.3	3	2	2.1	0.8	1.5	<0.5
Chloride (mg/L)	96	120	98	91	91	91	75	67	77	150	130	180
Sulphate (mg/L)	44	63	47	63	190	66	75	65	64	240	220	370
Carbonate (mg/L)	830	240	500	<1	<1	25	360	240	350	3500	2100	4100
Bicarbonate (mg/L)	<1	620	170	420	280	380	500	600	630	130	270	<1
Nitrate (mg/L)	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.2	<0.02	<0.02	<0.4
Nitrite (mg/L)	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.2	<0.02	<0.02	<0.4
Alkalinity (as mg/L $CaCO_3$)	420	120	250	<1	<1	12	180	120	170	1700	1100	2700
Hardness (as mg/L $CaCO_3$)	3	9	9.6	27	31	24	14	10	10	5	8	<3
Silica (mg/L)	7.1	2.1	5.6	3.6	5.2	5.4	5.7	3.6	6.7	12	8.3	12
Dissolved Organic Carbon (mg/L)	21	22	20	5	5	8.7	68	53	82	270	260	430
Filterable Reactive Phosphorus (mg/L)	0.18	0.1	0.074	<0.002	0.009	0.012	0.7	<0.1	0.61	1.3	<0.1	1.6
Total Phosphorus (mg/L)	0.19	0.18	0.071	0.03	0.03	0.04	0.7	0.48	0.54	1.3	0.16	0.73
Ammonia (mg/L)	0.74	1.5	0.42	0.47	0.72	0.41	0.77	1	0.77	1.4	1.2	1.8
Total Kjeldahl Nitrogen (mg/L)	1.5	3	1.2	0.8	1.4	0.77	2.2	2	2.5	5.5	4.6	10
Sodium/Chloride mass ratio	4.2	3.5	3.27	2.7	2.4	2.42	6.7	6.1	5.71	12	10	10.22

Table 11 (Cont): 2020-22 major component and trace element analyses of recovery bores

Analyte	RB001G			RB002G			RB003G			RB004G		
Aluminium (mg/L)	29	2.4	15	0.27	0.28	5	20	2.6	14	170	120	240
Arsenic (mg/L)	0.11	0.056	0.056	0.022	0.015	0.033	0.16	0.13	0.17	0.6	0.24	0.19
Boron (mg/L)	0.07	0.05	0.04	0.03	0.04	0.027	0.1	0.1	0.12	0.24	0.22	0.34
Cadmium (mg/L)	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0001	0.0002	0.00013	0.0003	0.0004	0.00031
Chromium (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.0012	0.003	0.002	0.0052
Copper (mg/L)	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	0.0053
Fluoride (mg/L)	2	1.7	1.3	0.8	0.4	0.94	11	7.8	6.1	22	4.6	3.7
Iron (mg/L)	0.002	0.025	0.007	0.044	0.095	0.021	1.9	4.4	2.8	0.012	0.014	0.21
Gallium (mg/L)	0.17	0.046	0.12	0.014	0.011	0.054	0.41	0.33	0.48	1.9	1.5	3
Mercury (mg/L)	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	0.00006	0.00006	0.000072	0.00012	<0.00005	<0.00005
Manganese (mg/L)	<0.001	<0.001	<0.001	0.001	0.006	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Molybdenum (mg/L)	0.18	0.14	0.17	0.048	0.047	0.1	0.73	0.67	0.78	2.5	1.9	1.6
Nickel (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	0.002	0.0023	0.013	0.009	0.027
Lead (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Selenium (mg/L)	0.013	0.002	0.0078	0.001	0.014	0.011	0.033	0.008	0.029	0.28	0.18	0.42
Thorium (mg/L)	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	0.00054	<0.0005	<0.0005	0.00086
Uranium (mg/L)	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	0.00074	0.0019	0.0018	0.0011	0.0084	0.0064	0.012
Vanadium (mg/L)	0.33	0.025	0.045	0.002	0.001	0.086	0.34	0.023	0.29	3.4	2.2	5.5
Zinc (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	0.002	0.0012
Total anions	650	690	550	410	460	410	680	640	740	2600	1600	3300
Total cations	410	420	320	250	230	220	510	410	440	1800	1400	2200
Ionic Equivalent difference	-7.2	-9	-9.4	-5	-8.3	-9.6	3.6	-5.3	-8.8	-0.69	6.2	-4.5

Table 12: Comprehensive laboratory analyses, RF043G and RF046G

Parameter	Units	Sample											
		RF043G						RF046G					
Sample date	-	Apr-20	Sept-20	Apr-21	Oct-21	May-22	Oct-22	Apr-20	Sept-20	Apr-21	Oct-21	May-22	Oct-22
pH (Field)	-	9.6	9.1	9.6	8.6	9.6	9.2	11.3	11.5	11	11.2	11.2	11
Redox (ORP)	mV	-311	-303	-238	-163	-340	-240	-405	-235	-307	-197	-360	-200
Aluminium	mg/L	0.1	0.06	0.09	0.07	0.09	0.076	53	46	35	20	23	12
Ammonia (N)	mg/L	0.48	0.4	0.41	0.4	0.43	0.29	1.4	1.2	0.79	0.33	0.26	0.11
Antimony	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Arsenic	mg/L	0.02	0.012	0.017	0.013	0.019	0.022	0.42	0.47	0.36	0.19	0.21	0.13
Bicarbonate (HCO3)	mg/L	160	310	220	320	270	310	<1	<1	<1	<1	<1	<1
Boron	mg/L	0.03	0.03	0.03	0.03	0.03	<0.02	0.2	0.2	0.2	0.07	0.06	<0.02
Cadmium	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0002	0.0001	0.0001	<0.0001	<0.0001	<0.0001
Calcium	mg/L	0.2	0.4	0.1	0.6	0.1	<0.5	0.3	0.2	0.2	0.1	0.1	<0.5
Carbonate (CO3)	mg/L	190	52	110	18	120	43	1400	1200	1000	530	530	390
Chloride	mg/L	82	93	100	100	99	110	68	67	80	51	55	60
Chromium	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.003	0.006	0.005	0.002	0.002	0.0043
Conductivity @ 25C	uS/cm	1000	1100	980	1000	1100	980	3300	3000	2500	1300	1500	970
Copper	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	0.003	0.001	<0.001	<0.001
DOC	mg/L	4	3	5	7	6	6	110	92	78	26	32	15
FRP	mg/L	<0.1	<0.1	0.14	0.09	<0.1	0.045	2	1.7	1.6	0.75	<0.4	0.49
Fluoride	mg/L	0.8	0.7	0.9	0.7	0.7	0.73	15	11	4.2	3.4	2.1	1.6
Gallium	mg/L	0.027	0.017	0.028	0.016	0.024	0.017	2.3	1.9	1.3	0.51	0.56	0.31
Hardness (CAC03)	mg/L	3	11	1	14	3	6.7	1	<1	<1	<1	<1	<3
Ionic equiv. Difference	mg/L	-4.1	-3	-7.9	-5.8	-7.5	-2.7	-2.2	1.6	-10	-5.5	-11	-3.3
Iron	mg/L	0.048	0.069	0.034	0.079	0.019	0.077	0.044	0.13	0.11	0.041	0.037	0.1
Lead	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.007	0.016	0.014	0.007	0.01	0.011
M Alkalinity	mg/L	350	360	330	340	390	360	1600	1300	1100	530	580	410
Magnesium	mg/L	0.7	2.4	0.3	3	0.6	1.4	0.06	0.07	<0.05	<0.05	0.05	<0.5
Manganese	mg/L	0.002	0.008	0.001	0.017	0.003	0.0053	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

Table 12 (Cont): Comprehensive laboratory analyses, RF043G and RF046G

Parameter	Units	Sample											
		RF043G						RF046G					
Mercury	mg/L	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	0.00053	0.00038	0.00035	0.00006	0.00008	0.000099
Molybdenum	mg/L	0.054	0.016	0.014	0.041	0.074	0.1	0.77	0.64	0.59	0.1	0.18	0.094
Sodium/Chloride mass ratio	-	2.5	2.4	1.9	2.1	2.3	2.09	11	10	6	4.9	4.5	3.67
Nickel	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.006	0.005	0.009	0.001	0.002	0.0012
Niobium	mg/L												
Nitrate (as NO3)	mg/L	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.024
Nitrate (N)	mg/L	<0.1	<0.005	<0.005	<0.005	<0.005	<0.005	<0.1	<0.05	<0.05	<0.005	<0.005	0.0054
Nitrite (as NO2)	mg/L	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Nitrite (N)	mg/L	<0.1	<0.005	<0.005	<0.005	<0.005	<0.005	<0.1	<0.05	<0.05	<0.005	<0.005	<0.005
P Alkalinity	mg/L	93	26	57	18	120	21	860	680	620	270	530	220
Phosphate (PO4)	mg/L	<0.007	<0.007	0.46	0.29	<0.007	0.14	6.4	5.5	5.3	2.4	<0.007	1.6
Potassium	mg/L	0.6	1.2	0.6	2.7	0.9	1.1	0.9	1.4	0.7	2	<0.5	<0.5
Selenium	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.052	0.05	0.039	0.007	0.009	0.0031
Silica (SiO2)	mg/L	4.3	5	4.3	5.3	4.4	5.2	6.7	7.9	9	8.2	7.9	7.3
Sodium	mg/L	210	230	200	210	220	230	760	680	480	250	250	220
Sulfate (SO4)	mg/L	27	39	31	48	37	39	48	45	43	12	16	8.3
Thorium	mg/L	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	0.002	0.0037	0.0033	0.0019	0.002	0.0025
Total Anions	meq/L	320	360	340	360	370	370	1100	910	810	390	420	330
Total Cations	meq/L	210	230	200	220	220	240	760	680	480	260	250	220
Total Dissolved Solids	mg/L	610	670	590	650	650	490	2400	2300	2100	730	1500	710
Total Kjeldahl Nitrogen	mg/L	0.8	0.8	0.8	0.7	0.7	0.96	3.9	3.3	2.8	1.3	2.3	0.83
Total Nitrogen	mg/L	0.8	0.8	0.8	0.7	0.7	0.96	3.9	3.3	2.8	1.3	2.3	0.83
Total Phosphorus (Total Phosphate)	mg/L	0.09	0.09	0.15	0.09	0.08	0.1	2.2	2.3	1.9	0.78	0.4	0.48
Uranium	mg/L	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	0.0014	0.0012	0.0013	0.0011	0.0007	0.00098
Vanadium	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	0.054	0.061	0.056	0.038	0.036	0.032
Zinc	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.003	0.002	0.019	<0.001	<0.001	<0.001

5.4.1 GENERAL CONCLUSIONS

Recovery pumping rates have increased since 2017, despite the cessation of pumping from RB002G for the majority of 2019 and part of 2020. Recovered alkali volumes have increased significantly since 2017, especially in the southern borefield. This has removed a large volume of alkali groundwater from these key locations. Monitoring data have been variable; however, key monitor bores have shown improving water quality trends.

5.5 GROUNDWATER DEPRESSURISING SYSTEMS

Groundwater levels in the formations underlying the Cooling Pond, Run-Off Water Storage (ROWS) Pond, Run-Off Collection Pond 2 (ROCP2), Run-Off Collection Pond 3 (ROCP3), and Residue Storage Area 9 (RSA9) are controlled by four separate groundwater depressurising systems, or borefields, and a dewatering sump at ROCP2 (UD14-). All depressurising bores and the dewatering sump draw groundwater from the lower superficial formations, comprising sandy units within the Yoganup and/or Ascot Formations, depending on the location.

DWER has issued a licence to take water, GWL102669(3), to Alcoa for the operation of the depressurising systems (Section 2.4). This licence includes groundwater abstraction from the Borrow Pit. The four licensed borefields consist of:

- Cooling Pond – production bore D-002G.
- ROWS Pond – production bores D-004G, D-006G, D-007G and D-008G.
- ROCP2 – production bores D-010G, D-013G, D-014G and UD014-.
- RSA9/ROCP3 – production bores D-019G to D-035G.

The depressurising system at RSA9/ROCP3 was partly commissioned in October 2012, with the remaining depressurising bores commissioned in the first quarter of 2013. This system was required for the construction of these areas and has not been actively operated since June 2014 except for one month in 2020 but is intended to be used for production purposes in the future.

The purpose of the depressurising systems at the Cooling Pond, ROWS Pond, ROCP2 and RSA9/ROCP3 is to manage groundwater levels beneath these facilities and prevent upward pressures on the clay liners developing to an extent that could compromise liner integrity. Decisions on which bores to operate are based on groundwater and pond water levels. The general operating criterion is to keep the groundwater levels in the underlying formations below the fluid/mud surface levels of the ponds. The water that is pumped from the depressurising bores is stored in the pond of the borefield they belong to (either ROWS or ROCP2) for use in refinery and residue processes.

Groundwater levels in the vicinity of the ponds are measured in several monitor bores and in pressure sensors (vibrating wire piezometers) as required by the Operating Strategy. Details of all production and monitor bores are included in Appendix D.

5.5.1 BOREFIELD PRODUCTION

Average and cumulative monthly production data (Figure 53; Table 13; Table 14) do not include data from production from bores D-001G and D-002G at the Cooling Pond prior to 1995 (these bores were constructed

and commissioned in 1981, then operated intermittently until detailed record collection commenced with the commissioning of the depressurising bores around the ROWS Pond in late-1995). Average monthly pumping rates and cumulative pumping volumes (Appendix I) are not provided for the ROCP1 or ROCP3/RSA9 bore fields (minimal water was abstracted from these borefields in 2020–2022 as they were only turned on for monitoring and testing purposes, aside from one month in 2020 when they were tested as production bores). Total groundwater production under this licence was 384,368 kL (2020), 373,862 kL (2021) and 406,149 kL (2022), against an annual water entitlement of 550,000 kL (GWL102669(3)).

5.5.2 BOREFIELD GROUNDWATER LEVEL DATA

Figure 52 to Figure 60 illustrate water levels in the ROWS Pond, Cooling Pond, ROCP2, ROCP3 and ROCP1 with associated groundwater hydrographs for monitor bores around the perimeters of these facilities and the average monthly pumping rate from the depressurising systems. The critical groundwater levels, which determine whether excessive uplift pressures act on the engineered liners of the ponds, are those from the lower superficial formations, as indicated by the G Series monitor bores and the vibrating wire piezometers. In the vicinity of the RSAs, the lower superficial formations (Yoganup and/or Ascot Formations) has a greater horizontal hydraulic conductivity than the upper superficial formations (Guildford Formation). This contrast between hydraulic conductivities results in the predominant direction of groundwater flow being horizontal in the lower superficial formations and vertical in the upper superficial formations.

Changes in groundwater pressures in the lower superficial formations, immediately beneath the water storage facilities, are inferred to be rapidly transferred to the base of the engineered liners by concomitant changes in pressure in the upper superficial formations. Elevated groundwater levels in the shallow, S Series, monitor bores around the perimeter of these facilities are generally believed to be influenced mainly by local recharge from rainfall or other surface water sources, and therefore are not necessarily indicative of groundwater levels in those parts of the upper superficial formations beneath the engineered liners of the ROWS Pond, Cooling Pond, and/or ROCP2.

ROWS Pond and Cooling Pond

Water level in the ROWS Pond during the 2020–2022 review period ranged between about 20–30.0 m AHD and were above the groundwater levels in all of the perimeter G Series monitor bores by about 4 m (Figure 52 and Figure 53). Long term groundwater levels trends from vibrating wire piezometers H-002-, H-003-, H-004-, and H-005- (installed beneath the liner of the ROWS Pond) were also about 4 m below the water level in the ROWS Pond during this period (H-005 shows period of high levels however this is likely to be a sensor issue). The level of water in the ROWS Pond was higher than groundwater levels in perimeter S Series monitor bores during the 2020–2022 review period, with minor, short-term exceptions in RS116S, RS117S, RS120S and RS121S.

Groundwater levels in the Cooling Pond (Figure 54 and Figure 55) were above G-series monitor bores' groundwater levels during the 2020–2022 review period, generally with a difference in the order of 5 m. Shallow S-series monitor bores' groundwater levels were also lower than Cooling Pond levels during the 2020–2022 review period. Water levels in shallow bores RS041S and RS045S are about 4 m higher that the surrounding monitoring points and at times are similar to the level in the Cooling Pond. The levels have remained at this level for some time however should still be monitored closely to ensure they do not rise above the pond level.

As the integrity of the liners of the ROWS Pond and Cooling Pond are dependent on groundwater levels in the lower superficial formations, as represented by the hydrographs of the G Series monitor bores, no risk to the integrity of either liner occurred from groundwater uplift pressures during the 2020–2022 review period.

Table 13: Groundwater production from depressurising systems, 1995–2022

Year	Production	Average rate	Cumulative Volume	Borefield contribution (%)				
				ROWS/ Cooling	ROCP1	ROCP2	RSA9/ ROCP3	Borrow Pit
	(kL)	(kL/day)	(ML)					
1995	26,253[A]	72[A]	26	100	0	0	n/a	n/a
1996	210,623	577	237	99	0	1	n/a	n/a
1997	282,801	774	520	17	0	83	n/a	n/a
1998	389,991	1,068	910	44	4	52	n/a	n/a
1999	385,884	1,057	1,296	59	0	41	n/a	n/a
2000	345,022	945	1,641	44	0	55	n/a	n/a
2001	208,307	570	1,849	16	0	84	n/a	n/a
2002	296,778	813	2,146	42	0	58	n/a	n/a
2003	174,262	477	2,320	17	0	83	n/a	n/a
2004	191,690	525	2,512	9	0	91	n/a	n/a
2005	196,599	538	2,708	4	0	96	n/a	n/a
2006	183,639	503	2,892	11	0	89	n/a	n/a
2007	221,447	606	3,113	31	0	69	n/a	n/a
2008	244,271	669	3,358	25	0	75	n/a	n/a
2009	193,989	531	3,552	19	0	81	n/a	n/a
2010	182,398	499	3,734	4	0	96	n/a	n/a
2011	298,206	816	4,032	37	0	63	n/a	n/a
2012	284,043[B]	778[B]	4,316	13	0	70	17	n/a
2013	596,986	1,634	4,913	2	0	37	62	n/a
2014	449,686	1,231	5,363	9	0	40	33	19
2015	179,900	493	5,543	28	0	72	0	0
2016	201,399	551	5,744	40	0	60	0	0
2017	229,164	627	5,973	56	0	41	3	0
2018	194,131	532	6,167	42	0	58	0	0
2019	329,657	903	6,497	59	0	41	0.1	0
2020	384,368	1,053	6,881	31	0	36	8.5	24
2021	373,862	1,024	7,255	33	0	25	6	36
2022	406,149	1,113	7,661	22	0	42	2	34

A. Production and average rate for one month only (Dec 1995)
B. Production from RSA9/ROCP3 Borefield in last quarter of 2012 only

Table 14: Groundwater production from depressurising systems, 2020–2022

Date	Pumping volume (kL)											
	ROWS/Cooling					ROCP2				RSA9/ ROCP3 bores	Borrow Pit	Total
	D-002G	D-004G	D-006G	D-007G	D-008G	D-010G	D-13G	D-014G[1]	UD014-			
Jan-20	0	11,038	0	10,973	0	0	1,704	5,669	5,016	0	4,636	39,035
Feb-20	0	10,217	0	10,157	0	0	1,539	24	5,314	0	20,252	47,503
Mar-20	0	11,311	0	11,246	0	0	1,704	51	5,621	0	6,402	36,335
Apr-20	0	6,151	0	10,520	0	0	1,649	953	5,008	0	-3,646	20,635
May-20	0	6,346	0	0	0	0	1,704	5,471	3,739	0	11,691	28,951
Jun-20	0	6,307	0	0	0	0	1,649	5,129	3,888	0	7,682	24,654
Jul-20	0	6,517	0	0	0	0	1,704	5,404	5,021	0	11,487	30,133
Aug-20	0	6,517	0	0	0	0	989	3,599	6,990	0	2,701	20,797
Sep-20	0	6,307	0	802	0	0	1,649	6,265	6,233	0	5,021	26,277
Oct-20	86	5,676	32	49	264	1,526	1,704	6,042	6,374	10,391	12,346	44,489
Nov-20	0	0	0	0	0	3,816	1,649	5,053	4,530	22,370	4,596	42,013
Dec-20	0	0	0	0	0	3,943	1,704	3,898	4,657	0	9,344	23,546
2020	**86**	**76,387**	**32**	**43,747**	**264**	**9,286**	**19,346**	**47,457**	**62,391**	**32,760**	**92,512**	**384,368**
Jan-21	2,458	8,196	0	0	0	0	1,659	0	5,703	0	23,122	41,138
Feb-21	2,220	7,402	0	0	0	0	1,499	0	5,605	0	9,102	25,828
Mar-21	2,458	8,196	0	0	0	0	1,659	0	5,811	0	7,599	25,723
Apr-21	2,379	7,931	0	0	0	0	1,606	0	4,565	0	2,362	18,842
May-21	2,458	8,196	0	0	0	0	1,659	0	3,274	0	-962	14,624
Jun-21	2,379	7,931	0	0	0	0	1,606	0	3,405	0	7,771	23,091
Jul-21	2,458	8,196	0	0	0	0	1,659	0	3,821	0	39,555	55,689
Aug-21	2,458	8,196	63	1,091	528	1,018	1,659	1,209	3,663	0	3,460	23,345
Sep-21	2,379	6,345	63	1,418	528	3,816	1,606	5,287	2,488	0	6,872	30,801
Oct-21	2,458	8,196	0	0	0	3,943	1,659	2,182	2,228	0	1,158	21,823
Nov-21	2,379	7,931	0	0	0	3,816	1,606	2,430	2,224	0	21,629	42,015
Dec-21	1,639	5,464	0	155	0	2,629	1,106	2,395	1,423	22,217	13,918	50,945
2021	**28,120**	**92,178**	**126**	**2,664**	**1,057**	**15,222**	**18,982**	**13,503**	**44,208**	**22,217**	**135,586**	**373,862**
Jan-22	0	3,437	0	0	0	1,654	1,659	0	2,623	0	27,823	37,195
Feb-22	0	7,402	0	0	0	3,562	1,499	0	3,497	0	13,335	29,294
Mar-22	0	8,196	0	0	0	3,943	1,659	1,668	3,871	0	3,885	23,222
Apr-22	0	7,931	0	0	0	3,816	1,606	4,087	3,747	0	4,718	25,904
May-22	0	8,196	0	1	0	3,943	1,659	6,692	3,871	0	4,068	28,431
Jun-22	0	7,931	0	2	0	3,816	1,606	3,107	3,747	0	9,930	30,138
Jul-22	0	8,196	0	0	0	3,943	1,659	3,211	3,871	0	22,453	43,333
Aug-22	0	8,196	0	0	0	3,943	1,659	3,211	6,757	0	2,023	25,789
Sep-22	0	7,931	0	0	0	3,816	1,606	5,910	7,329	0	12,722	39,314
Oct-22	0	8,196	0	0	0	3,943	1,659	10,053	8,135	0	8,525	40,512
Nov-22	0	7,931	32	0	264	3,816	1,606	7,378	5,403	8,960	4,048	39,438
Dec-22	0	5,737	0	0	0	2,760	1,659	4,226	5,725	1,175	22,816	44,098
2022	**0**	**89,278**	**32**	**3**	**264**	**42,955**	**19,535**	**49,543**	**58,058**	**10,135**	**136,346**	**406,149**

ROCP2

The level of water in ROCP2 during the 2020–2022 review period (Figure 56 and Figure 57) has been maintained between 17.4 m AHD and 18.5 m AHD, and was above the levels of groundwater in the G Series perimeter monitor bores by about 1–2 m. Pond water levels were also above the groundwater levels determined by the three vibrating wire piezometers installed in the lower superficial formations beneath the central part of this facility by about 1–2 m during the 2020–2022 review period. The level of water in ROCP2 was also higher than groundwater levels in the perimeter S Series monitor bores during the 2020–2022 review period. As discussed in Section 5.2.2, levels in VWPs located within ROCP2 (I-001 to 3) are approaching the pond levels and it is advised to increase the extraction from corresponding depressurising bores D-010G, D-013G and D-014G, and re-commission bores D-011G and 12G.

Bore RS142S is showing a slight increasing trend and is within 1 m of the pond level at times. This bore should be monitored closely in future operations to ensure the integrity of the pond liner. The level in this bore can easily be mitigated by running depressurising bore D-010G, located 50m to the north.

ROCP1

Depressurising bores have been installed in the vicinity of ROCP1; however, they are used only to facilitate maintenance on the water storage pond. Groundwater level data collected from monitor bores located around the perimeter of ROCP1 (Figure 58 and Figure 59) show water levels in ROCP1 of about 14–15 m AHD during the 2020–2022 review period. Prior to 2017 (when decommissioning commenced) the ROCP1 level ranged from about 12–14 m AHD and dropped below groundwater levels during winter peak periods. ROCP1's clay liner is likely to have been damaged soon after the pond was constructed in 1992 (Rockwater 2017); therefore, upward and downward migration of pond water and groundwater is possible. Alcoa's strategy for this pond has therefore been to keep water levels in the pond below the groundwater levels where possible. With the decommissioning of the area by filling with sand, which pushes the fine grained material and residual liquor to the opposite end of the pond, maintaining levels below the groundwater levels is not possible. However, the risk to groundwater is minimised as fluids are present in a smaller area and the overall outcome of the decommissioning is expected to result in reduced risk of leakage through the liner defects. Prior to the decommissioning, water levels in the pond were sometimes above the groundwater levels, as Alcoa sought to balance this strategy with minimising dust generation from within the pond. The decommissioning work at ROCP1 is largely complete, except for a small area at the southern end (where the liquor remains).

RSA9/ROCP3

Groundwater levels in the vicinity of ROCP3 (Figure 60) were well below the base of the engineered liners of these facilities during the 2020–2022 review period. Water levels in the vicinity of RSA9 fluctuate seasonally and are showing a slight increasing trend (Appendix F, page 84-86)

General conclusions

Based on available data (Figure 52 to Figure 60), management of groundwater levels in the lower superficial formations, and potential uplift pressures on the liners of the ROWS Pond, Cooling Pond, ROCP2 and ROCP3, has been satisfactory during the 2020–2022 review period and the integrity of the liners of these facilities was at no time compromised. ROCP1's clay liner is likely to have been damaged prior to this review period; therefore, a different strategy is typically utilised for this pond. This was not possible for most of the period of review due to decommissioning works; however, the outcome is likely to result in a reduced risk.

Groundwater level contours for the lower superficial formations (Figure 10) show the cones of depression resulting from pumping of the depressurising bores are localised, and relatively close to the pumping centres, and there is no evidence of long-term groundwater level decline in the groundwater hydrographs. Operation of these borefields, therefore, does not appear to be having a detrimental effect on groundwater levels in the area.

5.5.3 BOREFIELD GROUNDWATER CHEMISTRY DATA

Time-series groundwater quality data from the depressurising bores are presented in Appendix G.

ROWS Pond

Only depressurising bores D-002G [not operated in 2020 and 22], D-004G and D-007G were operated during the period of review. Other bores were not operational. Groundwater chemistry in the ROWS depressurising bores is somewhat variable, but with no significant trends. 2020 to 2022 data were within the range of historical values.

ROCP2

Maintenance work was undertaken at ROCP2 in 2014, including: repairs to depressions in the clay liner in the north eastern corner of the pond; and repairs to the HDPE liner on the western, eastern and northern embankments. The failure of the liner may have resulted in seepage into the underlying superficial formation and could explain recent trends in groundwater hydrochemistry in the vicinity (Section 5.3.3).

Groundwater has been abstracted in this area from depressurising bores D-010G, D013G and D-014G and the dewatering sump, UD014- since 1997 (Appendix I). Groundwater chemistry in the ROCP2 depressurising bores (Appendix G) is generally stable, and key parameters were within the range of historical values, except in bore D-014G. This bore shows erratic readings from 2016 to late 2020 and then stabilises from 2021 onwards. This bore was pumped at a comparatively high rate during this period and the fluctuating water quality is a likely result.

There is no indication of significant ingress of alkali water to the production bores at this location.

RSA9/ROCP3

Groundwater has only been abstracted from depressurising bores in this area (D-019G to D035G) during the period of review for sampling and equipment testing (Appendix I) and for one month in 2020 when they were tested as production bores. Groundwater chemistry in most of these depressurising bores (Appendix G) is generally stable to slightly variable. Alkalinity values greater than background values have been noted previously in bores D-023G, D-024G, D-025G, D-026G, D-028G and D-030G. This characteristic continues through 2020–2022. Alkalinity values in these bores are higher than those measured in either the shallow bores or the deeper bores completed in the underlying Mesozoic formation, and they are likely related to the calcareous nature of the Ascot Formation (Rockwater 2020) and slower recharge due to the lack of pumping from the depressurising bores.

5.6 SURFACE WATER MONITORING DATA

Surface water monitoring stations (Figure 3) were monitored during the 2020–2022 review period according to the schedules shown in Appendix D2. Specific data from station SP012-, as required by both the EP Act Licence and the Surface Water Licences Operating Strategy (Alcoa 2020), were also collected (Figure 61). The total monthly flow from surface water harvesting systems since 1989 are presented in Figure 62.

5.6.1 SURFACE WATER FLOW

Wagerup rainfall data and monthly flow graphs (Figure 62) displays flows at the major site entry points for surface water on North Yalup Brook (SP001-) and Detention Pond 1 Overflow (SP005-) and the major site exit point for surface water at Cooyah (SP012- (Table 15)). Flow metering equipment at surface water station SP012- was operated and maintained during 2020 to 2022 in accordance with Conditions W3(d) and W3(e) of the EP Act Licence. The monthly flow measurements, cumulative flows, and flow metering equipment availability at SP012- during the period of review are listed in Table 16. Flow volumes in 2020–2022 (Table 16; Figure 62) were consistent with longer-term flow trends. Lower flows were observed in 2020 owing to the relatively low rainfall received.

Total flow at the Wagerup site exit point, SP012- (immediately downstream from the RSAs) was 619 ML (2020), 5,396 ML (2021) and 3,222 ML (2022). Flow volumes at the high-flow surface sites were up to 83,710 ML (SP020-; 2020). These stations are located on natural stream channels or drains, and some flows are influenced by water harvesting and flow diversion.

Table 15: Monthly flows at surface water monitoring stations, 2020–2022

Site	Flow volume (ML)							
	SP001-	SP005-	SP006-	SP010-	SP012-	SP016-[1]	SP020-	SP026-
Jan-20	-	-	0.1	27.5	31.6	-	1,310.4	287.6
Feb-20	-	-	-	23.2	28.5	-	1,198.2	349.0
Mar-20	-	-	1.2	20.2	24.9	-	1,255.9	448.2
Apr-20	-	-	1.4	8.4	7.6	-	856.2	240.1
May-20	2.1	-	73.7	9.6	6.9	-	992.3	491.5
Jun-20	45.4	-	600.5	76.5	83.0	-	5,255.3	2,519.8
Jul-20	79.8	-	826.7	103.9	151.3	-	7,825.4	4,046.0
Aug-20	90.1	-	864.8	166.9	216.3	-	7,524.1	4,083.1
Sep-20	57.0	-	671.4	17.4	36.8	-	4,048.9	2,311.2
Oct-20	17.2	-	333.4	17.7	5.7	-	1,579.0	739.9
Nov-20	15.8	-	29.4	84.0	15.2	-	1,739.4	627.1
Dec-20	0.3	-	3.3	37.9	11.1	-	491.3	143.8
2020	**307.7**	**0**	**3,405.9**	**593.1**	**618.9**	**N.D.**	**34,076.4**	**16,287.4**
Jan-21	-	-	-	28.6	14.7	-	263.6	92.1
Feb-21	-	-	0.0	15.7	9.3	-	274.1	92.1
Mar-21	-	-	0.0	7.5	4.4	-	260.1	90.7
Apr-21	-	-	0.1	40.3	30.0	-	384.2	128.3
May-21	10.4	-	189.6	57.1	40.2	-	1,758.7	620.9
Jun-21	33.7	-	348.1	96.8	118.2	-	4,095.6	1,627.8
Jul-21	331.7	17.8	1,218.7	1,994.5	3,503.2	-	42,291.9	16,854.2
Aug-21	142.3	206.4	276.1	638.4	1,067.1	-	17,314.7	7,581.6
Sep-21	85.5	86.8	169.0	189.1	343.9	-	8,648.4	3,929.7
Oct-21	73.0	-	200.9	200.6	174.7	-	5,134.3	2,370.6
Nov-21	15.2	-	30.1	102.3	42.8	-	1,853.2	650.8
Dec-21	1.2	-	7.3	67.6	47.1	-	1,431.2	287.3
2021	**693.1**	**310.9**	**2,439.9**	**3,438.7**	**5,395.5**	**N.D.**	**83,710.0**	**34,326.3**
Jan-22	0.3	-	0.8	44.5	40.0	-	1004.1	157.3
Feb-22	-	-	0.0	14.0	15.3	-	1111.5	198.6
Mar-22	-	-	0.7	21.0	14.9	-	1361.0	261.3
Apr-22	-	-	2.0	9.4	2.0	-	1093.5	179.6
May-22	3.7	-	1.0	23.8	11.3	-	1782.8	412.6
Jun-22	21.6	-	-	6.6	5.2	-	3325.3	1,026.7
Jul-22	132.8	340.8	-	0.3	1,461.3	-	22717.4	8,756.0
Aug-22	208.0	948.6	-	-	1,548.8	-	24614.5	9,378.8
Sep-22	32.3	109.6	191.7	10.8	77.3	-	2623.5	67.6
Oct-22	6.0	47.6	145.2	19.8	22.0	79.8	1681.7	754.7
Nov-22	4.0	-	16.2	49.2	19.9	24.3	1586.0	544.7
Dec-22	0.0	-	22.4	13.3	4.2	0	1110.8	288.8
2022	**408.7**	**1,446.7**	**380.0**	**212.6**	**3,222.2**	**104.1[2]**	**64,012**	**22,026.9**

[1]N.D. – Not determined. [2]Incomplete data set, data only available for Oct-Dec 2022

Table 16: Monthly flow measurements at Station SP012-, 2020–2022

Date	Flow (m^3)	Annual cumulative flow (m^3)	Monthly flow metering equipment availability
Jan-20	31,566	31,566	100%
Feb-20	28,454	60,020	100%
Mar-20	24,931	84,952	100%
Apr-20	7,630	92,581	100%
May-20	6,933	99,514	100%
Jun-20	83,018	182,532	100%
Jul-20	151,318	333,850	100%
Aug-20	216,290	550,140	100%
Sep-20	36,790	586,930	100%
Oct-20	5,701	592,631	100%
Nov-20	15,162	607,793	100%
Dec-20	11,075	618,868	100%
Jan-21	14,722	14,722	100%
Feb-21	9,253	23,976	100%
Mar-21	4,386	28,361	100%
Apr-21	29,989	58,351	100%
May-21	40,179	98,529	100%
Jun-21	118,203	216,732	100%
Jul-21	3,503,183	3,719,916	100%
Aug-21	1,067,132	4,787,047	100%
Sep-21	343,902	5,130,950	100%
Oct-21	174,659	5,305,608	100%
Nov-21	42,790	5,348,398	100%
Dec-21	47,073	5,395,470	100%
Jan-22	40,031	40,031	100%
Feb-22	15,281	55,312	100%
Mar-22	14,884	70,196	100%
Apr-22	1,954	72,150	100%
May-22	11,347	83,497	100%
Jun-22	5,153	88,650	100%
Jul-22	1,461,328	1,549,978	100%
Aug-22	1,548,826	3,098,804	100%
Sep-22	77,344	3,176,148	100%
Oct-22	21,956	3,198,105	100%
Nov-22	19,941	3,218,046	100%
Dec-22	4,164	3,222,210	100%

5.6.2 SURFACE WATER CHEMISTRY

Time-series graphs of water quality data from the surface water monitoring stations are included as Appendix J. Results for comprehensive analyses of water samples collected in 2020-22 from most stations are shown in Appendix E. Cyclic variations in key water quality parameters, pH, EC, and alkalinity are apparent at most stations (Appendix J) and are typical of this moderately-modified environment, where early winter run-off is commonly more saline as salts are flushed from the soils, followed by a period of fresh rainfall runoff, and then a period of increasing salinity as low flows and evaporative processes become predominant. With the exception of the points noted below, there are no unusual or new trends in the surface-water quality time-series graphs and the 2020-22 data lie within past ranges.

Samples collected from South Yalup Lower Dam (SP003-), located at the refinery site, exhibit different hydrochemistry compared to those from the other surface water sites. The Lower Dam stores both runoff and high quality condensate. 2020-22 sampling results (Appendix E; Appendix J) show non-seasonal fluctuations in salinity but seasonal and relatively elevated values for alkalinity, as well as elevated ammonia (14 mg/L), TKN (total Kjeldahl nitrogen) (15 mg/L), and trace levels of heavy metals not seen elsewhere, and comparatively low values for silica and iron. The 2020-22 results are within the range of values recorded for the key hydrochemical parameters since 2001. No water from the South Yalup Lower Dam is released offsite as it is recycled within the refining circuit.

At SP012- (Table 17; Table 18; Appendix E), located just down-stream of the confluence between Sampson Brook and the Diversion Drain, concentrations of trace metals lead, nickel and zinc have shown considerable variability (Clifton 2014). SP012- experiences a moderate peak in alkalinity about a month after major winter rainfall events (Figure 61), sampling of nutrients has indicated this is due to flushing effects from up-gradient sources. Two comprehensive water quality samples for a limited suite of trace elements are routinely collected and analysed each year from this site (Table 18), one from the end-of-summer (about April) and one from the end-of-winter (about October), and additional opportunistic samples were also collected in August 2020 and December 2022. All results were at trace levels or below detection in the 2020-22 period.

Monthly samples of pH, EC, alkalinity, turbidity and sodium to chloride ratio (Table 17) are consistent with results for the previous period of review. Both the monthly and six monthly sampling are requirements of the EP Act licence and the Operating Strategy. Eleven samples returned alkalinity readings exceeding the trigger value of 50 mg/L. Naturally-occurring elevated alkalinity (> 50 mg/L) has been recorded in groundwater up-gradient of SP012-. This naturally-occurring alkalinity could also contribute to the elevated alkalinity in SP012- (360 Environmental 2016). No other trigger values were exceeded during the period of review.

Alcoa undertook nutrient analyses as follow up to the alkalinity exceedances (up to October 2021), which suggested the flushing of fertilisers from upstream was a potential source of contamination. There is a correlation between phosphorus values and alkalinity in the stream, whereby during times of heavy runoff, the excess phosphorus reacts with the stream bed and may release carbonates, resulting in elevated stream alkalinity. It is also noted that often fertilisers contain lime to neutralise the soil acidity, which can be directly related to stream alkalinity if the amount of fertiliser exceeds the amount required to fully neutralise the soil acidity.

Table 17: Results of monthly sampling at Station SP012-, 2020–2022

Date	pH	Conductivity	Alkalinity[1]	Turbidity	Na/Cl[1]
	(field)	(µS/cm)	(mg/L)	(NTU)	
23/01/2020	7.9	278	23	16	0.54
19/02/2020	7.7	266	21	15	0.54
16/03/2020	6.9	343	21	16	0.58
15/04/2020	6.7	450	15	13	0.63
14/05/2020	7.1	560	12	20	0.53
22/06/2020	6.5	1240	21	40	0.58
16/07/2020	6.9	540	55	31	0.62
5/08/2020	7	680	71	25	0.58
18/08/2020	7	306	56	21	0.67
15/09/2020	7	827	64	7.1	0.56
12/10/2020	7.1	1020	104	10	0.47
22/10/2020	7.2	1000	120	13	0.59
17/11/2020	7	493	36	16	0.45
16/12/2020	7.6	330	34	13	0.55
21/01/2021	6.8	432	31	33	0.48
15/02/2021	6.8	341	26	17	0.53
29/03/2021	6.7	329	16	39	0.52
21/04/2021	6.7	280	23	11	0.66
19/05/2021	6.9	307	24	20	0.56
8/06/2021	6.3	954	15	23	0.53
15/07/2021	6.9	295	46	12	0.73
17/08/2021	6.8	511	52	5.3	0.52
23/09/2021	7	505	53	6.3	0.52
20/10/2021	7	790	84	19	0.46
16/11/2021	7.1	417	41	12	0.48
7/12/2021	7.5	330	30	9.2	0.52
18/01/2022	7	350	37	16	0.50
17/02/2022	7.1	340	34	18	0.48
9/03/2022	6.7	430	7	18	0.46
27/04/2022	7	300	24	12	0.52
9/05/2022	6.9	310	15	11	0.56
21/06/2022	6.5	1000	28	36	0.48
25/07/2022	6.6	220	26	16	0.60
18/08/2022	7	310	40	12	0.64
8/09/2022	6.8	490	36	80	0.48
18/10/2022	7	480	65	35	0.50
15/11/2022	6.8	540	59	18	0.41
7/12/2022	7.5	330	32	7.4	0.53
Trigger levels[1]	**<5.0 or > 9.5**	**>2,000**	**>50**	**>250**	**>0.8**

1. Trigger level values for alkalinity and Na/Cl mass ratio are applied if values of pH or EC exceed the respective criteria (see Conditions W3(b) and W3(c) in Appendix A) for the Part V EP Act licence for the Surface Water Licences Operating Strategy the trigger applies at all times.
2. Shaded values are results above trigger values

Table 18: Results of six-monthly sampling at Station SP012-, 2020–2022

Date	Concentration (mg/L)							
	Al	As	Hg	Se	V	Mn	Mo	U
15/04/2020	<0.005	<0.001	<0.00005	<0.001	<0.001	0.025	<0.001	<0.0005
5/08/2020	0.21	<0.001	<0.00005	<0.001	0.001	0.048	<0.001	<0.0005
22/10/2020	0.02	<0.001	<0.00005	<0.001	0.002	0.13	<0.001	<0.0005
21/04/2021	<0.005	<0.001	<0.00005	<0.001	<0.001	0.003	<0.001	<0.0005
20/10/2021	0.01	<0.001	<0.00005	<0.001	<0.001	0.18	<0.001	<0.0005
27/04/2022	<0.005	<0.001	<0.00005	<0.001	<0.001	0.006	<0.001	<0.0005
18/10/2022	0.006	<0.001	<0.00005	<0.001	<0.001	0.043	<0.001	<0.0005
ANZECC Trigger levels	**5**	**0.5**	**0.002**	**0.02**	**0.1**	**1**	**0.15**	**0.2**
ANZG (2018) Trigger[1]	**0.055**	**0.013[2]**	**0.00006**	**0.005**	**0.006**	**1.9**	**0.034**	**0.0005**

1. Trigger level values for slightly to moderately disturbed ecosystems.
2. Arsenic V value used as it is the oxidised form and relevant to surface water systems.

Station SP017- is located on an ephemeral stream west of the refinery. Samples from SP017- have had slightly elevated alkalinity since this station was established in 1999 due to the periodic surface expression of a plume of dilute alkaline groundwater down slope (west) of the former Hydrate Stockpile (Figure 7). Alkalinities have continued to increase since about 2013. In 2022 alkalinities were in the range of about 350–360 mg/L. The inverse correlation between EC and alkalinity noted in some of the RS-Series groundwater monitor bores is evident at this site, and to a lesser extent at SP019-, on a similar easting to the north. There appears to be a gradual increasing trend in salinity at SP017-, with EC reaching 1,000 µS/cm for the first time in 2016 and remaining above 900µS/cm during the reporting period.

Other than the alkalinity exceedance in SP012- noted above, none of the surface water samples listed in Appendix E contain trace elements in concentrations above the stock watering guideline limits provided in the Australian Water Quality Guidelines for Fresh and Marine Waters (ANZECC and ARMCANZ 2000). A single sample in August 2020 returned an Aluminium value exceeding the Toxicant Default Guideline Value (ANZG, 2018). Subsequent samples all were below the guideline values.

The ion balances for the analyses presented in Appendix E generally have absolute values of less than ±5% indicating that an acceptable degree of precision in the results, with the exception of SP003-, where larger differences occur (both in the current reporting year and previous sampling) suggesting that the analysis suite does not include one of more of the metals/metalloids in this source, causing a charge imbalance.

In general, surface water at the site tends to be of a Na-Cl type (Rockwater 2017), with the proportion of Na at most stations ranging from about 60–70% and Cl ranging from about 70–85%.

5.6.3 SURFACE WATER VOLUMES

The refinery water demand is managed in part by the use of storage facilities at the refinery and the RSAs. Storage and transfer volumes, along with water use efficiency are also discussed in Section 5.7.

The Operating Strategy requires the following to be reported:

- Volume of water drawn by Alcoa from the various sources during the reporting period; and
- Volume released downstream from diversion/storage points (including excess winter flow releases and environmental releases) during the reporting period.

This information for the 2020–2022 review period is presented in Table 19 and Table 20. All volumes are within the annual water entitlements specified in the respective licences (Table 19).

Table 19: Surface water volumes drawn from sources, 2020–2022

Water source/licence	Storage facility	Volume drawn from source		
		2020	2021	2022
Yalup Brook [SWL97472(6)] (1,600)[1]	South Yalup Upper Dam (ML)	1,212	532	427
	Percentage of entitlement	76%	33%	27%
Black Tom Brook [SWL99246(5)] (2,500)[1]	Detention Pond 1 (ML)	-500	1,737	273
	Percentage of entitlement	0%	69%	11%
Harvey River Main Drain [SWL151027(4)] (4,400)[1]	ROWS Pond (ML)	332	0	0
	Detention Pond 1 (ML)	159	0	0
	Detention Pond 2 (ML)	668	643	967
	Total (ML)	1159	643	967
	Percentage of entitlement	26%	14%	22%
Purchased water (no licence required)	South Yalup Upper Dam (ML)	3,800	1,491	2,411
	Detention Pond 1 (ML)			
	Detention Pond 2 (ML)			
Total (ML)		5,671	4,403	4,078

1. Licence entitlement (see Appendix B)

Table 20: Surface water volumes released from storage, 2020–2022

Water storage facility	Volume released (ML)		
	2020	2021	2022
Detention Pond 1	0	311	656

The volume of water drawn from the Harvey River Main Drain during the review period was 643–1159 ML/year. Flow in the Harvey River Main Drain is measured downstream of the Harvey River Pump-back Station at surface water monitoring site SP020-. The total volume of water passing SP020- is estimated to be 34,076 ML (2020), 83,710 ML (2021) and 66,012 ML (2022) (Table 15). Therefore, the volume of water drawn from the Harvey River Main Drain in 2020-22 was <2% of the estimated annual flow in this drainage channel over the period of review.

5.7 REFINERY WATER INVENTORY

Alcoa has adopted the Minerals Council of Australia Water Accounting Framework (MCA 2014). A water inventory based on these guidelines is now presented rather than the version presented in historical reports (Rockwater 2017). The inventory (Table 21) shows that rainfall provides a significant input of water to ponds and low permeability areas that is directed to the ponds. This methodology (rainfall-capture and use within the process, rather than discharging it) prevents a potential source of contamination to the surrounding environment. The main outputs from the system are evaporation from cooling towers, tanks and vents at the refinery (plant), evaporation from ponds and entrainment in residue sand and mud. Output volumes were the highest of the triennial period in 2020 (11,004 ML), as a function of higher production resulting in greater losses due to evaporation from plant and entrainment in residue and higher Class A Pan evaporation resulting in significantly higher evaporation from ponds than in other years.

Seepage is used to balance the model as recommended by the guidelines (MCA 2014). There may be other areas in the model where estimations of inputs and/or outputs could be improved, such as rainfall capture. Ongoing improvements include runoff comparison between Alcoa sites, increased focus, assessment and calculation of reuse efficiency (percentage of water used in a task that has already been used in the process). Alcoa plans to continuously refine the balance for increased accuracy and transparency.

Table 21: Refinery water inventory

Site			Annual volume (ML)		
Site description	**Water balance description[1,2]**	**Category[1,3]**	**2020**	**2021**	**2022**
Rainfall on refinery and caustic ponds	(I/SW) Precipitation and runoff	3	3,120	4,469	3,164
Rainfall on freshwater storage ponds[4]	(I/SW) Precipitation and runoff	1	541	741	536
Black Tom Brook	(I/SW) Rivers and streams	1	-500[7]	1,737	273
Yalup Brook	(I/SW) Rivers and streams	1	1,212	532	427
Harvey Pumpback	(I/SW) Rivers and streams	1	1,159	643	967
Recovery bores	(I/GW) Borefields	3	39	40	61
Depressurising bores and sub-liner drains	(I/GW) Borefields	2	351	352	396
Production bores	(I/GW) Borefields	2	32	22	10
Water in bauxite	(I/GW) Entrainment	2	778	752	703
Water in caustic	(I/3rd) Water from caustic	3	115	111	104
Harvey water	(I/3rd) Contract/Municipal	2	3,800	1,491	2,411
Total inputs[6]			10,649	10,891	9,053
Evaporation from freshwater storage ponds[4]	(O/C) Evaporation	1	1,018	990	1,119
Sprinkler evaporation	(O/C) Evaporation	1	1,732	1,398	947
Evaporation from caustic storage ponds	(O/C) Evaporation	3	1,513	1,501	1,715
Evaporation from plant	(O/SW) Discharge	1	3,199	3,094	2,891
Discharge from DP1 (SP005-)	(O/SW) Discharge	1	0	311	656
Moisture in sand and mud	(O/C) Entrainment	3	2,882	2,787	2,605
Seepage (used to balance model)	(O/GW) Seepage	3	661	-50	-701
Total outputs[6]			11,004	10,081	9,932
Storage at beginning of period[5]			5,414	5,059	5,948
Storage at end of period[5]			5,059	5,919	5,770
Change in Storage[6]			-355	860	-178

1. Based on Water Accounting Framework Definitions (MCA 2014).
2. I – Input, O- Output, SW – Surface Water, GW – Groundwater, 3rd – Third Party Water, C – Consumption
3. Category 1 water is of a high quality and suitable of most purposes with little or no treatment. Category 2 water is of a medium quality and suitable for some purposes, such as irrigation. Category 3 water is of a low quality and suitable for limited purposes without significant treatment.
4. South Yalup Lower Dam and Detention Pond 2 (extraction from South Yalup Upper Dam and Detention Pond 1 is counted as inputs due to how the extraction from Yalup Brook and Black Tom Brook is calculated [Alcoa 2018]).
5. Includes South Yalup Lower Dam, Detention Pond 2 and the caustic storage ponds. South Yalup Upper Dam and Detention Pond 1 are excluded (footnote 4).
6. Totals may not equal the sum of the values due to rounding.
7. The negative value indicates that more Harvey Water was transferred to Detention Pond 1 in 2020 than Black Tom water was abstracted (DWER approved calculation).

5.8 RISK TO SENSITIVE RECEPTORS

Shallow groundwater in the superficial formations is the main receptor at risk from Alcoa's Wagerup Operations. This resource potentially has beneficial use as a water supply. Other receptors identified include surface water features (Black Tom Brook, North Yalup Brook and Harvey River) and neighbouring properties (Table 6).

Groundwater in the superficial formations continues to be affected by alkaline process fluids within and to the west of the Wagerup Refinery, and possibly in localised areas in the vicinity of the Residue Storage Areas. There is no indication of significant impact on groundwater quality in the deeper Mesozoic formations either at the refinery or within the RSA complex.

At the Wagerup Refinery, caustic fluids have seeped into both the upper and lower superficial formations. The upper superficial formations at the refinery site comprises several metres of Guildford Formation overlying clayey Yoganup Formation. The Guildford Formation is generally noted as having very low hydraulic conductivities, with limited potential for lateral and/or vertical migration of the alkali fluids. The lower superficial formations in this area comprise more sandy beds of the Yoganup Formation, which have higher hydraulic conductivities and alkali fluids that gravitate into this unit have the potential to move in the direction of the natural groundwater flow to the west. Some of the alkaline seepage in the refinery area is being intercepted by four alkali recovery bores that draw groundwater from the lower Yoganup Formation at Buildings 26 and 45.

Monitoring data, collected in the vicinity of the Wagerup RSAs during the period of review, suggest some infiltration of alkali liquor in the vicinity and to the north of RSA1/RSA2 and the Sand Lake, predominantly to the upper superficial formations. This could be due to the aged monitor bores acting as a conduit for contamination.

The quality of groundwater in the upper superficial formations around ROCP1 and ROCP2 may have low-level impact from residue leachate:

- The clay liner of ROCP1 was likely damaged by upward groundwater pressures soon after construction in 1992, which has provided an opportunity for residue leachate to enter the shallow formations beneath the liner when water levels in ROCP1 exceed groundwater levels. Alkalinity in monitor bore RS100S has increased over the 2020–2022 review period while decommissioning activities have been underway.

- The liner at ROCP2 was found to be damaged in 2013 and underwent maintenance and repair in 2014, and while a decrease in alkalinity was observed in the vicinity of this pond immediately following repair, some levels have increased again during the period of review, notably RS064S, RS126G and RS138S/G. Monitoring is ongoing.

Elevated groundwater salinity has been observed in monitor bores located on the northern and western perimeter of the RSAs and in isolated regional bores. In particular, high salinities (likely unrelated to the RSAs) occur in bores to the north and west of the RSAs. The relatively high salinity is generally not associated with elevated alkalinity however, and therefore does not appear to represent infiltration or migration of alkali fluids. The cause of elevated salinities in these locations is unclear.

There is no evidence of major changes to the chemistry of surface water exiting the Wagerup site during the 2020–2022 review period.

6 BUNBURY CAUSTIC LOADING FACILITY MONITORING REVIEW

6.1 BACKGROUND

The Bunbury Caustic Loading Facility is located at the Inner Harbour of the Port of Bunbury (Figure 1; Figure 63). Liquid caustic soda is unloaded from ships and temporarily stored in tanks at the site before being transported to the alumina refinery by truck and train. Alumina from the refinery is also stored on site before being shipped for further processing into aluminium.

The Bunbury facilities are used jointly by Alcoa and Worsley Alumina Pty Ltd. The total area of leased land is 29.9 ha: of this, 10.8 ha is held by Alcoa, 10.2 ha are held by Worsley, and 8.9 ha are held jointly.

6.2 SITE TOPOGRAPHY, SURFACE WATER AND HYDROGEOLOGY

The Bunbury Caustic Loading Facility is situated on reclaimed land, formed by the deposition of dredge spoil derived from the Inner Harbour. The site is flat-lying, with land surface elevations generally ranging between 2 m AHD and 5 m AHD. Most of the site (Figure 63) is surrounded by seawater.

The surface is covered by fine-grained, silty sand and some of the lower lying areas contain shallow pools of water during the wetter months. Rainfall readily infiltrates the surface sand and percolates to the water table where it develops a lens of fresh groundwater that sits above more-dense saline groundwater.

The hydrostratigraphic sequence at the site is heterogeneous and consists of four, relatively thin, sandy, groundwater-bearing layers separated by clayey aquitards to an elevation of about -18.5 m AHD. This sequence is underlain by the impermeable Bunbury Basalt (Haselgrove 2002). The upper, unconfined layer comprises entirely dredge spoil overlying natural estuarine deposits which sub-crop at an elevation of about 1 m AHD. The estuarine deposits are predominantly organic-rich silt and clay but include at least one sandy aquifer zone. Another sandy aquifer interval lies below -4 m AHD, comprising mainly Safety Bay Sand, and containing a fresh/saline groundwater interface at about -7 m AHD. This is underlain by a layer of silty clay and another sandy aquifer zone.

6.3 RAINFALL

Rainfall at Bunbury is recorded at the Bunbury Turf Club weather station (BoM Station No. 9965; Table 22), which provided its first full year of data in 1996. Previous records were collected at the Bunbury Post Office (BoM Station No. 9514), which has a record length of 108 years but is no longer in operation. There is no overlap in the periods of record for the two stations. The monthly mean data show a strong seasonal rainfall distribution, with June and July being the wettest months and about 80% of the total rainfall being recorded during May to September. Total 2021 and 2022 rainfall (964 mm and 772 mm respectively) was above the annual mean (730 mm). 2020 rainfall data is incomplete, however using nearby Marriwood station data for October and November, the rainfall was about 38 mm below average, which is consistent with rainfall trends in the Wagerup area (Section 2.2).

Table 22: Bunbury rainfall data, BoM Station 9965

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2020	1.2	12.4	35.2	23.6	114.4	152.2	129.0	65.6	88.2	22.8[A]	106.9[A]	5	692[A]
2021	0.2	54.6	36.4	74	147.8	101	199.8	108.2	95.2	123.4	12.6	10.6	963.8
2022	0	2.8	8.6	61.6	111	110.4	226.2	132.8	70.2	30.6	18	0	772.2
Mean	10.4	8.8	19.9	38.4	99.5	134.5	145.5	118.2	79.7	36.4	21.4	15.8	730.4[B]

A. Approximate value, based on October and November values from Marriwood Station (9629, 14 km away) (data gap)
B. Based on available data range (1995 to present)

6.4 RECEPTORS

Potential receptors, which could be affected should groundwater or surface-water runoff be impacted by activities at Alcoa's Bunbury Operations, have been identified (Table 23). A targeted monitoring program (outlined in Section 6.5) has been developed to provide data to assess any such effects.

Table 23: Potential receptors at Alcoa's Bunbury Operations

Type	Receptor	Area	Description/comment
Water supply	Superficial formations aquifer	Loading facility	Shallow groundwater in this area has limited beneficial use
Ecological	Bunbury Inner Harbour	Loading facility	The Inner Harbour is a very disturbed marine receptor
	Preston River	Loading facility	The Preston River is a moderately disturbed estuarine environment; surface water bodies at the Bunbury Caustic Loading Facility have in the past provided a pathway to this receptor; however, site filling has eliminated this pathway.
Land	Neighbouring properties	Beyond property boundary	All neighbouring properties are industrial

6.5 MONITORING PROGRAM, QUALITY ASSURANCE AND QUALITY CONTROL

Alcoa has developed groundwater and surface water monitoring programs for the Bunbury Operations using the same risk assessment methodology that has been applied to the Wagerup Operations (Section 2.5). As outlined in Section 3.4, the requirements and data quality-control procedures for groundwater and surface water monitoring programs currently undertaken at Alcoa's Western Australian Operations have been developed in accordance with AS/NZS 5667 (see Table 7 for a list of monitoring and quality control procedures). The monitoring programs recognise possible sources of alkaline fluids from spills or leaks of liquid caustic soda at the train and truck loading areas, storage tanks and pipelines. Potential receptors identified as part of the risk assessment are listed in Table 23.

The Environmental Objectives that are applicable to the Bunbury Operations are listed in Table 24. The 2009 environmental protection objectives and their associated monitoring objectives are listed in Table 1 and Table 24, and the monitoring program, designed to collect appropriate data to address these objectives, is detailed in Table 24.

Table 24: Bunbury Operations environmental protection and monitoring program

Monitoring objective	Monitoring sites	Monitoring program
3A) Assess changes in the extent and magnitude of alkaline plumes of groundwater within the superficial formations	B-012A/B/-, B-013A, B-014A/B, B-015A/B, B-016A/B, B-018A/B/-, B-020A/B, B-022A/B, B-023D/I/S	Annual groundwater levels
	B-012A/B/-, B-013A, B-014A/B, B-015A/B, B-016A/B, B-018-, B-023 D/I/S	Annual field pH and EC Annual laboratory analysis for pH, EC and alkalinity
3B) Assess changes in the extent and magnitude of hydrocarbons in groundwater within the superficial formations	B-018A/B, B-020A/B, B-022A/B	Annual laboratory analysis for pH, EC, and alkalinity Annual analysis for TPH, BTEX, and PAH
7A) Assess whether surface water runoff adversely affects the marine environment	SS003-, SS004-, SS005-, SS006-	Field pH, EC, and ORP, and laboratory comprehensive analysis of the first storm water flush

An inventory of groundwater, surface water, and storm water monitoring sites at the Bunbury Operations is included in Appendix D. Site locations are shown in Figure 64.

Groundwater monitor bores are located at eleven sites ('B-' prefix in Figure 64). Each site has either two or three monitoring casings installed to different depths, identified using a suffix to the site name: B (shallowest), A (intermediate) and – (deeper), or in the case of the newest bore, S (shallow), I (intermediate) and D (deeper). Lithological logs (Haselgrove 2002) indicate that some of the slotted sections of casing in the deeper bores extend over more than one thin, sandy, aquifer interval. These sites are monitored according to the schedule in Table 24. Groundwater hydrographs are provided in Appendix K; time-series groundwater-quality monitoring results are presented in Appendix L.

Four surface water monitoring sites ('BS' prefix in Figure 64) were established in 2000 at locations that could potentially be affected by caustic spills or leaks. There was some flow of water at these sites initially; however, additional dredging of the Inner Harbour and soil deposition has changed the drainage patterns in the area (Gilbert 2003). Any water that now collects at these sites is ephemeral and quickly becomes stagnant. Monitoring of these four surface-water sites was discontinued in 2006 in response to recommendations made following a site risk assessment and monitoring program review (Parsons Brinckerhoff 2006). The historical monitoring data are presented as time-series plots in Appendix L.

Four storm-water runoff monitoring sites ('SS' prefix in Figure 64) were established in August 2005. These are equipped with samplers to collect the first flush of storm water after a rainfall event. These sites are monitored according to the schedule in Table 24.

Alcoa no longer routinely monitors bores B-017B/A, B-019B/A, and B-021B/A, which are on the lease held by Worsley Alumina Pty Ltd. Two of these bores were last monitored for Alcoa, other than for contaminated site investigations (Section 6.6), in late-2010, and samples were obtained from B-021B/A in 2015 and B-017 in late 2019. No data were collected during the 2020-2022 period.

6.6 INVESTIGATIONS AND MONITORING PROGRAM MANAGEMENT

A detailed site investigation was completed in 2018 at the caustic train loading facility (360 Environmental 2019A). The investigation confirmed some shallow caustic contamination around the sumps and unloading arms. A recommendation of this investigation was to install a monitor bore down-gradient of caustic unloading to delineate the plume. This bore triplicate was installed in October 2019 (monitor bores B-023D/I/S [360 Environmental 2019D]).

Soil sampling was completed in 2019 around the buried caustic pipeline and laydown yard (360 Environmental 2019E). The report indicated that there was contamination around an un-bunded pump and valve set up, but no contamination around the buried pipeline. The recommendation of this report was to progress the site to a Site Management Plan. This work was completed and submitted to DWER in 2022.

6.7 GROUNDWATER AND STORM WATER MONITORING DATA

6.7.1 GROUNDWATER LEVELS

Hydrographs for the monitor bores are included as Appendix K. Groundwater-level data are also presented in Table 28, Figure 65 (groundwater levels), and Figure 66 (change in groundwater level). These data show that groundwater levels decrease towards the west and are generally higher in the upper, unconfined aquifer-interval, ranging from 1.87 m AHD in B-020B to 3.42 m AHD in B-016B. Downward hydraulic-head gradients exist at most sites between the upper aquifer and deeper aquifer intervals, supporting the conceptual hydrogeological model of a groundwater system recharged mainly by infiltration of rainfall across the site. There is virtually no surface runoff. Hydraulic heads are similar in monitor bores B-013B/A and B-015B/A, to the east of the site, indicating a greater degree of hydraulic connection between the aquifer intervals at this location.

Seasonal variations over the review period of 2020–2022 groundwater levels match the rainfall patterns outlined in Table 22. The 2019 and 2020 rainfall was below average, and the monitoring data displayed a decreasing trend in groundwater levels (average annual decrease: 0.43 m, 2018-20, [shallow bores]). This was followed by increasing groundwater levels in 2021-22 (average annual increase: 0.1 m [shallow bores]) corresponding with higher than average annual rainfall.

There is also a gradual, long-term water level rising-trend evident in a number of the bores, particularly those located to the east of the site (for example, B-013B/A, B-014A, B-015B/A and B-016B/A) (Appendix K). While some changes to groundwater level characteristics at the site are evident, they do not represent a significant adverse impact, with groundwater levels remaining below ground level and the magnitude of change being relatively small (groundwater level rise <0.3 m/yr).

Table 25: Bunbury groundwater monitoring summary

Bore	Groundwater level (m RL)											
	Upper ('B')				Middle ('A')				Lower ('-')			
	2020	2021	2022	Change[1]	2020	2021	2022	Change[1]	2020	2021	2022	Change[1]
B-012	1.98	1.91	2.07	0.09	1.61	1.59	1.72	0.11	0.78	0.83	1.15	0.37
B-013	2.19	2.16	2.3	0.11	2.09	2.14	2.23	0.14	-	-	-	-
B-014	3.15	3.09	3.3	0.15	1.89	2.15	2.08	0.19	-	-	-	-
B-015	2.56	2.5	3.03	0.47	2.15	2.32	2.37	0.22	-	-	-	-
B-016	3.27	3.2	3.42	0.15	2.39	2.5	2.45	0.06	-	-	-	-
B-018	2.43	2.9	2.64	0.21	1.66	1.75	1.64	-0.02	0.94	1.08	1.11	0.17
B-020	1.78	2.19	1.87	0.09	1.19	1.43	1.35	0.16	-	-	-	-
B-022	Blocked			-	0.93	1.08	1.1	0.17	-	-	-	-
B-023	2.93	3.01	3.12	0.19	2.05	2.29	2.63	0.58	0.6	0.83	0.93	0.33

1. 2020 to 2022 change in groundwater levels (negative numbers represent a decrease in groundwater levels)

6.7.2 GROUNDWATER CHEMISTRY

Hydrochemistry data from the monitor bores, surface-water monitoring stations, and storm-water monitoring stations, are displayed as time-series graphs in Appendix L. Figure 65 and Figure 66 show the spatial distribution and changes to key chemical parameters, pH, EC and alkalinity, in the groundwater system during the period of review.

Hydrochemistry data (Figure 65) indicate that groundwater salinity is generally fresh in the shallow aquifer interval (400–1,600 µS/cm EC), with the exception of B-012B to the east of the site, where EC is elevated at 7,500 µS/cm. The pH in the shallow aquifer interval generally ranges from neutral to slightly alkaline (7.3–7.9), except at B-012B, where highly alkaline values have been recorded in the reporting period (9.5–9.9 pH units). Similarly, alkalinity in the shallow aquifer ranges from 151–445 mg/L, except at B-012B where it is 2,380–3,060 mg/L. The results indicate minor to moderate impact in the shallow aquifer over most of the site, but significant impact to groundwater quality near the caustic spill collection pump, reflected in monitor bore B-012B (Figure 65 and Figure 66). Monitor bore B-012A data suggest that caustic seepage has infiltrated to the lower aquifer interval, with pH ranging between 7.8–8.0, EC ranging between 2,500–4,250 µS/cm and alkalinity ranging between 603 and 1,130 mg/L. Nearby bore B-023S/I, drilled in 2019 to determine the plume extent, did not show the same level of contamination, with neutral pH and background level alkalinity.

Deeper monitor bores ('A' and '-' suffix bores, excluding B012 monitor bores) show a general trend of alkalinity (242–1,780 mg/L) increasing towards the southwest. EC values (620 – 5,270 uS/cm ['A' series bores] and 11,000 – 19,600 ['-' series bores]) similarly generally increase towards the southwest. EC values reflect the saline interface (including monitor bores B-018- and B-012-) and are likely influenced by changes in the freshwater lens due to such impacts as seasonal changes in rainfall recharge. Previous assessments (Rockwater 2020) suggested that elevated pH, EC and alkalinity values (deeper monitor bores B-013A, B-014A, B-015A and B-018A) resulted from localised activities in the past. Appendix L show more-elevated values for these key parameters in the past, or from migration of the more-dense alkali fluids through the lower aquifer interval, where shallow bores have always had lower EC, pH and/or alkalinity. The high salinity the lower-most aquifer interval (B-018- and B-012-) is likely natural, representing completion of the monitor bores beneath the salt-water interface.

Monitor site B-012A shows a declining trend in EC (~1,750 uS/cm at 'B' depths; ~1,100 uS/cm in 'A' depths and ~1,200 uS/cm at '-' depths) and alkalinity (~527 mg/L at 'B' depths; ~10 mg/L in 'A' depths and ~680 mg/L at '-' depths) (Table 26). This may signify dissipation of alkali fluid; however nearby monitoring bores B-013, B-015 and B-023D have not shown any decreases at present.

Table 26: Bunbury groundwater geochemistry results

Parameter	Location	2020[A]			2021[A]			2022[A]		
		Upper	Middle	Lower	Upper	Middle	Lower	Upper	Middle	Lower
pH	B-012	9.9	8	7.5	9.5	7.8	7.4	9.7	7.8	7.4
	B-013	7.8	7.7	-	7.8	7.7	-	7.8	7.9	-
	B-014	7.4	8.1	-	7.5	7.9	-	7.4	8	-
	B-015	7.7	7.6	-	7.6	7.8	-	7.7	7.6	-
	B-016	7.9	7.9	-	7.8	7.8	-	7.9	7.7	-
	B-018	-	9.3	7.6	-	9.2	7.2	-	9.2	7.5
	B-020	7.7	7.7	-	7.5	7.6	-	7.7	7.7	-
	B-022	-	8	-	-	7.6	-	-	8	-
	B-023	7.6	7.7	7.3	7.4	7.9	7.3	7.6	7.6	7.4
EC[1]	B-012	7500	4250	15100	6670	4110	14700	6300	2500	14000
	B-013	1160	4850	-	1080	4710	-	1600	4700	-
	B-014	760	2930	-	647	2810	-	720	2900	-
	B-015	540	2200	-	664	2150	-	480	2200	-
	B-016	403	646	-	455	650	-	400	620	-
	B-018	-	3800	11000	-	3760	17100	-	3700	11000
	B-020	826	1910	-	1500	1900	-	880	1800	-
	B-022	-	3140	-	-	5270	-	-	2900	
	B-023	1300	2000	20000	917	2120	18700	810	1000	19000
Alkalinity[2]	B-012	3060	1130	1100	2500	1130	1160	2380	603	1090
	B-013	340	1570	-	315	1590	-	445	1590	-
	B-014	327	1210	-	277	1090	-	252	1200	-
	B-015	230	830	-	271	828	-	164	855	-
	B-016	151	242	-	184	247	-	170	245	-
	B-018	-	1780	948	-	1740	735	-	1500	800
	B-020	234	544	-	352	537	-	291	520	-
	B-022	-	865	-	-	888	-	-	859	-
	B-023	360	460	1100	323	497	1020	249	308	1060
Na:Cl[3]	B-012	2.4	1.1	0.80	1.9	1.1	0.77	1.9	0.85	0.83
	B-013	1.3	1.4	-	1.3	1.3	-	1.17	1.3	-
	B-014	0.81	2.2	-	1	1.9	-	0.69	2.04	-
	B-015	0.97	2.3	-	0.63	2.4	-	0.68	2.4	-
	B-016	0.68	0.93	-	0.96	0.85	-	0.9	0.94	-
	B-018	-	3.5	0.84	-	2.9	0.64	-	2.79	0.74
	B-020	1.8	2.1	-	1.6	2.3	-	1.53	2.08	-
	B-022	-	1.4	-	-	0.98	-	-	1.35	-
	B-023	0.88	1.1	0.76	1.3	0.99	0.69	0.42	0.71	0.89

A. 2020 sampling undertaken on 3–6 August; 2021 sampling undertaken on 13–16 August; 2022 sampling undertaken on 2–4 August. Upper sample interval: 'B' or 'S' suffix; Middle sample interval: 'A' or 'I' suffix; Lower sample interval: '-' or 'D' suffix.
1. Electrical conductivity (µS/cm).
2. M Alkalinity (CaCO3 at pH 4.5); mg/L.
3. Sodium to Chloride ratio.

Hydrocarbon analyses were conducted on groundwater samples collected during the 2020–2022 review period from two of the monitor bores listed Monitoring Objective 3B (Table 24). Monitor bores B-018B and B-022B were not sampled as they are blocked.

No guideline levels have been set for total recoverable hydrocarbons (TRH) in the non-potable domestic groundwater use assessment (DWER 2014), or ANZECC 2000 Guidelines for Fresh and Marine Water Quality, however some are listed within the ANZG (2018) toxicant guidelines (Table 27). There are currently no guidelines for TPH and TRH carbon ranges however the levels measured are below their practical quantification limits. No hydrocarbon spills are evident from the 2020–2022 review data.

Table 27: Results of groundwater hydrocarbon analyses

Analyte[1]	PQL[2]	B-018			B-018A			ANZG (2018) Trigger value[3]
Sample date:		4/08/20	14/09/21	4/08/22	4/08/20	14/09/21	4/08/22	
Benzene	1	<3	<3	<2	<3	<5	<10	950
Ethylbenzene	1	<3	<3	<2	<3	<5	<10	80
m+p Xylene	2	<6	<6	<4	<6	<10	<20	100
O Xylene	1	<3	<3	<2	<3	<5	<10	350
Toluene	1	<3	<3	<2	<3	<5	<10	180
Naphthalene	1	<3	<3	<2	<3	<5	<10	16
Hydrocarbon >C10-C16 less Naphthal. (F2)	50	<50	<50	<50	<50	<50	<50	NG
Hydrocarbon >C10-C16	50	<50	<50	<50	<50	<50	<50	NG
Hydrocarbon >C16-C34 (F3)	100	<100	<100	<100	<100	<100	<100	NG
Hydrocarbon >C34-C40 (F4)	100	<100	<100	<100	<100	<100	<100	NG
Hydrocarbon C10-C14	50	<50	<50	<50	<50	<50	<50	NG
Hydrocarbon C15-C28	100	<100	<100	<100	<100	<100	<100	NG
Hydrocarbon C29-C36	100	<100	<100	<100	<100	<100	<100	NG
Hydrocarbon C6-C10 less BTEX (F1)	10	<50	<50	<20	<50	<50	<100	NG
Hydrocarbon C6-C10	10	<50	<50	<20	<50	<50	<100	NG
Hydrocarbon C6-C9	10	<50	<50	<20	<50	<50	<100	NG
TRH Methyl tert-butyl ether	1	<3	<3	<2	<3	<5	<10	NG

1. All values expressed in µg/L. NG – No Guideline value
2. Practical quantification limit.
3. Trigger level values for slightly to moderately disturbed ecosystems.

6.7.3 STORM WATER CHEMISTRY

The four storm-water sampling stations ('SS' prefix) were established in August 2005 and are located between Alcoa's alumina storage bins and the Bunbury Inner Harbour (Figure 63). Water flows at these sites only during or immediately after rainfall. Samples were collected for comprehensive analysis from four stations (SS003- to SS006-) (Table 31). Sampling was attempted at station SS003 in 2020 and 2022; however, there was insufficient water to sample at on those occasions.

Rockwater's (2017) assessment of storm water chemistry data concluded that there may be small amounts of alkaline salts in all the surface samples, based on alkalinity and sodium to chloride mass-ratio data. Rockwater (2017) estimated that the concentrations of sodium hydroxide in the storm water runoff samples

were ≤0.0002% by weight. This very small amount is not a significant threat to the receiving environment of the Bunbury Inner Harbour.

Laboratory analyses (Table 28) show that all sample results are within guideline values, with the exception of:

- SS004- in 2021 – zinc concentrations of 0.049 mg/L (guideline value: 0.015 mg/L);
- SS005- in 2021 – total phosphorous concentrations of 0.04 mg/L (guideline value: 0.02 mg/L);
- SS004- in 2022 – zinc concentrations of 0.028 mg/L (guideline value: 0.015 mg/L); and
- SS006- in 2022 – total phosphorous concentrations of 0.04 mg/L (guideline value: 0.02 mg/L).

These low-level exceedances are within the range of historical values, and are unlikely to be attributed to Alcoa's operations. The trace element and nutrient concentrations will become much more dilute once the storm water enters the harbour.

The Bunbury Inner Harbour adjacent to the Caustic Loading Facility is a highly disturbed marine environment that is used by commercial shipping and would have a lower environmental value than some nearby coastal areas which are much less disturbed.

6.7.4 RISK TO SENSITIVE RECEPTORS

The shallow groundwater lens above the saltwater wedge is the main receptor (at the Bunbury Caustic Loading Facility) that is at risk from leaks and spills of caustic soda. This lens of fresher groundwater has limited beneficial use and a small environmental value, and these items are unlikely to change, given the industrial setting of the site. The shallow groundwater system, however, could provide a pathway to the adjacent marine or estuarine environments.

There is a small risk to the shallow groundwater system from operations at the Bunbury Caustic Loading Facility. This risk is small because the shallow groundwater system does not support an ecosystem, and is not utilised and is unlikely to be utilised as a groundwater resource in the foreseeable future.

The concentrations of petroleum hydrocarbons at all sites are below the practical quantification limit (PQL) and there appears to be no hydrocarbon risk (from this source) to the adjacent marine environment in the Bunbury Inner Harbour.

A report on the ecology of the Bunbury Inner Harbour by Oceanica (2011) concluded that Alcoa's activities were having no adverse effects on marine ecological health in the harbour, and posed no risks to human consumers of seafood. There is no reason to assume that this has changed, based on the water monitoring data that have been collected in 2020–2022.

Table 28: Results of comprehensive analyses of storm water samples

Analyte[1]	SS003-[3]	SS004-			SS005-			SS006-			Guideline Value[2]	
Sample date:	30/08/21	7/08/20	30/08/21	10/06/22	7/08/20	30/08/21	10/06/22	7/08/20	30/08/21	10/06/22	ANZECC	ANZG
TDS	150	42	76	55	54	110	32	72	86	120		
Conductivity @ 25C (Field) (uS/cm)	243	68	112	200	95	178	52	131	148	170		
pH (Field)	8	7.1	7.1	6.9	7.2	7.1	7.1	6.9	6.9	7.1		
pH (lab)	8	6.9	7	7	7.2	7.2	7.1	6.9	7	7.3		
Redox (ORP) (mV)	300	242	306	230	221	117	230	292	133	-40		
Aluminium	0.08	<0.005	0.01	0.01	0.01	0.03	0.02	<0.005	0.01	0.008	5	0.055
Ammonia (N)	<0.005	<0.005	<0.005	0.073	0.007	<0.005	0.04	0.026	0.039	<0.005	0.91	0.9
Antimony	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001		0.009
Arsenic	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001		0.013
Bicarbonate (HCO3)	56	16	11	13	25	23	16	26	23	83		
Boron	0.03	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.03		
Cadmium	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0055	
Calcium	23	4.4	2.8	2.2	10	5.2	3.9	8.9	5.6	22		
Carbonate (CO3)	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1		
Chloride	35	8	24	20	9	14	7	20	22	8		
Chromium	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.0274 (Cr III)	
Conductivity @ 25C	250	70	110	92	90	120	53	130	130	190		
Copper	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.0013	
Dissolved organic carbon (DOC)	<1	<1	<1	1	<1	1	<1	<1	<1	9		
Filterable reactive phosphorous (FRP)	<0.002	<0.002	<0.002	<0.002	<0.002	0.036	<0.002	<0.002	<0.002	<0.002		
Fluoride	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1		
Gallium	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001		
Hardness (CAC03)	71	16	13	11	30	18	13	32	22	74		
Iron	0.003	<0.002	<0.002	<0.002	0.002	<0.002	0.003	<0.002	<0.002	0.86		
Lead	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.0044	0.0034
M Alkalinity (CaCO3 at pH 4.5)	56	16	11	13	25	23	16	26	23	83		
Magnesium	3.2	1.1	1.4	1.2	1.2	1.1	0.8	2.3	1.9	5		
Manganese	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.077		1.9
Mercury	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	0.004	0.0006
Molybdenum	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001		0.034
NA/CL Ratio	0.68	0.83	0.51	0.59	0.72	0.75	0.59	0.71	0.62	0.89		
Nickel	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.007	0.011
Nitrate (as NO3)	6.1	0.97	0.55	0.23	0.89	5.9	1.7	0.95	0.39	<0.02		
Nitrate (N)	1.4	0.22	0.13	0.052	0.2	1.3	0.38	0.21	0.088	<0.005		
Nitrite (as NO2)	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02		
Nitrite (N)	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005		
P Alkalinity (CaCO3 at pH 8.3)	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1		
Phosphate (PO4)	<0.007	<0.007	<0.007	<0.007	<0.007	0.11	<0.007	<0.007	<0.007	<0.007		
Potassium	1.7	<0.5	0.7	0.6	0.5	0.8	1.1	1.3	0.9	1.8		
Selenium	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001		0.005
Silica (SiO2)	0.3	0.3	0.2	0.2	0.2	0.2	0.1	0.3	0.8	0.6		
Sodium	24	6.4	12	12	6.8	10	4.2	14	13	7.1		
Sulfate (SO4)	10	3	4	3	2	5	3	5	5	2		
Thorium	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005		
Total Kjeldahl Nitrogen	0.3	0.1	0.1	0.3	0.1	0.3	0.2	0.1	0.2	0.4		
Total Nitrogen	1.7	0.3	0.3	0.3	0.3	1.7	0.5	0.4	0.3	0.4		
Total Phosphorus (Total Phosphate)	0.02	<0.01	<0.01	0.01	<0.01	0.04	<0.01	0.01	<0.01	0.04	0.02	
Uranium	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005		
Vanadium	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.1	0.006
Zinc	<0.001	0.01	0.049	0.028	0.004	0.001	0.003	0.002	0.001	<0.001	0.015	0.008
Total Anion Equivalent (meq/L)	2	<1	<1	<1	<1	<1	<1	1	1	2		
Total Anions	85	22	35	31	28	38	22	42	42	60		
Total Cation Equivalent (meq/L)	3	<1	<1	<1	<1	<1	<1	1	1	2		
Total Cations	52	12	17	16	19	17	10	26	22	35		
Ionic Equivalent Difference	4.2	-0.88	-9	-8.5	5.3	-6.7	-11	3.7	-6.3	-2.2		

1. Values are expressed as mg/L unless otherwise indicated.
2. Assessment levels. DWER (2014) are trigger values that apply for marine water in typical slightly-moderately disturbed systems for 95% species protection (ANZECC & ARMCANZ 2000).
3. Monitor site dry in 2020 and 2022; therefore, unable to sample.

Shaded cells indicate results above guideline values.

7 CONCLUSIONS AND RECOMMENDATIONS

The water monitoring program for Alcoa's Wagerup Refinery and Bunbury Caustic Loading Facility has been undertaken in accordance with the terms and conditions of licences issued by DWER. The main findings from review of the 2020–2022 monitoring data are provided in the following sections.

7.1 EP ACT LICENCE

Groundwater and surface water monitoring required by EP Act Licence L6217/1983/15, Water Pollution Control Conditions, was undertaken during the 2020–2022 review period in accordance with licence conditions. These data are generally consistent with previous analyses and are mostly representative of naturally brackish groundwater. The mandated reporting of this data is via the annual report against this licence, produced by Alcoa.

7.2 GROUNDWATER LICENCES

DWER has issued Alcoa with two 5C licences to take groundwater at Wagerup Refinery. Groundwater licence GWL160881(3), allows recovery of up to 146,600 kL per annum of contaminated groundwater from the superficial aquifer in the refinery area, and expires in August 2026. Groundwater licence GWL102669(3), allows abstraction of groundwater for industrial purposes from the superficial aquifer in the vicinity of the residue storage areas, of up to 550,000 kL per annum, and expires in May 2023. They are managed under a Groundwater and Surface Water Licences Operating Strategy (Alcoa 2020).

Alcoa operates four alkali recovery-bores at the Wagerup Refinery, two bores adjacent to Building 26 and two bores near Building 45. The borefields produced a total of 39,700 kL (2020), 40,112 kL (2021) and 60,781 kL (2022) of groundwater, against an annual water entitlement of 146,000 kL. Groundwater licence GWL102669(3) abstraction was 384,368 kL (2020), 373,862 kL (2021) and 406,149 kL (2022), against an annual water entitlement of 550,000 kL.

All data required by the Operating Strategy for these licences were collected during 2020–2022 except where monitoring was not possible, as outlined in Section 5.1.

7.3 SURFACE WATER LICENCES

Alcoa has three surface-water harvesting licences issued by DWER for the Wagerup Operations (SWL151027[4] [Harvey River], SWL99246[5] [Black Tom Brook] and SWL97472[6]) [Yalup Brook]). The combined Annual Water Entitlement is 8,500 ML. These licences are valid until August 2023 and are managed under the Groundwater and Surface Water Licences Operating Strategy (Alcoa 2020).

The total volume of water drawn from all surface water sources was 5,672 ML (2020), 4,403 ML (2021) and 4,078 ML (2022). Included in these volumes are 1,491–3,800 ML of water was purchased from Harvey Water each year and not drawn from the licenced sources. All data required by the Operating Strategy for these licences were collected during 2020–2022.

7.4 ASSESSMENT OF ENVIRONMENTAL AND MONITORING OBJECTIVE OUTCOMES AT THE WAGERUP REFINERY

Environmental and monitoring objectives for Wagerup Refinery have been provided. This section assesses whether these have been met based on the monitoring data obtained during the 2020–2022 period of review. Where an objective has not been met recommendations are made for improvement in the monitoring program or water management strategies.

- Assessment of groundwater-level data shows no marked drawdown effects on groundwater levels at either the refinery or RSAs. Abstraction is currently being undertaken within sustainable yield from the superficial aquifer and there is no evidence to suggest abstraction from the superficial aquifer has any effect on surrounding properties or natural water courses.

- Groundwater-quality data assessment shows no changes to groundwater chemistry at either the refinery or RSAs that would adversely affect its suitability for use in the refinery processing or residue storage operations. The groundwater currently abstracted remains suitable for use in the water circuit.

- Surface water flows were measured to provide a reliable estimate of total surface water harvest volumes during the period of review.

- Assessment of surface-water quality data indicates no change to surface water chemistry that would adversely affect its suitability for use in the water circuit. The surface water currently harvested remains suitable for its intended use.

- Surface water harvesting data from the 2020–2022 review period do not suggest downstream flow or water quality impacts as a result of surface water harvesting.

- Assessment of groundwater quality data for the northern refinery area, near Building 26, suggests alkali fluids reaching the groundwater system are being largely contained. Operation of the two alkali recovery bores appears to have been effective at this site.

- Assessment of groundwater quality data for the southern refinery area, near Building 45, shows impact with alkali fluids at this location and likely migration of these fluids in the groundwater system, particularly within the lower Yoganup Formation. Groundwater quality parameters indicate significant impact on the superficial formation at this site. Operation of these bores should continue in order to maximise the effectiveness of alkali recovery and containment at this site. A total of approximately 55 tonnes (2020), 47.5 tonnes (2021) and 59 tonnes (2022) of alkali (expressed as Na_2CO_3) were recovered (via recovery bores RB003G and RB004G) from the refinery area in 2020-22, representing a fairly large increase in recovery that has occurred since about 2017.

- Groundwater flows from active depressurising and recovery bores were measured and calibrated to provide a reliable estimate of total groundwater production during the period of review. Total monthly flow volumes have been provided for each depressurising and recovery bore.

- Assessment of groundwater level and water quality data for the deeper Mesozoic formations indicates no significant impact by alkaline waters on these formations.

- Groundwater quality appears to be impacted in the area between RSA1/Sand Lake and RSA2, particularly in the upper superficial formations. Previous assessments (Rockwater 2020) have suggested that poor-condition monitor bores may be contaminant pathways, and that a program of bore-decommissioning be implemented (Alcoa has commenced this program, with some bores in the area being decommissioned). Monitor bores RS063S, RS064S and RS065G exhibited increasing alkalinities during the 2020–2022 review period, along with bores RS126S and RS138S/G slightly further to the north. This area requires further investigation; it may be that the prolonged use of depressurising bore D-014G is drawing alkali fluid leaching from neighbouring RSA6 and the Sand Lake.

- Monitor bores RS096S, RS097S and RS100S, on the south-western side of ROCP1, exhibited increasing alkalinities during the 2020–2022 review period and require further assessment.

- Elevated salinity occurs to the north and north-west of the RSAs, however there is no corresponding increase in alkalinity, and even decreasing alkalinity at a number of sites, suggesting a different source of salinity. Localised areas of elevated salinity and possibly alkalinity occur to the south-west and west of the RSAs. However, it is noted the alkalinity is not proportionally elevated.

- Slightly elevated alkalinity in groundwater to the west and south-west of the RSAs are considered to be naturally occurring within the calcareous Ascot Formation. Elevated groundwater levels and salinity occur in some monitor bores in the vicinity of the RSAs; however, they are not always accompanied by elevated alkalinity, and in a number of instances, there is an inverse relation (increasing EC with decreasing alkalinity and vice versa).

- Assessment of groundwater-level and hydrochemical data has shown no indication of alkaline waters affecting the Mesozoic formation in the residue area.

- Assessment of groundwater-level data in monitor bores around the perimeter of the RSA facilities and the wire-line piezometers underlying the storage ponds indicates abstraction rates from the superficial formations during the 2020–2022 review period were sufficient to generally maintain groundwater pressures in the lower superficial at least one metre below the surface water levels at the ROWS Pond, ROCP2, and ROCP3 to prevent upward groundwater pressures from potentially damaging the pond liners..

- The strategy used for the other water storage ponds is not utilised at ROCP1, as Alcoa has assessed the pond liner to be damaged by groundwater uplift pressures not long after pond was constructed. Assessment of groundwater-level data in monitor bores around the perimeter of ROCP1 shows water levels in the pond were above groundwater levels in the superficial formations during most of the 2020–2022 review period as the pond was being decommissioned, but below groundwater levels during peak groundwater levels. This indicates potential for seepage from the pond into the superficial formations some of the year, upward pressure on the lining at other times, and a period of equilibrium during transition from one state to the other. Decommissioning of this storage pond should result in a lower risk for groundwater contamination from this source.

- There have been no significant changes to groundwater quality abstracted from the depressurising bores during the period of review.

- Assessment of groundwater-level and water-quality data from the nominated regional monitor bores shows no evidence of an adverse impact on groundwater quality beyond Alcoa's property. Localised changes in some regional monitor bores are not readily explained by Alcoa's operations (due to distance from the operations and/or groundwater hydraulic gradients) and it is likely other activities or processes are affecting groundwater quality in the area.

- Assessment of stream flow and water quality data from the surface-water monitoring stations shows no evidence of an adverse impact on the quality of surface water bodies and streams.

7.5 ASSESSMENT OF ENVIRONMENTAL AND MONITORING OBJECTIVE OUTCOMES AT THE BUNBURY CAUSTIC LOADING FACILITIES

Environmental and monitoring objectives for the Bunbury Caustic Loading Facilities have been provided. This section assesses whether they have been met based on the monitoring data obtained during the 2020–2022 period of review. Where an objective has not been met recommendations are made for improvement in the monitoring program or water management strategies.

- Groundwater-level and water quality data at the Bunbury Caustic Loading Facilities site indicates the ongoing existence of an alkaline groundwater plume in the upper superficial aquifer to the east of the site, near the caustic spill collection point. The plume appears to be predominantly migrating downwards to deeper aquifer intervals and towards the southwest (confirmed with the construction and monitoring of additional monitor bore B-023D/I/S in 2019). Plume concentrations in the deeper aquifer intervals have reduced during the review period.

- Historical data suggest recharge to the upper aquifer interval has occurred with alkaline fluids of varying concentration over the site at different times. The plumes generally appear to migrate downwards to the underlying aquifer intervals, where horizontal migration may then occur. Discharge of alkaline groundwater to the Bunbury Inner Harbor is likely to be minimal and diffuse. Alkaline effects in the groundwater are likely to be minimised by chemical interactions between groundwater in the plume and the saline water interface.

- Assessment of hydrocarbon data for the monitor bores shows concentrations of petroleum hydrocarbons at all sites are below the practical quantification limit (PQL) and are of minimal risk to the adjacent marine environment in the Bunbury Inner Harbour. No hydrocarbon plume is evident.

- Assessment of surface water flow data at the Bunbury Caustic Loading Facilities indicates little to no runoff occurs from this site to the marine environment. The surface water quality shows little impact from caustic liquids and does not pose a significant risk for adverse effects to the marine environment.

7.6 RECOMMENDATIONS

Alcoa has worked to act upon previous recommendations (Rockwater 2020). The following additional recommendations are provided, based on the assessment provided in this report.

- Continue to implement a program of bore-condition assessments and bore-replacement where required. The redevelopment of B-018B (Bunbury) should be a priority, to help determine the extent of the plume originating nearby.
- Increase general-hydrochemistry (pH, EC and alkalinity) monitoring frequencies, from annual to bi-annual, in the following monitor bores:
    - RS063S, RS064S and RS065G, at the northern end of the Sand Lake, where alkalinity is elevated and increasing. Results could be due to infiltration down the bore annulus, or from extraction from nearby depressurising bore D-014G.
    - On the southern perimeter of ROCP2 (RS126G, RS137S/G and RS138S/G), where alkalinity is elevated and increasing.
    - Increased frequency of readings from D-014G to determine if the extraction from this bore is having an impact on the above bores.
- Existing bores north of the Sand Lake must be maintained to allow accurate groundwater characteristics beneath the RSA complex.
- If operationally feasible, one or two alternative monitoring sites should be identified, preferably to the west of the eastern dyke at RSA2, and new monitor bores installed and monitored to determine accurate groundwater quality characteristics beneath the RSA complex.
- Monitor water quality trends around ROCP1 as decommissioning is completed. This monitoring will assess if natural monitored attenuation can manage the contamination (due to liner defects when the pond was operated) to the underlying groundwater.
- Calibrate/service the vibrating wire piezometers at the RSAs.
- Increase the extraction from depressurising bores D-010G, D-013G and D-014G, and re-commission bores D-011G and D-012G to lower the underlying groundwater levels at ROCP2.

Dated: **26 April 2023** **Rockwater Pty Ltd**



Daisy Scott
Senior Environmental Scientist

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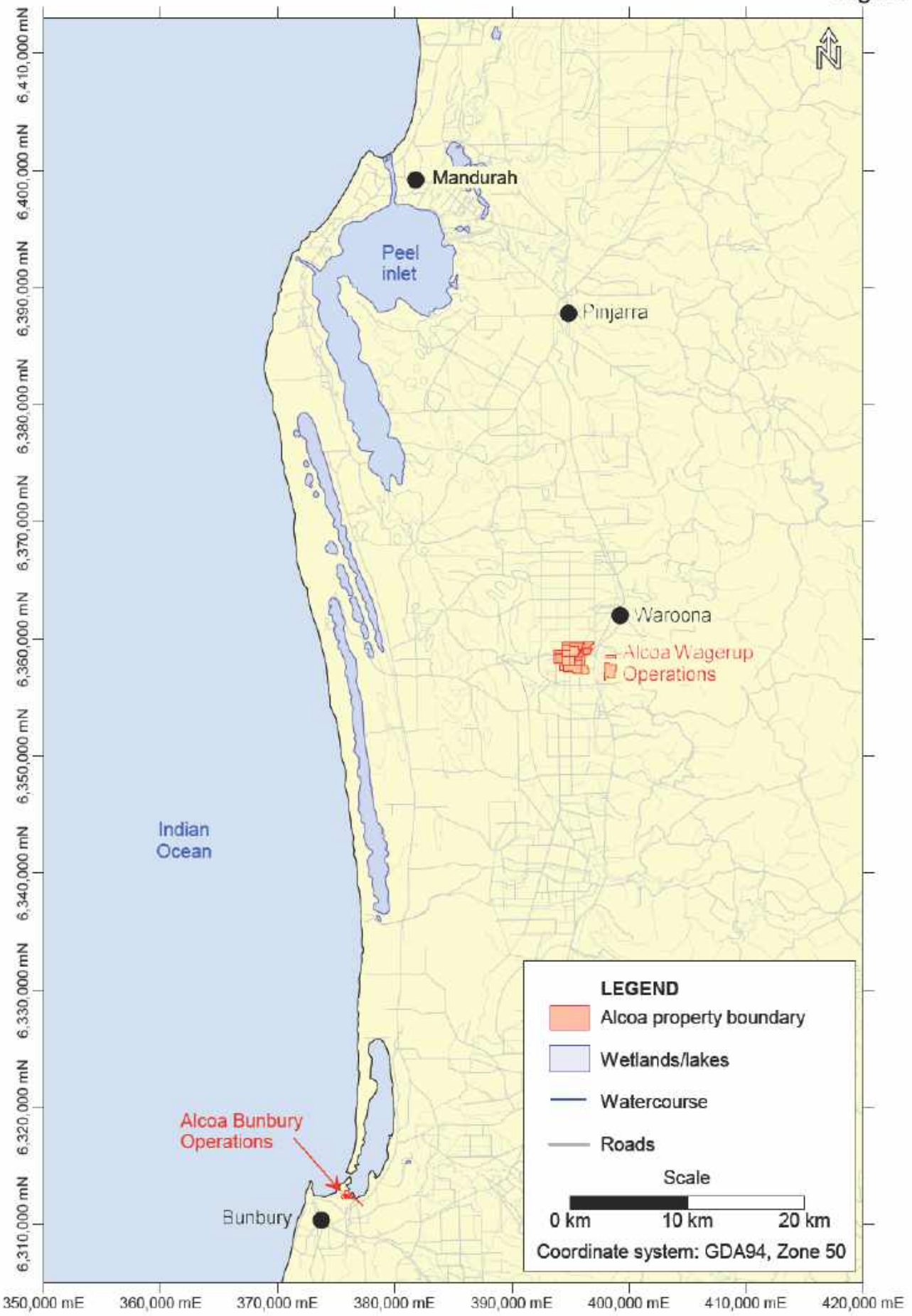
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FIGURES

Figure 1



308.8/Surfer/Figure 01.srf

CLIENT:	Alcoa of Australia Limited
PROJECT:	Wagerup and Bunbury 2020-2022 water report
DATE:	March 2023
Dwg. No:	308-8/23/1-01

Alcoa

Site setting

Rockwater

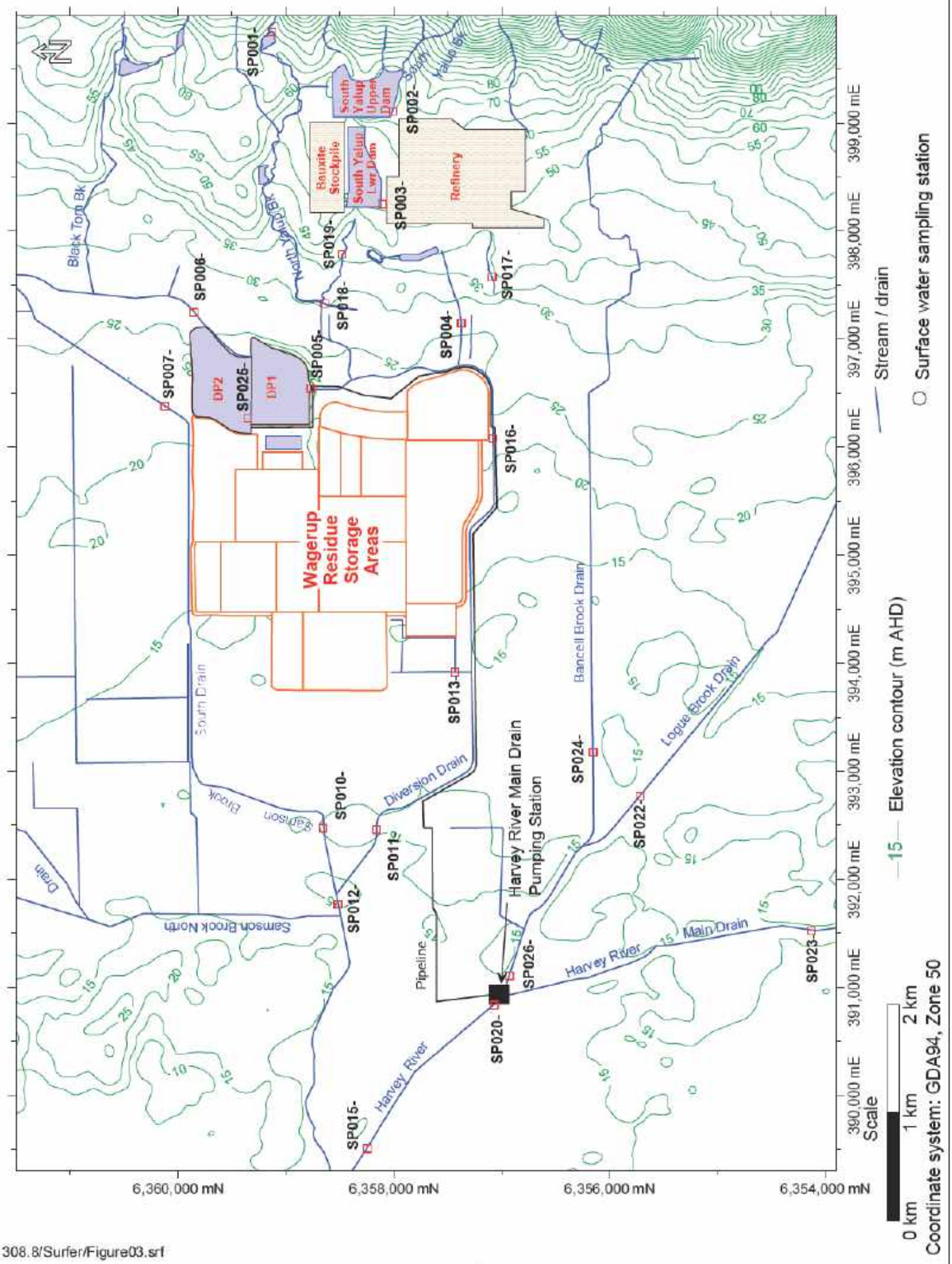
Figure 2

Wagerup Alumina Refinery
Aerial photograph and site layout

CLIENT: Alcoa of Australia Limited
PROJECT: Wagerup and Bunbury 2020-2022 water report
DATE: March 2023
Dwg. No: 308-8/23/1-02

308.8/Surfer/Figure02.srf

Figure 3



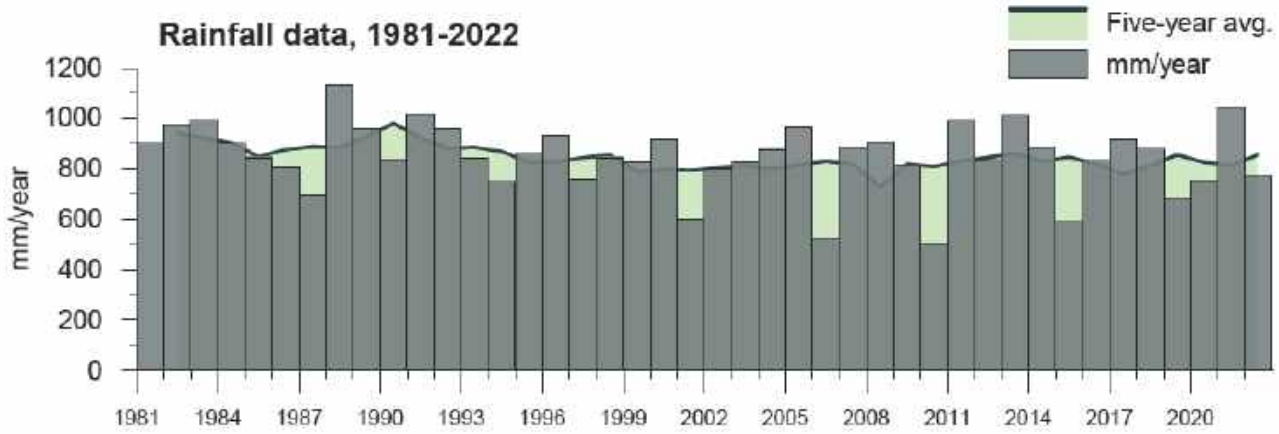
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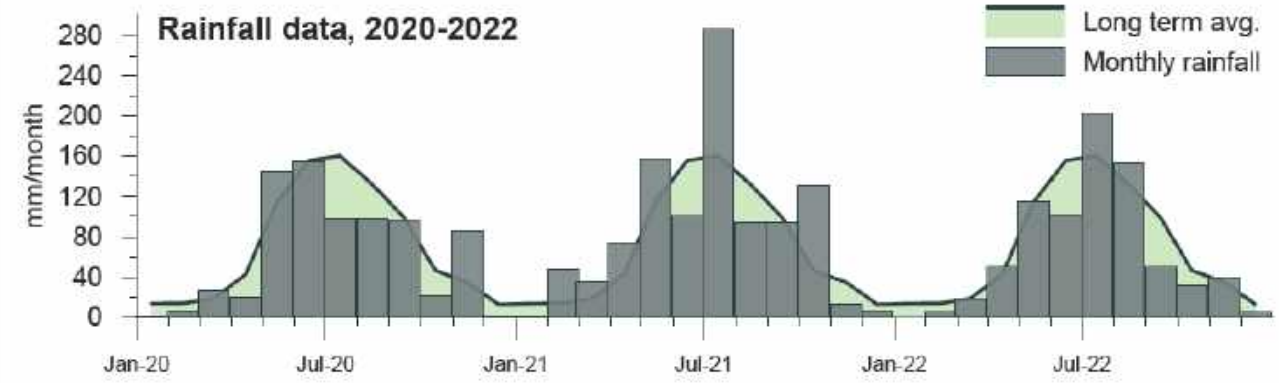
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PROJECT:	Wagerup and Bunbury 2020-2022 water report
DATE:	March 2023
Dwg. No:	308-8/23/1-03

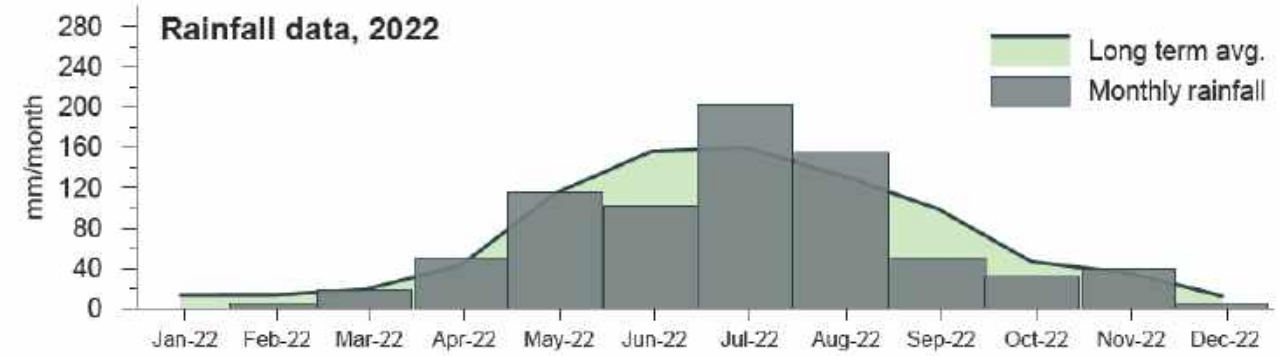
Wagerup area topography, surface water drainage and surface water sampling stations

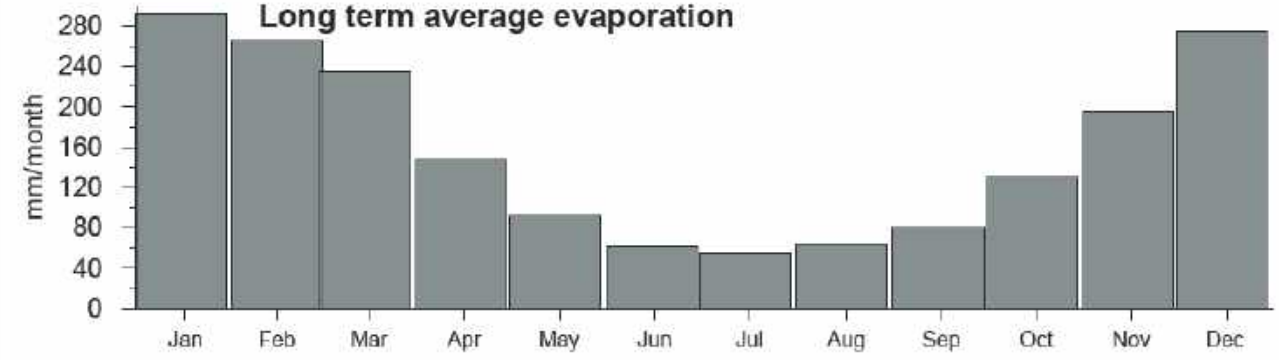
Rockwater

Figure 4









308-8/Grapher/Figure04.grf

CLIENT: Alcoa of Australia Limited PROJECT: Wagerup and Bunbury 2020-2022 water report DATE: March 2023 Dwg. No: 308-8/23/1-04	Wagerup rainfall and evaporation data

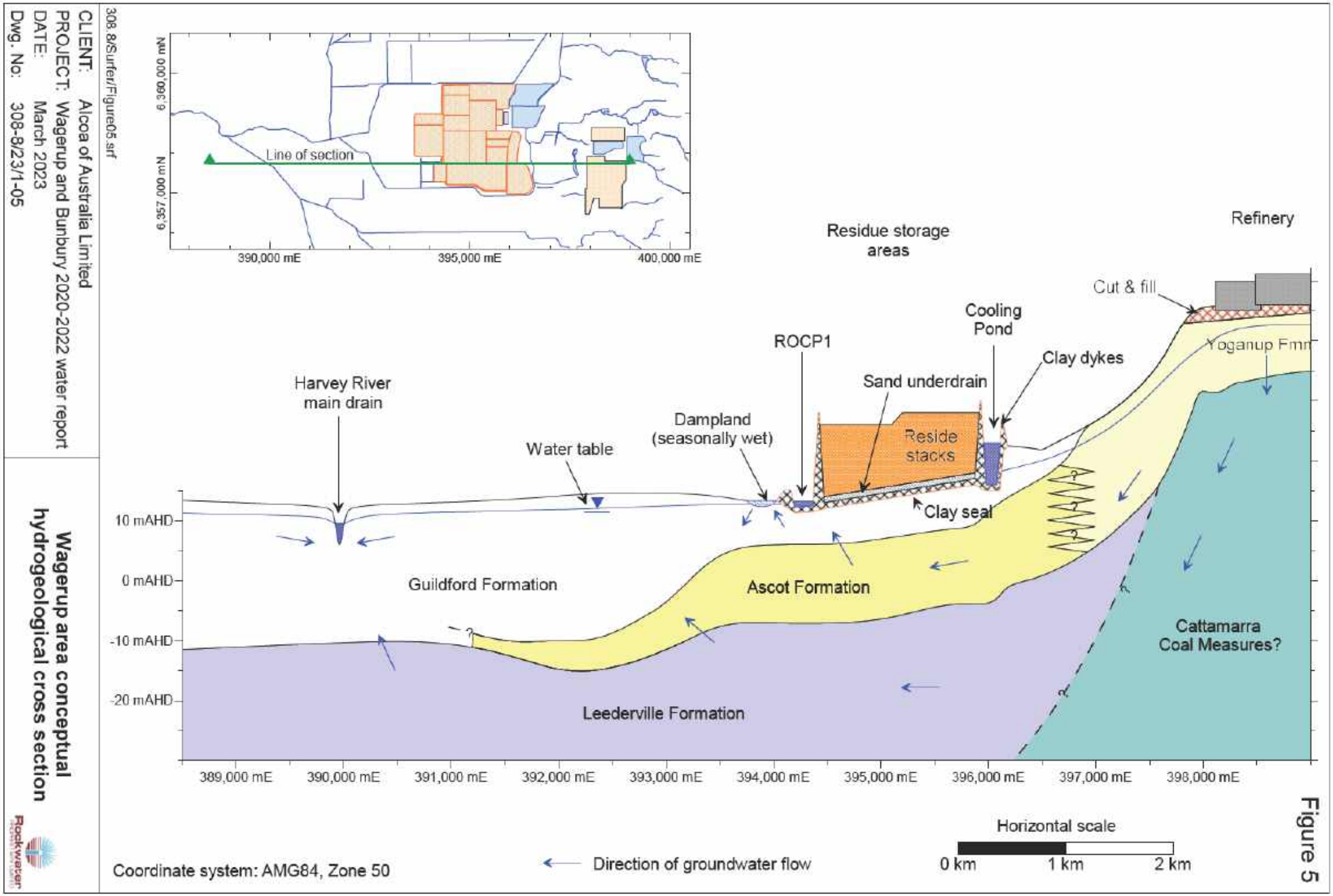
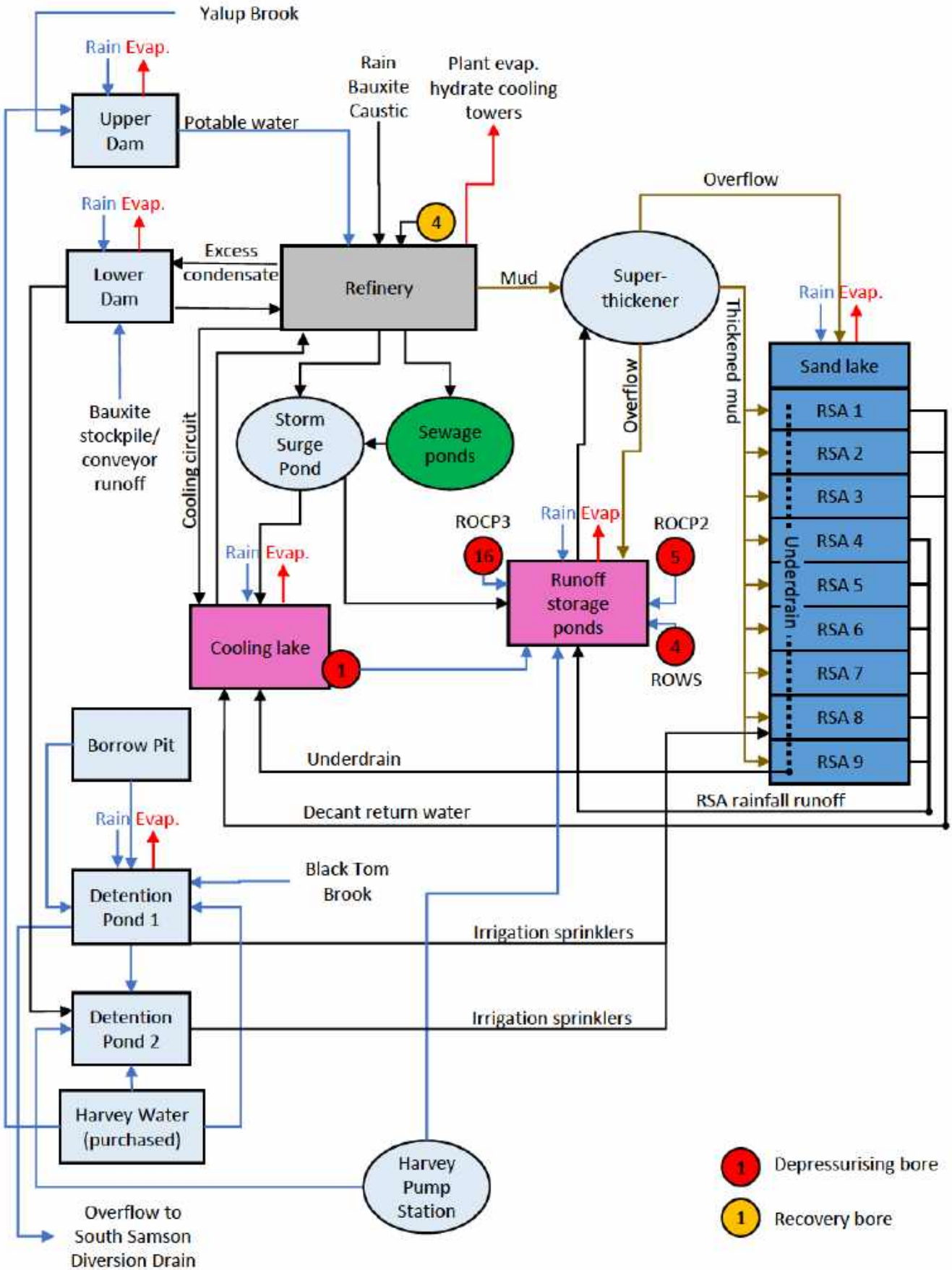

CLIENT: Alcoa of Australia Limited
PROJECT: Wagerup and Bunbury 2020-2022 water report
DATE: March 2023
Dwg. No: 308-8/23/1-05
308.8/Surfer/Figure05.srf
Wagerup area conceptual hydrogeological cross section
Line of section
6,360,000 mN
6,357,000 mN
390,000 mE
395,000 mE
400,000 mE
Residue storage areas
Refinery
Cut & fill
Cooling Pond
ROCP1
Clay dykes
Yoganup Fmn
Sand underdrain
Harvey River main drain
Dampland (seasonally wet)
Water table
Reside stacks
Clay seal
10 mAHD
0 mAHD
-10 mAHD
-20 mAHD
Guildford Formation
Ascot Formation
Cattamarra Coal Measures?
Leederville Formation
389,000 mE
390,000 mE
391,000 mE
392,000 mE
393,000 mE
394,000 mE
395,000 mE
396,000 mE
397,000 mE
398,000 mE
Horizontal scale
0 km
1 km
2 km
Coordinate system: AMG84, Zone 50
Direction of groundwater flow
Figure 5

Figure 6



308.8/Surfer/Figure 06.srf

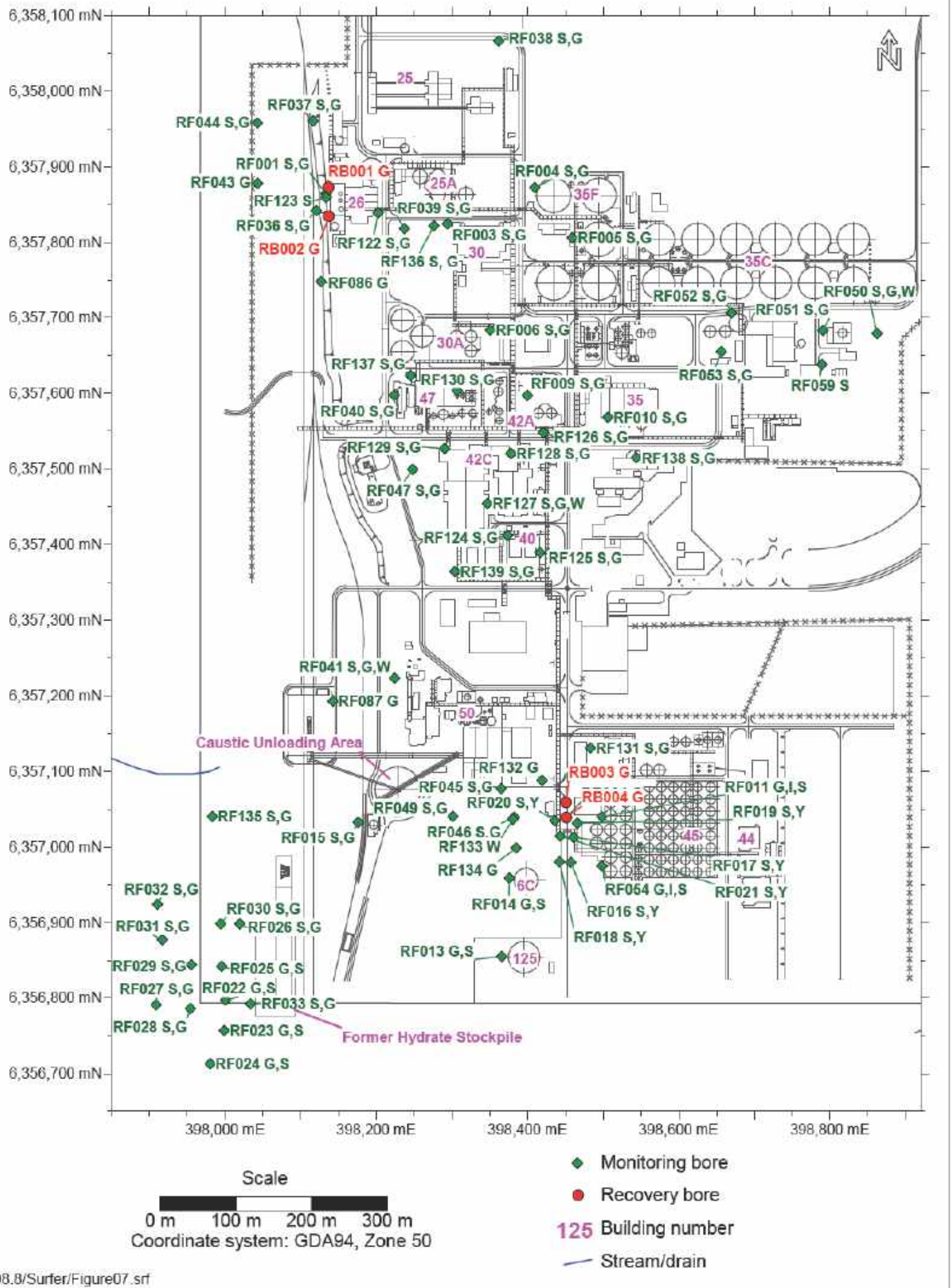
CLIENT:	Alcoa of Australia Limited
PROJECT:	Wagerup and Bunbury 2020-2022 water report
DATE:	March 2023
Dwg. No:	308-8/23/1-06

Alcoa

Wagerup Alumina Refinery water circuit

Rockwater

Figure 7



308.8/Surfer/Figure07.srf

CLIENT:	Alcoa of Australia Limited
PROJECT:	Wagerup and Bunbury 2020-2022 water report
DATE:	March 2023
Dwg. No:	308-8/23/1-07

Alcoa

Wagerup Alumina Refinery bore location plan

Rockwater

CLIENT: Alcoa of Australia Limited

PROJECT: Wagerup and Bunbury 2020-2022 water report

DATE: March 2023

Dwg. No: 308-8/23/1-08

Wagerup Residue Storage Areas
bore location plan

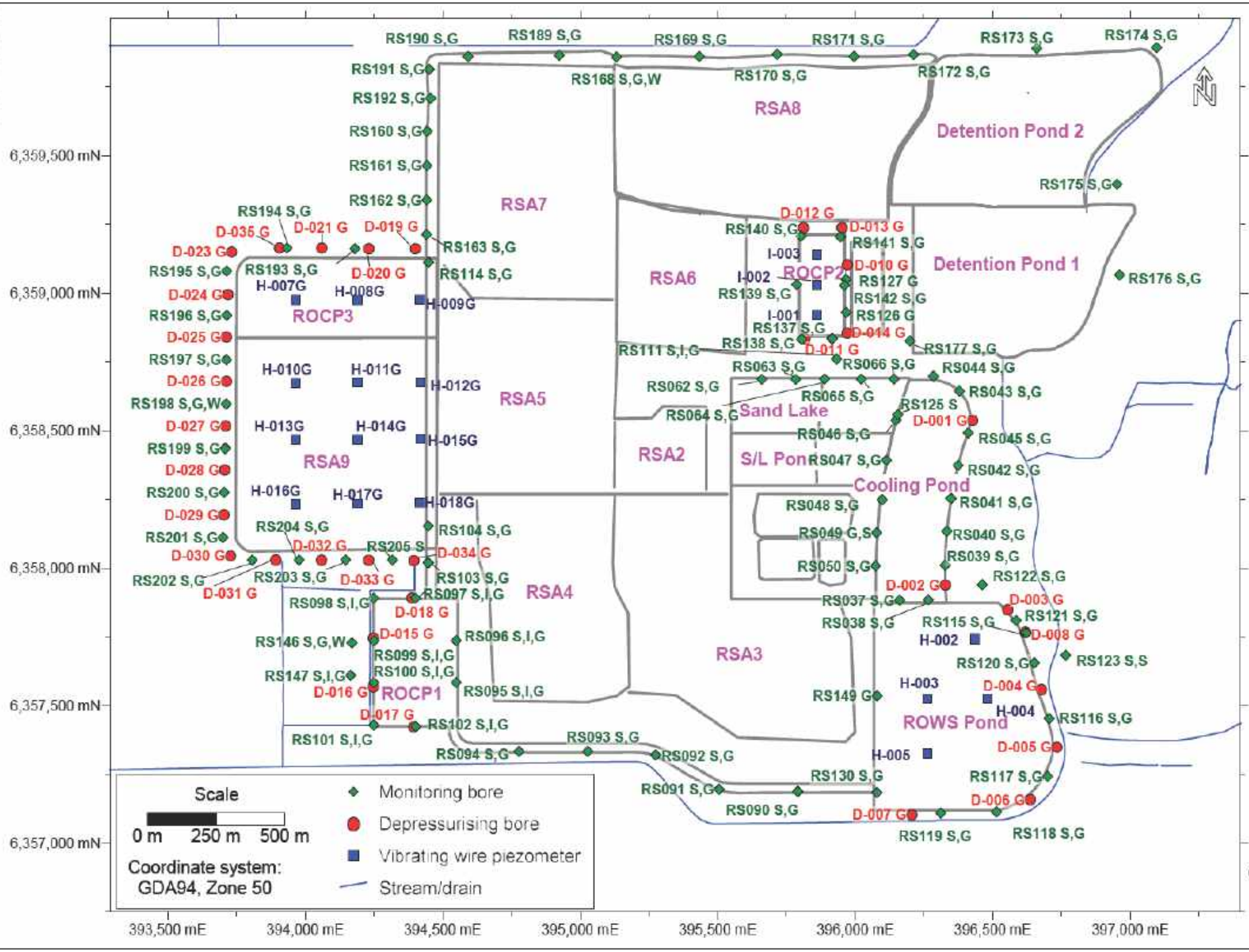
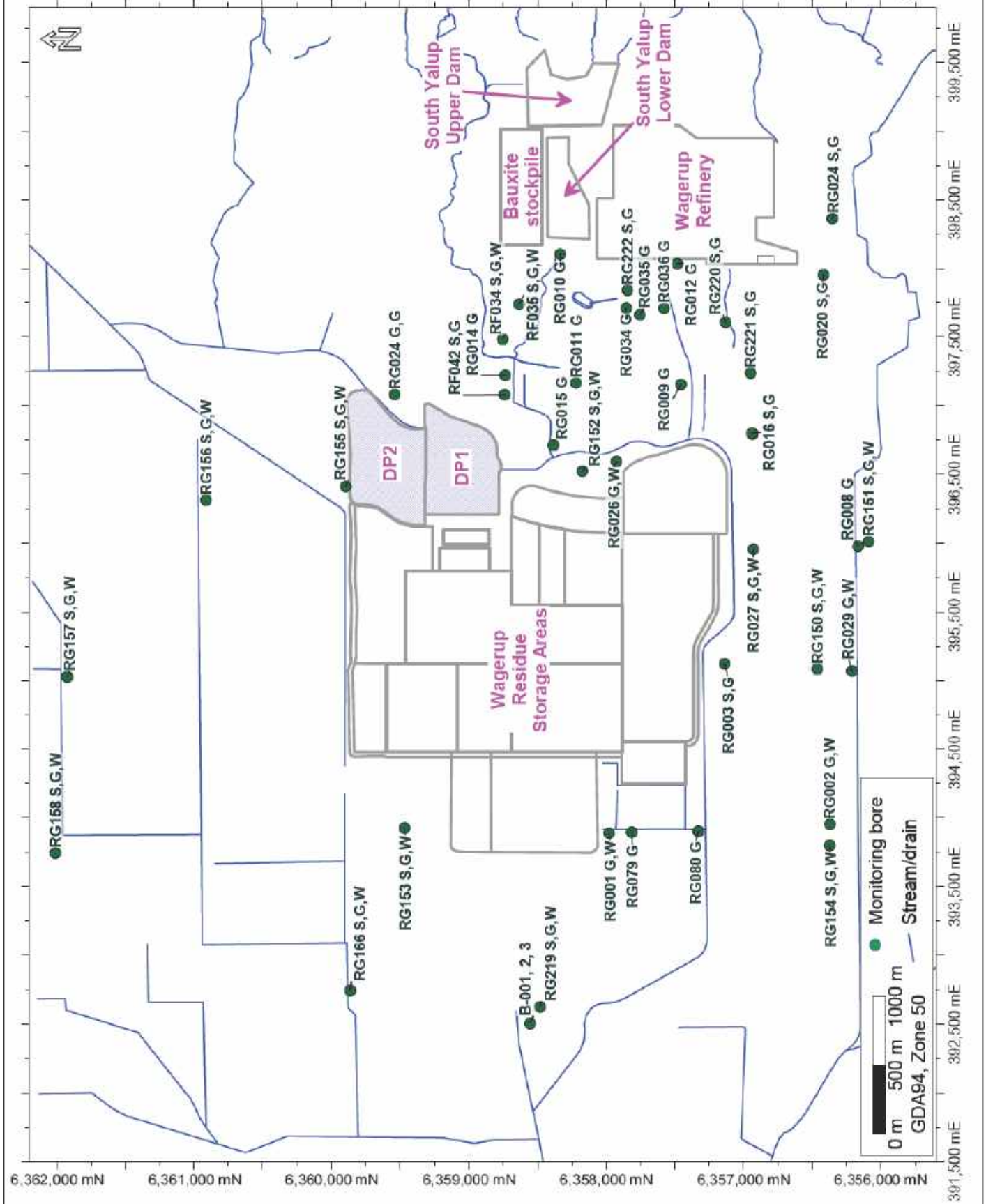


Figure 8

Figure 9



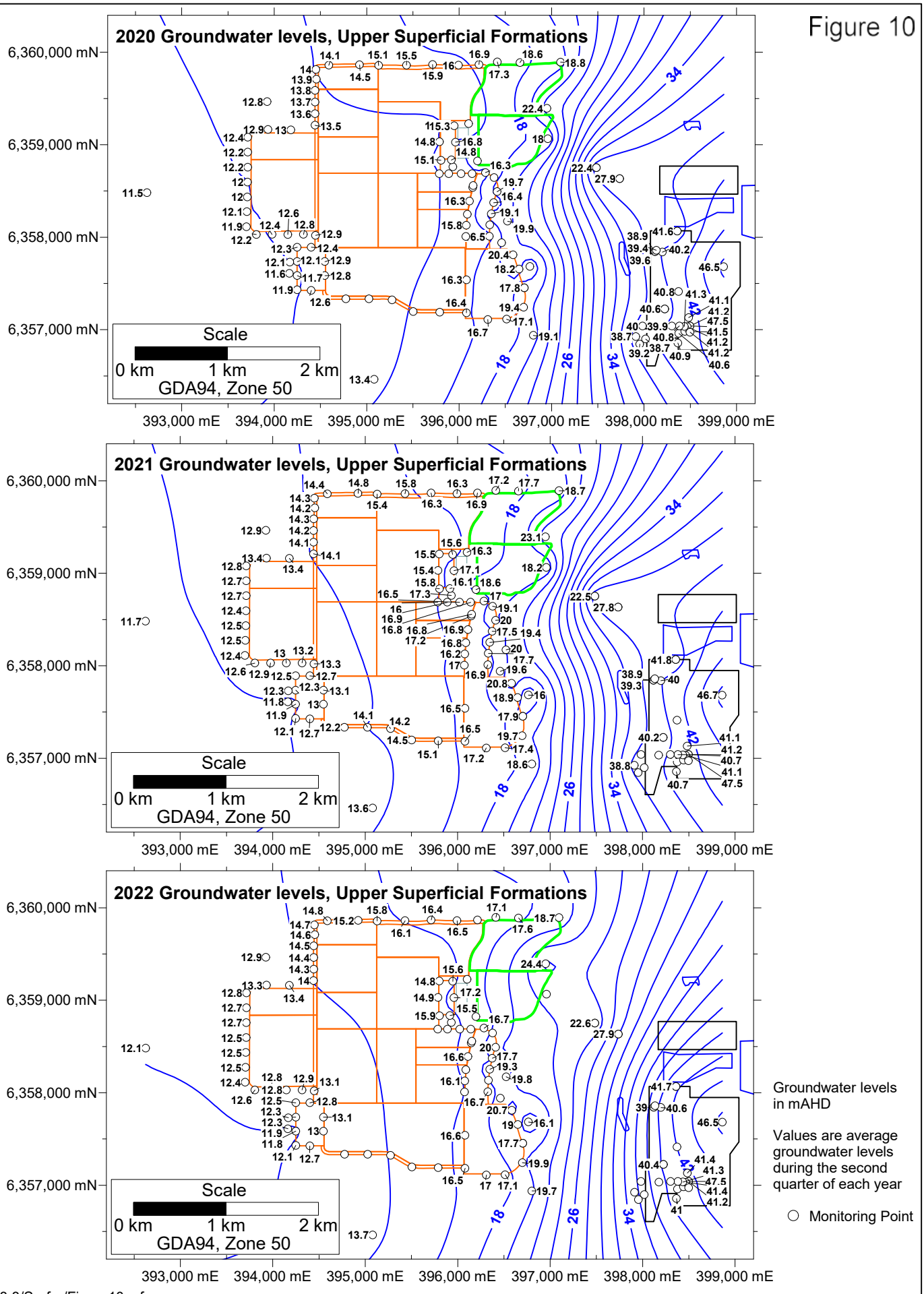
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CLIENT:	Alcoa of Australia Limited
PROJECT:	Wagerup and Bunbury 2020-2022 water report
DATE:	March 2023
Dwg. No:	308-8/23/1-09

Wagerup regional monitoring bore location plan

Rockwater

Figure 10



Groundwater levels in mAHD

Values are average groundwater levels during the second quarter of each year

○ Monitoring Point

308.8/Surfer/Figure10.srf

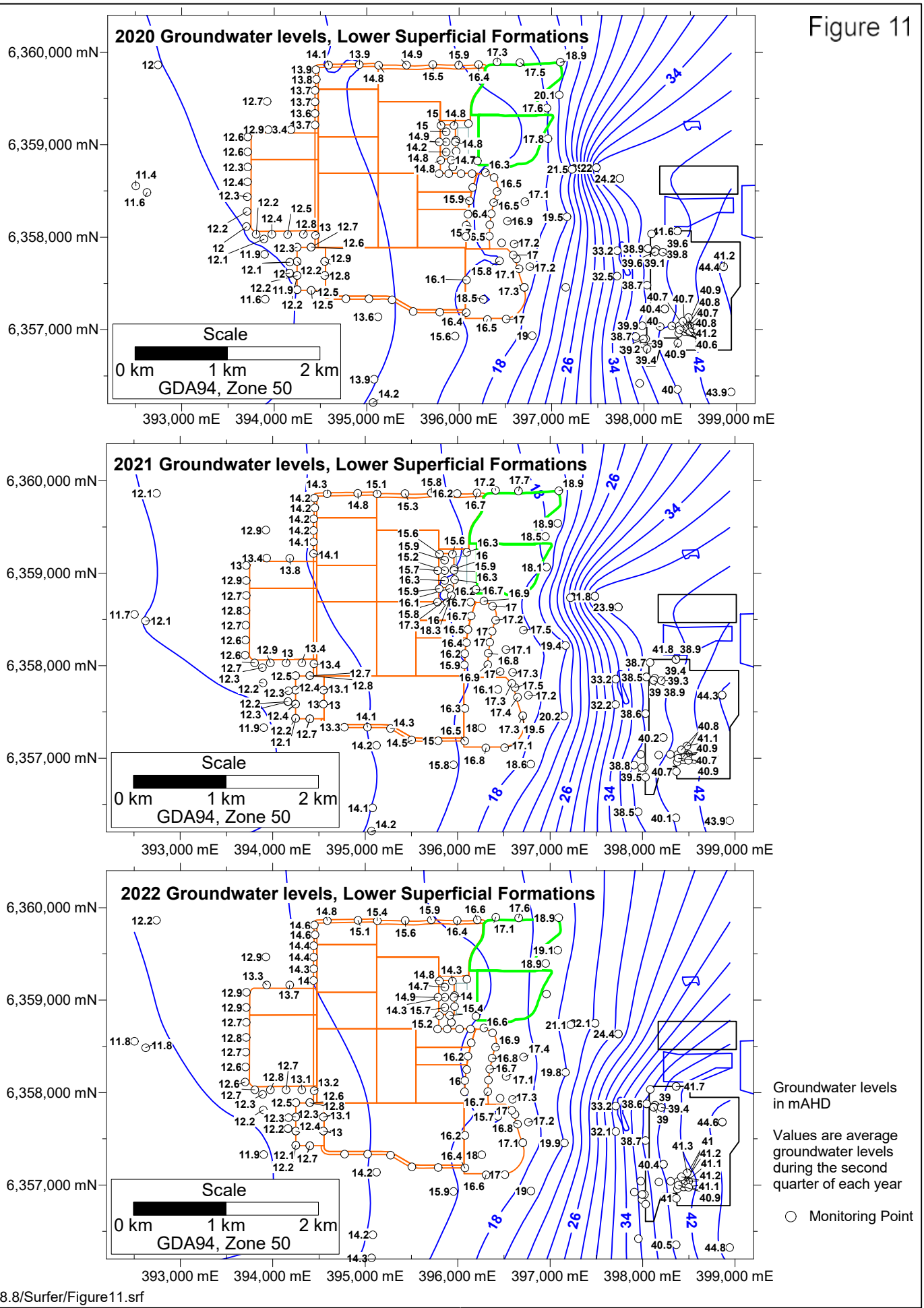
CLIENT:	Alcoa of Australia Limited
PROJECT:	Wagerup and Bunbury 2020-2022 water report
DATE:	March 2023
Dwg. No:	308-8/23/1-10

Wagerup Area groundwater level contours, Upper Superficial Formations 2020–22

Alcoa

Rockwater

Figure 11



Groundwater levels in mAHD

Values are average groundwater levels during the second quarter of each year

○ Monitoring Point

308.8/Surfer/Figure11.srf

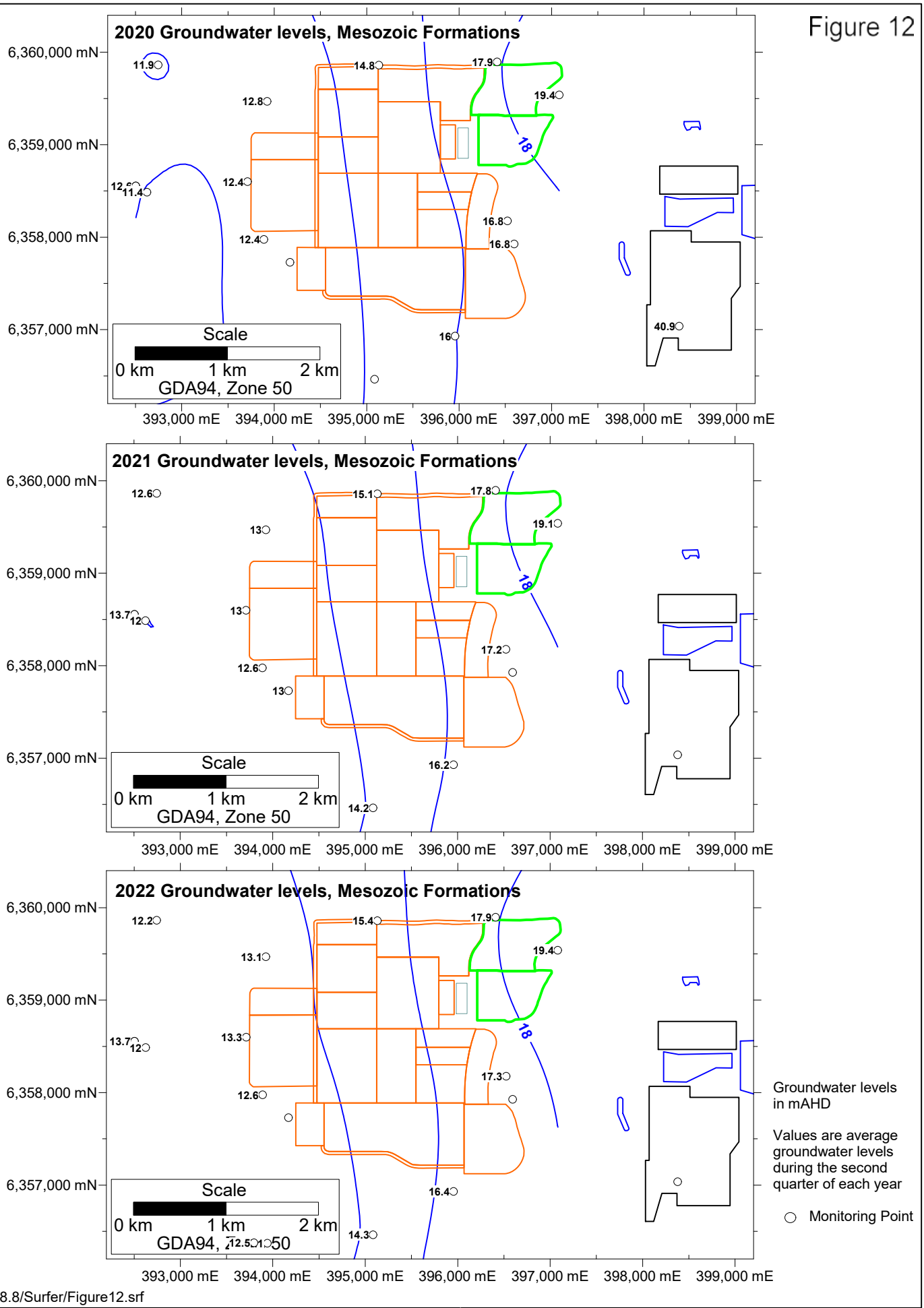
CLIENT:	Alcoa of Australia Limited
PROJECT:	Wagerup and Bunbury 2020-2022 water report
DATE:	March 2023
Dwg. No:	308-8/23/1-11

Wagerup Area groundwater level contours, Lower Superficial Formations 2020–22

Alcoa

Rockwater

Figure 12



308.8/Surfer/Figure12.srf

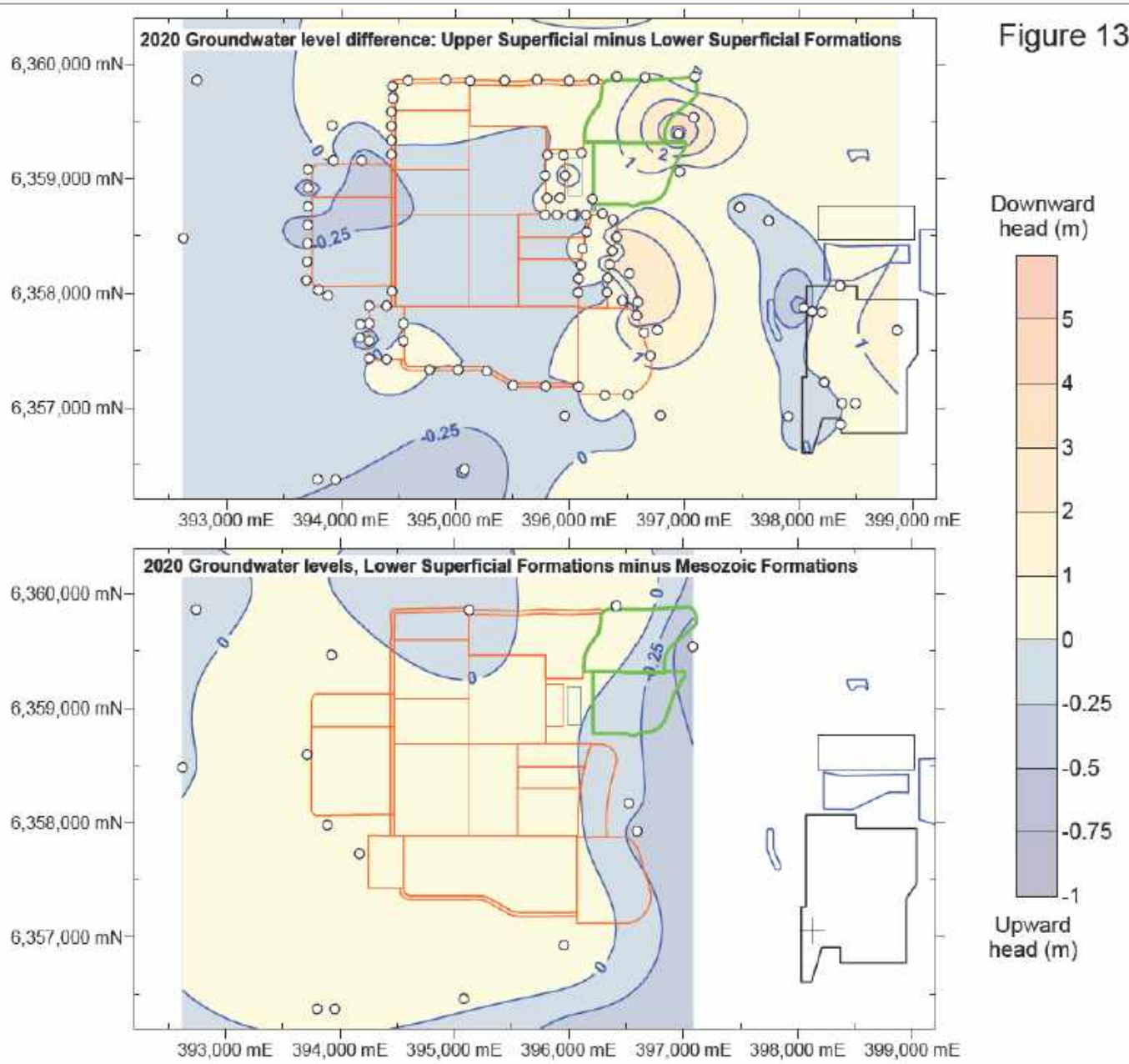
CLIENT:	Alcoa of Australia Limited
PROJECT:	Wagerup and Bunbury 2020-2022 water report
DATE:	March 2023
Dwg. No:	308-8/23/1-12

Wagerup Area groundwater level contours, Mesozoic Formations 2020–22

Alcoa

Rockwater

Figure 13



Groundwater levels in mAHD

Positive Values indicate potential for downward flow of groundwater

Values are average groundwater levels during the second quarter of 2020

Data monitoring point

Scale

0 km 1 km 2 km

GDA94, Zone 50

308.8/Surfer/Figure13.srf

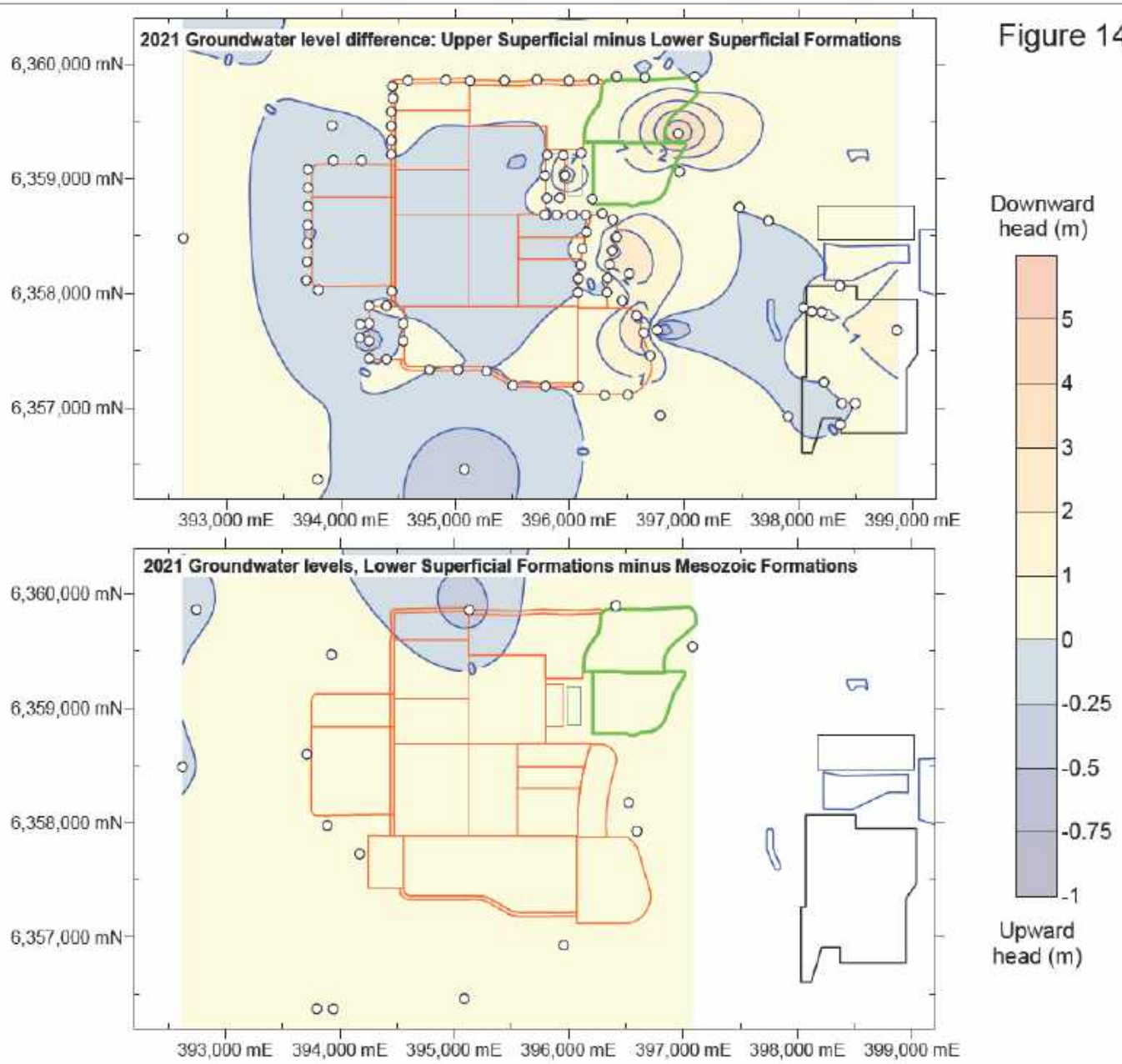
CLIENT:	Alcoa of Australia Limited
PROJECT:	Wagerup and Bunbury 2020-2022 water report
DATE:	March 2023
Dwg. No:	308-8/23/1-13

Contoured groundwater head differences 2020

Alcoa

Rockwater

Figure 14



Groundwater levels in mAHD

Positive Values indicate potential for downward flow of groundwater

Values are average groundwater levels during the second quarter of 2021

Data monitoring point

Scale

0 km 1 km 2 km

GDA94, Zone 50

308.8/Surfer/Figure14.srf

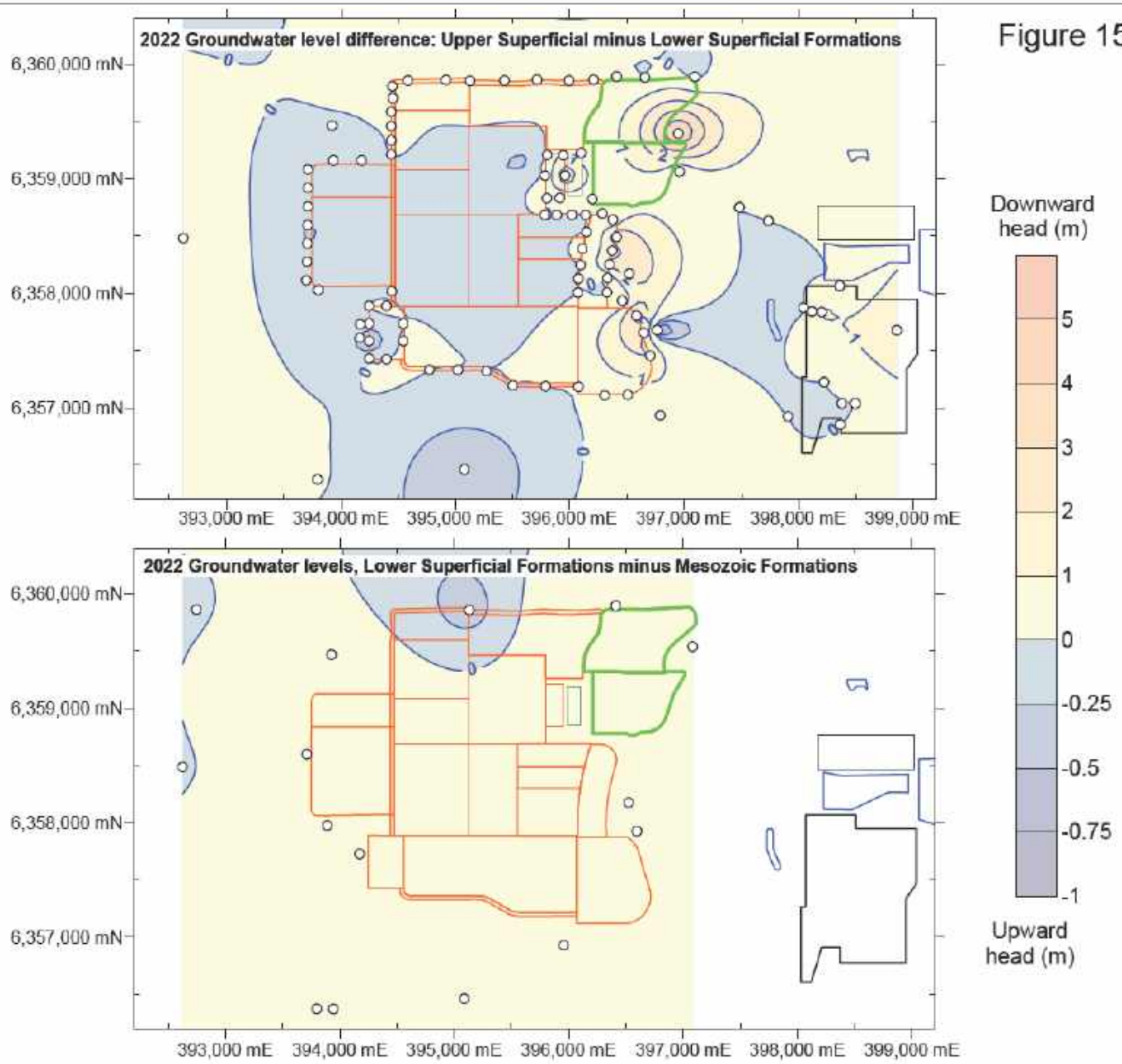
CLIENT:	Alcoa of Australia Limited
PROJECT:	Wagerup and Bunbury 2020-2021 water report
DATE:	March 2023
Dwg. No:	308-8/23/1-14

Contoured groundwater head differences 2021

Alcoa

Rockwater

Figure 15



Groundwater levels in mAHD

Positive Values indicate potential for downward flow of groundwater

Values are average groundwater levels during the second quarter of 2022

◯ Data monitoring point

Scale

0 km 1 km 2 km

GDA94, Zone 50

308.8/Surfer/Figure15.srf

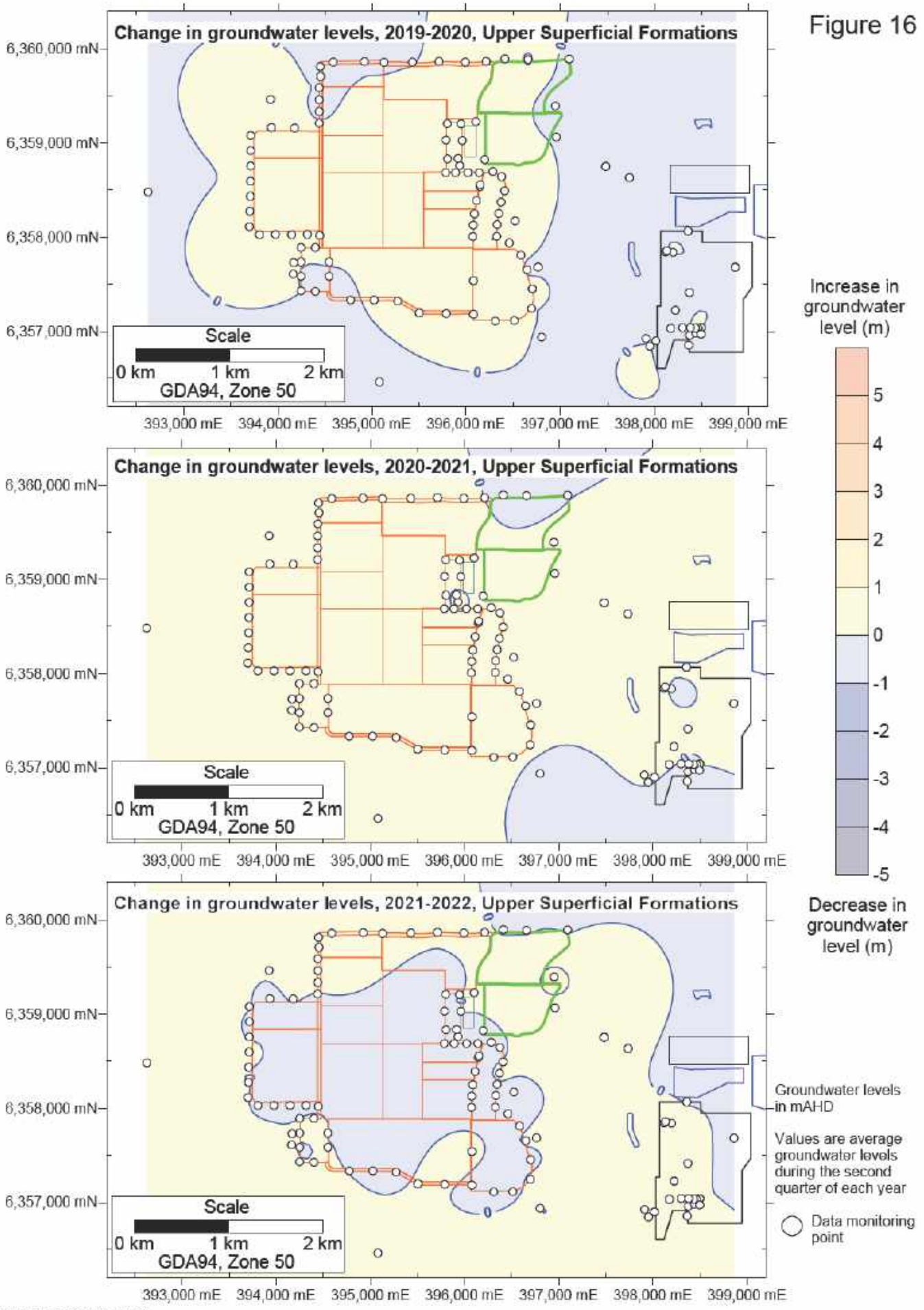
CLIENT:	Alcoa of Australia Limited
PROJECT:	Wagerup and Bunbury 2020-2022 water report
DATE:	March 2023
Dwg. No:	308-8/23/1-15

Contoured groundwater head differences 2022

Alcoa

Rockwater

Figure 16



308.8/Surfer/Figure16.srf

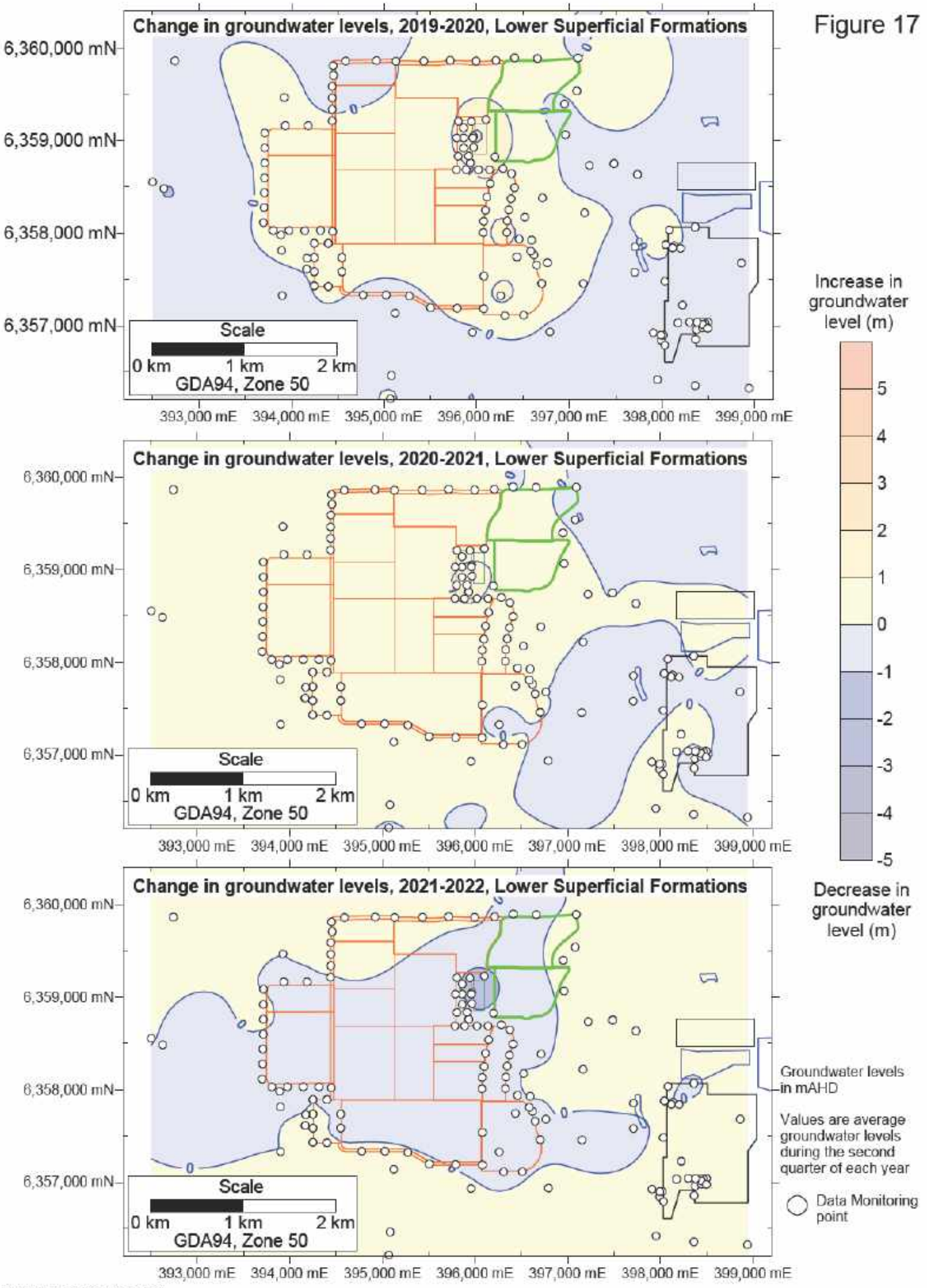
CLIENT:	Alcoa of Australia Limited
PROJECT:	Wagerup and Bunbury 2020-2022 water report
DATE:	March 2023
Dwg. No:	308-8/23/1-16

Wagerup Area, change in groundwater level, Upper Superficial Formations 2019–22

Alcoa

Rockwater

Figure 17



308.8/Surfer/Figure17.srf

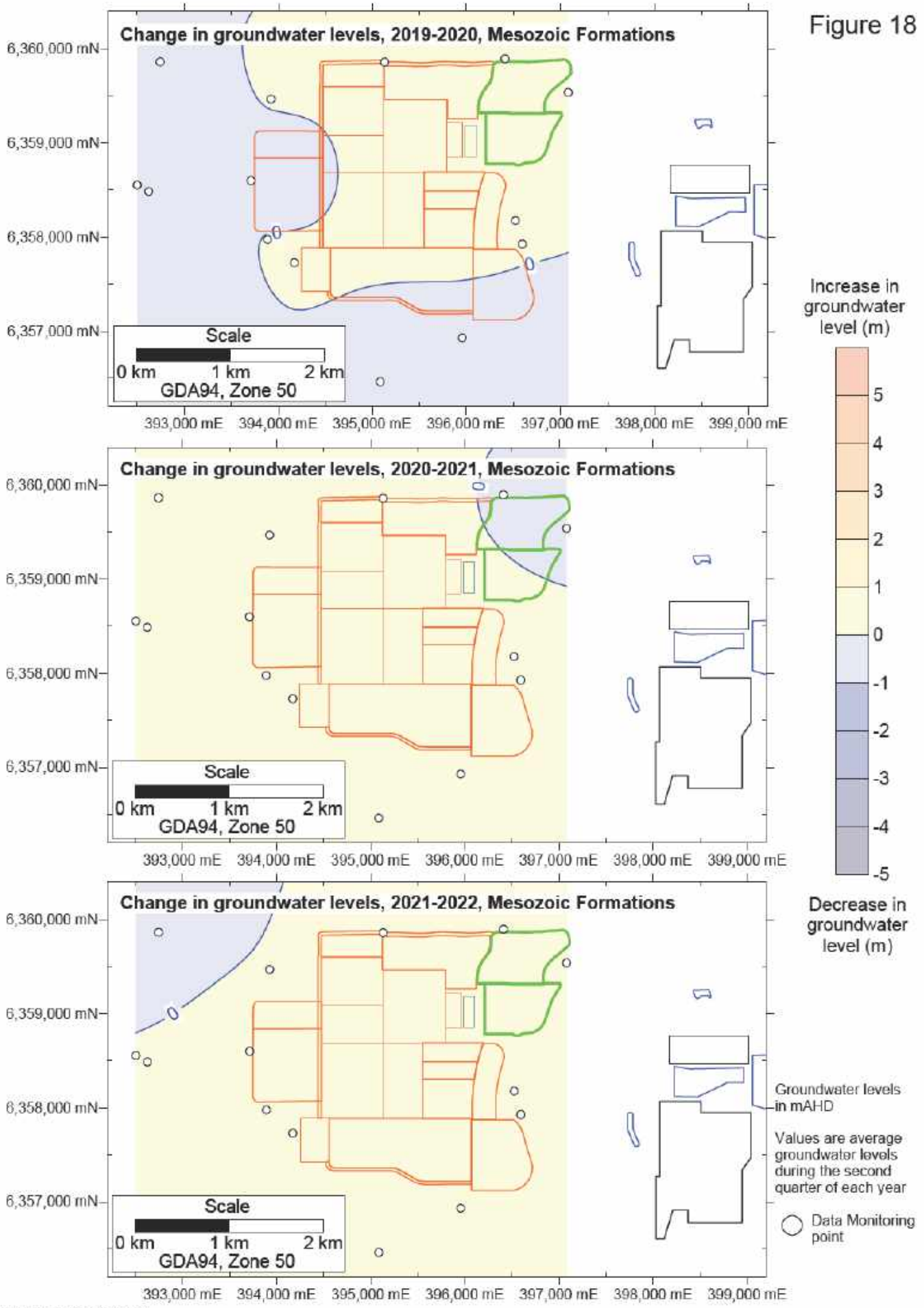
CLIENT:	Alcoa of Australia Limited
PROJECT:	Wagerup and Bunbury 2020-2022 water report
DATE:	March 2023
Dwg. No:	308-8/23/1-17

Wagerup Area, change in groundwater level, Lower Superficial Formations 2019–22

Alcoa

Rockwater

Figure 18



308.8/Surfer/Figure18.srf

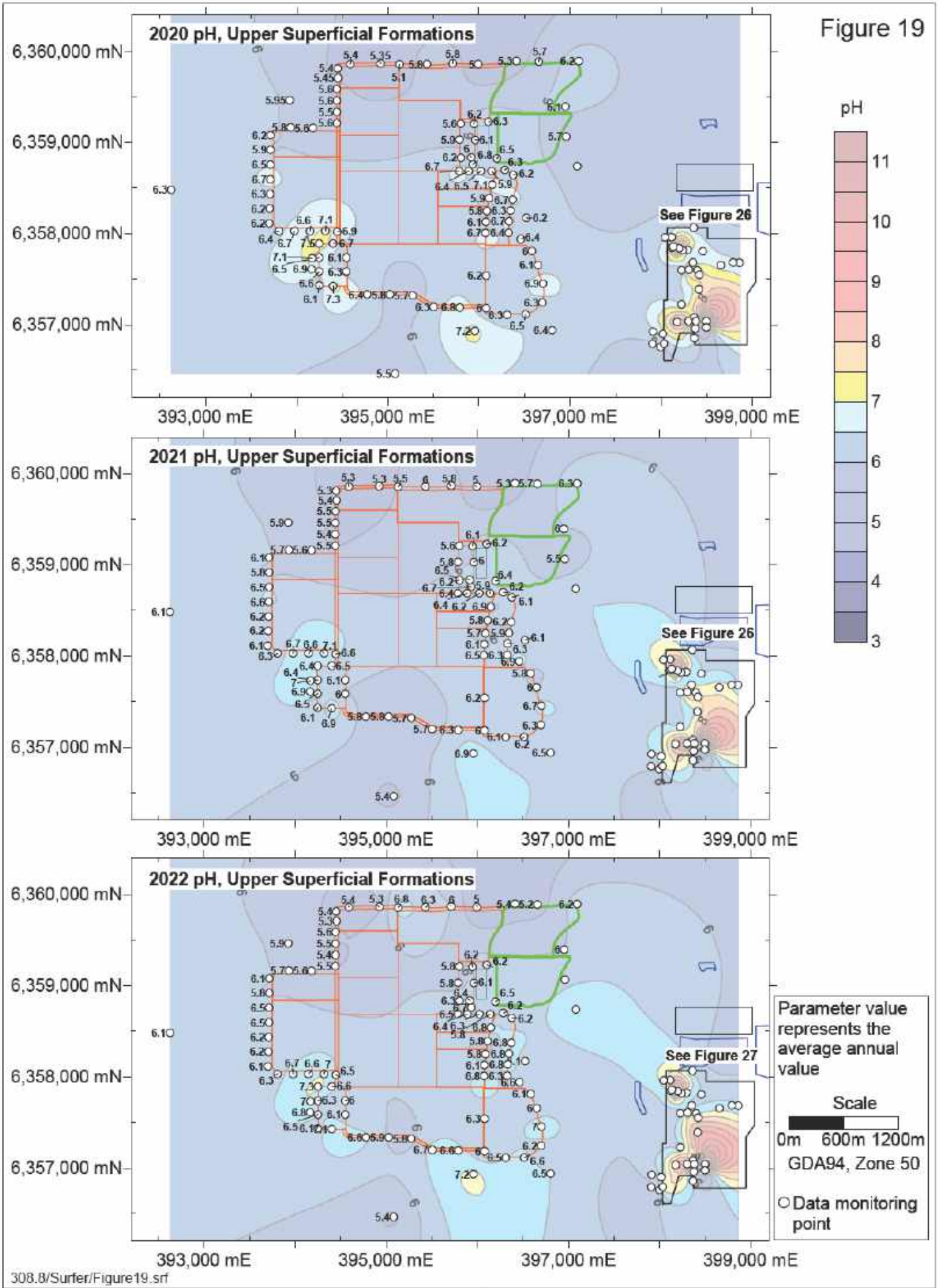
CLIENT:	Alcoa of Australia Limited
PROJECT:	Wagerup and Bunbury 2020-2022 water report
DATE:	March 2023
Dwg. No:	308-8/23/1-18

Alcoa

Wagerup Area, change in groundwater level, Mesozoic Formations 2019–22

Rockwater

Figure 19



308.8/Surfer/Figure19.srf

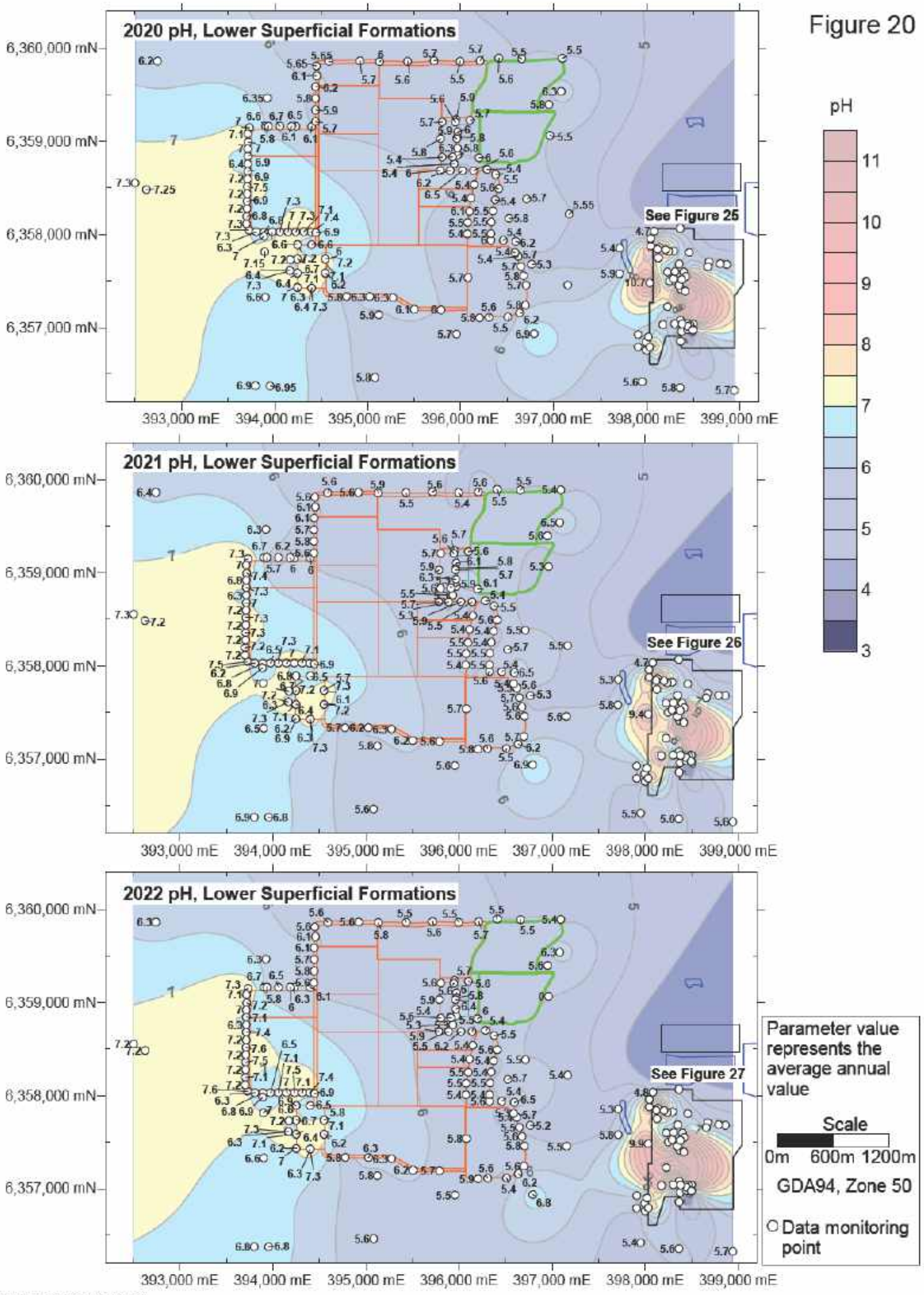
CLIENT:	Alcoa of Australia Limited
PROJECT:	Wagerup and Bunbury 2020-2022 water report
DATE:	March 2023
Dwg. No:	308-8/23/1-19

Wagerup Area Groundwater pH contours, Upper Superficial Formations 2020–22

Alcoa

Rockwater

Figure 20



308.8/Surfer/Figure20.srf

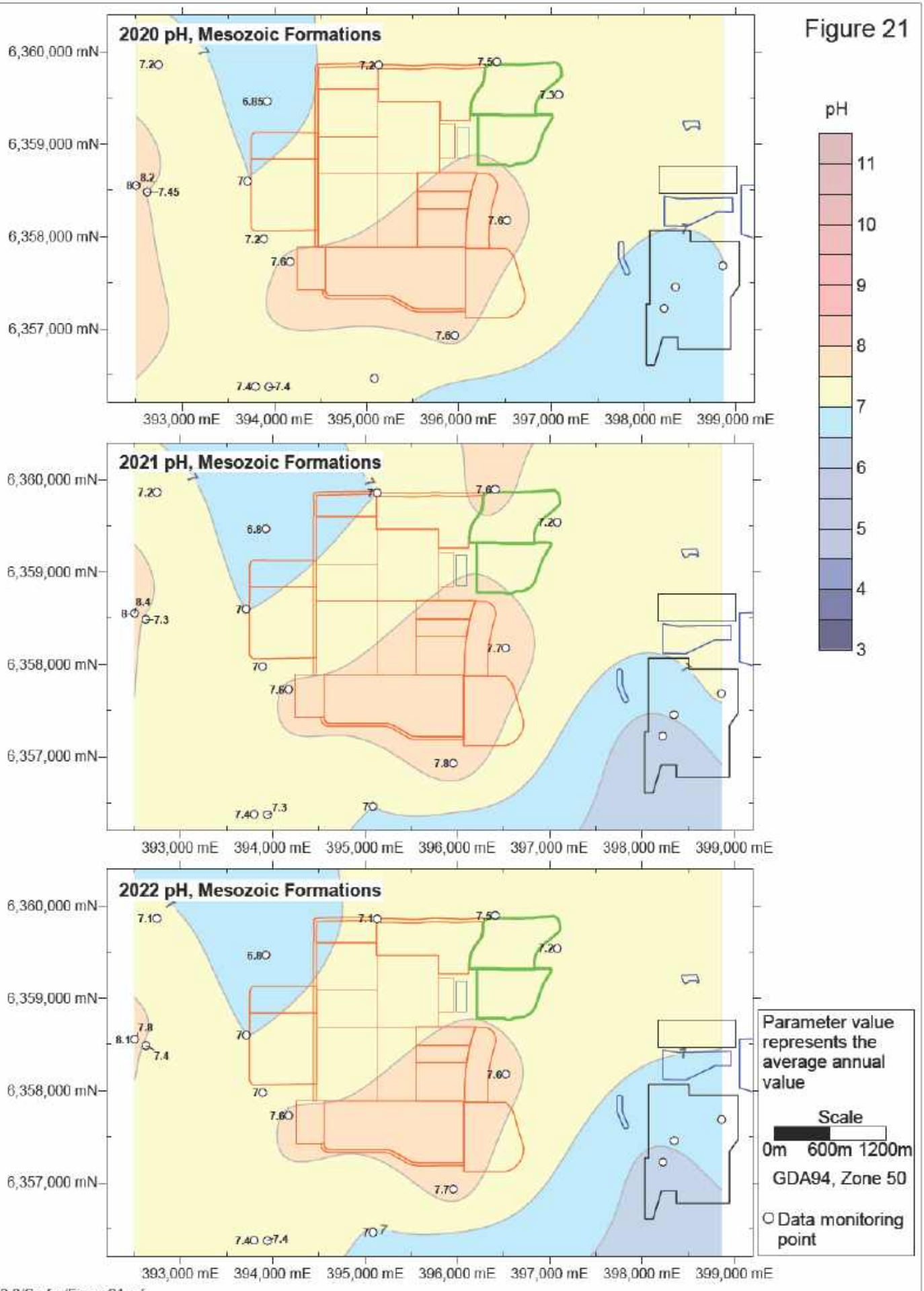
CLIENT:	Alcoa of Australia Limited
PROJECT:	Wagerup and Bunbury 2020-2022 water report
DATE:	March 2023
Dwg. No:	308-8/23/1-20

Wagerup Area Groundwater pH contours, Lower Superficial Formations 2020–22

Alcoa

Rockwater

Figure 21



308.8/Surfer/Figure21.srf

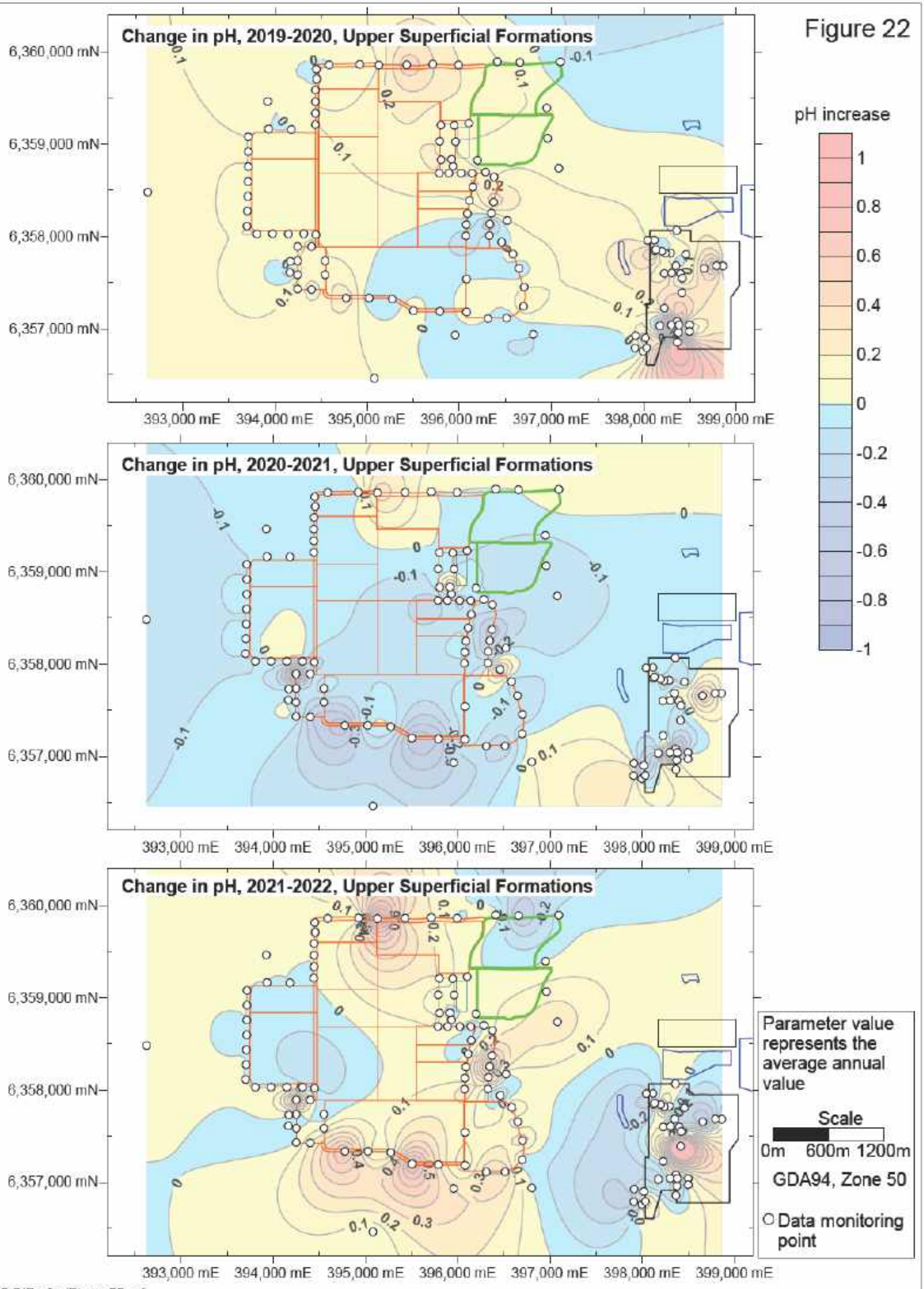
CLIENT:	Alcoa of Australia Limited
PROJECT:	Wagerup and Bunbury 2020-2022 water report
DATE:	March 2023
Dwg. No:	308-8/23/1-21

Wagerup Area Groundwater pH contours, Mesozoic Formations 2020–22

Alcoa

Rockwater

Figure 22



308.8/Surfer/Figure22.srf

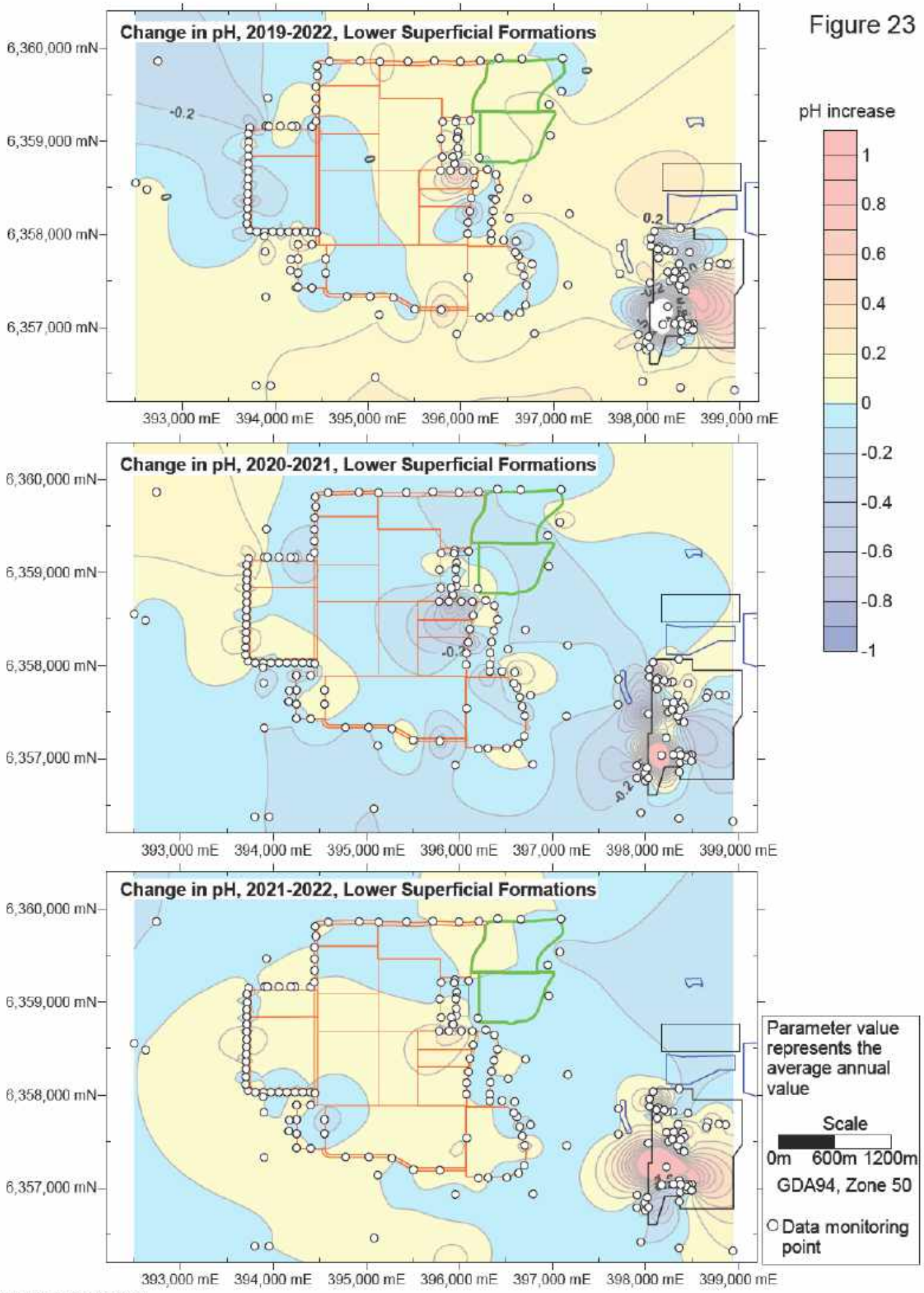
CLIENT:	Alcoa of Australia Limited
PROJECT:	Wagerup and Bunbury 2020-2022 water report
DATE:	March 2023
Dwg. No:	308-8/23/1-22

Wagerup Area, change in pH, Upper Superficial Formations 2019–22, contoured

Alcoa

Rockwater

Figure 23



308.8/Surfer/Figure23.srf

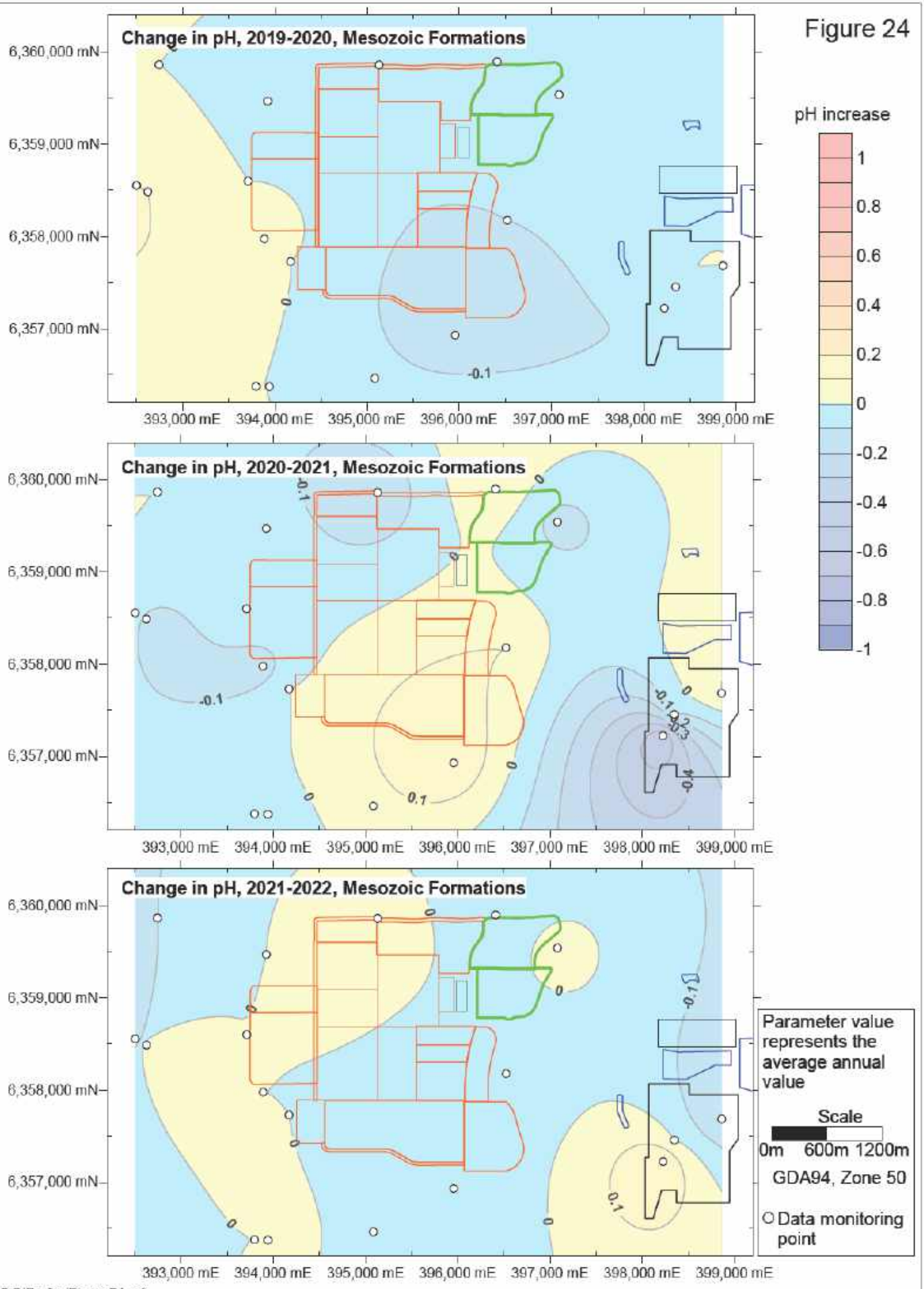
CLIENT:	Alcoa of Australia Limited
PROJECT:	Wagerup and Bunbury 2020-2022 water report
DATE:	March 2023
Dwg. No:	308-8/23/1-23

Wagerup Area, change in pH, Lower Superficial Formations 2019–22, contoured

Alcoa

Rockwater

Figure 24



308.8/Surfer/Figure24.srf

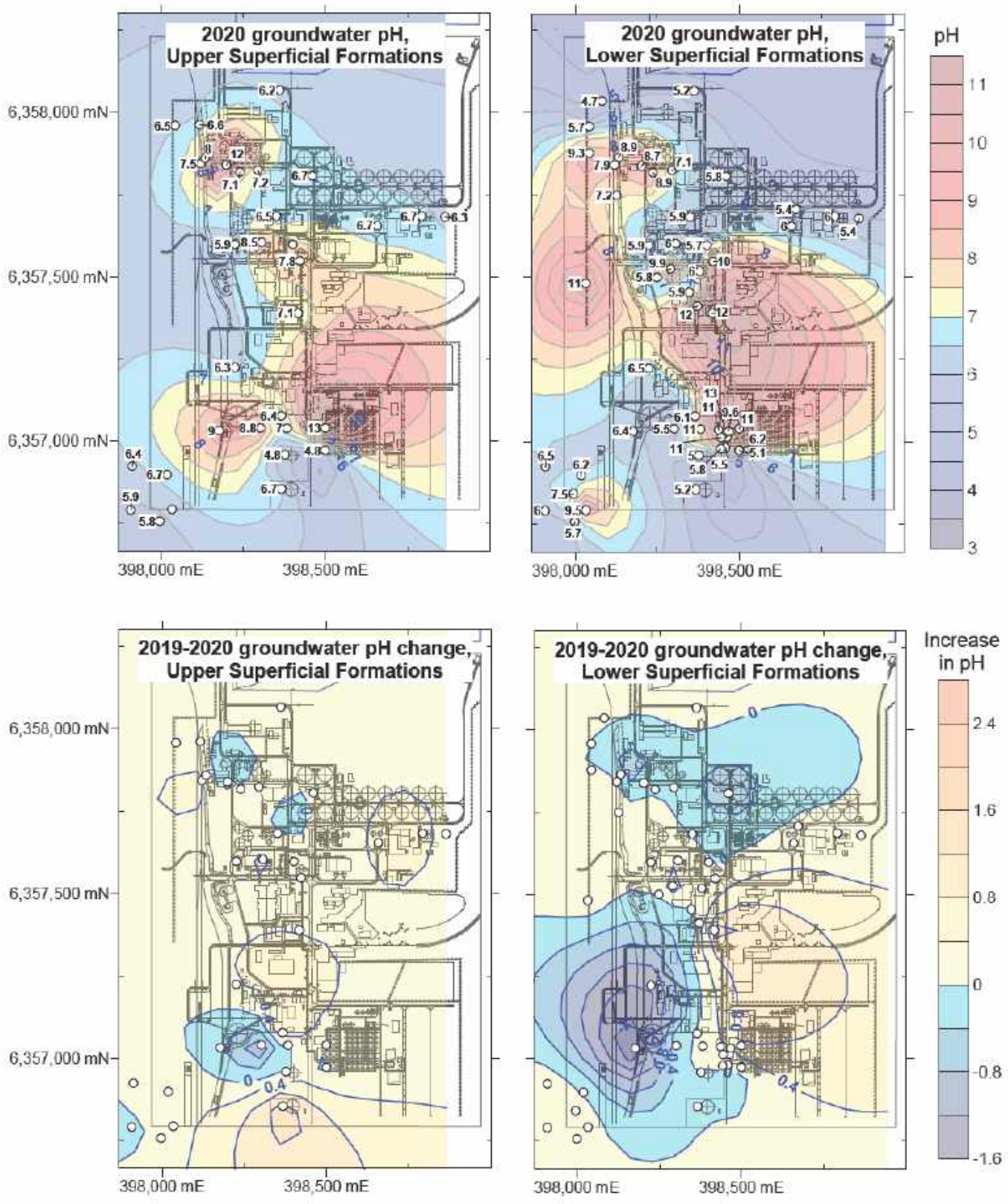
CLIENT:	Alcoa of Australia Limited
PROJECT:	Wagerup and Bunbury 2020-2022 water report
DATE:	March 2023
Dwg. No:	308-8/23/1-24

Wagerup Area, change in pH, Mesozoic Formations 2019–22, contoured

Alcoa

Rockwater

Figure 25



Scale

0 m 200 m 400 m

GDA94, Zone 50

Values are annual averages during 2019 & 2020

○ Data monitoring point

308.8/Surfer/Figure25.srf

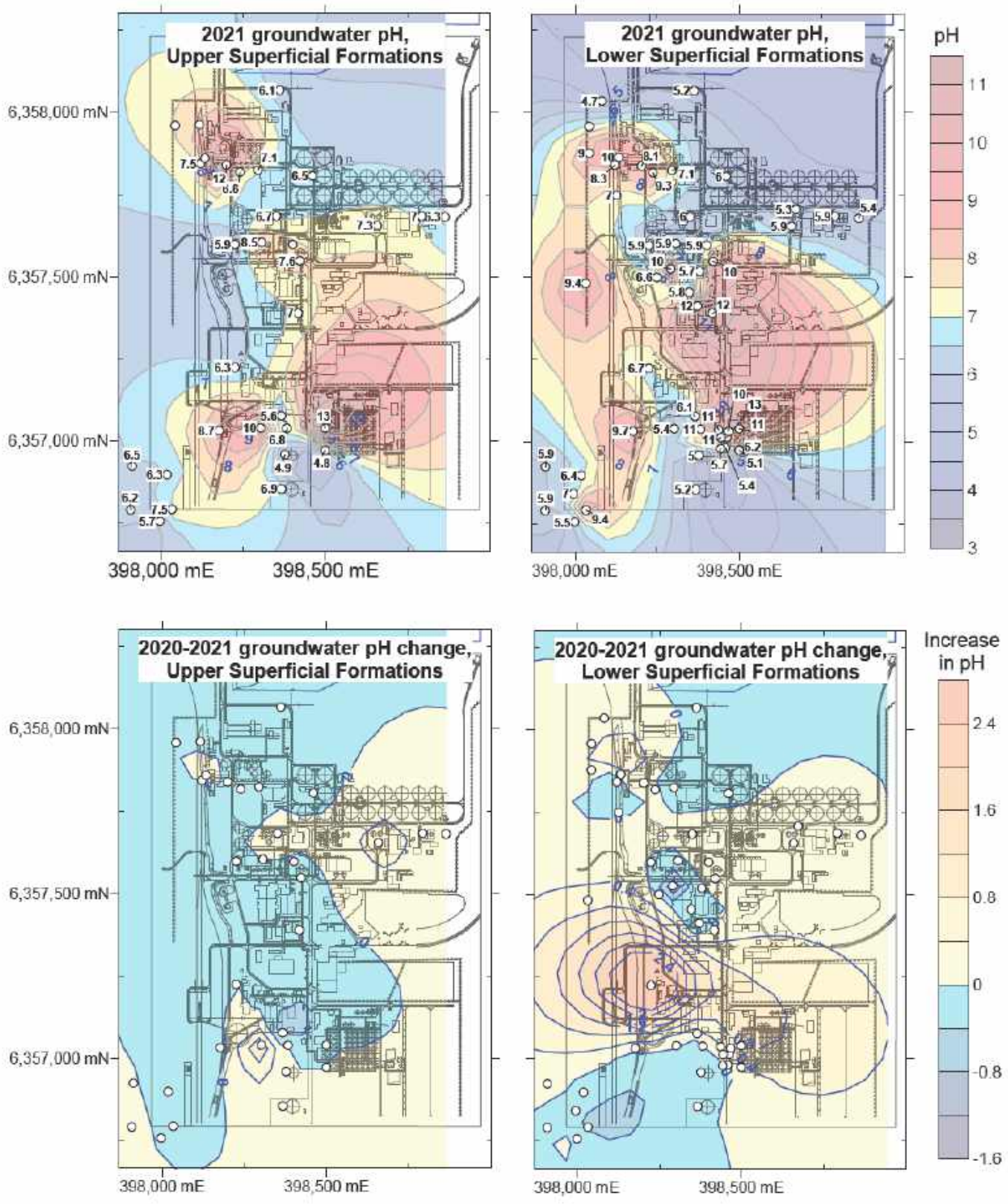
CLIENT:	Alcoa of Australia Limited
PROJECT:	Wagerup and Bunbury 2020-2022 water report
DATE:	March 2023
Dwg. No:	308-8/23/1-25

Refinery Area: 2020 groundwater pH & groundwater pH change, 2019-2020

Alcoa

Rockwater

Figure 26



Scale

0 m 200 m 400 m

GDA94, Zone 50

Values are annual averages during 2020 & 2021

○ Data monitoring point

308.8/Surfer/Figure26.srf

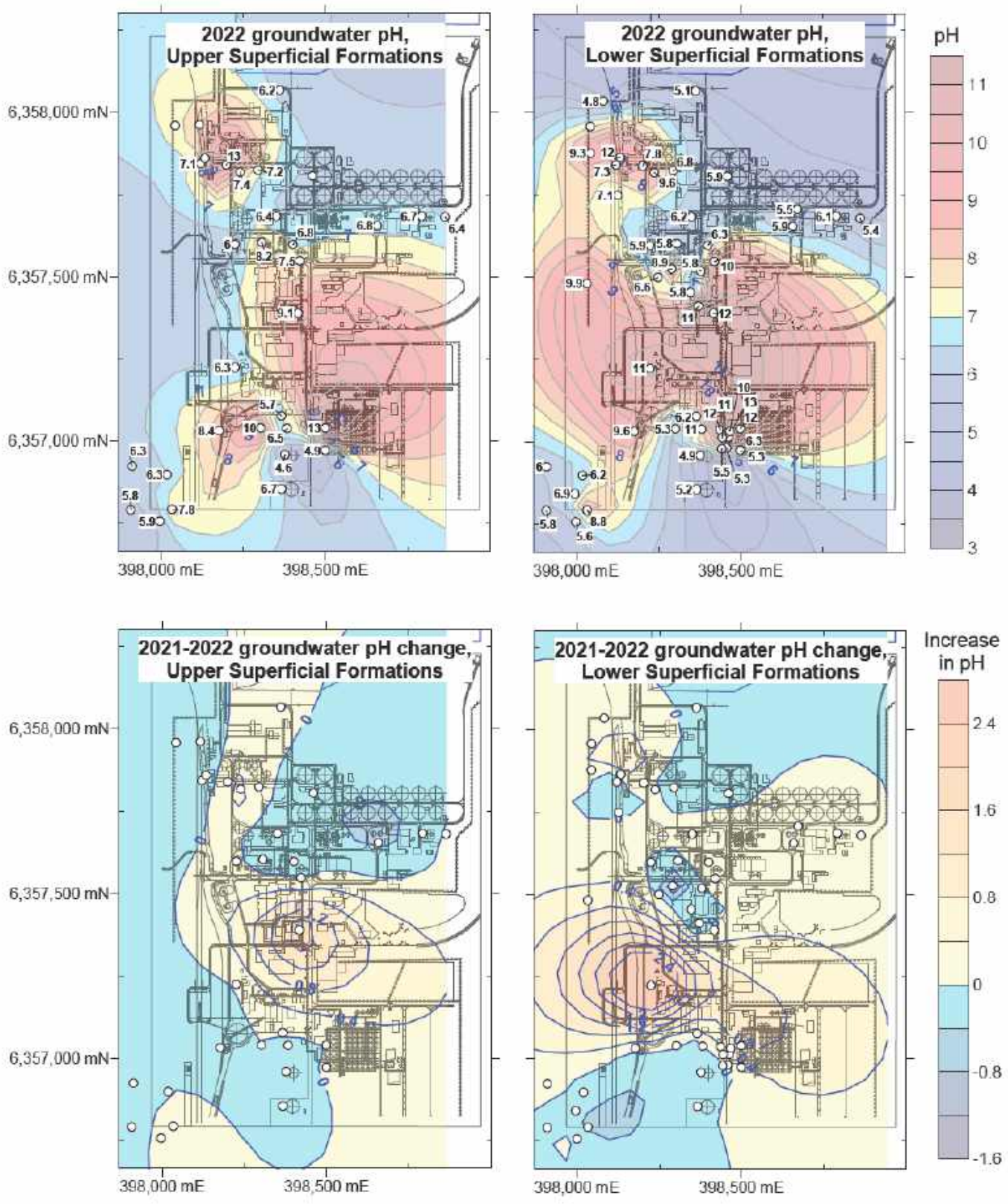
CLIENT:	Alcoa of Australia Limited
PROJECT:	Wagerup and Bunbury 2020-2022 water report
DATE:	March 2023
Dwg. No:	308-8/23/1-26

Refinery Area: 2021 groundwater pH & groundwater pH change, 2020-2021

Alcoa

Rockwater

Figure 27



Scale

0 m 200 m 400 m

GDA94, Zone 50

Values are annual averages during 2021 & 2022

○ Data monitoring point

308.8/Surfer/Figure27.srf

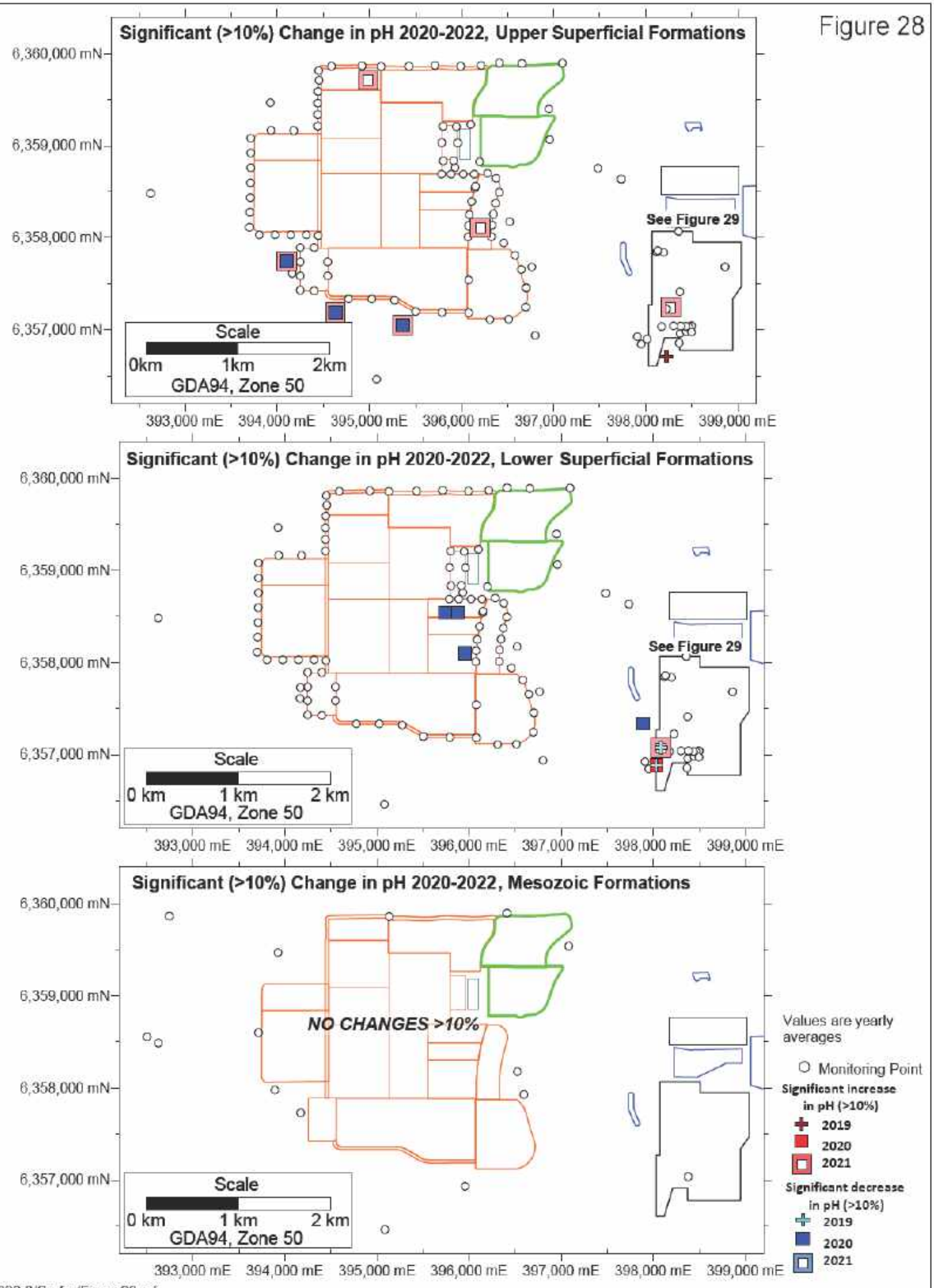
CLIENT:	Alcoa of Australia Limited
PROJECT:	Wagerup and Bunbury 2020-2022 water report
DATE:	March 2023
Dwg. No:	308-8/23/1-27

Refinery Area: 2022 groundwater pH & groundwater pH change, 2021-2022

Alcoa

Rockwater

Figure 28



308.8/Surfer/Figure28.srf

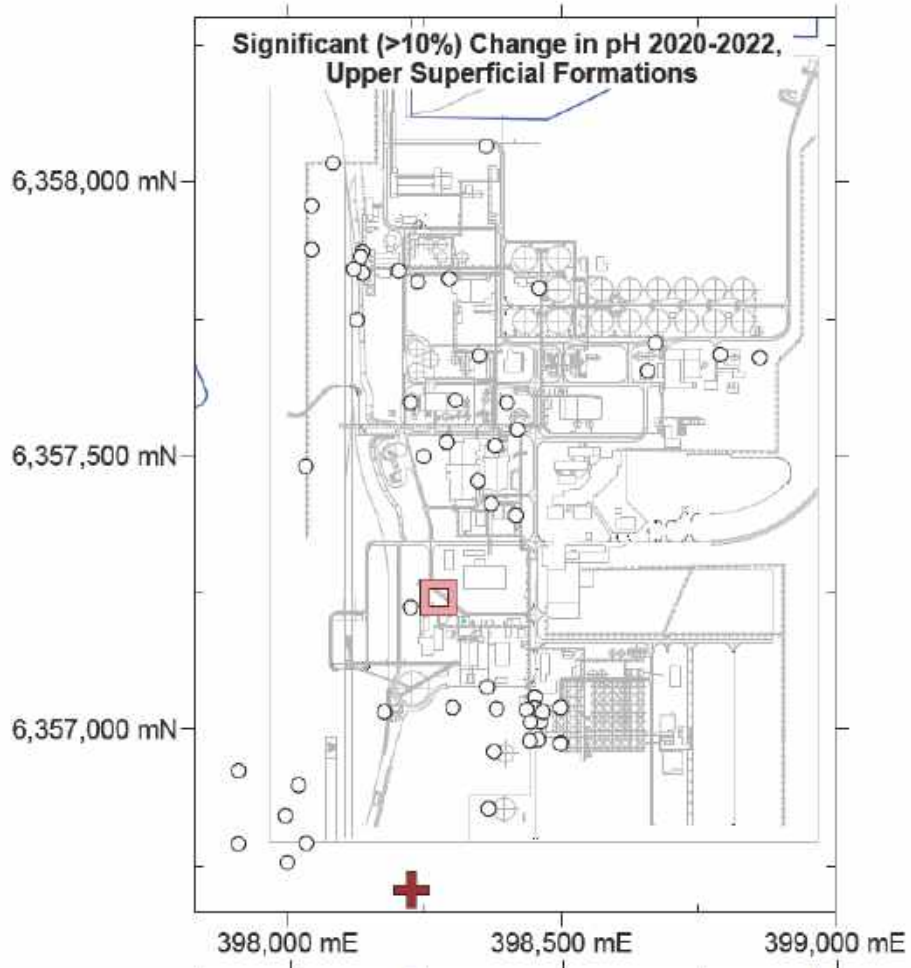
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PROJECT:	Wagerup and Bunbury 2020-2022 water report
DATE:	March 2023
Dwg. No:	308-8/23/1-28

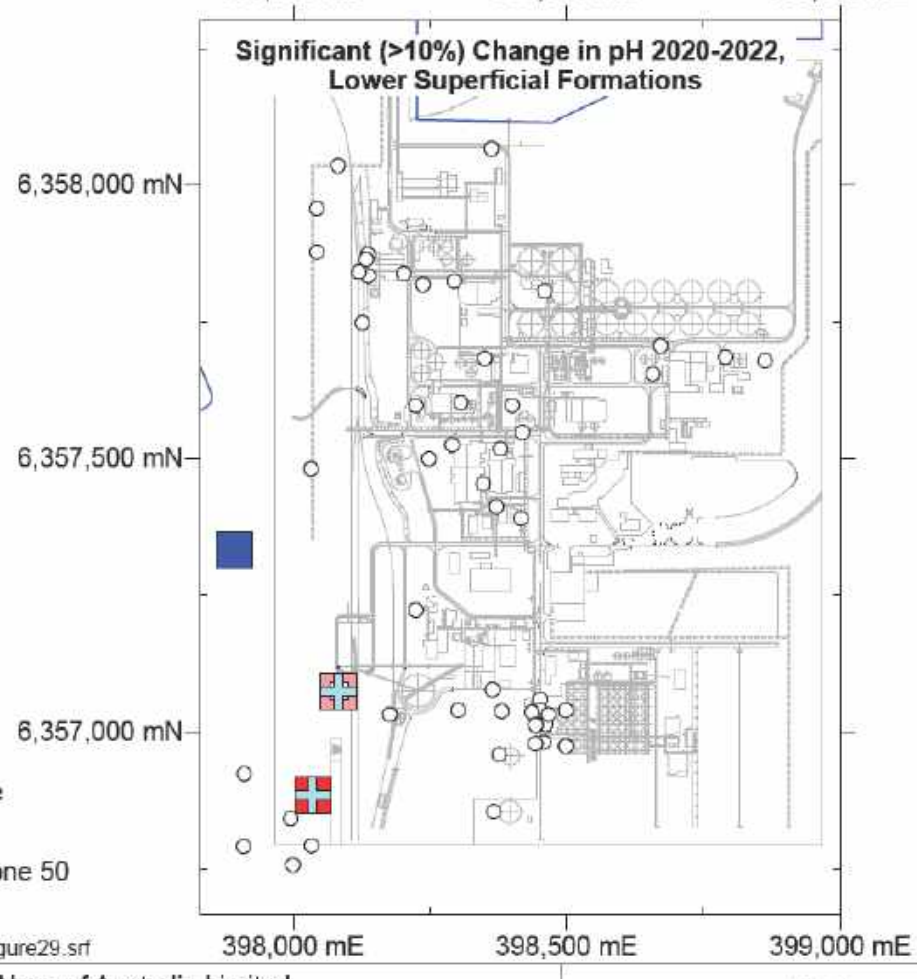
Alcoa

Wagerup Area
Sites with significant change in pH 2020–22

Rockwater

Figure 29





Values are yearly averages

Monitoring Point

Significant increase in pH (>10%)
- 2019
- 2020
- 2021

Significant decrease in pH (>10%)
- 2019
- 2020
- 2021

Scale

GDA94, Zone 50

308.8/Surfer/Figure29.srf

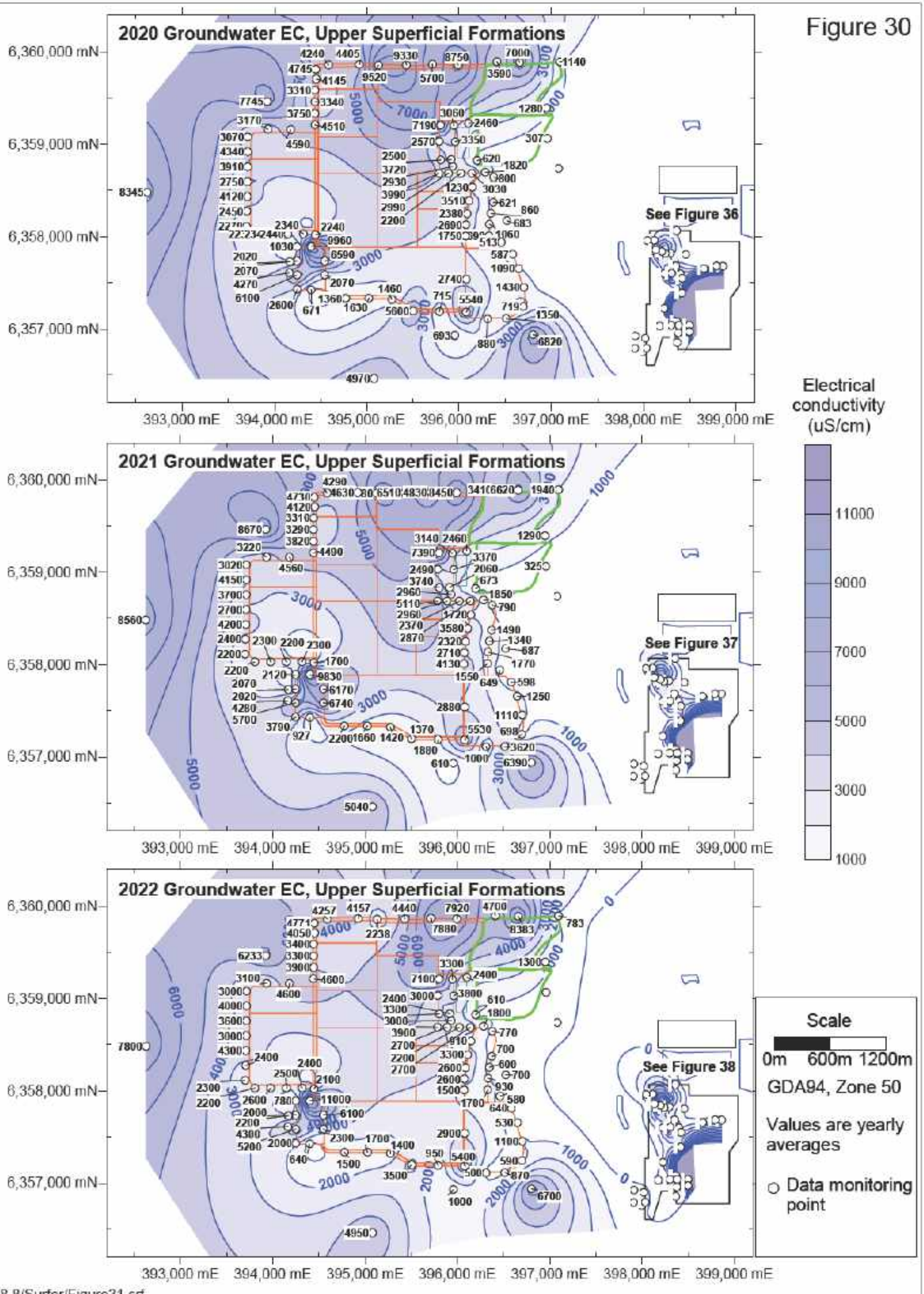
CLIENT:	Alcoa of Australia Limited
PROJECT:	Wagerup and Bunbury 2020-2022 water report
DATE:	March 2023
Dwg. No:	308-8/23/1-29

Alcoa

Refinery Area:
Sites with significant change in pH 2020–2022

Rockwater

Figure 30



308.8/Surfer/Figure31.srf

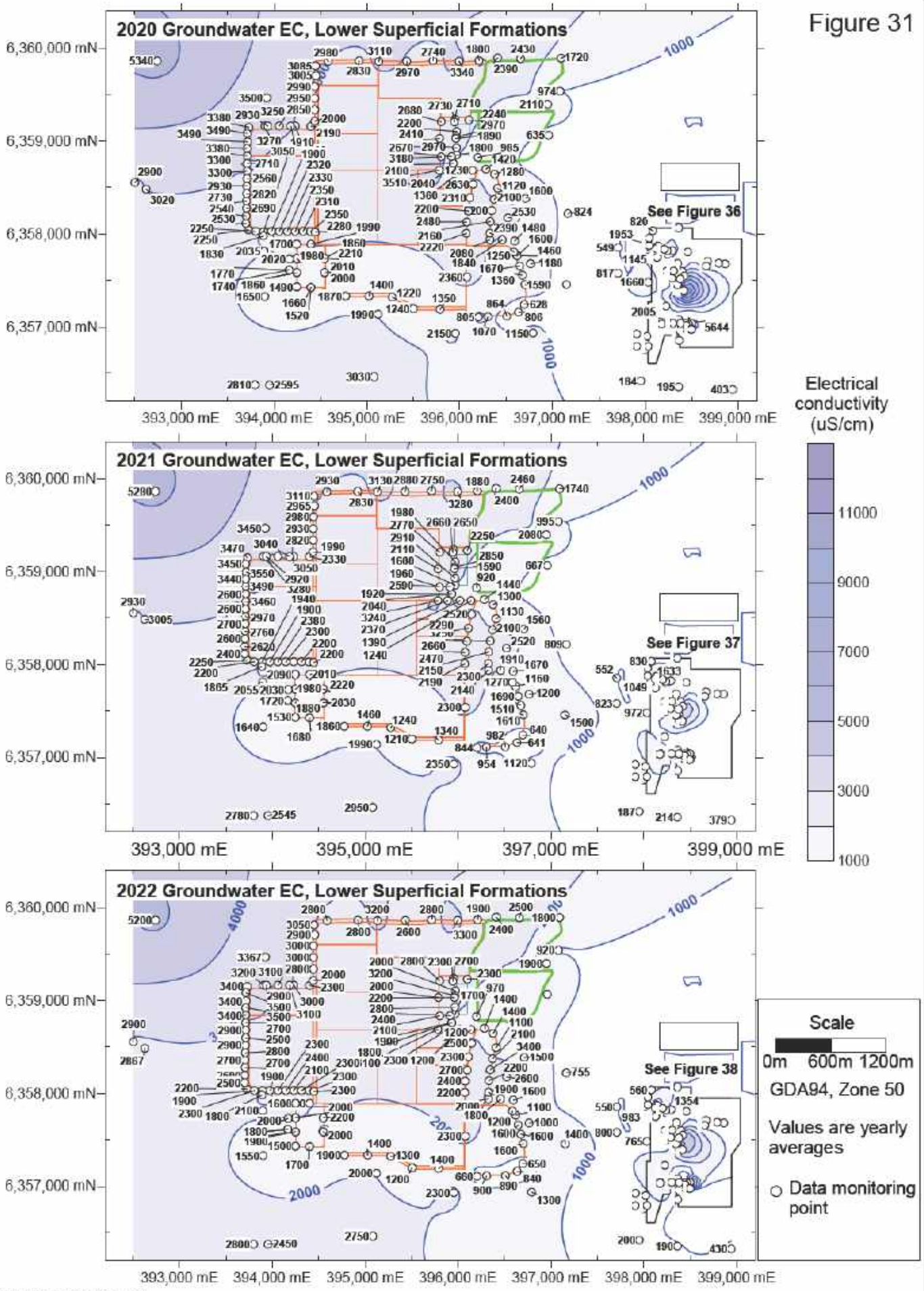
CLIENT:	Alcoa of Australia Limited
PROJECT:	Wagerup and Bunbury 2020-2022 water report
DATE:	March 2023
Dwg. No:	308-8/23/1-30

Wagerup Area groundwater EC contours, Upper Superficial Formations 2020–22

Alcoa

Rockwater

Figure 31



308.8/Surfer/Figure31.srf

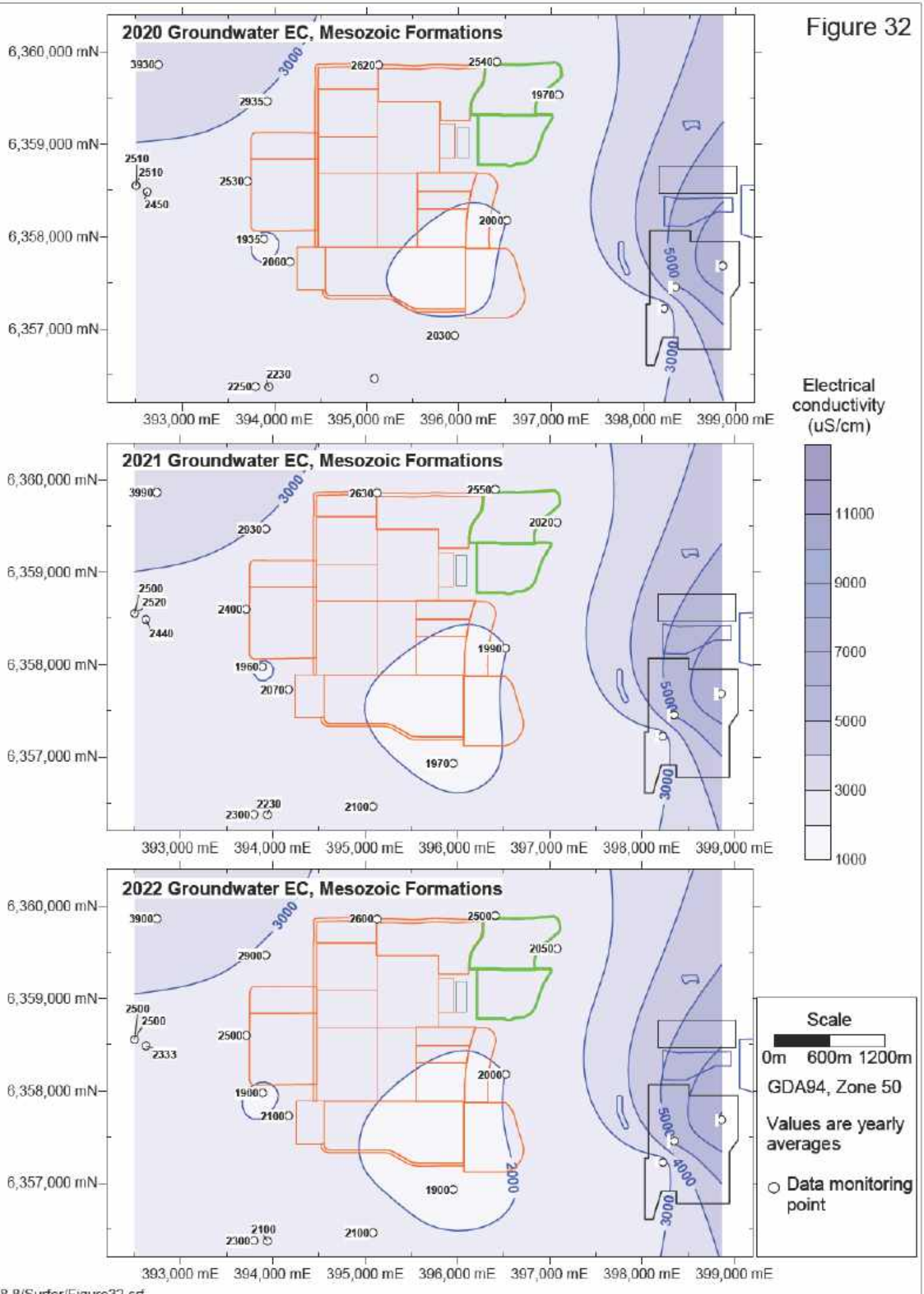
CLIENT:	Alcoa of Australia Limited
PROJECT:	Wagerup and Bunbury 2020-2022 water report
DATE:	March 2023
Dwg. No:	308-8/23/1-31

Wagerup Area groundwater EC contours, Lower Superficial Formations 2020–22

Alcoa

Rockwater

Figure 32



308.8/Surfer/Figure32.srf

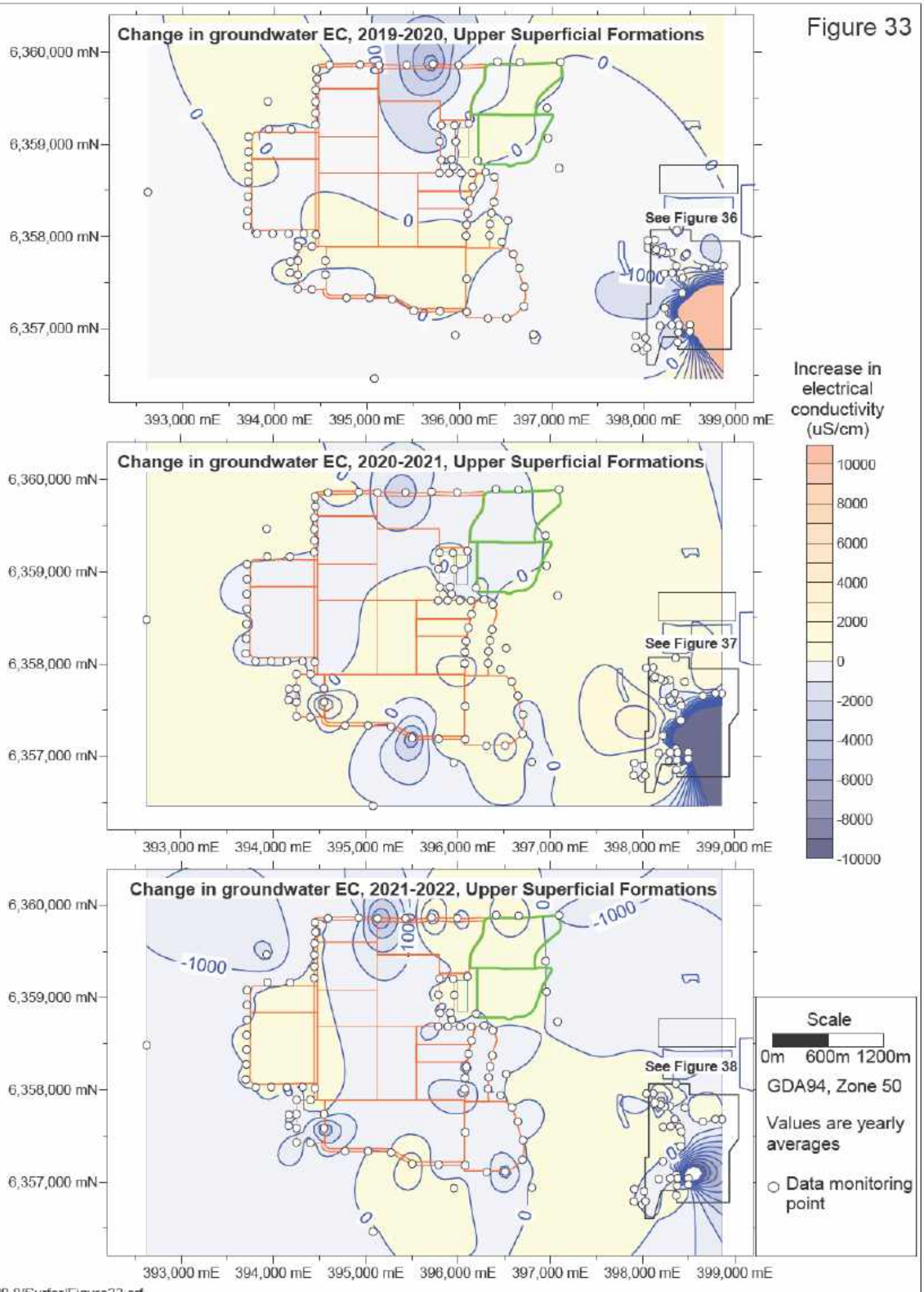
CLIENT:	Alcoa of Australia Limited
PROJECT:	Wagerup and Bunbury 2020-2022 water report
DATE:	March 2023
Dwg. No:	308-8/23/1-32

Wagerup Area groundwater EC contours, Mesozoic Formations 2020–22

Alcoa

Rockwater

Figure 33



308.8/Surfer/Figure33.srf

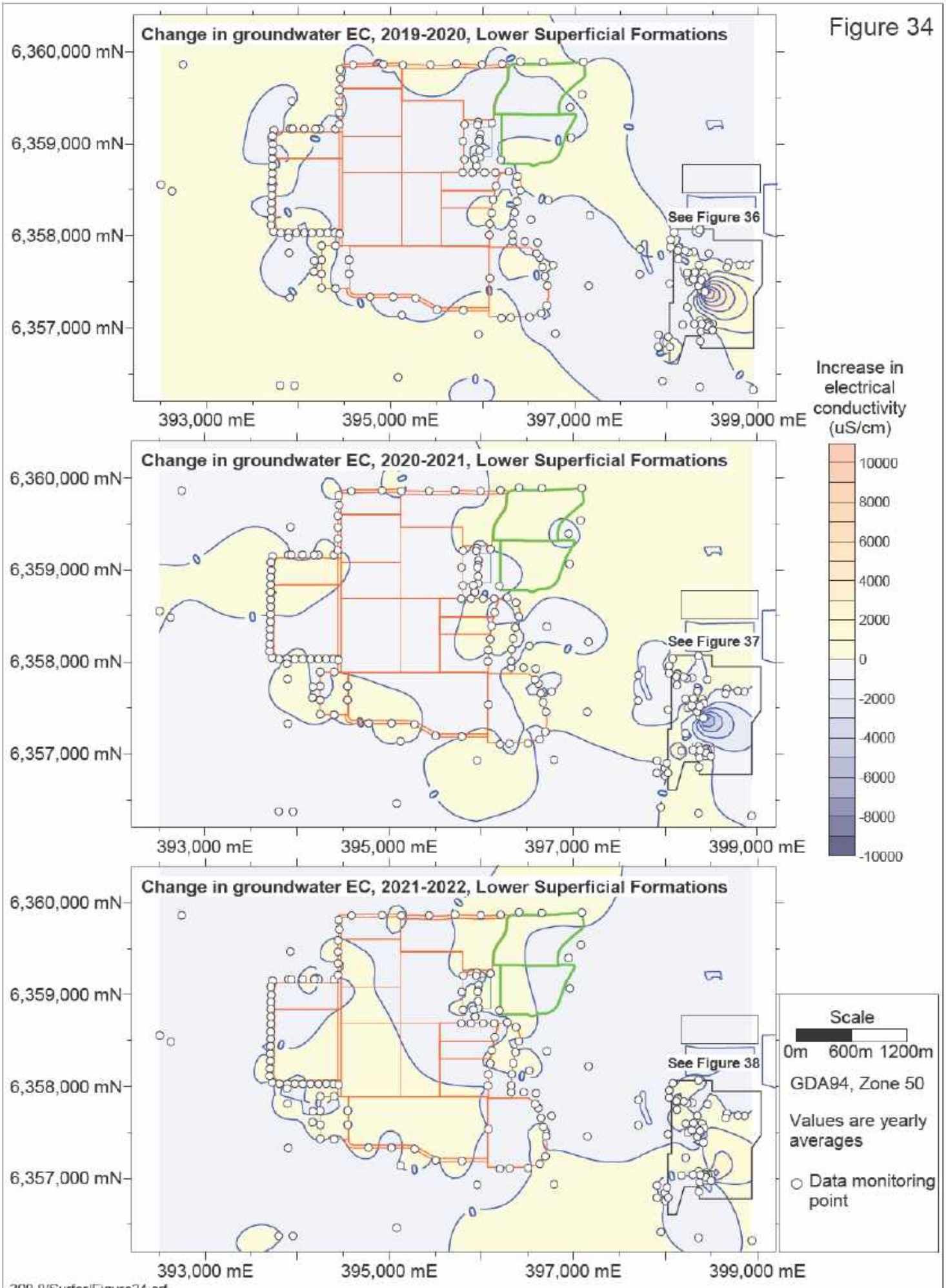
CLIENT:	Alcoa of Australia Limited
PROJECT:	Wagerup and Bunbury 2020-2022 water report
DATE:	March 2023
Dwg. No:	308-8/23/1-33

Wagerup Area, change in groundwater EC contours, Upper Superficial Formations, 2019-2022

Alcoa

Rockwater

Figure 34



308.8/Surfer/Figure34.srf

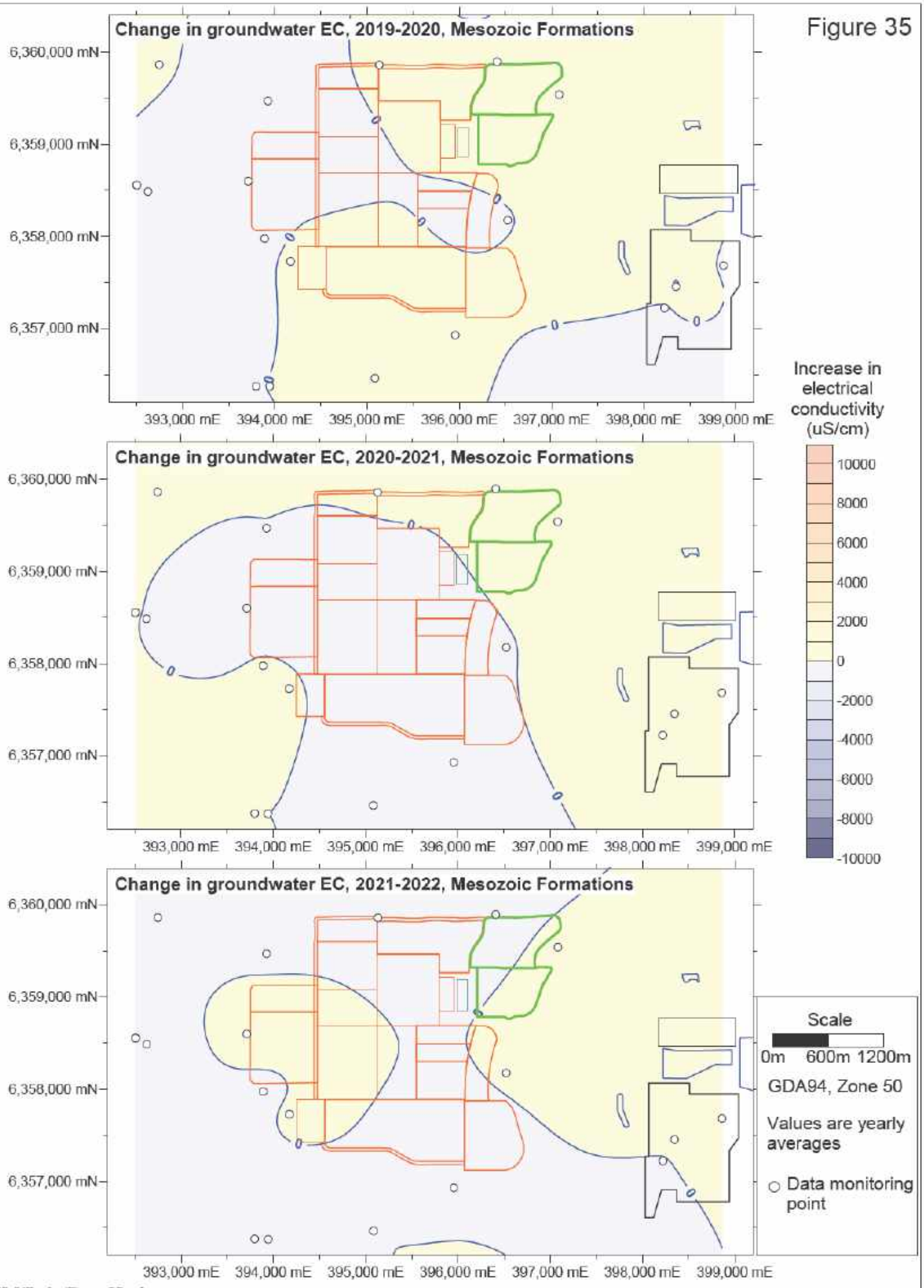
CLIENT:	Alcoa of Australia Limited
PROJECT:	Wagerup and Bunbury 2020-2022 water report
DATE:	March 2023
Dwg. No:	308-8/23/1-34

Wagerup Area, change in groundwater EC contours, Lower Superficial Formations, 2019-2022

Alcoa

Rockwater

Figure 35



308.8/Surfer/Figure35.srf

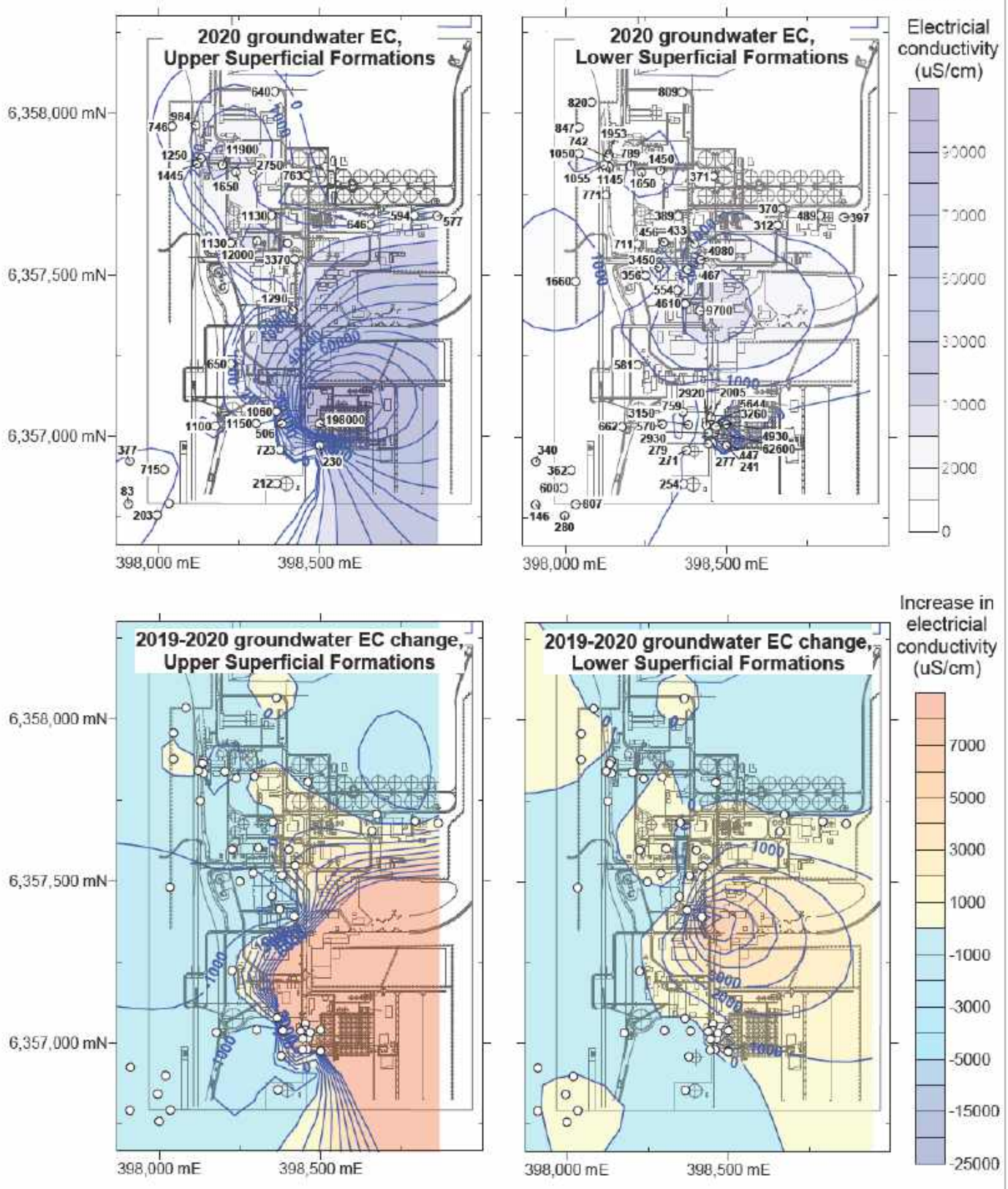
CLIENT:	Alcoa of Australia Limited
PROJECT:	Wagerup and Bunbury 2020-2022 water report
DATE:	March 2023
Dwg. No:	308-8/23/1-35

Wagerup Area, change in groundwater EC contours, Mesozoic Formations, 2019-2022

Alcoa

Rockwater

Figure 36



Scale

0 m 200 m 400 m

GDA94, Zone 50

Values are yearly averages

○ Data monitoring point

308.8/Surfer/Figure36.srf

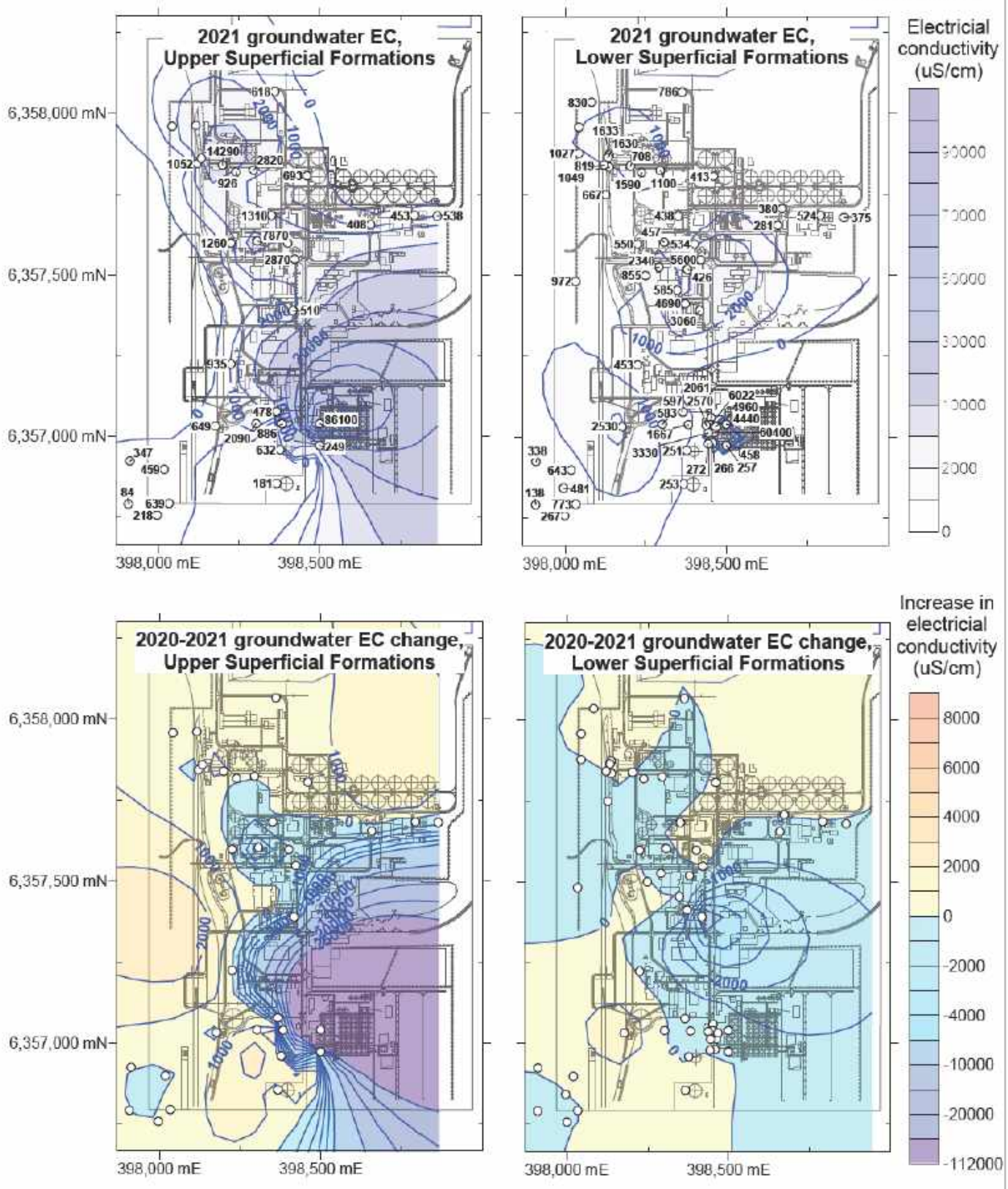
CLIENT:	Alcoa of Australia Limited
PROJECT:	Wagerup and Bunbury 2020-2022 water report
DATE:	March 2023
Dwg. No:	308-8/23/1-36

Refinery Area: 2020 groundwater EC & groundwater EC change, 2019-2020

Alcoa

Rockwater

Figure 37



Scale

0 m 200 m 400 m

GDA94, Zone 50

Values are yearly averages

○ Data monitoring point

308.8/Surfer/Figure37.srf

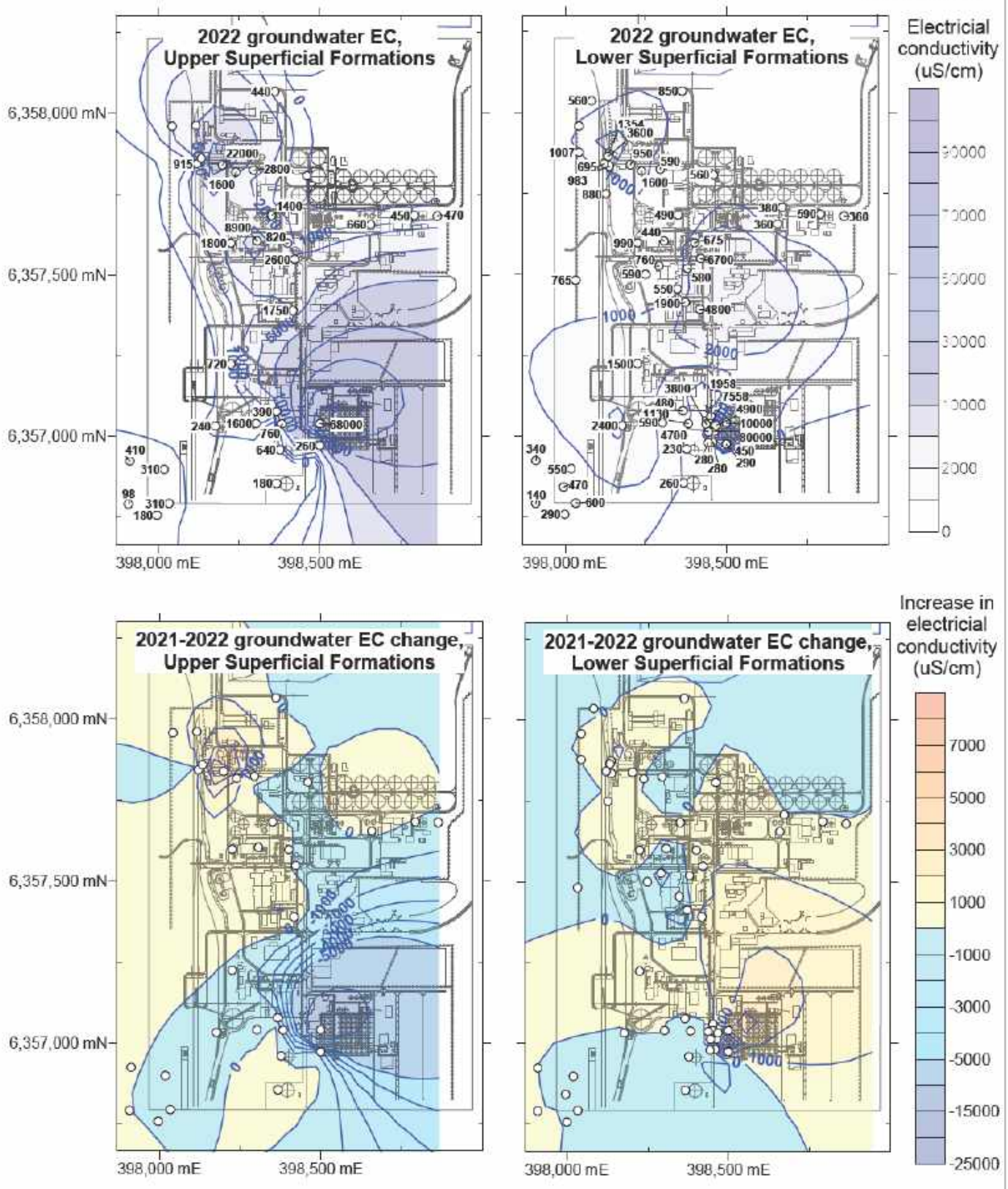
CLIENT:	Alcoa of Australia Limited
PROJECT:	Wagerup and Bunbury 2020-2022 water report
DATE:	March 2023
Dwg. No:	308-8/23/1-37

Refinery Area: 2021 groundwater EC & groundwater EC change, 2020-2021

Alcoa

Rockwater

Figure 38



Scale

0 m 200 m 400 m

GDA94, Zone 50

Values are yearly averages

○ Data monitoring point

308.8/Surfer/Figure38.srf

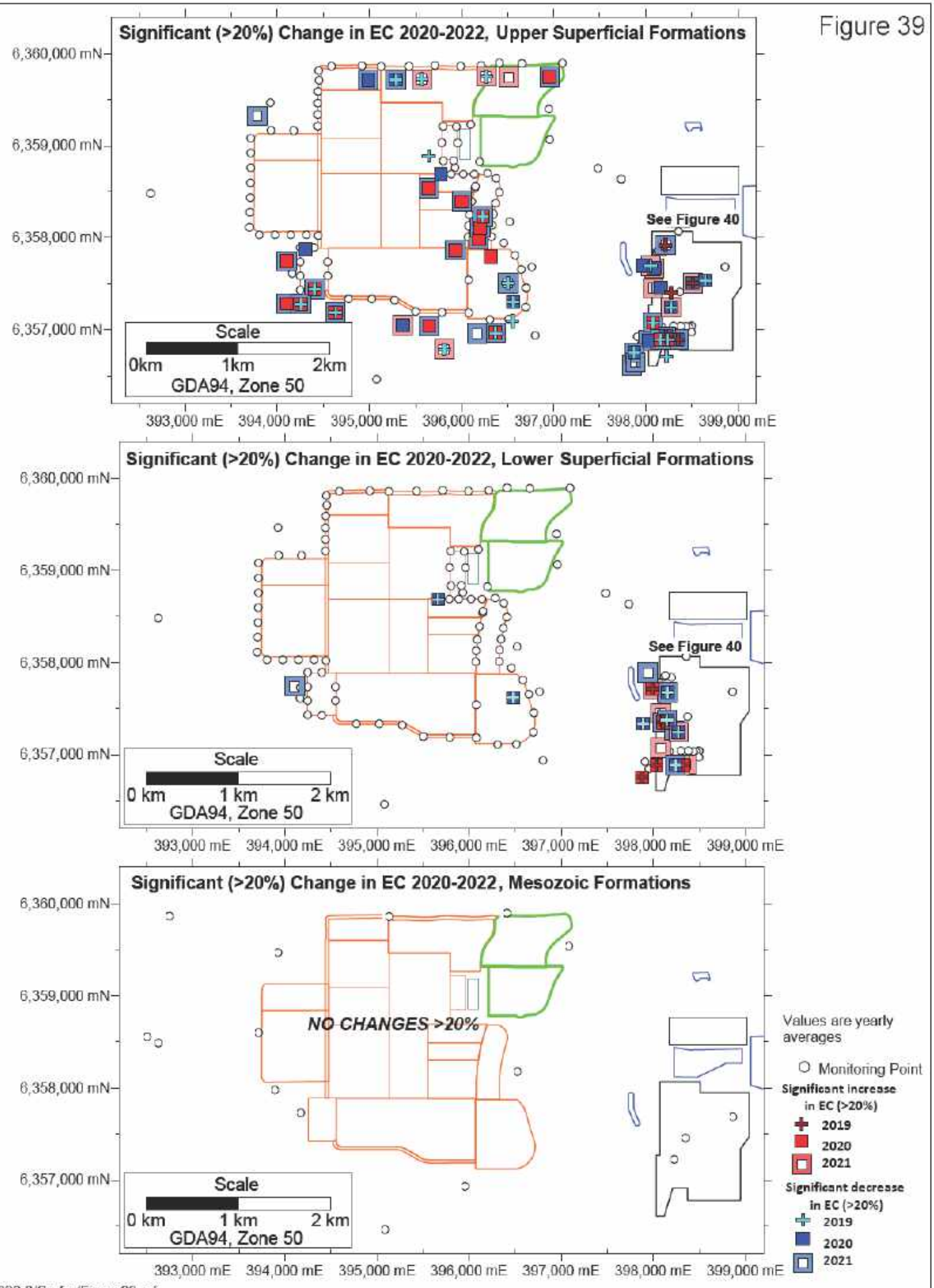
CLIENT:	Alcoa of Australia Limited
PROJECT:	Wagerup and Bunbury 2021-2022 water report
DATE:	March 2023
Dwg. No:	308-8/23/1-38

Refinery Area: 2022 groundwater EC & groundwater EC change, 2021-2022

Alcoa

Rockwater

Figure 39



308.8/Surfer/Figure39.srf

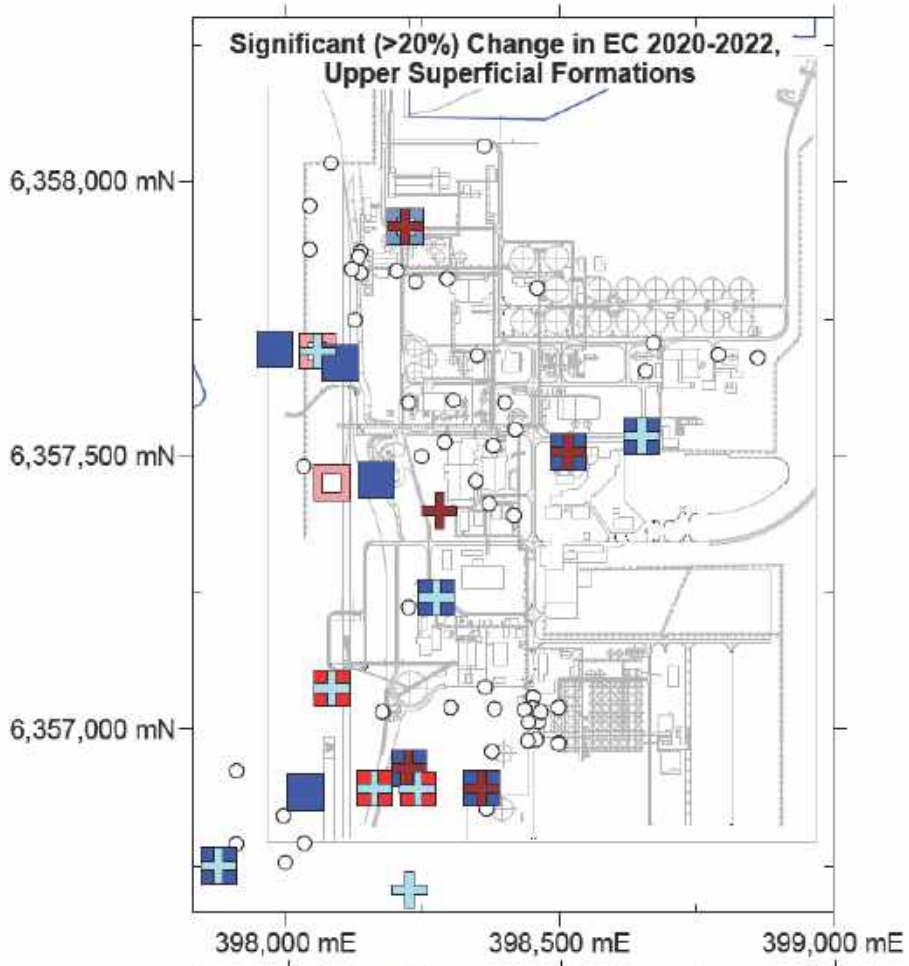
CLIENT:	Alcoa of Australia Limited
PROJECT:	Wagerup and Bunbury 2020-2022 water report
DATE:	March 2023
Dwg. No:	308-8/23/1-39

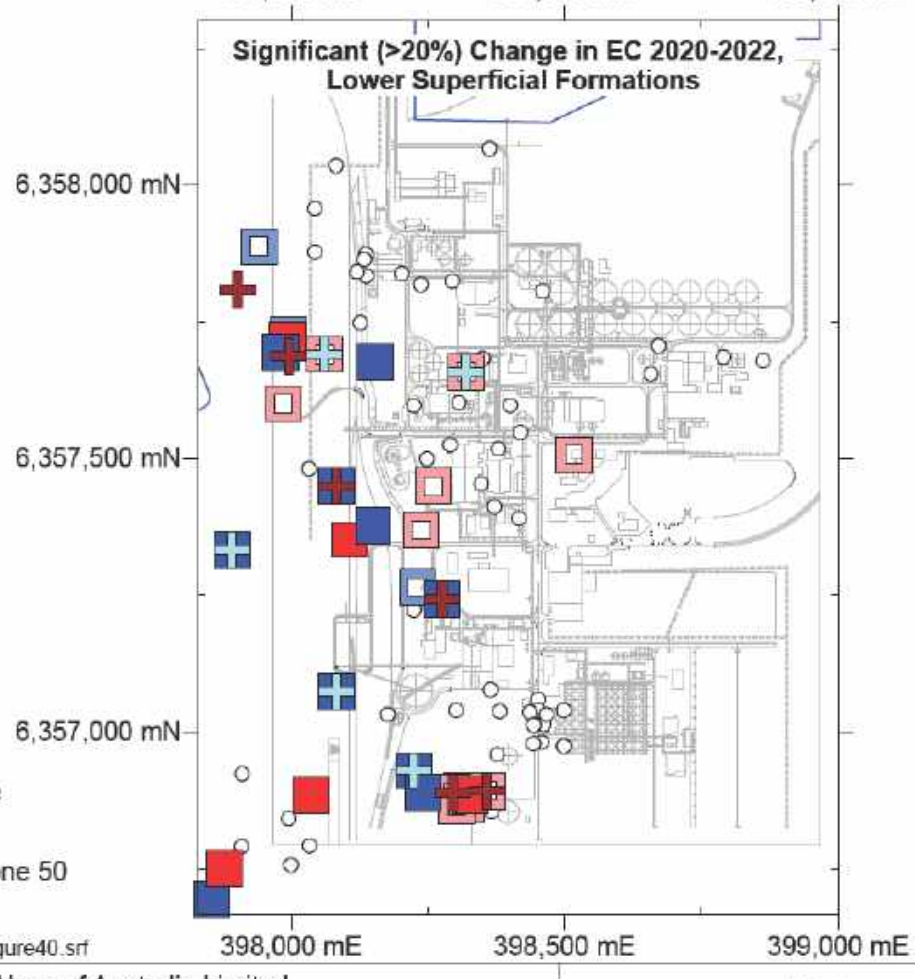
Alcoa

Wagerup Area
Sites with significant change in EC 2020–22

Rockwater

Figure 40





Values are yearly averages

Monitoring Point

Significant increase in EC (>20%)
- 2019
- 2020
- 2021

Significant decrease in EC (>20%)
- 2019
- 2020
- 2021

Scale

GDA94, Zone 50

308.8/Surfer/Figure40.srf

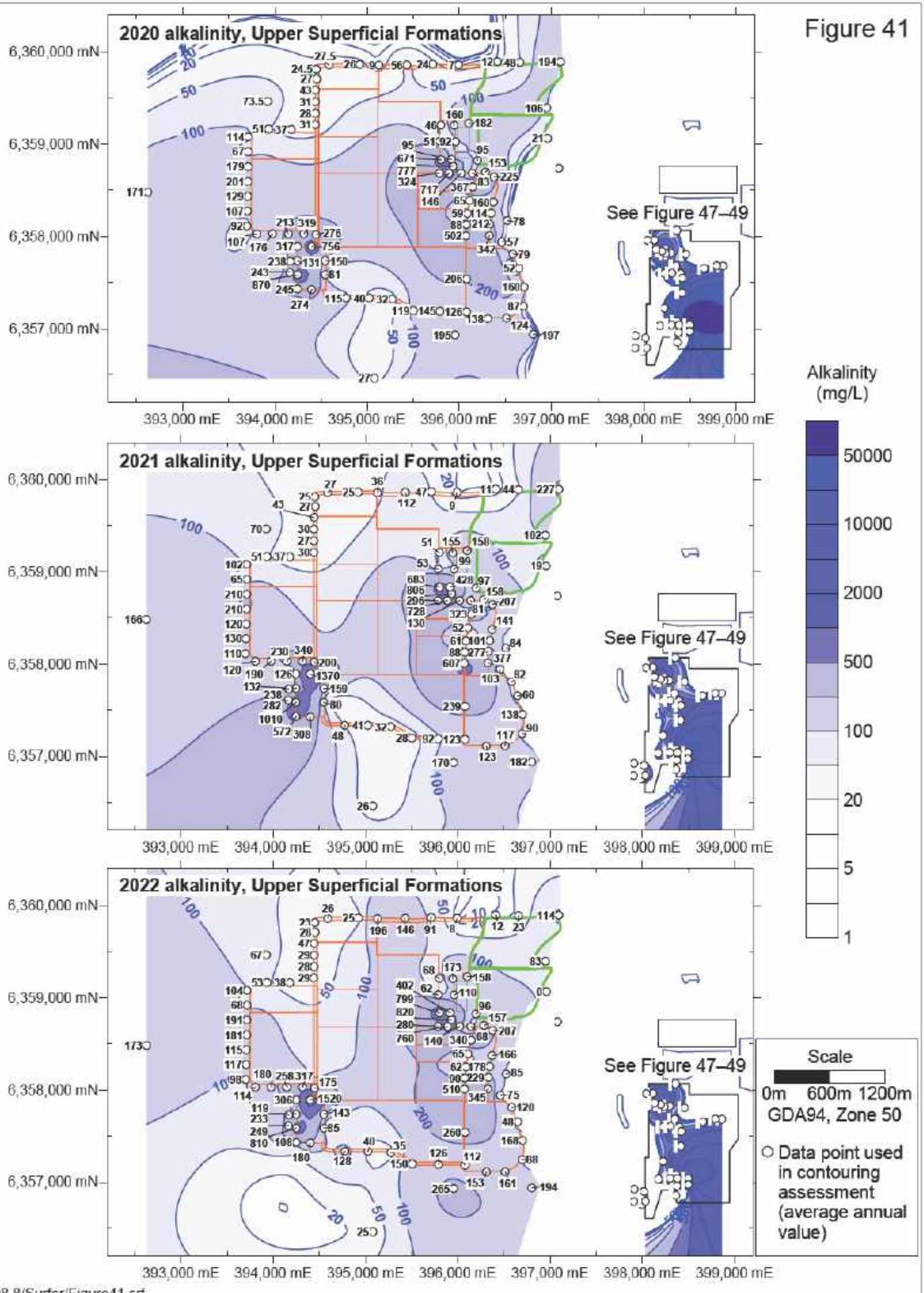
CLIENT:	Alcoa of Australia Limited
PROJECT:	Wagerup and Bunbury 2020-2022 water report
DATE:	March 2023
Dwg. No:	308-8/23/1-40

Alcoa

Refinery Area:
Sites with significant change in EC 2020–2022

Rockwater

Figure 41



308.8/Surfer/Figure41.srf

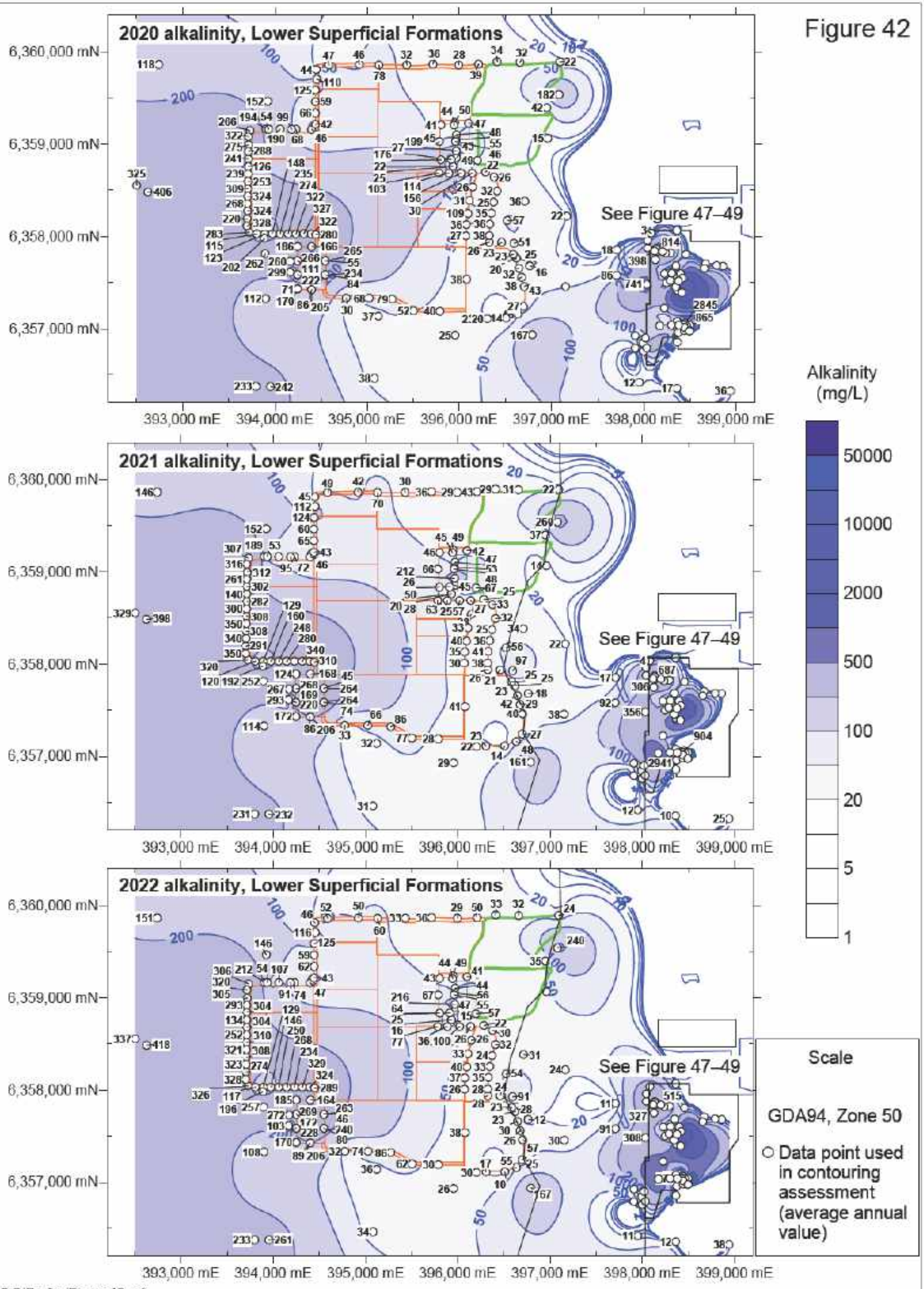
CLIENT:	Alcoa of Australia Limited
PROJECT:	Wagerup and Bunbury 2020-2022 water report
DATE:	March 2023
Dwg. No:	308-8/23/1-41

Wagerup Area, Groundwater alkalinity contours, Upper Superficial Formations 2020–22

Alcoa

Rockwater

Figure 42



308.8/Surfer/Figure42.srf

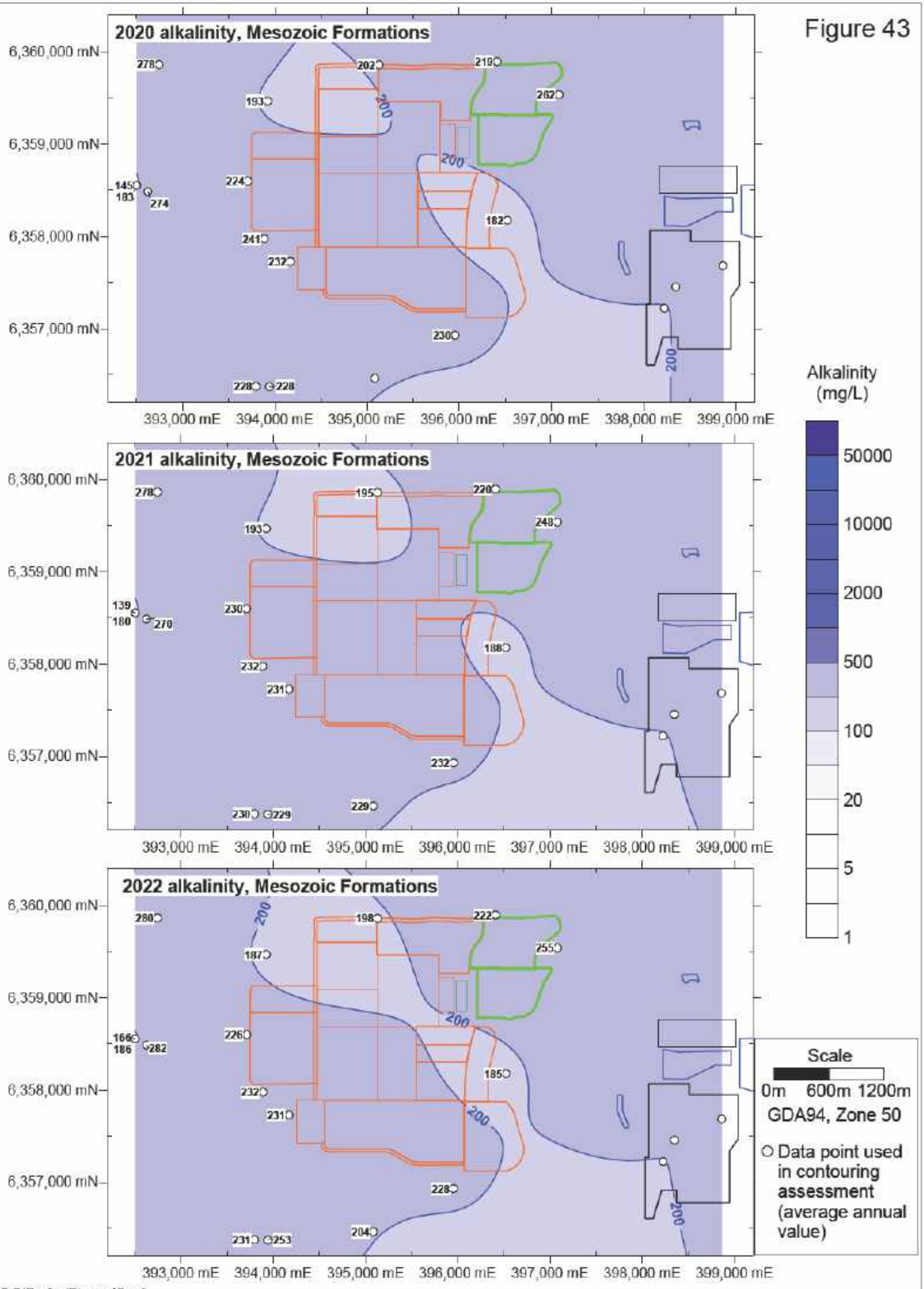
CLIENT:	Alcoa of Australia Limited
PROJECT:	Wagerup and Bunbury 2020-2022 water report
DATE:	March 2023
Dwg. No:	308-8/23/1-42

Wagerup Area, Groundwater alkalinity contours, Lower Superficial Formations 2020–22

Alcoa

Rockwater

Figure 43



308.8/Surfer/Figure43.srf

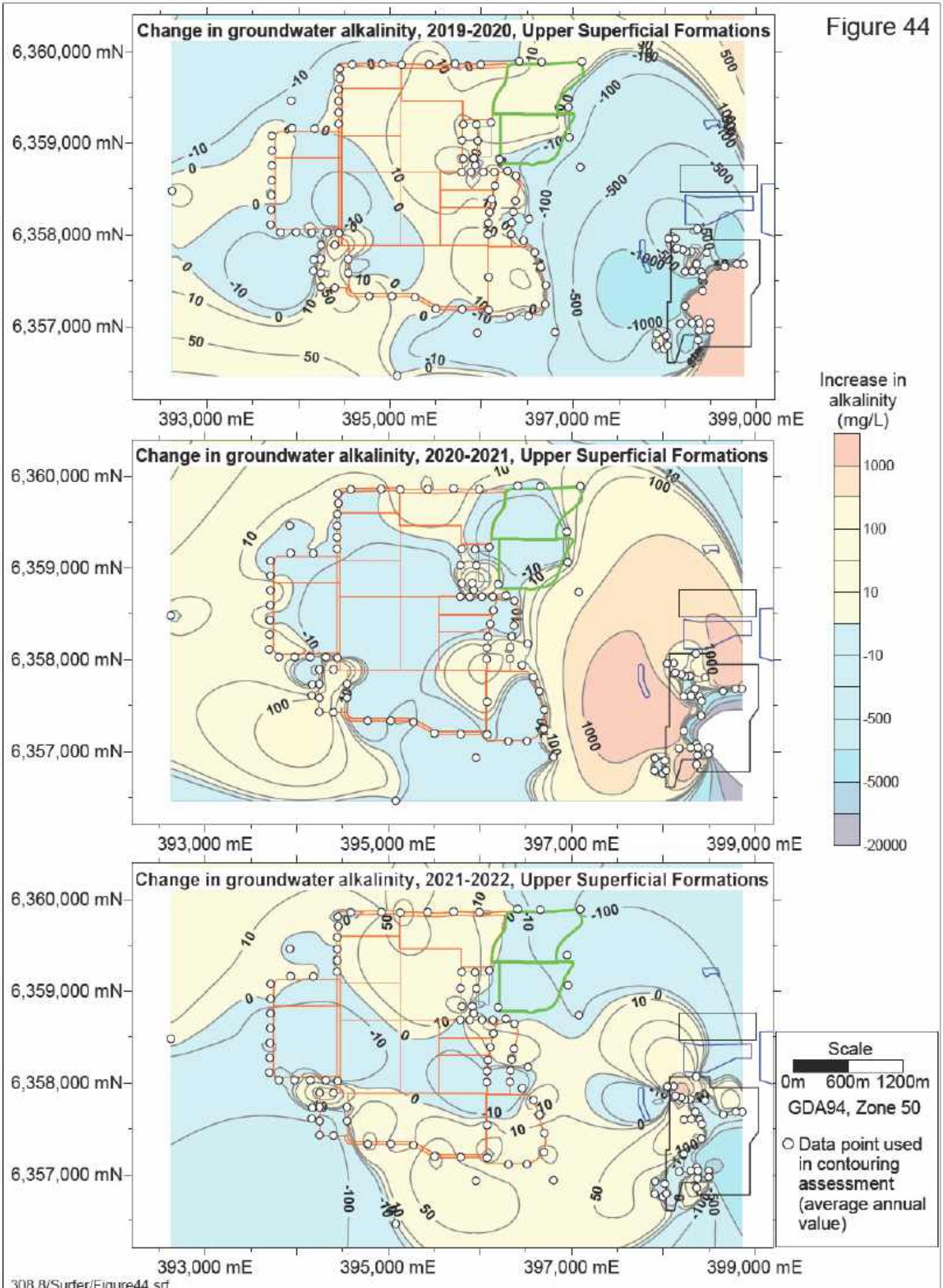
CLIENT:	Alcoa of Australia Limited
PROJECT:	Wagerup and Bunbury 2020-2022 water report
DATE:	March 2023
Dwg. No:	308-8/23/1-43

Wagerup Area
Groundwater alkalinity contours, Mesozoic Formations 2020–22

Alcoa

Rockwater

Figure 44



308.8/Surfer/Figure44.srf

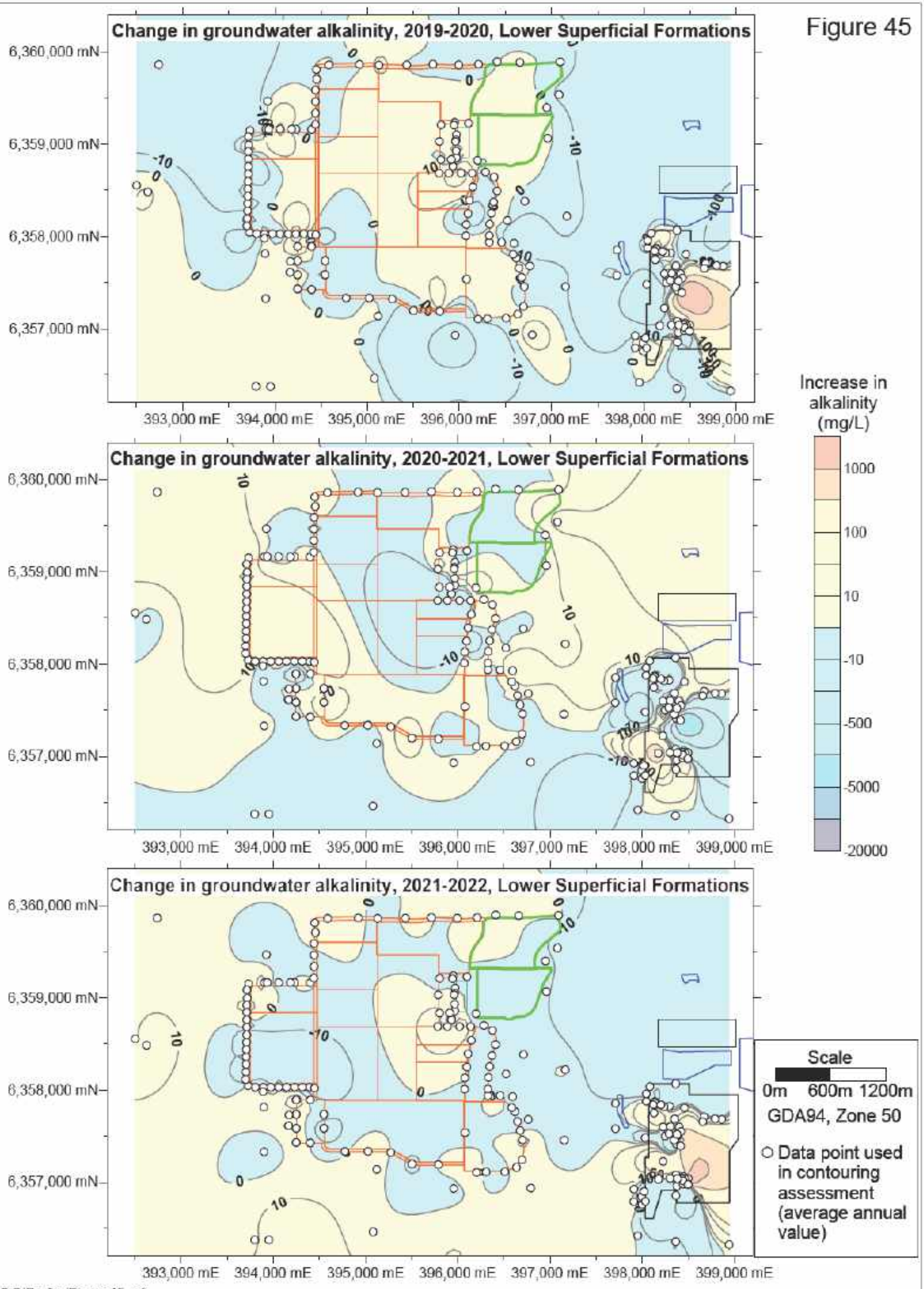
CLIENT:	Alcoa of Australia Limited
PROJECT:	Wagerup and Bunbury 2020-2022 water report
DATE:	March 2023
Dwg. No:	308-8/23/1-44

Wagerup Area, change in groundwater alkalinity contours, Upper Superficial Fmns 2019–2022

Alcoa

Rockwater

Figure 45



308.8/Surfer/Figure45.srf

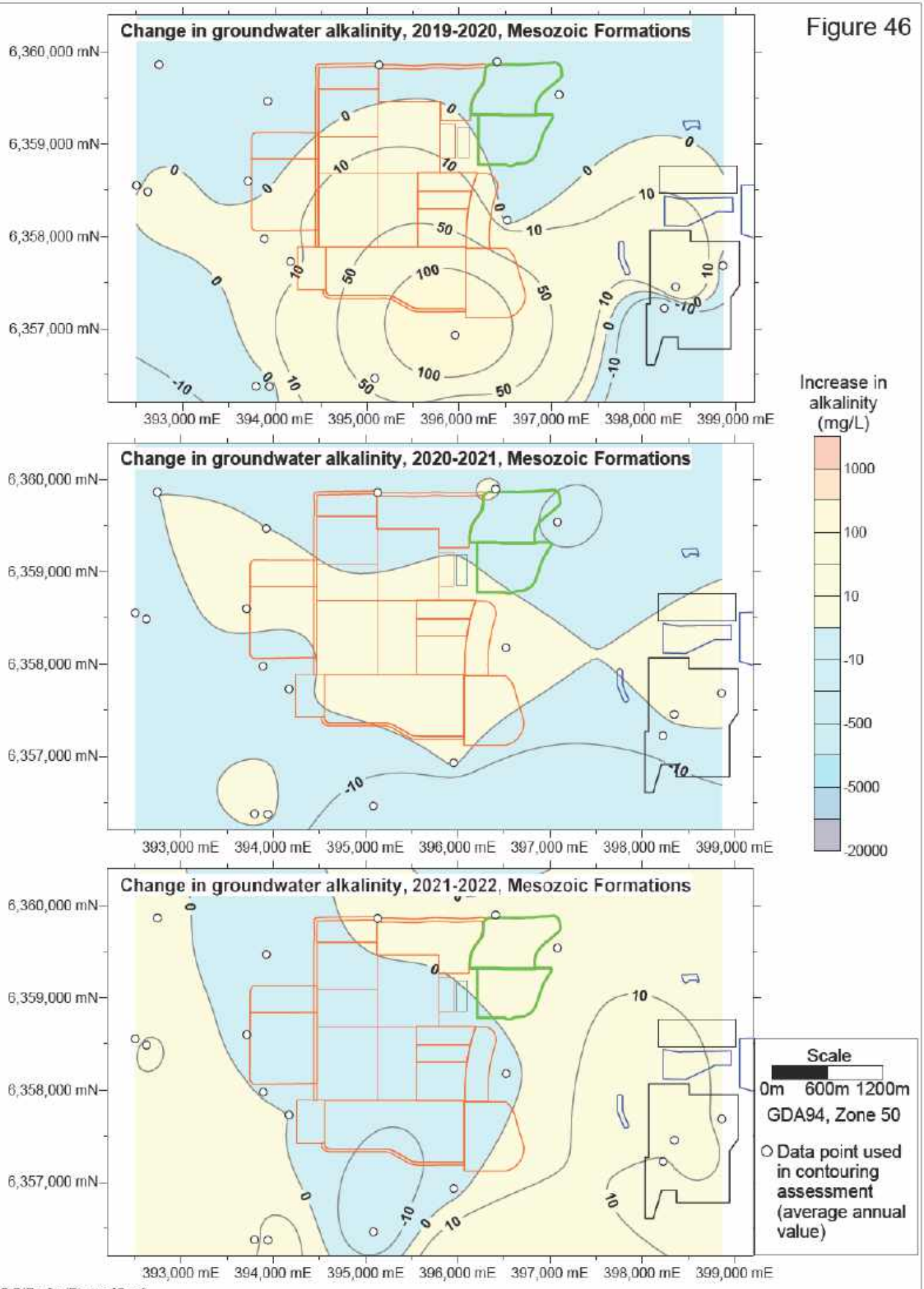
CLIENT:	Alcoa of Australia Limited
PROJECT:	Wagerup and Bunbury 2020-2022 water report
DATE:	March 2023
Dwg. No:	308-8/23/1-45

Wagerup Area, change in groundwater alkalinity contours, Lower Superficial Fmns 2019–2022

Alcoa

Rockwater

Figure 46



308.8/Surfer/Figure46.srf

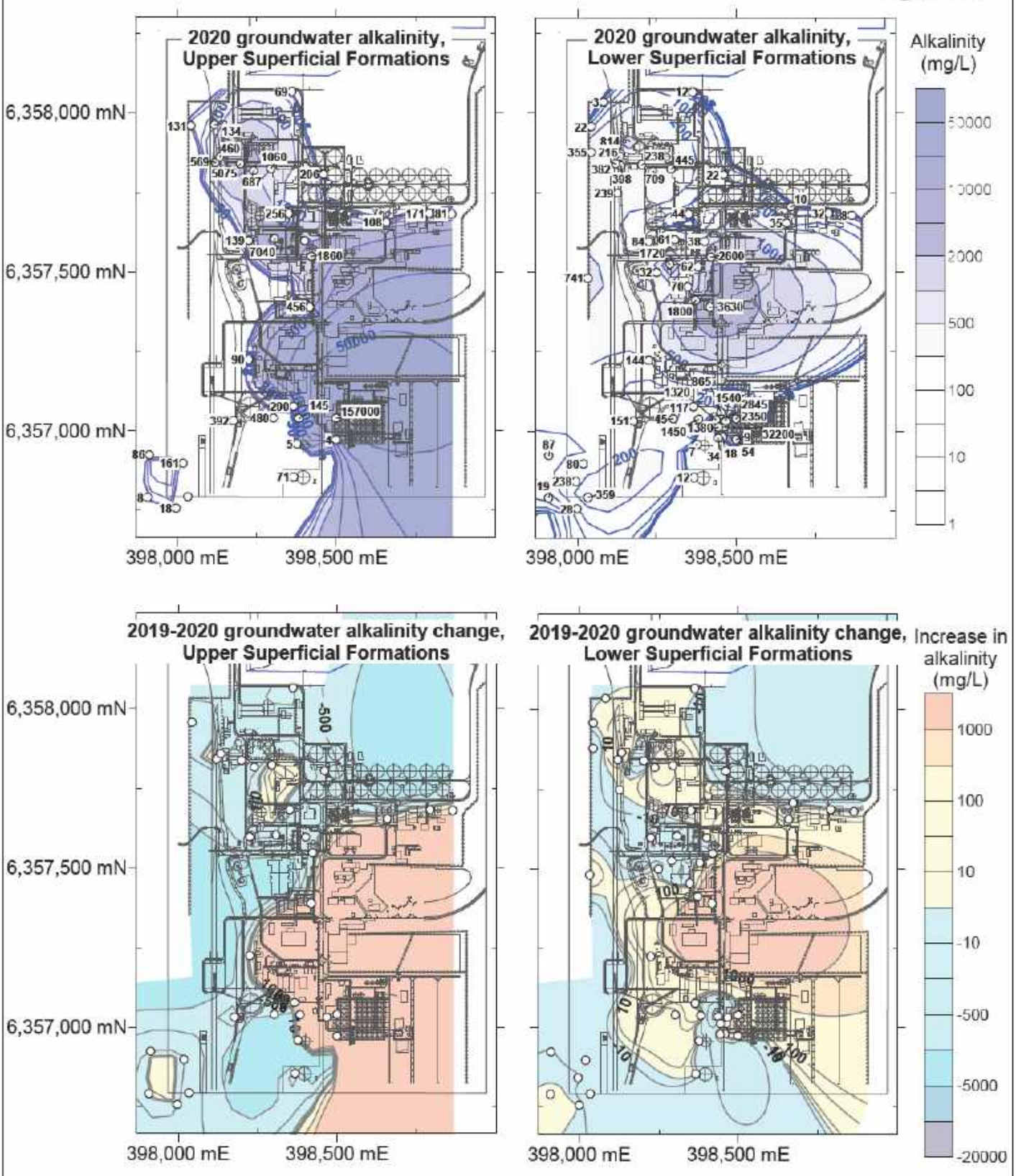
CLIENT:	Alcoa of Australia Limited
PROJECT:	Wagerup and Bunbury 2020-2022 water report
DATE:	March 2023
Dwg. No:	308-8/23/1-46

Wagerup Area, change in groundwater alkalinity contours, Mesozoic Fmns 2019–2022

Alcoa

Rockwater

Figure 47



308.8/Surfer/Figure47.srf

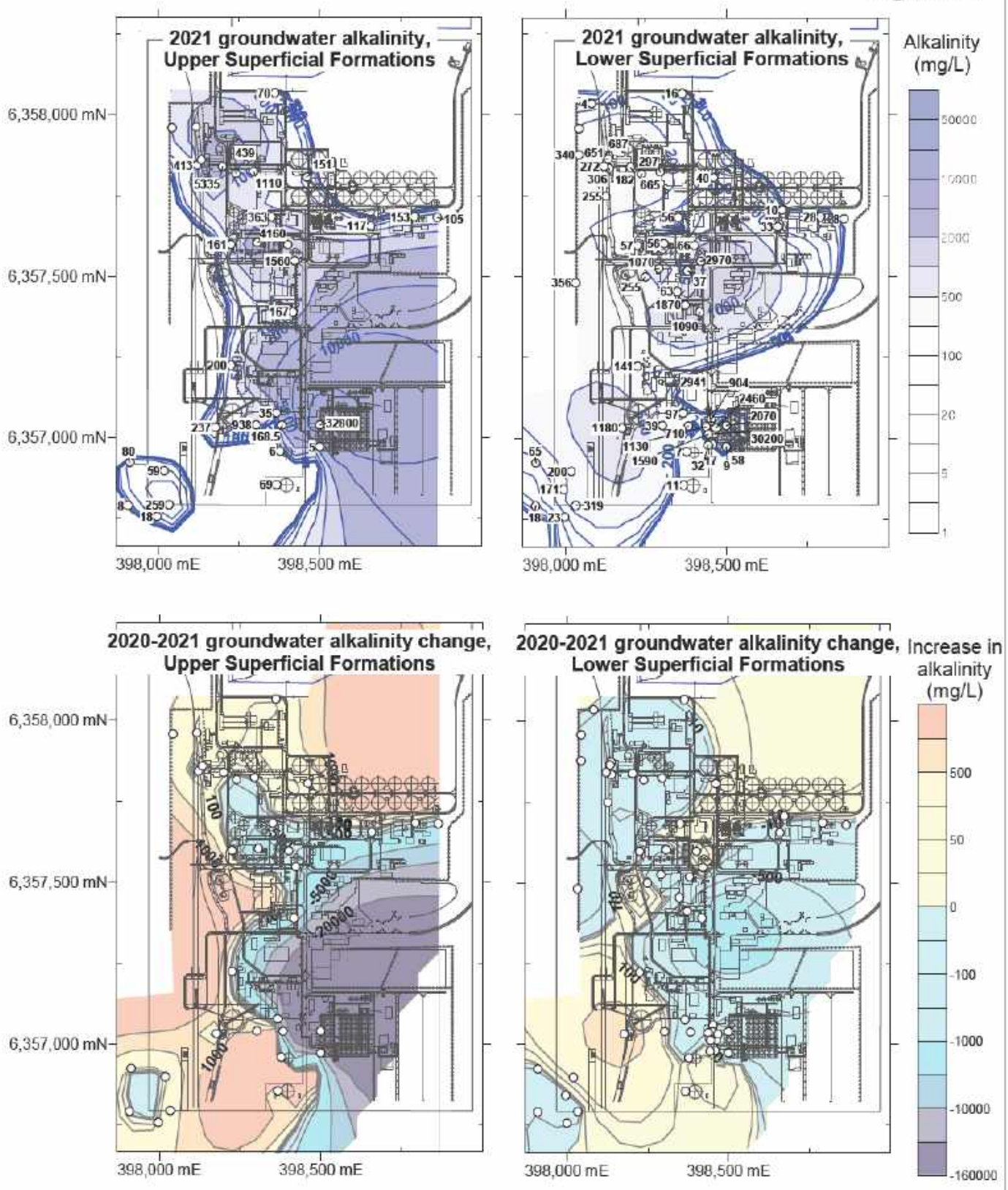
CLIENT:	Alcoa of Australia Limited
PROJECT:	Wagerup and Bunbury 2020-2022 water report
DATE:	March 2023
Dwg. No:	308-8/23/1-47

Refinery Area: 2020 groundwater alkalinity & groundwater alkalinity change, 2019-2020

Alcoa

Rockwater

Figure 48



Scale

0 m 200 m 400 m

GDA94, Zone 50

Values are annual averages during 2020 & 2021

○ Data point used in contouring assessment

308.8/Surfer/Figure48.srf

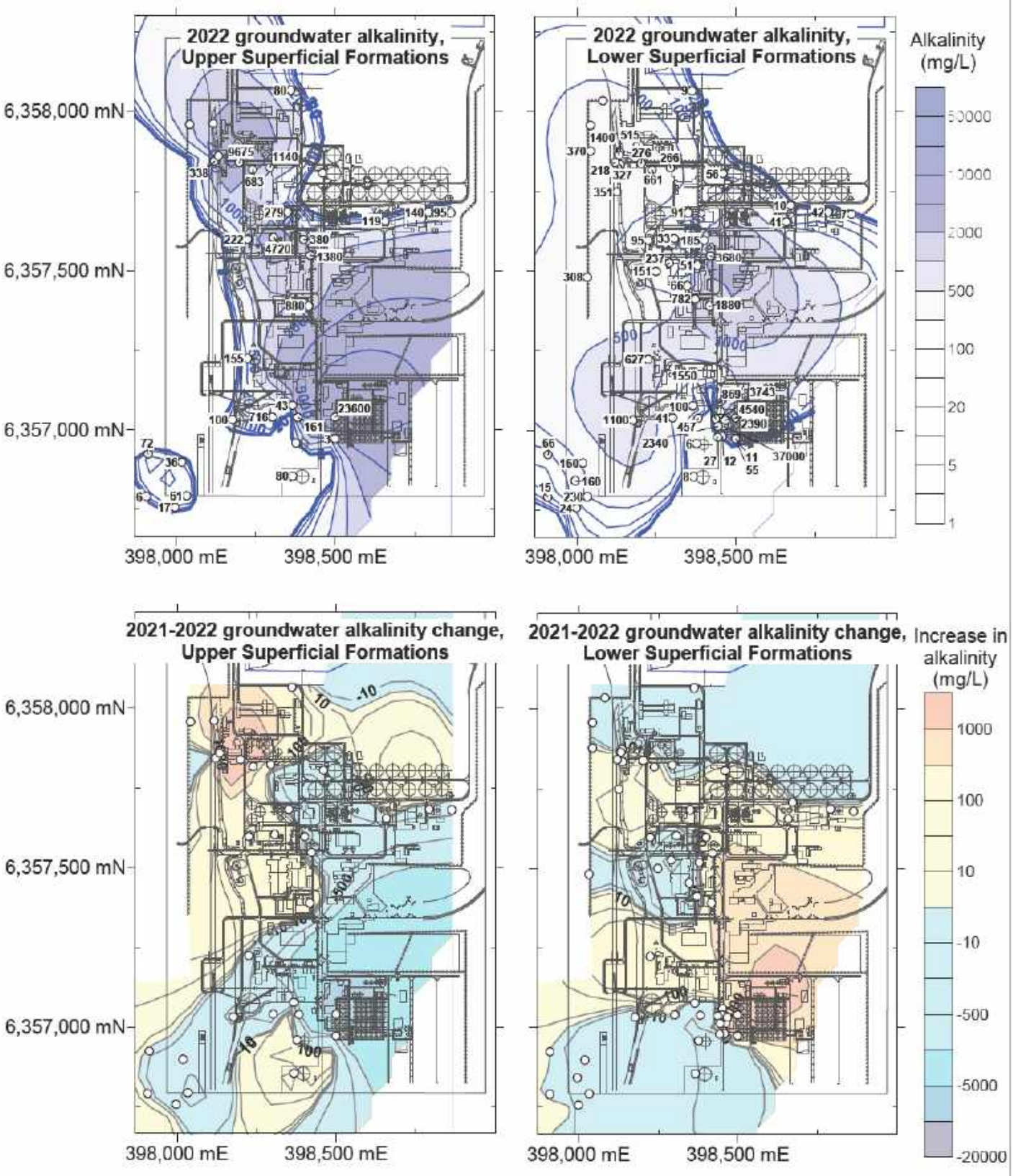
CLIENT:	Alcoa of Australia Limited
PROJECT:	Wagerup and Bunbury 2020-2022 water report
DATE:	March 2023
Dwg. No:	308-8/23/1-48

Refinery Area: 2021 groundwater alkalinity & groundwater alkalinity change, 2020-2021

Alcoa

Rockwater

Figure 49



Scale

0 m 200 m 400 m

GDA94, Zone 50

Values are annual averages during 20218 & 2022

○ Data point used in contouring assessment

308.8/Surfer/Figure49.srf

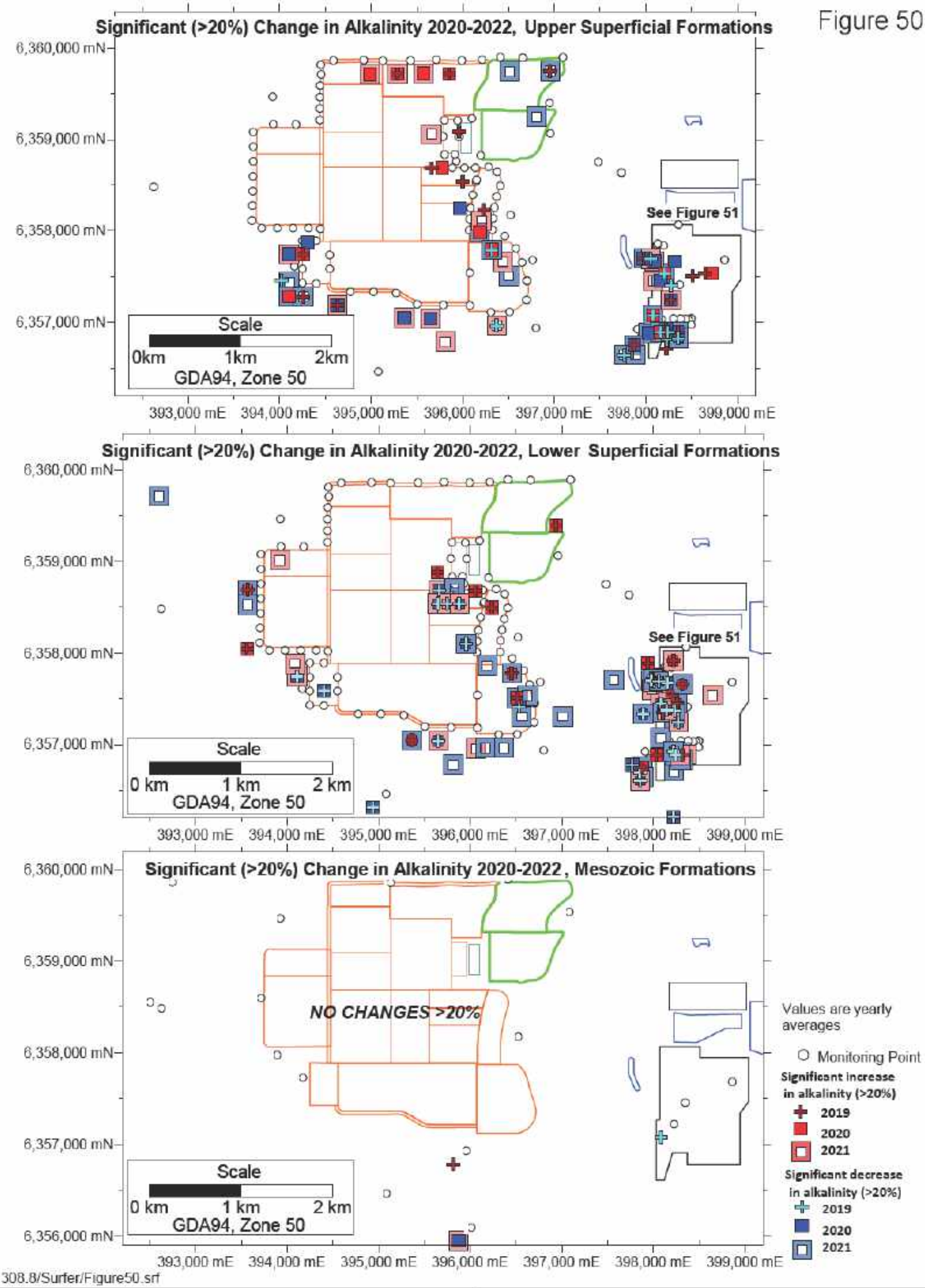
CLIENT:	Alcoa of Australia Limited
PROJECT:	Wagerup and Bunbury 2020-2022 water report
DATE:	March 2023
Dwg. No:	308-8/23/1-49

Refinery Area: 2022 groundwater alkalinity & groundwater alkalinity change, 2021-2022

Alcoa

Rockwater

Figure 50



308.8/Surfer/Figure50.srf

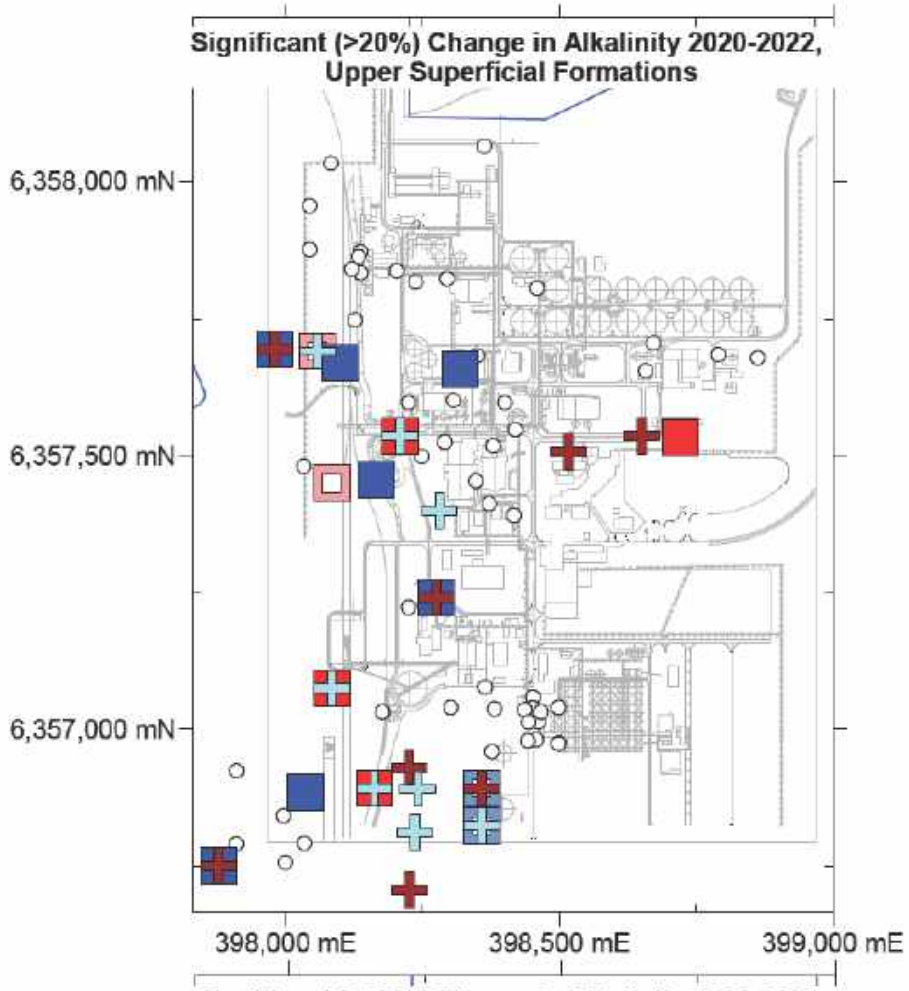
CLIENT:	Alcoa of Australia Limited
PROJECT:	Wagerup and Bunbury 2020-2022 water report
DATE:	March 2023
Dwg. No:	308-8/23/1-50

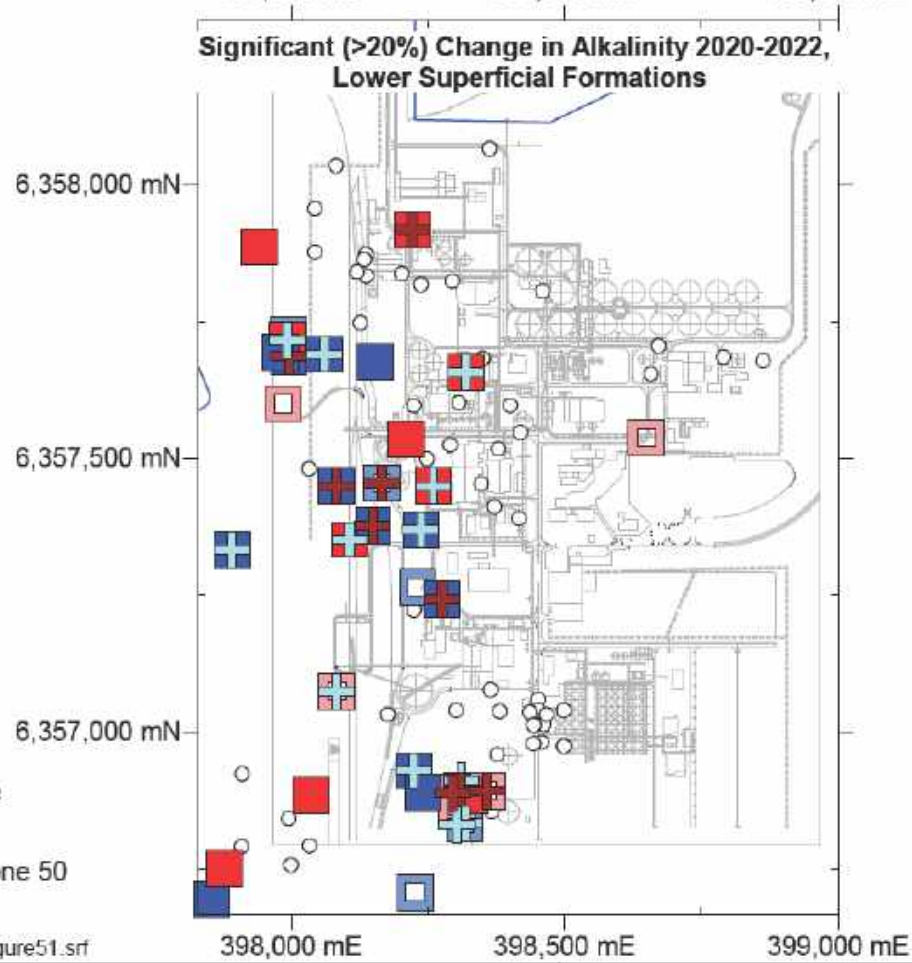
Alcoa

Wagerup Area
Sites with significant change in alkalinity 2020–22

Rockwater

Figure 51





Values are yearly averages

Monitoring Point

Significant increase in alkalinity (>20%)
- 2019
- 2020
- 2021

Significant decrease in alkalinity (>20%)
- 2019
- 2020
- 2021

Scale

GDA94, Zone 50

308.8/Surfer/Figure51.srf

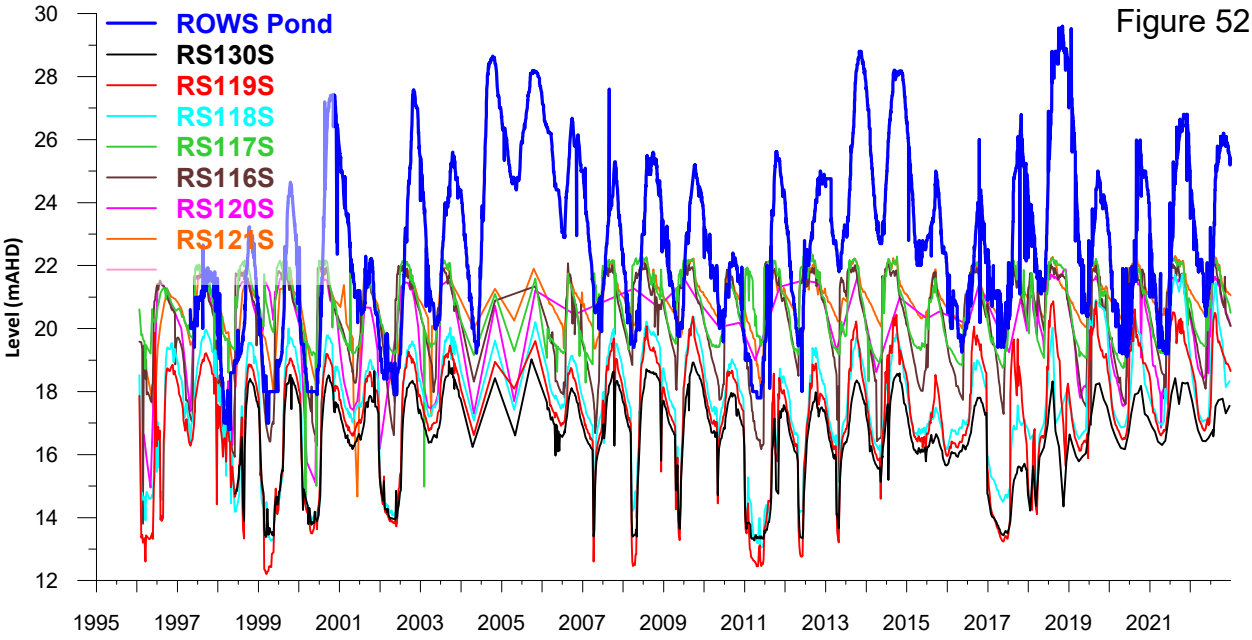
CLIENT:	Alcoa of Australia Limited
PROJECT:	Wagerup and Bunbury 2020-2022 water report
DATE:	March 2023
Dwg. No:	308-8/23/1-51

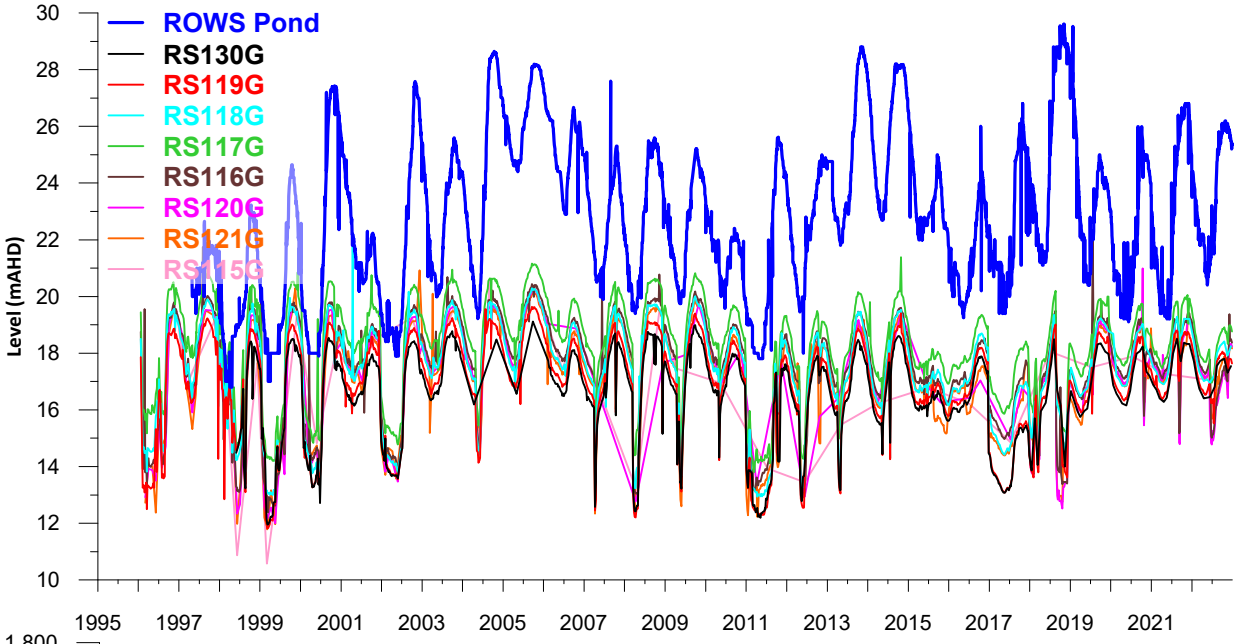
Alcoa

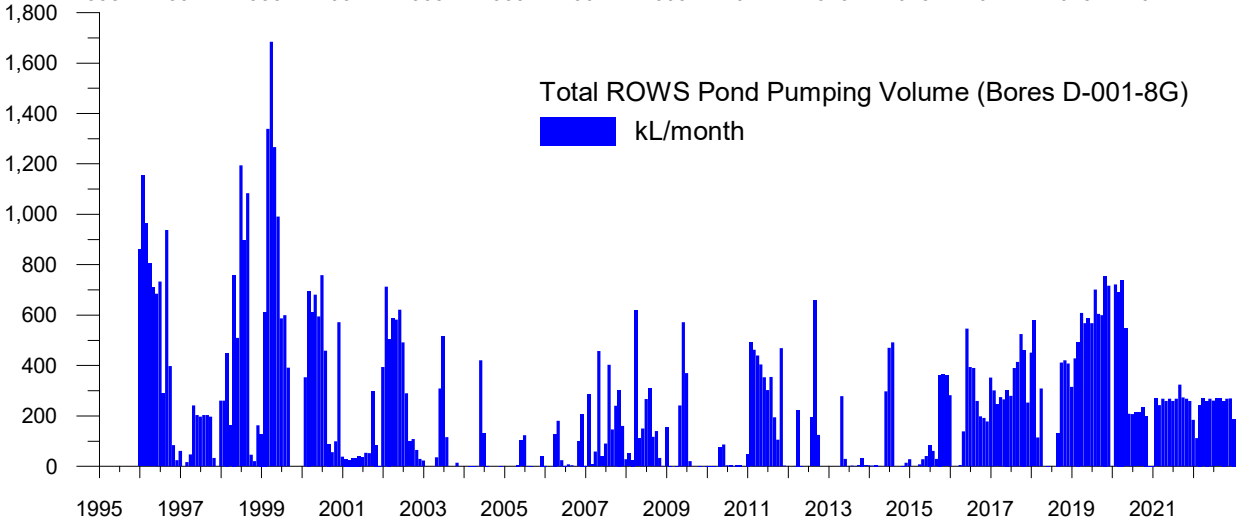
Refinery Area:
Sites with significant change in alkalinity 2020–2022

Rockwater

Figure 52



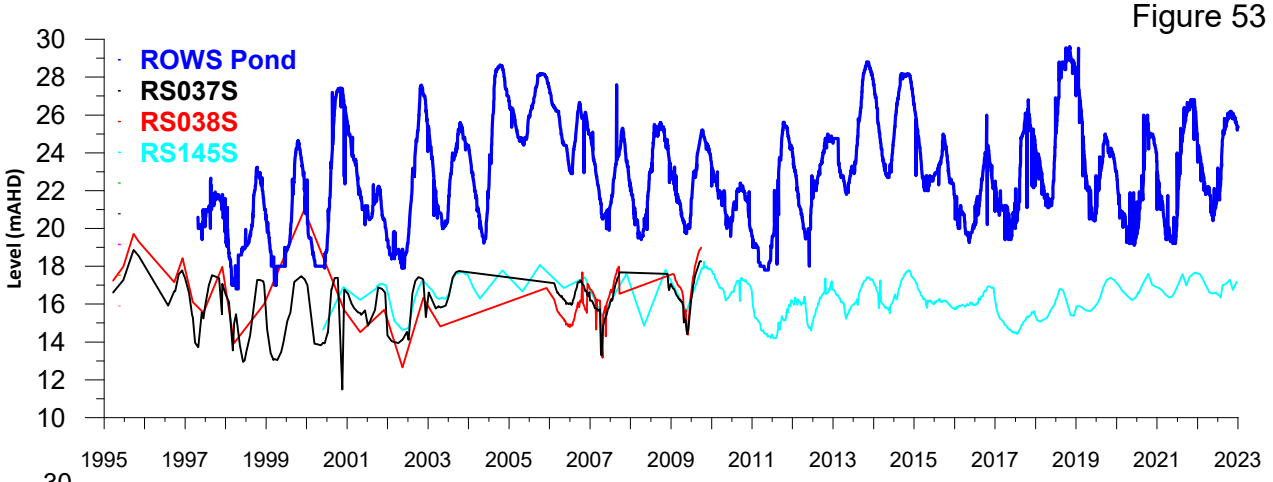


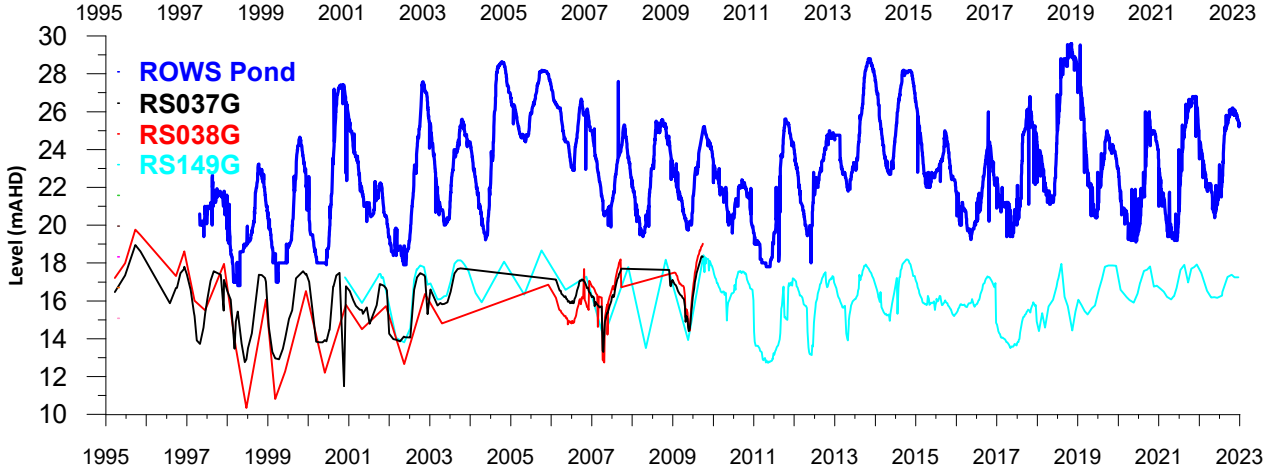


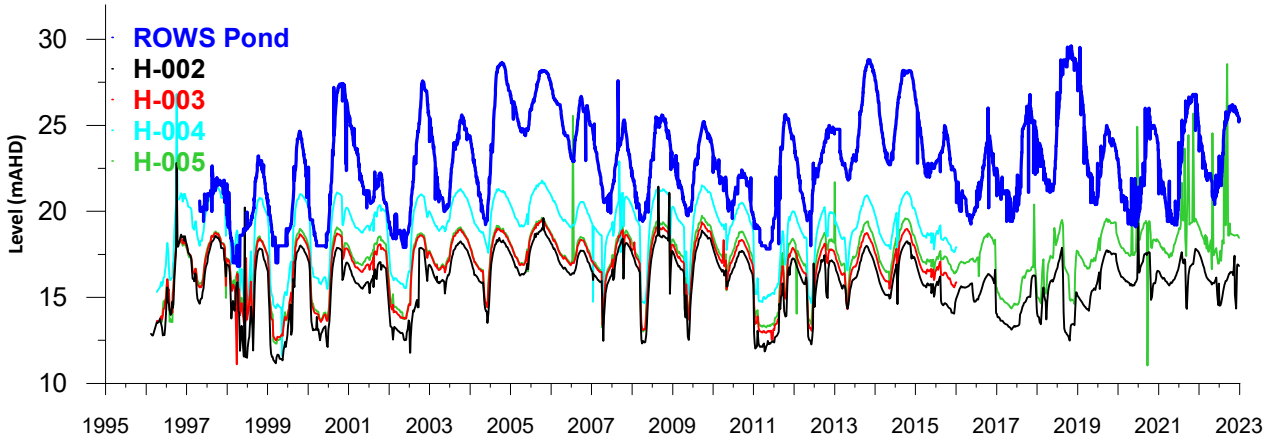
308-8/Grapher/Figure52.grf

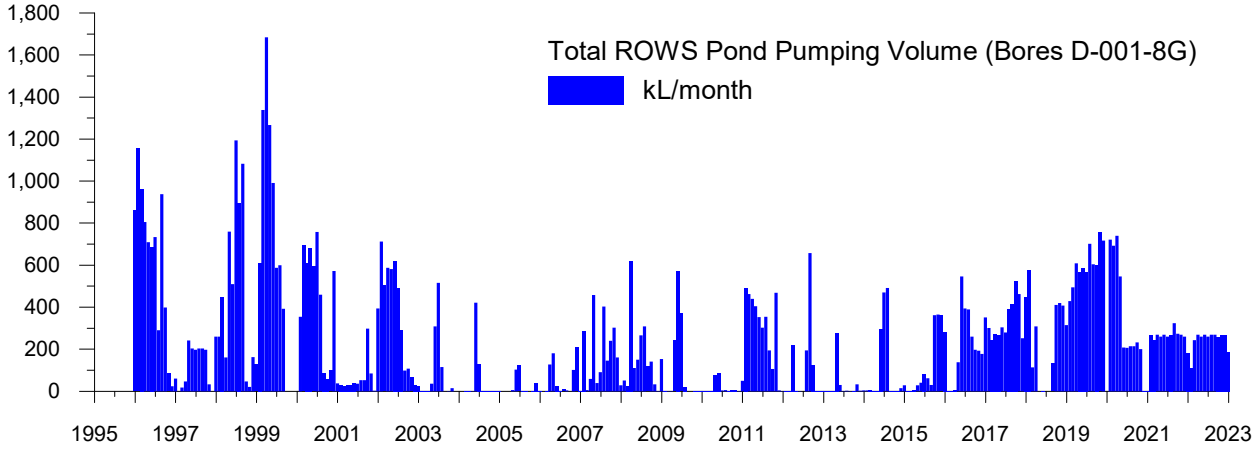
CLIENT: Alcoa of Australia Limited PROJECT: Wagerup and Bunbury 2020-2022 water report DATE: March 2023 Dwg. No: 308-8/23/1-52	ROWS Pond monitoring data 1 (monitoring bore & VWP water levels; depressurising bore pumping rates)

Figure 53





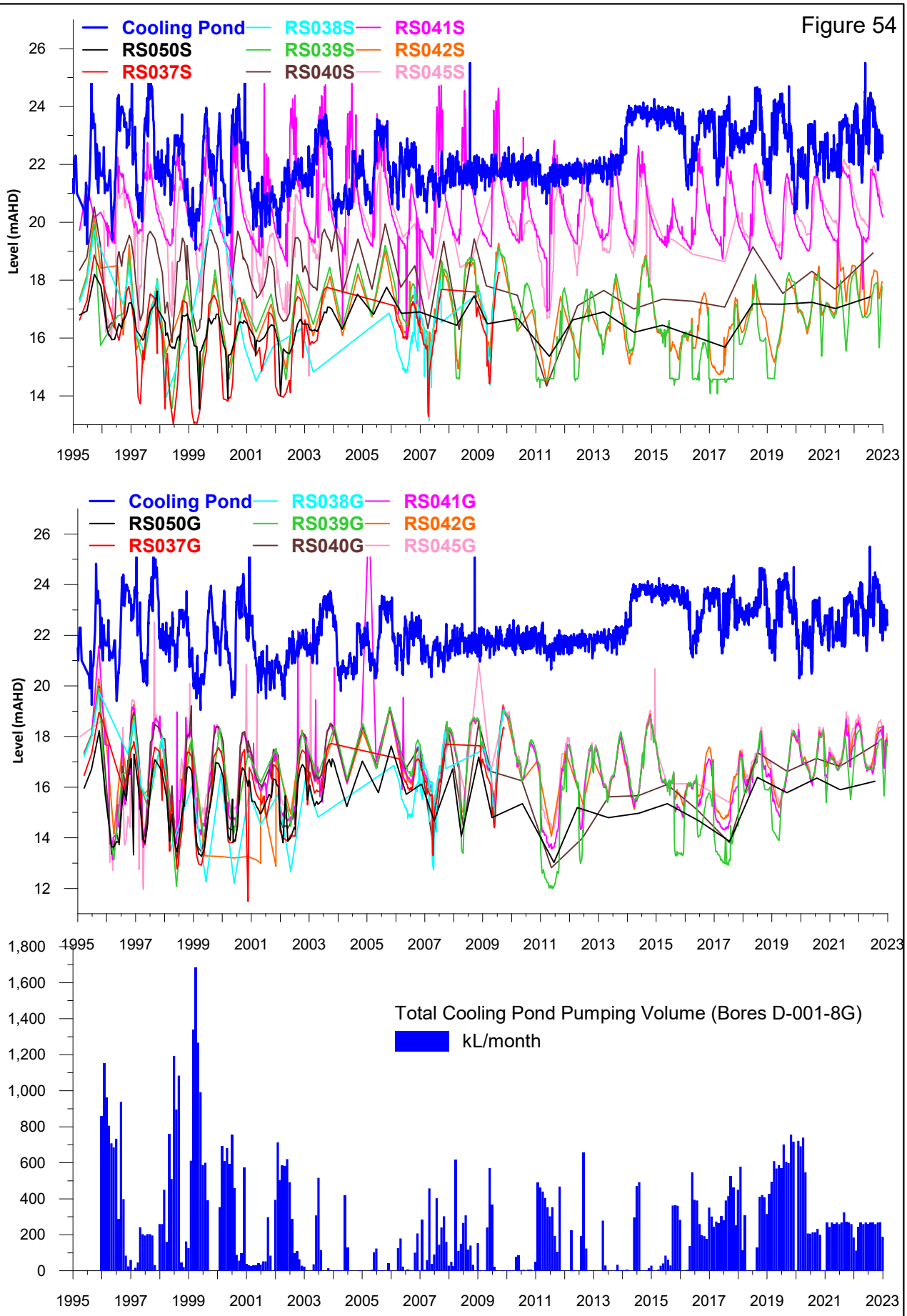




308-8/Grapher/Figure53.grf

CLIENT: Alcoa of Australia Limited PROJECT: Wagerup and Bunbury 2020-2022 water report DATE: March 2023 Dwg. No: 308-8/23/1-53	ROWS Pond monitoring data 2 (monitoring bore & VWP water levels; depressurising bore pumping rates)

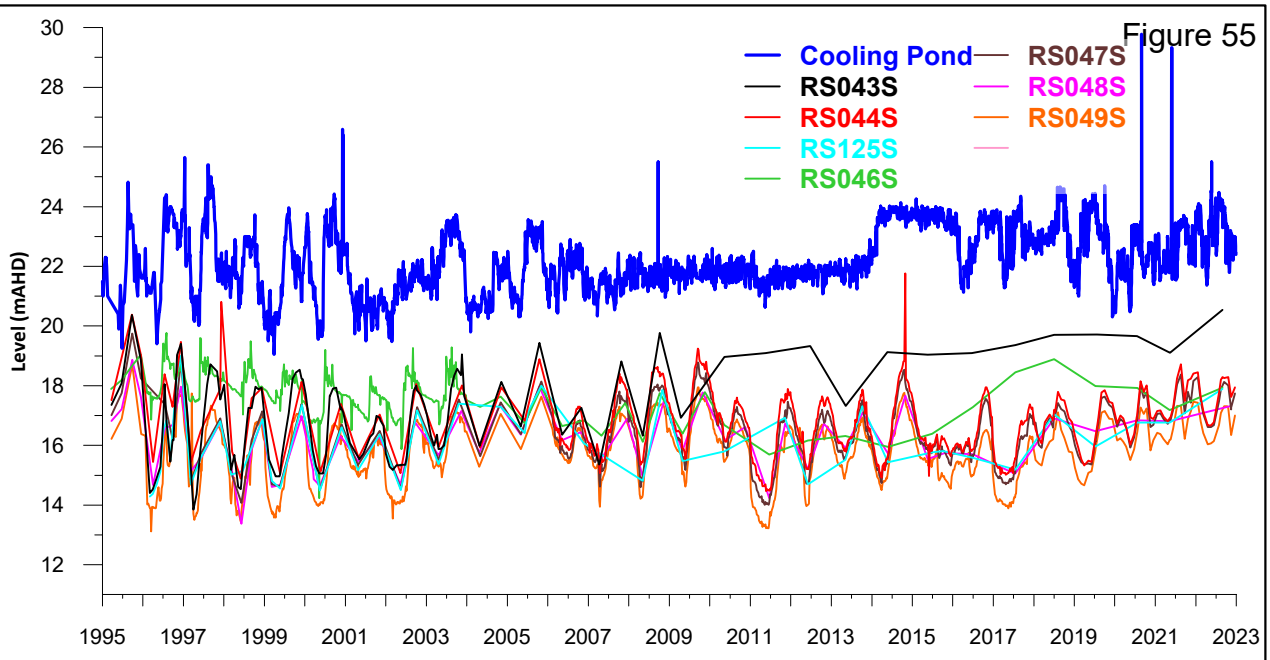
Figure 54

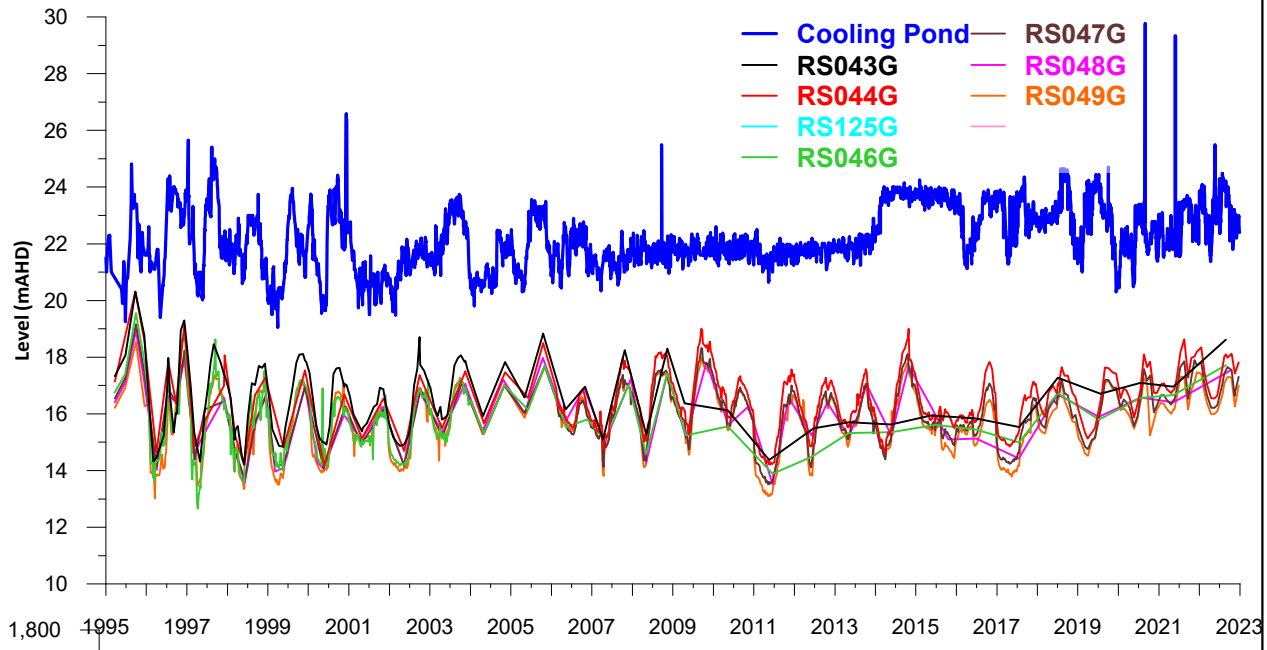


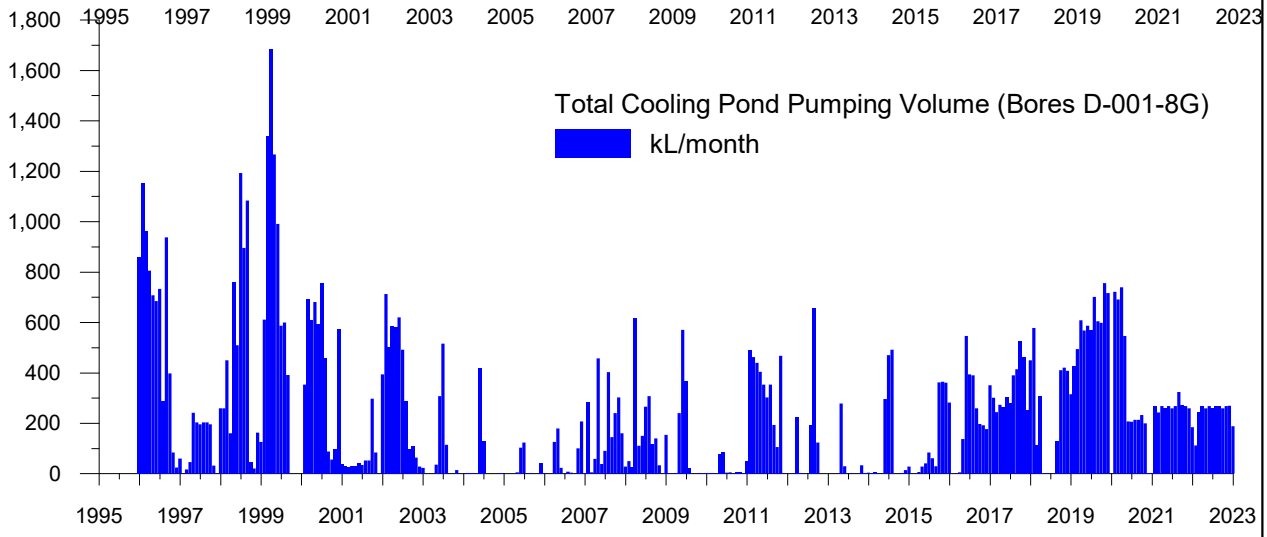
308-8/Grapher/Figure54.grf

CLIENT: Alcoa of Australia Limited PROJECT: Wagerup and Bunbury 2020-2022 water report DATE: March 2023 Dwg. No: 308-8/23/1-54	Cooling Pond monitoring data 1 (monitoring bore & VWP water levels; depressurising bore pumping rates)

Figure 55



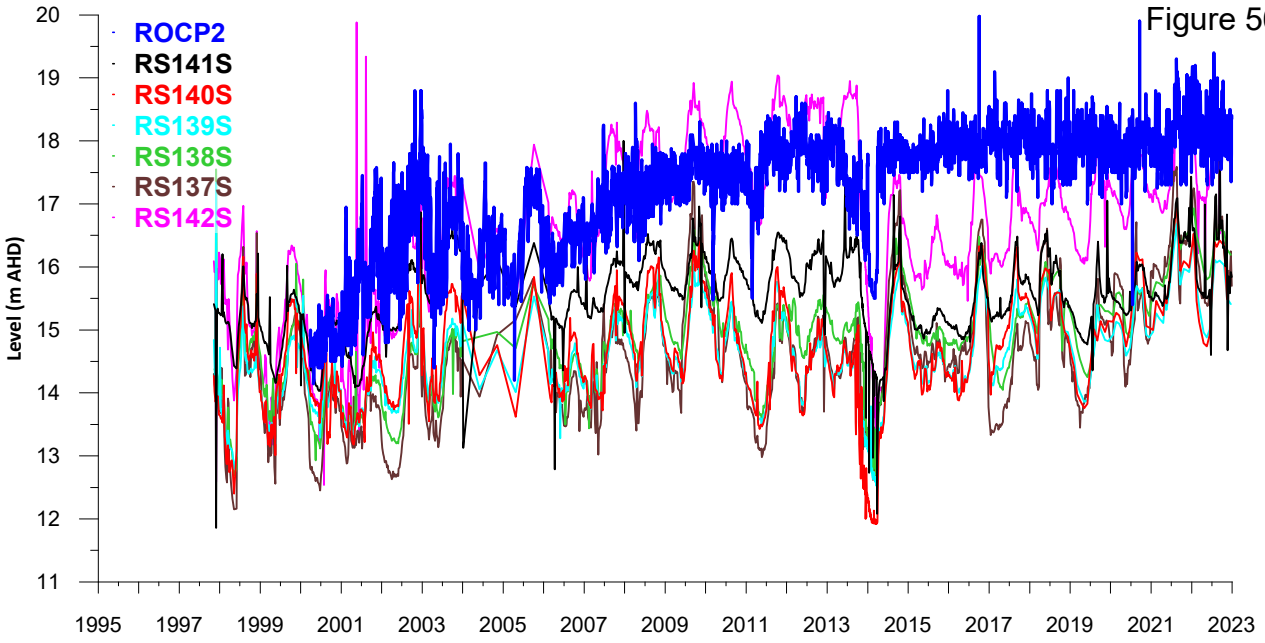


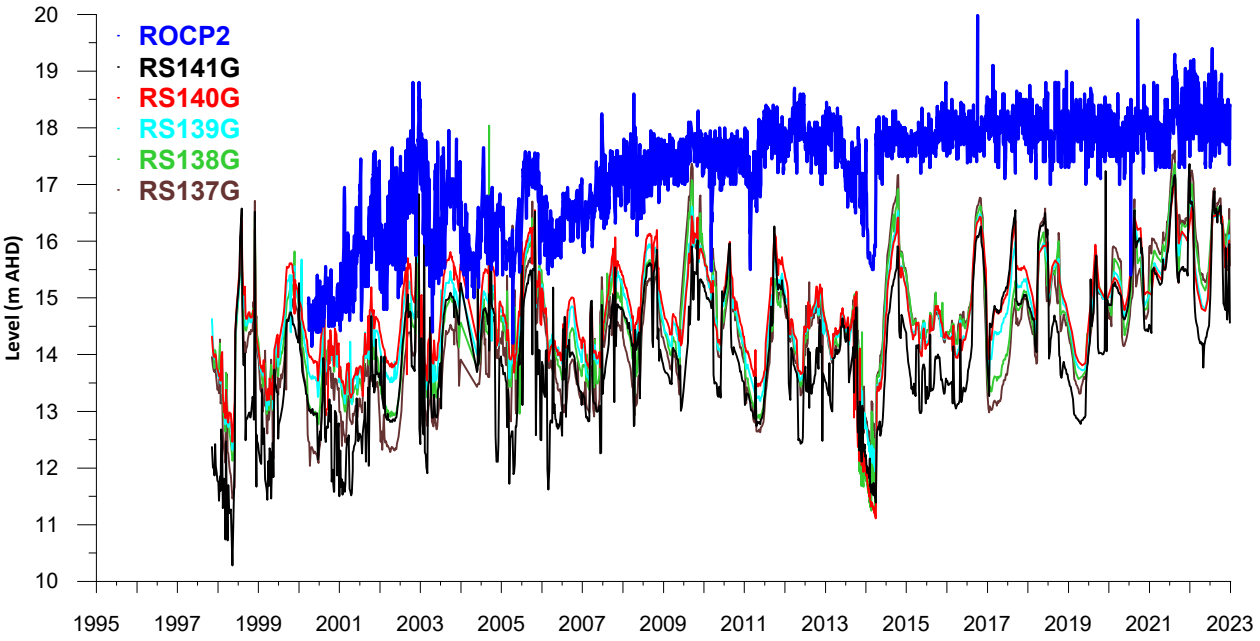


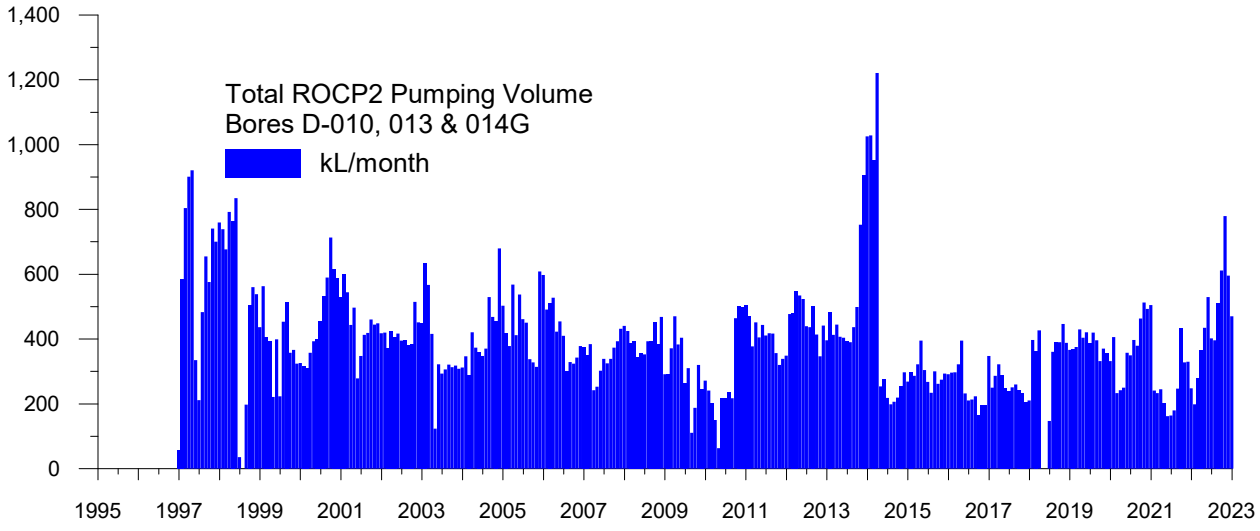
308-8/Grapher/Figure55.grf

CLIENT: Alcoa of Australia Limited PROJECT: Wagerup and Bunbury 2020-2022 water report DATE: March 2023 Dwg. No: 308-8/23/1-55	Cooling Pond monitoring data 2 (monitoring bore & VWP water levels; depressurising bore pumping rates)

Figure 56



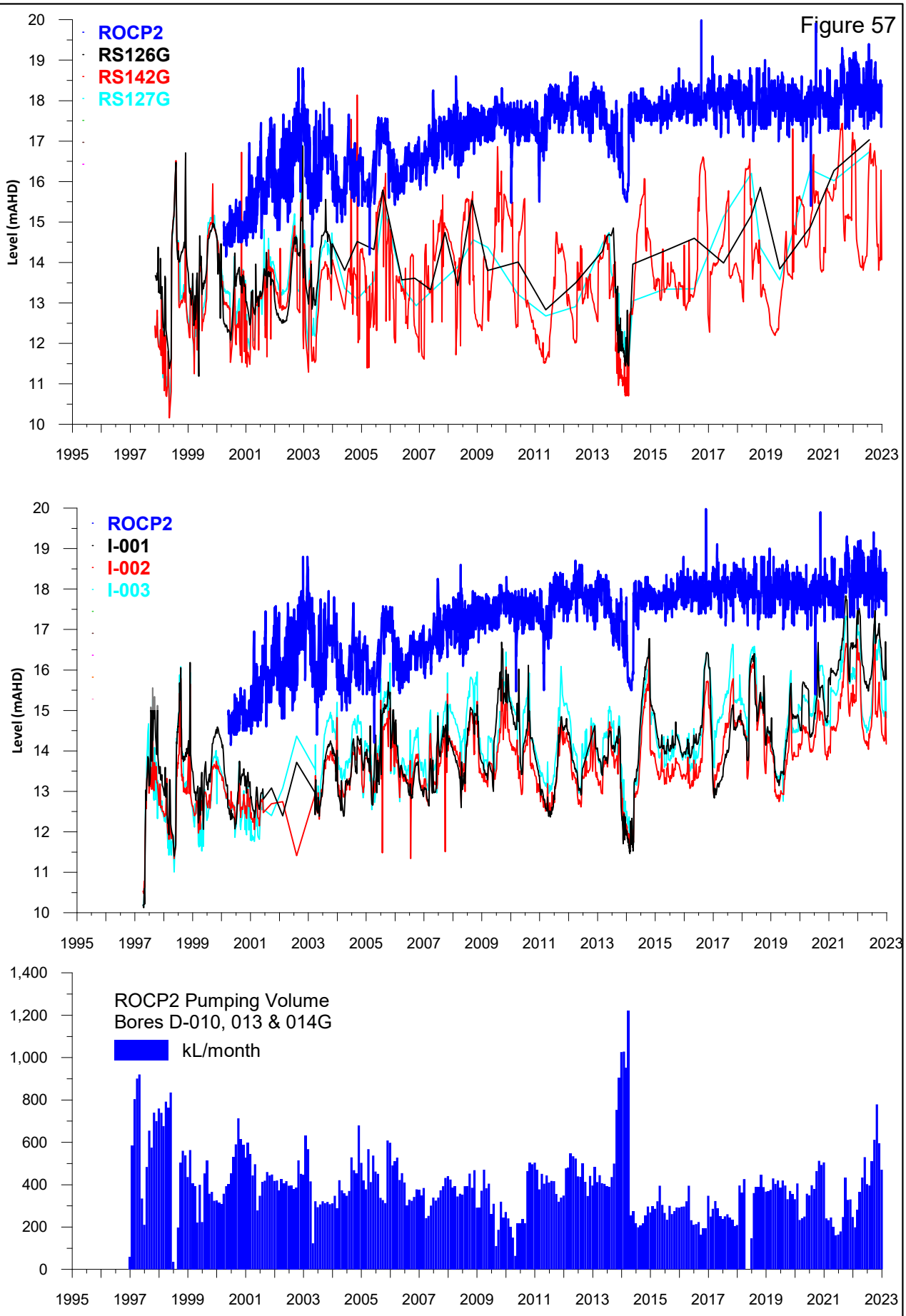




308-8/Grapher/Figure56.grf

CLIENT: Alcoa of Australia Limited	ROCP2 monitoring data 1 (monitoring bore & VWP water levels; depressurising bore pumping rates)
PROJECT: Wagerup and Bunbury 2020-2022 water report	
DATE: March 2023	
Dwg. No: 308-8/23/1-56	

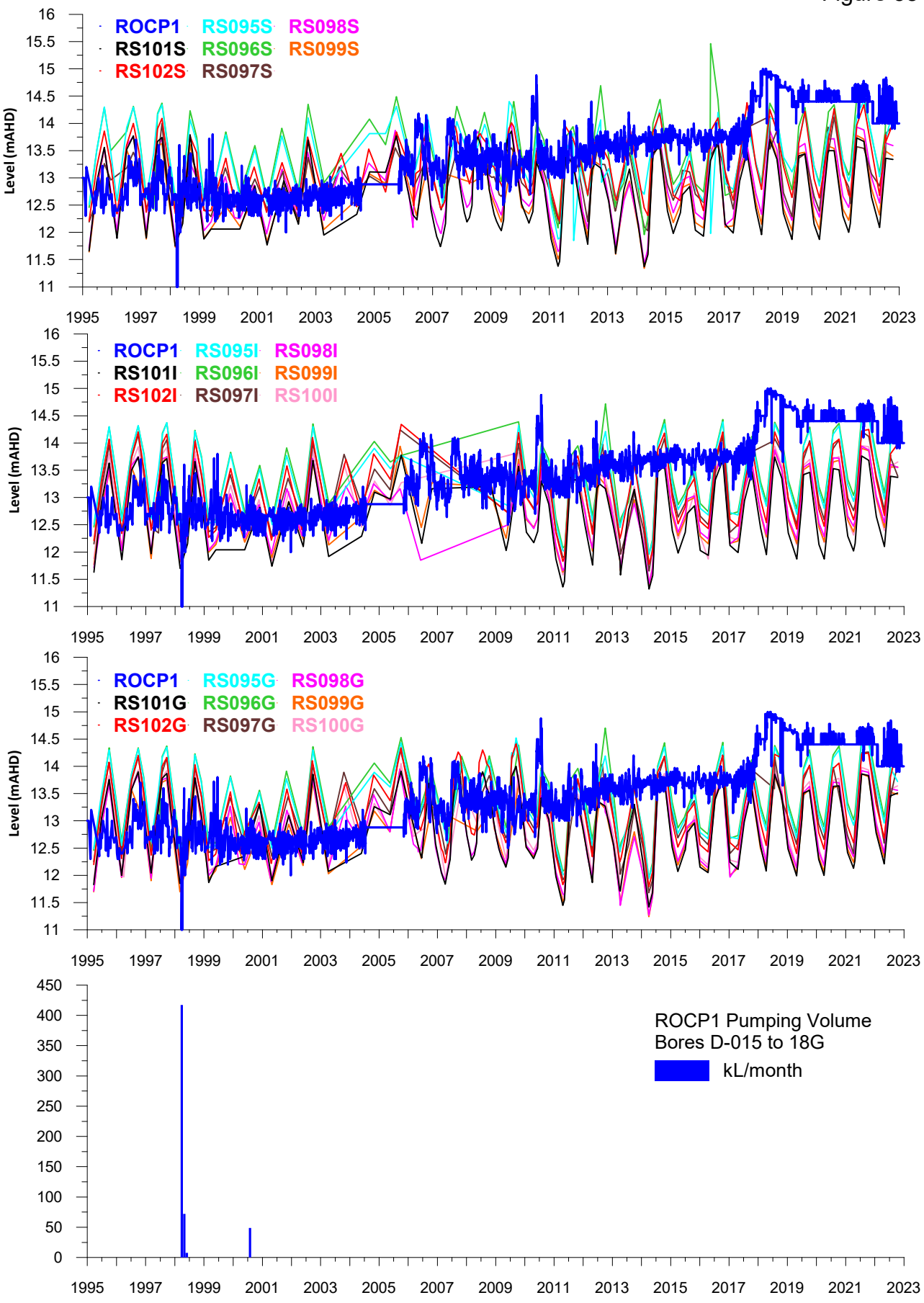
Figure 57



308-8/Grapher/Figure57.grf

CLIENT: Alcoa of Australia Limited	ROCP2 monitoring data 2 (monitoring bore & VWP water levels; depressurising bore pumping rates)
PROJECT: Wagerup and Bunbury 2020-2022 water report	
DATE: March 2023	
Dwg. No: 308-8/23/1-57	

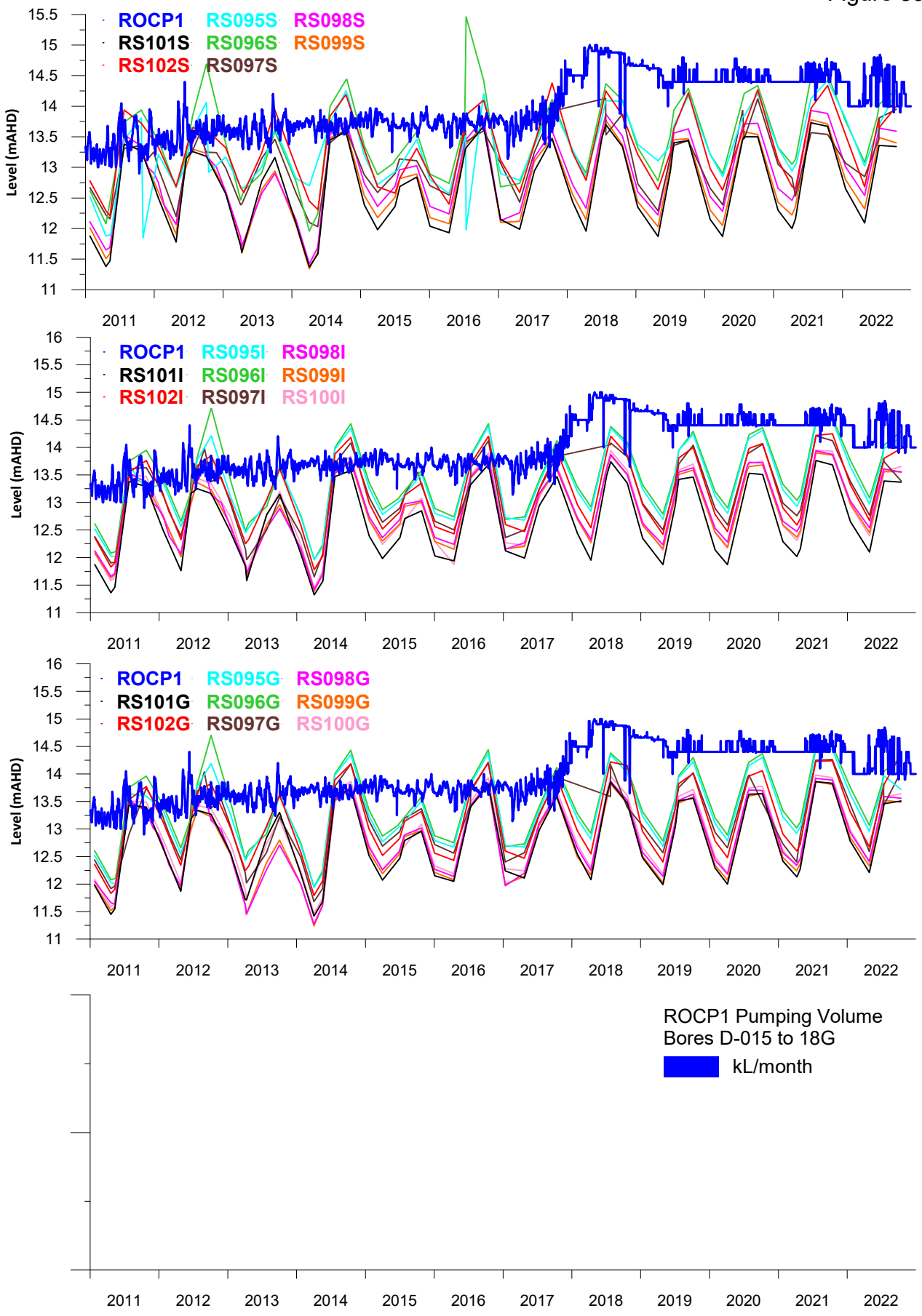
Figure 58



308-8/Grapher/Figure58.grf

CLIENT: Alcoa of Australia Limited PROJECT: Wagerup and Bunbury 2020-2022 water report DATE: March 2023 Dwg. No: 308-8/23/1-58	ROCP1 monitoring data (monitoring bore & VWP water levels; depressurising bore pumping rates)

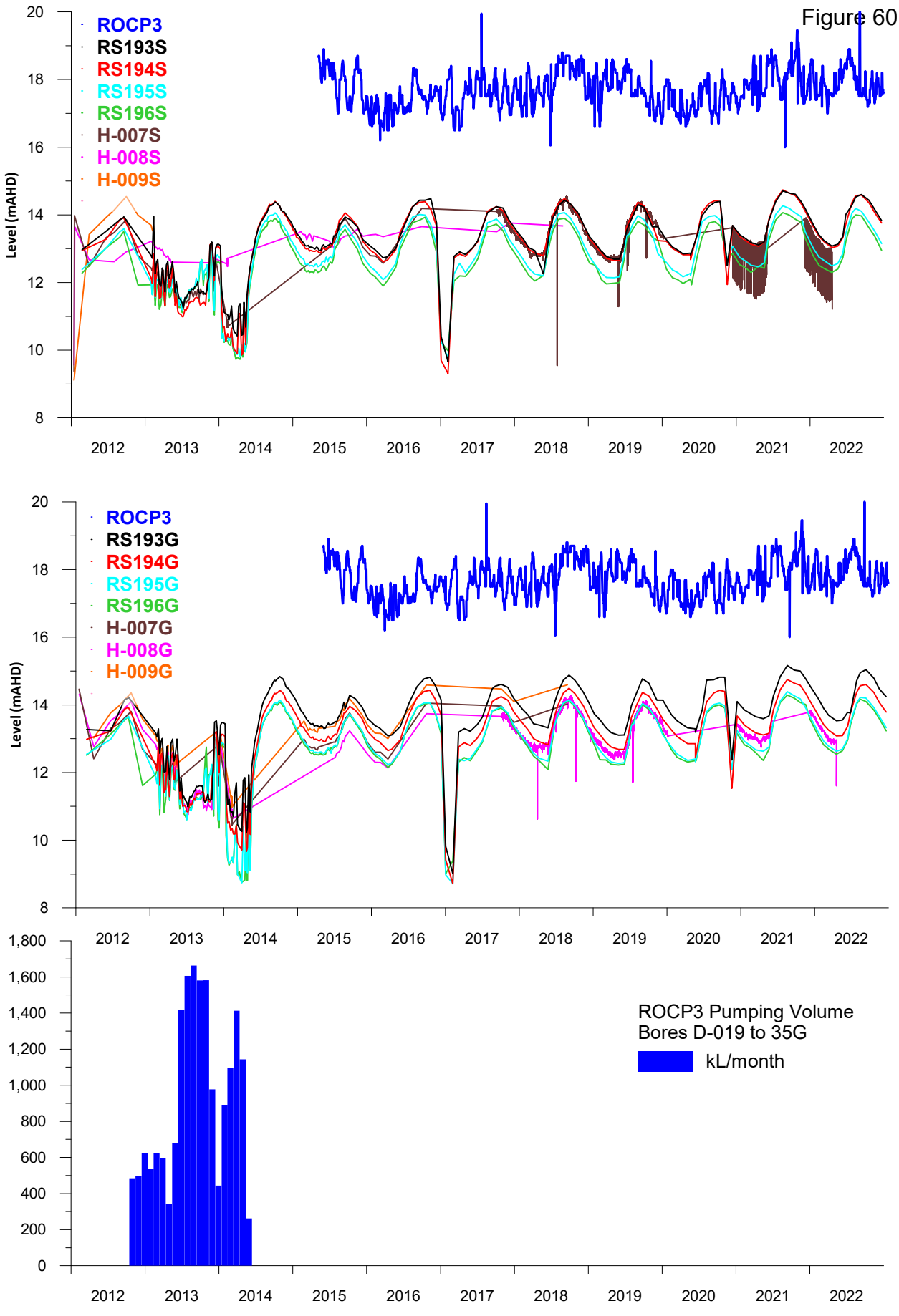
Figure 59



308-8/Grapher/Figure59.grf

CLIENT: Alcoa of Australia Limited PROJECT: Wagerup and Bunbury 2020-2022 water report DATE: March 2023 Dwg. No: 308-8/23/1-59	ROCP1 monitoring data, 2011 onwards, (monitoring bore & VWP water levels; depressurising bore pumping rates)

Figure 60



308-8/Grapher/Figure60.grf

CLIENT: Alcoa of Australia Limited	ROCP3 monitoring data (monitoring bore & VWP water levels; depressurising bore pumping rates)
PROJECT: Wagerup and Bunbury 2020-2022 water report	
DATE: March 2023	
Dwg. No: 308-8/23/1-60	

CLIENT: Alcoa of Australia Limited
PROJECT: Wagerup and Bunbury 2020-2022 water report
DATE: March 2023
Dwg. No: 308-8/23/1-61

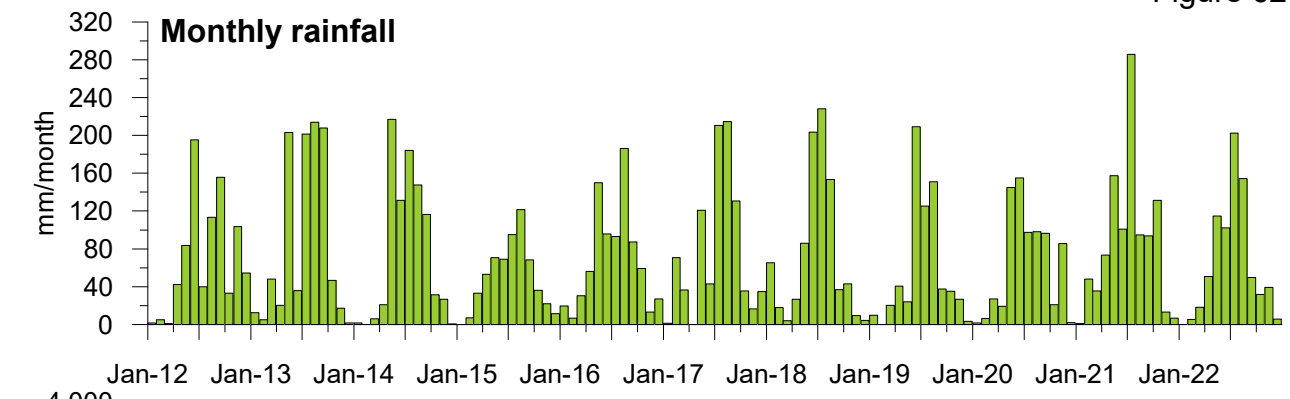
308-8/Graphs/figure61.grf

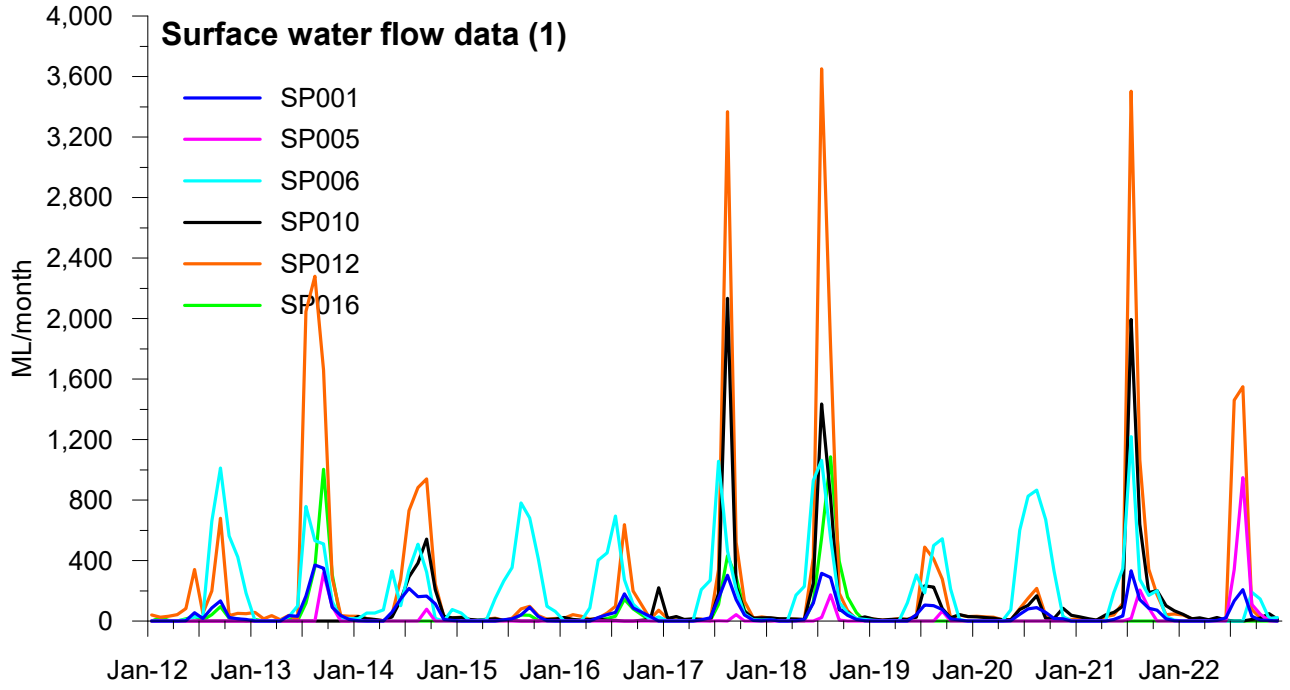
Alcoa

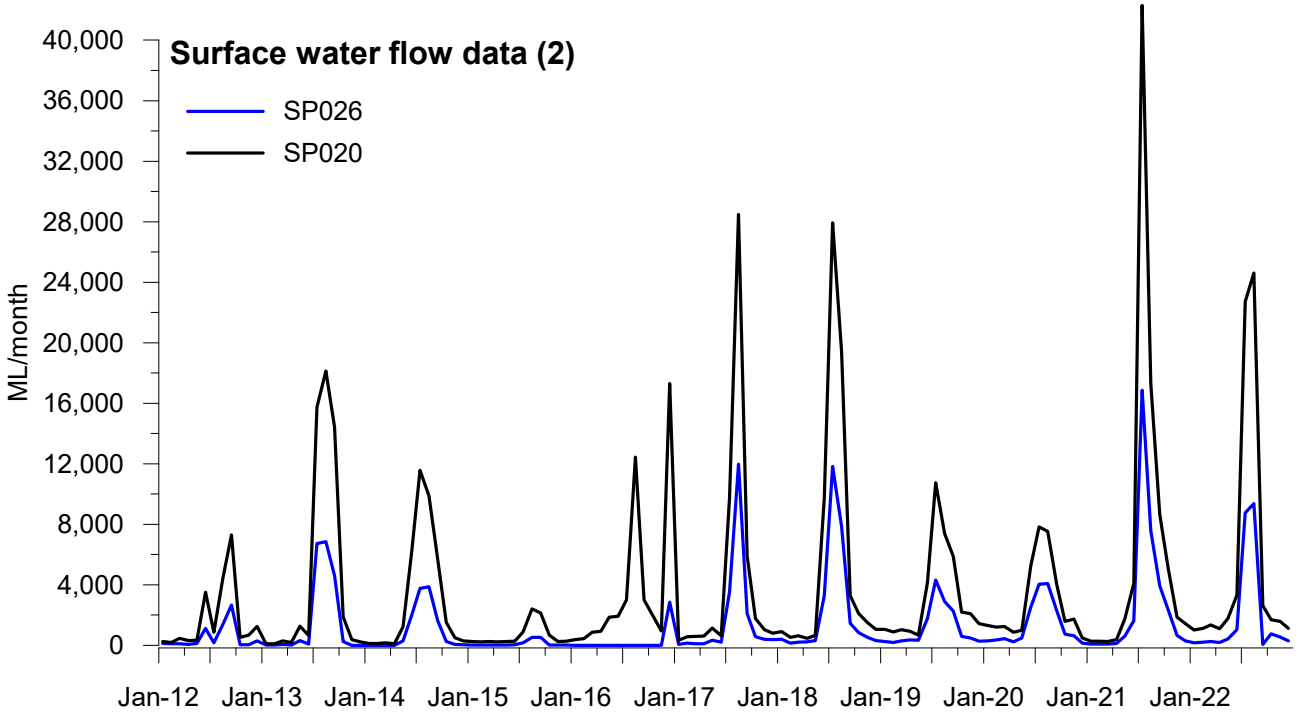
SP12 monitoring data, 1988 - 2022

Figure 61

Figure 62







308-8/Grapher/Figure62.grf

CLIENT: Alcoa of Australia Limited PROJECT: Wagerup and Bunbury 2020-2022 water report DATE: March 2023 Dwg. No: 308-8/23/1-62	Surface water flows; Wagerup rainfall data

CLIENT: Alcoa of Australia Limited
PROJECT: Wagerup and Bunbury 2020-2022 water report
DATE: March 2023
Dwg. No: 308-8/23/1-63

308.8\Surfer\Figure63.srf

Bunbury Caustic Loading Facility, aerial photograph and site layout

Aerial photograph reproduced by permission of DLI (March 2006, PA93-2003)

Date of photography: Nov 2000 and Jan 2001

0 m 200 m 400 m

Coordinate system: GDA94, Zone 50

Figure 63

CLIENT: Alcoa of Australia Limited
PROJECT: Wagerup and Bunbury 2020-2022 water report
DATE: March 2023
Dwg. No: 308-8/23/1-64

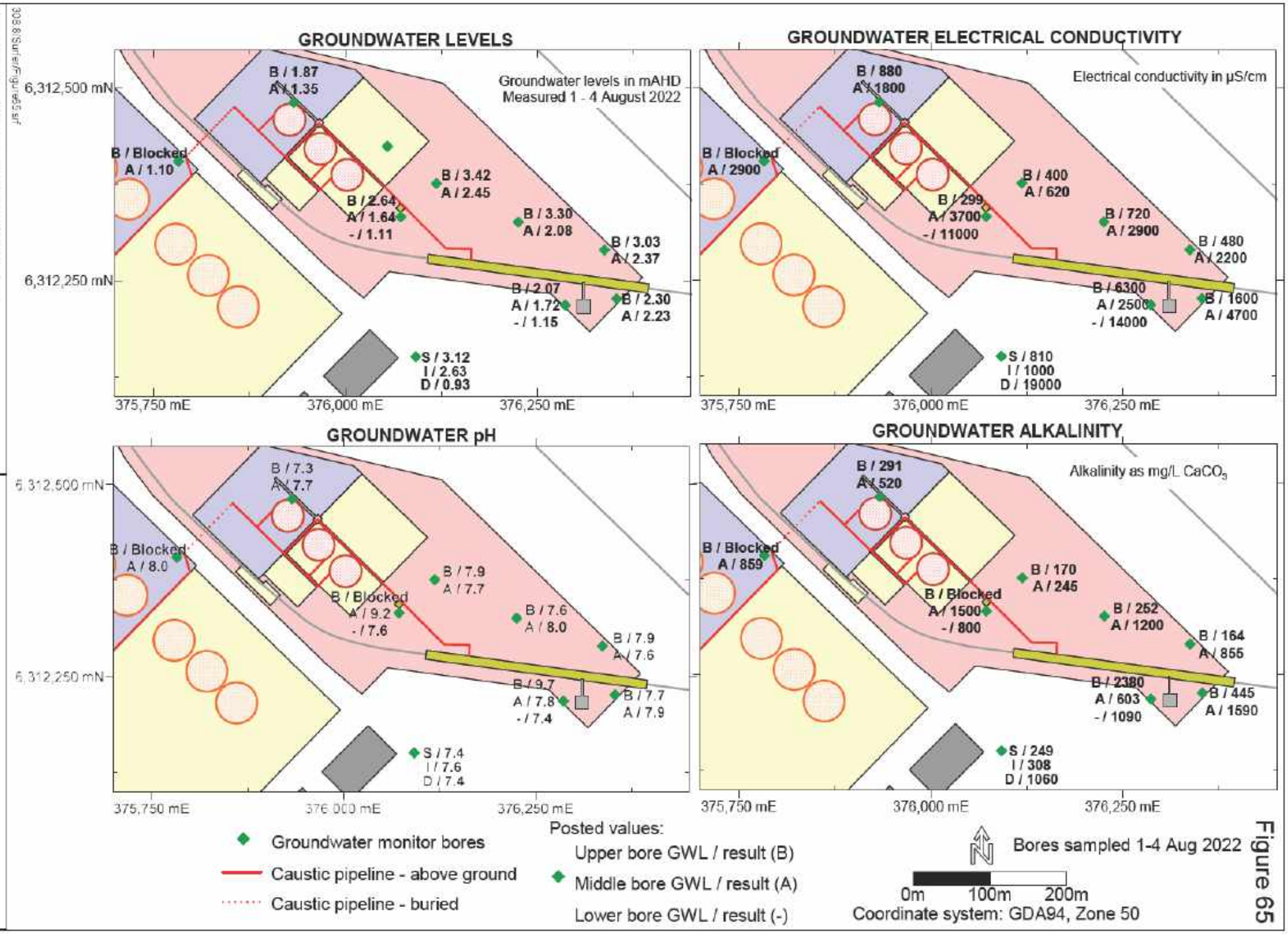
308.8\Surfer\Figure40.srf

Bunbury Caustic Loading Facility, surface water and groundwater monitoring sites

Figure 64

CLIENT: Alcoa of Australia Limited
PROJECT: Wagerup and Bunbury 2020-2022 water report
DATE: March 2023
Dwg. No: 308-8/23/1-65

308-8\Surfer\Figure65.srf



Spatial variations in groundwater levels and hydrochemistry, 2022

Figure 65

CLIENT: Alcoa of Australia Limited
PROJECT: Wagerup and Bunbury 2020-2022 water report
DATE: March 2023
Dwg. No: 308-8/23/1-66

308-8\Surfer\Fig-r66.srf

Bunbury Caustic Loading Facility, changes in groundwater levels and hydrochemistry, 2019–2022

GROUNDWATER LEVELS

Groundwater levels differences in metres
minus vaules denote a fall in water level

B / 0.09
A / 0.16
B / Blocked
A / 0.17
B / 0.15
A / 0.06
B / 0.21
A / -0.02
- / 0.17
B / 0.15
A / 0.19
B / 0.47
A / 0.22
B / 0.09
A / 0.11
- / 0.37
B / 0.11
A / 0.14
S / 0.19
I / 0.58
D / 0.33

GROUNDWATER ELECTRICAL CONDUCTIVITY

Groundwater EC changes in µS/cm; classes:
|change| >100µS/cm if 2019 EC <=2,000µS/cm
|change| >1,000µS/cm if 2019 EC >2,000µS/cm
101 Increase -101 Decrease

B / 54
A / -110
(n/a)
A / -240
B / -3
A / -26
(n/a)
A / -100
- / -0
B / -40
A / -30
B / -60
A / 0
B / -1200
A / -175
- / -1100
B / 440
A / -150
S / -490
I / -1000
D / -1000

GROUNDWATER pH

pH changes
0.3 Increase >0.2
-0.3 Decrease <-0.2

-0.4
A / 0.0
(n/a)
A / 0.0
B / 0.0
A / -0.2
(n/a)
A / -0.1
- / -0.1
B / 0.2
A / -0.1
B / 0.2
A / 0
-0.2
A / -0.2
- / -0.1
B / -0.1
A / 0.2
S / -0.2
I / -0.1
D / 0.1

GROUNDWATER ALKALINITY

Groundwater alkalinity change as mg/L $CaCO_3$; classes:
|change| >50mg/L if 2019 Alk <=700mg/L
|change| >150mg/L if 2019 Alk >700mg/L
51 Increase -51 Decrease

B / 57
A / -24
(n/a)
A / -6
B / 19
A / 3
(n/a)
A / -280
- / -148
B / -75
A / -10
B / -66
A / 25
B / -680
A / -527
- / -10
B / 105
A / 20
S / -111
I / -152
D / -40

6,312,500 mN
6,312,250 mN
375,750 mE
376,000 mE
376,250 mE

Posted values:
Upper bore GWL / result (B)
Middle bore GWL / result (A)
Lower bore GWL / result (-)

Groundwater monitor bores
Caustic pipeline - above ground
Caustic pipeline - buried

All 2019 samples collected 30 Jul - 1 Aug
All 2022 samples collected 1-4 Aug

0m 100m 200m
Coordinate system: AGD84, Zone 50

Figure 66

APPENDIX A

EP Act Licence L6217/1983/15

Government of **Western Australia**
Department of **Environment Regulation**

Our ref: L6217/1983/15
Enquiries: Agnes Tay
Email: strategyandreform@der.wa.gov.au

Jocelyn Zimmerman
Environmental Manager
Alcoa of Australia Ltd
PO Box 84,
Waroona WA 6215

Dear Ms Zimmerman

AMENDMENT OF LICENCE EXPIRY DATES

Further to our correspondence of 22 March 2016; the Department of Environment Regulation (DER) has now given effect to an extension of your expiry date through an administrative notice. The amendment has been made pursuant to section 59(1)(k) of the *Environmental Protection Act 1986* (EP Act).

Written notice of the amendment is given by administrative notice in accordance with section 59B(9) of the EP Act. Please note that a copy of the administrative notice is on DER's webpage at
https://www.der.wa.gov.au/our-work/licences-and-works-approvals/publications

Please be advised that the expiry date of your licence is as follows:

Licence Number	L6217/1983/15
Premises	Wagerup Alumina Refinery Willowdale Road, off South West Highway
Amended Expiry	12 October 2035

If you are concerned about, or object to any aspect of the amendment, you may lodge an appeal with the Minister for the Environment within 21 days from the date on which this notification is received. The Office of the Appeals Convenor can be contacted on 6467 5190 to find out the procedure and fee.

Members of the public may also appeal the amendment. The Appeals Registrar at the Office of the Appeals Convenor can be contacted after the closing date of appeals to check whether any appeals were received.

Should you wish to discuss any of the above please contact strategyandreform@der.wa.gov.au.

Yours sincerely

Agnes Tay
ACTING DIRECTOR STRATEGY AND REFORM

officer delegated under section 20
of the *Environmental Protection Act 1986*
29 April 2016

SECTION 6: WATER POLLUTION CONTROL CONDITIONS

INSTALLATION OF DRAINAGE BELOW RESIDUE DISPOSAL DAM

W1 The licensee shall maintain low permeability (10^{-9} metres per second) base and embankment seals and gravity base drainage systems on RDA's to minimise seepage and collect leachate.

CONTAINMENT OF CONTAMINATED OR POTENTIALLY CONTAMINATED WATERS

W2 The licensee shall minimise the release of contaminated water to the environment by providing containment systems to capture any spillages and minimise contact of process liquors to the ground.

WATER QUALITY MONITORING AND CRITERIA

W3(a) The licensee shall collect representative water samples at the frequencies specified in Table 9 from surface point 12 (SP12) depicted in Appendix B, and have them analysed for the parameters specified in Table 9. The licensee shall present the results of the analysis in the annual report.

Table 9: SP12 Water Quality Monitoring

Parameter	Frequency	Guideline
pH	Monthly when flowing	5.0 – 9.5
Electrical Conductivity (or equivalent TDS measurement)		Less than 2000 µS/cm
Nephelometric Turbidity units		no criteria set
Aluminium	6-monthly (during April – May , October – November)	5.0 mg/L
Arsenic		0.5 mg/L
Mercury		0.002 mg/L
Selenium		0.02 mg/L
Vanadium		0.1 mg/L
Manganese		1.0 mg/L
Molybdenum		0.15 mg/L
Uranium		0.2 mg/L

Note: Guideline for metals are taken from the livestock watering guidelines given in ANZECC 2000.

W3(b) Where analysis of a sample collected in accordance with condition W3(a) measures a pH and an electrical conductivity (or equivalent TDS measurement) above the guideline specified in Table 9, the licensee shall also analyse the same sample for sodium, chloride and alkalinity (as calcium carbonate) and calculate the sodium:chloride ratio.

W3(c) The licensee shall manage activities at the premises to ensure that its activities are not responsible for water samples collected and analysed in accordance with condition W3(a) and W3(b) to exceed the limits specified in Table 10.

Table 10: SP12 Water Quality Monitoring

Parameter	Frequency	Limit
Sodium:chloride ratio, alkalinity	In circumstances where both pH and EC are in excess of the guideline in Table 9.	sodium:chloride ratio no greater then 0.8 as well as alkalinity no greater than 50 mg/L as Calcium Carbonate.

W3(d) The licensee shall operate and maintain a flow metering device to measure the cumulative volume of stream flow (in cubic metres per month) at surface water station SP12 depicted at Appendix B. The licensee shall provide results on flow monitoring in the annual report.

W3(e) The licensee shall maintain the flow metering device referred to in condition W3(d) so as to provide reliable data for a response level of greater than 90 percent of the total time when the stream is flowing, over a calendar year.

W3(f) The licensee shall collect representative water samples from the groundwater monitoring bores (1G, 1W, 2G, 2W, 8G, 11G, 23G, 23W, 25G, 25W, 79G, 219S, 219G, 219W) depicted in Appendix B and have them analysed for the parameters and at the frequency specified in Table 11. The licensee shall present the results of the analysis in the annual report.

Table 11: Groundwater Quality Monitoring

Parameter	Frequency
pH, Electrical Conductivity (or equivalent TDS measurement), alkalinity, sodium:chloride ratio, Standing Water Level, Uranium	6 - monthly

W3(g) When any sample collected and analysed in accordance with condition W3(f) exceeds the guideline value for that parameter listed in Table 9 of condition W3(a), the licensee shall advise the CEO as soon as practicable.

W3(h) The licensee shall advise the CEO within 14 days of any surface water monitoring location described in condition W3(a) or groundwater monitoring bore described in condition W3(f) that is de-commissioned or rendered unusable.

GENERAL MONITORING REQUIREMENTS

W4(a) The licensee shall collect all water samples in accordance with the relevant part of AS 5667.1:1998.

W4(b) The licensee shall submit all water samples to a laboratory with current NATA accreditation for the specified parameters for analysis in accordance with the current "Standard Methods for Examination of Water and Wastewater-APHA-AWWA-WEF".

W4(c) The licensee shall keep the original laboratory analysis reports (or copies thereof) on record, and shall provide copies of these reports to an Inspector on request.

END OF SECTION

APPENDIX B

Groundwater and surface water licences and Operating Strategy (2020)

LICENCE TO TAKE WATER

Granted by the Minister under section 5C of the Rights in Water and Irrigation Act 1914

Licensee(s)	Alcoa of Australia Limited		
Description of Water Resource	Murray Perth - Superficial Swan	**Annual Water Entitlement**	550000 kL
Location of Water Source	Lot 205 On Plan 34250 - Volume/Folio 2540/866 - Lot 205 Somers Rd Wagerup		

Authorised Activities	**Taking of water for**	Location of Activity
	Water for Industrial purposes	Lot 205 On Plan 34250 - Volume/Folio 2540/866 - Lot 205 Somers Rd Wagerup Lot 700 On Plan 59305 - Volume/Folio 2708/955 - Lot 700 Willowdale Rd Wagerup

Duration of Licence	From 16 May 2013 to 16 May 2023

This Licence is subject to the following terms, conditions and restrictions:

1 In this licence "the strategy" means the water resource management operation strategy for Alcoa of Australia Limited - Wagerup Refinery as prepared by the licensee and approved by the Department of Water on 12 February 2013, and includes that water resource management operation strategy as modified from time to time during the term of this licence.

2 The licensee shall comply with the commitments or requirements of the operating strategy as prepared by the licensee and approved by the Department of Water on 12 February 2013 including any modifications to the strategy as approved during the term of the licence.

3 The annual water year for water taken under this licence is defined as 1 January to 31 December twelve months later.

4 The licensee must not, in any water year, take more water than the annual water entitlement specified in this licence.

5 The licensee must submit to the Department of Water the recorded meter readings and the volume of water taken within the water year by 14 January each year each year.

End of terms, conditions and restrictions

Instrument No. GWL160881(3)

LICENCE TO TAKE WATER

Granted by the Minister under section 5C of the Rights in Water and Irrigation Act 1914

Licensee(s)	Alcoa of Australia Limited		
Description of Water Resource	Murray Perth - Superficial Swan	**Annual Water Entitlement**	146600 kL
Location of Water Source	Lot 700 On Plan 59305 - Volume/Folio 2708/955 - Lot 700 Willowdale Rd Wagerup		

Authorised Activities	**Taking of water for**	**Location of Activity**
	Water for Industrial purposes	Lot 700 On Plan 59305 - Volume/Folio 2708/955 - Lot 700 Willowdale Rd Wagerup
Duration of Licence	From 12 August 2016 to 12 August 2026	

This Licence is subject to the following terms, conditions and restrictions:

1 The licensee shall comply with the commitments of the operating strategy Groundwater Licenses Operating Strategy, as prepared by the Licensee and approved by the Department of Water on 26 March 2015 including any modifications to the commitments as approved during the term of the licence.

2 The volume of all water taken under this licence must be metered using an approved meter fitted to each drawpoint.

3 The annual water year for water taken under this licence is defined as 1 January to 31 December.

4 The licensee must not, in any water year, take more water than the annual water entitlement specified in this licence.

5 The licensee must submit to the Department of Water the volume of water taken within the water year, every 12 month(s) commencing 14/01/2017.

6 Every 12 month(s) the licensee shall provide to the Department of Water a Groundwater Monitoring Summary for the preceding water year. The first report is due 31/03/2017.

End of terms, conditions and restrictions

LICENCE TO TAKE WATER

Granted by the Minister under section 5C of the Rights in Water and Irrigation Act 1914

Licensee(s)	Alcoa of Australia Limited		
Description of Water Resource	Yalup Brook Yalup Brook	**Annual Water Entitlement**	1600000 kL
Location of Water Source	Lot 351 On Plan 233046 - Volume/Folio 1403/508 - Lot 351 Willowdale Rd Wagerup Lot 700 On Plan 59305 - Volume/Folio 2708/955 - Lot 700 Willowdale Rd Wagerup		

Authorised Activities	**Taking of water for**	**Location of Activity**
	Water for Industrial purposes	Lot 205 On Plan 34250 - Volume/Folio 2540/866 - Lot 205 Somers Rd Wagerup Lot 700 On Plan 59305 - Volume/Folio 2708/955 - Lot 700 Willowdale Rd Wagerup

Duration of Licence	From 2 August 2013 to 1 August 2023

This Licence is subject to the following terms, conditions and restrictions:

1 The licensee shall comply with the commitments of the operating strategy Alcoa World Alumina - Australia, Wagerup Refinery Surface Water Licenses, as prepared by the licensee and approved by the Department of Water on 22 July 2013 including any modifications to the commitments as approved during the term of the licence.

2 The annual water year for water taken under this licence is defined as 1 January to 31 December twelve months later.

3 That the licensee shall record the volume of water drawn from the North and South Yalup Brook and forward the information to the Department of Water by 14 January.

4 The licensee is to provide an Annual Monitoring Report to the Department of Water by 31 March each year.

End of terms, conditions and restrictions

File No: RF1563-03

Government of Western Australia
Department of Water

Instrument No. SWL99246(5)

LICENCE TO TAKE WATER

Granted by the Minister under section 5C of the Rights in Water and Irrigation Act 1914

Licensee(s)	Alcoa of Australia Limited		
Description of Water Resource	Yalup Brook Yalup Brook	**Annual Water Entitlement**	2500000 kL
Location of Water Source	Lot 244 On Plan 254495 - Volume/Folio 1511/158 - Lot 244 South Western Hwy Wagerup		

Authorised Activities	**Taking of water for**	**Location of Activity**
	Water for Industrial purposes	Lot 205 On Plan 34250 - Volume/Folio 2540/866 - Lot 205 Somers Rd Wagerup Lot 700 On Plan 59305 - Volume/Folio 2708/955 - Lot 700 Willowdale Rd Wagerup
Duration of Licence	From 2 August 2013 to 1 August 2023	

This Licence is subject to the following terms, conditions and restrictions:

1 The licensee shall comply with the commitments of the operating strategy Alcoa World Alumina - Australia, Wagerup Refinery Surface Water Licenses, as prepared by the licensee and approved by the Department of Water on 22 July 2013 including any modifications to the commitments as approved during the term of the licence.

2 The annual water year for water taken under this licence is defined as 1 January to 31 December twelve months later.

3 That the licensee shall record the volume of water drawn from the South Samson Diversion Drain (including Black Tom Brook) and forward the information to the Department of Water by 14 January each year.

4 Data required to be submitted under the commitments of the operating strategy is to be forwarded to the Department of Water every 12 month(s), commencing 31/03/2014, unless otherwise specified under the approved strategy.

5 The licensee is to provide an Annual Monitoring Report to the Department of Water by 31 March each year.

End of terms, conditions and restrictions

File No: RF1563-03

Government of Western Australia
Department of Water

Instrument No. SWL151027(4)

LICENCE TO TAKE WATER

Granted by the Minister under section 5C of the Rights in Water and Irrigation Act 1914

Licensee(s)	Alcoa of Australia Limited		
Description of Water Resource	Harvey Main Drain Harvey Main Drain	**Annual Water Entitlement**	4400000 kL
Location of Water Source	Lot 358 On Deposited Plan 37518 - Volume/Folio Lr3132/239 - Lot 358 Wagerup		

Authorised Activities	**Taking of water for**	**Location of Activity**
	Water for Industrial purposes	Lot 205 On Plan 34250 - Volume/Folio 2540/866 - Lot 205 Somers Rd Wagerup Lot 700 On Plan 59305 - Volume/Folio 2708/955 - Lot 700 Willowdale Rd Wagerup

Duration of Licence	From 2 August 2013 to 1 August 2023

This Licence is subject to the following terms, conditions and restrictions:

1 The licensee shall comply with the commitments of the operating strategy Alcoa World Alumina - Australia, Wagerup Refinery Surface Water Licenses, as prepared by the licensee and approved by the Department of Water on 22 July 2013 including any modifications to the commitments as approved during the term of the licence.

2 The annual water year for water taken under this licence is defined as 1 January to 31 December twelve months later.

3 That the licensee shall record the volume of water drawn from the Harvey River and forward the information to the Department of Water by 14 January each year.

4 The licensee shall only take water from the Harvey River between May 1 and October 31, or as otherwise directed by the Department of Water.

5 The licensee is to provide an Annual Monitoring Report to the Department of Water by 31 March each year.

End of terms, conditions and restrictions

Alcoa of Australia Limited
Wagerup Alumina Refinery

Groundwater and Surface Water Licences
Operating Strategy

This Operating Strategy forms part of the Groundwater and Surface Water Licences issued to Alcoa of Australia Limited under the *Rights in Water and Irrigation Act 1914*. Licences issued cover abstraction of groundwater and surface water at the Wagerup Alumina Refinery. The purpose of this Strategy is to detail water resource management measures implemented at the Wagerup Alumina Refinery, and to ensure compliance with groundwater and surface water licences. This Strategy also describes measures proposed for efficient water use and the reduction of potential impacts on the environment and other water users.

Name of water licence licensee:	Alcoa of Australia Limited
Name of facility:	Wagerup Alumina Refinery
Legal description of properties:	*Lot 205 on Plan 34250 – Vol/Fol: 2540/866* *Lot 244 on Plan 254495 – Vol/Fol: 1511/158* *Lot 351 on Plan 233046 – Vol/Fol: 1403/508* *Lot 358 on Deposited Plan 37518 – Vol/Fol: Lr3132/239* *Lot 700 on Plan 59305 – Vol/Fol: 2708/955*

I understand that the commitments given in the attached operating strategy will be a condition of an associated water licence if approved and that a breach of a commitment or any licence condition may be an infringement of the Rights in Water and Irrigation Act 1914.

Signatures

Authorised By: _____ Date: 28/08/2020

Printed name: Adam Gilbert
Position: Wagerup Alumina Refinery Manager

Approved delegated authority Department of Water and Environmental Regulation

Regulation: _____ Date: 16/10/2020

Printed name: Leon Brouwer
Regional Manager - Kwinana Peel

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Introduction

Wagerup Alumina Refinery and associated bauxite residue storage areas (RSAs) (Wagerup Operations) are located 120 km south of Perth, 2 km north of Yarloop and 7.5 km south of Waroona (Figure 1). The refinery is located close to the foot of the Darling Scarp and is separated from the RSAs by the South West Highway and the Perth-Bunbury rail line. Bauxite is supplied to the refinery by overland conveyor from the Willowdale Mine located 15 km to the east. Alumina produced at Wagerup is shipped via the Alcoa shipping terminal at Bunbury. Transport between the refinery and port is by rail.

The refinery and residue operations are contained within freehold land owned by Alcoa. Land use on adjacent properties is primarily agricultural and operated by Alcoa. Alcoa currently hold three surface water abstraction licenses and two groundwater abstraction licenses for Wagerup Operations. The refinery and residue areas are situated within the Waroona subarea covered by the Murray Groundwater Allocation Plan.

This Groundwater and Surface Water Licences Operating Strategy (the Operating Strategy) has been developed in accordance with the guidance provided in Department of Water and Environmental Regulation (DWER), formerly Department of Water (DoW), 'Operational policy 5.08 – Use of operating strategies in the water licensing process (DoW 2011)'.

1 Administrative requirements

1.1 Current licences

Table 1 describes the water licences relevant to this Operating Strategy.

Table 1: Wagerup Operations Water Licences

Location	Source	Licence Number	Purpose	Amount (ML/pa)
Lot 700	Superficial Aquifer	GWL 160881	Water for Industrial Purposes	146.6
Lot 205	Superficial Aquifer	GWL 102669		550
Lots 351 and 700	Yalup Brook	SWL 97472		1,600
Lot 244	Yalup Brook (includes Black Tom Brook)	SWL 99246		2,500
Lot 358	Harvey River Main Drain	SWL 151027		4,400

1.2 Strategy type

Alcoa is required to provide a detailed operating strategy for the Wagerup Operations in line with Operational Policy 5.08 (DoW 2011). This is due to the volume of groundwater and surface water that is abstracted.

1.3 Environmental investigations

1.3.1 Groundwater

Alcoa regularly engages qualified consultants to review data collected in accordance with the licences listed in Table 1. These assessments show that despite localised cones of depression near the borefields, groundwater abstraction is being undertaken well within the sustainable yield and there is no evidence to suggest that it is having any effect on surrounding properties or natural water courses (Rockwater 2017).

1.3.2 Surface water

In 1978 Alcoa established a network of monitoring stations on a range of possible refinery surface water sources to provide ongoing data such that annual yields could be established. This was done with the support of the then Public Works Department and data were gathered for varying periods (Alcoa 1978). Prior to 2003, Alcoa had three surface water licences to allow diversion of water from Yalup Brook, Black Tom Brook and South Samson Drain for use by the refinery. The licence to use water from South

Samson Brook was issued on a temporary basis while Alcoa developed a scheme to harvest winter flow from the Harvey River Main Drain. The South Samson licence was rescinded in 2003 when a licence to extract water from Harvey River Main Drain was issued.

To review if surface water diversion by Wagerup Operations was impacting on the downstream environment and other users, Alcoa has completed several environmental water requirements studies of the local catchments. The study areas included:

1. Below Pipe Head Dam on the north tributary of Yalup Brook.
2. Downstream of the Lower Yalup Dam on the south tributary of Yalup Brook.
3. Downstream of confluence of Samson Brook South Channel and the Diversion Drain to the Harvey Main Drain.

An initial study (Streamtec 2000) focused on the potential local impacts from the various diversion structures associated with the refinery water supply system with subsequent follow up reports (Streamtec 2002, 2002a, 2005, 2006 and 2008).

All these reports highlight the historical and continued abstraction of water from these systems are not having an adverse effect on the ecological health of the water systems.

1.4 Responsible person

The Environmental Manager for the Wagerup Operations is responsible for establishment and review of the Operating Strategy. Contact details for the Environmental Manager are as follows:

Environmental Manager
Wagerup Refinery
PO Box 84
Waroona WA 6215
Phone: (08) 9733 8119

1.5 Reporting

The water year for reporting purposes is defined as 1 January to 31 December inclusive.

1.5.1 Meter readings

An annual meter reading compliance report including abstraction volumes all licences listed in Table 1 will be provided to the DWER by 30 January each year via the Department's electronic online system[1]. Where there are two or more meters installed to measure the quantity of water taken from two or more water draw-points, a combined abstraction reading for all the water taken under the licence will be provided instead of individual meter readings.

1.5.2 Annual report

The groundwater monitoring data collected in accordance with this strategy as outlined in Table 6 will be provided to DWER on 31 March annually, except in the years when a triennial report is due.

1.5.3 Triennial report

A comprehensive triennial report will be submitted to DWER by 30 April every 3 years commencing 30 April 2020. The content will be in line with DoW 'Operational policy no. 5.12 – Hydrological reporting associated with a groundwater well licence, Nov 2009' or any future updates.

1.6 Operating Strategy review

An Operating Strategy review will be initiated 10 years after approval. Amendments will occur in accordance with DoW Operational Policy 5.08. Amendments may be triggered by:

- A change to Alcoa Wagerup water requirements;

[1] Should problems arise with the Department's online system the data will be submitted by email.

- A significant change to the abstraction or groundwater monitoring scheme;
- Monitoring or reporting indicate adverse trends or unexpected performance; or
- As directed by the DWER following consultation with Alcoa.

2 Water source description

The Wagerup Alumina Refinery operates a water circuit, which is supplemented for water losses. Process make-up water for the alumina refining circuit is largely derived from runoff collected at the Wagerup Refinery and the RSAs, runoff from the Yalup Brook catchment and pumping from the Harvey River Main Drain. Water collected from the various surface water sources is stored on-site in five facilities: South Yalup Upper Dam, South Yalup Lower Dam, Detention Pond 1, Detention Pond 2 and the Run-off Water Storage (ROWS) Pond (Figure 1).

Small supplies of additional process water are obtained from groundwater sources by depressurising bores (which may also be utilised as production bores) and an underdrainage sump at the RSAs, alkali recovery bores at the Refinery and a borrow pit with a groundwater connection to the north of the RSAs (Figure 2). Discharge from the depressurising borefields is directed either to the adjacent water storage facility or Detention Pond 2. Groundwater produced by the recovery bores is directed into the alumina processing circuit.

Alcoa have a contract to purchase a minimum of 2 GL/year of irrigation water from Harvey Water, a privately-owned irrigation cooperative. During years when runoff yields have been insufficient to meet process water demands, up to an additional 4 GL can be purchased from Harvey Water. This water is Industrial Water, not the Irrigation Cooperative water.

2.1 Groundwater

Abstraction of groundwater is restricted entirely to the Superficial Aquifer at the Wagerup Operations. Details of abstraction bores are presented in Table 2. Alcoa has excavated clay for use in construction of the RSAs from an area north of the Refinery, this area is known as the Borrow Pit (Figure 1). The floor of the Borrow Pit has been compacted by heavy vehicle movement, but it is not formally lined. At times of the year the base of the Borrow Pit intersects the water table and therefore groundwater, in addition to rainfall and surface water runoff, can collect in the Borrow Pit (Table 3).

2.1.1 Superficial Aquifer

The stratigraphic sequence in the Wagerup area, relevant to Alcoa's operations, broadly consists of Cenozoic underlying Mesozoic deposits (Figure 3). The sequences making up the superficial formations in the Wagerup area are the Guildford Formation, Yoganup Formation and the Ascot Formation. These formations unconformably overlie the Leederville Formation and at the Wagerup Refinery may overlie the older Cattamarra Coal Measures.

The shallow stratigraphic sequence beneath the Wagerup Refinery mostly consists of a discontinuous layer of fill (sandy clay and small amounts of ironstone gravel) and a thin layer of Guildford Formation (<2–3 m thick) overlying the Yoganup Formation. The Yoganup Formation has a maximum thickness of approximately 10m near the refinery and consists of clayey sands that grade downwards to sand (Wyrwoll 2002). These units are underlain by a mostly fine-grained sequence of silt and clay which has a lower bulk hydraulic conductivity than the overlying sandy Yoganup-sediments. The deeper fined grained units are of Mesozoic age and form a basal aquitard to groundwater in the overlying Yoganup Formation.

In the vicinity of the Wagerup Refinery, the Yoganup Formation is partly saturated and forms a semi-confined to unconfined aquifer. The groundwater flow is predominantly westward towards the RSAs, with some potential for downward flow to the underlying Mesozoic Formations.

The recovery systems within the refinery collect water and other process liquids that may leak from refinery infrastructure before it reaches the saturated zone of the Superficial Aquifer. Recovery bore water is recycled into the refinery process. Due to the shallow nature of the groundwater at the RSAs,

sub-liner drains and/or depressurising bores are installed beneath new RSAs and water storages to reduce upward pressure from groundwater and protect the liners.

Table 2: Groundwater Abstraction Bores

Bore Name	Purpose	Location Coordinates		Formation	Bore Specifications			Primary Meter Type
		Northing GDA94	Easting GDA94		Elevation TOC[1] (mAHD)	Screen Interval Top (mbgl)	Screen Interval Bottom (mbgl)	
RB001G	Recovery	6357873	398135	Yoganup	47.57	8.0	14.0	Pulse Counter
RB002G	Recovery	6357835	398136		45.50	8.0	14.0	Pulse Counter
RB003G	Recovery	6357059	398450		49.07	12.0	15.0	Pulse Counter
RB004G	Recovery	6357039	398450		48.90	11.7	14.7	Pulse Counter
UD014-	Sump	6358717	395806	Guildford and Yoganup	21.20	N/A	10.7	Digital Magflow
D-002G	Depressurising	6357940	396326		26.82	19.5	28.4	Digital Magflow
D-004G	Depressurising	6357559	396675		22.22	9.8	19.7	Digital Magflow
D-006G	Depressurising	6357159	396635		20.88	11.1	20.0	Digital Magflow
D-007G	Depressurising	6357104	396204		19.00	13.2	22.1	Digital Magflow
D-008G	Depressurising	6357767	396617		22.93	11.3	20.2	Digital Magflow
D-010G	Depressurising	6359104	395970		19.30	14.6	23.6	Digital Magflow
D-013G	Depressurising	6359238	395950		19.50	14.6	23.6	Digital Magflow
D-014G	Depressurising	6358855	395969		19.36	15.6	24.6	Digital Magflow
D-019G	Depressurising	6359162	394399		16.46	15.2	21.2	Digital Magflow
D-020G	Depressurising	6359162	394229		16.10	15.2	21.2	Digital Magflow
D-021G	Depressurising	6359164	394058	Ascot	15.81	11.9 18.7	14.9 21.7	Digital Magflow
D-023G	Depressurising	6359150	393731		14.92	11.5 18.5	14.5 21.5	Digital Magflow
D-024G	Depressurising	6358995	393717		14.84	9.0 19.0	12.0 22.0	Digital Magflow
D-025G	Depressurising	6358841	393712		15.27	10.5 18.0	13.5 21.0	Digital Magflow
D-026G	Depressurising	6358679	393712		15.06	11.0 19.3	14.0 22.3	Digital Magflow
D-027G	Depressurising	6358517	393709		15.01	10.2 18.7	13.2 21.7	Digital Magflow
D-028G	Depressurising	6358357	393705		15.04	12.0 19.0	15.0 22.0	Digital Magflow
D-029G	Depressurising	6358194	393702		14.68	11.5	17.5	Digital Magflow
D-030G	Depressurising	6358045	393726		15.17	12.0 18.7	15.0 21.7	Digital Magflow
D-031G	Depressurising	6358030	393891		15.06	13.6 19.6	16.6 22.6	Digital Magflow
D-032G	Depressurising	6358029	394057		14.83	11.0	17.0	Digital Magflow
D-033G	Depressurising	6358029	394229		15.20	11.2 18.2	14.2 21.2	Digital Magflow
D-034G	Depressurising	6358028	394393		14.87	13.4	19.4	Digital Magflow
D-035G	Depressurising	6359164	393905		15.71	12.0 16.3	15.0 22.3	Digital Magflow
D-001G	Depressurising	6358538	396425	Guildford and Yoganup	25.58	8.8	26.7	
D-003G	Depressurising	6357849	396553		22.89	15.4	21.1	
D-005G	Depressurising	6357349	396731		20.53	7.3	18.8	
D-009G	Depressurising	6358957	395970		20.32	14.4	23.4	
D-011G	Depressurising	6358833	395815		21.45	17.1	26.1	
D-012G	Depressurising	6359238	395810		21.09	15.1	24.1	
D-015G	Depressurising	6357746	394247		15.43	12.8	21.8	
D-016G	Depressurising	6357568	394246		15.48	11.5	14.6	
D-017G	Depressurising	6357423	394392		15.79	12.3	21.3	
D-018G	Depressurising	6357892	394386		15.51	10.8	19.8	

[1] Top of casing
Shaded bores are currently inactive

Table 3: Borrow Pit Details

Source name	Location Coordinates		Formation	Elevation (mAHD)	Maximum depth (m)	Capacity (m³)
	Northing GDA94	Easting GDA94				
BP001G	6360056	397362	Guildford and Yoganup	24.9	9	900,000

2.2 Surface water

The Wagerup Refinery area is within the lower reaches of the Harvey River catchment. The section of the Harvey River upstream and adjacent to Alcoa's landholdings as well as its feeder streams that traverse the Pinjarra Plain have generally been highly modified into trapezoidal drains. The Harvey River Main Drain lies approximately 4 km to the west of the current residue areas and flows in a north-westerly direction to discharge into the Harvey Estuary (Figure 4).

The natural hydrology of the lower Harvey River catchment was comprised of streams draining relatively small catchments from the escarpment onto the plain and into the Harvey River. The natural condition was highly altered in the early 1900s due to the development of the irrigation and drainage systems servicing agricultural developments around the towns of Harvey and Waroona. A number of dams have been constructed within the larger Darling Range catchments to retain winter runoff for summer irrigation use and the watercourses on the Plain have been modified or replaced by constructed channels to distribute irrigation water and improve winter drainage.

Wagerup Refinery is almost totally dependent on surface water sources to provide for process make-up water. The catchments that provide water for Wagerup Refinery include the refinery and residue storage areas and surrounding land including Darling Range and agricultural catchments.

2.2.1 Yalup Brook

Yalup Brook catchment is located on the Darling escarpment to the north east of the refinery. It includes around 700 ha of cleared farming area (pasture) and 200 ha of forested area. The Yalup Brook catchment includes moderate to steep slopes and rocky areas of the Darling Escarpment grading to moderate to gentle slopes of Ridge Hill Shelf Formation which forms the foothills of the Darling Range. Soils vary from bauxite and granite derived soils on the escarpment to sandy soils of the Ridge Hill Shelf.

The northern arm of Yalup Brook is harvested by way of a small diversion dam (Pipe Head Dam) and gravity pipeline which feeds into the South Yalup Upper Dam (Table 4). Stream flows in excess of the pipeline capacity will overflow the diversion dam spillway. The southern arms of Yalup Brook feed directly into the South Yalup Upper Dam. If this dam is filled it will overflow via a spillway back into the North Yalup Brook channel.

2.2.2 Black Tom Brook

Black Tom Brook catchment is located on the Darling Escarpment immediately to the north of Yalup Brook. The catchment area of Black Tom Brook, including the contributing areas downstream of the confluence of Black Tom Brook and the Alcoa diversion drain to Detention Pond 1, is approximately 1,040 ha. This area does not include the "closed" catchment area associated with the decommissioned Iluka Mineral Sands Operation in Wagerup.

Black Tom Brook enters a drain near the South Western Highway which is intercepted by the South Samson Diversion Drain, constructed by Alcoa to divert drainage waters around the residue areas. The diversion drain flows into Detention Pond 1 (Table 4).

2.2.3 Harvey Main Drain

The Harvey Main Drain catchment area lies above the confluence with Logue Brook Drain. This is where Alcoa's Harvey Pumpback station (Table 4) is located. The overall catchment area includes Harvey Dam and its catchment which is the headwaters of the Harvey River, however for the purposes of this operating strategy the relevant catchment includes only that area downstream of Harvey Dam.

Table 4: Surface Water Abstraction Sites

Dam Name	Location Coordinates		Pump Capacity (kL/hr)	Meter Type	Approximate Capacity (m^3)	Dam Wall Height (m)	Spillway Height (m)
	Northing GDA94	Easting GDA94					
South Yalup Upper Dam	6360056	397362	N/A	Magflow	1536000	55	54.1
Detention Pond 1	6358162	399100	650 kL/h to UD,	Magflow	1745000	24	23.5
			2,000 kL/h to ROWS/Cooling Lake,	Magflow			
			2,000 kL/h to DP2	Magflow			
Harvey Pumpback	6356932	390694	1674	Magflow	N/A	N/A	N/A

Note: none of the dams have an under-wall bypass.

3 Management objectives

Alcoa has developed management objectives with the aim of minimising the impact of its operations on the environment and other water users. There are seven primary management objectives, of which four link directly to the implementation of the requirements under Wagerup Operations' groundwater and surface water licences. Table 5 details the management and monitoring objectives. Section 5 details the monitoring program, Section 6 provides more information on the potential receptors and Section 7 outlines the contingencies that align with Wagerup Operations' management objectives.

Table 5: Management and Monitoring Objectives

Management Objectives		Monitoring Objectives	
1	Abstraction of groundwater is undertaken in a manner that is sustainable and does not have a long-term detrimental effect on the environment or the beneficial use of groundwater resources.	1A	Measure and calibrate flow from the depressurising, production and recovery bores to provide a reliable estimate of abstraction volumes
		1B	Assess the suitability of abstracted and recovered water for its beneficial end use
		1C	Assess the change in water levels and water quality in the superficial formation due to abstraction
2	Surface water harvesting is undertaken in a manner that is sustainable and does not have a long-term detrimental effect on the environment or the beneficial use of surface water resources.	2A	Measure and calibrate flow of surface water harvesting systems to provide a reliable estimate of harvesting volumes
		2B	Assess whether downstream flow and water quality are adversely affected by surface water harvesting
4	Alkali recovery systems are operated to reduce the effect of seepage on groundwater receptors.	4C	Assess whether abstraction rates from the superficial formation recovery systems are sufficient to inhibit migration of alkaline water
6	The integrity of the clay-geomembrane composite liners for process water ponds is maintained.	6A	Assess whether abstraction rates from the depressurising bores are sufficient to maintain the target uplift pressure

4 Operating rules

Abstraction is managed in accordance with licence requirements and is maintained at or below licence limits.

4.1 Recovery bores

Recovery bores and wells are operated throughout the year to control and contain alkaline groundwater plumes in the Superficial aquifer within the refinery precinct. The bores are aimed to be operated on a continuous basis (allowing for maintenance when required). Airwell pumps are installed in the recovery network, these bores pulse (discharge) when the pump tube is full. Water from the recovery system is used within the refinery process.

4.2 Depressurising system

This system of bores and subliner drains is operated to reduce uplift pressure on RSAs and water storage ponds to maintain liner integrity. The general strategy is to maintain the groundwater levels beneath the pond levels. Abstraction by this system is required throughout the year as natural water levels are generally higher in the wetter months and pond levels are generally lower in drier months.

The bores listed as inactive in Table 2, are available to assist the groundwater level management during maintenance activities, however, these are not typically utilised during normal operating conditions. Water from depressurising bores is used within the refinery and residue processes. The bores may be used as production bores when additional make-up water is required.

4.3 Borrow Pit

Abstraction from the Borrow Pit will be metered[2]. To determine the groundwater contribution of the abstracted volume, a water balance will be calculated based on the monthly water levels in the Borrow Pit, rainfall, evaporation and the metered abstraction. This is further detailed in Section 5.1.

4.4 Yalup catchment

4.4.1 North Yalup Brook

The Pipe Head Dam collects all flow from the North Yalup Brook from where it is transferred to the South Yalup Upper Dam, with a small amount of water maintained in the Pipe Head Dam for stock watering purposes. An overflow spillway exists to cater for flows generated during storm events. A scour valve is provided to allow the dam to be drained for maintenance.

Any bypass water will enter Yalup Brook which traverses Alcoa land and then discharges into the Samson South Diversion Drain.

4.4.2 South Yalup Brook

The South Yalup Upper Dam receives direct runoff from the South Yalup Catchment and all runoff is collected. There is provision to transfer water to the South Yalup Lower Dam. Water in the South Yalup Upper Dam is primarily treated for use as a potable water source for the refinery and make up water to cooling towers.

4.5 Black Tom Brook

Water harvested from the Black Tom Brook catchments is stored in Detention Pond 1 located on the Samson South Diversion Drain. This water is used primarily for dust suppression on the residue storage area.

The un-allocated portion of winter flow draining from the Samson Brook South Channel, Black Tom Brook and North Yalup Catchments overflows Detention Pond 1 into the Diversion Drain. This drain discharges into the Samson Brook South Channel, just upstream of SP12 (Figure 4).

[2] Meter to be installed prior to abstraction.

4.6 Harvey Main Drain

The design of the Harvey River Main Drain pumping station provides for maintenance of base flow even during the pumping season of May – October. The pump inlet design allows for a minimum of 200mm water depth in the drain before pumping can start. Pumping commences when the river flow exceeds the minimum level and ramps up as flow into the pump chamber increases. The water is transferred to either the ROWS or Detention Ponds, depending on system requirements.

4.7 System Maintenance and Installation

Bore, pump and meter condition and efficacy are visually assessed regularly by experienced personnel and flow and performance statistics are reviewed regularly. Maintenance is assigned a priority based on these assessments.

Depending upon the location and severity, pumps may be removed, and acid washed/mechanically cleaned and bore screens redeveloped using acid/biocide/surfactants, and discharge piping and bore casings may be replaced.

To maintain and monitor operations, Wagerup Operations need to make changes to its abstraction and monitoring network from time to time. Bore alteration, installation and decommissioning will be completed in accordance with Minimum Construction Requirements for Water Bores in Australia (NUDLC 2012) or any future updates, by an appropriately certified driller. Details will be provided in the annual report. Where this work results in the need for an update to the Operating Strategy an amendment will be submitted to the DWER within 28 days.

5 Monitoring

Alcoa has a risk-based water monitoring program that is undertaken in accordance with the framework and guidelines provided by ANZECC and ARMCANZ (2000) to support the National Water Quality Management Strategy.

Monitoring is undertaken to ensure compliance with DWER licences and this Operating Strategy, and to allow Alcoa to assess the impacts of abstraction on the water resources, the environment and other users.

Table 6 details the monitoring schedules developed to identify the occurrence of potential impacts as defined in Section 6.

Tables 2, 3, 4, 7 and 8 provide the coordinates and construction details of the monitoring locations identified in Table 6, and Figure 2 shows the monitoring locations.

Flow meters and sampling locations may be exempt from metering accuracy requirements and/or monitoring in the following circumstances:

- the flow site is not operating or there is insufficient water to sample;
- the flow site, flow meter or monitoring location is not accessible;
- the monitoring location is blocked or has insufficient water to sample; or
- the calibration or monitoring equipment is not functioning/available.

5.1 Water use measurement

Groundwater abstraction is metered using two types of measurement devices at Wagerup Operations, pulse counters and magnetic flow meters, and via the use of surveyed pond levels.

Airwell pumps are favoured for abstraction in the Superficial Aquifer as recharge in systems installed in this aquifer can be slow. Airwell pumps are suited to these conditions as they only discharge when full. They use the ‘direct air displacement’ method of pumping fluids, where compressed air acts on the surface of a liquid to expel it from a sealed container. Airwell pumps are designed to eject a set volume of water with each pulse and flow rate is a function of pump volume and pulse rate. This method of pumping can cause the discharge to volatilise making measurement using magnetic flow meters impractical. Therefore, flow from an Airwell pump is metered using a pulse counter.

The groundwater abstracted from the Borrow Pit is calculated using the following equation:

*Groundwater = Volume (End of Month) - Volume (End of Previous Month) - (Month rainfall * Borrow Pit Surface Area) + (Month evaporation * Borrow Pit Surface Area at end of month water level) + Water Measured Out from Borrow Pit*

Direct metering is not an accurate measurement of surface water abstraction from Yalup and Black Tom Brooks and the utilisation of alternative measurement methods is required in accordance to Clause 42E of the *Rights in Water and Irrigation Amendment Regulations 2018.* Surface water abstracted from Yalup Catchment (SWL97472 and SWL99246) is measured via metered draw from the South Yalup Upper Dam and Detention Pond 1 respectively, subtracting the volume of water purchased from Harvey Water during the relevant water year and transfers from internal ponds. Draw from Harvey Main Drain (SWL151027) is metered directly.

Meter readings are taken regularly as outlined in Table 6. Some meters are connected to Wagerup Operations' telemetry network. Where manual readings are required, and do not align with calendar cut offs (for example end of month), flow rates are calculated pro rata.

Where estimation or correction of abstraction volume is necessary (for example, in the event of a meter or telemetry failure), reasonable estimates of the abstraction volumes will be applied for relevant operable pumps. Internal records will be kept of the abstraction volume estimation, reason and the applicable time periods.

Across the Alcoa Western Australian operations, we have seen bacterial and mineral deposits within pumping systems. Chemical reactions associated with alkali contamination of groundwater can result in scaling and bacteria in excess quantities can produce a voluminous mass of slime. These deposits can lead to blocking of bore casings, screens, pumps, meters and other components. Pump performance can deteriorate rapidly due to these depositions. As the inside of an Airwell pump becomes blocked, the volume decreases leading to overestimates of flow rate and maintaining measurements to within +/- 5% accuracy can become impractical.

To maximise the accuracy of the measurement of water abstracted, the following strategy is adopted:

- Meter readings are taken regularly as described in Table 6;
- Flow is reviewed regularly and, where required, bores and pumps are placed on a maintenance schedule;
- In situ volumetric tests are performed on the Airwell pumps using a mobile caltank rig specifically designed for this purpose or a NATA certified master meter. These recorded volumes are incorporated into flow calculations as soon as practical. Flows are back calculated to the date of the calibration. Frequency of calibration is adjusted based on the rate of change or drift in the pump volumes;
- Calibration of magnetic flow meters is carried out at a NATA accredited laboratory and verified on a NATA report/certificate or undertaken using a NATA certified master meter. Magnetic flow meter converters are calibrated in the field. Where operating conditions indicate a potential loss of meter accuracy, recalibration of the meter/converter is scheduled. Frequency of calibration may be adjusted based on the rate of change or drift in the meter; and
- Internal records are kept of flow meter replacement, maintenance and calibration.

Where meters are changed out for calibration the replacement meter is not regarded as a new installation. Meter serial numbers are subject to change as meters are swapped out for maintenance or calibration.

5.2 Groundwater levels and quality

Monitoring of groundwater levels and hydrochemistry occurs at monitoring bores, depressurising bores and recovery bores. Groundwater levels in some areas are monitored with vibrating wire piezometers.

Groundwater monitoring bores associated with this operating strategy are listed in Table 6, Table 7 and presented on Figure 2.

5.3 Surface water flow and quality

Surface water flows and quality are measured in accordance with Table 6 to ensure that the monitoring objectives are met. Continuous streamflow measurements are calculated based on water levels taken at set intervals that are downloaded on a periodic basis.

Table 6: Monitoring Schedule

Monitoring Objective	Monitoring Sites	Monitoring Program
1A) Measure and calibrate flow from the production, recovery and depressurising bores to provide a reliable estimate of abstraction volumes	D-002G, D-004G, D-006G, D-007G, D-008G, D-010G, D-013G, D-014G, RB001G, RB002G, RB003G, RB004G, UD014-	Monthly meter readings and calibration as described in section 5.1
	D-019G, D-020G, D-021G, D-023G, D-024G, D-025G, D-026G, D-027G, D-028G, D-029G, D-030G, D-031G, D-032G, D-033G, D-034G, D-035G, BP001G	6-monthly meter readings and calibration as described in section 5.1
1B) Assess the suitability of abstracted and recovered water for its beneficial end use	D-002G, D-004G, D-006G, D-007G, D-008G, D-010G, D-013G, D-014G, D-019G, D-020G, D-021G, D-023G, D-024G, D-025G, D-026G, D-027G, D-028G, D-029G, D-030G, D-031G, D-032G, D-033G, D-034G, D-035G, UD014, BP001G	Annual pH, EC, alkalinity
	RB001G, RB002G, RB003G, RB004G	Annual comprehensive analysis
1C) Assess the change in water levels and water quality in the superficial formation due to abstraction	RG012G, RG027S, RG027G, RG152S, RG152G, RG153S, RG153G, RG155S, RG155G, RG156S, RG156G, RG219S, RG219G, RS195S, RS195G, RS198S, RS198G, RS201S, RS201G	Quarterly groundwater levels Annual pH, EC, alkalinity
2A) Measure and calibrate flow of surface water harvesting systems to provide a reliable estimate of harvesting volumes	South Yalup Upper Dam, Detention Pond 1, Harvey Pumpback	Monthly meter readings and calibration as described in section 5.1
2B) Assess whether downstream flow and water quality are adversely affected by surface water harvesting	SP001-, SP005-, SP006-, SP012-, SP020-, SP026-	Continuous streamflow monitoring
	SP012-	Monthly pH, TDS or EC, alkalinity, Nephelometric turbidity units, Sodium:Chloride ratio
4C) Assess whether abstraction rates from the superficial formation recovery systems are sufficient to inhibit migration of alkaline water	RF043G, RF046G	6-monthly groundwater levels, pH, EC, alkalinity Annual comprehensive analysis
6A) Assess whether abstraction rates from the depressurising bores are sufficient to maintain the target uplift pressure	I-003-, I-002-, H-002- H-005-, RS041S, RS041G, RS045S, RS045G, RS116S, RS116G, RS117S, RS117G, RS119S, RS119G, RS120S, RS120G, RS121S, RS121G, RS137S, RS137G, RS141S, RS141G, RS142S, RS142G	Monthly groundwater levels

Table 7: Groundwater Monitoring Bores

Bore Name	Location Coordinates		Formation	Bore Specifications		
	Northing GDA94	Easting GDA94		Elevation TOC[1] (m AHD)	Screen Interval Top (mbgl)	Screen Interval Bottom (mbgl)
H-002-	6357743	396435	Upper Yoganup	-	-	-
H-005-	6357326	396260	Upper Yoganup	-	-	-
I-002-	6359029	395860	Upper Yoganup	-	-	-
I-003-	6359139	395860	Upper Yoganup	-	-	-
RF043G	6357878	398042	Yoganup	47.56	7.3	13.3
RF046G	6357039	398380	Yoganup	47.69	9.8	15.8
RG012G	6357481	398031	Yoganup	42.96	1.8	24.0
RG027G	6356929	395954	Guildford and Yoganup	20.54	1.4	21.4
RG027S	6356931	395953	Guildford	20.14	2.5	5.5
RG152G	6358174	396523	Yoganup	23.33	11.8	24.3
RG152S	6358172	396523	Guildford	23.36	2.8	10.5
RG153G	6359468	393924	Yoganup	15.47	11.8	23.8
RG153S	6359466	393924	Guildford	15.45	2.8	9.3
RG155G	6359897	396411	Yoganup	21.57	12.3	24.0
RG155S	6359897	396412	Guildford	21.58	3.7	9.9
RG156G	6360913	396311	Yoganup	23.05	13.9	23.8
RG156S	6360912	396311	Guildford	23.06	3.7	11.9
RG219G	6358485	392624	Ascot	15.54	10.0	22.5
RG219S	6358482	392624	Guildford	15.59	5.5	8.5
RS041G	6358254	396347	Yoganup	26.88	18.5	28.0
RS041S	6358254	396347	Guildford	26.88	5.5	13.8
RS045G	6358492	396409	Yoganup	26.60	15.0	27.5
RS045S	6358492	396409	Guildford	26.60	7.5	12.0
RS116G	6357457	396703	Yoganup	23.02	10.7	18.7
RS116S	6357454	396703	Guildford	23.02	2.7	6.7
RS117G	6357241	396696	Yoganup	23.00	10.7	19.7
RS117S	6357243	396698	Guildford	22.93	2.7	8.7
RS119G	6357111	396306	Yoganup	21.74	12.4	21.4
RS119S	6357111	396309	Guildford	21.74	2.7	9.7
RS120G	6357659	396648	Yoganup	22.74	10.5	19.7
RS120S	6357656	396649	Guildford	22.80	2.5	8.0
RS121G	6357807	396585	Yoganup	23.24	13.0	20.0
RS121S	6357810	396583	Guildford	23.28	2.5	9.5
RS137G	6358835	395913	Yoganup	20.98	12.9	24.9
RS137S	6358835	395915	Guildford	20.98	4.5	10.5
RS141G	6359206	395943	Yoganup	20.11	12.0	24.0
RS141S	6359204	395944	Guildford	20.11	3.0	9.0
RS142G	6359031	395959	Yoganup	20.14	12.9	24.9
RS142S	6359029	395959	Guildford	20.16	3.5	9.5
RS195G	6359083	393713	Ascot	15.53	15.5	22.5
RS195S	6359080	393713	Guildford	15.56	5.0	15.0
RS198G	6358597	393711	Ascot	15.43	16.0	20.8
RS198S	6358595	393711	Guildford	15.45	4.0	14.4
RS201G	6358114	393700	Ascot	15.35	16.5	22.5
RS201S	6358112	393699	Guildford	15.36	5.0	14.5

[1] Top of casing

Table 8: Surface Water Monitoring Sites

Site	Location Coordinates		Location
	Northing GDA94	Easting GDA94	
SP001-	6359124	399844	North Yalup Brook
SP005-	6358767	396548	Samson South Diversion Drain, detention pond overflow
SP006-	6359851	397249	South Samson Diversion Drain, above detention pond
SP012-	6358514	391763	Samson South Drain – Cooyah
SP016-	6357083	396080	South Samson Drain, Somers Rd
SP020-	6357068	390833	Harvey River Main Drain, below pump station
SP026-	6356928	391104	Logue Brook Drain, below pump station

6 Environmental impact management

Alcoa has conducted several investigations to understand the potential impacts of abstraction (Section 1.3) from surface and groundwater sources, as detailed below. Section 7 of the Operating Strategy identifies contingency measures to manage identified impacts and the triennial report (Section 1.6.3) will provide a broader review of potential impacts and will include management recommendations where required.

6.1 Groundwater

Alcoa's abstraction from the Superficial Aquifer at Wagerup Operations has not resulted in downward trends in water levels and only localised cones of depression (Section 1.3.1). No other users, including groundwater dependant ecosystems, have been identified within the localised cones of depression and therefore no impact is expected.

6.2 Surface water

Potential environmental impacts of surface water abstraction are managed primarily through the consideration of other water users, and maintenance of ecological water requirements (EWRs). An EWR was conducted by Streamtec Ecological Consultants in 2002 with a review in 2008. A further EWR is planned for 2020. The output of this work will aid in the determination of whether EWRs are being maintained and the consideration of any recommendations moving forward.

6.2.1 Yalup Brook

Other water users

There are no other licensed users of water within the Yalup Brook catchment.

Ecological water requirements

The Steamtec reports demonstrate that the historical and continued abstraction of water from these systems is not having an adverse effect on the ecological health of the water systems (Section 1.3.2) and no formal releases are required to meet local EWRs. The existing flow is adequate to meet these requirements (Streamtec 2002).

6.2.2 Black Tom Brook

Other water users

The majority of the catchment is within state forest. Several small private farming lots exist at the foot of the Darling Escarpment and may utilise Black Tom Brook for stock watering. These operations are all upstream of Alcoa's interception point so are not impacted by Alcoa's use of this source. There are no other users licensed to use water from Black Tom Brook.

Ecological water requirements

Alcoa's diversion of Black Tom Brook is at the point where it discharges into the South Samson Diversion Drain. This is well downstream of the natural streambed and as a result the diversion has no impact on

the upstream ecology. An assessment of EWRs for Black Tom Brook is therefore not relevant to this strategy.

6.2.3 Harvey River

Other major users

The headwaters of the Harvey River above the Harvey Dam are licensed to Harvey Water primarily for agriculture and to the Water Corporation for public water supply. Within the catchment that is relevant to this strategy there are no other licensed users. There is some minor use of water from the Harvey River Main Drain for stock watering.

Ecological water requirements

The lower Harvey Main Drain and the South Samson Drain are constructed trapezoidal channels, and as such, characterised by limited ecological values and, due to past catchment clearing, conveying far more water than in the pre-European setting (Streamtec 2008). The design of the pumping station allows for baseflow to be maintained during the pumping season (Section 4.6).

7 Contingency program

7.1 Total annual water requirement shortfall

Supply of ground and surface water to the Wagerup Refinery is supplemented by water purchased from Harvey Water (see Section 2 for details). During periods of limited surface water supply, the Wagerup Operations water balance is carefully managed to ensure adequate fit-for-purpose water is available including through the purchase of additional water.

Water demand management will be considered as part of any expansion projects for the refinery and residue area. Outcomes of the considerations will be documented within relevant works approvals applications where appropriate,

7.2 Unexpected surface water quality trends

The parameters analysed and associated trigger levels for action have been identified in Table 9.

Table 9: Trigger levels – SP12

Parameter	Trigger level
pH	<5 or >9.5
EC	>2,000 µS/cm
Alkalinity*	>50 mg/L
Turbidity	>250 NTU
Sodium:chloride ratio*	>0.8

* Will only be reported upon when it coincides with an exceedance of pH or EC.

In the event that any of the trigger levels are exceeded (other than alkalinity or sodium:chloride ratio), monitoring will be repeated to confirm the result, and DWER will be notified within 14 days of the exceedance being confirmed. Once the matter has been investigated, Alcoa will ensure appropriate remedial actions are implemented to address identified deficiencies. Results of any investigations will be included in the annual report.

7.3 Flow meter failure

In the event of flow meter failure on an operable abstraction point, repair or replacement of the meter will be scheduled as soon as reasonably practical. For the period of flow meter failure, where the abstraction point is operating, reasonable estimates of abstraction volume will be applied. Internal records will be kept of the abstraction volume estimation.

8 Water use efficiency

Alcoa has developed a Water Efficiency Management Plan to ensure efficient, safe and sustainable management and protection of water resources and ecosystems in and around this facility. The plan is a working document and outlines potential pathways and action plans, to improve water efficiencies for the refinery and residue areas

Wagerup Refinery operates an efficient closed water circuit, which is supplemented for water losses. Aside from evaporation, there is no discharge of process water to the environment. Alcoa Wagerup has implemented a number of water efficiency measures in the past and has implemented systems to manage water use and loss on an ongoing basis. These are described below:

8.1 Water Accounting Loss and Control

Water is a critical raw material for refinery operations. Alcoa Wagerup reviews and updates the total water inventory, water demand and water usage monthly and reports corporate metrics in accordance with the Minerals Council of Australia's Water Accounting Framework. Important parameters such as inventory and inputs are trended over time and where applicable seasonal targets are set for management of levels and inputs.

Losses of water (from all water sources) from the refinery and residue include:

- Use of water for dust control;
- Evaporation from wet surface drying area;
- Evaporation from water storage areas;
- Water bound within the residue mud and sand;
- Steam and moisture from the refining process;
- Evaporation from cooling towers; and
- Moisture associated with products.

8.2 Minimising sprinkler water use

The largest use of water at the residue facilities is for operating sprinklers to control dust. Water use for the sprinkler system has increased significantly over the last few years, in response to more conservative dust management practices. While this has resulted in a significant improvement in dust management, the current dust management focus is now on maintaining dust performance while optimising water use. Alcoa use weather reports and real time monitoring to define where and when sprinklers will be used Where possible, pasture and residue rehabilitation are planted to provide dust control that does not need ongoing sprinkler water.

8.3 Water use efficiency pathways

Existing practices:
Wagerup Refinery operates a closed water circuit. A large percentage is recycled back into the process (2019 figure, 78%). The use of dewatering aid reduces the water content in products prior to the calcination process. This minimises water loss via steam from calcination.

Potential pathways:
Alcoa is exploring various water efficiency measures as detailed below in Table 10. Alcoa will provide an update on the status of these measures in the annual water monitoring summary.

Table 10: Proposed Water Efficiency Measures

Proposed Water Efficiency Measure	Proposed timing*
Increase condensate to lower dam to improve water reuse efficiency.	2020
Investigate technology options to reduce absolute use.	2020
Investigate potential alternative water supply options: • Less impacted by climate change • Available in summer • Minimal competing users • Drought provision	2021
Investigate options for improving abstraction of Harvey Pump Back.	2021
Evaluate options for evaporation control within the refinery.	2021
Review water dam design to determine best practice for reduced evaporation.	2022
Ensure ongoing demonstration of water management improvements (eg filtration).	2025 - 2029

*dates subject to change

8.4 Training

Personnel working for or on behalf of Alcoa Wagerup are made aware of their environmental responsibilities, including water conservation, prior to beginning work on site. Mandated online training packages, such as the 'General Environmental Awareness' package specifically mentions the importance of water conservation. Periodically the importance of water conservation, for example, the importance of reporting water leaks, may be reinforced via "toolbox talks".

8.5 Reporting

Refer to sections 1.5 and 7.2 of this document.

9 References

Alcoa of Australia 1978, Wagerup Alumina Project Environmental Review and Management Programme.

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Streamtec 2002a, Assessment of proposed water abstraction from the Lower Harvey River.

Streamtec 2005, Ecological Water Requirements and Water Availability in the Lower Harvey River (Main drain) Catchment Associated with the Proposed Wagerup 3 Expansion.

Streamtec 2006, Yalup Brooks & South Samson Drain: Adequacy of Environmental Water Provisions: Results from Biomonitoring, Streamtec Report 07/06.

Streamtec 2008, Sustainable yield: flows in the lower Harvey River Main Drain and South Samson Drain, Streamtec Report 06/08.

Water and Rivers Commission 1998, Proposed Harvey Basin Surface Water Allocation Plan. Water Resource Allocation and Planning Series. Water and Rivers Commission Report WRAP 14.

10 List of commitments

A summary of the commitments made in this Operating Strategy is provided in Table 10.

Table 10: Summary of Commitments

Section	Commitment
1.5.1	Abstraction volumes calculated from meter readings from all licences will be submitted to DWER by 30 January annually.
1.5.2	An annual report will be submitted to DWER by 31 March each year detailing the previous year's monitoring data.
1.5.3	A comprehensive triennial report will be submitted to DWER by 30 April every 3 years commencing 30 April 2020, for the period 2017-2019.
1.6	The Operating Strategy review will be initiated 10 years after approval.
4	Abstraction is managed in accordance with licence requirements and is maintained at or below licence limits.
4.7	Bore alteration, installation and decommissioning will be completed in accordance with Minimum construction requirements for water bores in Australia (NUDLC 2012) or any future updates, by an appropriately certified driller. Details will be provided in the annual report. Where this work results in the need for an update to the Operating Strategy an amendment will be submitted to the DWER within 28 days.
5	Water monitoring completed as per Section 5 of this document.
7.2	In the event that any of the trigger levels are exceeded (other than alkalinity or sodium:chloride ratio), monitoring will be repeated to confirm the result, and DWER will be notified within 14 days of the exceedance being confirmed. Once the matter has been investigated, Alcoa will ensure appropriate remedial actions are implemented to address identified deficiencies. Results of any investigations will be included in the annual report.
7.3	In the event of flow meter failure on an operable abstraction point, repair or replacement of the meter will be scheduled as soon as reasonably practical. For the period of flow meter failure, where the abstraction point is operating, reasonable estimates of abstraction volume will be applied. Internal records will be kept of the abstraction volume estimation.

11 Figures

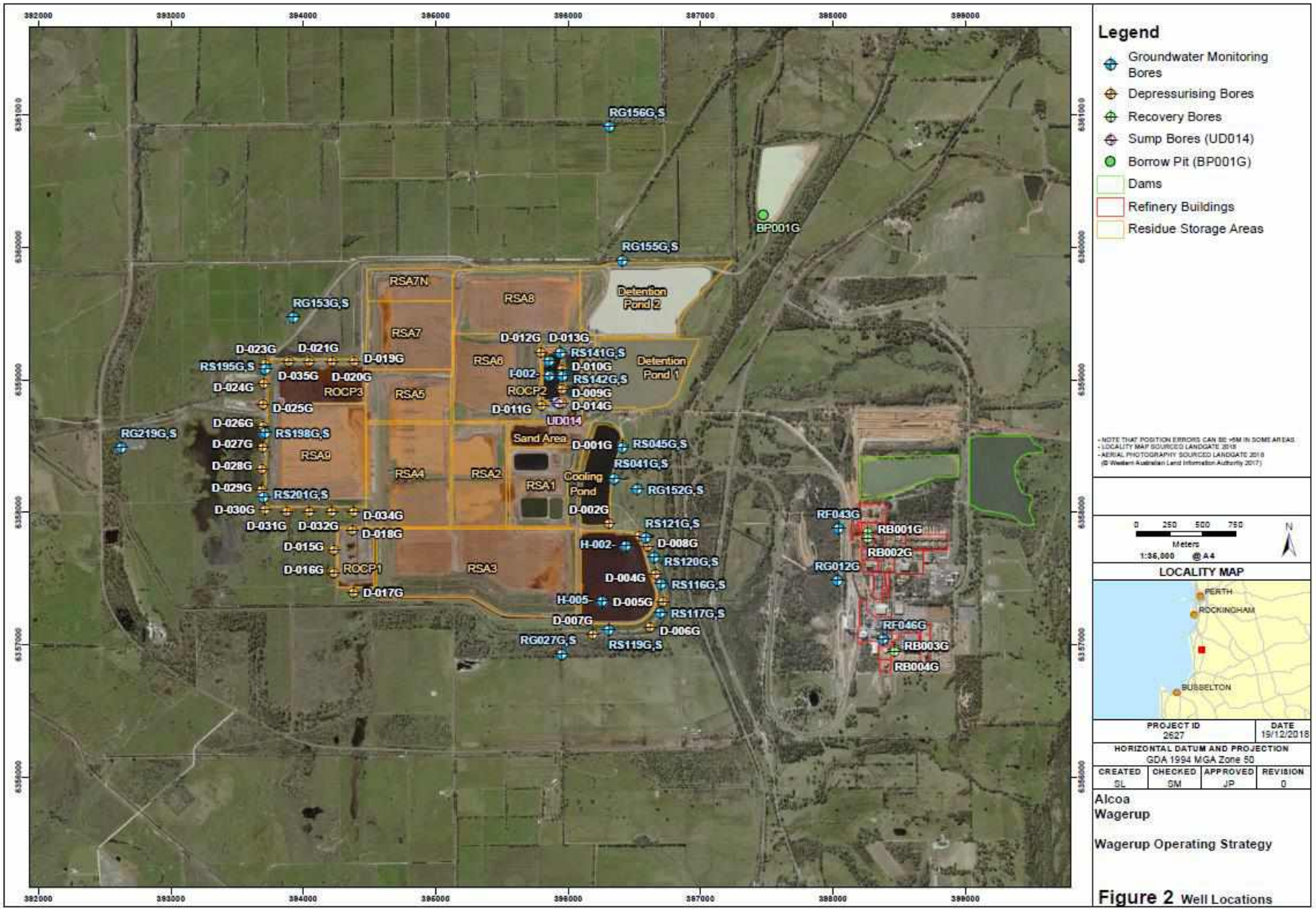
Figure 1: Wagerup Operations Site Location

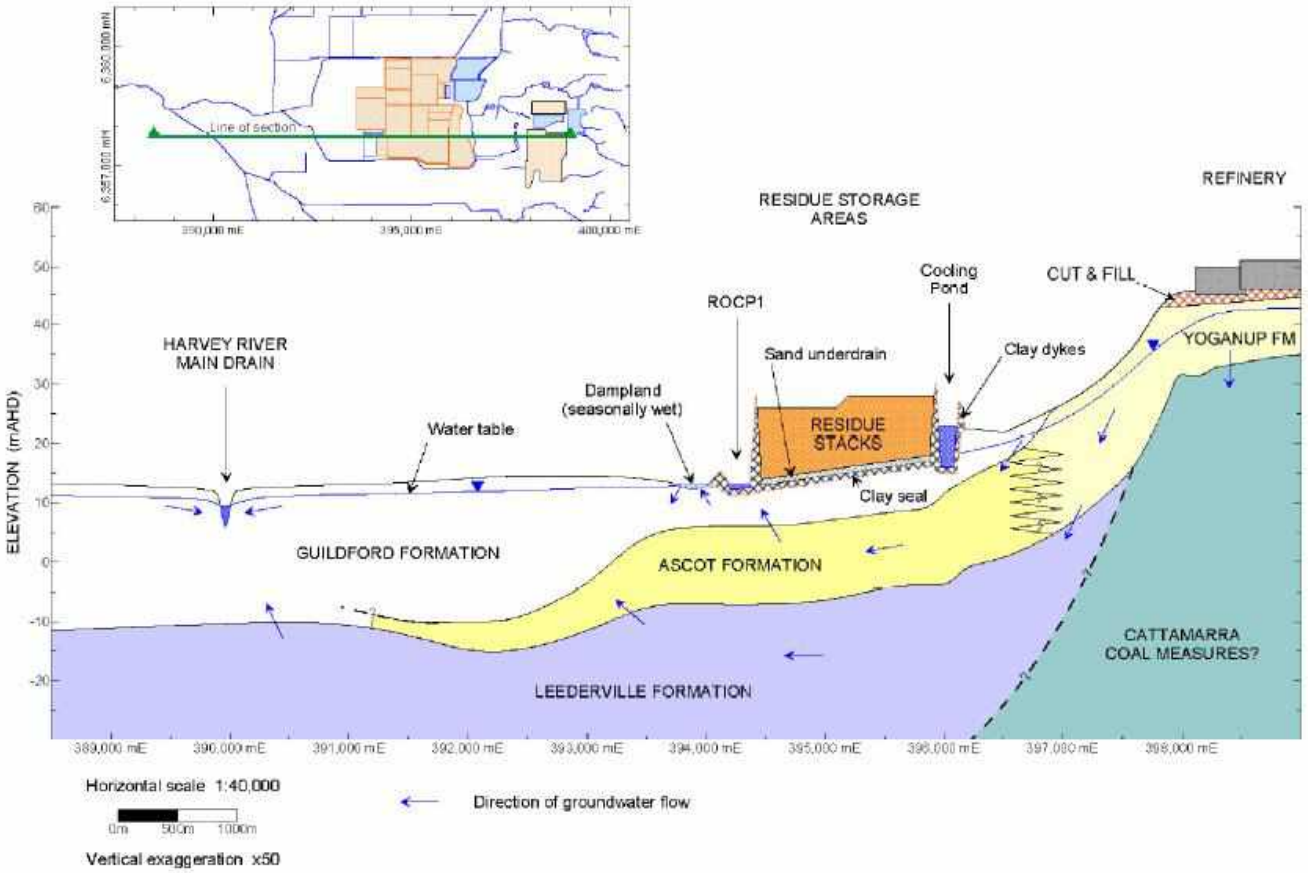
Figure 2: Well locations

Figure 3: Conceptual hydrogeological cross section of Wagerup region (Rockwater, 2017)

Figure 4: Wagerup surface water locations


384000
386000
388000
389000
6361000
6360000
6359000
6358000
6357000
6356000
John Rd
Borrow Pit
RSA7N
RSA8
Detention Pond 2
RSA7
Willowdale Rd
ROCP3
RSA6
ROCP2
Detention Pond 1
RSA5
Sand Area
RSA9
RSA4
RSA2
RSA1
Cooling Pond
South Yalup Lower Dam
South Yalup Upper Dam
ROCP1
RSA3
ROWS Pond
Marriott Rd
Hayes Rd
Trotter Rd
Somers Rd
Brockman Rd
Wellington Rd
Browns L
Bancell Rd
Legend
Refinery Buildings
Residue Storage Areas
Dams
Local Road
- NOTE THAT POSITION ERRORS CAN BE >5M IN SOME AREAS
- LOCALITY MAP SOURCED LANDGATE 2016
- AERIAL PHOTOGRAPHY SOURCED LANDGATE 2016
(© Western Australian Land Information Authority 2017)
0
500
1,000
N
Meters
1:30,000 @ A4
LOCALITY MAP
PERTH
ROCKINGHAM
BUSSELTON
PROJECT ID
2627
DATE
16/12/2016
HORIZONTAL DATUM AND PROJECTION
GDA 1994 MGA Zone 50
CREATED
SL
CHECKED
SM
APPROVED
JP
REVISION
0
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Wagerup
Wagerup Operating Strategy
Figure 1 Site Location


392000
393000
394000
396000
398000
397000
388000
399000
RG156G,S
BP001G
RG155G,S
RSA7N
RSA8
Detention Pond 2
RG153G,S
RSA7
D-012G
D-013G
D-023G
D-021G
RS141G,S
D-019G
RS195G,S
RSA6
D-010G
Detention Pond 1
D-035G
D-020G
I-002-
RS142G,S
D-024G
ROCP3
RSA5
ROCP2
D-009G
D-025G
D-011G
D-014G
UD014
D-026G
RS198G,S
RG219G,S
Sand Area
D-001G
RS045G,S
D-027G
RSA9
RS041G,S
D-028G
RSA4
RSA2
Cooling Pond
RG152G,S
RSA1
D-029G
RS201G,S
D-002G
D-030G
D-034G
RS121G,S
D-031G
D-032G
D-018G
H-002-
D-008G
D-015G
RS120G,S
D-016G
ROCP1
RSA3
D-004G
RS116G,S
D-017G
H-005-
D-005G
RS117G,S
D-007G
D-006G
RG027G,S
RS119G,S
RF043G
RB001G
RB002G
RG012G
RF046G
RB003G
RB004G
Legend
Groundwater Monitoring Bores
Depressurising Bores
Recovery Bores
Sump Bores (UD014)
Borrow Pit (BP001G)
Dams
Refinery Buildings
Residue Storage Areas
- NOTE THAT POSITION ERRORS CAN BE +5M IN SOME AREAS
- LOCALITY MAP SOURCED LANDGATE 2015
- AERIAL PHOTOGRAPHY SOURCED LANDGATE 2016
(© Western Australian Land Information Authority 2017)
0 250 500 750
Meters
1:36,000 @ A4
N
LOCALITY MAP
PERTH
ROCKINGHAM
BUSSELTON
PROJECT ID
2627
DATE
19/12/2018
HORIZONTAL DATUM AND PROJECTION
GDA 1994 MGA Zone 50
CREATED
SL
CHECKED
SM
APPROVED
JP
REVISION
0
Alcoa
Wagerup
Wagerup Operating Strategy
Figure 2 Well Locations



- NOTE THAT POSITION ERRORS CAN BE +5M IN SOME AREAS
- LOCALITY MAP SOURCED LANDGATE 2018
- AERIAL PHOTOGRAPHY SOURCED LANDGATE 2018
(© Western Australian Land Information Authority 2017)

LOCALITY MAP



PROJECT ID	DATE
2627	13/11/2018

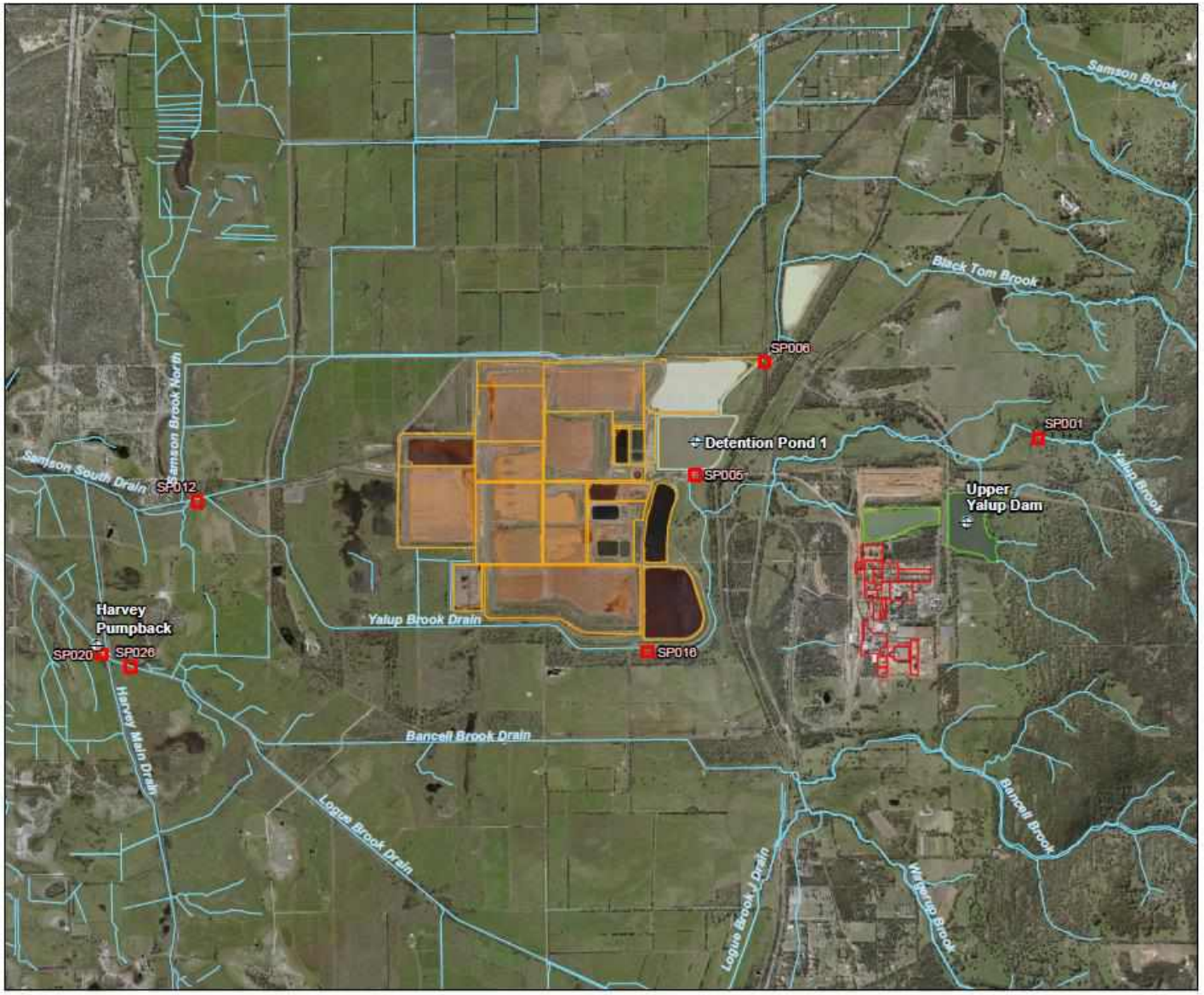
HORIZONTAL DATUM AND PROJECTION
GDA 1994 MGA Zone 50

CREATED	CHECKED	APPROVED	REVISION
SL	SM	JP	0

Alcoa
Wagerup

Wagerup Operating Strategy

Figure 3 Cross Section



Legend

- Surface Water Abstraction sites
- Surface Water Sampling Stations
- Stream/ Drain
- Residue Storage Areas
- Refinery Buildings
- Dams

- NOTE THAT POSITION ERRORS CAN BE >5M IN SOME AREAS
- LOCALITY MAP SOURCED LANDGATE 2016
- AERIAL PHOTOGRAPHY SOURCED LANDGATE 2016
(© Western Australian Land Information Authority 2017)

0 500 1,000 1,500 Meters
1:51,211 @ A4
N

LOCALITY MAP



PROJECT ID	DATE
2527	19/12/2016

HORIZONTAL DATUM AND PROJECTION
GDA 1994 MGA Zone 50

CREATED	CHECKED	APPROVED	REVISION
SL	SM	JP	0

Alcoa
Wagerup

Wagerup Operating Strategy

Figure 4
Surface Water Locations

APPENDIX C

Previous groundwater and surface water operating strategies (2017 & 2018)

Addendum to a water resource operating strategy associated with a water licence issued by the Department of Water

Name of licensee: Alcoa of Australia Limited

This addendum applies to:

- Water resource licence number: **GWL160881, GWL102669**
- The associated water resource operating strategy approved by the Department of Water on 26/3/2015

Intent

The intent of this addendum is to formalise the licensee's commitment to:

- provide data collected in accordance with this operating strategy to the department by 31st March annually; and
- to provide a comprehensive report triennially in line with Department of Water (DOW) 'Operational Policy no. 5.12 – Hydrogeological reporting associated with a groundwater well licence, Nov 2009' commencing 30th April 2020; and
- amend Table 5.1.1 to reflect accurate meter details.
- amend Table 5.1.2 to reflect accurate meter characteristics for Bore D002G
- monitor according to the updated table 5.2.1

Commitment(s)

The following commitments/text within the operating strategy is amended by the following:

1. Section 1.5 replaced

Section 1.5 of the operating strategy is deleted, and replaced with:

1.5 Reporting

Meter Readings

Abstraction volumes calculated from meter readings for all licences listed in Section 1.2 will be provided to the Department of Water and Environmental Regulation (DWER) on an annual basis as required by the respective licences.

Annual Report

The groundwater monitoring data collected in accordance with this strategy as outlined in Table 5.2.1 will be provided to DWER on 31st March annually.

Triennial Report

A comprehensive triennial report will be submitted to DWER by 30th April every 3 years commencing 30 April 2020. The content will be in line with DoW 'Operational policy no. 5.12 – Hydrogeological reporting associated with a groundwater well licence, Nov 2009'.

2. Tab le 5.1.1 amendment

Delete Table 5.1.1 'Flow meter details for recovery bores' and replace with:

Table 5.1.1. Flow meter details for recovery bores

Bore name	*Type of Flow Meter*	*Meter Recording Frequency*	*Calibration checks*	*Emergency Notification for Meter Failure*
RB001G	*Magflow and pulse flow*	*Continuous*	*6-monthly*	*Regular operator checks*
RB002G	*Magflow and pulse flow*	*Continuous*	*6-monthly*	*Regular operator checks*
RB003G	*Magflow and pulse flow*	*Continuous*	*6-monthly*	*Regular operator checks*
RB004G	*Magflow and pulse flow*	*Continuous*	*6-monthly*	*Regular operator checks*

3. Table 5.1.2 amendment

Table 5.1.2 of the operating strategy is amended for Bore name 'D-002G'

Bore name	*Type of Flow Meter*	*Meter Recording Frequency*	*Calibration Checks*	*Emergency Notification for Meter Failure*
D-002G	*Digital Magflow*	*Continuous*	*Annual*	*Regular operator checks*

4. Table 5.2.1 replaced

Table 5.2.1 of the operating strategy is deleted, and replaced with:

Table 5.2.1. Wagerup Operations Groundwater Monitoring Objectives and Monitoring Program

Monitoring Objective	*Groundwater Monitoring Sites*	*Monitoring Program*
1A) Measure and calibrate flow from the production, recovery and depressurising bores to provide a reliable estimate of abstraction volumes	*D-002G, D-004G, D-006G, D-007G, D-008G, D-010G, D-013G, D-014G, D-019G, D-020G, D-021G, D-023G, D-024G, D-025G, D-026G, D-027G, D-028G, D-029G, D-030G, D-031G, D-032G, D-033G, D-034G, D-035G, RB001G, RB002G, RB003G, RB004G, UD014-*	*Flow measurements and calibration as detailed in Tables 5.1.1 and 5.1.2*
1B) Access the suitability of abstracted and recovered water for its beneficial end use	*D-002G, D-004G, D-006G, D-007G, D-008G, D-010G, D-013G, D-014G, D-019G, D-020G, D-021G, D-023G, D-024G, D-025G, D-026G, D-027G, D-028G, D-029G, D-030G, D-031G, D-032G, D-033G, D-034G, D-035G, UD014-*	*Annual pH, EC, alkalinity*
	RB001G, RB002G, RB003G, RB004G	*Annual comprehensive analysis*
1C) Access the change in water levels and water quality in the superficial formation due to abstraction	*RG012G, RG027S, RG027G, RG152S, RG152G, RG153S, RG153G, RG155S, RG155G, RG156S, RG156G, RG219S, RG219G, RS195S, RS195G, RS198S, RS198G, RS201S, RS201G*	*Quarterly groundwater levels* *Annual pH, EC, alkalinity*
4C) Access whether abstraction rates from the superficial formation recovery systems are sufficient to inhibit migration of alkaline water	*RF043G, RF046G*	*6-monthly groundwater levels, pH, EC, alkalinity* *Annual comprehensive analysis*
6A) Access whether abstraction rates from the depressurising bores are sufficient to maintain the target uplift pressure	*I-003-, I-002-, I-003-, H-002- H-005-, RS041S, RS041G, RS045S, RS045G, RS116S, RS116G, RS117S, RS117G, RS119S, RS119G, RS120S, RS120G, RS121S, RS121G, RS137S, RS137G, RS141S, RS141G, RS142S, RS142G*	*Monthly groundwater levels*

Notes:

1) *The monitoring program is based on the 2015 Alcoa Water Monitoring Programme Review (Ecotech, 2015).*
2) *Flow meters and sampling locations may be exempt from calibration checks and/or monitoring in the following circumstances:*
   - *the flow site is not operating or there is insufficient water to sample;*
   - *the flow site, flow meter or sampling location is not accessible;*
   - *the sampling location is blocked;*
   - *the sampling location has insufficient water to sample;*
   - *the calibration or monitoring equipment is not functioning; or*
   - *the calibration or monitoring equipment is not available.*

3. Section 10 amended

Section 10 of the operating strategy 'Summary List of Commitments' table deleted for 'Topic – Reporting' and replaced with:

Topic	*Operating Strategy Section*	*Commitment*
Reporting	*1.5*	*Abstraction volumes calculated from meter readings from all licences will be submitted to DWER as required by the respective licences.*
		The groundwater monitoring data collected in accordance with this strategy as outlined in Table 5.2.1 will be provided to DWER on 31st March annually.
		A comprehensive triennial report will be submitted to DWER by 30th April every 3 years commencing 30 April 2020 in accordance with 'Operational policy no. 5.12'.

Amending the addendum to the water resource operating strategy

The licensee may apply to amend this addendum at any time, to account for exceptional circumstances.

Agreement

I acknowledge that compliance with the approved addendum to the operating strategy is a condition of holding a licence, as issued under Section 5C of the Rights in Water and Irrigation Act 1914, to take and use water and I hereby agree to implement the commitment(s) within this operating strategy addendum.

Signatures

Person legally responsible for water licence ..... **Date** 28/11/2017

printed name: Mark Hodgson

Approved by Department of Water delegated authority ..... **Date** 28/11/17

printed name: CARMEL SULLIVAN

Addendum to a water resource operating strategy associated with a water licence issued by the Department of Water

Name of licensee: Alcoa of Australia Ltd.

This addendum applies to:

- Water resource licence number: **GWL102669, GWL160881**
- The associated water resource operating strategy approved by the Department of Water on 26/3/2015

Intent

The intent of this addendum is to formalise the licensee's commitment to record the amount of water abstracted from the borrow pit (BP001G) and subliner drain (UD014-).

This water will be licensed as part surface water and part groundwater due to a potential groundwater connection within the borrow pit.

Commitment(s)

The following commitments/text within the operating strategy is amended by the following:

1. Section 1.1 amendment

The following sentence of Section 1.1 of the operating strategy is deleted:

> *The groundwater abstraction system at Wagerup Refinery consists of four groundwater recovery bores and a series of shallow depressuring bores.*

And replaced with:

> *The groundwater abstraction system at Wagerup Refinery consists of four groundwater recovery bores, a series of shallow depressurising bores, a subliner drain and a borrow pit with a potential groundwater connection.*

2. Section 1.2 replaced

Section 1.2 of the operating strategy is deleted, and replaced with:

> *The water year for the purposes of reporting against this Strategy is from 1st January to 31st December twelve months later (as specified by the licences in table 1.2.1).*
>
> *Licences covered by this Operating Strategy are listed in table 1.2.1.*

Table** Error! No text of specified style in document..**1. Licensed volumes

Source	*Licence Number*	*Licensed Amount (kLpa)*
Lot 700	*GWL 160881*	*146,600*
Lot 205	*GWL 102669*	*550,000*

3. Section 2.1 amendment

Section 2.1 of the operating strategy is deleted, and replaced with:

Maps showing bore, subliner and borrow pit locations are provided in Section 7.

4. Section 2.3 amendment

Section 2.3 of the operating strategy is deleted, and replaced with:

The eight shallow groundwater wells (depressurising bores D-002G, D-004G, D-006G, D-007G, D-008G, D-010G, D-013G, D-014G) managed under GWL 102669 were constructed between 1985 – 1997 in the vicinity of lined storage facilities in the residue storage area.

The purpose of the depressurising systems is to manage the groundwater levels beneath these facilities, and prevent upward pressures on the clay liners developing to an extent that could compromise liner integrity. All bores draw groundwater from the Superficial Formation.

Depressurising systems are used to control groundwater pressures beneath the residue storage area. To further reduce uplift pressure on the ROCP2 liner a subliner drainage system was installed. Groundwater that is collected by this system collects in a sump and is pumped out by UD014-.

Water derived from the depressurising bores and the subliner drainage system is used in the alumina refining circuit. The discharge from these bores and subliner drains is directed into adjacent water storage facilities.

Bores D-019G – D-021G and D-023G – D-035G were installed outside the footprint of Residue Storage Area 9 (RSA9) and Run-Off Collection Pond 3 (ROCP3). These bores were used to maintain the groundwater level below the base of the liner during the construction of these facilities. RSA9 now contains sufficient residue to balance maximum groundwater uplift pressures on the liner and under standard operating conditions ROCP3 contains sufficient water to balance maximum groundwater uplift pressures (Clifton, 2016). These bores may be utilised again to reduce the pressure build up under ROCP3 if it is required to be emptied for maintenance or repair work, they may also be used as production bores for make up water for use in the alumina refining circuit.

Details of the depressurising bores and subliner drain sumps are provided Table 2.3.1

There are an additional 10 depressurising bores currently out of circuit, which are utilised to further reduce the pressure build up under storage areas if ponds are required to be emptied for maintenance or repair work. These bores are listed in Table 2.3.2.

5. Table 2.3.1 amendment

Delete Table 2.3.1 heading and replace with:

Table 2.3.1. Depressurising bore and subliner sump details

Insert the following row to Table 2.3.1.

Bore name	AMG84 grid coordinates		Formation	Elevation TOC (mAHD)	Slot/Screen Interval (m)	
	East	North			Top	Bottom
UD014-	395,805.9	6,358,704.5	Guildford Clay and Yoganup Formation	21.20	N/A	10.7

6. Insert Section 2.4

Insert Section 2.4 to the operating strategy:

2.4 Borrow Pit

Alcoa has excavated clay for use in construction of the residue storage areas from an area north of the Refinery, this area is known as the Borrow Pit. The floor of the Borrow Pit has been compacted by heavy vehicle movement but it is not formally lined. At times of the year the base of the borrow pit intersects the water table and therefore groundwater can collect in the Borrow Pit. Rainfall and surface water runoff also collect in the Borrow Pit. Water derived from this source is used in the alumina refining circuit.

Detail of the Borrow Pit is provided Table 2.4.1

Table 2.4.2. Borrow Pit Details

Source name	AMG84 grid coordinates		Formation	Elevation (mAHD)	Maximum depth (m)	Capacity (m^3)
	East	North				
BP001G	397,362	6,360,044	Guildford Clay and Yoganup Formation	24.9	9	900,000

7. Section 4.2 amendment

Section 4.2 of the operating strategy is deleted, and replaced with:

4.2 Depressurisng bores and Subliner Sump

Depressurising bores are operated in accordance with licence requirements and groundwater abstraction is maintained at or below licence limits.

Groundwater levels in the formations underlying the ponds are controlled by separate bore fields. The licensed bore fields consist of:

- *Cooling Pond production bore D-002G*
- *ROWS Pond production bores D-004G, D-006G, D-007G, D-008G*
- *ROCP2 production bores D-010G, D-013G, D-014G and subliner UD014-*
- *ROCP3 production bores D-019G, D-020G, D-021G, D-023G, D-024G, D-025G, D-035G*

- *RSA9 production bores D-026G, D-027G, D-028G, D-029G, D-030G, D-031G, D-032G, D-033G, D-034G*

There are 10 additional bores, as listed in ***Table 2.3.2****, available to assist the groundwater level management during maintenance activities; however these are not utilised during normal operating conditions.*

Groundwater levels in the vicinity of the ponds are measured in several monitor bores and in pressure sensors (vibrating wire piezometers).

Decisions on which bores to operate are based on groundwater and pond water levels. The general operating criterion is to keep the groundwater levels in the underlying formations below the fluid surface levels of the ponds.

Water from all depressurising bores is used within the Refinery and residue processes.

8. Insert Section 4.3

Section 4.3 is inserted in the operating strategy:

4.3 Borrow Pit

The borrow pit is operated in accordance with this operating strategy and groundwater abstraction is maintained at or below licence limits.

Abstraction from the Borrow Pit will be metered. To determine the groundwater contribution of the abstracted volume a water balance will be calculated based on the monthly water levels in the Borrow Pit, rainfall, evaporation and the metered abstraction.

9. Section 5.1 "Depressurising bores" amendment

The following sentence of Section 5.1 "Depressurising bores" of the operating strategy is deleted:

Depressurising bores are monitored daily by the Process Operators. Flow rates and abstraction figures are recorded on the Alcoa data system (LCN).

And replaced with:

Flow rates and abstraction figures are recorded in Alcoa's data system.

10. Table 5.1.2 replaced

Delete Table 5.1.2 heading and replace with:

Table 5.1.2 Flow meter details for residue bores and subliners

Insert the following row to Table 5.1.2

Bore name	Type of Flow Meter	Meter Recording Frequency	Calibration Checks	Emergency Notification for Meter Failure
UD014-	Digital Magflow	Continuous	Annual	Regular operator checks

11. Section 5.1 Insert 'Borrow Pit'

Insert the below section in the operating strategy after Table 5.1.2

Borrow Pit

Water is extracted from the Borrow Pit in winter or early summer, as required. A summary of flow metering is provided in Table 5.1.3.

Table 5.1.3. Flow metering details for the Borrow Pit

Site name	Type of Flow Meter	Meter Recording Frequency	Calibration Checks	Emergency Notification for Meter Failure
BP001G	Mechanical	Monthly	Annual	Regular operator checks

The groundwater abstracted from the borrow pit is calculated using the following equation:

*Groundwater = Volume (End of Month) - Volume (End of Previous Month) - (Month rainfall * Borrow Pit Surface Area) + (Month evaporation * Borrow Pit Surface Area at end of month water level) + Water Measured Out from Borrow Pit*

12. Section 5.2 Amendment

Insert the below sentence at the end of section 5.2.

BP001G will be monitored annually for pH, EC and alkalinity.

13. Figure 7.4 Addition

Insert Figure 7.4 to the operating strategy

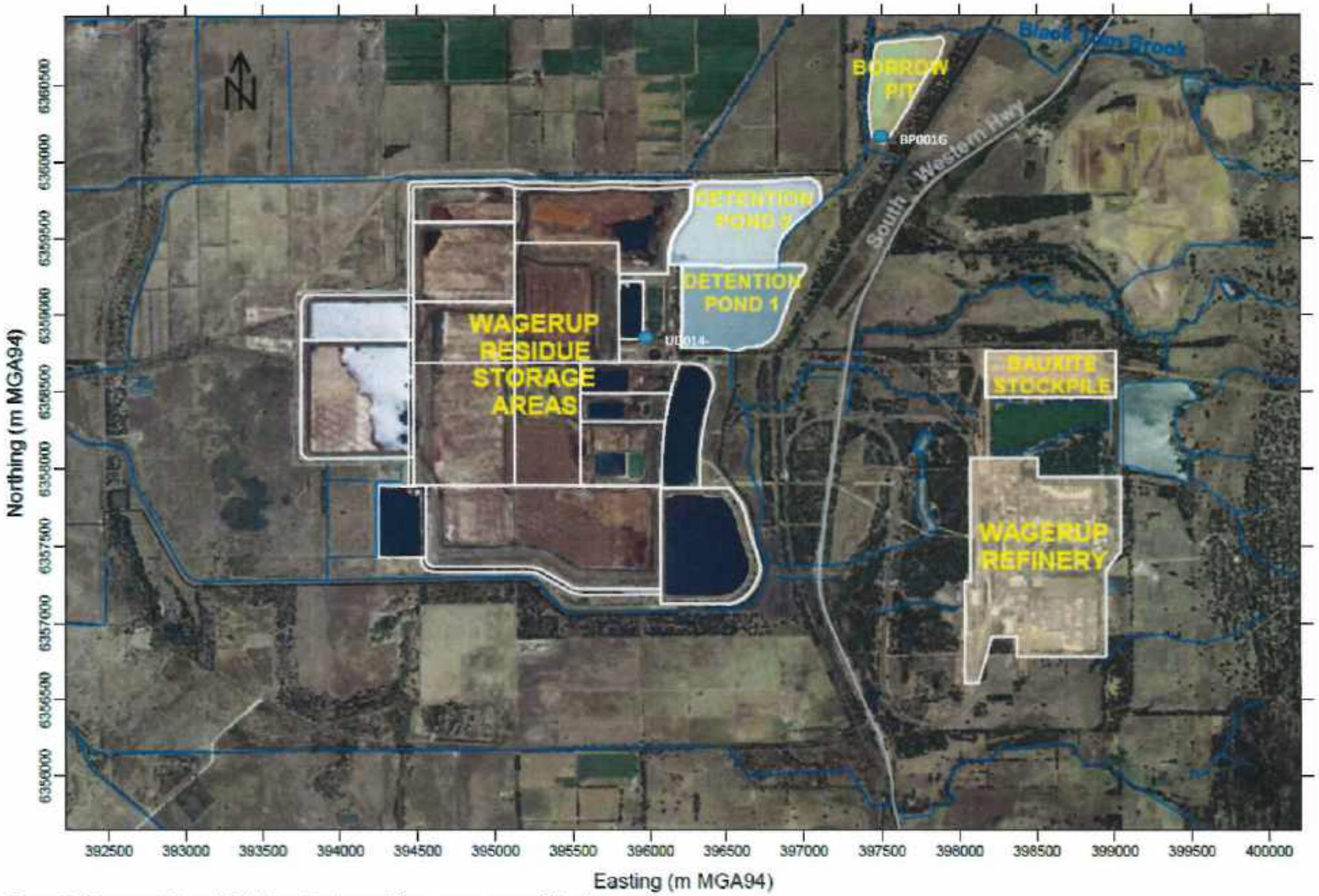


Figure 7.4 Borrow Pit and Subliner Drainage (figure courtesy of Rockwater)

14. Section 10 amended

Section 10 of the operating strategy 'Summary List of Commitments' table addition for 'Operating Rules – Borrow Pit'.

Topic	*Operating Strategy Section*	*Commitment*
Operating Rules – Borrow Pit	*4.3*	*The borrow pit is operated in accordance with this operating strategy and groundwater abstraction is maintained at or below licence limits. **Abstraction from the Borrow Pit will be metered. To determine the** groundwater contribution of the abstracted volume a water balance will be calculated based on the monthly water levels in the Borrow Pit, rainfall, evaporation and the metered abstraction.*

Amending the addendum to the water resource operating strategy

The licensee may apply to amend this addendum at any time, to account for exceptional circumstances.

Agreement

I acknowledge that compliance with the approved addendum to the operating strategy is a condition of holding a licence, as issued under Section 5C of the Rights in Water and Irrigation Act 1914, to take and use water and I hereby agree to implement the commitment(s) within this operating strategy addendum.

Signatures

Person legally responsible for water licence ..... **Date** 28/11/2017

printed name: Mark Hodgson

Approved by Department of Water delegated authority ..... **Date** 28/11/17

printed name: CARMEL SULLIVAN

Alcoa World Alumina – Australia

Wagerup Refinery

Ground Water Licences

Operating Strategy

This Operating Strategy has been developed as a requirement of Ground Water Licences issued to Alcoa of Australia Ltd under the *Rights in Water and Irrigation Act 1914.* Licences issued cover extraction of groundwater at the Wagerup Refinery. The purpose of this Strategy is to detail water resource management measures implemented at the Wagerup Refinery, and to ensure compliance with groundwater licences. This Strategy also describes measures proposed for efficient water use and the reduction of potential impacts on the environment and other water users.

Name of water licence licensee:	Alcoa of Australia Ltd
Name of facility:	Wagerup Alumina Refinery
Legal description of properties:	*Lot 205 on Plan 34250 – Vol/Fol: 2540/866* *Lot 700 on Plan 59305 – Vol/Fol: 2708/955*

I understand that the commitments given in the attached operating strategy will be a condition of an associated water licence if approved and that a breach of a commitment or any licence condition may be an infringement of the Rights in Water and Irrigation Act 1914.

Signatures

Authorised by: _____ Date: 25/3/2015

Printed name: Jocelyn Zimmerman Position: Environmental Manager

Approved delegated authority Department of Water: _____ Date: 26/3/15.

Printed name: ALAN COOK

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Revision History

Revision number	Date	Revision Details
1	February 2013	First issue
2	March 2015	• Two new recovery bores included • Monitoring Program updated

1. Administrative Requirements

1.1. Overview of Operations

Wagerup Refinery and associated bauxite residue storage facilities are located 120 km south of Perth, 2 km north of Yarloop and 7.5 km south of Waroona. The Refinery is located close to the foot of the Darling Scarp and is separated from the residue storage areas (RSAs) by the South West Highway and the Perth-Bunbury rail line. Bauxite is supplied to the Refinery by overland conveyor from the Willowdale Mine located 15 km to the east. Alumina produced at Wagerup is shipped via the Alcoa shipping terminal at Bunbury. Transport between the Refinery and port is by rail.

The Refinery and residue operations are contained within freehold land owned by Alcoa. Land use on adjacent properties is primarily agricultural.

The groundwater abstraction system at Wagerup Refinery consists of four groundwater recovery bores and a series of shallow depressurising bores.

1.2. Applicability

The water year for the purposes of reporting against this Strategy is from 1 January to 31 December.

Licences covered by this Operating Strategy include:

- GWL 160881 (Recovery Bores)
- GWL 102669 (Depressurising Bores)

1.3. Contacts

Department of Water

Program Manager
Department of Water
PO Box 332
Mandurah WA 6210
Phone: (08) 9550 4217

Wagerup Refinery

Environmental Manager
Wagerup Refinery
PO Box 84
Waroona WA 6215
Phone: (08) 9733 8119 *Fax:* (08) 9733 8534

1.4. Duration of Strategy

This strategy shall remain current for a maximum of five years from the date of approval by the Department of Water (DoW). The strategy should be reviewed under the following circumstances:

- at least three months prior to the expiry of this Strategy;
- if monitoring indicates adverse trends or unexpected performance;
- if there is a significant change to the refinery's water requirements;
- if requested by Alcoa and agreed by the DoW; or
- if directed by the DoW following consultation with Alcoa.

1.5. Reporting

Meter Readings

Abstraction volumes are recorded monthly for all licences listed in **Section 1.2** and are provided to the DoW on an annual basis as required by the respective licences.

Annual Report

To meet the reporting requirements of this Strategy, an annual report will be submitted to the DoW by 31 March each year to cover the previous reporting period (being 1 January to 31 December). In recent years, the report has been in the form of Wagerup Refinery's Annual Review of Groundwater and Surface Water Monitoring Data, which has been determined to meet this annual reporting requirement. Alcoa routinely reviews all of its reports to ensure they remain appropriate and current and as such the format or information covered within the report is subject to periodic change. The following minimum reporting requirements will be retained:

- volume of water used by Alcoa from the various licensed sources during the reporting period;
- groundwater quality data as required by DoW licence conditions;
- groundwater level data as required by DoW licence conditions;
- an assessment of the effects of draw on the underground water resources of the area as determined from the monitoring data;
- an assessment of the monitoring program and recommendations for any desirable changes to the program;
- reporting of adverse trends or unexpected performance noted during reporting period;
- breaches of operating strategy and corresponding remedial actions;
- rainfall data; and
- an outline of any likely changes to the refinery water requirements / operational strategy for next reporting period.

2. Water Source Description

2.1. Summary of groundwater licences

Wagerup Refinery's current groundwater licences are detailed in **Table 2.1.1**.

Table 2.1.1. Licensed volumes

SOURCE	Licence Number	Licensed Amount (kLpa)
Recovery Bores	GWL 160881	146,600
Depressurising Bores	GWL 102669	550,000

Maps showing bore locations are provided in **Section 7**.

2.2. Recovery bores

Two groundwater wells were installed in the Refinery in 2006, and a further two in 2014, for the purposes of recovering groundwater contaminated with high pH liquors from the refining process. These bores were commissioned in late 2007 (RB001G and RB002G) and 2014 (RB003G and RB004G).

These recovery bores pump contaminated groundwater from the aquifer into nearby process tanks, from where it is utilised in the refinery.

The bores are equipped with air-displacement pumps and have screens within the Lower Superficial Formation. Details of the bores are provided in **Table 2.2.1**.

Table 2.2.1. Recovery bore details

Bore name	AMG84 grid coordinates		Formation	Elevation TOC (mAHD)	Slot/Screen Interval (m bgl*)	
	East	North			Top	Bottom
RB001G	397,996.4	6,357,724.5	Yoganup Formation	47.57	8.0	14.0
RB002G	397,996.9	6,357,686.1	Yoganup Formation	45.50	8.0	14.0
RB003G	398,310.8	6,356,910.7	Yoganup Formation	49.07	12.0	15.0
RB004G	398,311.0	6,356,890.7	Yoganup Formation	48.90	11.7	14.7

*bgl: below ground level

2.3. Depressurising bores

The eight shallow groundwater wells (depressurising bores D-002G, D-004G, D-006G, D-007G, D-008G, D-010G, D-013G, D-014G) covered under GWL 102669 were constructed between 1985 – 1997 in the vicinity of lined storage facilities in the residue storage area. Sixteen shallow depressurising bores have also been installed outside the footprint of Residue Storage Area 9 (RSA9) and Run-Off Collection Pond 3 (ROCP3).

The purpose of the depressurising systems is to manage the groundwater levels beneath these facilities, and prevent upward pressures on the clay liners developing to an extent that could compromise liner integrity. All bores draw groundwater from the Lower Superficial Formation.

Depressurising systems are used to control groundwater pressures beneath four water storage facilities: Cooling Pond, Run-Off Water Storage (ROWS) Pond, Run-Off Collection Pond 2 (ROCP2) and ROCP3.

Depressurising bores have also being used to initially control groundwater pressures beneath RSA9 during commissioning.

Water derived from the depressurising bores is used in the alumina refining circuit. The discharge from these bores is directed into adjacent water storage facilities.

Details of the depressurising bores are provided in **Table 2.3.1.**

Table 2.3.1. Depressurising bore details

Bore name	AMG84 grid coordinates		Formation	Elevation TOC (mAHD)	Slot/Screen Interval (m)	
	East	North			Top	Bottom
D-002G	396,186.9	6,357,791.1	Guildford Clay and Yoganup Formation	26.82	19.5	28.4
D-004G	396,535.8	6,357,410.1		22.22	9.8	19.7
D-006G	396,496.3	6,357,010.2		20.88	11.1	20.0
D-007G	396,065.0	6,356,955.7		19.00	13.2	22.1
D-008G	396,478.1	6,357,619.0		22.93	11.3	20.2
D-010G	395,830.8	6,358,955.5		19.30	14.6	23.6
D-013G	395,811.0	6,359,089.3		19.50	14.6	23.6
D-014G	395,830.0	6,358,706.5		19.36	15.6	24.6
D-019G	394,259.9	6,359,013.2	Ascot Formation	16.46	15.2	21.2
D-020G	394,090.5	6,359,013.6		16.10	15.2	21.2
D-021G	393,919.2	6,359,015.6		15.81	11.9 18.7	14.9 21.7
D-023G	393,592.1	6,359,001.3		14.92	11.5 18.5	14.5 21.5
D-024G	393,578.4	6,358,846.5		14.84	9.0 19.0	12.0 22.0
D-025G	393,573.0	6,358,692.5		15.27	10.5 18.0	13.5 21.0
D-026G	393,573.3	6,358,530.7		15.06	11.0 19.3	14.0 22.3
D-027G	393,570.0	6,358,368.5		15.01	10.2 18.7	13.2 21.7
D-028G	393,566.4	6,358,208.5		15.04	12.0 19.0	15.0 22.0
D-029G	393,563.4	6,358,045.8		14.68	11.5	17.5
D-030G	393,587.4	6,357,896.8		15.17	12.0 18.7	15.0 21.7
D-031G	393,752.2	6,357,881.5		15.06	13.6 19.6	16.6 22.6
D-032G	393,918.6	6,357,880.8		14.83	11.0	17.0
D-033G	394,089.9	6,357,880.7		15.20	11.2 18.2	14.2 21.2
D-034G	394,254.3	6,357,879.5		14.87	13.4	19.4
D-035G	393,765.9	6,359,015.5		15.71	12.0 16.3	15.0 22.3

There are an additional 10 depressurising bores currently out of circuit, which are utilised to further reduce the pressure build up under storage areas if ponds are required to be emptied for maintenance or repair work. These bores are listed in **Table 2.3.2.**

Table 2.3.2. Additional depressurising bore details

Bore name	AMG84 grid coordinates		Formation	Elevation TOC (mAHD)	Slot/Screen Interval (m)	
	East	North			Top	Bottom
D-001G	396,286.0	6,358,389.1	Guildford Clay and Yoganup Formation	25.58	8.8	26.7
D-003G	396,413.8	6,357,700.7		22.89	15.4	21.1
D-005G	396,592.1	6,357,200.7		20.53	7.3	18.8
D-009G	395,831.0	6,358,808.5		20.32	14.4	23.4
D-011G	395,676.0	6,358,684.6		21.45	17.1	26.1
D-012G	395,671.1	6,359,089.4		21.09	15.1	24.1
D-015G	394,107.6	6,357,597.8		15.43	12.8	21.8
D-016G	394,107.4	6,357,419.8		15.48	11.5	14.6
D-017G	394,253.5	6,357,275.0		15.79	12.3	21.3
D-018G	394,247.2	6,357,743.9		15.51	10.8	19.8

3. Identifying & Managing Impacts

3.1. Environmental Protection and Monitoring Objectives

Alcoa has established a set of Environmental Protection Objectives for the Wagerup Alumina Refinery using a risk assessment methodology that is consistent with guidelines published as part of the National Water Quality Management Strategy. The Environmental Protection Objectives relevant to the groundwater licences are listed in **Table 3.1.1**.

Table 3.1.1. Ground Water Environmental Protection Objectives for the Wagerup Alumina Refinery

Relevant objective number	Environmental Protection Objective	Applicability
1	Abstraction of groundwater is undertaken in a manner that is sustainable and does not have a long-term detrimental effect on the environment or the beneficial use of groundwater resources.	Groundwater Licences Operating Strategy
4	Alkali recovery systems are operated to reduce the effect of seepage on groundwater receptors.	Groundwater Licences Operating Strategy
6	The integrity of the clay-geomembrane composite liners for process water ponds is maintained.	Groundwater Licences Operating Strategy

Monitoring is used to identify environmental impacts, and assist in achieving the environmental protection objectives. **Table 3.1.2** shows Monitoring Objectives to achieve the Environmental Protection Objectives as identified in **Table 3.1.1** above as being applicable to the Groundwater Licences Operating Strategy.

Table 3.1.2. Environmental Monitoring Objectives relating to Ground Water Environmental Protection Objectives

Environmental Protection Objective	Monitoring objectives
Objective 1: Abstraction of groundwater is undertaken in a manner that is sustainable and does not have a long-term detrimental effect on the environment or the beneficial use of groundwater resources.	1A) Maintain abstraction below sustainable yield from the superficial aquifer 1C) Assess whether abstraction from the superficial aquifer affects surrounding properties and natural water courses
Objective 4: Alkali recovery systems are operated to reduce the effect of seepage on groundwater receptors.	4A) Measure and calibrate flows from recovery bores to provide reliable estimates of groundwater production volumes 4C) Assess whether recovery system production rates are sufficient to inhibit the vertical migration of alkaline water from the superficial aquifer to the deeper formations
Objective 6: The integrity of the clay-geomembrane composite liners for process water ponds is maintained.	6A) Measure and calibrate flows from the depressurising bores to provide a reliable estimate of abstraction 6B) Assess whether abstraction rates from the superficial formations are sufficient to maintain groundwater pressures 1 m below the surface water levels at the ROWS Pond, Cooling Pond, ROCP2, RSA9 and ROCP3. 6D) Assess whether operation of the depressurising system affects water quality beneath the ROWS Pond, Cooling Pond, ROCP2, RSA9 and ROCP3.

Management response when Environmental Protection Objectives are threatened will consider modifications to abstraction regimes, commissioning of further studies / monitoring, sourcing alternative water supplies or other actions which address the identified issue. Management response is further outlined in **Section 6** of this report.

4. Operating Rules

4.1. Recovery Bores

Recovery bores are operated in accordance with licence requirements and groundwater abstraction is maintained at or below licence limits.

The two recovery bores (RB001G and RB002G) adjacent to Building 26 and two recovery bores (RB003G and RB004G) adjacent to Building 45 at Wagerup Refinery are operated on a continuous basis (allowing for maintenance when required) to enable maximum recovery of contaminated groundwater. Performance of these bores is assessed annually as part of the annual report.

Recovery bores are monitored daily by the Process Operators with the aim of being online continuously through the year. The abstraction rate and flow rates for the recovery system are calculated from information provided by water monitoring and continuous flow monitoring.

Water from the recovery system is used within the Refinery process.

4.2. Depressurising Bores

Depressurising bores are operated in accordance with licence requirements and groundwater abstraction is maintained at or below licence limits.

Groundwater levels in the formations underlying the ponds are controlled by separate bore fields. The licensed bore fields consist of:

- Cooling Pond production bore D-002G
- ROWS Pond production bores D-004G, D-006G, D-007G, D-008G
- ROCP2 production bores D-010G, D-013G, D-014G
- ROCP3 production bores D-019G, D-020G, D-021G, D-023G, D-024G, D-025G, D-035G
- RSA9 production bores D-026G, D-027G, D-028G, D-029G, D-030G, D-031G, D-032G, D-033G, D34G

There are 10 additional bores, as listed in **Table 2.3.2**, available to assist the groundwater level management during maintenance activities; however these are not utilised during normal operating conditions.

Groundwater levels in the vicinity of the ponds are measured in several monitor bores and in pressure sensors (vibrating wire piezometers).

Decisions on which bores to operate are based on groundwater and pond water levels. The general operating criterion is to keep the groundwater levels in the underlying formations below the fluid surface levels of the ponds.

Water from all depressurising bores is used within the Refinery and residue processes.

5. Monitoring & Reporting

Objectives of the groundwater monitoring program are listed in **Section 3.1**.

5.1. Water use measurement

The volume of water drawn by Alcoa from the various sources will be measured to:

- gauge compliance with the Operating Strategy;
- maintain abstraction within licence limits; and
- understand the impact of water abstraction on water resources.

Recovery bores

The recovery system is operated with the aim of being online continuously through the year. The performance and status of the recovery system can be viewed by operators on a screen. The abstraction rate and flow rates for the recovery system are calculated from information provided by water monitoring and continuous flow monitoring. Flow rates and abstraction figures are recorded on the Alcoa data system (LCN).

Water monitoring consultants conduct flow calibrations on each recovery bore on a regular basis. The flow calibration quantifies the groundwater volume that is delivered from the bore per pulse.

Flow rates are derived using a pulse counter and the flow calibration data. Magflow meters are also installed to provide flow rate data for comparison and troubleshooting purposes. A summary of flow metering is provided in **Table 5.1.1**.

Table 5.1.1. Flow meter details for recovery bores

Bore name	Type of Flow Meter	Meter Recording Frequency	Calibration Checks	Emergency Notification for Meter Failure
RB001G	Magflow and pulse flow	Continuous	6-monthly	Alarm on control board
RB002G	Magflow and pulse flow	Continuous	6-monthly	Alarm on control board
RB003G	Magflow and pulse flow	Continuous	6-monthly	Alarm on control board
RB004G	Magflow and pulse flow	Continuous	6-monthly	Alarm on control board

Depressurising bores

Depressurising bores are monitored daily by the Process Operators. Flow rates and abstraction figures are recorded on the Alcoa data system (LCN).

A summary of flow metering is provided in
Table 5.1.2.

Table 5.1.2. Flow meter details for depressurising bores

Bore name	Type of Flow Meter	Meter Recording Frequency	Calibration Checks	Emergency Notification for Meter Failure
D-002G	Mechanical	Continuous	Not Applicable	Regular operator checks
D-004G	Digital Magflow	Continuous	Annual	Regular operator checks
D-006G	Digital Magflow	Continuous	Annual	Regular operator checks
D-007G	Digital Magflow	Continuous	Annual	Regular operator checks
D-008G	Digital Magflow	Continuous	Annual	Regular operator checks
D-010G	Digital Magflow	Continuous	Annual	Regular operator checks
D-013G	Digital Magflow	Continuous	Annual	Regular operator checks
D-014G	Digital Magflow	Continuous	Annual	Regular operator checks
D-019G	Digital Magflow	Continuous	Annual	Regular operator checks
D-020G	Digital Magflow	Continuous	Annual	Regular operator checks
D-021G	Digital Magflow	Continuous	Annual	Regular operator checks
D-023G	Digital Magflow	Continuous	Annual	Regular operator checks
D-024G	Digital Magflow	Continuous	Annual	Regular operator checks
D-025G	Digital Magflow	Continuous	Annual	Regular operator checks
D-026G	Digital Magflow	Continuous	Annual	Regular operator checks
D-027G	Digital Magflow	Continuous	Annual	Regular operator checks
D-028G	Digital Magflow	Continuous	Annual	Regular operator checks
D-029G	Digital Magflow	Continuous	Annual	Regular operator checks
D-030G	Digital Magflow	Continuous	Annual	Regular operator checks
D-031G	Digital Magflow	Continuous	Annual	Regular operator checks
D-032G	Digital Magflow	Continuous	Annual	Regular operator checks
D-033G	Digital Magflow	Continuous	Annual	Regular operator checks
D-034G	Digital Magflow	Continuous	Annual	Regular operator checks
D-035G	Digital Magflow	Continuous	Annual	Regular operator checks

5.2. Groundwater monitoring program

Alcoa has developed a groundwater monitoring program for the Wagerup Operations to satisfy the requirements of the regulatory licences as well as Alcoa's own environmental operating policies and procedures. The monitoring programs are reviewed annually, and modified where necessary.

The groundwater monitoring program has been developed using a risk assessment methodology which involved the following steps:

- identify exposure scenarios;
- conduct preliminary risk assessment;
- define environmental protection objects;
- define monitoring objections;
- conduct site-specific risk assessment;
- develop the monitoring program; and
- develop performance criteria for the monitoring program and identify management responses to anomalous or critical data.

Monitoring of groundwater levels and hydrochemistry occurs at monitor bores, depressurising bores and the four alkali recovery bores. Groundwater levels in some areas are also monitored with vibrating wire piezometers.

Bores RF043G (AMG84 397902.6E, 6357729.4N) and RF046G (AMG84 398241.2E, 6356890.2N) are used to measure the influence of the recovery system on groundwater quality. These monitor bores are in the Yoganup Formation and are monitored on a six-monthly basis.

Bores used to measure the performance of the depressurising borefield are listed in **Table 5.2.1.**

Table 5.2.1. Wagerup Operations Groundwater Monitoring Objectives and Monitoring Program [1]

Monitoring Objective	Groundwater Monitoring Sites	Monitoring Program
1A) Maintain abstraction below sustainable yield from the superficial aquifer	D-002G, D-004G, D-006G, D-007G, D-008G, D-010G, D-013G, D-014G, D-019G, D-020G, D-021G, D-023G, D-024G, D-025G, D-026G, D-027G, D-028G, D-029G, D-030G, D-031G, D-032G, D-033G, D-034G, D-035G, RB001G, RB002G, RB003G, RB004G, UD014-	Continuous flow measurements
	RF001G, RF013S/G, RF034S/G, RF036S/G, RF038S/G, RF041S/G, RF050S/G, RF123S, RG003G, RG009G, RG014G, RG016S/G, RG025G, RG027S/G, RG029G, RG150S/G, RG151S/G, RG152S/G, RG153S/G, RG154S/G, RG155S/G, RG156S/G, RS123S/G, RS124S, RS138S/G, RS139S/G, RS140S/G, RS146S/G	Quarterly groundwater levels
1C) Assess whether abstraction from the superficial aquifer affects surrounding properties and natural water courses	RF034S/G/W, RF035S/G/W, RF041S/G/W, RF050S/G/W, RG003G, RG009G, RG014G, RS123S/G, RS124S, RS146S/G/W	Six-monthly groundwater levels
4A) Measure and calibrate flows from recovery bores to provide reliable estimates of groundwater production volumes	RB001G, RB002G, RB003G, RB004G	Continuous flow measurements, with six-monthly calibration check of meters
4C) Assess whether recovery system production rates are sufficient to inhibit the vertical migration of alkaline water from the superficial aquifer to the deeper formations	RF043G, RF046G	6-monthly pH, EC 6-monthly comprehensive laboratory analysis
6A) Measure and calibrate flows from the depressurising bores to provide a reliable estimate of abstraction	D-002G, D-004G, D-006G, D-007G, D-008G, D-010G, D-013G, D-014G, D-019G, D-020G, D-021G, D-023G, D-024G, D-025G, D-026G, D-027G, D-028G, D-029G, D-030G, D-031G, D-032G, D-033G, D-034G, D-035G, UD014-	Continuous flow measurements, with annual calibration checks of meters
6B) Assess whether abstraction rates from the superficial formations are sufficient to maintain groundwater pressures 1 m below the surface water levels at	H-002-, H-003-, H-004-, H-005-, I-001-, I-002-, I-003-, RS039S/G, RS041S/G, RS042S/G, RS044S/G, RS047S/G, RS049S/G, RS116S/G, RS117S/G, RS118S/G, RS119S/G, RS121S/G, RS130S/G, RS137S/G, RS138S/G, RS139S/G, RS140S/G, RS141S/G, RS142S/G, RS145S, RS149G	Weekly groundwater levels

Monitoring Objective	Groundwater Monitoring Sites	Monitoring Program
the ROWS Pond, Cooling Pond, ROCP2, RSA9 and ROCP3.	RS103S, RS103G, RS163S, RS163G, RS193S, RS193G, RS194S, RS194G, RS195S, RS195G, RS196S, RS196G, RS197S, RS197G, RS198S, RS198G, RS198W, RS199S, RS199G, RS200S, RS200G, RS201S, RS201G, RS202S, RS202G, RS203S, RS203G, RS204S, RS204G, RS205S, RS205G, H-007S, H-007G, H-008G, H-009S, H-009G, H-010G, H-011S, H-011G, H-012S, H-012G, H-013S, H-013G, H-014S, H-014G, H-015S, H-015G, H-016S, H-016G, H-017S, H-017G, H-018S, H-018G	6-monthly water levels
6D) Assess whether operation of the depressurising system affects water quality beneath the ROWS Pond, Cooling Pond, ROCP2, RSA9 and ROCP3.	D-002G, D-004G, D-006G, D-007G, D-008G, D-010G, D-013G, D-014G, D-019G, D-020G, D-021G, D-023G, D-024G, D-025G, D-026G, D-027G, D-028G, D-029G, D-030G, D-031G, D-032G, D-033G, D-034G, D-035G, UD014-	Annual groundwater levels Annual field pH, EC, and Eh Annual comprehensive laboratory analysis
	RG034G, RG035G, RG036G, RG079G, RG080G, RS039S/G, RS040S/G, RS041S/G, RS042S/G, RS043S/G, RS044S/G, RS045S/G, RS046S/G, RS047S/G, RS048S/G, RS049S/G, RS050S/G, RS058S/G, RS059S/G, RS060S/G, RS061S/G, RS062S/G, RS063S/G, RS064S/G, RS065S/G, RS066S/G, RS090S/G, RS091S/G, RS092S/G, RS093S/G, RS094S/G, RS095S/I/G, RS096S/I/G, RS097S/I/G, RS098S/I/G, RS099S/I/G, RS100S/I/G, RS101S/I/G, RS102S/I/G, RS103S/G, RS115G, RS116S/G, RS117S/G, RS118S/G, RS119S/G, RS120S/G, RS121S/G, RS122S/G, RS123S/G, RS124S, RS125S, RS126G, RS127G, RS130S/G, RS137S/G, RS138S/G, RS139S/G, RS140S/G, RS141S/G, RS142S/G, RS145S, RS146S/G, RS147S/I/G, RS149G, RS160S/G, RS161S/G, RS162S/G, RS163S/G, RS168S/G, RS169S/G, RS170S/G, RS171S/G, RS172S/G, RS173S/G, RS174S/G, RS175S/G, RS176S/G, RS177S/G, RS178S/G, RS193S, RS193G, RS194S, RS194G, RS195S, RS195G, RS196S, RS196G, RS197S, RS197G, RS198S, RS198G, RS198W, RS199S, RS199G, RS200S, RS200G, RS201S, RS201G, RS202S, RS202G, RS203S, RS203G, RS204S, RS204G, RS205S, RS205G	Annual groundwater levels Annual field pH and EC Annual laboratory analysis for pH, EC and alkalinity

Notes:

1) Most of the monitoring program in Table 8 has applied since September 2009. Some changes have been made annually to the bores included in each list.
2) Comprehensive analysis includes Al, Alkalinity, As, B, CO3, Ca, Cd, Cl, EC, Cr, Cu, DOC, F, Fe, Ga, HCO3, Hardness, Hg, K, Mg, Mn, Mo, NH3, NO2, NO3, TKN, Total N, Na, Ni, FRP, Total P, Pb, SO4, Se, SiO2, TDS, U, V, Zn, pH, ionic balance, and Na/Cl mass ratio.

5.3. Quality Control

The requirements and data quality control procedures for the groundwater monitoring program have been developed in accordance with Australian and New Zealand Standard AS/NZS 5667.11:1998 *"Water Quality Sampling – Guidance on Sampling of Groundwater"*.

Water samples are analysed by NATA accredited laboratories.

6. Contingency Program

6.1. Breach of the Operating Strategy or Water Licence

In the event of a breach of the Operating Strategy, Alcoa will notify the DoW and undertake appropriate corrective actions as soon as practicable. All remedial actions will be documented and reference made to any breaches in the annual report for that year.

6.2. Unexpected Aquifer Response

Groundwater abstraction is via depressurising bores or recovery bores. Assessment of the impact of groundwater abstraction is made by the consulting hydrogeologist as part of the annual report.

Contours of groundwater levels in the Lower Superficial Formation show that the cones of depression due to pumping of the depressurising systems are localised, and relatively close to the pumping centres. Operation of these borefields is therefore not having a detrimental effect on groundwater levels, and is also not having any discernible adverse effect on the yield of groundwater from the aquifer. (Clifton, 2014)

6.3. Impact on Other Users

If Alcoa's abstraction affects another user of the aquifer, the following actions will be taken:

- complete an internal investigation of the aquifer drawdown and assess Alcoa's contribution; and
- if the drawdown is attributed to Alcoa's abstraction then Alcoa will identify solutions and negotiate corrective actions with the other user.

As discussed in **Section 6.2**, operation of the borefields is not having a detrimental effect on groundwater levels, and is also not having any discernible adverse effect on the yield of groundwater from the aquifer. (Clifton, 2014)

7. Associated Maps

Figure 7.1 shows the network of bores at the refinery, including the four recovery bores. The bore network at the Residue area is shown in **Figure 7.2**.

Regional monitor bores are shown in **Figure 7.3**.

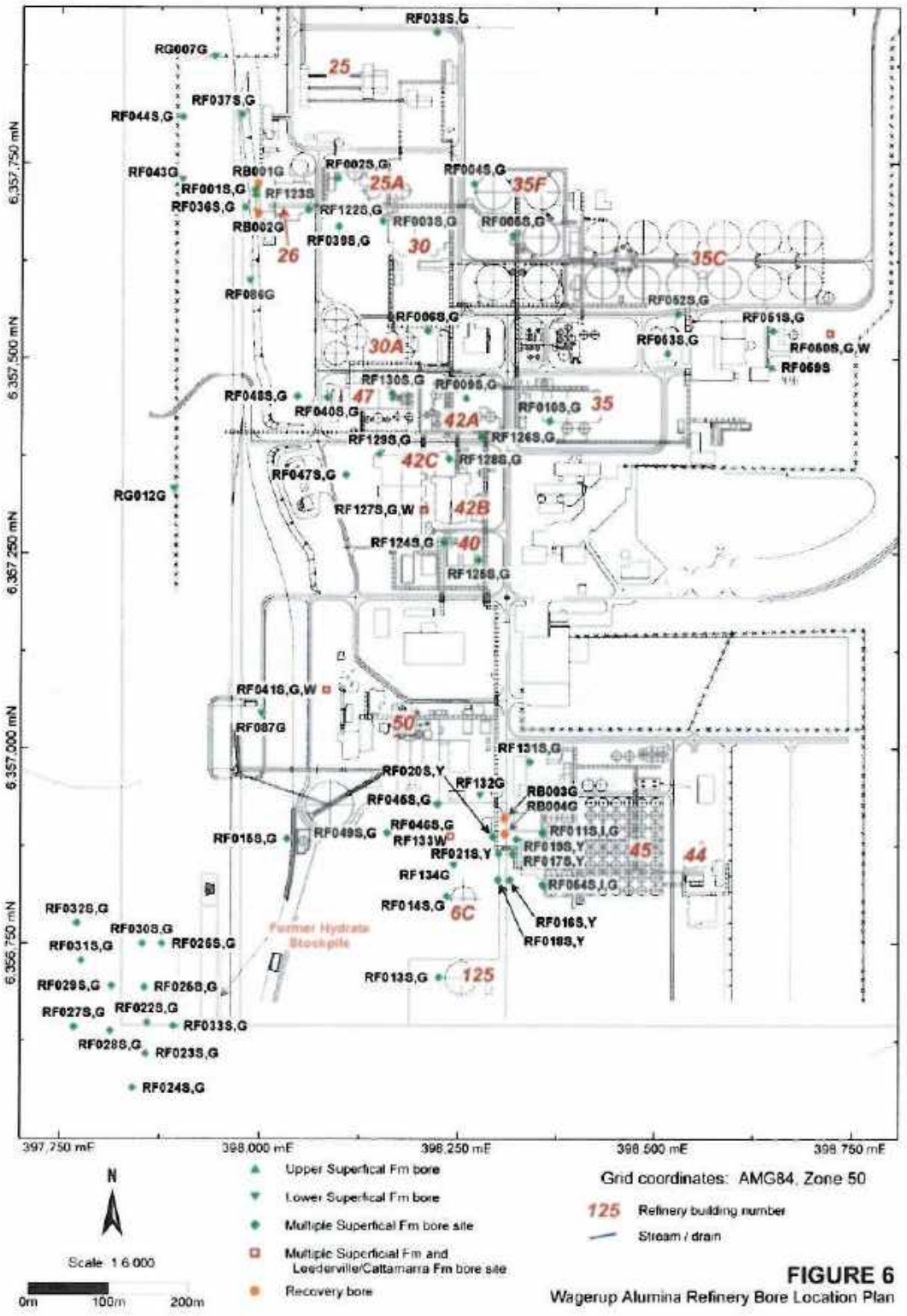


Figure 7.1 Refinery bore network

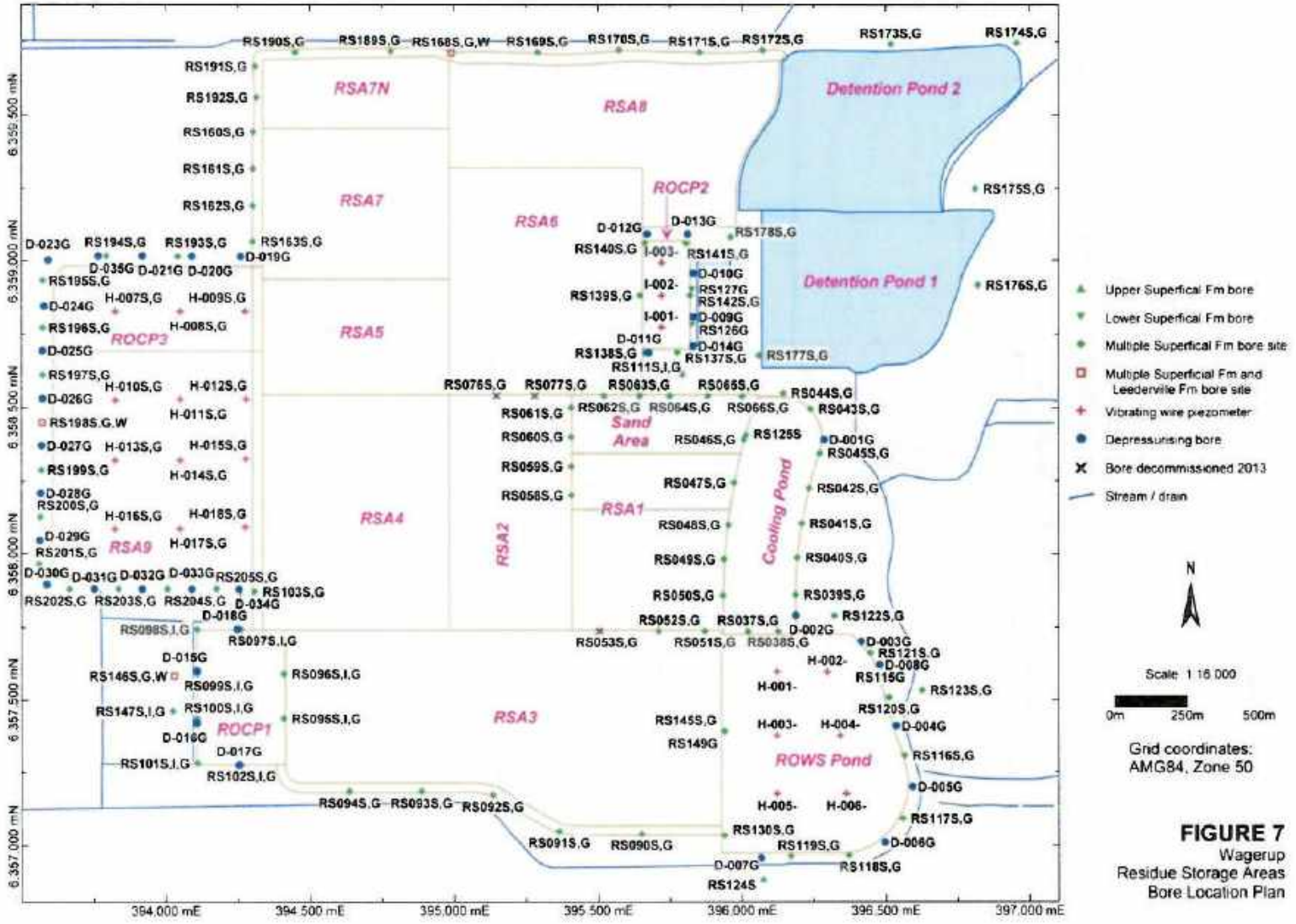


FIGURE 7
Wagerup
Residue Storage Areas
Bore Location Plan

Figure 7.2 Residue bore network

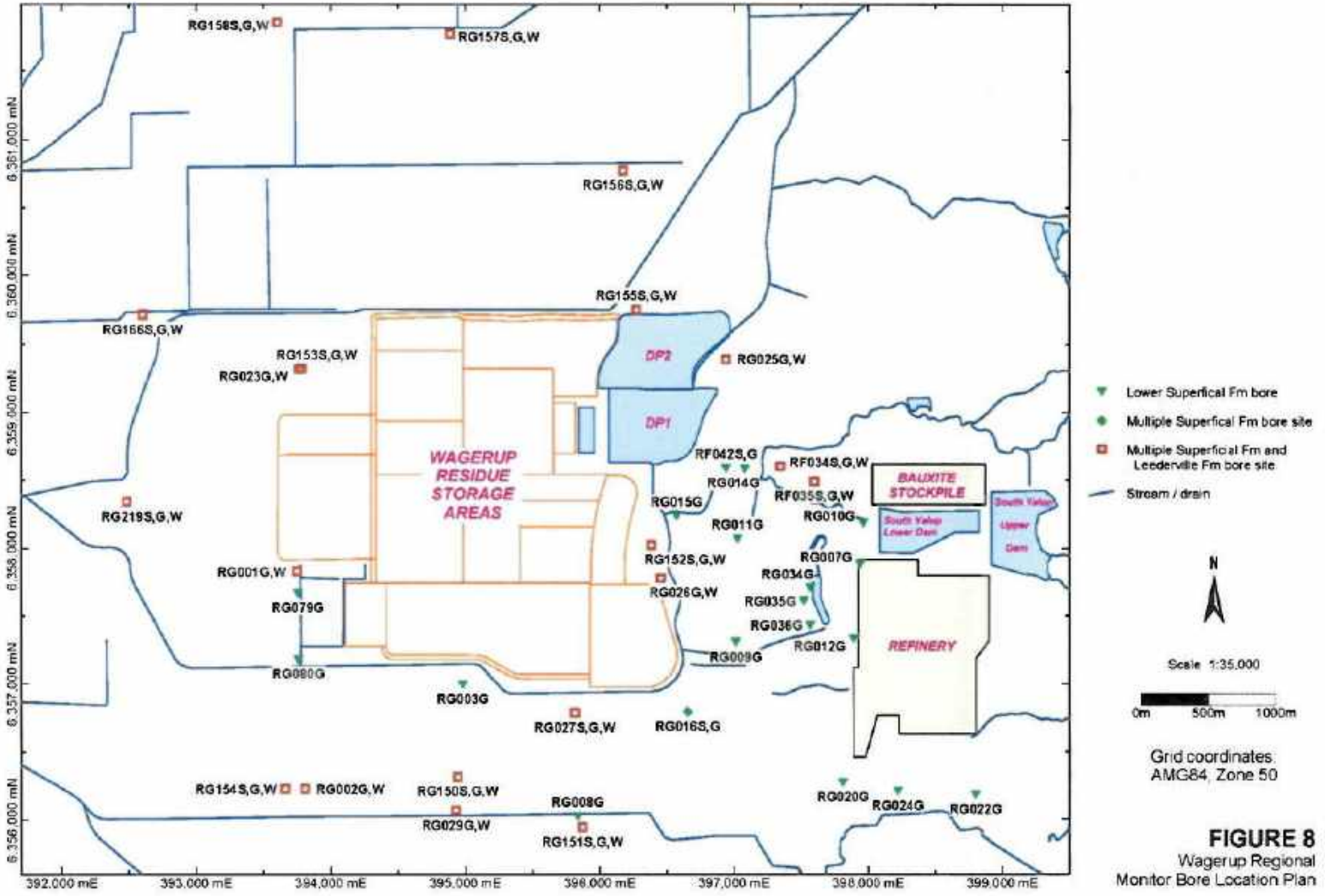


Figure 7.3 Regional bore network

8. Water use efficiency

Alcoa has developed a water conservation strategy for its Western Australian operations that is primarily aimed at reducing the dependency on high quality water resources. Opportunities such as harvesting lower grade agricultural drainage water and treated effluent are being pursued under this strategy.

The refinery water requirements are largely determined by the refinery process design and opportunities to achieve major reductions in water consumption are limited due to the close relationship between the energy and water balance. Nevertheless, water use efficiency is a key environmental metric and opportunities to improve water use efficiency are identified and evaluated. Examples include the potential for carbonation of residue mud, using pasture as a means of dust control in lieu of applying water and using fit for purpose water for dust suppression and in cooling towers.

The production bores at Wagerup Refinery are used for groundwater recovery and depressurisation; hence they are operated independently of Alcoa's water use efficiency strategies.

9. References

Clifton, P M, 2014, "2013 Annual Review of Groundwater and Surface Water Monitoring Data from the Wagerup Alumina Refinery and Bunbury Caustic Loading Facility", consultant report prepared for Alcoa of Australia Limited by Peter Clifton & Associates, 1304_R01, March 2014.

10. Summary List of Commitments

Topic	Operating Strategy Section	Commitment
Tenure	1.4	This strategy shall remain current for a maximum of five years from the date of approval by the Department of Water (DoW).
Updates	1.4	The Operating Strategy will be reviewed in accordance with requirements listed in Section 1.4 of this document.
Reporting	1.5	Abstraction volumes calculated from meter readings from all licences will be submitted to DoW as required by the relevant licence.
		An annual report will be submitted to DoW by 31 March each year
Action taken in the event of a Breach of the Operating Strategy	6.1	Report a non-compliance with the Operating Strategy to the DoW within 14 days of the identified non-compliance
		In the event of non-compliance, corrective action will be taken following discussion with DoW. All remedial actions will be documented and reference made to any breaches in the annual report for that water year.
Operating Rules	4	Recovery bores are operated in accordance with licence requirements and groundwater abstraction is maintained at or below licence limits. The four recovery bores (RB001G, RB002G, RB003G and RB004G) are operated on a continuous basis (allowing for maintenance when required) to enable maximum recovery of contaminated groundwater.
		Depressurising bores are operated in accordance with licence requirements and groundwater abstraction is maintained at or below licence limits. Decisions on which bores to operate are based on groundwater and pond water levels. The general operating criterion is to keep the groundwater levels in the underlying formations below the fluid surface levels of the ponds.
Flow Meter Maintenance and Calibration	5.1	Flow meter calibrations and/or calibration checks completed as per Section 5.1 of this document.
Monitoring	5	Groundwater monitoring completed as per Section 5 of this document.
Impacts on other users	6.3	If abstraction affects another user, actions detailed in Section 6.3 to be undertaken.

Addendum 2

Addendum to a water resource operating strategy associated with a water licence issued by the Department of Water and Environmental Regulation

Name of licensee: Alcoa of Australia Limited

This addendum applies to:

- Water resource licence number: **SWL 97472, SWL 99246, SWL 151027**
- The associated water resource operating strategy approved by the Department of Water on 1 August 2013 and Addendum 1 approved on 28 November 2017.

Intent

The intent of this addendum is to formalise the licensee's commitment to:

- *Measure abstracted volumes for SWL 97472 (North and South Yalup Catchment) and SWL 99246 (Black Tom Brook) by draw from storage, subtracting the volume of purchased water.*

Commitment(s)

The following commitments/text within the operating strategy is amended by the following:

Section 1.5 amended

Section 1.5 Reporting 'Meter Readings' is to be deleted and replaced with the below section:

Meter Readings
Abstraction volumes for licences listed in Section 1.2 will be provided to the Department of Water and Environmental Regulation (DWER) by 14 January each year.

Abstraction volumes are calculated/metered in accordance to the below methodologies:

- *North and South Yalup Catchment (SWL 97472) and Black Tom Brook (SWL 99246) is measured via metered draw from storage subtracting the volume of water purchased from Harvey Water during the relevant water year.*
- *Harvey Main Drain (SWL 151027) is metered.*

Amending the addendum to the water resource operating strategy

The licensee may apply to amend this addendum at any time, to account for exceptional circumstances.

Agreement

I acknowledge that compliance with the approved addendum to the operating strategy is a condition of holding a licence, as issued under Section 5C of the Rights in Water and Irrigation Act 1914, to take and use water and I hereby agree to implement the commitment (s) within this operating strategy addendum.

Signatures

Person legally responsible for water licence ..... Date 26/3/2018

printed name MARK HODSON

Approved by Department of Water and Environmental Regulation delegated authority ..... Date 27/3/2018

printed name Matt Viskovich

Addendum to a water resource operating strategy associated with a water licence issued by the Department of Water

Name of licensee: Alcoa of Australia Limited

This addendum applies to:

- Water resource licence number: **SWL 97472, SWL 99246, SWL 151027**
- The associated water resource operating strategy approved by the Department of Water on 1 August 2013

Intent

The intent of this addendum is to formalise the licensee's commitment to:

- provide data collected in accordance with this operating strategy to the department by 31st March annually; and
- to provide a comprehensive report triennially in line with Department of Water (DOW) 'Operational Policy no. 5.12 – Hydrogeological reporting associated with a groundwater well licence, Nov 2009' commencing 30th April 2020; and
- Update the water circuit schematic to reflect the current system.

Commitment(s)

The following commitments/text within the operating strategy is amended by the following:

1. Section 1.5 replaced

Section 1.5 of the operating strategy is deleted, and replaced with:

1.5 Reporting

Meter Readings

Abstraction volumes calculated from meter readings for all licences listed in Section 1.2 will be provided to the Department of Water and Environmental Regulation (DWER) by 14 January each year.

Annual Report

The surface water monitoring data collected in accordance with this strategy as outlined in Table 5.2 will be provided to DWER on 31st March annually.

Triennial Report

A comprehensive triennial report will be submitted to DWER by 30th April every 3 years commencing 30 April 2020. The content will be in line with DoW 'Operational policy no. 5.12 – Hydrogeological reporting associated with a groundwater well licence, Nov 2009'

2. Figure 4.1 replaced

Figure 4.1 of the operating strategy is deleted, and replaced with:

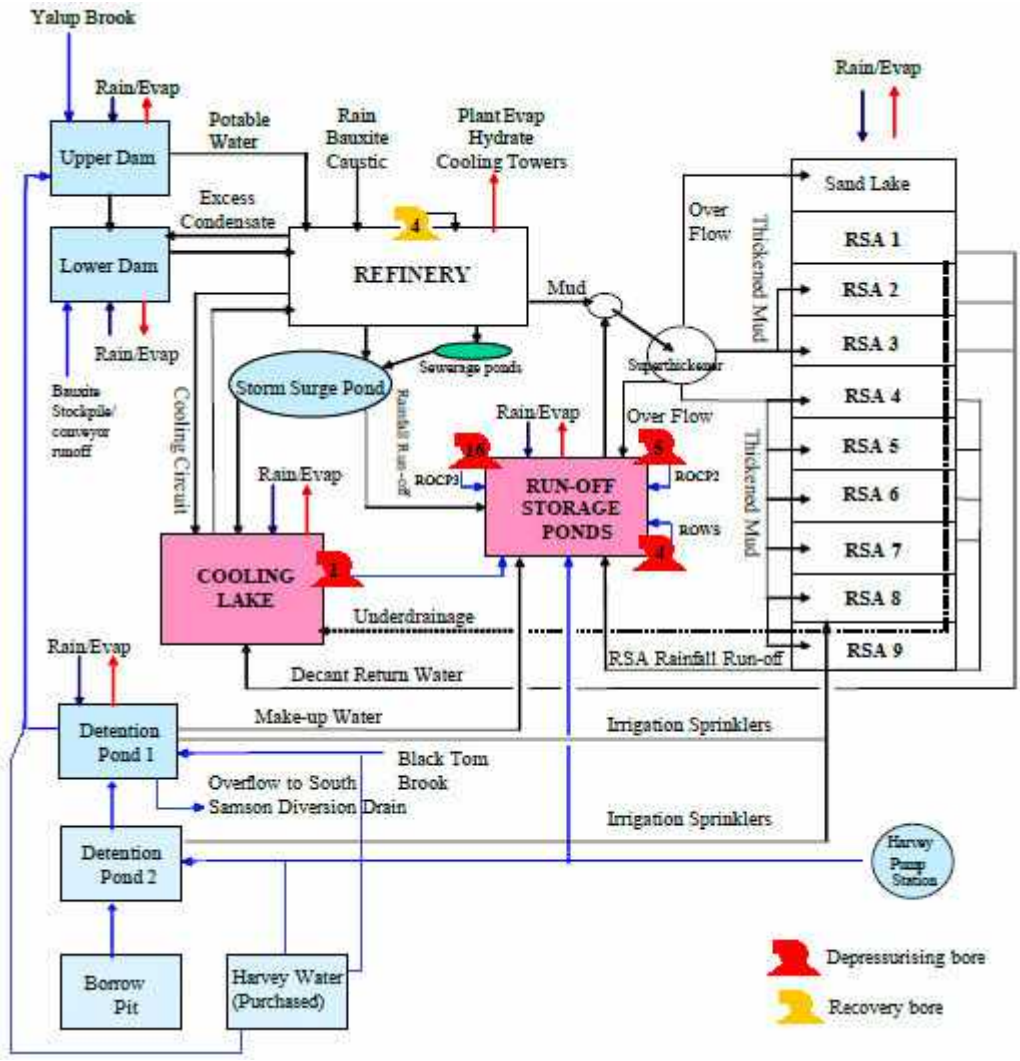


Figure 4.1. Schematic of the Water Circuit

3. Section 10 amended

Section 10 of the operating strategy 'Summary List of Commitments' table deleted for 'Topic – Reporting' and replaced with:

Topic	***Operating Strategy Section***	***Commitment***
Reporting	*1.5*	*Abstraction volumes calculated from meter readings from all licences will be submitted to DWER as required by the respective licences.*
		The surface water monitoring data collected in accordance with this strategy as outlined in Table 5.2 will be provided to DWER on 31st March annually.

		A comprehensive triennial report will be submitted to DWER by 30th April every 3 years commencing 30 April 2020 in accordance with 'Operational policy no. 5.12'.

Amending the addendum to the water resource operating strategy

The licensee may apply to amend this addendum at any time, to account for exceptional circumstances

Agreement

I acknowledge that compliance with the approved addendum to the operating strategy is a condition of holding a licence, as issued under Section 5C of the Rights in Water and Irrigation Act 1914, to take and use water and I hereby agree to implement the commitment(s) within this operating strategy addendum.

Signatures

Person legally responsible for water licence ..... **Date** 28/11/2017

printed name: Mark Hodgson

Approved by Department of Water delegated authority ..... **Date** 28/11/17

printed name: CARMEL SULLIVAN.

Alcoa World Alumina – Australia

Wagerup Refinery

Surface Water Licences

Operating Strategy

This Operating Strategy has been developed as a requirement of Surface Water Licences issued to Alcoa of Australia Ltd under the *Rights in Water and Irrigation Act 1914.* Licences issued cover extraction of surface water for use at the Wagerup Refinery, located within the catchments of Black Tom Brook, North Yalup Brook and South Yalup Brook. The purpose of this Strategy is to detail water resource management measures implemented at the Wagerup Refinery, to ensure compliance with surface water licences. This Strategy also describes measures proposed for efficient water use and the reduction of potential impacts on the environment and other water users.

Name of water license licensee:	Alcoa of Australia Ltd
Name of facility:	Wagerup Alumina Refinery
Legal description of properties:	*Lot 205 on Plan 34250 – Vol/Fol: 2540/866* *Lot 700 on Plan 59305 – Vol/Fol: 2708/955*

I understand that the commitments given in the attached operating strategy will be a condition of an associated water license if approved and that a breach of a commitment or any license condition may be an infringement of the Rights in Water and Irrigation Act 1914.

Signatures

Authorised by: _____ Date: 24/7/2013

Printed name: Jocelyn Zimmerman Position: Environmental Manager - Wagerup.

Approved delegated authority Department of Water: _____ Date: 1/8/13

Printed name: Alan Cook.

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1. Administrative Requirements

1.1. Overview of Operations

Wagerup Refinery and associated bauxite residue storage facilities are located 120 km south of Perth, 2 km north of Yarloop and 7.5 km south of Waroona. The Refinery is located close to the foot of the Darling Scarp and is separated from the residue storage areas (RSAs) by the South West Highway and the Perth-Bunbury rail line (Figure 1.2). Bauxite is supplied to the Refinery by overland conveyor from the Willowdale Mine located 15 km to the east and alumina produced at Wagerup is shipped via the Alcoa shipping terminal at Bunbury. Transport between the Refinery and port is by rail.

The Refinery and residue operations are contained within freehold land owned by Alcoa. Land use on adjacent properties is primarily agricultural.

1.2. Applicability

The water year for the purposes of reporting against this Strategy is from 1 January to 31 December. Licences covered by this Operating Strategy include:

- SWL 97472 (North and South Yalup Brooks) 1600 MLpa
- SWL 99246 (Black Tom Brook) 2500 MLpa
- SWL 151027 (Harvey Main Drain) 4400 MLpa.

1.3. Contacts

Department of Water

Program Manager
Department of Water
PO Box 332
Mandurah WA 6210
Phone: (08) 9550 4217

Wagerup Refinery

Environmental Manager
Wagerup Refinery
PO Box 84
Waroona WA 6215
Phone: (08) 9733 8119 *Fax:* (08) 9733 8534

1.4. Duration of Strategy

This strategy shall remain current for a maximum of five years from the date of approval by the Department of Water (DoW). The strategy should be reviewed under the following circumstances:

- at least three months prior to the expiry of this Strategy;
- if monitoring indicates adverse trends or unexpected performance;
- if there is a significant change to the refinery's water requirements, releases and/or purpose of surface water diversion or use;
- if requested by Alcoa and agreed by the DoW; or
- if directed by the DoW following consultation with Alcoa.

1.5. Reporting

Meter Readings

Abstraction volumes calculated from meter readings for all licences listed in **Section 1.2** will be provided to the DoW by 14 January each year.

Annual Report

To meet the reporting requirements of this Strategy, an annual report will be submitted to the DoW by 31 March each year to cover the previous reporting period (being 1 January to 31 December). In recent years, the report has been in the form of Wagerup Refinery's Annual Review of Groundwater and Surface Water Monitoring Data from the Wagerup Alumina Refinery and Bunbury Caustic Loading Facility, which has been determined to meet this annual reporting requirement. Alcoa routinely reviews all of its reports to ensure they remain appropriate and current and as such the format or information covered within the report is subject to periodic change. The following minimum reporting requirements will be retained:

- volume of water used by Alcoa from the various licensed sources during the reporting period;
- surface water flows and chemistry data;
- reporting of adverse trends or unexpected performance noted during reporting period;
- breaches of operating strategy and corresponding remedial actions;
- rainfall data;
- brief discussion of effectiveness of the monitoring program to ensure compliance with the DoW surface water license conditions; and
- outline of any likely changes to the refinery water requirements / operational strategy for next reporting period.

2. Water Source Description

2.1 Surface Water Overview

The Wagerup Refinery area is within the lower reaches of the Harvey River catchment. The section of the Harvey River upstream and adjacent to Alcoa's landholdings as well as its feeder streams that traverse the Pinjarra Plain have generally been highly modified into trapezoidal drains. The Harvey River Main Drain lies approximately 4 km to the west of the current residue areas and flows in a north-westerly direction to discharge into the Harvey Estuary.

The natural hydrology of the lower Harvey River catchment was comprised of streams draining relatively small catchments from the escarpment onto the plain and hence to the Harvey River. The natural condition was highly altered in the early 1900s due to the development of the irrigation and drainage systems servicing agricultural developments around the towns of Harvey and Waroona. A number of dams have been constructed within the larger Darling Range catchments to retain winter runoff for summer irrigation use and the watercourses on the Plain have been modified or replaced by constructed channels to distribute irrigation water and improve winter drainage.

In 1978 Alcoa established a network of hydrometric stations on a range of possible refinery surface water sources to provide ongoing data such that annual yields could be established. This was done with the support of the then Public Works Department (now Department of Environment and Conservation) and data were gathered for varying periods. Some of these hydrometric stations are still operational.

Wagerup Refinery is almost totally dependent on surface water sources to provide for process make-up water. The catchments that provide water for Wagerup Refinery include the refinery and residue storage areas and surrounding land including Darling Range and agricultural catchments.

Surface runoff is highly dependent on weather conditions and may vary by orders of magnitude depending upon the intensity, frequency, duration and pattern of rainfall. Rainfall runoff primarily occurs during the months of April – September, so storage facilities are provided to store the runoff for year round use by the refinery.

Water storage facilities for Wagerup Refinery include the Upper and Lower Yalup Dams (combined total storage capacity of (2270 ML), Detention Pond 1 (1745 ML), Detention Pond 2 (2000 ML) and the Runoff Water Storage (ROWS) Pond (4000 ML capacity). Detention Pond 2 was commissioned in March 2008 to provide additional water storage to meet the refinery's summer water needs.

Prior to 2003, Alcoa had three surface water licences to allow diversion of water from Yalup Brook, Black Tom Brook and South Samson Drain for use by the refinery.

The licence to use water from South Samson Brook was issued on a temporary basis while Alcoa developed a scheme to harvest winter flow from the Harvey River Main Drain. The Samson South licence was rescinded in 2003 when a licence to extract water from Harvey River Main Drain was issued.

2.2 Summary of surface water licences

Wagerup Refinery's current water licences are detailed in **Table 2.2.1.**

Table 2.2.1. Licensed volumes

SOURCE	Licence Number	Licensed Amount (MLpa)
North & South Yalup Brooks	SWL 97472	1,600[1]
South Samson Diversion Drain (includes Black Tom Brook)	SWL 99246	2,500[1]
Harvey River Main Drain	SWL151027	4,400[2]

Notes

1 The volume reported is that abstracted from the storage facilities rather than that diverted from the water source directly.

2 The volume reported is that abstracted directly from the source.

2.3 Description of water sources and storage facilities

Figure 8.1 shows the various water catchments, diversion points and storage facilities.

2.3.1 Yalup Brook

Catchment Description

Yalup Brook catchment is located on the Darling escarpment to the north east of the refinery. It includes around 700 ha of cleared farming area (pasture) and 200 ha of forested area. The Yalup Brook catchment includes moderate to steep slopes and rocky areas of the Darling Escarpment grading to moderate to gentle slopes of Ridge Hill Shelf Formation which forms the foothills of the Darling Range. Soils vary from bauxite and granite derived soils on the escarpment to sandy soils of the Ridge Hill Shelf.

Development

The northern arm of Yalup Brook is harvested by way of a small diversion dam (Pipe Head Dam) and gravity pipeline which feeds into the Upper Yalup Dam. Stream flows in excess of the pipeline capacity will overflow the diversion dam spillway. The southern arms of Yalup Brook feed directly into the Upper Yalup Dam. If this dam is filled it will overflow via a spillway back into the North Yalup Brook channel.

The Lower Yalup Dam is directly below the Upper dam. While it has a very limited catchment of its own, (mainly the bauxite storage areas), it has the capacity to be used to store water released from the Upper Dam via a gravity pipeline. However, the Lower Dam was converted for condensate storage and recycling duty some years ago and continues to be used in this way.

Water is drawn directly from the Upper Dam and treated prior to use in the refinery as potable, safety and eye wash stations, fire mains water, ablutions and process makeup water.

Hydrology / Flow

Data from the Yalup Brook gauging station (#613015) as well as storage volume and extraction data for the Upper Dam were used by Sinclair Knight Merz in 1991 to estimate catchment yields. In an average rainfall and runoff year it was estimated that the South Yalup Catchment will yield approximately 580 ML and the North Yalup Catchment will yield 1500 ML (Sinclair Knight, 1991). These estimates are lower than those that were made prior to construction of Wagerup Refinery and trends over the past 20 - 30 years of lower rainfall and even less runoff mean that recent yields tend to be well below even the 1991 estimates. The average yield for the combined North Yalup and South Yalup catchments over the period 1995 - 2005 was 1029 ML per annum.

2.3.2 Black Tom Brook

Catchment Description

Black Tom Brook catchment is located on the Darling escarpment immediately to the north of Yalup Brook. The catchment area of Black Tom Brook, including the contributing areas downstream of the confluence of Black Tom Brook and the Alcoa diversion drain to Detention Pond 1, is approximately 1040 ha. This area does not include the "closed" catchment area associated with the decommissioned Iluka Mineral Sands Operation in Hamel

The Black Tom Brook catchment includes moderate to steep slopes and rocky areas of the Darling Escarpment grading to gentle to moderate slopes on the foothills of the Ridge Hill Shelf formation. Soils vary from bauxite and granite derived soils on the escarpment to sandy soils of the Ridge Hill Shelf.

Development

Black Tom Brook enters a drain near the South Western Highway which is intercepted by the South Samson Diversion Drain, constructed by Alcoa to divert drainage waters around the residue areas. The Diversion Drain flows into Detention Pond 1 from where water taken for use by the refinery.

Hydrology / Flow

The Water and Rivers Commission operated a stream flow gauging station in the upper reaches of Black Tom Brook between 1981 and 1982. Alcoa installed a monitoring station on South Samson Diversion Drain in 1997 (SP6). This station is downstream of the Black Tom Brook confluence and measures the contribution of Black Tom Brook along with any other flow which is diverted into the diversion from South Samson Drain. The mean annual flow recorded for the period 1997-2012 is 2120ML.

2.3.3 Harvey River

Catchment Description

The Harvey River catchment area lies above the confluence with Logue Brook Drain. This is where Alcoa's Harvey Pumpback station is located. The overall catchment area includes the new Harvey Dam and its catchment which is the headwaters of the Harvey River, however for the purposes of this operating strategy the relevant catchment includes only that area downstream of the new Harvey Dam.

Water from the catchment between the Harvey Dam and Harvey townsite can be diverted down the Myalup Drain which was constructed as a flood control structure in the 1960's, however it is understood that since the construction of the new dam the operating strategy is not to divert Harvey River flow into the Myalup Drain but rather retain all available flow for the downstream reaches of the Harvey River.

The relevant catchment area below the Harvey Dam is approximately 280 km^2 in area with approximately 35% of the catchment in the scarp/hills area and the remainder on the coastal plain. The catchment includes the towns of Harvey and Yarloop. Land use is predominantly agricultural and includes the Harvey Irrigation Area. Irrigation water may be distributed to the Harvey Irrigation Area from a number of dams both within and outside of the Harvey River catchment. Irrigation water return flow and losses contribute to summer base flow in drains within the catchment including the Harvey River Main Drain.

Development

The Harvey River catchment has been highly altered from its natural condition to provide water storage, distribution and drainage for land development. Apart from the historical agricultural development, water resources within the catchment are increasingly being utilised by the Water Corporation for the integrated water supply network servicing the Perth region. Industrial development within the catchment includes Wagerup Refinery and Iluka Minerals mineral sands operations.

Water flows within the catchment have been monitored at a number of different sites over the years. Most gauging stations have been discontinued, although Alcoa and the Department of Environment and Conservation maintain several stations.

Hydrology/Flow

Alcoa installed a gauging station on the Harvey River Main Drain at the Bristol Road bridge (# 613016) in 1977, which was operated in conjunction with the Public Works Department/Water and

Rivers Commission until 1986. Over this period, about 80GL/annum was recorded with approximately 59GL of this flowing during the winter period (May – September). To provide more recent data on flows available around the Harvey Pumpback a gauging station was located immediately downstream of the location of the abstraction pumps in the Harvey Main Drain. The gauging station was installed in February 2005 and is still operational.

The estimated mean annual flow (2005 – 2008, 2011 and 2012) at the Pumpback location is 35GL. For the years 2009* and 2010* there was a large number of days where there was no data collected. The lowest recorded flow for the May – Sept period was 11GL in 2006 (**Table 2.3.1**).

Table 2.3.1 Monthly Surface Flows - Harvey Main Drain

	Stream Flow (GL)												
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**	**Total**
2005	0.2	0.9	1.0	0.6	6.1	18.6	5.6	12.5	10.9	6.7	1.5	0.9	65.44
2006	0.7	0.6	0.9	0.6	0.1	0.2	0.9	7.8	1.9	0.7	0.7	0.6	15.93
2007	0.7	0.5	0.4	0.1	0.4	1.2	10.3	13.0	7.9	2.1	0.5	0.3	37.36
2008	0.2	0.2	0.2	0.5	3.8	9.9	20.9	3.3	1.2	0.6	0.5	0.9	42.20
2009*	0.2	0.3	0.3	No data	No data	No data	No data	No data	No data	No data	No data	No data	0.73
2010*	No data	No data	No data	No data	0.2	0.3	2.3	1.5	0.5	0.2	0.1	0.1	5.10
2011	0.2	0.3	0.4	0.2	0.2	3.8	6.3	9.3	7.4	1.3	0.6	0.4	30.26
2012	0.2	0.2	0.5	0.3	0.3	3.5	0.9	4.4	7.3	0.5	0.7	1.3	20.08

Table 2.3.3 Surface Water Storage Details

Dam name	Location coordinates (AMG)		Name river/stream	On-stream or off-stream	Water Source	Capacity (ML)
	Northing	**Easting**				
Pipe Head Dam	6358893	399480	North Yalup Brook	On-stream	North Yalup Brook	14
Upper Yalup Dam	6358150	399100	North & South Yalup Brooks	On-stream	North and South Yalup Brook	1595
Lower Yalup Dam	6358278	398145	N/A		North and South Yalup Brook	675
Detention Pond #1	6358900	396500	Black Tom Brook	On-stream	South Samson Drain, Black Tom Brook, Harvey River main Drain	1745
Detention Pond #2			Harvey River		South Samson Drain, Black Tom Brook, Harvey River main Drain	2000 currently, increasing eventually to 3200
Runoff water storage (ROWS) Pond	6357250	396250	Harvey River		Refinery and RSA runoff, Harvey River main Drain	4000

3. Identifying & Managing Impacts

Alcoa has established a set of Environmental Protection Objectives for the Wagerup Alumina Refinery using a risk assessment methodology that is consistent with guidelines published as part of the National Water Quality Management Strategy. The Environmental Protection Objectives for the Wagerup Alumina Refinery are listed in **Table 3.1**.

Table 3.1 Environmental Protection Objectives for the Wagerup Alumina Refinery

	Environmental Protection Objective	Applicability
1	Surface water harvesting is undertaken in a manner that is sustainable and does not have a long-term detrimental effect on the environment or the beneficial use of surface water resources.	Surface Water Licences Operating Strategy
2	The environmental values of environmental receptors surrounding Alcoa's operations are sustained.	Surface Water Licences Operating Strategies

Monitoring will be used to identify environmental impacts, and assist in achieving the environmental protection objections. **Table 3.2** shows Monitoring Objectives to achieve Environmental Protection Objectives which have been identified in **Table 3.1** above as being applicable to the Surface Water Licences Operating Strategy.

Table 3.2 Environmental Monitoring Objectives relating to Surface Water Environmental Protection Objectives

Environmental Protection Objective	Monitoring objectives
1) Surface water harvesting is undertaken in a manner that is sustainable and does not have a long-term detrimental effect on the environment or the beneficial use of surface water resources.	1A) Measure & calibrate flow of surface water harvesting systems to provide a reliable estimate of harvesting volumes 1B)Assess whether harvested surface water remains suitable for use in the water circuit 1C)Assess whether surface water harvesting adversely affects downstream flow and water quality
2) The environmental values of environmental receptors surrounding Alcoa's operations are sustained.	2A) Assess whether site operations adversely affect the quality of surface water bodies and streams

Management response when Environmental Protection Objectives are threatened will consider modifications to abstraction regimes, commissioning of further studies / monitoring, sourcing alternative water supplies or other actions which address the identified issue. Management response is further outlined in Section 6 and Section 7 of this report.

4. Operating Rules

4.1 Water Allocation

The current water allocation for Wagerup Refinery is based on a production capacity of 2.87 Mtpa. There are currently no plans to expand Wagerup Refinery and as such additional surface water requirements are unlikely to be required in the near future.

Historical data indicates that even under average conditions the full allocation from the Yalup or Black Tom catchments may not be available. The Harvey Main Drain is more capable of providing its full allocation, however some modifications to the existing pumping arrangement would be required before this could be realised (Section 4.5).

4.2 Description of refinery water circuit

The overall water circuit is shown schematically in **Figure 4.1**. It is a "closed" water circuit, with all rainfall run-off from the refinery, residue storage areas and process water ponds transferred to the Run-off Storage Pond and then used as make-up water for the refinery. Although not shown in Figure 4.1, approximately 126 MLpa of water is used in the Alinta co-generation plant, primarily for emissions control when burning distillate, power augmentation and potable water consumption.

Losses from the process are primarily through evaporation, although there is a relatively high portion of water retained within the residue after it has been dry stacked. All of the residue storage areas have base drainage systems, and these systems collect residue leachate and rainfall infiltration, which is also returned to the refinery as make-up water.

4.3 Yalup Catchment

The refinery's historical diversion of 1600 ML/yr from the Yalup Catchment may continue for the long-term as "existing industrial use", as implied under the management guidelines set for Management Area 5 of the Harvey Basin Allocation Plan (Northern Unregulated and Semi-regulated Darling Range Streams).

North Yalup – Pipe Head Dam

The Pipe Head Dam collects all flow from the North Yalup Brook from where it is transferred to the Upper Yalup Dam, with a small amount of water maintained in the Pipe Head Dam for stock watering purposes. An overflow spillway exists to cater for flows generated during storm events. A scour valve is provided to allow the dam to be drained for maintenance.

Any bypass water will enter Yalup Brook which traverses Alcoa land and then discharges into the Samson South Diversion Drain, which flows to the Harvey River Main Drain.
No formal releases are required for EWRs as existing flows from the local catchment and small tributaries are considered adequate for the section of watercourse downstream of the Pipe Head Dam (Streamtec, April 2002).

South Yalup Catchment – Upper Yalup Dam & Lower Yalup Dam

The Upper Yalup Dam receives direct runoff from the South Yalup Catchment. All runoff is collected. There is provision to transfer water to the Lower Yalup Dam, however this is not normally done. Water in the Upper Yalup Dam is used primarily as a potable water source for the refinery and make up water to cooling towers.

No formal releases are required to meet local EWRs. The ecological value of the downstream riparian zone can be maintained by local run-off (Streamtec, April 2002).

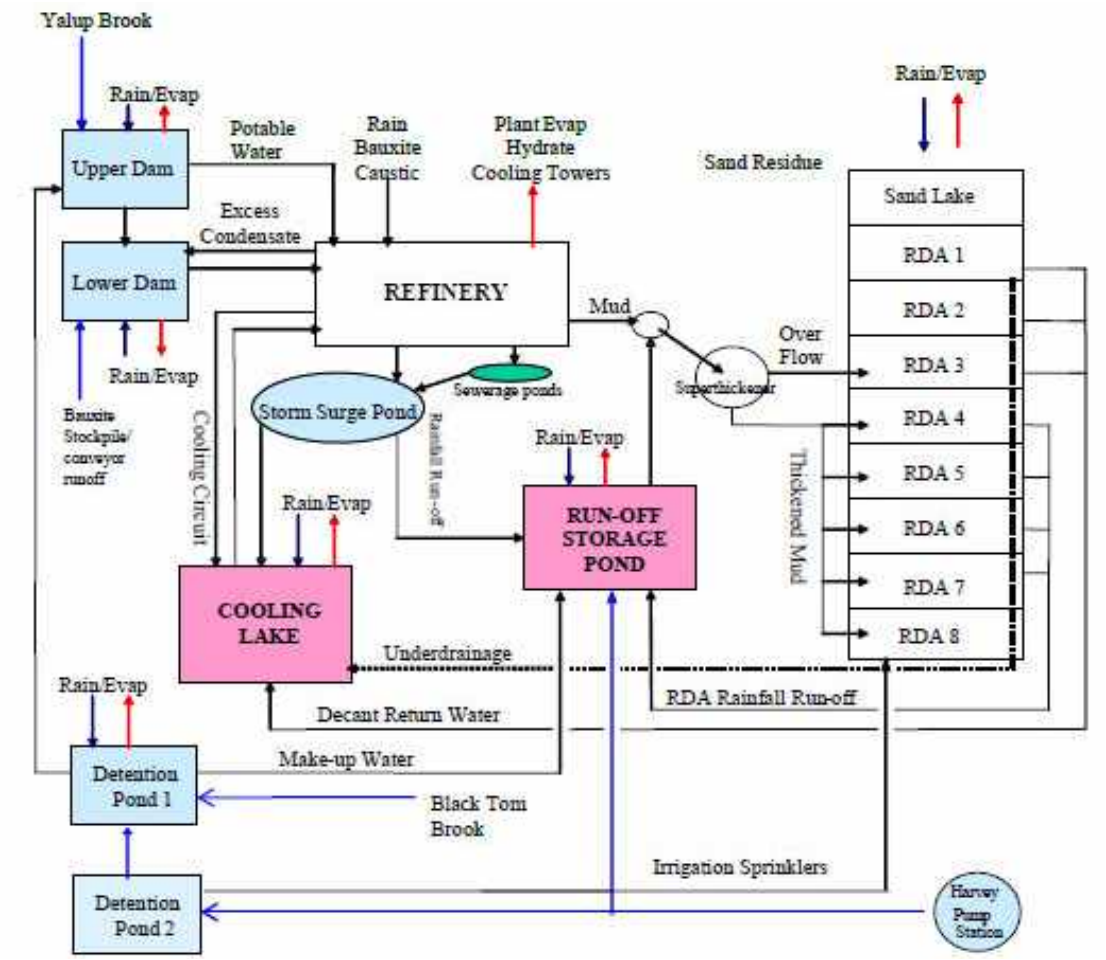


Figure 4.1. Schematic of the Water Circuit

4.4 Black Tom Brook

Over the past five years the refinery has harvested, on average 1550 ML/yr (based on those years of highest draw). In light of the management guidelines set for Management Area 5 of the Harvey Basin Allocation Plan (Northern Unregulated and Semi-regulated Darling Range Streams) the refinery may continue to harvest up to 2500 ML/yr for the long-term from the Black Tom Catchment as "existing industrial use".

Water harvested from the Black Tom Brook catchments is stored in Detention Pond 1 located on the Samson South Diversion Drain. This water is used primarily for dust suppression on the residue storage area.

The un-allocated portion of winter flow draining from the Samson Brook South Channel, Black Tom Brook and North Yalup Catchments overflows the Alcoa Detention Pond into the Diversion Drain. This drain discharges into the Samson Brook South Channel, just upstream of SP12 (see **Figure 8.1**).

The EWR study completed by Streamtec recommends a flow of 3010 ML/yr to maintain the ecology at a low level of risk, for the portion of Samson Brook South Channel between SP12 and the Harvey River Main Drain. It is believed that flows from the Samson Brook North Channel are likely to meet this EWR requirement. SP14 represents Alcoa's monitoring point on the Samson Brook North Channel (see **Figure 8.1**).

4.5 Harvey River

The diversion of 4.4 GL represents less than 5% of the total modelled flow. The design of the Harvey River Main Drain pumping station provides for maintenance of base flow even during the pumping season of May – October. The pump inlet design allows for a minimum of 200mm water depth in the drain before pumping can start. Pumping commences when the river flow exceeds the minimum level and ramps up as flow into the pump chamber increases. The maximum pumping rate with all 4 pumps operating is 465 L/s. The water is transferred to either the ROWS or Detention Ponds, depending on system requirements.

5. Monitoring & Reporting

Objectives of the surface water monitoring program are listed in **Table 3.2**

5.1 Quantity

The volume of water drawn by Alcoa from the various sources will be measured so as to gauge compliance with the Operating Strategy. Similarly the volume released downstream from diversion/storage points, including excess winter flow releases and environmental releases will be monitored. **Table 5.1** summarises the location of the monitoring stations.

Table 5.1. Flow Monitoring Stations

Location	**Alcoa ID**	**DEC (AWRC Ref.)**	**Period of Record**
Nth Yalup Brook	SP1	613015	1978 - Present
South Samson Drain - Cooyah	SP12	613023	1978 - Present
South Samson Diversion Drain – Detention Pond Overflow	SP5	613024	1978 - Present
South Samson Diversion Drain – above detention pond	SP6		1997 - Present
South Samson Drain at Somers Rd	SP16		1997 - Present
Harvey River Main Drain below Pump Station	SP20		2005 - Present
Logue Brook Drain below Pump Station	SP26		2005 - Present

5.2 Quality

Surface water quality monitoring is conducted at station SP12 (see **Figure 8.1**) in accordance with the monitoring parameters and frequency set within Wagerup Refinery's DEC licence. **Table 5.2** outlines the parameters consistent with the licence current at the time of the last review of this Strategy (Licence 6217/14). The licence requires that the physical parameters be sampled monthly when water is flowing and metals six monthly.

Table 5.2 Water Quality Parameters Measured at SP12

Physical parameters	PH, TDS or EC, Alkalinity, Nephelometric turbidity units, Sodium:Chloride ratio (sampled monthly)
Metals	Al, As, Hg, Mn, Mo, Se, U and V

5.3 Frequency

Table 5.3 summarises the sampling frequency at the surface water flow monitoring stations.

Table 5.3 Summary of Monitoring Program

Type	Location	Parameter	Frequency
Quantity	North Yalup (SP1)	Flow volume	Monthly[#]
	Samson South Diversion Drain – detention pond overflow (SP5)	Release/Overflow volume	Monthly[#]
	Samson South Drain – Cooyah (SP12)	Release/Overflow volume	Monthly[#]
	Harvey River Main Drain (SP20)	Flow volume – Harvey	Monthly[$]
	Upper Yalup Dam	Draw volume	Continuous[&]
	Detention Pond	Draw volume	Continuous[&]
	Harvey River Pump Station	Draw volume	Continuous[&]

[#] control weir with level probes reading continuously and recorded on a logger. Data downloaded monthly.

[$] natural channel control with level probe reading continuously and recorded on a logger. Data downloaded monthly.

[&] in-line flow meters (magflow).

5.4 Ecological Assessment

In the context of Adaptive Environmental Assessment and Management (AEAM) the EWRs were evaluated in detail after an initial period.

The need for further monitoring of stream ecology will be reviewed periodically in consultation with the DoW.

6. Environmental Impact Management

Potential environmental impacts of surface water abstraction are managed primarily through the consideration of other water users, and maintenance of ecological water requirements as detailed below:

6.1 Yalup Brook

Other Water Users

There are no other licensed users of water within the catchments.

Ecological Water Requirements

To minimise the adverse impact of surface water diversion by Wagerup Refinery on the downstream environment and other users, Alcoa has completed several environmental water requirements (EWRs) studies of the local catchments. The study areas included:

1. Below Pipe Head Dam on the north tributary of Yalup Brook.
2. Downstream of the Lower Yalup Dam on the south tributary of Yalup Brook.
3. Downstream of confluence of Samson Brook South Channel and the Diversion Drain to the Harvey Main Drain.

The initial study focused on the potential local impacts from the various diversion structures associated with the refinery water supply system. The results of this study have been documented in the following report:

Streamtec (May 2000) Yalup & Samson Brook: Environmental Water Requirements, Streamtec Report 07/00.

Follow up studies were undertaken in 2001 and 2006 to assess any impacts caused by the diversion of water. The results of this study are documented in the following reports:

Streamtec (April 2002) Yalup Brooks & South Samson Drain: Adequacy of Environmental Water Provisions: Results from Biomonitoring, Streamtec Report 04/02

Streamtec (June 2006) Yalup Brooks & South Samson Drain: Adequacy of Environmental Water Provisions: Results from Biomonitoring, Streamtec Report 07/06

All of these reports reinforced that the historical and continued abstraction of water from these systems is not having an adverse effect on their ecological health.

6.2 Black Tom Brook

Other Water Users

The majority of the catchment is within State Forest. Several small private farming lots exist at the foot of the Darling Escarpment and may utilise the Brook for stock watering. This part of the catchment also includes Iluka Minerals (Hamel) mineral sands operations. These operations are all upstream of Alcoa's interception point so are not impacted by Alcoa's use of this source. There are no other users licensed to use water from Black Tom Brook.

Ecological Water Requirements

Alcoa's diversion of Black Tom Brook is at the point where it discharges into South Samson Diversion Drain. This is well downstream of the natural streambed and as a result the diversion has no impact on the upstream ecology. An assessment of EWR for Black Tom Brook is therefore not relevant to this strategy.

6.3 Harvey River

Other major users within catchment

The headwaters of the Harvey River above the new dam are licensed to Harvey Water primarily for agriculture and to the Water Corporation for public water supply. Within the catchment that is relevant to this strategy there are no other licensed users. There is some minor use of water from the Harvey River Main Drain for stock watering.

Ecological Water Requirements

Wagerup Refinery falls within the Harvey River Basin. Allocation of surface water resources in this area need to take into consideration the management guidelines set in the Water and Rivers Commission Report *WRAP 14 (1998) Proposed Harvey Basin Surface Water Allocation Plan,* which determined the EWRs for the greater Harvey River Basin. The plan identifies the ecological importance of flow from the forested scarp catchments reaching the lower river system and Harvey Estuary.

The report "Assessment of proposed water abstraction from the Lower Harvey River" Streamtec 2002, submitted to support the licence application for abstraction from the Harvey Pumpback, includes a desktop analysis of EWR requirements for the Harvey River. A EWR of 3.3 GL/yr has been calculated at the abstraction point.

Further work reported in "Ecological Water Requirements and Water Availability in the Lower Harvey River (Main drain) Catchment Associated with the Proposed Wagerup 3 Expansion" Streamtec 2005, utilised a more conservative 'rule of thumb' approach for estimating EWRs. The method was based on previous work in the greater Harvey River catchment and estimated that up to 25 GL/yr should be available for allocation from the Harvey River Main Drain at Bristol Road crossing, which is just downstream of the pump station.

7. Contingency Program

7.1 Drought and other circumstances of limited water supply

Supply of surface water to the Wagerup Refinery is supplemented by other sources such as groundwater and water purchased from Harvey Water. During periods of limited surface water supply, the Refinery water balance is carefully managed to ensure adequate fit-for-purpose water is available, and additional water may be purchased.

Alcoa Western Australian Operations have a long term water management strategy which aims to reduce Refinery reliance on surface water sources, and use lower grade or recycled water in the process.

7.2 Flooding

The potential impact of high rainfall events is managed by controlling levels in water storage dams, and ensuring that Residue Storage Area's (RSA's) have the capacity to hold stormwater (attenuate). Attenuation is managed by the residue civil engineer, who uses modelling and survey information to understand where residue construction should be targeted, and where mud should be poured.

During periods of high rainfall, water abstraction from surface water sources may be reduced, or cease, increasing the flow of water to downstream users & environments. Where there is capacity to move water between storage areas; this is managed through the use of the Refinery water balance.

7.3 Breach of the Operating Strategy or Water Licence

In the event of a breach of the Operating Strategy, Alcoa will notify the DoW and undertake appropriate corrective actions as soon as practicable. All remedial actions will be documented and reference made to any breaches in the annual report for that year.

7.4 Unexpected water quality trends

The parameters analysed and associated trigger levels for action have been identified in **Table 7.1.**

Table 7.1. Trigger levels – SP12

Parameter	Trigger level	Reason for Trigger
pH	<5 or >9.5	Indicates a result outside of the Guideline value within the DEC operating licence.
EC	>2,000 µS/cm	Indicates a result outside of the Guideline value within the DEC operating licence.
Alkalinity	>50 mg/L	Indicates a result outside of the Guideline value within the DEC operating licence.
Turbidity	>250 NTU	Indicates significant change from natural variations
Al	>5 mg/L	Indicates a result outside of the Guideline value within the DEC operating licence.
As	>0.5 mg/L	Indicates a result outside of the Guideline value within the DEC operating licence.
Hg	>0.002 mg/L	Indicates a result outside of the Guideline value within the DEC operating licence.
Se	>0.02 mg/L	Indicates a result outside of the Guideline value within the DEC operating licence.
V	>0.1 mg/L	Indicates a result outside of the Guideline value within the DEC operating licence.
Mn	>1 mg/L	Indicates a result outside of the Guideline value within the DEC operating licence.
Mo	>0.15 mg/L	Indicates a result outside of the Guideline value within the DEC operating licence.
U	>0.2 mg/L	Indicates a result outside of the Guideline value within the DEC operating licence.
Sodium:chloride ratio	>0.8	Indicates a result outside of the Guideline value within the DEC operating licence.

Corrective Actions

In the event that any of the trigger levels are exceeded, notification will be sent to the DoW. Once the matter has been investigated, Alcoa will ensure appropriate remedial actions are implemented to address identified deficiencies. Results of any investigations will be forwarded to the DoW.

8. Associated Maps

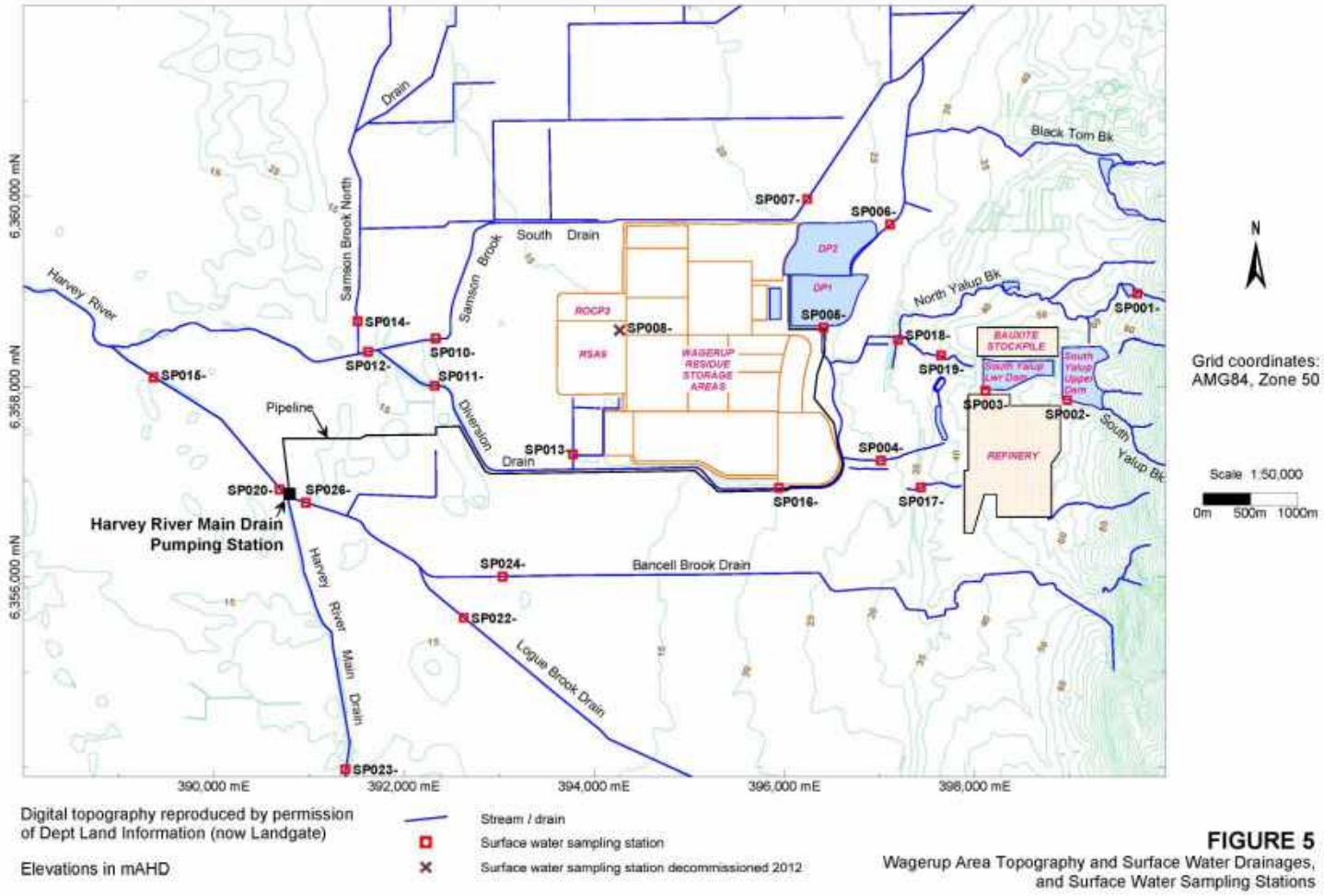


FIGURE 5
Wagerup Area Topography and Surface Water Drainages, and Surface Water Sampling Stations

Figure 8.1 Catchment & Monitoring Location Plan

9. Water use efficiency

Alcoa has developed a water conservation strategy for its Western Australian operations that is primarily aimed at reducing the dependency on high quality water resources. Opportunities such as harvesting lower grade agricultural drainage water and treated effluent are being pursued under this strategy.

The refinery water requirements are largely determined by the refinery process design and opportunities to achieve major reductions in water consumption are limited due to the close relationship between the energy and water balance. Nevertheless, water use efficiency is a key environmental metric and opportunities to improve water use efficiency are identified and evaluated. Examples include the potential for carbonation of residue mud, using pasture as a means of dust control in lieu of applying water and using fit for purpose water for dust suppression and in cooling towers.

10. Summary List of Commitments

Topic	Operating Strategy Section	Commitment
Tenure	1.4	This strategy shall remain current for a maximum of five years from the date of approval by the Department of Water (DoW).
Updates	1.4	The Operating Strategy will be reviewed in accordance with requirements listed in Section 1.4 of this document.
Reporting	1.5	Abstraction volumes calculated from meter readings from all licences will be submitted to DoW as required by the relevant licence.
		An Annual Report will be submitted to DoW by 31 March each year
Action taken in the event of a Breach of the Operating Strategy	7	Report a non-compliance with the Operating Strategy to the DoW within 14 days of the identified non-compliance
		In the event of non-compliance, corrective action will be taken following discussion with DoW. All remedial actions will be documented and reference made to any breaches in the Annual Report for that water year.
Flow Meter Maintenance and Calibration	1.5	Flow meters are maintained and calibrated as per license requirements.
Monitoring	5	Surface Water monitoring completed as per Section 5 of this document
Impacts on Other Users	3	Surface water harvesting is undertaken in a manner that is sustainable and does not have a long-term detrimental effect on the environment or the beneficial use of surface water resources.

APPENDIX D

Sampling Site nomenclature and inventory, Wagerup Alumina Refinery and Bunbury Caustic Loading Facility; Wagerup monitoring programs

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Table D1-D4 Wagerup Refinery Area Bores

Table D1-D5 Wagerup Bore Inventory

Table D1-D6 Wagerup Vibrating Wire Piezometer Inventory

Table D1-D7 Wagerup Surface Water Sampling Site Inventory

Table D1-D8 List of Prefixes used for Sampling Site Nomenclature, Bunbury Caustic Loading Facility

Table D1-D9 List of Suffixes used for Sampling Site Nomenclature, Bunbury Caustic Loading Facility

Table D1-D10 Bunbury Groundwater Monitor Bore Inventory

Table D1-D11 Bunbury Surface Water and Storm Water Sampling Site Inventory

ALCOA'S GENERAL SAMPLING SITE NAMING CONVENTIONS

Alcoa standardised the naming convention for production and monitor bores and other water sampling sites at all facilities in their Western Australian Operations (WAO) in 2004, including the Wagerup Alumina Refinery and Bunbury Caustic Loading Facility.

Names for water sampling sites at all of Alcoa's WAO facilities consist of six characters in the following order:

- A prefix of two characters – usually used to identify the general location or purpose of the sampling site
- Three digits indicating site number
- A single character suffix – in the case of bores, this is used to indicate the aquifer or zone that contributes groundwater to the bore screen or slotted casing

WAGERUP ALUMINA REFINERY

Sampling Site Nomenclature

The prefixes and suffixes used to identify bores and surface water sampling stations at the

Wagerup Alumina Refinery are listed in Tables D1 and D2.

Table D1-1: List of prefixes used for sampling site nomenclature, Wagerup Alumina Refinery

Site Prefix	Site type or purpose
RG, A-, or B-	Regional groundwater monitor bore
RS	Residue Storage Area groundwater monitor bore
RF	Refinery groundwater monitor bore
UD	Residue Storage Area underdrain sump
H- or I-	Vibrating wire piezometer
D-	Groundwater level control / depressurising bore
RB	Recovery bore
SP	Surface water sampling station

Table D1-2: List of suffixes used for sampling site nomenclature, Wagerup Alumina Refinery

Site suffix	Site type	Aquifer exposed to screen or slotted casing of bore
S or E	Bore	Upper Superficial Formations
Y	Bore	Guildford Formation and/or Yoganup Formation
I or G	Bore	Yoganup Formation or Ascot Formation
W	Bore	Cattamarra Coal Measures or Leederville Formation
-	Bore	(No information implied)
-	Surface water	(No information implied)

There are some exceptions to the above sampling site nomenclature at Wagerup:

- Monitor bores RG007G and RG012G – these bores are located in the vicinity of the Wagerup Refinery
- Monitor bores RF034S,G,W, RF035S,G,W, and RF042S,G – these bores are located between the refinery and the RSAs.

Sampling Site Inventory

Tables D3 and D4 list general information about groups of bores at Wagerup, installation dates, and the formations exposed to the casings. Inventories of the groundwater sampling sites and the vibrating wire piezometers are listed in Tables D5 and D6, respectively. Table D7 lists the inventory of the surface water sampling sites.

The bore inventory for Wagerup has recently been updated by Ecotech to include details of location, formation, status, monitoring objectives etc.

Table D1-3: Wagerup Regional and Residue Storage Area Bores

Site	Date	Location and description
A-, B-	1979 to 1980	Regional exploration bores, originally drilled to investigate water supply in deep aquifers. Later converted to monitor bores, after sealing of deeper sections. 1: Slotted throughout the Guildford Clay and Yoganup Formations 2: Slotted in the upper part of the Leederville Formation 3: Slotted in the lower part of the Leederville Formation A-001- to A-003- inactive – last monitored 2002.
RG001 to RG036	10/80 to 3/81	Regional monitoring bores, some near the refinery. G: Slotted through the superficial formations. (Note: Bores RG007G, RG010G, RG012G, RG018G, RG020G, RG022G, RG024G, RG034G, RG035G, RG036G are slotted in the Yoganup Formation and the upper part of the Cattamarra Coal Measures). W: Slotted in the top 15 m to 20 m of the Leederville Formation. RG004G to RG006G decommissioned RG010G inactive RG013G decommissioned 8/12/1998. RG017G/W decommissioned RG018G decommissioned 1/9/2000. RG019G/W decommissioned RG021G/W decommissioned RG023G/W decommissioned 19/10/2015. Replaced with RG153S/G/W RG028G/W decommissioned RG030G to RG033G decommissioned RG035G blocked – water level only
RG016S, RG027S	12/95 – 2/96	Companion shallow bores to RG016G and RG027G. Installed to monitor drawdown from the ROWS Pond depressurising system.
RG078 to RG080	9/89	G: Regional observation bores, downgradient of the RSAs. Slotted in the Yoganup Formation. RG078G decommissioned 2012. No records for RG079 or RG080
RG150 to RG154	4/01 to 5/01	Regional bores, installed to investigate regional stratigraphy and monitor regional changes in water quality and groundwater levels. S: Slotted in upper, clayey aquifer (Guildford Clay). G: Slotted in lower, sandy aquifer (Yoganup or Ascot Formations). W: Slotted below the superficial formations, in the Leederville Formation.
RG155 to RG159	4/01 to 5/01	Regional bores, installed to investigate regional stratigraphy and monitor regional changes in water quality and groundwater levels. S: Slotted in upper, clayey aquifer (Guildford Clay). G: Slotted in lower, sandy aquifer (Yoganup or Ascot Formations). W: Slotted below the superficial formations, in the Leederville Formation. RG159S,G decommissioned 24/11/2003 to allow RSA7 construction. (There was no RG159W.)
RG160 to RG162	7/2003	Regional bores 2 km south of the refinery at former fuel storage and distribution station; S bores only; used to assess hydrocarbon concentrations in shallow groundwater; Decommissioned November 2006
RG166	2006	RG166S not sampled since 2014. Water level only S, G, W: Regional monitor bore triple west of RSAs. S: Slotted in upper, clayey aquifer (Guildford Clay). G: Slotted in lower, sandy aquifer (Yoganup or Ascot Formations). W: Slotted in the Leederville Formation.

Site	Date	Location and description
RG219	2012	Installed east of the RSAs. S: Slotted in Guildford Clay G: Slotted in Ascot Formation W: Slotted in Leederville Formation
RG220, RG221	2017	S and G. Installed downgradient of the former hydrate stockpile. S: Slotted in Guildford Clay G: Slotted in Yoganup Formation
RG222	2020	Regional bore west of the refinery to monitor plume delineation from Building 26. S: Slotted in the upper, clayey aquifer (Guildford Clay). G: Slotted in the lower, sandy aquifer (Yoganup Formation).
RS037 to RS066	8/81 to 5/82	Embankments of the Cooling Pond, RSA1 and Sand Area 1. S: Slotted in upper Guildford Clay. G: Slotted in lower, sandy Yoganup Formation. RS037S/G inactive from 2009 RS038S/G inactive from 2009 RS045S water level only since 2009 – 30 mm tube. RS051S/G to RS057S/G decommissioned 2011 RS058S/G to RS060S/G decommissioned 3/11/2015 RS061S/G decommissioned 29/11/2017 RS062S/G inactive from 2007
RS067 to RS077	8/89 to 10/89	RSA2 embankments. S: Slotted in the Guildford Clay. Note: RS069S is slotted at the base of the dyke. G: Slotted the Yoganup Formation. E: At sites RS069, RS070, RS073 and RS075: slotted in the Guildford Clay. Note: Additional, 15 mm diameter piezometers were installed in the same holes as RS070S, RS070E, RS073S and RS073E for monitoring groundwater levels at the base of the dyke. RS067S/G to RS072S/G decommissioned 2011 (including E bores) RS073S/G to RS075S/G decommissioned 2012 (including E bores) RS076S/G and RS077S/G decommissioned 2013
RS081 to RS085	9/89	S: Along the leach drain on the west dyke wall of RSA2 Drilled to 6 m and slotted over lower 5 m (Guildford Clay). RS081S to RS085S decommissioned
RS088 to RS094	2/92	Embankment of RSA3. S: Slotted through dyke clay and into native soil (Guildford Clay). I: At site RS079, slotted in intermediate, predominantly sandy aquifer (Yoganup Formation). G: Slotted in the lower, predominantly sandy aquifer (Yoganup Formation). RS088S/G decommissioned (replaced by RS145S/G) RS089S/I/G decommissioned (replaced by RS130S/G)
RS095 to RS102	8/91	Embankment of the Runoff Collection Pond. S: Slotted through dyke clay and into native soil (Guildford Clay). I: Slotted in intermediate, predominantly sandy aquifer (Yoganup Formation). G: Slotted in the lower, predominantly sandy aquifer (Yoganup Formation). RS095S insufficient water to sample, water level only
RS103 to RS108,	4/92	Embankment of RSA4. S: Slotted through dyke clay and into native soil (Guildford Clay).

Site	Date	Location and description
RS111		I: At sites RS106, RS107 and RS111, slotted in intermediate, predominantly sandy aquifer (Yoganup Formation). G: Slotted in the lower, predominantly sandy aquifer (Yoganup Formation). RS104S/G to RS108S/G decommissioned 2012 (including I bores). RS108S replaced by RS148S
RS109, RS110, RS112 to RS114	12/93	RSA5 dyke bores. S: Slotted in upper, clayey aquifer (Guildford Clay). G: Slotted in lower, sandy aquifer (Yoganup Formation). B: At site RS112, slotted through dyke clay and into native soil (Guildford Clay). RS109S,G and RS110S,G decommissioned on 24/11/2003. RS112B,S,G, RS113S,G, and RS114S,G decommissioned 2012.
RS115 to RS123	11/95 to 2/96	(S and G): Monitor bores near the Runoff Water Storage Pond (note there is no RS115S). RS123S insufficient water to sample, water level only
RS124S	2/96	Installed in the Guildford Clay, south of the Runoff Storage Pond. Inactive since 2001 due to access
RS125S	2/96	Installed in Guildford Clay, adjacent to RS046S,G, on the western boundary of the Cooling Pond. Inactive since 2005 due to blocked casing
RS126 to RS129, RS131 to RS136	1996, 1997	Installed around Runoff Collection Pond 2, and RSA6. RS128G, RS129G and RS131G to RS133G have been decommissioned. RS134S, RS135S and RS136S (under Runoff Collection Pond 2) were decommissioned. Vibrating wire piezometers I-001-, I-002- and I-003- have been installed at these locations.
RS130	1998	(S and G): Replacement bore for RS089S/I/G.
RS137 to RS142	5/97 to 6/97	(S and G): Installed around Runoff Collection Pond 2.
RS143, RS144	3/99	(S and G): Installed on the eastern side of RSA6. Both bores decommissioned late-2005.
RS145	3/99	(S and G): Installed close to RS088S/G, to investigate possible causes of elevated alkalinity in bore RS088G. RS145G decommissioned 1/9/2000, due to partial obstruction preventing pumped sampling. (Replaced by RS149G)
RS146, RS147	2000	RS146S/G/W; RS147S/I/G: Installed west of ROCP1, to monitor effects of ROCP1 on groundwater quality.
RS148	2000	(S only): Replacement for RS108S. Decommissioned 2012.
RS149	9/00	(G only): Replacement for RS145G, which could not be sampled due to a bent casing.
RS160 to RS164	2004	S and G: Installed around RSA7. RS164W installed into Leederville Formation. RS164S/G/W decommissioned June 2006 before construction of RSA7.
RS165	2005	S and G: Installed to investigate water levels beneath proposed RSA8. Decommissioned in December 2005.
RS167 to RS178	2006	S, G, and RS168W: Monitor bores around RSA8 and Detention Pond 2. S: Slotted in upper, clayey aquifer (Guildford Clay). G: Slotted in lower, sandy aquifer (Yoganup or Ascot Formations). W: Slotted in the Leederville Formation. RS167S/G decommissioned 2009 RS172S Blocked at 4.82m, unable to sample

Site	Date	Location and description
RS179 to RS188	2009	S only. Shallow monitor bores around southern half of RSA2; all slotted casing in upper Guildford Clay. All bores decommissioned in 2011
RS189 to RS192	2010	S and G. Installed around RSA7N. S: Slotted in upper, clayey aquifer (Guildford Clay). G: Slotted in lower, sandy aquifer (Ascot Formation).
RS193 to RS205	2012	S and G. Installed at ROCP3 and RSA9. S: Slotted in upper, clayey aquifer (Guildford Clay). G: Slotted in lower, sandy aquifer (Ascot Formation).
H-001- to H-006-	1/96	Vibrating wire piezometers under the Runoff Water Storage Pond. Slotted from about 6 m to 12 m below ground level (11 mAHD to 5 mAHD), in the Yoganup Formation. H-001- inactive since 1999 H-006- inactive since 2000
I-1-, I-0-, I-003-	12/96	Vibrating wire piezometers under Runoff Collection Pond 2. Placed at the locations of decommissioned bores RG136S, RG135S and RG134S, respectively. Slotted from about 9.5 m to 12.5 m below ground level (8 mAHD to 5 mAHD), in the Yoganup Formation.
H-007 to H-018	2012	Vibrating wire piezometers beneath ROCP3 and RSA9. S: Slotted in upper, clayey aquifer (Guildford Clay). G: Slotted in lower, sandy aquifer (Ascot Formation). H-016S/G inactive since 2013
D-001G, D-002G	7/81 to 8/81	Depressurising bores on the east embankment of the Cooling Pond. Screened in Guildford Clay and Yoganup Formation. D-001G inactive, last monitored 2004
D-003G to D-008G	10/95 to 11/95	Depressurising bores on the east and south embankments of the Runoff Water Storage Pond. Screened in the Yoganup Formation. D-003G inactive, last monitored 2004 D-005G inactive, last monitored 2004
D-009G to D-014G	12/96 to 2/97	Depressurising bores around Runoff Collection Pond 2. Screened in the Yoganup Formation. D-009G inactive 2004 - 2012 D-011G inactive 2004 - 2012 D-012G inactive 2004 - 2012
D-015G to D-018G	2/98	Depressurising bores located around Runoff Collection Pond 1. Screened in the Yoganup Formation. All bores inactive
D-019G to D-035G	2012	Depressurising bores around ROCP3 and RSA9. Screened in the Ascot Formation. D-022G decommissioned 2012.
P-001 to P- 009	7/86 to 8/86	Refinery monitor bores. Drilled to approximately 6 m below ground level and slotted at base. All bores inactive or decommissioned.

Table D1-4: Wagerup Refinery Area Bores

Site	Date	Location and description
RF001 to RF015	1/93 to 3/93	Refinery monitor bores, located in areas of potential contamination. S: Slotted in the upper, clayey aquifer (Yoganup Formation) G: Slotted in the lower, sandy aquifer (Yoganup Formation). RF002S/G inactive since 2012, damaged casing RF004S inactive since 2006, casing blocked RF007S/G and RF008S/G decommissioned RF008S/G decommissioned RF010S/G inactive since 2010, buried RF012S/G decommissioned
RF016 to RF021	12/97	Refinery monitor bores, to investigate the alkaline plume west of Building 45. S: Slotted in the upper, clayey aquifer (Yoganup Formation). Y: Slotted in the lower, sandy aquifer (Yoganup Formation). RF016S inactive, dry RF017S inactive, dry RF018S inactive since 2015 RF021S inactive since 2015, dry
RF022 to RF033	11/98 to 12/98	Bores installed west of the refinery's hydrate stockpile, to delineate a plume of hydrate stockpile leachate. S: Slotted in the upper, clayey aquifer (Yoganup Formation). G: Slotted in the lower, sandy aquifer (Yoganup Formation). RF025S inactive since 2015, dry RF031S/G inactive since 2009, access
RF034 to RF049	9/99 to11/99	Bores installed at various sites in the refinery. S: Slotted in the upper superficial formations (Yoganup Formation or Guildford Clay). G: Slotted in the lower, sandy aquifer (Yoganup Formation). W: At sites RF034, RF035 and RF041, slotted in the strata underlying the superficial formations (Leederville Formation or Cattamarra Coal Measures). RF037S inactive, damaged casing RF039S, insufficient water to sample, water level only. RF042S/G inactive since 2011, damaged casing RF048S/D decommissioned 2018
RF050 to RF053	3/2000	Located near the refinery's powerhouse. S: Slotted in the upper superficial formations (Yoganup Formation). G: Slotted in the lower, sandy aquifer (Yoganup Formation). RF052S, insufficient water to sample, mainly dry.
RF050W	5/2001	Companion to RF050S,G, slotted in the Cattamarra Coal Measures near the refinery powerhouse.
RF054	9/2000	Replacement for RF012SG. S: Slotted in the upper superficial formations (Yoganup Formation). I: Slotted at intermediate depth (Yoganup Formation) G: Slotted in the lower, sandy aquifer (Yoganup Formation).

Site	Date	Location and description
RF059	3/2000	S only; located near the refinery's powerhouse. Initially a soil investigation hole, completed as a monitor bore due to the large water yield. Inactive since 2010, casing blocked
RF086G, RF087G	1989	Located near the refinery. Slotted casing extends across the Yoganup Fm and upper part of the Cattamarra Coal Measures. RF087G inactive since 2007 due to access
RF122 to RF130	2006	S, G, and RF127W: Monitor bores located near Buildings 26, 40, 42A, 42B, 42C, and 47A. RF124S, insufficient water to sample, mainly dry since 2008 RF126S, insufficient water to sample, water level only RF127S, insufficient water to sample, water level only RF128S, insufficient water to sample, water level only RF129S, insufficient water to sample, water level only
RF131 to RF134	2014	Additional monitor bores located near Building 45. S: Slotted in the upper, clayey aquifer (Guildford Clay). G: Slotted in the lower, sandy aquifer (Yoganup Formation). W: Slotted in the Cattamarra Coal Measures.
RF135	2017	S and G. Installed downgradient of the former hydrate stockpile. S: Slotted in Guildford Clay G: Slotted in Yoganup Formation
RF136 to RF139	2020	Additional monitor bores for further plume delineation located near Building 26 (RF136), Building 47 (RF137), Building 35 (RF138), and Building 40 (RF139). S: Slotted in the upper, clayey aquifer (Guildford Clay). G: Slotted in the lower, sandy aquifer (Yoganup Formation).
RB001G, RB002G	2006	Recovery bores located adjacent to Building 26 at the refinery. Screened across the Yoganup Formation.
RB003G, RB004G	2014	Recovery bores located adjacent to Building 45 at the refinery. Screened across the Yoganup Formation.

Table D1-5: Wagerup Bore Inventory

Bore	Casing ND (mm)	Monitoring start date	Status	AMG84 Coordinates (Zn50)		TOC (mAHD)	Slotted/screen interval (mBGL)		Formation
				mE	mN		Top	Bottom	
A-001-	50	1981	Inactive	396,192.0	6,358,645.0	21.78	6.0	30.0	Guildford Clay and Yoganup Formation
A-002-	50	1981	Inactive	396,192.0	6,358,645.0	21.47	52.1	55.0	Leederville Formation
A-003-	50	1981	Inactive	396,192.0	6,358,645.0	21.38	89.9	92.9	Leederville Formation
B-001-	50	1981	Active	392,364.1	6,358,405.9	15.09	6.0	30.0	Guildford Clay and Yoganup Formation
B-002-	50	1981	Active	392,364.1	6,358,405.9	15.44	71.4	74.4	Leederville Formation
B-003-	50	1981	Active	392,364.1	6,358,405.9	15.44	94.8	97.8	Leederville Formation
D-001G	100	1985	Inactive	396,286.0	6,358,389.1	25.58	8.8	26.7	Guildford Clay and Yoganup Formation
D-002G	100	1985	Active	396,186.9	6,357,791.1	26.82	19.5	28.4	Guildford Clay and Yoganup Formation
D-003G	100	1998	Inactive	396,413.8	6,357,700.7	22.89	15.4	21.1	Guildford Clay and Yoganup Formation
D-004G	100	1996	Active	396,535.8	6,357,410.1	22.22	9.8	19.7	Guildford Clay and Yoganup Formation
D-005G	100	1996	Inactive	396,592.1	6,357,200.7	20.53	7.3	18.8	Guildford Clay and Yoganup Formation
D-006G	100	1996	Active	396,496.3	6,357,010.2	20.88	11.1	20.0	Guildford Clay and Yoganup Formation
D-007G	100	1996	Active	396,065.0	6,356,955.7	19.00	13.2	22.1	Guildford Clay and Yoganup Formation
D-008G	100	1996	Active	396,478.1	6,357,619.0	22.93	11.3	20.2	Guildford Clay and Yoganup Formation
D-009G	100	1997	Inactive	395,831.0	6,358,808.5	20.32	14.4	23.4	Guildford Clay and Yoganup Formation
D-010G	100	1997	Active	395,830.8	6,358,955.5	19.30	14.6	23.6	Guildford Clay and Yoganup Formation
D-011G	100	1997	Inactive	395,676.0	6,358,684.6	21.45	17.1	26.1	Guildford Clay and Yoganup Formation
D-012G	100	1997	Inactive	395,671.1	6,359,089.4	21.09	15.1	24.1	Guildford Clay and Yoganup Formation
D-013G	100	1997	Active	395,811.0	6,359,089.3	19.50	14.6	23.6	Guildford Clay and Yoganup Formation
D-014G	100	1997	Active	395,830.0	6,358,706.5	19.36	15.6	24.6	Guildford Clay and Yoganup Formation
D-015G	100	1998	Inactive	394,107.6	6,357,597.8	15.43	12.8	21.8	Guildford Clay and Yoganup Formation
D-016G	100	1998	Inactive	394,107.4	6,357,419.8	15.48	11.5	14.6	Guildford Clay and Yoganup Formation
D-017G	100	1998	Inactive	394,253.5	6,357,275.0	15.79	12.3	21.3	Guildford Clay and Yoganup Formation
D-018G	100	1998	Inactive	394,247.2	6,357,743.9	15.51	10.8	19.8	Guildford Clay and Yoganup Formation
D-019G	155	2012	Active	394,259.9	6,359,013.2	16.46	15.2	21.2	Ascot Formation
D-020G	155	2012	Active	394,090.5	6,359,013.6	16.10	15.2	21.2	Ascot Formation
D-021G	155	2012	Active	393,919.2	6,359,015.6	15.81	11.9	14.9	Ascot Formation
							18.7	21.7	Ascot Formation

Bore	Casing ND (mm)	Monitoring start date	Status	AMG84 Coordinates (Zn50)		TOC (mAHD)	Slotted/screen interval (mBGL)		Formation
				mE	mN		Top	Bottom	
D-022G	155	2012	Decommissioned	393,750.1	6,359,015.8	n/a	n/a	n/a	Ascot Formation
D-022G	155	2012	Decommissioned	393,750.1	6,359,015.8	n/a	n/a	n/a	Ascot Formation
D-023G	155	2012	Active	393,592.1	6,359,001.3	14.92	11.5	14.5	Ascot Formation
							18.5	21.5	Ascot Formation
D-024G	155	2012	Active	393,578.4	6,358,846.5	14.84	9.0	12.0	Ascot Formation
							19.0	22.0	Ascot Formation
D-025G	155	2012	Active	393,573.0	6,358,692.5	15.27	10.5	13.5	Ascot Formation
							18.0	21.0	Ascot Formation
D-026G	155	2012	Active	393,573.3	6,358,530.7	15.06	11.0	14.0	Ascot Formation
							19.3	22.3	Ascot Formation
D-027G	155	2012	Active	393,570.0	6,358,368.5	15.01	10.2	13.2	Ascot Formation
							18.7	21.7	Ascot Formation
D-028G	155	2012	Active	393,566.4	6,358,208.5	15.04	12.0	15.0	Ascot Formation
							19.0	22.0	Ascot Formation
D-029G	155	2012	Active	393,563.4	6,358,045.8	14.68	11.5	17.5	Ascot Formation
D-030G	155	2012	Active	393,587.4	6,357,896.8	15.17	12.0	15.0	Ascot Formation
							18.7	21.7	Ascot Formation
D-031G	155	2012	Active	393,752.2	6,357,881.5	15.06	13.6	16.6	Ascot Formation
							19.6	22.6	Ascot Formation
D-032G	155	2012	Active	393,918.5	6,357,880.8	14.83	11.0	17.0	Ascot Formation
D-033G	155	2012	Active	394,089.9	6,357,880.7	15.20	11.2	14.2	Ascot Formation
							18.2	21.2	Ascot Formation
D-034G	155	2012	Active	394,254.3	6,357,879.5	14.87	13.4	19.4	Ascot Formation
D-035G	155	2012	Active	393,765.9	6,359,015.5	15.71	12.0	15.0	Ascot Formation
							16.3	22.3	Ascot Formation
P-001	N/A	N/A	Decommissioned	398,050.7	6,357,178.7	42.07	0.0	6.2	Yoganup Formation
P-002	N/A	N/A	Decommissioned	397,984.5	6,357,660.7	41.84	0.0	5.3	Yoganup Formation
P-003	N/A	N/A	Inactive	398,233.9	6,357,911.4	46.71	0.0	7.2	Yoganup Formation
P-004	N/A	N/A	Decommissioned	398,391.4	6,357,719.3	46.80	0.0	5.9	Yoganup Formation

Bore	Casing ND (mm)	Monitoring start date	Status	AMG84 Coordinates (Zn50)		TOC (mAHD)	Slotted/screen interval (mBGL)		Formation
				mE	mN		Top	Bottom	
P-005	N/A	N/A	Decommissioned	398,714.0	6,357,646.1	48.27	0.0	5.9	Yoganup Formation
P-006	N/A	N/A	Inactive	398,796.8	6,357,236.4	54.77	0.0	6.7	Yoganup Formation
P-007	N/A	N/A	Inactive	398,515.8	6,357,180.1	51.14	0.0	7.3	Yoganup Formation
P-008	N/A	N/A	Inactive	398,685.2	6,356,685.2	52.94	0.0	5.8	Yoganup Formation
P-009	N/A	N/A	Decommissioned	398,211.5	6,356,652.7	47.13	0.0	7.4	Yoganup Formation
RB001G	200	2007	Active	397,996.4	6,357,724.5	47.57	8.0	14.0	Yoganup Formation
RB002G	200	2007	Active	397,996.9	6,357,686.1	47.50	8.0	14.0	Yoganup Formation
RB003G	200	2014	Active	398,310.8	6,356,910.7	49.07	12.0	15.0	Yoganup Formation
RB004G	200	2014	Active	398,311.0	6,356,890.7	48.90	11.7	14.7	Yoganup Formation
RF001S	50	1995	Inactive	397,993.0	6,357,716.4	47.15	0.5	6.5	Yoganup Formation
RF001G	50	1995	Active	397,993.0	6,357,716.4	47.15	9.0	15.0	Yoganup Formation
RF002S	50	1995	Inactive	398,096.6	6,357,730.9	47.23	1.0	7.0	Yoganup Formation
RF002G	50	1995	Inactive	398,096.6	6,357,730.9	47.23	9.0	15.0	Yoganup Formation
RF003S	50	1995	Active	398,153.9	6,357,676.1	46.29	1.0	7.0	Yoganup Formation
RF003G	50	1995	Active	398,153.9	6,357,676.1	46.29	9.5	15.5	Yoganup Formation
RF004S	50	1995	Inactive	398,269.2	6,357,724.2	46.43	1.0	7.0	Yoganup Formation
RF004G	50	1995	Active	398,269.2	6,357,724.2	46.43	8.0	15.0	Yoganup Formation
RF005S	50	1995	Active	398,319.0	6,357,657.8	46.52	1.0	7.0	Yoganup Formation
RF005G	50	1995	Active	398,319.0	6,357,657.8	46.52	8.0	15.0	Yoganup Formation
RF006S	50	1995	Active	398,210.4	6,357,535.5	46.44	1.0	7.0	Yoganup Formation
RF006G	50	1995	Active	398,210.4	6,357,535.5	46.44	8.5	15.0	Yoganup Formation
RF007S	50	1995	Decommissioned	398,100.6	6,357,474.1	46.52	1.0	7.0	Yoganup Formation
RF007G	50	1995	Decommissioned	398,100.6	6,357,474.1	46.52	8.0	15.3	Yoganup Formation
RF008S	50	1995	Decommissioned	398,174.7	6,357,342.2	46.65	1.0	8.5	Yoganup Formation
RF008G	50	1995	Decommissioned	398,174.7	6,357,342.2	46.65	9.5	15.6	Yoganup Formation
RF009S	50	1995	Active	398,259.8	6,357,449.0	46.63	1.0	6.0	Yoganup Formation
RF009G	50	1995	Active	398,259.8	6,357,449.0	46.63	7.0	14.7	Yoganup Formation
RF010S	50	1995	Inactive	398,366.0	6,357,420.0	46.37	1.0	7.0	Yoganup Formation
RF010G	50	1995	Inactive	398,366.0	6,357,420.0	46.37	8.0	14.6	Yoganup Formation

Bore	Casing ND (mm)	Monitoring start date	Status	AMG84 Coordinates (Zn50)		TOC (mAHD)	Slotted/screen interval (mBGL)		Formation
				mE	mN		Top	Bottom	
RF011S	50	1995	Active	398,357.9	6,356,891.9	48.82	0.5	2.5	Yoganup Formation
RF011I	50	1995	Active	398,357.9	6,356,891.9	48.82	3.5	7.5	Yoganup Formation
RF011G	50	1995	Active	398,357.9	6,356,891.9	48.82	8.5	16.9	Yoganup Formation
RF012S	50	1995	Decommissioned	398,353.7	6,356,831.5	48.91	1.0	7.0	Yoganup Formation
RF012G	50	1995	Decommissioned	398,353.7	6,356,831.5	48.87	8.0	17.0	Yoganup Formation
RF013S	50	1995	Active	398,225.8	6,356,706.9	47.58	1.0	10.0	Yoganup Formation
RF013G	50	1995	Active	398,225.8	6,356,706.9	47.58	11.0	15.9	Yoganup Formation
RF014S	50	1995	Active	398,235.8	6,356,810.8	47.53	1.0	9.0	Yoganup Formation
RF014G	50	1995	Active	398,235.8	6,356,810.8	47.53	10.0	15.6	Yoganup Formation
RF015S	50	1995	Active	398,035.6	6,356,884.3	42.61	1.0	7.0	Yoganup Formation
RF015G	50	1995	Active	398,035.6	6,356,884.3	42.61	8.0	14.3	Yoganup Formation
RF016S	50	1998	Active	398,317.1	6,356,831.3	48.93	5.6	8.6	Yoganup Formation
RF016Y	50	1998	Active	398,317.1	6,356,832.5	48.93	9.6	15.6	Yoganup Formation
RF017S	50	1998	Active	398,320.5	6,356,864.5	49.26	2.7	5.7	Yoganup Formation
RF017Y	50	1998	Active	398,320.6	6,356,865.6	49.26	9.3	15.3	Yoganup Formation
RF018S	50	1998	Active	398,302.2	6,356,832.3	49.07	4.6	7.6	Yoganup Formation
RF018Y	50	1998	Active	398,302.3	6,356,831.2	49.04	9.3	15.3	Yoganup Formation
RF019S	50	1998	Active	398,325.6	6,356,883.2	49.47	6.1	9.1	Yoganup Formation
RF019Y	50	1998	Active	398,325.6	6,356,884.2	49.47	10.2	15.7	Yoganup Formation
RF020S	50	1998	Active	398,295.8	6,356,886.6	49.27	5.1	8.1	Yoganup Formation
RF020Y	50	1998	Active	398,295.8	6,356,887.7	49.16	9.2	15.2	Yoganup Formation
RF021S	50	1998	Active	398,303.1	6,356,866.0	48.92	4.6	7.6	Yoganup Formation
RF021Y	50	1998	Active	398,303.0	6,356,865.2	48.91	8.7	14.7	Yoganup Formation
RF022S	50	1999	Active	397,858.5	6,356,649.0	43.97	3.3	6.3	Yoganup Formation
RF022G	50	1999	Active	397,860.2	6,356,649.0	43.98	6.5	12.5	Yoganup Formation
RF023S	50	1999	Active	397,856.1	6,356,609.0	43.73	2.8	8.8	Yoganup Formation
RF023G	50	1999	Active	397,858.7	6,356,609.0	43.78	8.8	14.8	Yoganup Formation
RF024S	50	1999	Active	397,841.8	6,356,565.0	43.39	2.7	5.7	Yoganup Formation
RF024G	50	1999	Active	397,839.9	6,356,565.0	43.42	5.7	11.7	Yoganup Formation

Bore	Casing ND (mm)	Monitoring start date	Status	AMG84 Coordinates (Zn50)		TOC (mAHD)	Slotted/screen interval (mBGL)		Formation
				mE	mN		Top	Bottom	
RF025S	50	1999	Active	397,856.6	6,356,694.0	44.21	3.2	6.2	Yoganup Formation
RF025G	50	1999	Active	397,855.2	6,356,694.0	44.21	6.0	12.0	Yoganup Formation
RF026S	50	1999	Active	397,877.5	6,356,750.0	43.62	2.8	5.8	Yoganup Formation
RF026G	50	1999	Active	397,879.4	6,356,750.0	43.62	6.3	12.3	Yoganup Formation
RF027S	50	1999	Active	397,767.3	6,356,643.0	43.23	3.8	6.8	Yoganup Formation
RF027G	50	1999	Active	397,768.6	6,356,643.0	43.23	6.8	12.8	Yoganup Formation
RF028S	50	1999	Active	397,812.3	6,356,638.0	43.61	2.8	5.8	Yoganup Formation
RF028G	50	1999	Active	397,813.8	6,356,638.0	43.60	7.3	13.3	Yoganup Formation
RF029S	50	1999	Active	397,814.1	6,356,695.0	44.08	2.8	5.8	Yoganup Formation
RF029G	50	1999	Active	397,815.2	6,356,696.0	44.08	7.3	13.3	Yoganup Formation
RF030S	50	1999	Active	397,852.1	6,356,750.0	43.70	2.2	5.2	Yoganup Formation
RF030G	50	1999	Active	397,854.0	6,356,750.0	43.67	5.7	11.7	Yoganup Formation
RF031S	50	1999	Active	397,777.3	6,356,727.0	44.11	2.7	5.7	Yoganup Formation
RF031G	50	1999	Active	397,776.7	6,356,729.0	44.03	6.2	13.2	Yoganup Formation
RF032S	50	1999	Active	397,772.2	6,356,776.0	43.77	3.2	7.2	Yoganup Formation
RF032G	50	1999	Active	397,770.2	6,356,776.0	43.78	8.8	12.2	Yoganup Formation
RF033S	50	1999	Active	397,893.4	6,356,645.0	44.16	2.8	5.8	Yoganup Formation
RF033G	50	1999	Active	397,893.4	6,356,644.0	44.18	6.8	11.8	Yoganup Formation
RF034S	50	1999	Active	397,344.1	6,358,604.3	31.95	7.3	13.3	Yoganup Formation
RF034G	50	1999	Active	397,344.9	6,358,603.4	31.90	17.8	22.3	Yoganup Formation
RF034W	50	1999	Active	397,345.9	6,358,602.4	31.87	23.2	28.1	Cattamarra Coal Measures
RF035S	50	1999	Active	397,596.9	6,358,484.8	34.07	3.3	6.3	Yoganup Formation
RF035G	50	1999	Active	397,597.8	6,358,485.8	34.00	8.3	17.3	Yoganup Formation
RF035W	50	1999	Active	397,598.7	6,358,486.9	33.97	19.3	25.3	Cattamarra Coal Measures
RF036S	50	1999	Active	397,980.3	6,357,694.5	43.16	3.3	7.3	Yoganup Formation
RF036G	50	1999	Active	397,980.3	6,357,693.3	43.20	7.8	9.9	Yoganup Formation
RF037S	50	1999	Inactive	397,976.2	6,357,813.4	43.06	2.8	5.8	Yoganup Formation
RF037G	50	1999	Active	397,976.2	6,357,812.1	43.02	5.8	9.8	Yoganup Formation
RF038S	50	1999	Active	398,220.4	6,357,918.0	47.03	3.8	9.8	Yoganup Formation

Bore	Casing ND (mm)	Monitoring start date	Status	AMG84 Coordinates (Zn50)		TOC (mAHD)	Slotted/screen interval (mBGL)		Formation
				mE	mN		Top	Bottom	
RF038G	50	1999	Active	398,221.8	6,357,917.9	47.04	10.9	16.6	Yoganup Formation
RF039S	50	1999	Active	398,098.6	6,357,669.0	47.24	6.8	9.8	Yoganup Formation
RF039G	50	1999	Active	398,097.0	6,357,669.7	47.28	9.8	12.8	Yoganup Formation
RF040S	50	1999	Active	398,083.5	6,357,450.3	46.85	4.6	7.6	Yoganup Formation
RF040G	50	1999	Active	398,083.6	6,357,449.2	46.86	8.7	14.7	Yoganup Formation
RF041S	50	1999	Active	398,083.7	6,357,076.4	47.36	5.3	11.3	Yoganup Formation
RF041G	50	1999	Active	398,083.9	6,357,075.2	47.36	11.4	17.4	Yoganup Formation
RF041W	50	1999	Active	398,083.9	6,357,074.0	47.36	19.8	29.8	Cattamarra Coal Measures
RF042S	50	1999	Inactive	396,941.4	6,358,591.0	28.02	1.8	4.8	Yoganup Formation
RF042G	50	1999	Inactive	396,940.2	6,358,591.0	28.05	8.3	14.3	Yoganup Formation
RF043G	50	1999	Active	397,902.6	6,357,729.4	47.56	7.3	13.3	Yoganup Formation
RF044S	50	2000	Active	397,902.3	6,357,809.5	47.65	8.3	11.3	Yoganup Formation
RF044G	50	1999	Active	397,903.3	6,357,809.4	47.63	11.3	14.3	Yoganup Formation
RF045S	50	2000	Active	398,224.8	6,356,928.8	47.29	4.3	9.3	Yoganup Formation
RF045G	50	2000	Active	398,223.5	6,356,928.8	47.28	9.3	15.3	Yoganup Formation
RF046S	50	2000	Decommissioned	398,242.1	6,356,891.0	47.65	4.8	9.8	Yoganup Formation
RF046G	50	2000	Decommissioned	398,241.2	6,356,890.2	47.69	9.8	15.8	Yoganup Formation
RF047S	50	2000	Active	398,108.0	6,357,351.3	47.32	4.3	7.3	Yoganup Formation
RF047G	50	2000	Active	398,107.9	6,357,350.5	47.33	7.9	15.4	Yoganup Formation
RF048S	50	2000	Decommissioned	398,046.9	6,357,452.0	47.25	5.8	8.8	Yoganup Formation
RF048G	50	2000	Decommissioned	398,047.5	6,357,451.7	47.26	9.3	15.3	Yoganup Formation
RF049S	50	2000	Active	398,161.9	6,356,891.7	47.05	5.8	13.8	Yoganup Formation
RF049G	50	2000	Active	398,160.9	6,356,892.3	47.05	14.9	16.9	Yoganup Formation
RF050S	50	2000	Active	398,722.0	6,357,533.0	50.06	1.8	5.3	Yoganup Formation
RF050G	50	2000	Active	398,722.0	6,357,531.0	42.98	6.3	13.3	Yoganup Formation
RF050W	50	2000	Active	398,722.1	6,357,534.6	50.04	18.7	40.7	Yoganup Formation
RF051S	50	2000	Active	398,650.5	6,357,535.0	48.68	1.7	5.2	Yoganup Formation
RF051G	50	2000	Active	398,650.0	6,357,537.0	48.72	5.8	13.3	Yoganup Formation
RF052S	50	2000	Active	398,529.5	6,357,558.0	48.07	1.8	4.8	Yoganup Formation

Bore	Casing ND (mm)	Monitoring start date	Status	AMG84 Coordinates (Zn50)		TOC (mAHD)	Slotted/screen interval (mBGL)		Formation
				mE	mN		Top	Bottom	
RF052G	50	2000	Active	398,531.0	6,357,558.0	48.14	4.8	12.8	Yoganup Formation
RF053S	50	2000	Active	398,516.0	6,357,507.0	48.76	1.8	5.8	Yoganup Formation
RF053G	50	2000	Active	398,517.0	6,357,507.0	48.73	4.8	12.8	Yoganup Formation
RF054S	50	2000	Active	398,357.8	6,356,823.9	49.74	7.3	13.3	Yoganup Formation
RF054I	50	2000	Active	398,357.9	6,356,826.5	49.75	13.9	16.9	Yoganup Formation
RF054G	50	2000	Active	398,357.9	6,356,827.0	49.76	16.9	20.9	Yoganup Formation
RF059S	50	2000	Inactive	398,649.0	6,357,490.0	49.23	3.0	6.0	Yoganup Formation
RF086G	50	1990	Active	397,986.5	6,357,599.7	42.13	4.6	28.6	Yoganup Fm. and Cattamarra Coal Measures
RF087G	50	1990	Inactive	398,002.4	6,357,044.6	41.67	3.5	22.5	Yoganup Fm. and Cattamarra Coal Measures
RF122S	50	2006	Active	398,058.4	6,357,690.6	46.58	2.3	7.8	Yoganup Formation
RF122G	50	2006	Active	398,062.1	6,357,690.5	46.46	7.8	13.8	Yoganup Formation
RF123S	50	2006	Active	397,993.2	6,357,711.2	46.98	3.8	9.8	Yoganup Formation
RF124S	50	2006	Active	398,233.2	6,357,263.8	47.46	3.6	6.6	Yoganup Formation
RF124G	50	2006	Active	398,231.2	6,357,263.8	47.42	6.6	12.6	Yoganup Formation
RF125S	50	2006	Active	398,276.5	6,357,241.2	46.36	2.8	8.8	Yoganup Formation
RF125G	50	2006	Active	398,276.4	6,357,243.0	46.40	7.6	13.6	Yoganup Formation
RF126S	50	2006	Active	398,280.7	6,357,399.9	47.01	3.6	6.6	Yoganup Formation
RF126G	50	2006	Active	398,278.9	6,357,399.9	46.99	6.6	12.6	Yoganup Formation
RF127S	50	2006	Active	398,204.5	6,357,305.9	46.39	2.8	5.8	Yoganup Formation
RF127G	50	2006	Active	398,206.6	6,357,305.9	46.37	5.8	11.8	Yoganup Formation
RF127W	50	2006	Active	398,208.4	6,357,305.9	46.31	17.8	29.8	Yoganup Formation
RF128S	50	2006	Active	398,237.9	6,357,372.4	47.30	3.6	6.6	Yoganup Formation
RF128G	50	2006	Active	398,237.9	6,357,370.3	47.30	6.6	12.6	Yoganup Formation
RF129S	50	2006	Active	398,150.0	6,357,378.7	46.44	2.9	5.9	Yoganup Formation
RF129G	50	2006	Active	398,150.0	6,357,376.6	46.41	5.9	11.9	Yoganup Formation
RF130S	50	2006	Active	398,166.4	6,357,455.9	47.32	4.6	7.6	Yoganup Formation
RF130G	50	2006	Active	398,166.4	6,357,453.9	47.35	8.6	14.6	Yoganup Formation

Bore	Casing ND (mm)	Monitoring start date	Status	AMG84 Coordinates (Zn50)		TOC (mAHD)	Slotted/screen interval (mBGL)		Formation
				mE	mN		Top	Bottom	
RF131S	50	2014	Inactive	398,341.2	6,356,982.7	48.73	5.2	8.2	Guildford Clay
RF131G	50	2014	Inactive	398,343.0	6,356,982.8	49.71	9.7	14.7	Yoganup Formation
RF132G	50	2014	Inactive	398,279.1	6,356,939.6	49.22	9.7	14.2	Yoganup Formation
RF133W	50	2014	Inactive	398,240.5	6,356,888.4	48.49	18.2	29.8	Cattamarra Coal Measures
RF134G	50	2014	Inactive	398,244.8	6,356,850.3	48.37	8.6	13.0	Yoganup Formation
RF135G	50	2017	Active	397,841	6,356,893	45.865	12	15	Yoganup Formation
RF135S	50	2017	Active	397,843	6,356,892	45.88	4.5	7.5	Guildford Clay
RF136G	50	2020	Active	398,136	6,357,673	46.975	9.5	12.5	Yoganup Formation
RF136S	50	2020	Active	398,136	6,357,674	47.014	3.0	6.0	Guildford Clay
RF137G	50	2020	Active	398,105	6,357,475	46.265	12.0	15.0	Yoganup Formation
RF137S	50	2020	Active	398,105	6,357,476	46.302	5.0	8.0	Guildford Clay
RF138G	50	2020	Active	398,404	6,357,367	47.099	8.5	11.5	Yoganup Formation
RF138S	50	2020	Active	398,404	6,357,366	47.163	3.5	6.5	Guildford Clay
RF139G	50	2020	Active	398,164	6,357,216	46.961	10.0	13.0	Yoganup Formation
RF139S	50	2020	Active	398,163	6,357,217	46.986	3.0	6.0	Guildford Clay
RG001G	50	1981	Active	393,736.0	6,358,014.7	14.79	1.5	22.8	Guildford Clay and Yoganup Formation
RG001W	50	1981	Active	393,736.0	6,358,013.8	14.81	25.2	41.2	Leederville Formation
RG002G	50	1981	Active	393,814.4	6,356,224.2	15.17	2.3	27.1	Guildford Clay and Yoganup Formation
RG002W	50	1981	Active	393,802.4	6,356,223.2	15.29	23.0	41.0	Leederville Formation
RG003G	50	1981	Active	394,982.1	6,356,990.0	16.69	2.0	20.0	Guildford Clay and Yoganup Formation
RG004G	50	1981	Decommissioned	394,952.1	6,358,055.7	16.06	1.7	21.2	Guildford Clay and Yoganup Formation
RG005G	50	1981	Decommissioned	394,946.0	6,359,042.4	17.33	1.6	26.6	Guildford Clay and Yoganup Formation
RG006G	50	1981	Decommissioned	394,950.1	6,359,719.0	18.21	2.6	26.6	Guildford Clay and Yoganup Formation
RG007G	50	1981	Active	397,942.0	6,357,886.8	46.83	2.8	26.8	Yoganup Formation
RG008G	50	1981	Active	395,836.9	6,356,018.6	22.29	2.0	25.6	Guildford Clay and Yoganup Formation
RG009G	50	1981	Active	397,014.5	6,357,307.5	25.39	1.6	25.6	Guildford Clay and Yoganup Formation
RG010G	50	1981	Inactive	397,963.2	6,358,184.6	38.69	2.3	24.3	Yoganup Formation
RG011G	50	1981	Active	397,026.5	6,358,070.9	28.22	2.0	27.5	Guildford Clay and Yoganup Formation
RG012G	50	1981	Active	397,892.4	6,357,332.8	42.96	1.8	24.0	Yoganup Formation

Bore	Casing ND (mm)	Monitoring start date	Status	AMG84 Coordinates (Zn50)		TOC (mAHD)	Slotted/screen interval (mBGL)		Formation
				mE	mN		Top	Bottom	
RG013G	50	1981	Decommissioned	395,966.5	6,359,310.9	20.67	2.0	27.0	Guildford Clay and Yoganup Formation
RG014G	50	1981	Active	397,081.0	6,358,586.1	29.00	3.0	27.5	Guildford Clay and Yoganup Formation
RG015G	50	1981	Active	396,572.8	6,358,234.7	24.67	2.0	25.6	Guildford Clay and Yoganup Formation
RG016S	50	1981	Active	396,661.7	6,356,789.5	24.26	2.6	6.6	Guildford Clay
RG016G	50	1981	Active	396,652.1	6,356,787.2	24.51	1.9	25.5	Guildford Clay and Yoganup Formation
RG017G	50	1981	Decommissioned	394,979.1	6,358,571.6	16.48	1.7	18.7	Guildford Clay and Yoganup Formation
RG017W	50	1981	Decommissioned	394,979.1	6,358,571.6	16.48	30.7	47.7	Leederville Formation
RG018G	50	1981	Decommissioned	397,879.1	6,356,744.3	44.16	3.6	21.6	Yoganup Formation
RG019G	50	1981	Decommissioned	394,965.2	6,357,475.9	15.83	0.4	18.4	Guildford Clay and Yoganup Formation
RG019W	50	1981	Decommissioned	394,965.2	6,357,475.9	15.83	21.0	39.0	Leederville Formation
RG020G	50	1981	Active	397,813.4	6,356,270.2	44.17	1.8	23.8	Yoganup Formation
RG021G	50	1981	Decommissioned	395,428.1	6,359,327.8	19.19	3.1	21.1	Guildford Clay and Yoganup Formation
RG021W	50	1981	Decommissioned	395,428.2	6,359,327.7	19.06	23.8	41.2	Leederville Formation
RG022G	50	1981	Active	398,801.7	6,356,175.9	54.13	3.7	21.7	Yoganup Formation
RG023G	50	1981	Decommissioned	393,761.7	6,359,314.6	15.63	3.2	18.2	Guildford Clay and Yoganup Formation
RG023W	50	1981	Decommissioned	393,761.6	6,359,314.6	15.61	20.0	38.0	Leederville Formation
RG024G	50	1981	Active	398,222.4	6,356,205.7	44.04	3.8	21.8	Yoganup Formation
RG025G	50	1981	Active	396,941.8	6,359,390.6	27.76	3.2	21.2	Guildford Clay and Yoganup Formation
RG025W	50	1981	Active	396,941.8	6,359,390.8	27.82	24.0	42.0	Leederville Formation
RG026G	50	1981	Active	396,454.7	6,357,777.8	23.98	2.8	20.8	Guildford Clay and Yoganup Formation
RG026W	50	1981	Active	396,454.7	6,357,777.8	23.95	23.2	41.2	Leederville Formation
RG027S	50	1981	Active	395,814.5	6,356,782.5	20.14	2.5	5.5	Guildford Clay
RG027G	50	1981	Active	395,815.1	6,356,780.5	20.54	1.4	21.4	Guildford Clay and Yoganup Formation
RG027W	50	1981	Active	395,815.2	6,356,780.6	20.51	23.0	42.0	Leederville Formation
RG028G	50	1981	Decommissioned	396,979.7	6,356,137.5	29.65	2.0	18.5	Guildford Clay and Yoganup Formation
RG028W	50	1981	Decommissioned	396,979.7	6,356,137.5	29.60	21.0	39.0	Leederville Formation
RG029G	50	1981	Active	394,929.2	6,356,063.4	17.26	2.0	11.0	Guildford Clay and Yoganup Formation
RG029W	50	1981	Inactive	394,929.2	6,356,063.5	17.24	13.0	31.0	Leederville Formation
RG030G	50	1981	Decommissioned	394,956.6	6,358,734.9	17.07	1.5	25.5	Guildford Clay and Yoganup Formation

Bore	Casing ND (mm)	Monitoring start date	Status	AMG84 Coordinates (Zn50)		TOC (mAHD)	Slotted/screen interval (mBGL)		Formation
				mE	mN		Top	Bottom	
RG031G	50	1981	Decommissioned	394,983.1	6,358,308.6	15.72	2.0	20.0	Guildford Clay and Yoganup Formation
RG032G	50	1981	Decommissioned	394,976.1	6,357,718.9	15.13	2.0	31.0	Guildford Clay and Yoganup Formation
RG033G	50	1981	Decommissioned	394,993.2	6,357,201.0	15.82	2.0	24.0	Guildford Clay and Yoganup Formation
RG034G	50	1981	Active	397,569.8	6,357,705.5	36.08	3.0	21.0	Yoganup Formation
RG035G	50	1981	Active	397,522.4	6,357,606.2	33.58	2.0	20.0	Yoganup Formation
RG036G	50	1981	Active	397,568.7	6,357,430.9	33.31	3.0	15.0	Yoganup Formation
RG078G	50	1990	Decommissioned	393,750.2	6,358,558.9	14.83	10.5	21.5	Yoganup Formation
RG079G	50	1990	Active	393,755.6	6,357,665.3	14.77	10.9	22.9	Yoganup Formation
RG080G	50	1990	Active	393,762.1	6,357,181.2	14.68	6.4	21.4	Yoganup Formation
RG150S	50	2001	Active	394,940.0	6,356,314.4	17.07	2.7	8.2	Guildford Clay
RG150G	50	2001	Active	394,942.4	6,356,314.3	17.07	9.0	20.5	Yoganup Formation
RG150W	50	2001	Active	394,945.0	6,356,314.3	17.09	21.7	37.2	Leederville Formation
RG151S	50	2001	Active	395,871.2	6,355,940.0	22.54	2.8	9.3	Guildford Clay
RG151G	50	2001	Active	395,871.4	6,355,942.1	22.53	10.3	22.8	Yoganup Formation
RG151W	50	2001	Active	395,871.7	6,355,944.4	22.53	24.3	40.8	Leederville Formation
RG152S	50	2001	Active	396,384.3	6,358,023.6	23.36	2.8	10.5	Guildford Clay
RG152G	50	2001	Active	396,384.2	6,358,025.6	23.33	11.8	24.3	Yoganup Formation
RG152W	50	2001	Active	396,384.3	6,358,027.9	23.36	25.7	40.7	Leederville Formation
RG153S	50	2001	Active	393,785.4	6,359,317.4	15.45	2.8	9.3	Guildford Clay
RG153G	50	2001	Active	393,785.3	6,359,319.4	15.47	11.8	23.8	Yoganup Formation
RG153W	50	2001	Active	393,785.3	6,359,321.3	15.47	25.8	40.8	Leederville Formation
RG154S	50	2001	Active	393,660.9	6,356,223.6	14.94	2.8	7.3	Guildford Clay
RG154G	50	2001	Active	393,658.8	6,356,224.8	14.93	7.8	25.8	Yoganup Formation
RG154W	50	2001	Active	393,657.1	6,356,225.8	14.87	27.2	41.3	Leederville Formation
RG155S	50	2002	Active	396,273.2	6,359,748.3	21.58	3.7	9.9	Guildford Clay
RG155G	50	2002	Active	396,271.7	6,359,748.2	21.57	12.3	24.0	Yoganup Formation
RG155W	50	2002	Active	396,270.2	6,359,748.3	21.59	26.7	40.5	Leederville Formation
RG156S	50	2002	Active	396,172.3	6,360,763.2	23.06	3.7	11.9	Guildford Clay
RG156G	50	2002	Active	396,172.4	6,360,764.4	23.05	13.9	23.8	Yoganup Formation

Bore	Casing ND (mm)	Monitoring start date	Status	AMG84 Coordinates (Zn50)		TOC (mAHD)	Slotted/screen interval (mBGL)		Formation
				mE	mN		Top	Bottom	
RG156W	50	2002	Active	396,172.6	6,360,765.9	23.10	26.8	40.6	Leederville Formation
RG157S	50	2002	Active	394,885.8	6,361,773.1	20.94	4.3	14.3	Guildford Clay
RG157G	50	2002	Active	394,885.4	6,361,774.1	20.90	16.5	27.7	Yoganup Formation
RG157W	50	2002	Active	394,885.0	6,361,775.1	20.88	30.7	40.7	Leederville Formation
RG158S	50	2002	Active	393,602.3	6,361,861.1	18.09	3.8	9.8	Guildford Clay
RG158G	50	2002	Active	393,603.6	6,361,861.2	18.06	12.2	26.2	Yoganup Formation
RG158W	50	2002	Active	393,604.8	6,361,861.3	18.04	29.5	40.7	Leederville Formation
RG159S	50	2002	Decommissioned	394,567.9	6,359,160.6	16.99	2.8	10.8	Guildford Clay
RG159G	50	2002	Decommissioned	394,570.2	6,359,161.0	16.91	12.9	23.4	Yoganup Formation
RG160S	50	2003	Decommissioned	397,878.6	6,354,261.7	47.83	7.2	11.5	Guildford Clay
RG161S	50	2003	Decommissioned	397,885.1	6,354,241.3	47.89	7.2	11.5	Guildford Clay
RG162S	50	2003	Decommissioned	397,910.9	6,354,258.4	47.85	7.2	11.5	Guildford Clay / Yoganup Formation
RG166S	50	2008	Active	392,600.9	6,359,714.4	15.11	1.5	6.5	Guildford Clay
RG166G	50	2008	Active	392,602.7	6,359,714.3	15.11	9.0	22.0	Yoganup Formation
RG166W	50	2008	Active	392,604.7	6,359,714.2	15.11	24.0	40.0	Leederville Formation
RG219S	50	2012	Active	392,484.9	6,358,333.4	15.59	5.5	8.5	Guildford Clay
RG219G	50	2012	Active	392,485.0	6,358,336.2	15.54	10.0	22.5	Ascot Formation
RG219W	50	2012	Active	392,485.0	6,358,338.4	15.52	24.2	39.2	Leederville Formation
RG220G	50	2017	Active	397,469	6,356,984	31.704	10	13	Yoganup Formation
RG220S	50	2017	Active	397,468	6,356,983	31.725	2	5	Guildford Clay
RG221G	50	2017	Active	397,097	6,356,802	26.318	11.5	14.5	Yoganup Formation
RG221S	50	2017	Active	397,098	6,356,800	26.348	4.5	7.5	Guildford Clay
RG222G	50	2020	Active	397,701	6,357,696	41.048	8.0	11.0	Yoganup Formation
RG222S	50	2020	Active	397,702	6,357,697	41.042	3.5	6.5	Guildford Clay
RS037S	50	1982	Inactive	396,020.6	6,357,736.0	28.68	5.0	14.0	Guildford Clay
RS037G	50	1982	Inactive	396,020.6	6,357,736.0	28.68	18.5	30.0	Yoganup Formation
RS038S	50	1982	Inactive	396,125.1	6,357,737.2	28.62	5.0	12.5	Guildford Clay
RS038G	50	1982	Inactive	396,125.1	6,357,737.2	28.62	14.4	28.6	Yoganup Formation
RS039S	50	1982	Active	396,186.0	6,357,861.9	26.94	6.2	11.9	Guildford Clay

Bore	Casing ND (mm)	Monitoring start date	Status	AMG84 Coordinates (Zn50)		TOC (mAHD)	Slotted/screen interval (mBGL)		Formation
				mE	mN		Top	Bottom	
RS039G	50	1982	Active	396,186.0	6,357,861.9	26.94	16.0	28.2	Yoganup Formation
RS040S	50	1982	Active	396,192.1	6,357,986.2	26.95	6.0	14.0	Guildford Clay
RS040G	50	1982	Active	396,192.1	6,357,986.2	26.95	20.0	28.2	Yoganup Formation
RS041S	50	1982	Active	396,207.6	6,358,105.1	26.88	5.5	13.8	Guildford Clay
RS041G	50	1982	Active	396,207.6	6,358,105.1	26.88	18.5	28.0	Yoganup Formation
RS042S	50	1982	Active	396,232.9	6,358,225.2	26.83	5.9	11.8	Guildford Clay
RS042G	50	1982	Active	396,232.9	6,358,225.2	26.83	16.9	26.3	Yoganup Formation
RS043S	50	1982	Active	396,238.1	6,358,495.8	26.83	6.0	12.9	Guildford Clay
RS043G	50	1982	Active	396,238.1	6,358,495.8	26.83	15.1	27.1	Yoganup Formation
RS044S	50	1982	Active	396,143.6	6,358,549.5	26.89	8.2	14.0	Guildford Clay
RS044G	50	1982	Active	396,143.6	6,358,549.5	26.89	16.0	29.1	Yoganup Formation
RS045S	50	1982	Active	396,269.9	6,358,343.6	26.60	7.5	12.0	Guildford Clay
RS045G	50	1982	Active	396,269.9	6,358,343.6	26.60	15.0	27.5	Yoganup Formation
RS046S	65	1982	Active	396,006.7	6,358,389.2	33.49	13.0	19.0	Guildford Clay
RS046G	65	1982	Active	396,007.2	6,358,390.2	33.50	25.8	36.5	Yoganup Formation
RS047S	65	1982	Active	395,971.9	6,358,243.2	33.26	13.4	23.9	Guildford Clay
RS047G	65	1982	Active	395,972.3	6,358,244.2	33.26	26.9	36.9	Yoganup Formation
RS048S	65	1982	Active	395,948.5	6,358,099.5	33.32	14.6	24.6	Guildford Clay
RS048G	65	1982	Active	395,957.2	6,358,100.2	33.39	30.6	36.6	Yoganup Formation
RS049S	65	1982	Active	395,936.9	6,357,979.6	33.32	15.8	25.8	Guildford Clay
RS049G	65	1982	Active	395,937.0	6,357,980.6	33.31	28.9	36.9	Yoganup Formation
RS050S	65	1982	Active	395,933.0	6,357,859.3	33.30	14.3	20.3	Guildford Clay
RS050G	65	1982	Active	395,933.0	6,357,860.2	33.27	27.0	36.5	Yoganup Formation
RS051S	65	1982	Decommissioned	395,870.1	6,357,737.0	33.28	15.3	22.6	Guildford Clay
RS051G	65	1982	Decommissioned	395,871.2	6,357,737.0	33.29	26.7	36.7	Yoganup Formation
RS052S	65	1982	Decommissioned	395,709.1	6,357,736.9	33.32	15.1	22.1	Guildford Clay
RS052G	65	1982	Decommissioned	395,710.4	6,357,736.9	33.33	24.4	36.4	Yoganup Formation
RS053S	65	1982	Decommissioned	395,503.9	6,357,737.0	33.31	14.9	21.9	Guildford Clay
RS053G	65	1982	Decommissioned	395,505.1	6,357,737.1	33.25	24.8	36.8	Yoganup Formation

Bore	Casing ND (mm)	Monitoring start date	Status	AMG84 Coordinates (Zn50)		TOC (mAHD)	Slotted/screen interval (mBGL)		Formation
				mE	mN		Top	Bottom	
RS054S	65	1982	Decommissioned	395,407.3	6,357,801.0	33.29	15.5	22.5	Guildford Clay
RS054G	65	1982	Decommissioned	395,407.2	6,357,799.7	33.30	24.8	36.8	Yoganup Formation
RS055S	65	1982	Decommissioned	395,407.7	6,357,896.9	33.26	15.9	22.9	Guildford Clay
RS055G	65	1982	Decommissioned	395,407.7	6,357,898.2	33.19	24.8	36.8	Yoganup Formation
RS056S	65	1982	Decommissioned	395,407.0	6,357,998.5	33.23	15.6	22.6	Guildford Clay
RS056G	65	1982	Decommissioned	395,407.0	6,357,999.7	33.23	25.1	36.1	Yoganup Formation
RS057S	65	1982	Decommissioned	395,406.8	6,358,109.6	33.21	15.0	22.0	Guildford Clay
RS057G	65	1982	Decommissioned	395,406.7	6,358,108.3	33.21	25.8	36.8	Yoganup Formation
RS058S	65	1982	Decommissioned	395,407.7	6,358,200.6	33.00	15.4	22.4	Guildford Clay
RS058G	65	1982	Decommissioned	395,407.7	6,358,201.7	33.16	26.0	36.4	Yoganup Formation
RS059S	65	1982	Decommissioned	395,406.9	6,358,299.1	33.17	15.0	23.0	Guildford Clay
RS059G	65	1982	Decommissioned	395,406.9	6,358,298.0	33.18	27.6	35.6	Yoganup Formation
RS060S	65	1982	Decommissioned	395,406.8	6,358,399.7	33.27	15.4	23.0	Guildford Clay
RS060G	65	1982	Decommissioned	395,406.8	6,358,398.6	33.36	30.7	36.7	Yoganup Formation
RS061S	65	1982	Decommissioned	395,406.9	6,358,500.6	33.33	15.1	22.1	Guildford Clay
RS061G	65	1982	Decommissioned	395,406.9	6,358,499.4	33.40	28.4	36.4	Yoganup Formation
RS062S	65	1982	Inactive	395,521.2	6,358,539.2	33.58	15.0	22.0	Guildford Clay
RS062G	65	1982	Inactive	395,519.9	6,358,539.2	33.55	25.0	35.5	Yoganup Formation
RS063S	50	1982	Active	395,644.8	6,358,539.1	33.52	14.8	21.8	Guildford Clay
RS063G	65	1982	Active	395,642.6	6,358,539.2	33.51	24.6	36.1	Yoganup Formation
RS064S	65	1982	Active	395,749.4	6,358,539.3	33.19	15.5	22.5	Guildford Clay
RS064G	65	1982	Active	395,747.9	6,358,539.3	33.33	24.3	36.3	Yoganup Formation
RS065S	65	1982	Active	395,882.0	6,358,539.0	33.61	15.2	22.2	Guildford Clay
RS065G	65	1982	Active	395,881.0	6,358,539.3	33.39	24.5	36.5	Yoganup Formation
RS066S	65	1982	Active	396,001.2	6,358,538.8	33.38	15.4	22.4	Guildford Clay
RS066G	65	1982	Active	396,000.0	6,358,538.7	33.27	24.7	36.8	Yoganup Formation
RS067S	50	1990	Decommissioned	395,275.3	6,357,736.9	32.35	16.7	24.7	Guildford Clay
RS067G	50	1990	Decommissioned	395,274.1	6,357,736.9	32.35	30.1	36.6	Yoganup Formation
RS068S	50	1990	Decommissioned	395,128.4	6,357,737.1	32.49	18.5	28.5	Guildford Clay

Bore	Casing ND (mm)	Monitoring start date	Status	AMG84 Coordinates (Zn50)		TOC (mAHD)	Slotted/screen interval (mBGL)		Formation
				mE	mN		Top	Bottom	
RS068G	50	1990	Decommissioned	395,127.6	6,357,737.2	32.57	35.0	39.0	Yoganup Formation
RS069S	50	1990	Decommissioned	394,982.4	6,357,765.0	31.95	17.5	21.5	Guildford Clay
RS069E	50	1990	Decommissioned	394,982.4	6,357,764.8	32.24	18.5	24.0	Guildford Clay
RS069G	50	1990	Decommissioned	394,993.3	6,357,766.1	31.96	27.0	37.5	Yoganup Formation
RS070S	50	1990	Decommissioned	394,982.0	6,357,893.7	32.39	16.5	20.5	Guildford Clay
RS070E	50	1990	Decommissioned	394,988.9	6,357,894.3	32.18	18.5	22.0	Guildford Clay
RS070G	50	1990	Decommissioned	394,981.9	6,357,894.8	32.42	24.9	36.9	Yoganup Formation
RS071S	50	1990	Decommissioned	394,981.8	6,358,023.6	32.33	16.0	24.0	Guildford Clay
RS071G	50	1990	Decommissioned	394,981.8	6,358,024.8	32.35	25.3	36.8	Yoganup Formation
RS072S	50	1990	Decommissioned	394,981.5	6,358,153.3	32.35	18.0	23.5	Guildford Clay
RS072G	50	1990	Decommissioned	394,981.4	6,358,154.6	32.37	27.0	38.5	Yoganup Formation
RS073S	50	1990	Decommissioned	394,981.4	6,358,283.7	32.38	18.0	24.0	Guildford Clay
RS073E	50	1990	Decommissioned	394,987.5	6,358,283.7	32.40	18.0	24.0	Guildford Clay
RS073G	50	1990	Decommissioned	394,981.4	6,358,285.0	32.39	29.0	38.0	Yoganup Formation
RS074S	50	1990	Decommissioned	394,981.4	6,358,413.5	32.37	12.9	20.9	Guildford Clay
RS074G	50	1990	Decommissioned	394,981.5	6,358,414.5	32.38	23.0	38.5	Yoganup Formation
RS075S	50	1990	Decommissioned	395,013.3	6,358,533.9	32.78	16.7	22.7	Guildford Clay
RS075E	50	1990	Decommissioned	395,012.3	6,358,539.9	32.81	15.5	21.5	Guildford Clay
RS075G	50	1990	Decommissioned	395,012.0	6,358,533.7	32.53	27.0	38.5	Yoganup Formation
RS076S	50	1990	Decommissioned	395,147.0	6,358,539.6	32.58	12.2	18.2	Guildford Clay
RS076G	50	1990	Decommissioned	395,148.1	6,358,539.6	32.56	20.5	44.5	Yoganup Formation
RS077S	50	1990	Decommissioned	395,279.9	6,358,539.5	32.66	15.0	19.0	Guildford Clay
RS077G	50	1990	Decommissioned	395,279.9	6,358,539.5	32.65	20.9	38.9	Yoganup Formation
RS081S	50	1990	Decommissioned	394,969.7	6,357,639.6	15.61	1.5	6.5	Guildford Clay
RS082S	50	1990	Decommissioned	394,928.8	6,357,660.9	15.35	1.8	6.8	Guildford Clay
RS083S	50	1990	Decommissioned	394,918.6	6,357,894.7	15.42	1.9	6.9	Guildford Clay
RS084S	50	1990	Decommissioned	394,918.7	6,358,285.5	15.82	1.9	7.9	Guildford Clay
RS085S	50	1990	Decommissioned	394,918.9	6,358,538.2	16.19	1.8	6.8	Guildford Clay
RS088S	50	1992	Decommissioned	395,936.9	6,357,408.4	32.38	3.6	9.8	Guildford Clay

Bore	Casing ND (mm)	Monitoring start date	Status	AMG84 Coordinates (Zn50)		TOC (mAHD)	Slotted/screen interval (mBGL)		Formation
				mE	mN		Top	Bottom	
RS088G	50	1992	Decommissioned	395,936.9	6,357,408.4	32.38	13.0	26.0	Yoganup Formation
RS089S	50	1992	Decommissioned	395,937.6	6,357,040.9	32.34	1.5	5.1	Guildford Clay
RS089I	50	1992	Decommissioned	395,937.6	6,357,041.0	32.34	7.5	12.0	Yoganup Formation
RS089G	50	1992	Decommissioned	395,937.6	6,357,040.9	32.34	15.0	24.0	Yoganup Formation
RS090S	50	1992	Active	395,650.1	6,357,039.9	18.40	1.5	9.5	Guildford Clay
RS090G	50	1992	Active	395,650.1	6,357,039.9	18.40	12.5	20.5	Yoganup Formation
RS091S	50	1992	Active	395,364.1	6,357,048.2	17.04	1.5	8.9	Guildford Clay
RS091G	50	1992	Active	395,364.1	6,357,048.2	17.04	12.0	20.0	Yoganup Formation
RS092S	50	1992	Active	395,134.0	6,357,173.1	16.60	1.5	8.9	Guildford Clay
RS092G	50	1992	Active	395,134.0	6,357,173.1	16.60	12.0	20.0	Yoganup Formation
RS093S	50	1992	Active	394,886.3	6,357,185.8	15.76	1.4	8.9	Guildford Clay
RS093G	50	1992	Active	394,886.3	6,357,185.8	15.76	12.0	16.0	Yoganup Formation
RS094S	50	1992	Active	394,636.1	6,357,185.9	15.40	1.5	7.6	Guildford Clay
RS094G	50	1992	Active	394,636.1	6,357,185.9	15.40	12.0	17.5	Yoganup Formation
RS095S	50	1992	Active	394,408.5	6,357,436.4	19.02	5.6	8.6	Guildford Clay
RS095I	50	1992	Active	394,408.5	6,357,436.4	19.02	10.3	16.3	Yoganup Formation
RS095G	50	1992	Active	394,408.5	6,357,436.4	19.02	18.9	25.3	Yoganup Formation
RS096S	50	1992	Active	394,408.4	6,357,588.4	20.86	6.2	9.2	Guildford Clay
RS096I	50	1992	Active	394,408.4	6,357,588.4	20.86	11.4	17.9	Yoganup Formation
RS096G	50	1992	Active	394,408.4	6,357,588.4	20.86	20.0	26.0	Yoganup Formation
RS097S	50	1992	Active	394,261.1	6,357,742.5	15.27	2.0	4.0	Guildford Clay
RS097I	50	1992	Active	394,261.1	6,357,742.5	15.27	5.4	8.0	Yoganup Formation
RS097G	50	1992	Active	394,261.1	6,357,742.5	15.27	10.0	15.0	Yoganup Formation
RS098S	50	1992	Active	394,108.7	6,357,742.5	15.27	2.5	4.5	Guildford Clay
RS098I	50	1992	Active	394,108.7	6,357,742.5	15.27	6.5	8.9	Yoganup Formation
RS098G	50	1992	Active	394,108.7	6,357,742.5	15.27	11.5	20.5	Yoganup Formation
RS099S	50	1992	Active	394,109.2	6,357,587.6	15.18	2.0	7.1	Guildford Clay
RS099I	50	1992	Active	394,109.2	6,357,587.6	15.18	9.0	10.2	Yoganup Formation
RS099G	50	1992	Active	394,109.2	6,357,587.6	15.18	12.0	20.5	Yoganup Formation

Bore	Casing ND (mm)	Monitoring start date	Status	AMG84 Coordinates (Zn50)		TOC (mAHD)	Slotted/screen interval (mBGL)		Formation
				mE	mN		Top	Bottom	
RS100S	50	1992	Active	394,109.1	6,357,435.7	15.16	2.0	5.0	Guildford Clay
RS100I	50	1992	Active	394,109.1	6,357,435.7	15.16	6.9	19.9	Yoganup Formation
RS100G	50	1992	Active	394,109.1	6,357,435.7	15.16	22.0	24.0	Yoganup Formation
RS101S	50	1992	Active	394,109.0	6,357,281.5	15.25	2.1	5.8	Guildford Clay
RS101I	50	1992	Active	394,109.0	6,357,282.0	15.22	7.1	9.6	Yoganup Formation
RS101G	50	1992	Active	394,109.0	6,357,281.5	15.25	12.5	17.5	Yoganup Formation
RS102S	50	1992	Active	394,261.2	6,357,276.2	15.70	1.9	5.1	Guildford Clay
RS102I	50	1992	Active	394,261.2	6,357,276.2	15.70	7.9	16.4	Yoganup Formation
RS102G	50	1992	Active	394,261.2	6,357,276.2	15.70	18.0	21.0	Yoganup Formation
RS103S	50	1993	Active	394,307.3	6,357,871.7	15.44	2.9	9.9	Guildford Clay
RS103G	50	1993	Active	394,307.3	6,357,871.7	15.44	12.5	20.5	Yoganup Formation
RS104S	50	1993	Decommissioned	394,307.0	6,358,004.6	16.46	2.9	7.9	Guildford Clay
RS104G	50	1993	Decommissioned	394,307.0	6,358,004.6	16.46	11.4	21.4	Yoganup Formation
RS105S	50	1993	Decommissioned	394,307.2	6,358,137.8	15.64	2.9	12.4	Guildford Clay
RS105G	50	1993	Decommissioned	394,307.2	6,358,137.8	15.64	16.0	20.5	Yoganup Formation
RS106S	50	1993	Decommissioned	394,307.3	6,358,270.9	15.76	3.0	7.5	Guildford Clay
RS106I	50	1993	Decommissioned	394,307.3	6,358,270.9	15.76	9.4	12.1	Yoganup Formation
RS106G	50	1993	Decommissioned	394,307.3	6,358,270.9	15.76	14.8	20.8	Yoganup Formation
RS107S	50	1993	Decommissioned	394,307.3	6,358,404.3	15.82	3.0	7.8	Guildford Clay
RS107I	50	1993	Decommissioned	394,307.3	6,358,404.3	15.82	9.0	11.0	Yoganup Formation
RS107G	50	1993	Decommissioned	394,307.3	6,358,404.3	15.82	14.1	22.1	Yoganup Formation
RS108S	50	1993	Decommissioned	394,307.3	6,358,532.7	15.92	3.0	11.0	Guildford Clay
RS108G	50	1993	Decommissioned	394,307.3	6,358,532.7	15.92	16.0	22.5	Yoganup Formation
RS109S	50	1995	Decommissioned	394,496.1	6,358,962.8	19.75	8.0	14.0	Guildford Clay
RS109G	50	1995	Decommissioned	394,496.1	6,358,962.8	19.75	24.5	30.5	Yoganup Formation
RS110S	50	1995	Decommissioned	394,656.4	6,358,963.0	21.68	9.0	15.0	Guildford Clay
RS110G	50	1995	Decommissioned	394,656.4	6,358,963.0	21.68	29.5	35.5	Yoganup Formation
RS111S	50	1995	Active	395,791.5	6,358,611.7	19.80	3.0	5.7	Guildford Clay
RS111I	50	1995	Active	395,791.5	6,358,611.7	19.80	7.6	19.3	Yoganup Formation

Bore	Casing ND (mm)	Monitoring start date	Status	AMG84 Coordinates (Zn50)		TOC (mAHD)	Slotted/screen interval (mBGL)		Formation
				mE	mN		Top	Bottom	
RS111G	50	1992	Active	395,791.5	6,358,611.7	19.80	20.9	23.4	Yoganup Formation
RS112S	50	1995	Decommissioned	394,307.5	6,358,671.2	16.22	8.0	14.0	Guildford Clay
RS112I	50	1995	Decommissioned	394,307.1	6,358,673.4	16.24	1.0	7.0	Guildford Clay
RS112G	50	1995	Decommissioned	394,307.1	6,358,671.4	16.22	17.0	23.0	Yoganup Formation
RS113S	50	1995	Decommissioned	394,306.6	6,358,841.5	16.69	3.5	9.5	Guildford Clay
RS113G	50	1995	Decommissioned	394,306.7	6,358,841.6	16.69	16.0	22.0	Yoganup Formation
RS114S	50	1995	Decommissioned	394,308.0	6,358,964.0	17.17	3.0	9.0	Guildford Clay
RS114G	50	1995	Decommissioned	394,308.0	6,358,964.1	17.15	18.5	24.5	Yoganup Formation
RS115G	50	1997	Active	396,480.7	6,357,615.9	23.28	10.5	20.1	Yoganup Formation
RS116S	50	1996	Active	396,564.1	6,357,305.5	23.02	2.7	6.7	Guildford Clay
RS116G	50	1996	Active	396,563.7	6,357,308.5	23.02	10.7	18.7	Yoganup Formation
RS117S	50	1996	Active	396,558.6	6,357,094.7	22.93	2.7	8.7	Guildford Clay
RS117G	50	1996	Active	396,557.0	6,357,092.2	23.00	10.7	19.7	Yoganup Formation
RS118S	50	1996	Active	396,373.0	6,356,965.3	22.89	2.5	10.5	Guildford Clay
RS118G	50	1996	Active	396,370.2	6,356,964.6	22.90	12.5	19.5	Yoganup Formation
RS119S	50	1996	Active	396,170.5	6,356,962.1	21.74	2.7	9.7	Guildford Clay
RS119G	50	1996	Active	396,167.4	6,356,962.2	21.74	12.4	21.4	Yoganup Formation
RS120S	50	1996	Active	396,510.1	6,357,507.4	22.80	2.5	8.0	Guildford Clay
RS120G	50	1996	Active	396,509.2	6,357,510.4	22.74	10.5	19.7	Yoganup Formation
RS121S	50	1996	Active	396,444.3	6,357,661.4	23.28	2.5	9.5	Guildford Clay
RS121G	50	1996	Active	396,446.1	6,357,659.0	23.24	13.0	20.0	Yoganup Formation
RS122S	50	1996	Active	396,320.8	6,357,792.1	22.74	2.7	10.7	Guildford Clay
RS122G	50	1996	Active	396,320.3	6,357,789.0	22.68	12.7	21.7	Yoganup Formation
RS123S	50	1996	Active	396,624.9	6,357,535.1	23.58	2.6	9.1	Guildford Clay
RS123G	50	1996	Active	396,624.9	6,357,532.0	23.57	13.6	21.6	Yoganup Formation
RS124S	50	1996	Inactive	396,074.4	6,356,884.9	20.93	2.6	6.6	Guildford Clay
RS125S	50	1996	Inactive	396,013.2	6,358,409.3	33.37	16.1	22.1	Guildford Clay
RS126G	50	1997	Active	395,827.0	6,358,782.0	19.61	7.5	23.0	Yoganup Formation
RS127G	50	1997	Active	395,826.0	6,358,901.0	19.64	7.0	22.5	Yoganup Formation

Bore	Casing ND (mm)	Monitoring start date	Status	AMG84 Coordinates (Zn50)		TOC (mAHD)	Slotted/screen interval (mBGL)		Formation
				mE	mN		Top	Bottom	
RS128G	50	1997	Decommissioned	395,614.0	6,358,996.0	18.66	7.0	22.0	Yoganup Formation
RS129G	50	1997	Decommissioned	395,614.0	6,358,730.0	18.59			Yoganup Formation
RS130S	50	1998	Active	395,939.0	6,357,034.2	32.96	13.7	19.7	Guildford Clay
RS130G	50	1998	Active	395,938.4	6,357,036.0	32.98	24.4	36.4	Yoganup Formation
RS131G	50	1998	Decommissioned	394,931.1	6,358,634.6				not known
RS132G	50	1998	Decommissioned	395,291.0	6,358,996.0	18.41			not known
RS133G	50	1998	Decommissioned	394,971.0	6,358,996.0	17.77			not known
RS134S	50	1998	Decommissioned	395,728.0	6,358,991.0	19.61			not known
RS135S	50	1998	Decommissioned	395,728.0	6,358,881.0	19.23			not known
RS136S	50	1998	Decommissioned	395,728.0	6,358,773.0	19.15			not known
RS137S	50	1997	Active	395,776.2	6,358,686.6	20.98	4.5	10.5	Guildford Clay
RS137G	50	1998	Active	395,774.1	6,358,686.1	20.98	12.9	24.9	Yoganup Formation
RS138S	50	1997	Active	395,664.5	6,358,684.2	21.80	6.5	11.5	Guildford Clay
RS138G	50	1997	Active	395,662.6	6,358,684.1	21.82	13.5	25.5	Yoganup Formation
RS139S	50	1997	Active	395,646.5	6,358,882.9	22.14	6.5	10.5	Guildford Clay
RS139G	50	1997	Active	395,646.2	6,358,880.8	22.14	13.8	25.8	Yoganup Formation
RS140S	50	1997	Active	395,662.4	6,359,058.7	21.59	5.6	9.6	Guildford Clay
RS140G	50	1997	Active	395,664.3	6,359,059.7	21.60	14.1	26.1	Yoganup Formation
RS141S	50	1997	Active	395,805.5	6,359,056.0	20.11	3.0	9.0	Guildford Clay
RS141G	50	1997	Active	395,804.3	6,359,057.6	20.11	12.0	24.0	Yoganup Formation
RS142S	50	1997	Active	395,819.9	6,358,880.3	20.16	3.5	9.5	Guildford Clay
RS142G	50	1997	Active	395,819.9	6,358,882.2	20.14	12.9	24.9	Yoganup Formation
RS143S	50	1999	Decommissioned	395,669.9	6,359,293.5	20.96	5.1	10.1	Guildford Clay
RS143G	50	1999	Decommissioned	395,669.9	6,359,294.7	20.94	12.7	24.7	Yoganup Formation
RS144S	50	1999	Decommissioned	395,670.4	6,359,200.5	21.13	4.7	9.7	Guildford Clay
RS144G	50	1999	Decommissioned	395,670.4	6,359,198.5	21.15	11.7	23.7	Yoganup Formation
RS145S	50	2000	Active	395,938.9	6,357,391.4	32.84	13.6	19.6	Guildford Clay
RS145G	50	2000	Inactive	395,939.0	6,357,392.7	32.86	22.6	34.6	Yoganup Formation
RS146S	50	2000	Active	394,028.5	6,357,581.4	15.08	4.8	10.8	Guildford Clay

Bore	Casing ND (mm)	Monitoring start date	Status	AMG84 Coordinates (Zn50)		TOC (mAHD)	Slotted/screen interval (mBGL)		Formation
				mE	mN		Top	Bottom	
RS146G	50	2000	Active	394,029.7	6,357,580.6	15.06	13.8	24.8	Yoganup Formation
RS146W	50	2000	Active	394,030.8	6,357,580.0	15.04	26.3	40.8	Leederville Formation
RS147S	50	2000	Active	394,023.6	6,357,460.6	14.96	3.3	3.8	Guildford Clay
RS147I	50	2000	Active	394,025.7	6,357,463.2	14.97	4.8	7.7	Guildford Clay
RS147G	50	2000	Active	394,024.8	6,357,461.9	14.99	9.6	21.0	Yoganup Formation
RS148S	50	2000	Decommissioned	394,307.4	6,358,534.7	16.58	3.0	11.0	Guildford Clay
RS149G	50	2000	Active	395,939.0	6,357,387.8	32.87	22.8	34.8	Yoganup Formation
RS160S	50	2004	Active	394,303.3	6,359,438.9	17.77	2.8	15.0	Guildford Clay
RS160G	50	2004	Active	394,303.3	6,359,440.4	17.77	15.0	23.2	Yoganup Formation
RS161S	50	2004	Active	394,302.4	6,359,313.5	17.58	2.8	12.5	Guildford Clay
RS161G	50	2004	Active	394,302.4	6,359,315.2	17.56	13.5	23.0	Yoganup Formation
RS162S	50	2004	Active	394,301.7	6,359,188.3	17.52	3.0	9.0	Guildford Clay
RS162G	50	2004	Active	394,301.7	6,359,190.3	17.51	13.0	21.5	Yoganup Formation
RS163S	50	2004	Active	394,300.9	6,359,063.4	17.35	2.5	10.0	Guildford Clay
RS163G	50	2004	Active	394,300.9	6,359,065.1	17.35	13.0	23.0	Yoganup Formation
RS164S	50	2004	Decommissioned	395,053.3	6,359,450.7	26.23	8.0	15.0	Guildford Clay
RS164G	50	2004	Decommissioned	395,055.0	6,359,449.8	26.22	16.0	30.0	Yoganup Formation
RS164W	50	2004	Decommissioned	395,051.7	6,359,450.7	26.21	31.5	45.5	Leederville Formation
RS165S	50	2005	Decommissioned	395,600.7	6,359,630.3	19.06	2.3	8.3	Guildford Clay
RS165G	50	2005	Decommissioned	395,602.2	6,359,630.5	19.05	9.8	23.0	Yoganup Formation
RS167S	50	2006	Decommissioned	394,935.6	6,359,528.6	18.83	2.0	9.5	Guildford Clay
RS167G	50	2006	Decommissioned	394,935.3	6,359,526.7	18.86	11.0	23.0	Yoganup Formation
RS168S	50	2006	Active	394,988.8	6,359,708.8	19.22	2.5	9.5	Guildford Clay
RS168G	50	2006	Active	394,990.5	6,359,709.9	19.25	10.0	24.4	Yoganup Formation
RS168W	50	2006	Active	394,992.3	6,359,711.1	19.31	25.5	41.5	Leederville Formation
RS169S	50	2006	Active	395,289.9	6,359,712.1	19.64	1.5	8.5	Guildford Clay
RS169G	50	2006	Active	395,292.0	6,359,711.9	19.59	10.0	25.0	Yoganup Formation
RS170S	50	2006	Active	395,572.7	6,359,720.1	20.03	2.0	8.0	Guildford Clay
RS170G	50	2006	Active	395,574.9	6,359,720.1	20.09	9.5	23.0	Yoganup Formation

Bore	Casing ND (mm)	Monitoring start date	Status	AMG84 Coordinates (Zn50)		TOC (mAHD)	Slotted/screen interval (mBGL)		Formation
				mE	mN		Top	Bottom	
RS171S	50	2006	Active	395,852.9	6,359,712.5	20.49	2.0	9.7	Guildford Clay
RS171G	50	2006	Active	395,854.8	6,359,712.5	20.44	11.3	23.3	Yoganup Formation
RS172S	50	2006	Blocked	396,073.6	6,359,719.7	21.62	2.0	11.0	Guildford Clay
RS172G	50	2006	Active	396,071.5	6,359,719.6	21.59	12.5	24.0	Yoganup Formation
RS173S	50	2006	Active	396,517.5	6,359,741.1	23.03	1.5	9.0	Guildford Clay
RS173G	50	2006	Active	396,519.2	6,359,741.2	23.08	10.0	20.3	Yoganup Formation
RS174S	50	2006	Active	396,956.4	6,359,744.5	25.35	1.5	8.3	Guildford Clay
RS174G	50	2006	Active	396,954.4	6,359,744.4	25.39	9.5	20.0	Yoganup Formation
RS175S	50	2006	Active	396,810.6	6,359,245.9	26.56	1.5	9.8	Guildford Clay
RS175G	50	2006	Active	396,811.2	6,359,247.7	26.68	11.0	21.5	Yoganup Formation
RS176S	50	2006	Active	396,819.9	6,358,915.7	26.01	1.5	10.5	Guildford Clay
RS176G	50	2006	Active	396,820.6	6,358,917.5	26.00	12.0	21.0	Yoganup Formation
RS177S	50	2006	Active	396,058.2	6,358,675.4	21.28	1.5	10.0	Guildford Clay
RS177G	50	2006	Active	396,058.2	6,358,677.4	21.26	11.5	23.0	Yoganup Formation
RS178S	50	2006	Active	395,962.0	6,359,079.1	22.30	2.0	13.0	Guildford Clay
RS178G	50	2006	Active	395,959.9	6,359,079.0	22.33	14.0	24.5	Yoganup Formation
RS179S	50	2009	Decommissioned	394,987.2	6,358,131.0	32.93	14.0	21.3	Guildford Clay
RS180S	50	2009	Decommissioned	394,987.3	6,358,009.7	33.00	14.0	21.5	Guildford Clay
RS181S	50	2009	Decommissioned	394,989.0	6,357,868.9	32.75	14.0	21.8	Guildford Clay
RS182S	50	2009	Decommissioned	394,993.4	6,357,752.6	32.73	15.0	22.0	Guildford Clay
RS183S	50	2009	Decommissioned	395,114.8	6,357,734.8	32.88	14.2	21.2	Guildford Clay
RS184S	50	2009	Decommissioned	395,282.9	6,357,735.0	32.91	14.1	21.1	Guildford Clay
RS185S	50	2009	Decommissioned	395,407.4	6,357,780.8	33.21	14.9	21.9	Guildford Clay
RS186S	50	2009	Decommissioned	395,407.7	6,357,888.0	33.34	14.9	21.9	Guildford Clay
RS187S	50	2009	Decommissioned	395,407.7	6,357,990.1	33.42	15.1	22.1	Guildford Clay
RS188S	50	2009	Decommissioned	395,407.1	6,358,089.0	33.40	14.7	21.7	Guildford Clay
RS189S	50	2010	Active	394,782.7	6,359,716.2	18.75	8.3	12.3	Guildford Clay
RS189G	50	2010	Active	394,780.6	6,359,716.1	18.75	13.5	25.0	Ascot Formation
RS190S	50	2010	Active	394,451.3	6,359,711.2	17.76	7.3	10.5	Guildford Clay

Bore	Casing ND (mm)	Monitoring start date	Status	AMG84 Coordinates (Zn50)		TOC (mAHD)	Slotted/screen interval (mBGL)		Formation
				mE	mN		Top	Bottom	
RS190G	50	2010	Active	394,449.2	6,359,711.3	17.78	12.0	23.0	Ascot Formation
RS191S	50	2010	Active	394,310.8	6,359,665.0	17.28	6.0	11.8	Guildford Clay
RS191G	50	2010	Active	394,310.9	6,359,662.9	17.26	12.5	19.5	Ascot Formation
RS192S	50	2010	Active	394,315.3	6,359,560.4	17.12	6.0	12.0	Guildford Clay
RS192G	50	2010	Active	394,315.6	6,359,558.4	17.13	13.0	20.0	Ascot Formation
RS193S	50	2012	Active	394,040.4	6,359,013.3	16.06	5.5	7.5	Guildford Clay
RS193G	50	2012	Active	394,043.6	6,359,013.6	16.07	9.2	20.8	Ascot Formation
RS194S	50	2012	Active	393,793.2	6,359,015.7	16.03	4.0	6.0	Guildford Clay
RS194G	50	2012	Active	393,795.1	6,359,015.4	16.02	8.0	21.7	Ascot Formation
RS195S	50	2012	Active	393,573.7	6,358,931.6	15.56	5.0	15.0	Guildford Clay
RS195G	50	2012	Active	393,573.7	6,358,934.5	15.53	15.5	22.5	Ascot Formation
RS196S	50	2012	Active	393,573.9	6,358,771.0	15.57	3.5	10.0	Guildford Clay
RS196G	50	2012	Active	393,573.5	6,358,772.9	15.65	11.0	23.0	Ascot Formation
RS197S	50	2012	Active	393,573.1	6,358,609.3	15.35	4.0	6.8	Guildford Clay
RS197G	50	2012	Active	393,573.3	6,358,611.3	15.32	8.5	14.0	Ascot Formation
RS198S	50	2012	Active	393,571.7	6,358,446.6	15.45	4.0	14.4	Guildford Clay
RS198G	50	2012	Active	393,571.9	6,358,448.9	15.43	16.0	20.8	Ascot Formation
RS198W	50	2012	Active	393,572.1	6,358,451.3	15.43	22.0	36.5	Leederville Formation
RS199S	50	2012	Active	393,568.5	6,358,285.9	15.54	4.5	7.5	Guildford Clay
RS199G	50	2012	Active	393,569.1	6,358,288.5	15.55	10.0	21.8	Ascot Formation
RS200S	50	2012	Active	393,565.1	6,358,127.1	15.12	4.5	8.5	Guildford Clay
RS200G	50	2012	Active	393,565.7	6,358,129.4	15.12	13.0	21.5	Ascot Formation
RS201S	50	2012	Active	393,560.4	6,357,963.5	15.36	5.0	14.5	Guildford Clay
RS201G	50	2012	Active	393,560.8	6,357,966.0	15.35	16.5	22.5	Ascot Formation
RS202S	50	2012	Active	393,666.8	6,357,881.2	15.53	4.0	9.0	Guildford Clay
RS202G	50	2012	Active	393,664.5	6,357,881.5	15.52	10.5	21.0	Ascot Formation
RS203S	50	2012	Active	393,837.0	6,357,881.7	15.47	5.0	8.0	Guildford Clay
RS203G	50	2012	Active	393,834.9	6,357,881.7	15.48	10.0	21.0	Ascot Formation
RS204S	50	2012	Active	394,006.6	6,357,881.3	15.27	4.7	8.0	Guildford Clay

Bore	Casing ND (mm)	Monitoring start date	Status	AMG84 Coordinates (Zn50)		TOC (mAHD)	Slotted/screen interval (mBGL)		Formation
				mE	mN		Top	Bottom	
RS204G	50	2012	Active	394,004.5	6,357,881.4	15.27	11.0	21.2	Ascot Formation
RS205S	50	2012	Active	394,177.1	6,357,881.8	15.16	6.0	12.0	Guildford Clay
RS205G	50	2012	Active	394,175.4	6,357,881.8	15.25	14.5	21.0	Ascot Formation
UD014-	-	2001	Active	395568.03	6358886.3	-	-	-	Guildford Clay and Yoganup Formation

Table D1-6: Wagerup Vibrating Wire Piezometer Inventory

Site	Monitored from	Status	AMG84 Grid Coords (50)		Formation
			East	North	
H-1-	1996	Unit failed 1999	396,121.0	6,357,595.0	Upper Yoganup Formation
H-2-	1996	Active	396,295.8	6,357,594.8	Upper Yoganup Formation
H-3-	1996	Active	396,120.8	6,357,376.9	Upper Yoganup Formation
H-4-	1996	Active	396,340.7	6,357,376.9	Upper Yoganup Formation
H-5-	1996	Active	396,120.8	6,357,178.0	Upper Yoganup Formation
H-6-	1996	Unit failed 2000	396,361.7	6,357,178.0	Upper Yoganup Formation
I-1-	1997	Active	395,721.0	6,358,772.0	Upper Yoganup Formation
I-2-	1997	Active	395,721.0	6,358,881.0	Upper Yoganup Formation
I-3-	1997	Active	395,721.0	6,358,991.0	Upper Yoganup Formation
H-007S	2012	Active	393,825.0	6,358,826.9	Guildford Clay
H-007G	2012	Active	393,825.0	6,358,826.9	Ascot Formation
H-008S	2012	Active	394,049.9	6,358,826.9	Guildford Clay
H-008G	2012	Active	394,049.9	6,358,826.9	Ascot Formation
H-009S	2012	Active	394,274.8	6,358,827.3	Guildford Clay
H-009G	2012	Active	394,274.8	6,358,827.3	Ascot Formation
H-010S	2012	Active	393,825.2	6,358,524.9	Guildford Clay
H-010G	2012	Active	393,825.2	6,358,524.9	Ascot Formation
H-011S	2012	Active	394,050.1	6,358,527.0	Guildford Clay
H-011G	2012	Active	394,050.1	6,358,527.0	Ascot Formation
H-012S	2012	Active	394,279.1	6,358,527.3	Guildford Clay
H-012G	2012	Active	394,279.1	6,358,527.3	Ascot Formation
H-013S	2012	Active	393,824.8	6,358,318.3	Guildford Clay
H-013G	2012	Active	393,824.8	6,358,318.3	Ascot Formation
H-014S	2012	Active	394,050.5	6,358,318.5	Guildford Clay
H-014G	2012	Active	394,050.5	6,358,318.5	Ascot Formation
H-015S	2012	Active	394,277.9	6,358,323.3	Guildford Clay
H-015G	2012	Active	394,277.9	6,358,323.3	Ascot Formation
H-016S	2012	Active	393,824.6	6,358,085.0	Guildford Clay
H-016G	2012	Active	393,824.6	6,358,085.0	Ascot Formation
H-017S	2012	Active	394,050.0	6,358,085.3	Guildford Clay
H-017G	2012	Active	394,050.0	6,358,085.3	Ascot Formation
H-018S	2012	Active	394,276.2	6,358,091.0	Guildford Clay
H-018G	2012	Active	394,276.2	6,358,091.0	Ascot Formation

Table D1-7: Wagerup Surface Water Sampling Site Inventory

Station	AMG84 Grid Coords (50)		Status	Site Name
	East	North		
SP1-	399,705	6,358,976	Active	North Yalup Brook
SP2-	398,972	6,357,858	Active	South Yalup Upper Dam
SP3-	398,114	6,357,958	Active	South Yalup Lower Dam
SP4-	397,012	6,357,224	Active	
SP5-	396,409	6,358,619	Active	Detention Pond 1 - Overflow
SP6-	397,110	6,359,703	Active	Detention Pond 1 - Inflow
SP7-	396,239	6,359,971	Active	Samson Brook South Drain (East)
SP8-	394,266	6,358,593	Decommissioned 2012	
SP10-	392,333	6,358,505	Active	Samson Brook South Drain (West)
SP11-	392,322	6,358,009	Active	Diversion Drain (West)
SP12-	391,624	6,358,366	Active	Cooyah
SP13-	393,779	6,357,287	Active	
SP14-	391,513	6,358,687	Inactive	Samson Brook North Drain
SP15-	389,369	6,358,096	Active	Harvey River Main Drain (North)
SP16-	395,941	6,356,935	Active	Diversion Drain (East)
SP17-	397,435	6,356,939	Active	
SP18-	397,193	6,358,491	Active	
SP19-	397,646	6,358,328	Active	
SP20-	390,694	6,356,920	Active	Harvey River Main Drain
SP22-	392,628	6,355,571	Active	Logue Brook Drain
SP23-	391,382	6,353,981	Active	Harvey River Main Drain (South)
SP24-	393,038	6,356,005	Active	Bancell Brook Drain
SP025	396,134	6,359,204	Active	Detention Pond 2
SP026-	390,965	6,356,780	Active	Logue Brook Drain

BUNBURY CAUSTIC LOADING FACILITY

Sampling Site Nomenclature

The prefixes and suffixes used to identify monitor bores and other sampling stations at the Bunbury Caustic Loading Facility are listed in Tables D8 and D9.

Table D1-8: List of prefixes used for sampling site nomenclature, Bunbury Caustic Loading Facility

Site prefix	Site type or purpose
B-	Groundwater monitor bore
BS	Surface water monitoring station
SS	Storm water monitoring station
MW	Groundwater monitor bore

Table D1-9: List of suffixes used for sampling site nomenclature, Bunbury Caustic Loading Facility

Site suffix	Site type	Relative depth of slotted casing of bore
B/S	Bore	Upper
A/I	Bore	Middle
-/D	Bore	Lower
-	Surface water / storm water	(No information implied)

Sampling Site Inventory

Table D10 lists the groundwater monitor bore inventory at the Bunbury Caustic Loading Facility.

The inventories for the surface water and storm water sampling site are listed in Table D11.

Table D1-10: Bunbury Groundwater Monitor Bore Inventory

Bore	Casing ND (mm)	Monitored from	Status	AMG84 Coords (Zn 50)		TOC (mAHD)	Slot/screen interval (m)		Formation
				mE	mN		Top	Bottom	
B-012-	50	1997	Active	376,285.2	6,312,220.6	3.93	9.00	13.00	Fill, estuarine deposits, Safety Bay Sand
B-012A	50	1996	Active	376,287.5	6,312,216.8	3.07	3.10	5.60	Fill, estuarine deposits, Safety Bay Sand
B-012B	50	1996	Active	376,286.4	6,312,217.5	3.00	1.60	2.60	Fill, estuarine deposits, Safety Bay Sand
B-013A	50	2002	Active	376,354.1	6,312,226.2	4.01	5.20	5.90	Fill, estuarine deposits, Safety Bay Sand
B-013B	50	2002	Active	376,352.6	6,312,226.5	3.99	1.40	3.20	Fill, estuarine deposits, Safety Bay Sand
B-014A	50	2002	Active	376,226.1	6,312,325.6	4.13	4.50	5.80	Fill, estuarine deposits, Safety Bay Sand
B-014B	50	2002	Active	376,224.9	6,312,326.6	4.13	1.70	3.80	Fill, estuarine deposits, Safety Bay Sand
B-015A	50	1997	Active	376,336.7	6,312,289.7	4.22	4.30	6.00	Fill, estuarine deposits, Safety Bay Sand
B-015B	50	1997	Active	376,337.9	6,312,289.9	4.18	2.00	3.20	Fill, estuarine deposits, Safety Bay Sand
B-016A	50	2002	Active	376,119.6	6,312,375.2	4.73	3.70	5.90	Fill, estuarine deposits, Safety Bay Sand
B-016B	50	2002	Active	376,117.8	6,312,377.3	4.73	1.70	2.80	Fill, estuarine deposits, Safety Bay Sand
B-017A	50	1997	Inactive	375,923.0	6,312,270.0	4.93	6.00	18.00	Fill, estuarine deposits, Safety Bay Sand
B-017B	50	1997	Inactive	375,922.0	6,312,270.8	4.95	2.80	4.30	Fill, estuarine deposits, Safety Bay Sand
B-018-	50	1997	Active	376,071.1	6,312,332.5	4.14	11.00	13.80	Fill, estuarine deposits, Safety Bay Sand
B-018A	50	1997	Active	376,072.1	6,312,332.8	4.17	4.70	8.70	Fill, estuarine deposits, Safety Bay Sand
B-018B	50	1997	Active	376,073.3	6,312,333.2	4.23	2.00	3.90	Fill, estuarine deposits, Safety Bay Sand
B-019A	50	2002	Inactive	375,937.5	6,312,384.8	5.53	8.70	13.00	Fill, estuarine deposits, Safety Bay Sand
B-019B	50	2002	Inactive	375,936.3	6,312,383.6	5.53	2.70	6.20	Fill, estuarine deposits, Safety Bay Sand
B-020A	50	1997	Active	375,932.4	6,312,481.8	5.43	8.00	12.50	Fill, estuarine deposits, Safety Bay Sand
B-020B	50	1997	Active	375,933.9	6,312,481.4	5.40	2.80	6.20	Fill, estuarine deposits, Safety Bay Sand
B-021A	50	2002	Inactive	376,054.3	6,312,425.3	4.58	5.30	6.30	Fill, estuarine deposits, Safety Bay Sand
B-021B	50	2002	Inactive	376,055.4	6,312,424.2	4.58	1.60	3.20	Fill, estuarine deposits, Safety Bay Sand
B-022A	50	2002	Active	375,783.6	6,312,404.8	5.19	7.50	13.50	Fill, estuarine deposits, Safety Bay Sand
B-022B	50	2002	Active	375,782.5	6,312,405.8	5.20	1.70	5.70	Fill, estuarine deposits, Safety Bay Sand
B-023D	50	2019	Active	376249	6312297	5.518	9	12	Fill, esturine deposits, Safety Bay Sand
B-023I	50	2019	Active	376250	6312297	5.518	5	7	Fill, esturine deposits, Safety Bay Sand
B-023S	50	2019	Active	376250	6312297	5.518	1.5	4.5	Fill, esturine deposits, Safety Bay Sand
MW02	50	2017	Active	376207	6313053	4.24	1.5	4.5	Fill, esturine deposits, Safety Bay Sand
MW05	50	2017	Active	375709	6312842	4.39	2	5	Fill, esturine deposits, Safety Bay Sand
MW06	50	2018	Active	376128	6313233	3.06	1	4	Fill, esturine deposits, Safety Bay Sand
MW07	50	2018	Active	376517	6312691	3.73	1	4	Fill, esturine deposits, Safety Bay Sand
MW08	50	2018	Active	376359	6312171	4.63	1	4	Fill, esturine deposits, Safety Bay Sand

Table D1-11: Bunbury Surface Water and Storm Water Sampling Site Inventory

Site Name	Type	Status	AMG84 Coords (Zn 50)	
			East	North
BS1-	Surface water	All sites inactive	376,351	6,312,268
BS2-			376,342	6,312,222
BS3-			376,183	6,312,290
BS4-			375,740	6,312,775
SS3-	Storm water	All sites active	375,547	6,312,348
SS4-			375,574	6,312,317
SS5-			375,620	6,312,262
SS6-			375,506	6,312,437

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Table D2-1: Wagerup groundwater monitoring program

	Borehole type	Licence	Monitoring objective				Current monitoring program							
			1	2	3	4	Extraction volumes download frequency	Flow Meter Calibration	SWL	Standard (pH, EC, temp)	Eh	General (pH, EC or TDS, alkalinity)	Na, Cl, Na:Cl, U	Comprehensive Analysis
B-001-	Regional monitoring		1C	1C					6-monthly	Annual		Annual		
B-002-	Regional monitoring		1D	1D					Annual	Annual		Annual		
B-003-	Regional monitoring		1D	1D					Annual	Annual		Annual		
D-002G	Depressurising bore	GWL102669 ,OS[A]	1A		1B		Monthly		Annual	Annual		Annual		
D-004G	Depressurising bore	GWL102669 ,OS[A]	1A	1A	1B		Monthly		Annual	Annual		Annual		
D-006G	Depressurising bore	GWL102669, OS[A]	1A	1A	1B		Monthly		Annual	Annual		Annual		
D-007G	Depressurising bore	GWL102669, OS[A]	1A	1A	1B		Monthly		Annual	Annual		Annual		
D-008G	Depressurising bore	GWL102669, OS[A]	1A	1A	1B		Monthly		Annual	Annual		Annual		
D-010G	Depressurising bore	GWL102669, OS[A]	1A	1A	1B		Monthly		Annual	Annual		Annual		
D-013G	Depressurising bore	GWL102669, OS[A]	1A	1A	1B		Monthly		Annual	Annual		Annual		
D-014G	Depressurising bore	GWL102669, OS[A]	1A	1A	1B		Monthly		Annual	Annual		Annual		
D-019G	Depressurising bore	GWL102669, OS[A]	1A	1A	1B		Monthly		Annual	Annual		Annual		
D-020G	Depressurising bore	GWL102669, OS[A]	1A	1A	1B		Monthly		Annual	Annual		Annual		
D-021G	Depressurising bore	GWL102669, OS[A]	1A	1A	1B		Monthly		Annual	Annual		Annual		
D-023G	Depressurising bore	GWL102669, OS[A]	1A	1A	1B		Monthly		Annual	Annual		Annual		
D-024G	Depressurising bore	GWL102669, OS[A]	1A	1A	1B		Monthly		Annual	Annual		Annual		
D-025G	Depressurising bore	GWL102669, OS[A]	1A	1A	1B		Monthly		Annual	Annual		Annual		
D-026G	Depressurising bore	GWL102669, OS[A]	1A	1A	1B		Monthly		Annual	Annual		Annual		
D-027G	Depressurising bore	GWL102669, OS[A]	1A	1A	1B		Monthly		Annual	Annual		Annual		
D-028G	Depressurising bore	GWL102669, OS[A]	1A	1A	1B		Monthly		Annual	Annual		Annual		
D-029G	Depressurising bore	GWL102669, OS[A]	1A	1A	1B		Monthly		Annual	Annual		Annual		
D-030G	Depressurising bore	GWL102669, OS[A]	1A	1A	1B		Monthly		Annual	Annual		Annual		
D-031G	Depressurising bore	GWL102669, OS[A]	1A	1A	1B		Monthly		Annual	Annual		Annual		
D-032G	Depressurising bore	GWL102669, OS[A]	1A	1A	1B		Monthly		Annual	Annual		Annual		
D-033G	Depressurising bore	GWL102669, OS[A]	1A	1A	1B		Monthly		Annual	Annual		Annual		

	Borehole type	Licence	Monitoring objective				Current monitoring program							
			1	2	3	4	Extraction volumes download frequency	Flow Meter Calibration	SWL	Standard (pH, EC, temp)	Eh	General (pH, EC or TDS, alkalinity)	Na, Cl, Na:Cl, U	Comprehensive Analysis
D-034G	Depressurising bore	GWL102669, OS[A]	1A	1A	1B		Monthly		Annual	Annual		Annual		
D-035G	Depressurising bore	GWL102669, OS[A]	1A	1A	1B		Monthly		Annual	Annual		Annual		
H-001	VWP[B]	OS[A]	6A						Unit Failed					
H-002	VWP[B]		6A						VWP Download 6-monthly					
H-003	VWP[B]		6A						Unit Failed					
H-004	VWP[B]	OS[A]	6A						Unit Failed					
H-007G	VWP[B]		6A						VWP Download 6-monthly					
H-007S	VWP[B]		6A											
H-008G	VWP[B]		6A											
H-008S	VWP[B]		6A											
H-009G	VWP[B]		6A											
H-009S	VWP[B]		6A						Unit Failed					
H-010G	VWP[B]		6A						VWP Download 6-monthly					
H-010S	VWP[B]		6A											
H-011G	VWP[B]		6A											
H-011S	VWP[B]		6A											
H-012G	VWP[B]		6A											
H-012S	VWP[B]		6A											
H-013G	VWP[B]		6A											
H-013S	VWP[B]		6A											
H-014G	VWP[B]		6A											
H-014S	VWP[B]		6A											
H-015G	VWP[B]		6A											
H-015S	VWP[B]		6A											
H-016G	VWP[B]		6A											
H-016S	VWP[B]		6A											
H-017G	VWP[B]		6A											
H-017S	VWP[B]		6A											
H-018G	VWP[B]		6A											
H-018S	VWP[B]		6A											
I-001	VWP[B]	OS[A]	6A						Weekly[C]					
I-002	VWP[B]	OS[A]	6A											
I-003	VWP[B]	OS[A]	6A											

	Borehole type	Licence	Monitoring objective				Current monitoring program							
			1	2	3	4	Extraction volumes download frequency	Flow Meter Calibration	SWL	Standard (pH, EC, temp)	Eh	General (pH, EC or TDS, alkalinity)	Na, Cl, Na:Cl, U	Comprehensive Analysis
RB001G	Recovery bore	GWL160881, OS[A]	1A	1A	1B	4A		6-monthly		2-monthly		2-monthly		Annual
RB002G	Recovery bore	GWL160881, OS[A]	1A	1A	1B	4A		6-monthly		2-monthly		2-monthly		Annual
RB003G	Recovery bore	GWL160881, OS[A]	1A	1A	1B	4A		6-monthly		Monthly		Monthly		Annual
RB004G	Recovery bore	GWL160881, OS[A]	1A	1A	1B	4A		6-monthly		Monthly		Monthly		Annual
RF001G	Refinery monitoring				4B	4C			Quarterly	6-monthly		6-monthly		
RF001S	Refinery monitoring				4B	4C								
RF002G	Refinery monitoring		3A						Annual	Annual		Annual		
RF002S	Refinery monitoring		3A						Annual	Annual		Annual		
RF003G	Refinery monitoring		3A						Annual	Annual		Annual		
RF003S	Refinery monitoring		3A						Annual	Annual		Annual		
RF004G	Refinery monitoring		3C						Annual	Annual		Annual		
RF004S	Refinery monitoring		3C						Annual	Annual		Annual		
RF005G	Refinery monitoring		3C						Annual	Annual		Annual		
RF005S	Refinery monitoring		3C						Annual	Annual		Annual		
RF006G	Refinery monitoring		3C						6-monthly	Annual		Annual		
RF006S	Refinery monitoring		3C						Annual	Annual		Annual		
RF009G	Refinery monitoring		3A						Annual	Annual		Annual		
RF009S	Refinery monitoring		3A						Annual	Annual		Annual		
RF010G	Refinery monitoring		3A											
RF010S	Refinery monitoring		3A											
RF011G	Refinery monitoring				4B	4C			Quarterly	Annual		Annual		
RF011I	Refinery monitoring				4B	4C			Quarterly					
RF011S	Refinery monitoring				4B	4C			Quarterly	Annual		Annual		
RF013G	Refinery monitoring		3C						Quarterly	Annual		Annual		
RF013S	Refinery monitoring		3C						Quarterly	Annual		Annual		
RF014G	Refinery monitoring		3A						6-monthly	Annual		Annual		
RF014S	Refinery monitoring		3A						Annual	Annual		Annual		
RF015G	Refinery monitoring		3A						Annual	Annual		Annual		
RF015S	Refinery monitoring		3A						Annual	Annual		Annual		
RF016S	Refinery monitoring		3A						Annual	Annual		Annual		
RF016Y	Refinery monitoring		3A						Annual	Annual		Annual		
RF017S	Refinery monitoring		3A											
RF017Y	Refinery monitoring		3A						Monthly	Annual		Annual		
RF018S	Refinery monitoring		3A						6-monthly					
RF018Y	Refinery monitoring		3A						Monthly	Annual		Annual		

	Borehole type	Licence	Monitoring objective				Current monitoring program							
			1	2	3	4	Extraction volumes download frequency	Flow Meter Calibration	SWL	Standard (pH, EC, temp)	Eh	General (pH, EC or TDS, alkalinity)	Na, Cl, Na:Cl, U	Comprehensive Analysis
RF019S	Refinery monitoring				4B	4C			Quarterly	Annual		Annual		
RF019Y	Refinery monitoring				4B	4C			Quarterly	Annual		Annual		
RF020S	Refinery monitoring				4B	4C			Quarterly					
RF020Y	Refinery monitoring				4B	4C			Quarterly	Annual		Annual		
RF021S	Refinery monitoring		3A						Annual					
RF021Y	Refinery monitoring		3A						Monthly	Annual		Annual		
RF022G	Refinery monitoring		3A						Annual					
RF022S	Refinery monitoring		3A						Annual					
RF023G	Refinery monitoring		3A						Annual	Annual		Annual		
RF023S	Refinery monitoring		3A						Annual	Annual		Annual		
RF024G	Refinery monitoring		3A						Annual					
RF024S	Refinery monitoring		3A						Annual					
RF025G	Refinery monitoring		3A						Annual	Annual		Annual		
RF025S	Refinery monitoring		3A						Annual	Annual		Annual		
RF026G	Refinery monitoring		3A						Annual	Annual		Annual		
RF026S	Refinery monitoring		3A						Annual	Annual		Annual		
RF027G	Refinery monitoring		3A						Annual	Annual		Annual		
RF027S	Refinery monitoring		3A						Annual	Annual		Annual		
RF028G	Refinery monitoring		3A						Annual					
RF028S	Refinery monitoring		3A						Annual					
RF029G	Refinery monitoring		3A						Annual					
RF029S	Refinery monitoring		3A						Annual					
RF030G	Refinery monitoring		3A						Annual					
RF030S	Refinery monitoring		3A						Annual					
RF031G	Refinery monitoring		3A						Annual					
RF031S	Refinery monitoring		3A						Annual					
RF032G	Refinery monitoring		3A						Annual	Annual		Annual		
RF032S	Refinery monitoring		3A						Annual	Annual		Annual		
RF033G	Refinery monitoring		3A						Annual	Annual		Annual		
RF033S	Refinery monitoring		3A						Annual	Annual		Annual		
RF034G	Regional monitoring		1C	1C					Quarterly					
RF034S	Regional monitoring		1C	1C					Quarterly					
RF034W	Regional monitoring		1D	1D	3C				6-monthly					
RF035G	Regional monitoring		1C	1C					Quarterly					
RF035S	Regional monitoring		1C	1C					Quarterly					

	Borehole type	Licence	Monitoring objective				Current monitoring program							
			1	2	3	4	Extraction volumes download frequency	Flow Meter Calibration	SWL	Standard (pH, EC, temp)	Eh	General (pH, EC or TDS, alkalinity)	Na, Cl, Na:Cl, U	Comprehensive Analysis
RF035W	Regional monitoring		1D	1D	3C				6-monthly					
RF036G	Refinery monitoring				4B	4C			Quarterly	6-monthly		6-monthly		
RF036S	Refinery monitoring				4B	4C			Quarterly	6-monthly		6-monthly		
RF037G	Refinery monitoring				3C				Annual	Annual		Annual		
RF037S	Refinery monitoring				3C				6-monthly	Annual		Annual		
RF038G	Refinery monitoring				3C				Quarterly	Annual		Annual		
RF038S	Refinery monitoring				3C				Quarterly	Annual		Annual		
RF039G	Refinery monitoring				3A				Annual	Annual		Annual		
RF039S	Refinery monitoring				3A				Annual	Annual		Annual		
RF040G	Refinery monitoring				3A				Annual	Annual		Annual		
RF040S	Refinery monitoring				3A				Annual	Annual		Annual		
RF041G	Refinery monitoring				3A				Quarterly	Annual		Annual		
RF041S	Refinery monitoring				3A				Quarterly	Annual		Annual		
RF041W	Refinery monitoring				3A				6-monthly	Annual		Annual		
RF042G	Regional monitoring		1C	1C					Annual	Annual		Annual		
RF042S	Regional monitoring		1C	1C					Annual	Annual		Annual		
RF043G	Refinery monitoring	OS[A]			4B	4C			Quarterly	6-monthly	6-monthly	6-monthly		6-monthly
RF044G	Refinery monitoring				3C				Annual	Annual		Annual		
RF044S	Refinery monitoring				3C				Annual	Annual		Annual		
RF045G	Refinery monitoring				3A				Annual	Annual		Annual		
RF045S	Refinery monitoring				3A				6-monthly	Annual		Annual		
RF046G	Refinery monitoring	OS[A]			3A	4C			6-monthly	6-monthly	6-monthly	Annual		6-monthly
RF046S	Refinery monitoring				3A				Annual	Annual		Annual		
RF047G	Refinery monitoring				3A				Annual	Annual		Annual		
RF047S	Refinery monitoring				3A				Annual	Annual		Annual		
RF048G	Refinery monitoring				3A									
RF048S	Refinery monitoring				3A									
RF049G	Refinery monitoring				3A				6-monthly	Annual		Annual		
RF049S	Refinery monitoring				3A				Annual	Annual		Annual		
RF050G	Refinery monitoring				3C				Quarterly	Annual		Annual		
RF050S	Refinery monitoring				3C				Quarterly	Annual		Annual		
RF050W	Refinery monitoring				3C				6-monthly	Annual		Annual		
RF051G	Refinery monitoring				3C				Annual	Annual		Annual		
RF051S	Refinery monitoring				3C				Annual	Annual		Annual		
RF052G	Refinery monitoring				3C				Annual	Annual		Annual		

	Borehole type	Licence	Monitoring objective				Current monitoring program							
			1	2	3	4	Extraction volumes download frequency	Flow Meter Calibration	SWL	Standard (pH, EC, temp)	Eh	General (pH, EC or TDS, alkalinity)	Na, Cl, Na:Cl, U	Comprehensive Analysis
RF052S	Refinery monitoring				3C				Annual	Annual		Annual		
RF053G	Refinery monitoring				3C				Annual	Annual		Annual		
RF053S	Refinery monitoring				3C				Annual	Annual		Annual		
RF054G	Refinery monitoring				3A				Annual	Annual		Annual		
RF054I	Refinery monitoring				3A				Annual	Annual		Annual		
RF054S	Refinery monitoring				3A				Annual	Annual		Annual		
RF059S	Refinery monitoring				3C				Annual	Annual		Annual		
RF086G	Refinery monitoring				3A				6-monthly	Annual		Annual		
RF087G	Refinery monitoring				3A									
RF122G	Refinery monitoring				4B	4C			Quarterly	6-monthly		6-monthly		
RF122S	Refinery monitoring				4B	4C			Quarterly	6-monthly		6-monthly		
RF123S	Refinery monitoring				4B	4C			Quarterly	6-monthly		6-monthly		
RF124G	Refinery monitoring				3A				6-monthly	Annual		Annual		
RF124S	Refinery monitoring				3A				6-monthly					
RF125G	Refinery monitoring				3A				Annual	Annual		Annual		
RF125S	Refinery monitoring				3A				Annual	Annual		Annual		
RF126G	Refinery monitoring				3A				6-monthly	Annual		Annual		
RF126S	Refinery monitoring				3A				6-monthly	Annual		Annual		
RF127G	Refinery monitoring				3A				Annual	Annual		Annual		
RF127S	Refinery monitoring				3A				Annual					
RF127W	Refinery monitoring				3A				Annual	Annual		Annual		
RF128G	Refinery monitoring				3A				Annual	Annual		Annual		
RF128S	Refinery monitoring				3A				Annual					
RF129G	Refinery monitoring				3A				Annual	Annual		Annual		
RF129S	Refinery monitoring				3A				Annual	Annual		Annual		
RF130G	Refinery monitoring				3A				Annual	Annual		Annual		
RF130S	Refinery monitoring				3A				Annual	Annual		Annual		
RF131G	Refinery monitoring				4B	4C			Monthly	6-monthly		6-monthly		
RF131S	Refinery monitoring				4B	4C			Monthly	6-monthly		6-monthly		
RF132G	Refinery monitoring				4B	4C			Monthly	6-monthly		6-monthly		
RF133W	Refinery monitoring				3A				Annual	6-monthly		6-monthly		
RF134G	Refinery monitoring				3A				Monthly	6-monthly		6-monthly		
RF135G	Refinery monitoring		3C						Annual#	Annual#		Annual#		
RF135S	Refinery monitoring		3C						Annual#	Annual#		Annual#		
RF136G	Refinery Monitoring													

	Borehole type	Licence	Monitoring objective				Current monitoring program							
			1	2	3	4	Extraction volumes download frequency	Flow Meter Calibration	SWL	Standard (pH, EC, temp)	Eh	General (pH, EC or TDS, alkalinity)	Na, Cl, Na:Cl, U	Comprehensive Analysis
RF136S	Refinery Monitoring								^	^		^		^
RF137G	Refinery Monitoring								^	^		^		^
RF137S	Refinery Monitoring								^	^		^		^
RF138G	Refinery Monitoring								^	^		^		^
RF138S	Refinery Monitoring								^	^		^		^
RF139G	Refinery Monitoring								^	^		^		^
RF139S	Refinery Monitoring								^	^		^		^
RG001G	Regional monitoring	L6217/1983/15	1C	1C					6-monthly	6-monthly		6-monthly	6-monthly	
RG001W	Regional monitoring	L6217/1983/15	1D	1D					6-monthly	6-monthly		6-monthly	6-monthly	
RG002G	Regional monitoring	L6217/1983/15	1C	1C					6-monthly	6-monthly		6-monthly	6-monthly	
RG002W	Regional monitoring	L6217/1983/15	1D	1D					6-monthly	6-monthly		6-monthly	6-monthly	
RG003G	Regional monitoring		1C	1C					Quarterly	Annual		Annual		
RG007G	Refinery monitoring		1C	1C	3C				Annual	Annual		Annual		
RG008G	Regional monitoring	L6217/1983/15	1C	1C					6-monthly	6-monthly		6-monthly	6-monthly	
RG009G	Regional monitoring		1C	1C					Quarterly	Annual		Annual		
RG011G	Regional monitoring	L6217/1983/15	1C	1C					6-monthly	6-monthly		6-monthly	6-monthly	
RG012G	Refinery monitoring	OS[A]	1C	1C	3C				Quarterly	Annual		Annual		
RG014G	Regional monitoring		1C	1C					Quarterly					
RG015G	Regional monitoring		1C	1C					Quarterly	Annual		Annual		
RG016G	Regional monitoring		1C	1C					Quarterly	Annual		Annual		
RG016S	Regional monitoring		1C	1C					Quarterly	Annual		Annual		
RG020G	Regional monitoring		1C	1C					6-monthly	Annual		Annual		
RG022G	Regional monitoring		1C	1C					6-monthly	Annual		Annual		
RG024G	Regional monitoring		1C	1C					Quarterly	Annual		Annual		
RG025G	Regional monitoring	L6217/1983/15	1C	1C					Quarterly	6-monthly		6-monthly	6-monthly	
RG025W	Regional monitoring	L6217/1983/15	1D	1D					6-monthly	6-monthly		6-monthly	6-monthly	
RG026G	Regional monitoring		1C	1C					Quarterly	Annual		Annual		
RG026W	Regional monitoring		1D	1D					Annual					
RG027G	Regional monitoring	OS[A]	1C	1C					Quarterly	Annual		Annual		
RG027S	Regional monitoring	OS[A]	1C	1C					Quarterly	Annual		Annual		
RG027W	Regional monitoring		1D	1D					Annual	Annual		Annual		
RG029G	Regional monitoring		1C	1C					Quarterly					
RG029W	Regional monitoring		1D	1D					Annual					
RG034G	Regional monitoring		1C	1C					Quarterly	Annual		Annual		
RG035G	Regional monitoring		1C	1C					Quarterly	Annual		Annual		

	Borehole type	Licence	Monitoring objective				Current monitoring program							
			1	2	3	4	Extraction volumes download frequency	Flow Meter Calibration	SWL	Standard (pH, EC, temp)	Eh	General (pH, EC or TDS, alkalinity)	Na, Cl, Na:Cl, U	Comprehensive Analysis
RG036G	Regional monitoring		1C	1C					Quarterly	Annual		Annual		
RG079G	Regional monitoring	L6217/1983/15	1C	1C					6-monthly	6-monthly		6-monthly	6-monthly	
RG080G	Regional monitoring		1C	1C					Quarterly	Annual		Annual		
RG150G	Regional monitoring		1C	1C					Quarterly	Annual		Annual		
RG150S	Regional monitoring		1C	1C					Quarterly	Annual		Annual		
RG150W	Regional monitoring		1D	1D					Annual	Annual		Annual		
RG151G	Regional monitoring		1C	1C					Quarterly	Annual		Annual		
RG151S	Regional monitoring		1C	1C					Quarterly	Annual		Annual		
RG151W	Regional monitoring		1D	1D					Annual	Annual		Annual		
RG152G	Regional monitoring	OS[A]	1C	1C					Quarterly	Annual		Annual		
RG152S	Regional monitoring	OS[A]	1C	1C					Quarterly	Annual		Annual		
RG152W	Regional monitoring		1D	1D					Annual	Annual		Annual		
RG153G	Regional monitoring	OS[A]	1C	1C					Quarterly	6-monthly		6-monthly	6-monthly	
RG153S	Regional monitoring	OS[A]	1C	1C					Quarterly	6-monthly		6-monthly	6-monthly	
RG153W	Regional monitoring		1D	1D					6-monthly	6-monthly		6-monthly	6-monthly	
RG154G	Regional monitoring		1C	1C					Quarterly	Annual		Annual		
RG154S	Regional monitoring		1C	1C					Quarterly	Annual		Annual		
RG154W	Regional monitoring		1D	1D					Annual	Annual		Annual		
RG155G	Regional monitoring	OS[A]	1C	1C					Quarterly	Annual		Annual		
RG155S	Regional monitoring	OS[A]	1C	1C					Quarterly	Annual		Annual		
RG155W	Regional monitoring		1D	1D					Annual	Annual		Annual		
RG156G	Regional monitoring	OS[A]	1C	1C					Quarterly	Annual		Annual		
RG156S	Regional monitoring	OS[A]	1C	1C					Quarterly	Annual		Annual		
RG156W	Regional monitoring		1D	1D					Annual	Annual		Annual		
RG157G	Regional monitoring		1C	1C					6-monthly	Annual		Annual		
RG157S	Regional monitoring		1C	1C					6-monthly	Annual		Annual		
RG157W	Regional monitoring		1D	1D					Annual	Annual		Annual		
RG158G	Regional monitoring		1C	1C					6-monthly	Annual		Annual		
RG158S	Regional monitoring		1C	1C					6-monthly	Annual		Annual		
RG158W	Regional monitoring		1D	1D					Annual	Annual		Annual		
RG166G	Regional monitoring		1C	1C					6-monthly	Annual		Annual		
RG166S	Regional monitoring		1C	1C					6-monthly	Annual		Annual		
RG166W	Regional monitoring		1D	1D					Annual	Annual		Annual		
RG219G	Regional monitoring	L6217/1983/15, OS[A]	1C	1C					Quarterly[E]	6-monthly		6-monthly	6-monthly	

	Borehole type	Licence	Monitoring objective				Current monitoring program							
			1	2	3	4	Extraction volumes download frequency	Flow Meter Calibration	SWL	Standard (pH, EC, temp)	Eh	General (pH, EC or TDS, alkalinity)	Na, Cl, Na:Cl, U	Comprehensive Analysis
RG219S	Regional monitoring	L6217/1983/15, OS[A]	1C	1C					Quarterly[E]	6-monthly		6-monthly	6-monthly	
RG219W	Regional monitoring	L6217/1983/15	1D	1D					Quarterly	6-monthly		6-monthly	6-monthly	
RG220G	Regional monitoring		3C						Annual#	Annual#		Annual#		
RG220S	Regional monitoring		3C						Annual#	Annual#		Annual#		
RG221G	Regional monitoring		3C						Annual#	Annual#		Annual#		
RG221S	Regional monitoring		3C						Annual#	Annual#		Annual#		
RG222G	Regional Monitoring								^	^		^		^
RG222S	Regional Monitoring								^	^		^		^
RS039G	RSA Monitoring		6A	5A	5B				Monthly[D]	Annual		Annual		
RS039S	RSA Monitoring		6A	5A	5B				Monthly[D]	Annual		Annual		
RS040G	RSA Monitoring			5A	5B				Annual	Annual		Annual		
RS040S	RSA Monitoring			5A	5B				Annual	Annual		Annual		
RS041G	RSA Monitoring	OS[A]	6A	5A	5B				Weekly	Annual		Annual		
RS041S	RSA Monitoring	OS[A]	6A	5A	5B				Weekly	Annual		Annual		
RS042G	RSA Monitoring		6A	5A	5B				Monthly[D]	Annual		Annual		
RS042S	RSA Monitoring		6A	5A	5B				Monthly[D]	Annual		Annual		
RS043G	RSA Monitoring			5A	5B				Annual	Annual		Annual		
RS043S	RSA Monitoring			5A	5B				Annual	Annual		Annual		
RS044G	RSA Monitoring		6A	5A	5B				Monthly[D]	Annual		Annual		
RS044S	RSA Monitoring		6A	5A	5B				Monthly[D]	Annual		Annual		
RS045G	RSA Monitoring	OS[A]	6A	5A	5B				Weekly^	Annual		Annual		
RS045S	RSA Monitoring	OS[A]	6A	5A	5B				Weekly^	Annual		Annual		
RS046G	RSA Monitoring			5A	5B				Annual	Annual		Annual		
RS046S	RSA Monitoring			5A	5B				Annual	Annual		Annual		
RS047G	RSA Monitoring		6A	5A	5B				Monthly[D]	Annual		Annual		
RS047S	RSA Monitoring		6A	5A	5B				Monthly[D]	Annual		Annual		
RS049G	RSA Monitoring		6A	5A	5B				Monthly[D]	Annual		Annual		
RS049S	RSA Monitoring		6A	5A	5B				Monthly[D]	Annual		Annual		
RS050G	RSA Monitoring			5A	5B				Annual	Annual		Annual		
RS050S	RSA Monitoring			5A	5B				Annual	Annual		Annual		
RS061G	RSA Monitoring			5A	5B									
RS061S	RSA Monitoring			5A	5B									
RS062G	RSA Monitoring			5A	5B				Annual	Annual		Annual		
RS062S	RSA Monitoring			5A	5B				Annual	Annual		Annual		

	Borehole type	Licence	Monitoring objective				Current monitoring program							
			1	2	3	4	Extraction volumes download frequency	Flow Meter Calibration	SWL	Standard (pH, EC, temp)	Eh	General (pH, EC or TDS, alkalinity)	Na, Cl, Na:Cl, U	Comprehensive Analysis
RS063G	RSA Monitoring			5A	5B				Annual	Annual		Annual		
RS063S	RSA Monitoring			5A	5B				Annual	Annual		Annual		
RS064G	RSA Monitoring			5A	5B				Annual	Annual		Annual		
RS064S	RSA Monitoring			5A	5B				Annual	Annual		Annual		
RS065G	RSA Monitoring			5A	5B				Annual	Annual		Annual		
RS065S	RSA Monitoring			5A	5B				Annual	Annual		Annual		
RS066G	RSA Monitoring			5A	5B				Annual	Annual		Annual		
RS066S	RSA Monitoring			5A	5B				Annual	Annual		Annual		
RS090G	RSA Monitoring			5A	5B				Annual	Annual		Annual		
RS090S	RSA Monitoring			5A	5B				Annual	Annual		Annual		
RS091G	RSA Monitoring			5A	5B				Annual	Annual		Annual		
RS091S	RSA Monitoring			5A	5B				Annual	Annual		Annual		
RS092G	RSA Monitoring			5A	5B				Annual	Annual		Annual		
RS092S	RSA Monitoring			5A	5B				Annual	Annual		Annual		
RS093G	RSA Monitoring			5A	5B				Annual	Annual		Annual		
RS093S	RSA Monitoring			5A	5B				Annual	Annual		Annual		
RS094G	RSA Monitoring			5A	5B				Annual	Annual		Annual		
RS094S	RSA Monitoring			5A	5B				Annual	Annual		Annual		
RS095G	RSA Monitoring		5B	6B					Quarterly	Annual		Annual		
RS095I	RSA Monitoring		5B	6B					Quarterly	Annual		Annual		
RS095S	RSA Monitoring		5B	6B					Quarterly	Annual		Annual		
RS096G	RSA Monitoring		5B	6B					Quarterly	Annual		Annual		
RS096I	RSA Monitoring		5B	6B					Quarterly	Annual		Annual		
RS096S	RSA Monitoring		5B	6B					Quarterly	Annual		Annual		
RS097G	RSA Monitoring		5B	6B					Quarterly	Annual		Annual		
RS097I	RSA Monitoring		5B	6B					Quarterly	Annual		Annual		
RS097S	RSA Monitoring		5B	6B					Quarterly	Annual		Annual		
RS098G	RSA Monitoring		5B	6B					Quarterly	Annual		Annual		
RS098I	RSA Monitoring		5B	6B					Quarterly	Annual		Annual		
RS098S	RSA Monitoring		5B	6B					Quarterly	Annual		Annual		
RS099G	RSA Monitoring		5B	6B					Quarterly	Annual		Annual		
RS099I	RSA Monitoring		5B	6B					Quarterly	Annual		Annual		
RS099S	RSA Monitoring		5B	6B					Quarterly	Annual		Annual		
RS100G	RSA Monitoring		5B	6B					Quarterly	Annual		Annual		
RS100I	RSA Monitoring		5B	6B					Quarterly	Annual		Annual		

	Borehole type	Licence	Monitoring objective				Current monitoring program							
			1	2	3	4	Extraction volumes download frequency	Flow Meter Calibration	SWL	Standard (pH, EC, temp)	Eh	General (pH, EC or TDS, alkalinity)	Na, Cl, Na:Cl, U	Comprehensive Analysis
RS100S	RSA Monitoring		5B	6B					Quarterly	Annual		Annual		
RS101G	RSA Monitoring		5B	6B					Quarterly	Annual		Annual		
RS101I	RSA Monitoring		5B	6B					Quarterly	Annual		Annual		
RS101S	RSA Monitoring		5B	6B					Quarterly	Annual		Annual		
RS102G	RSA Monitoring		5B	6B					Quarterly	Annual		Annual		
RS102I	RSA Monitoring		5B	6B					Quarterly	Annual		Annual		
RS102S	RSA Monitoring		5B	6B					Quarterly	Annual		Annual		
RS103G	RSA Monitoring		5B	6B					Monthly	Annual		Annual		
RS103S	RSA Monitoring		5B	6B					Monthly	Annual		Annual		
RS111G	RSA Monitoring			5A	5B				Annual	Annual		Annual		
RS111I	RSA Monitoring			5A	5B				Annual	Annual		Annual		
RS111S	RSA Monitoring			5A	5B				Annual	Annual		Annual		
RS115G	RSA Monitoring			5A	5B				Annual	Annual		Annual		
RS116G	RSA Monitoring	OS[A]	6A		5B				Weekly	Annual		Annual		
RS116S	RSA Monitoring	OS[A]	6A		5B				Weekly	Annual		Annual		
RS117G	RSA Monitoring	OS[A]	6A		5B				Weekly	Annual		Annual		
RS117S	RSA Monitoring	OS[A]	6A		5B				Weekly	Annual		Annual		
RS118G	RSA Monitoring		6A		5B				Monthly[D]	Annual		Annual		
RS118S	RSA Monitoring		6A		5B				Monthly[D]	Annual		Annual		
RS119G	RSA Monitoring	OS[A]	6A		5B				Weekly	Annual		Annual		
RS119S	RSA Monitoring	OS[A]	6A		5B				Weekly	Annual		Annual		
RS120G	RSA Monitoring	OS[A]	6A		5B				Weekly[E]	Annual		Annual		
RS120S	RSA Monitoring	OS[A]	6A		5B				Weekly[E]	Annual		Annual		
RS121G	RSA Monitoring	OS[A]	6A		5B				Weekly	Annual		Annual		
RS121S	RSA Monitoring	OS[A]	6A		5B				Weekly	Annual		Annual		
RS122G	RSA Monitoring			5A	5B				Annual	Annual		Annual		
RS122S	RSA Monitoring			5A	5B				Annual	Annual		Annual		
RS123G	RSA Monitoring		1C	1C	5B				Quarterly	Annual		Annual		
RS123S	RSA Monitoring		1C	1C	5B				Quarterly	Annual		Annual		
RS124S	RSA Monitoring		1C	1C	5B				Quarterly	Annual		Annual		
RS125S	RSA Monitoring			5A	5B				Annual	Annual		Annual		
RS126G	RSA Monitoring			5A	5B				Annual	Annual		Annual		
RS127G	RSA Monitoring			5A	5B				Annual	Annual		Annual		
RS130G	RSA Monitoring		6A		5B				Monthly[D]	Annual		Annual		
RS130S	RSA Monitoring		6A		5B				Monthly[D]	Annual		Annual		

	Borehole type	Licence	Monitoring objective				Current monitoring program							
			1	2	3	4	Extraction volumes download frequency	Flow Meter Calibration	SWL	Standard (pH, EC, temp)	Eh	General (pH, EC or TDS, alkalinity)	Na, Cl, Na:Cl, U	Comprehensive Analysis
RS137G	RSA Monitoring	OS[A]	6A		5B				Weekly	Annual		Annual		
RS137S	RSA Monitoring	OS[A]	6A		5B				Weekly	Annual		Annual		
RS138G	RSA Monitoring		6A		5B				Monthly[D]	Annual		Annual		
RS138S	RSA Monitoring		6A		5B				Monthly[D]	Annual		Annual		
RS139G	RSA Monitoring		6A		5B				Monthly[D]	Annual		Annual		
RS139S	RSA Monitoring		6A		5B				Monthly[D]	Annual		Annual		
RS140G	RSA Monitoring		6A		5B				Monthly[D]	Annual		Annual		
RS140S	RSA Monitoring		6A		5B				Monthly[D]	Annual		Annual		
RS141G	RSA Monitoring	OS[A]	6A		5B				Weekly	Annual		Annual		
RS141S	RSA Monitoring	OS[A]	6A		5B				Weekly	Annual		Annual		
RS142G	RSA Monitoring	OS[A]	6A		5B				Weekly	Annual		Annual		
RS142S	RSA Monitoring	OS[A]	6A		5B				Weekly	Annual		Annual		
RS145S	RSA Monitoring		6A		5B				Monthly[D]	Annual		Annual		
RS146G	RSA Monitoring		1C	1C	5B				Quarterly	Annual		Annual		
RS146S	RSA Monitoring		1C	1C	5B				Quarterly	Annual		Annual		
RS146W	RSA Monitoring		1D	1D	5A	5B			6-monthly	Annual		Annual		
RS147G	RSA Monitoring		1C	1C	5B				Quarterly	Annual		Annual		
RS147I	RSA Monitoring		1C	1C	5B				Quarterly	Annual		Annual		
RS147S	RSA Monitoring		1C	1C	5B				Quarterly	Annual		Annual		
RS149G	RSA Monitoring		6A		5B				Monthly[D]	Annual		Annual		
RS160G	RSA Monitoring			5A	5B				Annual	Annual		Annual		
RS160S	RSA Monitoring			5A	5B				Annual	Annual		Annual		
RS161G	RSA Monitoring			5A	5B				Annual	Annual		Annual		
RS161S	RSA Monitoring			5A	5B				Annual	Annual		Annual		
RS162G	RSA Monitoring			5A	5B				Annual	Annual		Annual		
RS162S	RSA Monitoring			5A	5B				Annual	Annual		Annual		
RS163G	RSA Monitoring			5A	5B				Monthly	Annual		Annual		
RS163S	RSA Monitoring			5A	5B				Monthly	Annual		Annual		
RS168G	RSA Monitoring			5A	5B				Annual	Annual		Annual		
RS168S	RSA Monitoring			5A	5B				Annual	Annual		Annual		
RS168W	RSA Monitoring		1D	1D	5A	5B			Annual	Annual		Annual		
RS169G	RSA Monitoring			5A	5B				Annual	Annual		Annual		
RS169S	RSA Monitoring			5A	5B				Annual	Annual		Annual		
RS170G	RSA Monitoring			5A	5B				Annual	Annual		Annual		
RS170S	RSA Monitoring			5A	5B				Annual	Annual		Annual		

	Borehole type	Licence	Monitoring objective				Current monitoring program							
			1	2	3	4	Extraction volumes download frequency	Flow Meter Calibration	SWL	Standard (pH, EC, temp)	Eh	General (pH, EC or TDS, alkalinity)	Na, Cl, Na:Cl, U	Comprehensive Analysis
RS171G	RSA Monitoring			5A	5B				Annual	Annual		Annual		
RS171S	RSA Monitoring			5A	5B				Annual	Annual		Annual		
RS172G	RSA Monitoring			5A	5B				Annual	Annual		Annual		
RS172S	RSA Monitoring			5A	5B				Annual	Annual		Annual		
RS173G	RSA Monitoring			5A	5B				Annual	Annual		Annual		
RS173S	RSA Monitoring			5A	5B				Annual	Annual		Annual		
RS174G	RSA Monitoring			5A	5B				Annual	Annual		Annual		
RS174S	RSA Monitoring			5A	5B				Annual	Annual		Annual		
RS175G	RSA Monitoring			5A	5B				Annual	Annual		Annual		
RS175S	RSA Monitoring			5A	5B				Annual	Annual		Annual		
RS176G	RSA Monitoring			5A	5B				Annual	Annual		Annual		
RS176S	RSA Monitoring			5A	5B				Annual	Annual		Annual		
RS177G	RSA Monitoring			5A	5B				Annual	Annual		Annual		
RS177S	RSA Monitoring			5A	5B				Annual	Annual		Annual		
RS178G	RSA Monitoring			5A	5B				Annual	Annual		Annual		
RS178S	RSA Monitoring			5A	5B				Annual	Annual		Annual		
RS189G	RSA Monitoring			5A	5B				6-monthly	6-monthly		6-monthly		
RS189S	RSA Monitoring			5A	5B				6-monthly	6-monthly		6-monthly		
RS190G	RSA Monitoring			5A	5B				6-monthly	6-monthly		6-monthly		
RS190S	RSA Monitoring			5A	5B				6-monthly	6-monthly		6-monthly		
RS191G	RSA Monitoring			5A	5B				6-monthly	6-monthly		6-monthly		
RS191S	RSA Monitoring			5A	5B				6-monthly	6-monthly		6-monthly		
RS192G	RSA Monitoring			5A	5B				6-monthly	6-monthly		6-monthly		
RS192S	RSA Monitoring			5A	5B				6-monthly	6-monthly		6-monthly		
RS193G	RSA Monitoring		6A		5B				Monthly	Annual		Annual		
RS193S	RSA Monitoring		6A		5B				Monthly	Annual		Annual		
RS194G	RSA Monitoring		6A		5B				Monthly	Annual		Annual		
RS194S	RSA Monitoring		6A		5B				Monthly	Annual		Annual		
RS195G	RSA Monitoring	OS[A]	1C	1C	5B				Monthly	Annual		Annual		
RS195S	RSA Monitoring	OS[A]	1C	1C	5B				Monthly	Annual		Annual		
RS196G	RSA Monitoring		6A		5B				Monthly	Annual		Annual		
RS196S	RSA Monitoring		6A		5B				Monthly	Annual		Annual		
RS197G	RSA Monitoring		6A		5B				Monthly	Annual		Annual		
RS197S	RSA Monitoring		6A		5B				Monthly	Annual		Annual		
RS198G	RSA Monitoring	OS[A]	1C	1C	5B				Monthly	Annual		Annual		

	Borehole type	Licence	Monitoring objective				Current monitoring program							
			1	2	3	4	Extraction volumes download frequency	Flow Meter Calibration	SWL	Standard (pH, EC, temp)	Eh	General (pH, EC or TDS, alkalinity)	Na, Cl, Na:Cl, U	Comprehensive Analysis
RS198S	RSA Monitoring	OS[A]	1C	1C	5B				Monthly	Annual		Annual		
RS198W	RSA Monitoring		1D	1D	5A	5B			6-monthly	Annual		Annual		
RS199G	RSA Monitoring		6A		5B				Monthly	Annual		Annual		
RS199S	RSA Monitoring		6A		5B				Monthly	Annual		Annual		
RS200G	RSA Monitoring		6A		5B				Monthly	Annual		Annual		
RS200S	RSA Monitoring		6A		5B				Monthly	Annual		Annual		
RS201G	RSA Monitoring	OS[A]	1C	1C	5B				Monthly	Annual		Annual		
RS201S	RSA Monitoring	OS[A]	1C	1C	5B				Monthly	Annual		Annual		
RS202G	RSA Monitoring		6A		5B				Monthly	Annual		Annual		
RS202S	RSA Monitoring		6A		5B				Monthly	Annual		Annual		
RS203G	RSA Monitoring		6A		5B				Monthly	Annual		Annual		
RS203S	RSA Monitoring		6A		5B				Monthly	Annual		Annual		
RS204G	RSA Monitoring		6A		5B				Monthly	Annual		Annual		
RS204S	RSA Monitoring		6A		5B				Monthly	Annual		Annual		
RS205G	RSA Monitoring		6A		5B				Monthly	Annual		Annual		
RS205S	RSA Monitoring		6A		5B				Monthly	Annual		Annual		

The table represents the program from 1/1/2020 to 31/12/2022 with changes marked as below

^ - Annual Sampling 1/1/2020/ to 31/12/2022

A. OS - Operating Strategy

B. Vibrating wire piezometer

C. Vibrating wire piezometer monitoring frequency

D. Weekly monitoring 1/1/2020 to 31/12/2022

Table D2-2: Wagerup Underdrain Monitoring Program

Sump ID	Description	Licence	Monitoring objective and program			Current monitoring program								
			1	2	3	Extraction volumes download frequency	Flow meter calibration	SWL	Standard (pH, EC, temp)	Eh	General Analysis	Na, Cl, Na:Cl	Turbidity	Comprehensive analysis
UD014-	ROCP2 subliner drainage	GWL102669 Operating Strategy	6C			Monthly		Annual	Annual	^	Annual#			^
BP001G	Borrow Pit	GWL102669 Operating Strategy				Monthly			Annual	^	Annual#			

The table represents the program from 1/1/2018 to 31/12/2019 with changes marked as below

^ - annual monitoring 1/1/2017 to 31/12/2017

- no monitoring 1/1/2017/ to 31/12/2017

Table D2-3: Wagerup Surface Water Monitoring Program

Site ID	Stream system, station location	Licence	Monitoring objective			Current monitoring program							
			1	2	3	Extraction volumes download frequency	Flow meter calibration	Standard (pH, EC, temp)	Eh	General Analysis	Na, Cl, Na:Cl	Turbidity	Comprehensive analysis
SP1-	North Yalup Brook	OS[1]	2B	2B	7A	Monthly		Quarterly	Annual	Quarterly			Annual
SP2-	South Yalup Upper Dam		7A					Quarterly	Annual	Quarterly			Annual
SP3-	South Yalup Lower Dam		7A					Monthly	Annual	Monthly			Annual
SP4-			7A					Monthly[A]	Annual	Monthly[B]			Annual
SP5-	South Samson Diversion Drain Detention Pond 1 - Overflow	OS[1]	2B	2B	7A	Monthly		Monthly	Annual	Monthly			Annual
SP6-	South Samson Diversion Drain Detention Pond 1 - Inflow	OS[1]	2B	2B	7A	Monthly		Quarterly	Annual	Quarterly			Annual
SP7-	Samson Brook South Drain (East)		7A					Quarterly	Annual	Quarterly			Annual
SP10-	Samson Brook South Drain (West)		7A					Weekly	Annual	Monthly			Annual
SP11-	Diversion Drain (West)		7A					Monthly[A]	Annual	Monthly[B]			Annual
SP12-	South Samson Drain - Cooyah	L6217/1983/15, OS[1]	2B	2B		Monthly		Weekly	6-monthly	Monthly	Monthly	Monthly	6-monthly

Site ID	Stream system, station location	Licence	Monitoring objective			Current monitoring program							
			1	2	3	Extraction volumes download frequency	Flow meter calibration	Standard (pH, EC, temp)	Eh	General Analysis	Na, Cl, Na:Cl	Turbidity	Comprehensive analysis
SP13-	RSA9 diversion drain		7A					Monthly[A]	Annual	Monthly[B]			Annual
SP14-	Samson Brook North Drain												
SP15-	Harvey River Main Drain (North)		7A					Monthly	Annual	Monthly			Annual
SP16-	South Samson Diversion Drain (East) at Somers Road	OS[1]	2B	2B	7A	Monthly		Monthly[A]	Annual	Monthly[B]			Annual
SP17-	Surface drainage diversion from refinery		7A						Annual				Annual
SP18-	convergence of South Yalup lower dam diversion with North Yalup Brook		7A						Annual				Annual
SP19-	South Yalup Lower Dam diversion drain		7A						Annual				Annual
SP20-	Harvey River Main Drain - below pump	OS[1]	2B	2B		Monthly							
SP22-	Logue Brook Drain		7A					Quarterly	Annual	Quarterly			Annual
SP23-	Harvey River Main Drain (South)		7A					Quarterly	Annual	Quarterly			Annual
SP24-	Bancell Brook Drain		7A					Quarterly	Annual	Quarterly			Annual
SP25-	Detention Pond 2							Monthly	Annual	Monthly			Annual
SP26-	Logue Brook Drain - below pump station	OS[1]	2B	2B	7A	Monthly							
	Upper Yalup Dam Draw Volume Meter	SWL97472, OS[1]	2A	2A		Monthly	Annual						
	Detention Pond draw volume	SWL99246, OS[1]	2A	2A		Monthly	Annual						
	Harvey Pumpback draw volume	SWL151027, OS[1]	2A	2A		Monthly	Annual						
W001-	Paddock sample, RSA4 near RS104SG							Annual	Annual				Annual[C]
SW1-	Paddock sample, RSA4 near RS103SG							Annual	Annual				Annual[C]
SW2-	Paddock sample, RCOP1 north		7A					Annual	Annual				Annual[C]
SW3-	Paddock sample, RCOP1 middle		7A					Annual	Annual				Annual[C]
SW4-	Paddock sample, RCOP1 south		7A					Annual	Annual				Annual[C]
SWBKGR	Paddock sample, background near SP007-		7A					Annual	Annual				Annual[C]

1. Operating Strategy
A. During summer and seekly from Jun - Nov inclusive
B. No sampling during summer and monthly from Jun - Nov inclusive
C. +Th & U

Table D2-4: Bunbury Groundwater Monitoring Program

Bore ID	Monitoring objective and program				Current monitoring program								
	1	2	3	4	Extraction volumes download frequency	Flow meter calibration	SWL	Standard (pH, EC, temp))	Eh	General Analysis (pH, EC or TDS, alkalinity)	Na, Cl, Na:Cl, U	Bunbury contaminated sites comprehensive	Bunbury groundwater hydrocarbons: Product thickness, TRH/BTEXN
B-012-	3A						Annual	Annual	Annual	Annual		Annual	
B-012A	3A						Annual	Annual	Annual	Annual		Annual	
B-012B	3A						Annual	Annual	Annual	Annual		Annual	
B-013A	3A						Annual	Annual	Annual	Annual		Annual	
B-013B	3A						Annual	Annual	Annual	Annual		Annual	
B-014A	3A						Annual	Annual	Annual	Annual		Annual	
B-014B	3A						Annual	Annual	Annual	Annual		Annual	
B-015A	3A						Annual	Annual	Annual	Annual		Annual	
B-015B	3A						Annual	Annual	Annual	Annual		Annual	
B-016A	3A						Annual	Annual	Annual	Annual		Annual	
B-016B	3A						Annual	Annual	Annual	Annual		Annual	
B-018-	3A						Annual	Annual	Annual	Annual		Annual	Annual
B-018A	3A						Annual	Annual	Annual	Annual		Annual	Annual
B-018B	3A						Annual	Annual	Annual	Annual		Annual	Annual
B-020A	3A						Annual	Annual	Annual	Annual		Annual	
B-020B	3A						Annual	Annual	Annual	Annual		Annual	
B-022A	3A						Annual	Annual	Annual	Annual		Annual	
B-022B	3A						Annual	Annual	Annual	Annual		Annual	

Table D2-5: Bunbury Surface Water Monitoring Program

Site ID	Site location	Monitoring objective and program						CURRENT MONITORING PROGRAM							
		1		2		3		Extraction volumes download frequency	Flow meter calibration	Standard (pH, EC, temp)	Eh	General Analysis	Na, Cl, Na:Cl	Turbidity	Bunbury contaminated sites comprehensive
		Objective	Program	Objective	Program	Objective	Program								
SS003-	Storm water drain	7B	B7B.1							Annual	Annual				Annual
SS004-	Storm water drain	7B	B7B.1							Annual	Annual				Annual
SS005-	Storm water drain	7B	B7B.1							Annual	Annual				Annual
SS006-	Storm water drain	7B	B7B.1							Annual	Annual				Annual

APPENDIX E

Comprehensive analyses of surface water samples, 2020–2022

Appendix E : Comprehensive analyses of surface water samples, 2020-2022

Analyte/Sampling details	SP001			SP002			SP003			SP004			SP005		
Sampling date:	15/09/2020	23/09/2021	8/09/2022	15/09/2020	23/09/2021	8/09/2022	15/09/2020	23/09/2021	8/09/2022	15/09/2020	23/09/2021	8/09/2022	15/09/2020	23/09/2021	8/09/2022
pH (field measurement)	7.2	7.3	7.1	7.7	7.5	7.7	8.2	8.5	8.2				7.5	8.5	7.7
Electrical Conductivity (µS/cm)	330	290	270	430	330	330	330	290	310				350	320	340
Total Dissolved Salts (mg/L)	190	120	150	140	160	170	250	150	280				200	170	190
Sodium (mg/L)	42	35	35	58	40	40	32	28	30				45	38	42
Potassium (mg/L	1.3	0.8	1.1	2.7	2	2.1	1.2	0.7	0.9				2.8	2.7	2.6
Calcium (mg/L)	4.6	4.5	4.1	7	5.7	5.8	5.6	6.3	4.9				5.9	6.5	6.3
Magnesium (mg/L)	6.7	6	5.9	8.5	6.3	6.7	3	2.4	2.4				7.1	6.3	6.8
Chloride (mg/L)	73	63	68	97	72	79	34	28	31				78	68	83
Sulphate (mg/L)	15	13	13	19	15	14	11	10	11				17	14	16
Carbonate (mg/L)	<1	<1	<1	<1	<1	<1	<1	6	<1				<1	<1	<1
Bicarbonate (mg/L)	21	23	21	26	25	32	89	87	100				20	30	31
Nitrate (mg/L)	0.053	0.013	0.09	0.032	0.14	0.079	0.052	0.073	0.085				0.17	0.17	0.16
Nitrite (mg/L)	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.0067				<0.005	0.01	0.0066
Alkalinity (as mg/L $CaCO_3$)	21	23	21	26	25	32	89	93	100				20	30	31
Hardness (as mg/L $CaCO_3$)	39	36	34	53	40	42	26	26	22				44	42	44
Silica (mg/L)	14	9.7	13	6.7	8.1	6.6	1.2	1.3	0.9				6	3.6	5
Dissolved Organic Carbon (mg/L)	2	2	2.1	6	5	4.6	6	7	9.2				4	8	5.9
Filterable Reactive Phosphorus (mg/L)	0.003	<0.002	0.0036	<0.002	<0.002	0.0028	<0.002	<0.002	0.0031				0.002	0.004	0.04
Total Phosphorus (mg/L)	0.01	0.01	<0.01	0.02	0.01	<0.01	0.01	<0.01	<0.01				0.02	0.03	<0.01
Ammonia (mg/L)	<0.005	0.008	<0.005	0.017	0.037	0.023	13	12	14				<0.005	0.021	0.01
Total Kjeldahl Nitrogen (mg/L)	0.2	0.2	0.14	0.6	0.4	0.5	15	13	15	No flow, unable to sample	No flow, no sample	No flow, no sample	0.5	0.7	0.58
Sodium/Chloride mass ratio	0.58	0.56	0.51	0.6	0.55	0.51	0.92	0.97	0.97				0.58	0.56	0.51
Aluminium (mg/L)	0.01	0.007	0.018	0.008	0.01	0.015	0.31	0.82	0.25				0.02	0.06	0.019
Arsenic (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001				<0.001	<0.001	<0.001
Boron (mg/L)	0.03	0.02	<0.02	0.04	0.03	<0.02	<0.02	<0.02	<0.02				0.04	0.03	<0.02
Cadmium (mg/L)	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001				<0.0001	<0.0001	<0.0001
Chromium (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001				<0.001	<0.001	<0.001
Copper (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001				<0.001	0.002	<0.001
Fluoride (mg/L)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1				<0.1	<0.1	<0.1
Iron (mg/L)	0.032	0.095	0.022	0.016	0.079	0.076	0.022	0.045	0.025				0.09	0.31	0.13
Gallium (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.003	0.005	0.0039				<0.001	<0.001	<0.001
Mercury (mg/L)	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005				<0.00005	<0.00005	<0.00005
Manganese (mg/L)	0.005	0.01	0.0054	<0.001	0.004	0.0018	<0.001	<0.001	<0.001				<0.001	0.001	<0.001
Molybdenum (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.012	0.011	0.012				<0.001	<0.001	<0.001
Nickel (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001				<0.001	<0.001	<0.001
Lead (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001				<0.001	<0.001	<0.001
Selenium (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.003	0.003	0.003				<0.001	<0.001	<0.001
Uranium (mg/L)	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005				<0.0005	<0.0005	<0.0005
Vanadium (mg/L)	0.001	<0.001	0.0015	<0.001	<0.001	<0.001	0.002	0.005	0.0024				<0.001	<0.001	<0.001
Zinc (mg/L)	<0.001	<0.001	0.0013	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001				0.002	<0.001	<0.001
Total anions (meq/L)	110	99	110	140	110	120	100	96	100				110	100	120
Total cations (meq/L)	55	46	46	76	54	55	41	37	39				61	54	58
Ion Balance (%)	-2.6	-5	-8.1	-0.15	-4.8	-9.1	-21	-25	-5.9				-0.38	-4.4	-9.1

Appendix E : Comprehensive analyses of surface water samples, 2020-2022

Analyte/Sampling details	SP006			SP007			SP010			SP011			SP012					
Sampling date:	24/09/2020	23/09/2021	8/09/2022	24/09/2020	23/09/2021	8/09/2022	22/10/2020	23/09/2021	18/10/2022	22/10/2020	20/10/2021	18/10/2022	15/04/2020	22/10/2020	21/04/2021	20/10/2021	27/04/2022	18/10/2022
pH (field measurement)	8	9.3	8.8	7.3	7.2	6.9	7.1	7	7.5	7	7	6.9	6.7	7.2	6.7	7	7	7
Electrical Conductivity (µS/cm)	270	450	320	570	630	680	590	560	3000	1100	830	420	450	1000	280	790	300	480
Total Dissolved Salts (mg/L)	160	240	180	330	380	410	370	320	2200	730	540	330	280	700	170	530	140	310
Sodium (mg/L)	32	55	41	65	75	80	76	61	390	150	97	61	62	140	40	86	37	70
Potassium (mg/L	2	1.9	2.1	5.8	4.7	6.5	3.3	3.8	6.6	1.4	1.8	1.4	3.9	1.7	4	3	2.3	1.2
Calcium (mg/L)	3.8	9.5	6.2	13	14	16	16	17	89	23	19	8.5	9.4	23	5.5	20	5.4	9.7
Magnesium (mg/L)	4.8	9.4	6.5	12	13	15	14	14	110	26	21	10	10	25	6.3	20	5.9	12
Chloride (mg/L)	59	97	81	120	140	180	130	120	1100	260	190	120	98	250	62	190	71	140
Sulphate (mg/L)	12	20	17	23	32	22	14	25	180	2	36	13	44	5	6	17	9	15
Carbonate (mg/L)	<1	13	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Bicarbonate (mg/L)	12	33	24	53	58	53	68	63	140	120	74	60	15	120	23	84	24	65
Nitrate (mg/L)	0.17	<0.005	0.2	0.21	0.29	0.093	0.006	0.052	0.0065	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Nitrite (mg/L)	<0.005	<0.005	<0.005	0.023	0.008	0.0091	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Alkalinity (as mg/L $CaCO_3$)	12	46	24	53	58	53	68	63	140	120	74	60	15	120	23	84	24	65
Hardness (as mg/L $CaCO_3$)	29	63	42	82	89	100	99	100	660	170	130	65	65	160	40	130	38	73
Silica (mg/L)	5.4	4.4	4.6	3.6	5.9	3.5	7.9	5.5	5.3	21	9.4	6.6	14	16	5.1	9.9	5.7	7.5
Dissolved Organic Carbon (mg/L)	2	8	4.6	7	13	6.6	7	15	14	23	18	8.8	5	22	3	17	5	9.4
Filterable Reactive Phosphorus (mg/L)	0.003	0.007	0.0066	0.008	0.008	0.0037	0.004	0.014	0.0055	0.39	0.073	0.044	0.008	0.42	0.004	0.07	0.004	0.024
Total Phosphorus (mg/L)	0.03	0.03	<0.01	0.05	0.06	0.042	0.03	0.07	0.018	0.44	0.18	0.14	0.07	0.63	0.02	0.24	0.02	0.22
Ammonia (mg/L)	0.013	0.006	0.0063	0.12	0.041	0.2	0.025	0.018	<0.005	0.033	0.042	0.0076	0.035	0.1	<0.005	0.015	0.01	0.0082
Total Kjeldahl Nitrogen (mg/L)	0.2	0.6	0.43	0.7	1.1	0.83	0.6	1.3	0.96	1.8	1.3	0.8	0.8	1.8	0.4	1.7	0.4	1
Sodium/Chloride mass ratio	0.54	0.57	0.51	0.54	0.55	0.44	0.6	0.51	0.35	0.59	0.5	0.51	0.63	0.59	0.66	0.46	0.52	0.5
Aluminium (mg/L)	0.02	0.03	0.044	0.005	0.02	<0.005	<0.005	0.006	<0.005	0.03	0.009	0.0078	<0.005	0.02	<0.005	0.01	<0.005	0.006
Arsenic (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Boron (mg/L)	0.04	0.03	<0.02	0.05	0.03	<0.02	0.04	0.03	<0.02	0.04	0.07	<0.02	0.1	0.03	0.09	0.05	0.05	<0.02
Cadmium (mg/L)	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Chromium (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Copper (mg/L)	0.002	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	0.0011	0.001	0.007	0.0024	<0.001	<0.001	0.001	0.003	<0.001	<0.001
Fluoride (mg/L)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.1	0.1	0.14	0.1	<0.1	<0.1	<0.1	0.1	<0.1	0.1	<0.1	<0.1
Iron (mg/L)	0.071	0.54	0.29	0.21	0.65	0.092	0.023	0.43	0.075	5.5	0.68	0.51	0.017	4	0.037	0.85	0.032	0.35
Gallium (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Mercury (mg/L)	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005
Manganese (mg/L)	0.023	0.012	0.014	0.13	0.049	0.18	0.029	0.036	0.25	0.13	0.096	0.037	0.025	0.13	0.003	0.18	0.006	0.043
Molybdenum (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Nickel (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Lead (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Selenium (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Uranium (mg/L)	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	0.0017	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Vanadium (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.003	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	<0.001	<0.001
Zinc (mg/L)	0.003	<0.001	<0.001	0.001	0.001	<0.001	<0.001	0.006	0.0025	0.002	0.002	0.0031	0.006	0.001	0.002	0.003	<0.001	<0.001
Total anions (meq/L)	84	150	120	180	210	240	190	190	1400	360	280	170	160	340	86	260	99	200
Total cations (meq/L)	43	76	56	96	110	120	110	95	590	210	140	81	85	190	56	130	50	93
Ion Balance (%)	-2.8	-4.9	-8.2	-3	-4.9	-8.3	1.4	-4.2	-9.8	1.5	-4.8	-9.3	1.7	0.37	6.9	-5.7	-4.8	-8.9

Appendix E : Comprehensive analyses of surface water samples, 2020-2022

Analyte/Sampling details	SP013			SP015			SP016			SP017			SP018			SP019		
Sampling date:	15/09/2020	23/09/2021	8/09/2022	15/09/2020	23/09/2021	8/09/2022	15/09/2020	23/09/2021	8/09/2022	15/09/2020	23/09/2021	8/09/2022	15/09/2020	23/09/2021	8/09/2022	15/09/2020	23/09/2021	8/09/2022
pH (field measurement)			7.1	7.9	7.5	7.3	7	7	7		8	8.1	7.1	7.2	7.2	6.7	6.7	7
Electrical Conductivity (µS/cm)			2300	690	550	640	640	500	400		900	960	640	520	530	870	690	740
Total Dissolved Salts (mg/L)			1400	380	340	400	350	290	210		560	580	350	250	300	500	350	440
Sodium (mg/L)			230	83	61	77	90	62	49		140	160	88	66	71	120	91	95
Potassium (mg/L			4.9	3.6	2.8	4.9	3.3	2.2	2.6		2.3	2.7	3	1.7	2	2.5	1.9	2.7
Calcium (mg/L)			86	16	13	15	12	10	7.7		22	19	9.6	8.8	7.4	15	13	18
Magnesium (mg/L)			79	17	13	16	13	10	8.4		21	19	12	11	10	15	14	15
Chloride (mg/L)			570	150	120	160	140	110	96		71	90	140	110	140	170	130	150
Sulphate (mg/L)			270	38	26	34	17	18	19		48	63	16	16	22	52	43	68
Carbonate (mg/L)			<1	<1	<1	<1	<1	<1	<1		<1	<1	<1	<1	<1	<1	<1	<1
Bicarbonate (mg/L)			100	53	46	51	64	62	42		350	360	58	60	45	93	100	99
Nitrate (mg/L)			0.0053	0.23	0.18	0.19	<0.005	<0.005	0.042		<0.005	<0.005	0.06	0.015	<0.005	<0.005	<0.005	<0.005
Nitrite (mg/L)			<0.005	<0.005	<0.005	0.0083	<0.005	<0.005	<0.005		<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Alkalinity (as mg/L $CaCO_3$)			100	53	46	51	64	62	42		350	360	58	60	45	93	100	99
Hardness (as mg/L $CaCO_3$)			540	110	89	110	83	68	54		140	120	75	66	60	100	92	110
Silica (mg/L)			5.9	3.9	5.9	4.8	3.4	1	0.9		6.3	7.1	7.9	8.6	7.8	12	12	13
Dissolved Organic Carbon (mg/L)			22	12	16	21	13	10	7.5		10	10	10	8	7.9	11	12	13
Filterable Reactive Phosphorus (mg/L)			0.0091	0.057	0.072	0.14	0.006	0.003	0.0036		0.002	0.0033	0.009	0.004	0.0039	0.003	<0.002	0.0021
Total Phosphorus (mg/L)			0.023	0.1	0.14	0.15	0.04	0.02	<0.01	No flow, no pooled water, unable to sample	0.01	<0.01	0.03	0.02	<0.01	0.02	0.02	<0.01
Ammonia (mg/L)	No flow, unable to sample	No flow, unable to sample	0.15	<0.005	0.01	0.013	<0.005	<0.005	0.0065		<0.005	0.0062	0.016	0.008	0.0077	0.006	0.006	0.0083
Total Kjeldahl Nitrogen (mg/L)			1.9	0.9	1.1	1.4	1.1	0.7	0.55		0.6	0.57	0.7	0.5	0.44	0.6	0.6	0.67
Sodium/Chloride mass ratio			0.4	0.56	0.5	0.48	0.63	0.58	0.51		1.9	1.78	0.61	0.57	0.51	0.69	0.7	0.63
Aluminium (mg/L)			<0.005	0.04	0.06	0.091	0.02	0.01	0.013		0.03	0.033	0.03	0.01	0.012	0.03	0.03	0.027
Arsenic (mg/L)			<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Boron (mg/L)			<0.02	0.04	0.03	0.021	0.04	0.03	0.02		<0.02	<0.02	0.04	0.03	0.025	0.05	0.04	0.045
Cadmium (mg/L)			<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Chromium (mg/L)			<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Copper (mg/L)			<0.001	0.003	0.002	0.0027	<0.001	0.001	<0.001		0.001	<0.001	<0.001	0.002	<0.001	<0.001	0.002	<0.001
Fluoride (mg/L)			0.11	0.1	0.1	0.1	<0.1	<0.1	<0.1		0.2	0.2	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Iron (mg/L)			0.17	0.43	0.56	0.51	0.57	0.24	0.12		0.11	0.1	0.46	0.25	0.13	1.1	1.1	0.74
Gallium (mg/L)			<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Mercury (mg/L)			<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005		<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005
Manganese (mg/L)			1.1	0.018	0.03	0.026	0.013	0.005	0.0033		0.001	<0.001	0.088	0.059	0.036	0.25	0.23	0.15
Molybdenum (mg/L)			<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Nickel (mg/L)			0.0029	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Lead (mg/L)			<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Selenium (mg/L)			<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Uranium (mg/L)			0.00089	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005		0.0017	0.0029	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Vanadium (mg/L)			<0.001	0.001	0.001	0.0014	<0.001	<0.001	<0.001		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Zinc (mg/L)			0.0069	<0.001	0.002	0.0032	<0.001	0.002	<0.001		<0.001	<0.001	0.001	<0.001	0.0011	0.002	0.002	0.0013
Total anions (meq/L)			900	220	180	230	200	160	140		340	380	200	170	190	290	250	290
Total cations (meq/L)			400	120	91	110	120	84	68		180	200	110	87	90	150	120	130
Ion Balance (%)			-6.6	-1.4	-4.1	-6.6	0.23	-5.8	-9		-7.1	-6.7	-1.5	-5.9	-9	-3.4	-6	-9.8

Appendix E : Comprehensive analyses of surface water samples, 2020-2022

Analyte/Sampling details	SP022			SP023			SP024			SP025		
Sampling date:	24/09/2020	23/09/2021	8/09/2022	24/09/2020	23/09/2021	8/09/2022	24/09/2020	23/09/2021	8/09/2022	15/09/2020	23/09/2021	8/09/2022
pH (field measurement)	8.4	8.2	8.5	8.1	7.9	7.6	8.4	7.6	7.3	7.6	8	7
Electrical Conductivity (µS/cm)	650	540	560	780	650	730	250	240	240	410	360	350
Total Dissolved Salts (mg/L)	370	310	340	480	360	470	140	110	120	270	260	290
Sodium (mg/L)	72	59	67	90	76	88	31	30	29	55	42	43
Potassium (mg/L	3	2.4	3.2	5.1	3.7	6	1.3	1.1	1.1	2.9	2.2	2.9
Calcium (mg/L)	12	11	11	17	16	18	3.2	3.6	3.1	8.4	7.5	8.6
Magnesium (mg/L)	17	14	15	17	15	17	4.4	4.6	4.3	8.8	6.9	7.8
Chloride (mg/L)	140	120	140	170	140	190	58	57	64	85	72	80
Sulphate (mg/L)	35	29	33	38	34	37	10	9	12	19	17	17
Carbonate (mg/L)	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Bicarbonate (mg/L)	49	46	49	59	63	60	10	12	13	29	32	36
Nitrate (mg/L)	<0.005	0.15	0.021	0.27	0.31	0.31	0.099	0.052	0.035	1.8	1.9	2
Nitrite (mg/L)	<0.005	<0.005	0.0051	0.015	<0.005	0.008	<0.005	<0.005	0.0085	0.006	0.1	0.0052
Alkalinity (as mg/L $CaCO_3$)	49	46	49	59	63	59	10	12	13	29	32	36
Hardness (as mg/L $CaCO_3$)	99	85	89	110	100	120	26	28	26	57	47	54
Silica (mg/L)	5	9	4.2	2.9	4.4	4.1	5.9	7.3	6.5	5.7	4.9	6.5
Dissolved Organic Carbon (mg/L)	7	7	7.9	15	17	23	2	2	2.8	5	6	7.4
Filterable Reactive Phosphorus (mg/L)	0.009	0.04	0.0095	0.083	0.081	0.17	<0.002	<0.002	0.0021	0.016	0.009	0.031
Total Phosphorus (mg/L)	0.04		0.022	0.22	0.14	0.75	0.01	<0.01	<0.01	0.03	0.04	0.035
Ammonia (mg/L)	<0.005	0.005	<0.005	0.007	0.009	0.013	<0.005	<0.005	0.0072	0.011	0.25	<0.005
Total Kjeldahl Nitrogen (mg/L)	0.6	0.6	0.62	1.2	1.2	2.2	0.2	0.2	0.17	0.5	0.9	0.82
Sodium/Chloride mass ratio	0.52	0.49	0.48	0.53	0.53	0.46	0.54	0.53	0.45	0.65	0.58	0.54
Aluminium (mg/L)	0.01	0.01	0.021	0.03	0.04	0.07	0.02	0.01	0.016	0.01	0.06	0.065
Arsenic (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Boron (mg/L)	0.06	0.03	0.026	0.06	0.03	0.021	0.07	0.04	<0.02	0.04	0.02	<0.02
Cadmium (mg/L)	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Chromium (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Copper (mg/L)	<0.001	0.001	0.0014	0.001	0.001	0.0023	<0.001	<0.001	<0.001	0.001	0.001	0.0017
Fluoride (mg/L)	<0.1		<0.1	<0.1	0.1	0.11	<0.1	<0.1	<0.1	0.2	0.2	0.16
Iron (mg/L)	0.4	0.31	0.36	0.39	0.55	0.43	0.11	0.098	0.069	0.051	0.07	0.11
Gallium (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Mercury (mg/L)	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005
Manganese (mg/L)	0.021	0.028	0.024	0.018	0.036	0.0096	0.003	0.008	0.012	0.001	<0.001	0.0012
Molybdenum (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	0.003	0.0025
Nickel (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Lead (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Selenium (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Uranium (mg/L)	<0.0005		<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Vanadium (mg/L)	<0.001		<0.001	0.001	0.002	0.0015	<0.001	<0.001	<0.001	0.001	0.001	0.0015
Zinc (mg/L)	<0.001		0.0011	<0.001	<0.001	0.0013	<0.001	0.002	<0.001	<0.001	<0.001	<0.001
Total anions (meq/L)	210	190	210	250	220	260	80	81	90	140	120	130
Total cations (meq/L)	100	86	96	130	110	130	40	39	37	75	58	62
Ion Balance (%)	-3.7	-6.3	-7.9	-3.2	-5	-7.1	-2.6	-3.6	-13	3.4	-3.6	-11

APPENDIX F

Time-series groundwater levels

CLIENT: Alcoa of Australia Limited
PROJECT: Wagerup and Bunbury 2020-2022 water report
DATE: March 2023
Dwg. No: 308-8/23/1-App. F

308-8\Graphs\Appendix F.grf

Alcoa

Appendix F
Time-series groundwater levels

Page 1

Graph colour nomenclature (screened aquifer depth): **Upper**, **Middle**, **Lower**

CLIENT: Alcoa of Australia Limited
PROJECT: Wagerup and Bunbury 2020-2022 water report
DATE: March 2023
Dwg. No: 308-8/23/1-App. F

308-8/Graphs/Appendix F.grf

Graph colour nomenclature (screened aquifer depth): **Upper**, **Middle**, **Lower**

Alcoa

Appendix F
Time-series groundwater levels

Rockwater

CLIENT: Alcoa of Australia Limited
PROJECT: Wagerup and Bunbury 2020-2022 water report
DATE: March 2023
Dwg. No: 308-8/23/1-App. F

308-8/Graphs/Appendix F.grf

Alcoa

Rockwater

Appendix F
Time-series groundwater levels

Graph colour nomenclature (screened aquifer depth): **Upper**, **Middle**, **Lower**

CLIENT: Alcoa of Australia Limited
PROJECT: Wagerup and Bunbury 2020-2022 water report
DATE: March 2023
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308-8/Graphs/Appendix F.grf

Alcoa

Rockwater

Appendix F
Time-series groundwater levels

Graph colour nomenclature (screened aquifer depth): **Upper**, **Middle**, **Lower**

CLIENT: Alcoa of Australia Limited
PROJECT: Wagerup and Bunbury 2020-2022 water report
DATE: March 2023
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Graph colour nomenclature (screened aquifer depth): **Upper**, **Middle**, **Lower**

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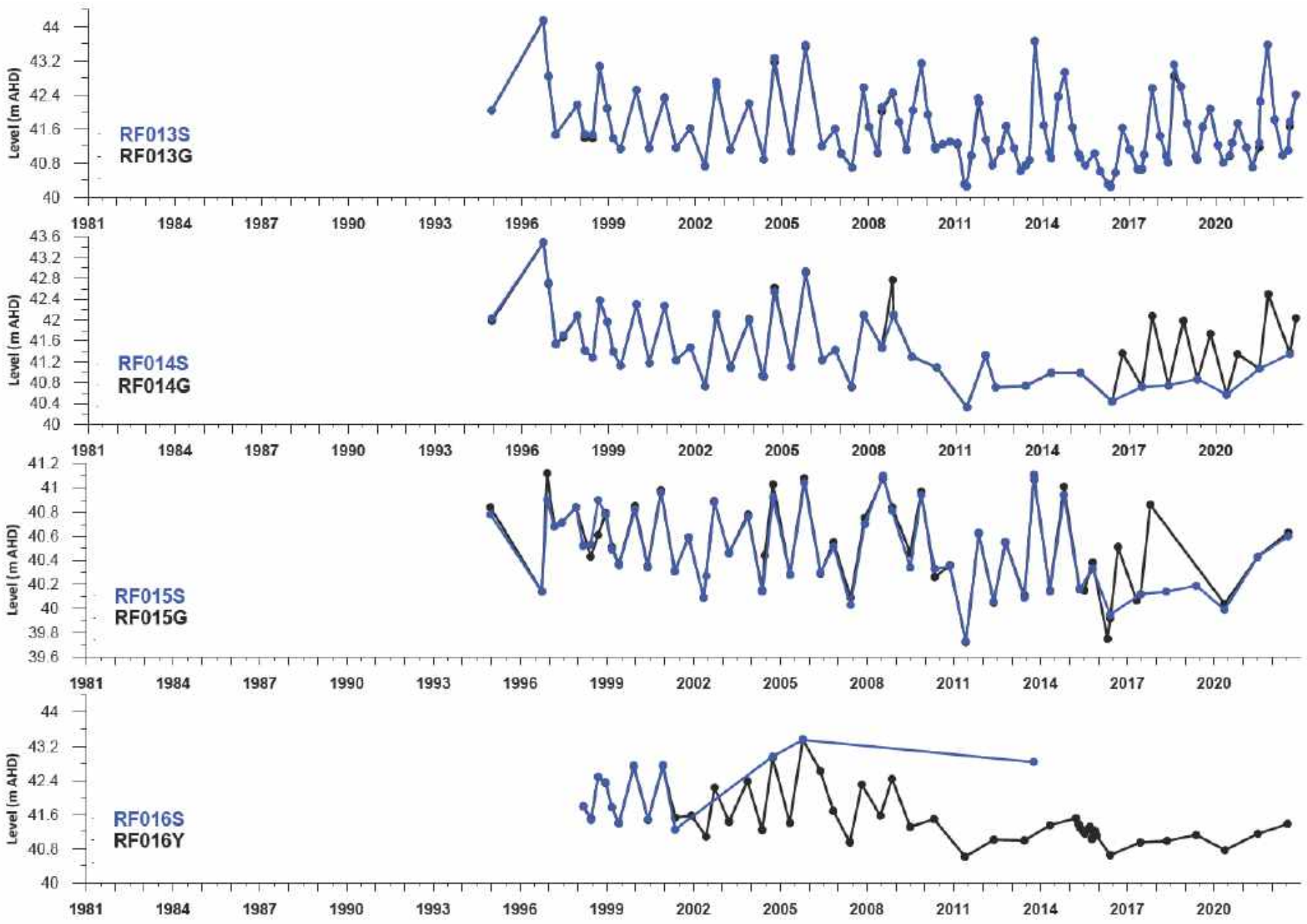
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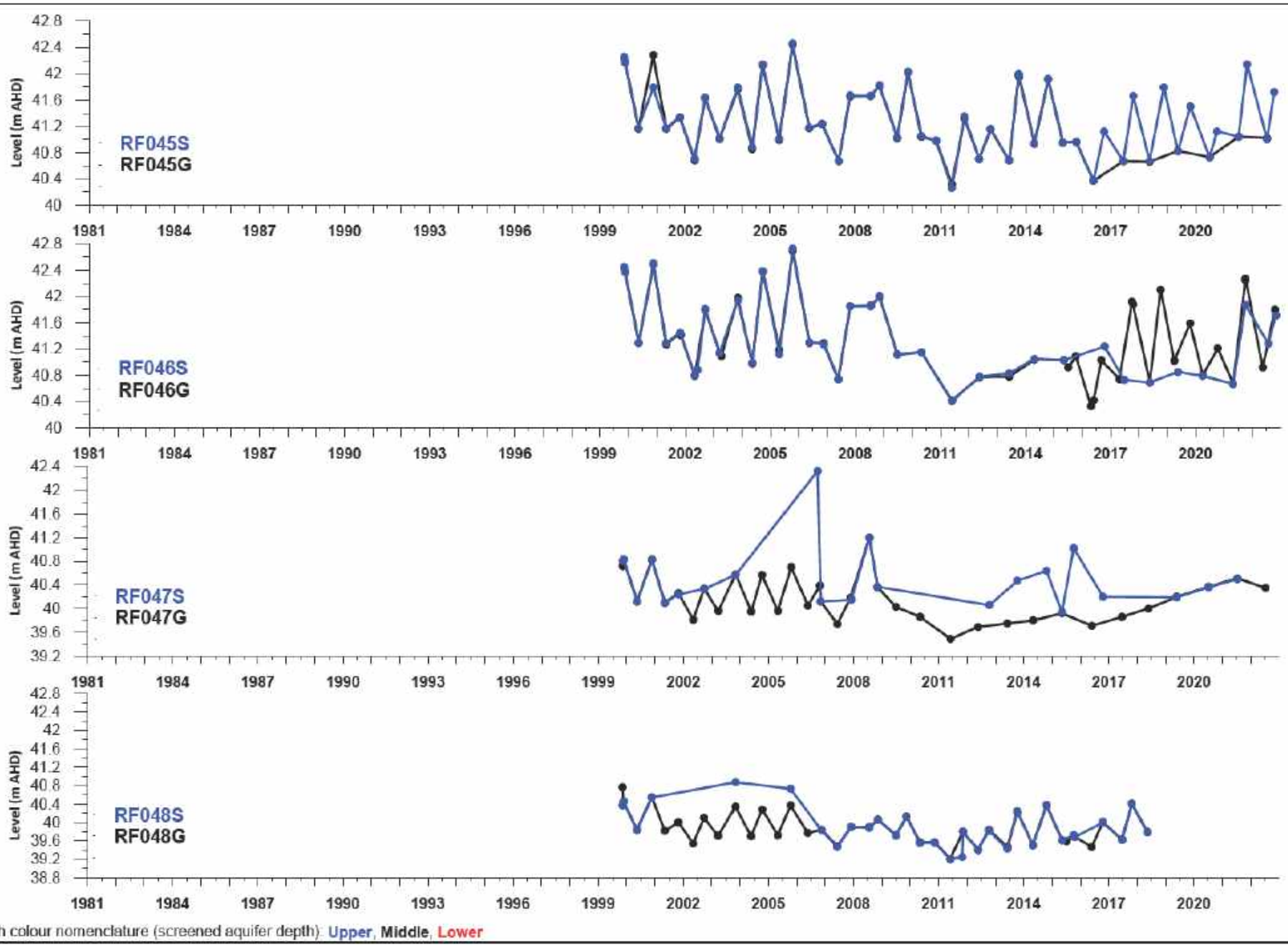
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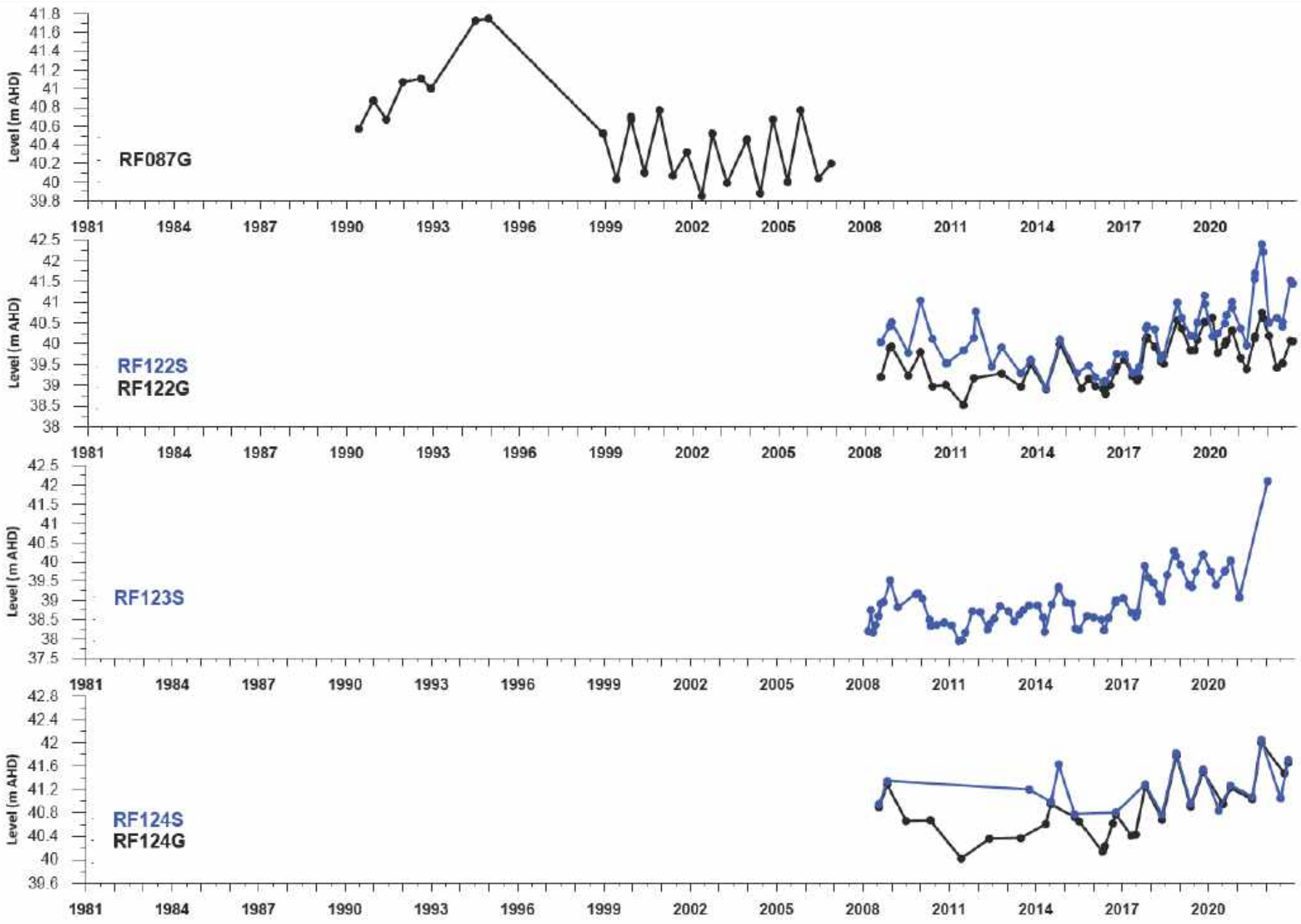
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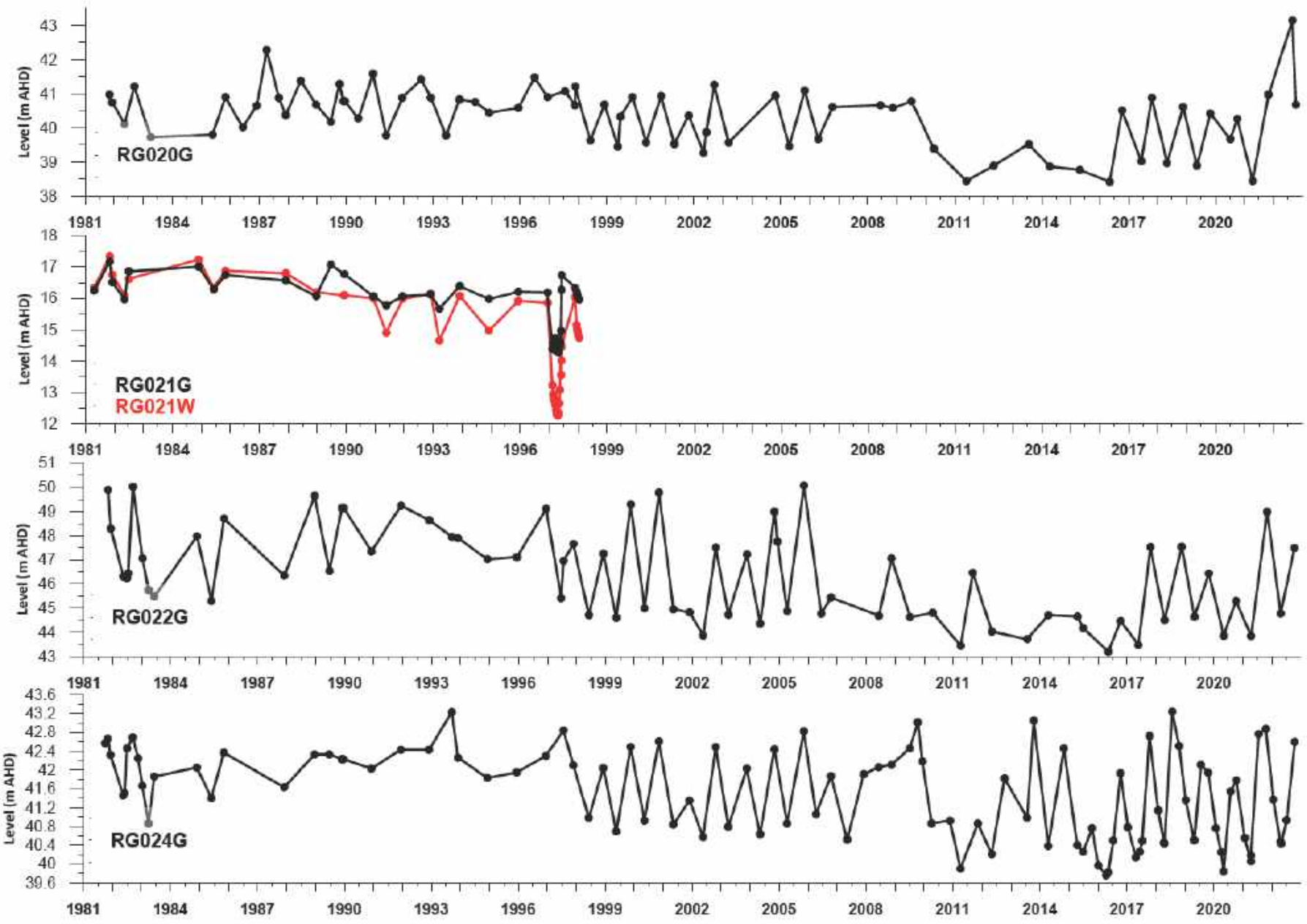
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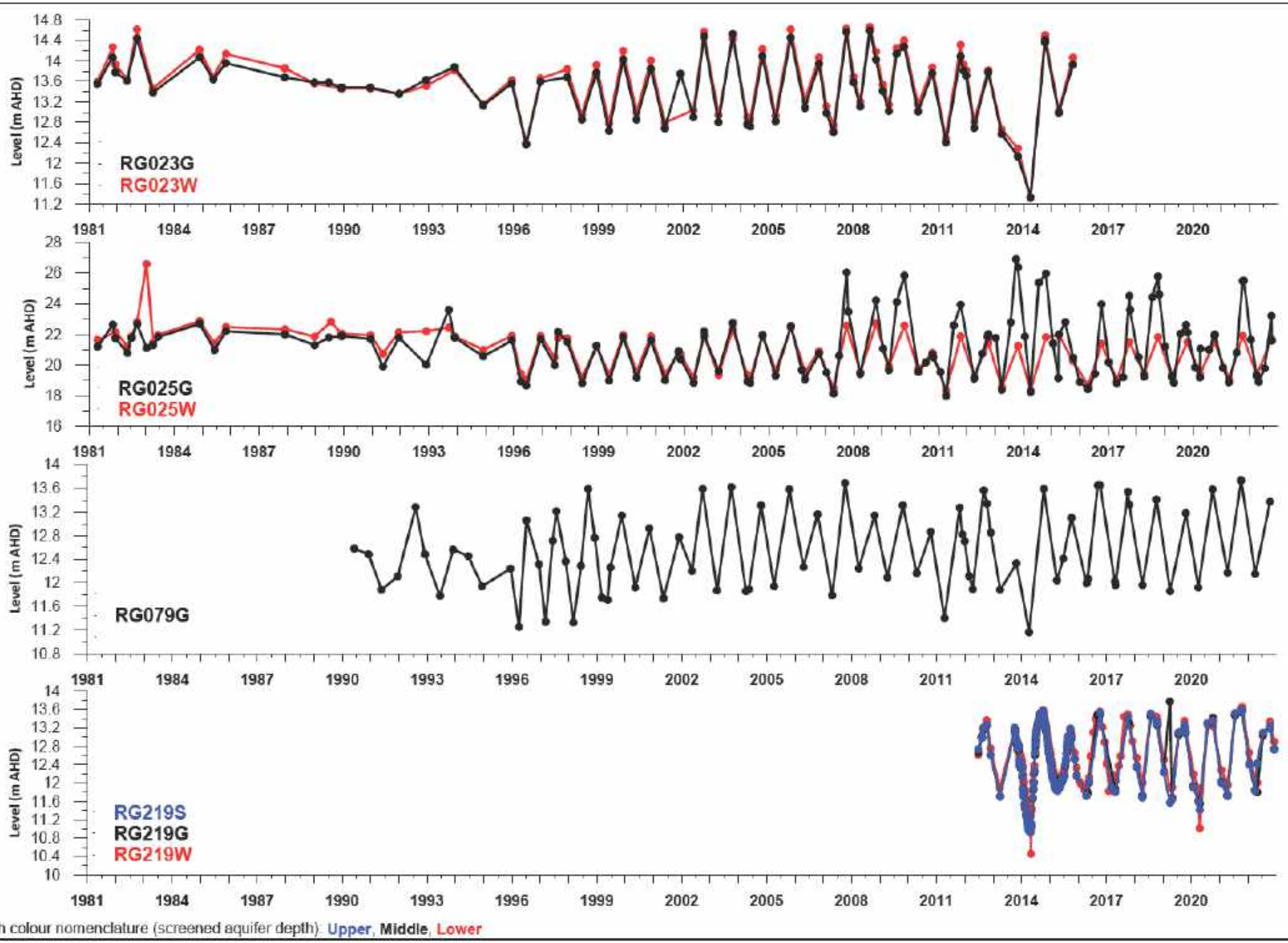
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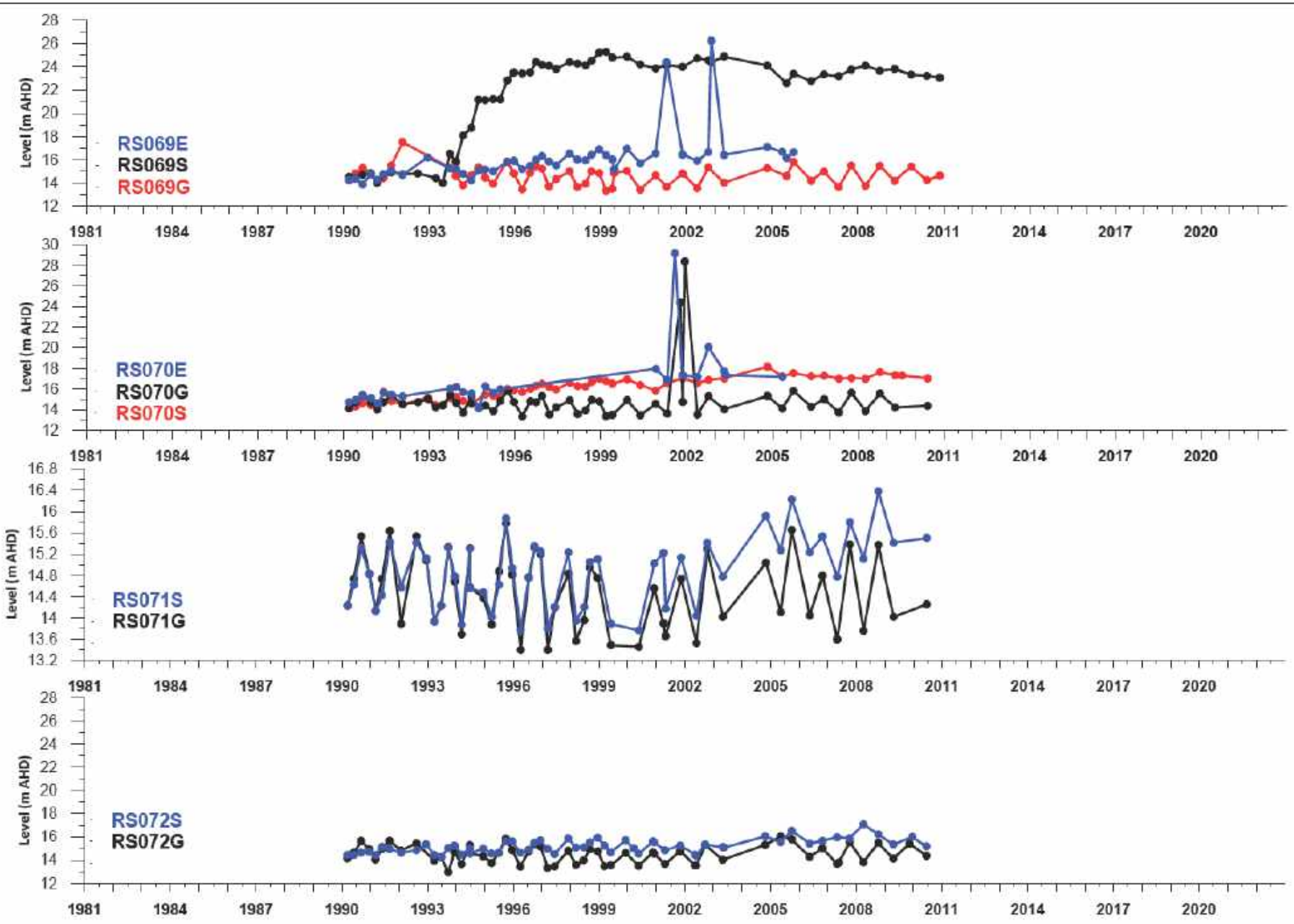
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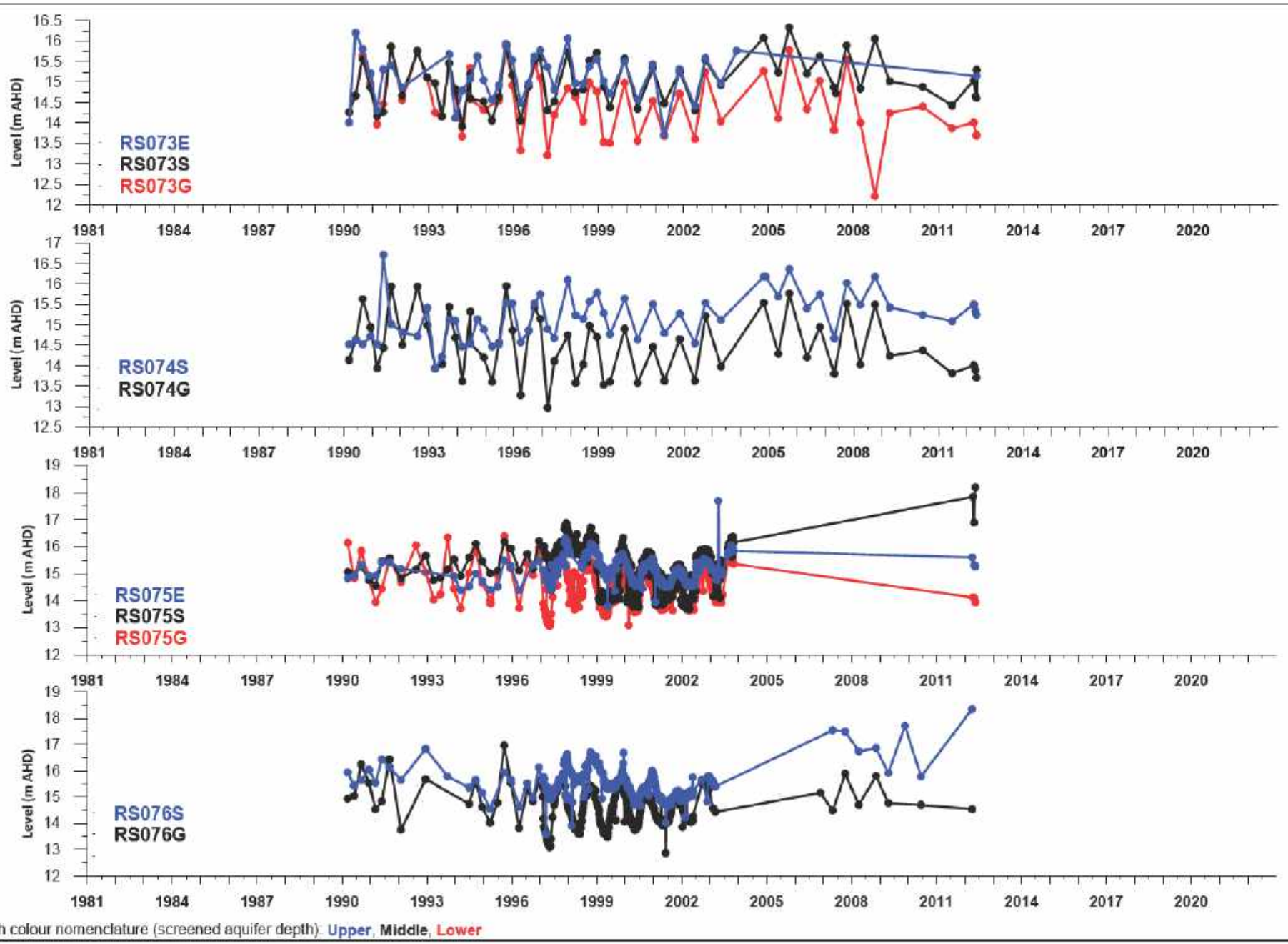
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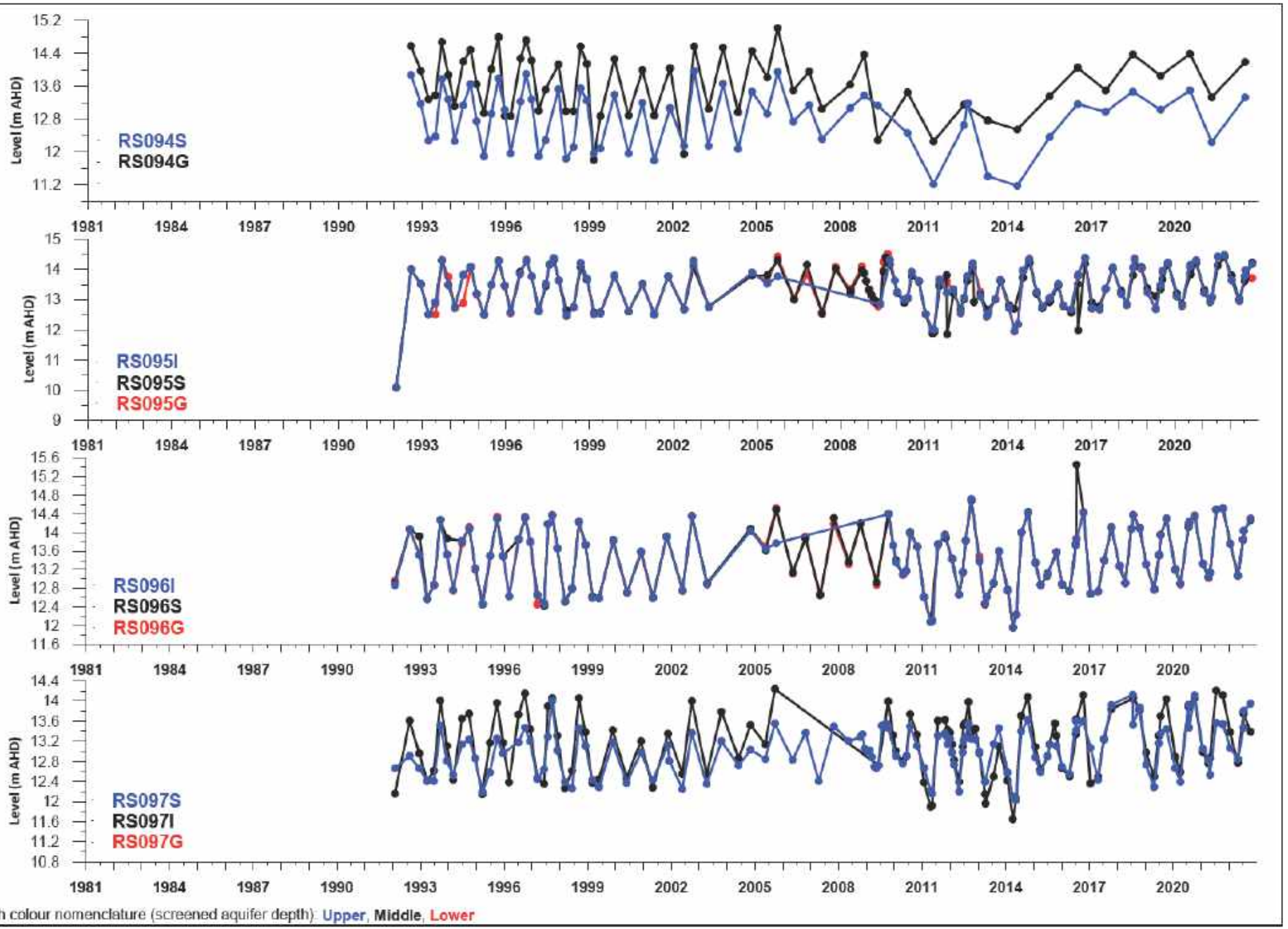
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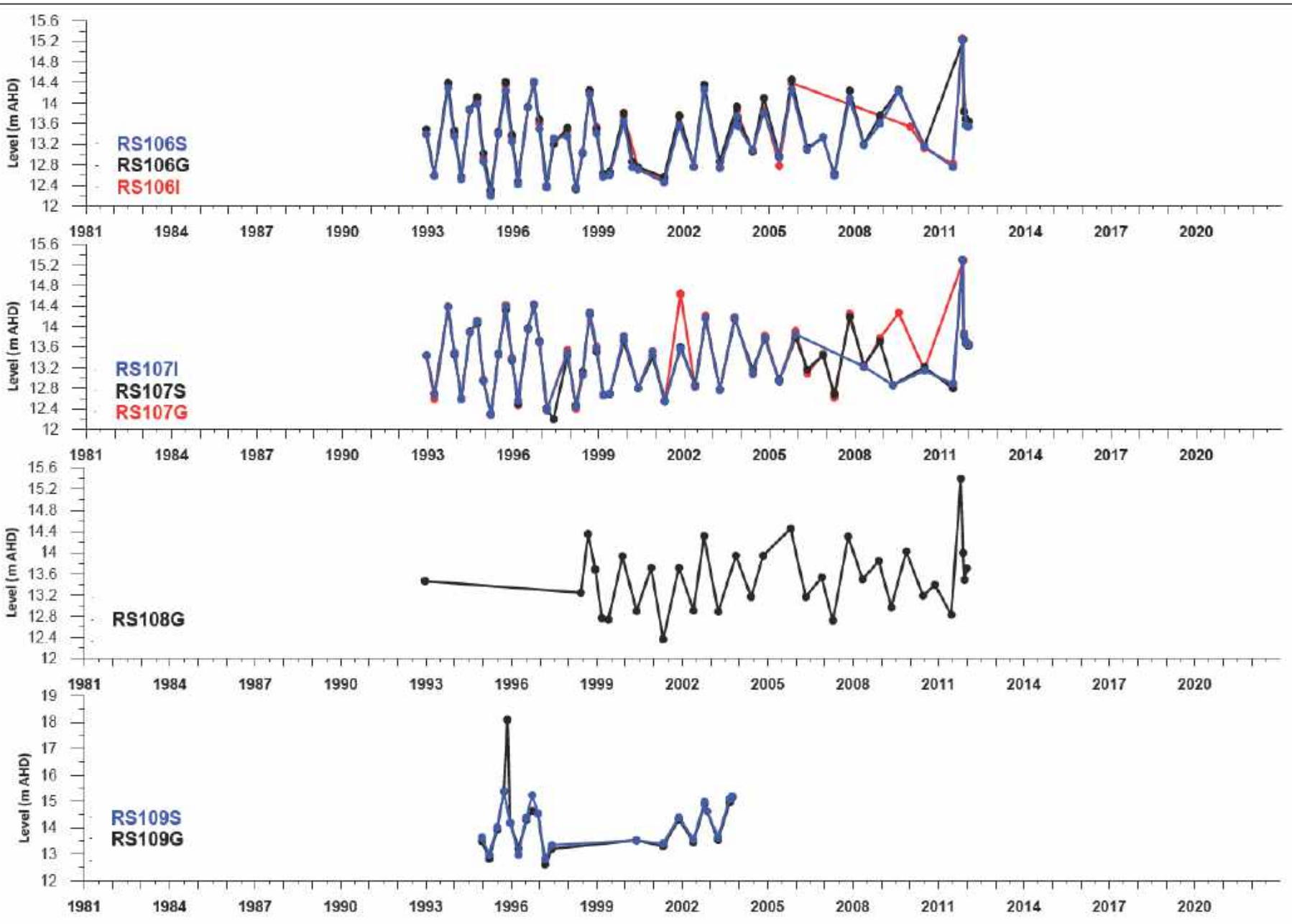
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Alcoa

Rockwater

Appendix F
Time-series groundwater levels

Graph colour nomenclature (screened aquifer depth): **Upper**, **Middle**, **Lower**

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Time-series groundwater levels

Rockwater

Graph colour nomenclature (screened aquifer depth): Upper, Middle, Lower

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Time-series groundwater levels

Rockwater

Graph colour nomenclature (screened aquifer depth): Upper, Middle, Lower

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Time-series groundwater levels

Rockwater

Graph colour nomenclature (screened aquifer depth): Upper, Middle, Lower

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Time-series groundwater levels

Rockwater

Graph colour nomenclature (screened aquifer depth): **Upper**, **Middle**, **Lower**

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Graph colour nomenclature (screened aquifer depth): **Upper**, **Middle**, **Lower**

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Time-series groundwater levels

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Time-series groundwater levels

Rockwater

Graph colour nomenclature (screened aquifer depth): **Upper**, **Middle**, **Lower**

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Time-series groundwater levels

Rockwater

Graph colour nomenclature (screened aquifer depth): **Upper**, **Middle**, **Lower**

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Graph colour nomenclature (screened aquifer depth): **Upper**, **Middle**, **Lower**

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Time-series groundwater levels

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Time-series groundwater levels

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Graph colour nomenclature (screened aquifer depth): **Upper**, **Middle**, **Lower**

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Graph colour nomenclature (screened aquifer depth): **Upper**, **Middle**, **Lower**

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Time-series groundwater levels

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Graph colour nomenclature (screened aquifer depth): **Upper**, **Middle**, **Lower**

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Time-series groundwater levels

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Time-series groundwater levels

Graph colour nomenclature (screened aquifer depth): **Upper**, **Middle**, **Lower**

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Time-series groundwater levels

Rockwater

Graph colour nomenclature (screened aquifer depth): **Upper**, **Middle**, **Lower**

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Appendix F
Time-series groundwater levels

Graph colour nomenclature (screened aquifer depth): **Upper**, **Middle**, **Lower**

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Time-series groundwater levels

Rockwater

Graph colour nomenclature (screened aquifer depth): **Upper**, **Middle**, **Lower**

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Time-series groundwater quality data

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Time-series groundwater quality data

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Time-series groundwater quality data

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D-011G

D-012G

D-013G

D-014G

Na/Cl ratio- Alkalinity (mg/L) - EC (uS/cm) - pH

1981 1984 1987 1990 1993 1996 1999 2002 2005 2008 2011 2014 2017 2020

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Time-series groundwater quality data

Rockwater

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Time-series groundwater quality data

D-024G

D-025G

D-026G

D-027G

Na/Cl ratio- Alkalinity (mg/L) - EC (uS/cm) - pH

1981 1984 1987 1990 1993 1996 1999 2002 2005 2008 2011 2014 2017 2020

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Time-series groundwater quality data

RF007S

RF008G

RF008S

RF009G

Na/Cl ratio- Alkalinity (mg/L) - EC (uS/cm) - pH

1981 1984 1987 1990 1993 1996 1999 2002 2005 2008 2011 2014 2017 2020

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Time-series groundwater quality data

Rockwater

RF013G

RF013S

RF014G

RF014S

Na/Cl ratio- Alkalinity (mg/L) - EC (uS/cm) - pH

1981 1984 1987 1990 1993 1996 1999 2002 2005 2008 2011 2014 2017 2020

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Appendix G Time-series groundwater quality data

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Time-series groundwater quality data

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Appendix G Time-series groundwater quality data

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Time-series groundwater quality data

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Time-series groundwater quality data

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Rockwater

RG026W

Na/Cl ratio- Alkalinity (mg/L) - EC (uS/cm) - pH

RG027G

Na/Cl ratio- Alkalinity (mg/L) - EC (uS/cm) - pH

RG027S

Na/Cl ratio- Alkalinity (mg/L) - EC (uS/cm) - pH

RG027W

Na/Cl ratio- Alkalinity (mg/L) - EC (uS/cm) - pH

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RG029G

RG029W

RG030G

RG031G

Na/Cl ratio- Alkalinity (mg/L) - EC (uS/cm) - pH

1981 1984 1987 1990 1993 1996 1999 2002 2005 2008 2011 2014 2017 2020

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Appendix G
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RG151S

RG151W

RG152G

RG152S

Na/Cl ratio- Alkalinity (mg/L) - EC (uS/cm) - pH

1981 1984 1987 1990 1993 1996 1999 2002 2005 2008 2011 2014 2017 2020

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Appendix G
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Time-series groundwater quality data

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Rockwater

RS047S

Na/Cl ratio- Alkalinity (mg/L) - EC (uS/cm) - pH

RS048G

Na/Cl ratio- Alkalinity (mg/L) - EC (uS/cm) - pH

RS048S

Na/Cl ratio- Alkalinity (mg/L) - EC (uS/cm) - pH

RS049G

Na/Cl ratio- Alkalinity (mg/L) - EC (uS/cm) - pH

1981 1984 1987 1990 1993 1996 1999 2002 2005 2008 2011 2014 2017 2020

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Rockwater

RS053S

Na/Cl ratio- Alkalinity (mg/L) - EC (uS/cm) - pH

RS054G

Na/Cl ratio- Alkalinity (mg/L) - EC (uS/cm) - pH

RS054S

Na/Cl ratio- Alkalinity (mg/L) - EC (uS/cm) - pH

RS055G

Na/Cl ratio- Alkalinity (mg/L) - EC (uS/cm) - pH

1981 1984 1987 1990 1993 1996 1999 2002 2005 2008 2011 2014 2017 2020

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RS093G

RS093S

RS094G

RS094S

Na/Cl ratio- Alkalinity (mg/L) - EC (uS/cm) - pH

1981 1984 1987 1990 1993 1996 1999 2002 2005 2008 2011 2014 2017 2020

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RS095G

RS095I

RS095S

RS096G

Na/Cl ratio- Alkalinity (mg/L) - EC (uS/cm) - pH

1981 1984 1987 1990 1993 1996 1999 2002 2005 2008 2011 2014 2017 2020

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RS100I

RS100S

RS101G

RS101I

Na/Cl ratio- Alkalinity (mg/L) - EC (uS/cm) - pH

1981 1984 1987 1990 1993 1996 1999 2002 2005 2008 2011 2014 2017 2020

CLIENT: Alcoa of Australia Limited
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RS103G

RS103S

RS104G

RS104S

Na/Cl ratio- Alkalinity (mg/L) - EC (uS/cm) - pH

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RS105G

RS105S

RS106G

RS106I

Na/Cl ratio- Alkalinity (mg/L) - EC (uS/cm) - pH

1981 1984 1987 1990 1993 1996 1999 2002 2005 2008 2011 2014 2017 2020

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RS147S

Na/Cl ratio- Alkalinity (mg/L) - EC (uS/cm) - pH

RS148S

Na/Cl ratio- Alkalinity (mg/L) - EC (uS/cm) - pH

RS149G

Na/Cl ratio- Alkalinity (mg/L) - EC (uS/cm) - pH

RS160G

Na/Cl ratio- Alkalinity (mg/L) - EC (uS/cm) - pH

1981 1984 1987 1990 1993 1996 1999 2002 2005 2008 2011 2014 2017 2020

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RS168S

RS168W

RS169G

RS169S

Na/Cl ratio- Alkalinity (mg/L) - EC (uS/cm) - pH

1981 1984 1987 1990 1993 1996 1999 2002 2005 2008 2011 2014 2017 2020

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RS174S

RS175G

RS175S

RS176G

Na/Cl ratio- Alkalinity (mg/L) - EC (uS/cm) - pH

1981 1984 1987 1990 1993 1996 1999 2002 2005 2008 2011 2014 2017 2020

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RS192S

RS193G

RS193S

RS194G

Na/Cl ratio- Alkalinity (mg/L) - EC (uS/cm) - pH

1981 1984 1987 1990 1993 1996 1999 2002 2005 2008 2011 2014 2017 2020

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Time-series groundwater quality data

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RS194S

RS195G

RS195S

RS196G

Na/Cl ratio- Alkalinity (mg/L) - EC (uS/cm) - pH

1981 1984 1987 1990 1993 1996 1999 2002 2005 2008 2011 2014 2017 2020

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RS196S

RS197G

RS197S

RS198G

Na/Cl ratio- Alkalinity (mg/L) - EC (uS/cm) - pH

1981 1984 1987 1990 1993 1996 1999 2002 2005 2008 2011 2014 2017 2020

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RS198S

Na/Cl ratio- Alkalinity (mg/L) - EC (uS/cm) - pH

RS198W

Na/Cl ratio- Alkalinity (mg/L) - EC (uS/cm) - pH

RS199G

Na/Cl ratio- Alkalinity (mg/L) - EC (uS/cm) - pH

RS199S

Na/Cl ratio- Alkalinity (mg/L) - EC (uS/cm) - pH

1981 1984 1987 1990 1993 1996 1999 2002 2005 2008 2011 2014 2017 2020

CLIENT: Alcoa of Australia Limited
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RS202G

RS202S

RS203G

RS203S

Na/Cl ratio- Alkalinity (mg/L) - EC (uS/cm) - pH

1981 1984 1987 1990 1993 1996 1999 2002 2005 2008 2011 2014 2017 2020

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RS204G

RS204S

RS205G

RS205S

Na/Cl ratio- Alkalinity (mg/L) - EC (uS/cm) - pH

1981 1984 1987 1990 1993 1996 1999 2002 2005 2008 2011 2014 2017 2020

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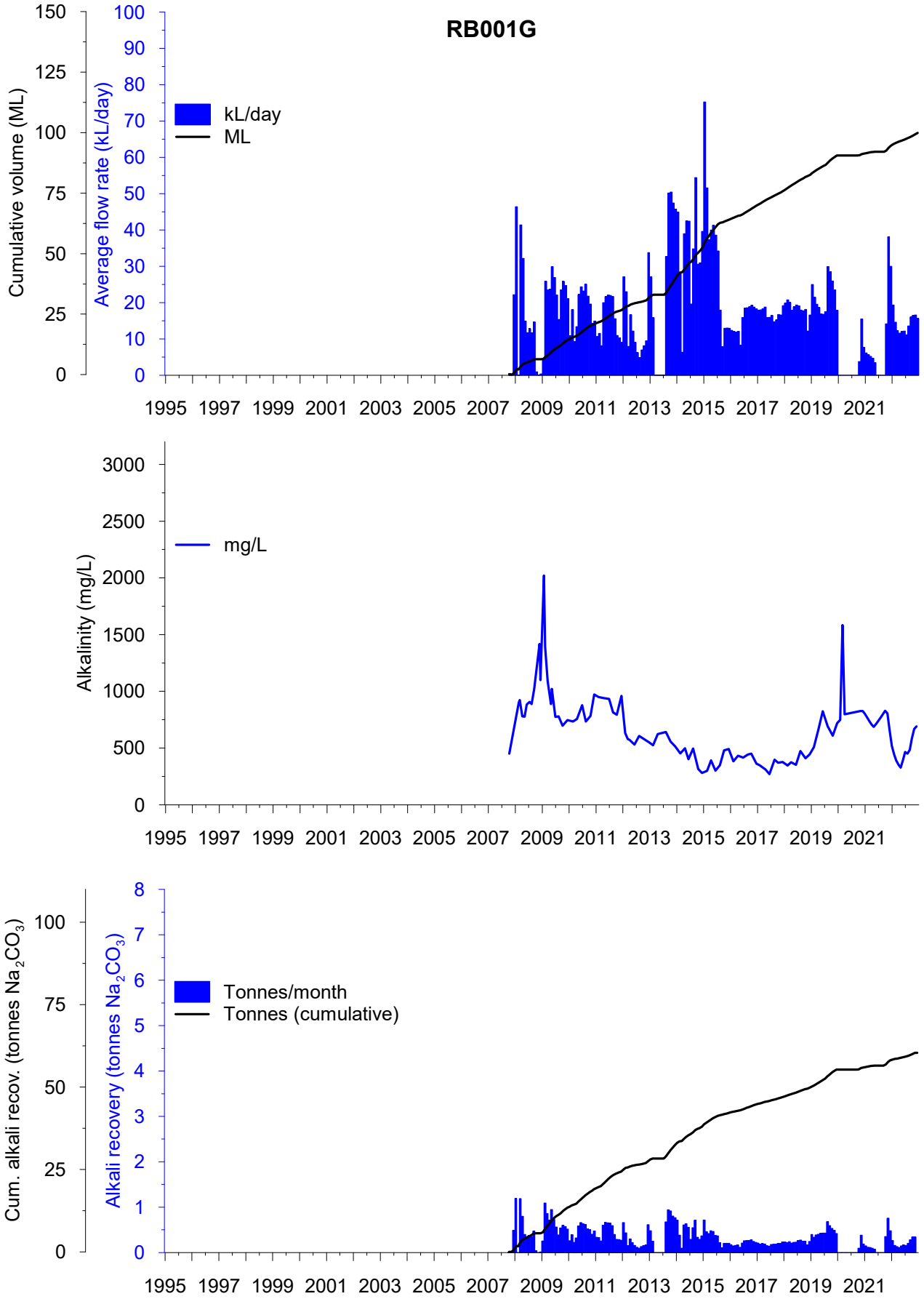
Appendix G

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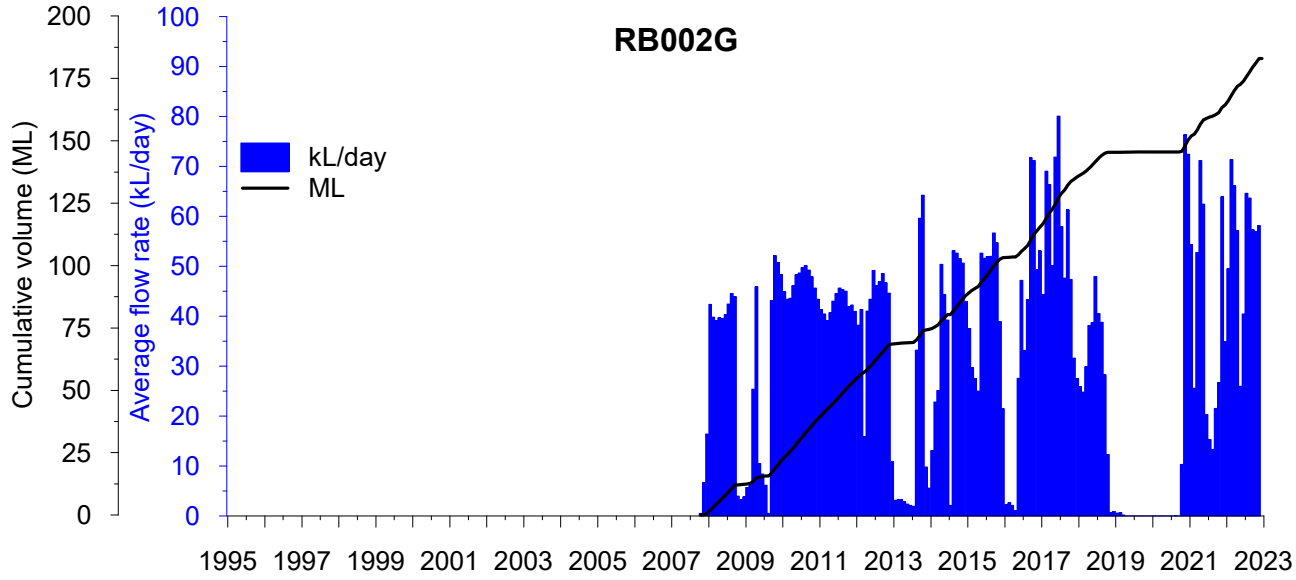
Groundwater and alkali production graphs, Wagerup Operations recovery bores

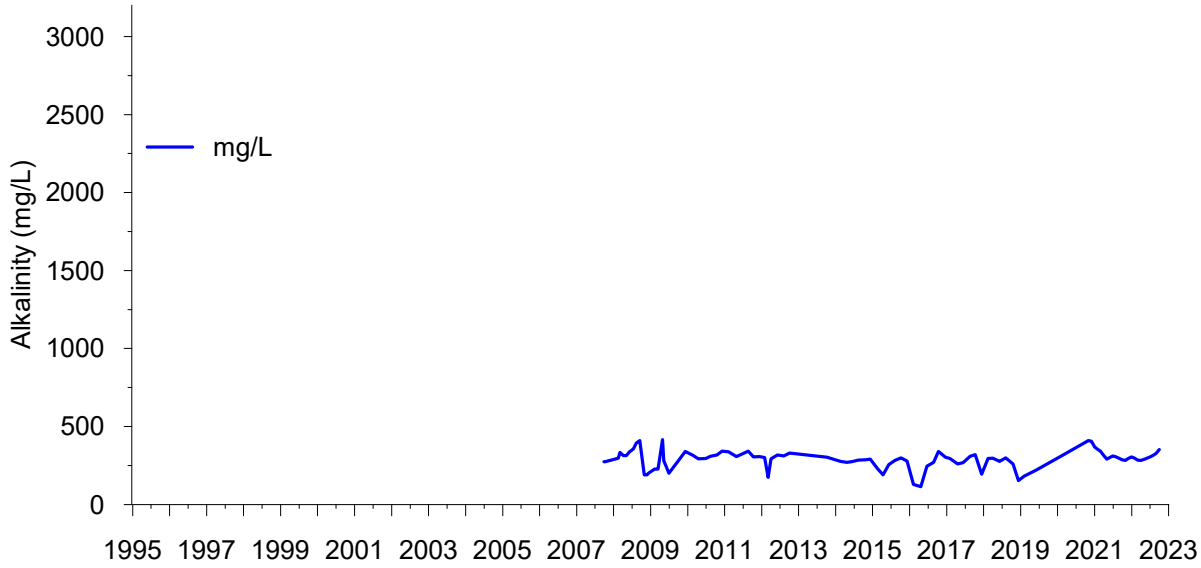


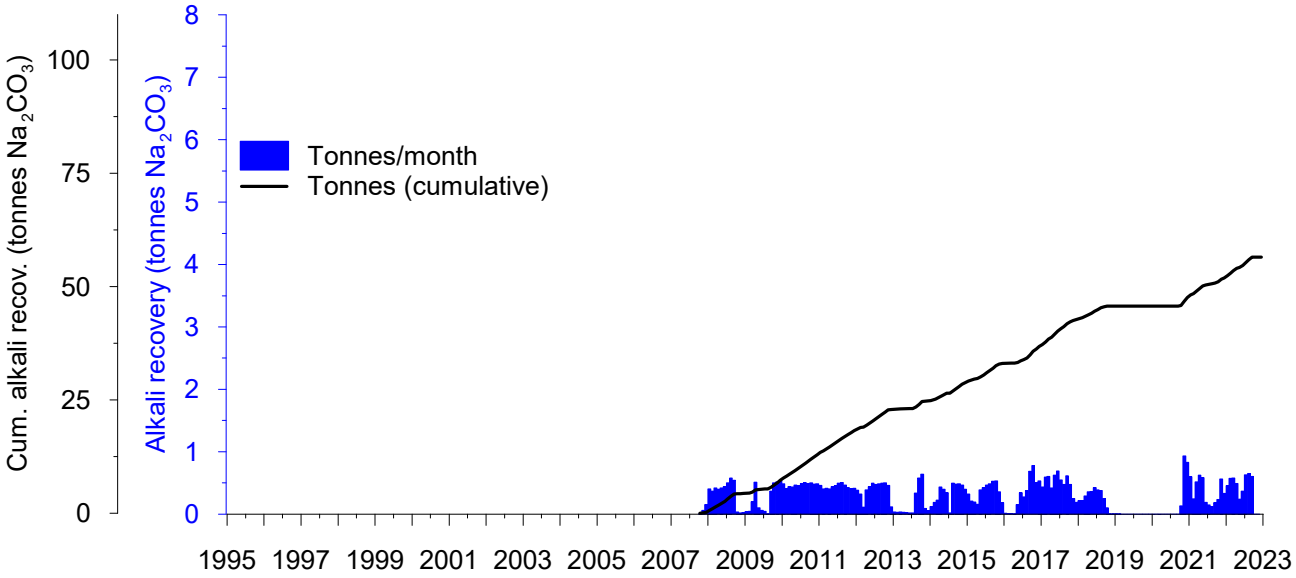
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Figure 1

CLIENT: Alcoa of Australia Limited PROJECT: Wagerup and Bunbury 2020-2022 water report DATE: March 2023 Dwg. No: 308-8/23/1/App. H	Appendix H - Groundwater and alkali production graphs, Wagerup Operations recovery bores



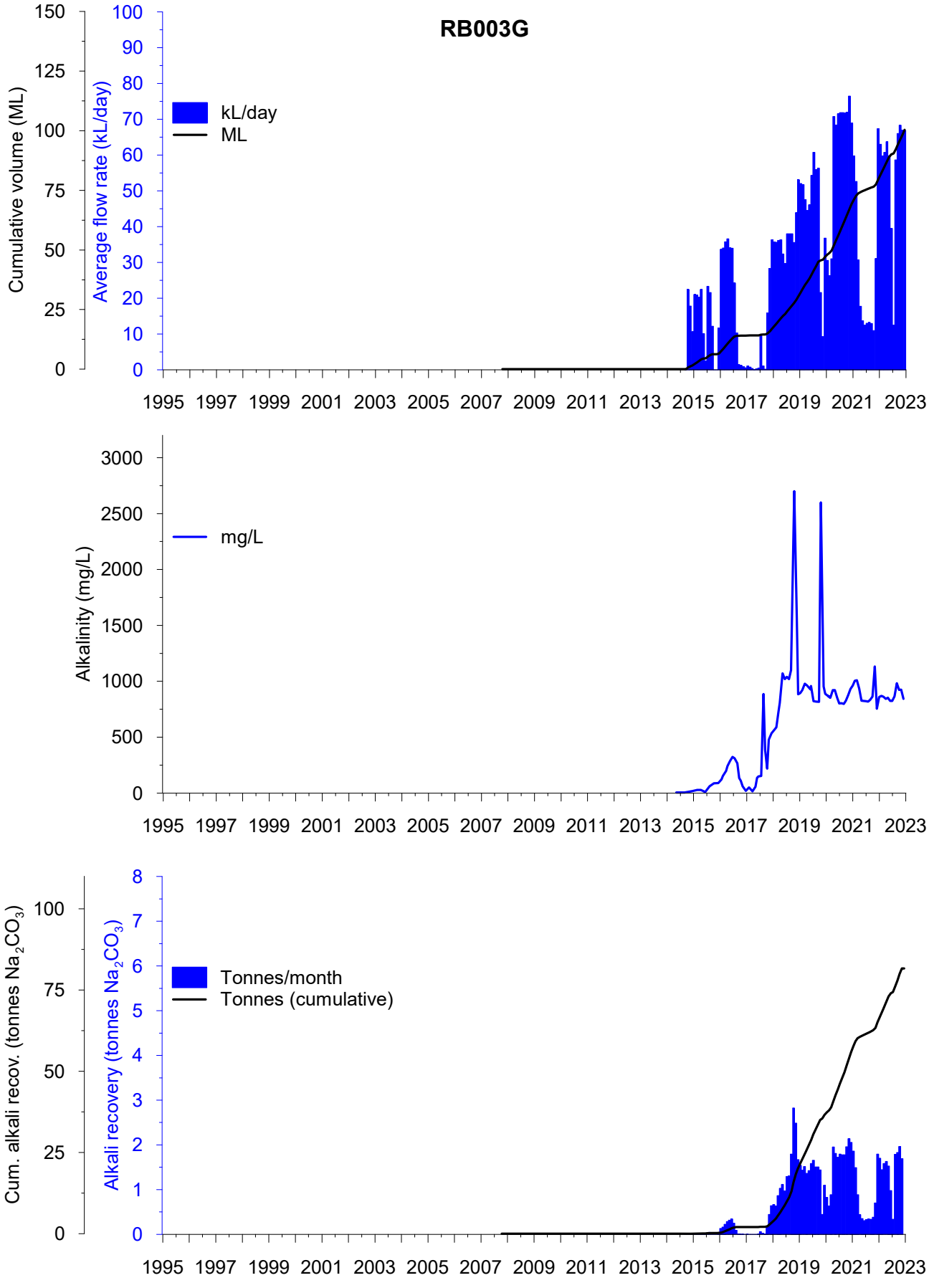




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Figure 2

CLIENT: Alcoa of Australia Limited PROJECT: Wagerup and Bunbury 2020-2022 water report DATE: March 2023 Dwg. No: 308-8/23/1/App. H	Appendix H - Groundwater and alkali production graphs, Wagerup Operations recovery bores

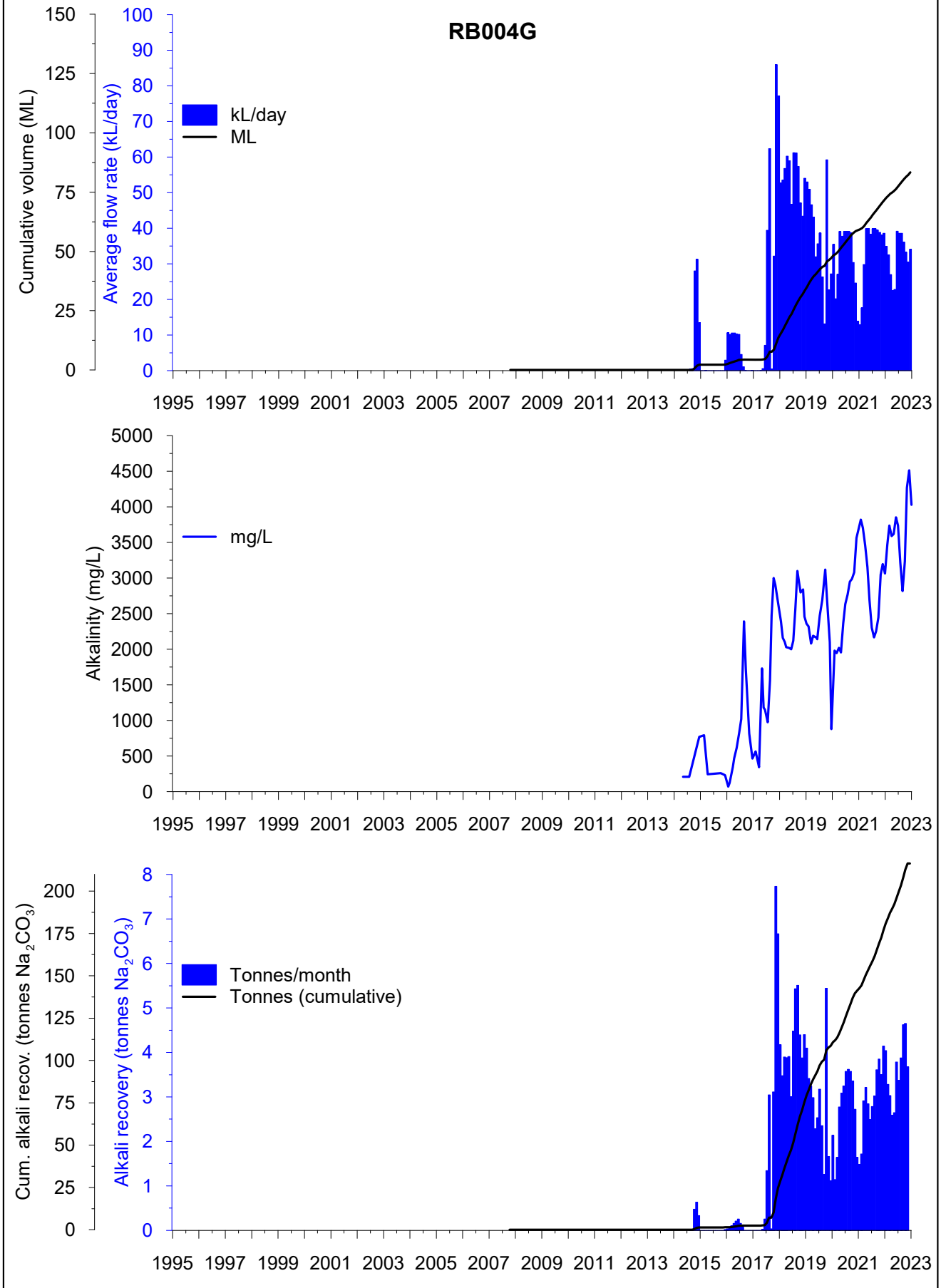


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Figure 3

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DATE:	March 2023
Dwg. No:	308-8/23/1/App. H

Appendix H - Groundwater and alkali production graphs, Wagerup Operations recovery bores



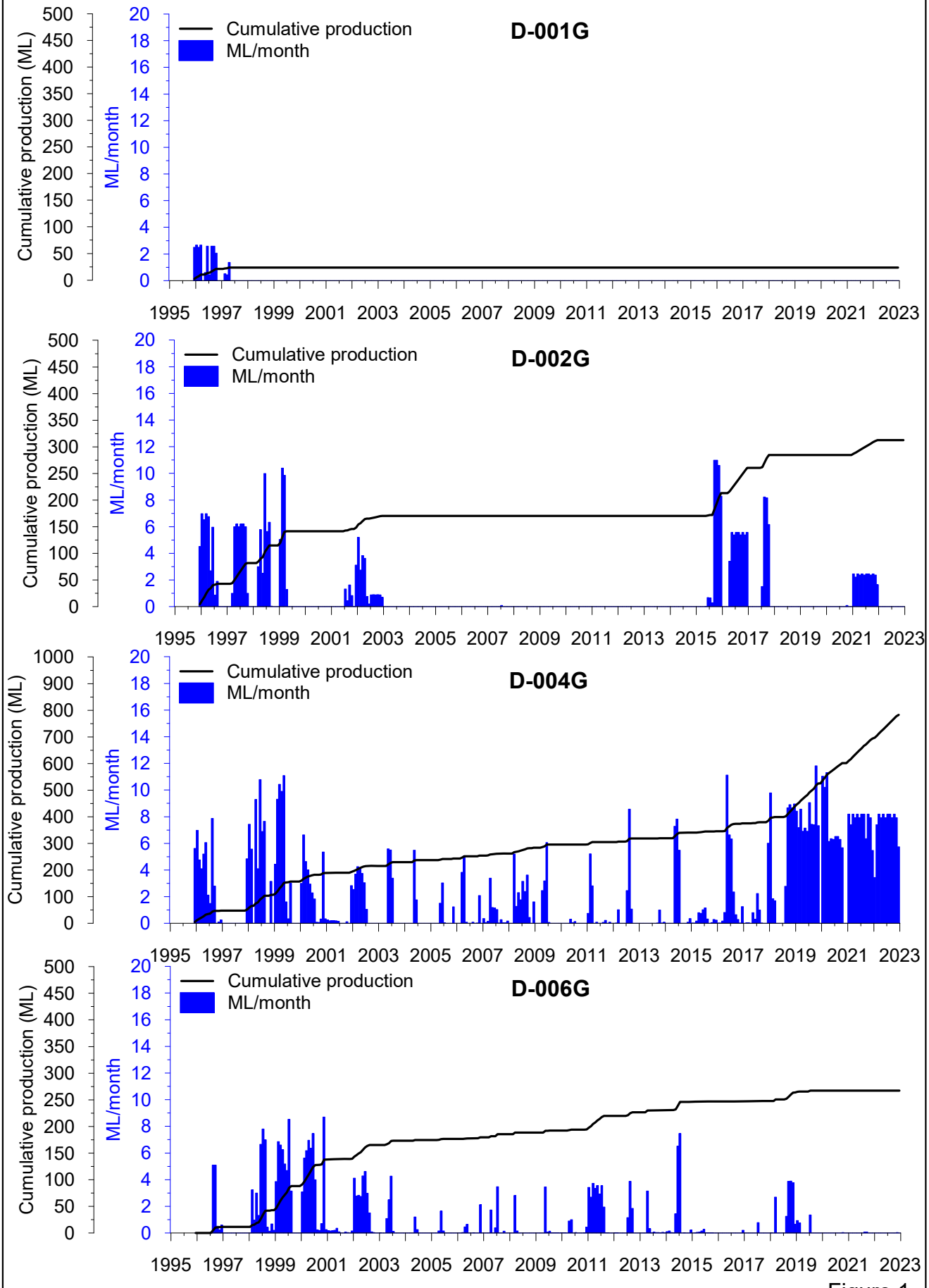
308-8/Grapher/Appendix H.grf

Figure 4

CLIENT: Alcoa of Australia Limited	Appendix H - Groundwater and alkali production graphs, Wagerup Operations recovery bores
PROJECT: Wagerup and Bunbury 2020-2022 water report	
DATE: March 2023	
Dwg. No: 308-8/23/1/App. H	

APPENDIX I

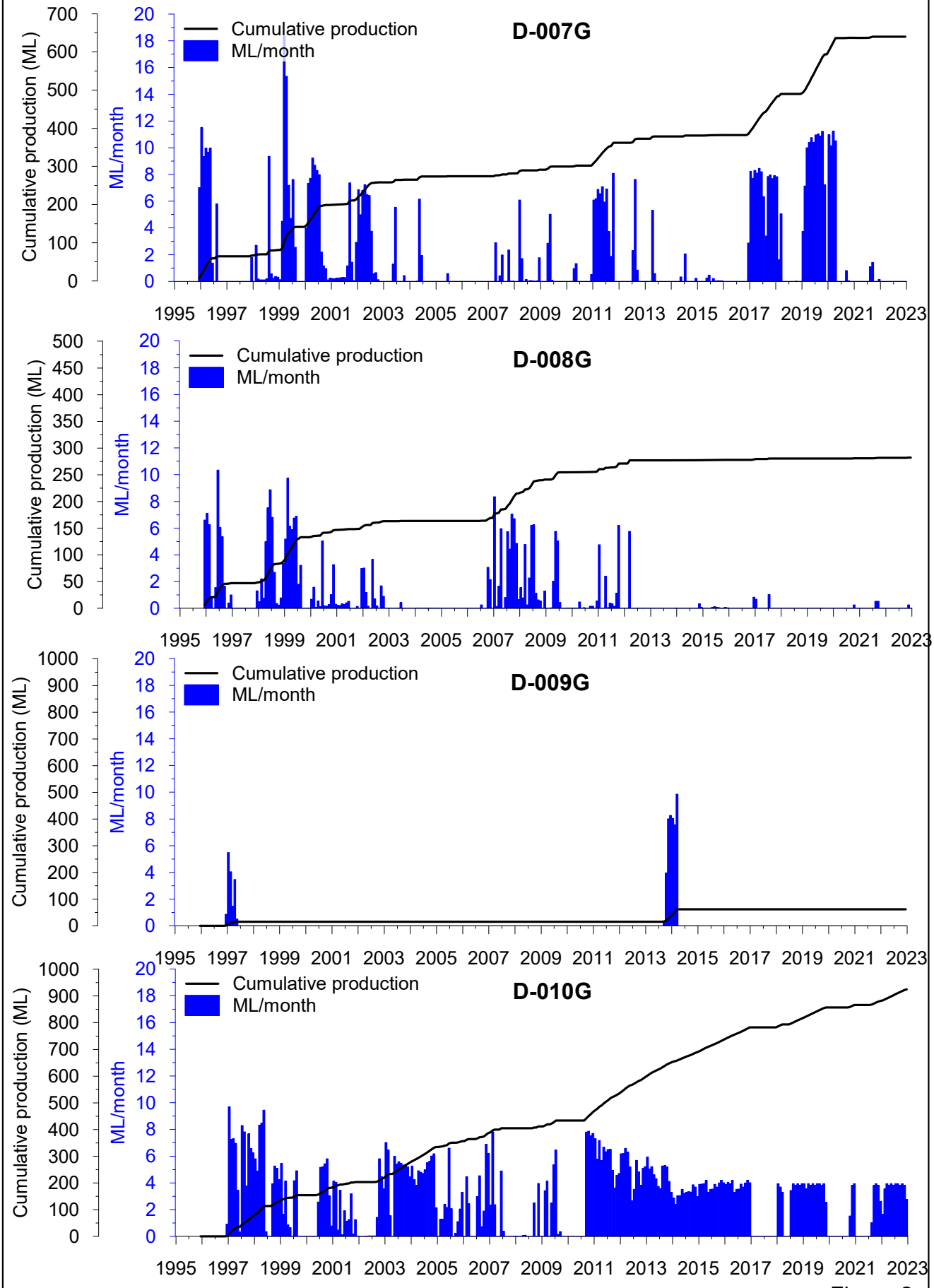
Wagerup groundwater production: depressurising bores and dewatering sump



308-8/Grapher/Appendix I.grf

Figure 1

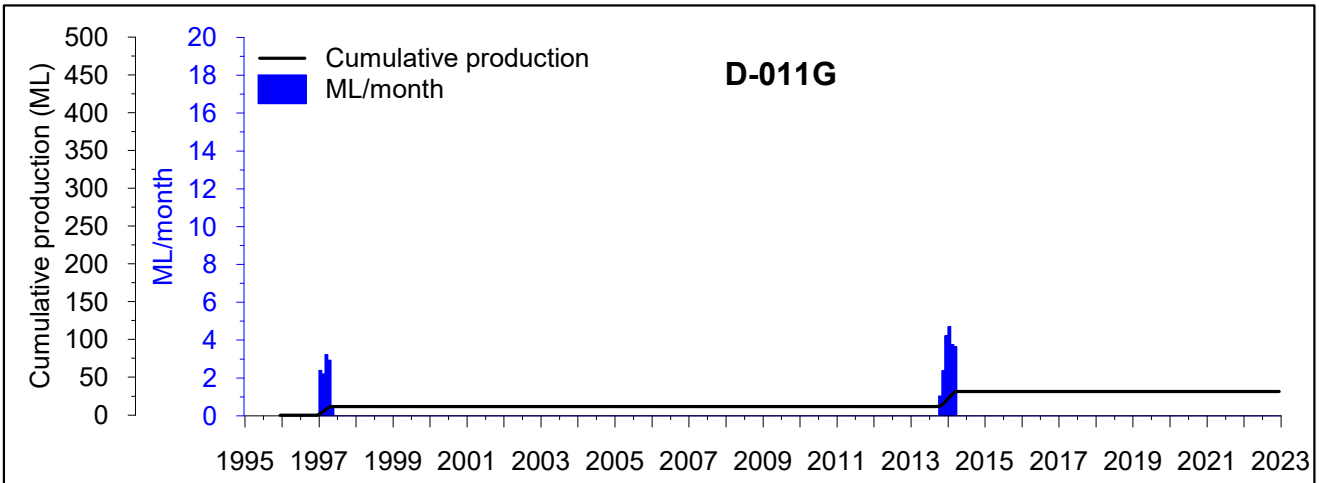
CLIENT: Alcoa of Australia Limited PROJECT: Wagerup and Bunbury 2020-2022 water report DATE: March 2023 Dwg. No: 308-8/23/1/App. I	Appendix I - Wagerup groundwater production: depressurising bores and dewatering sump

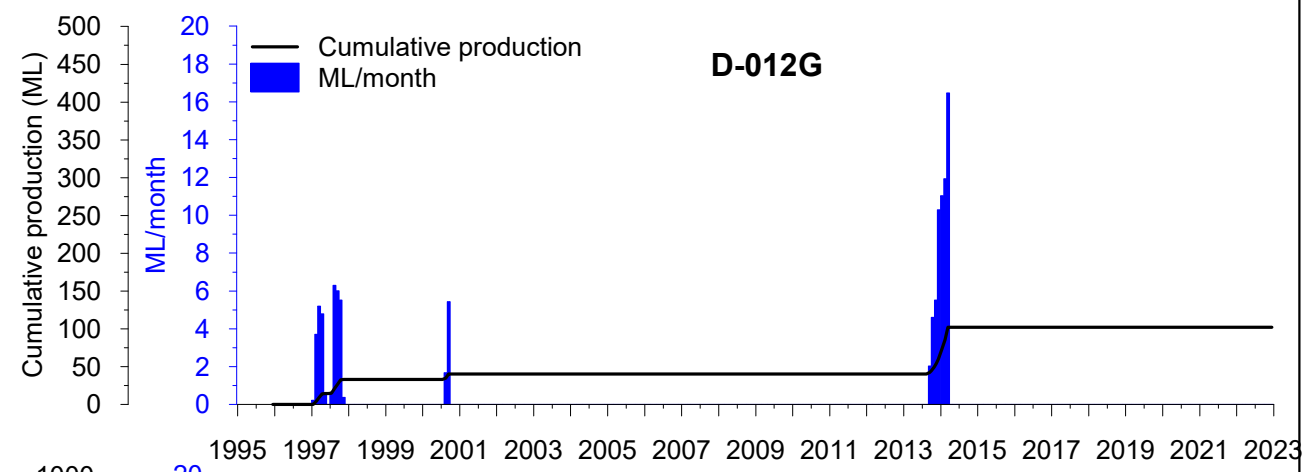


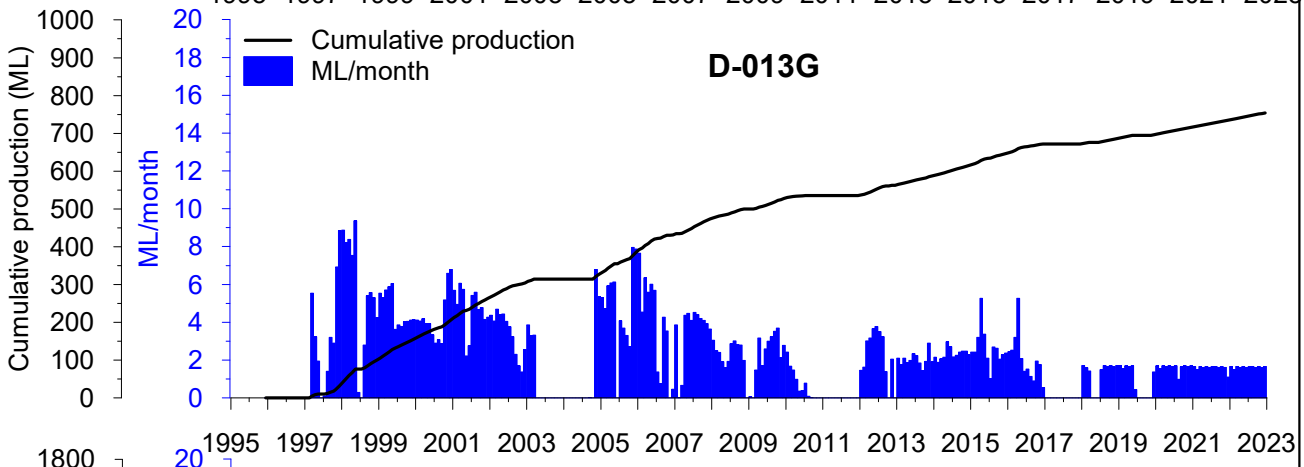
308-8/Grapher/Appendix I.grf

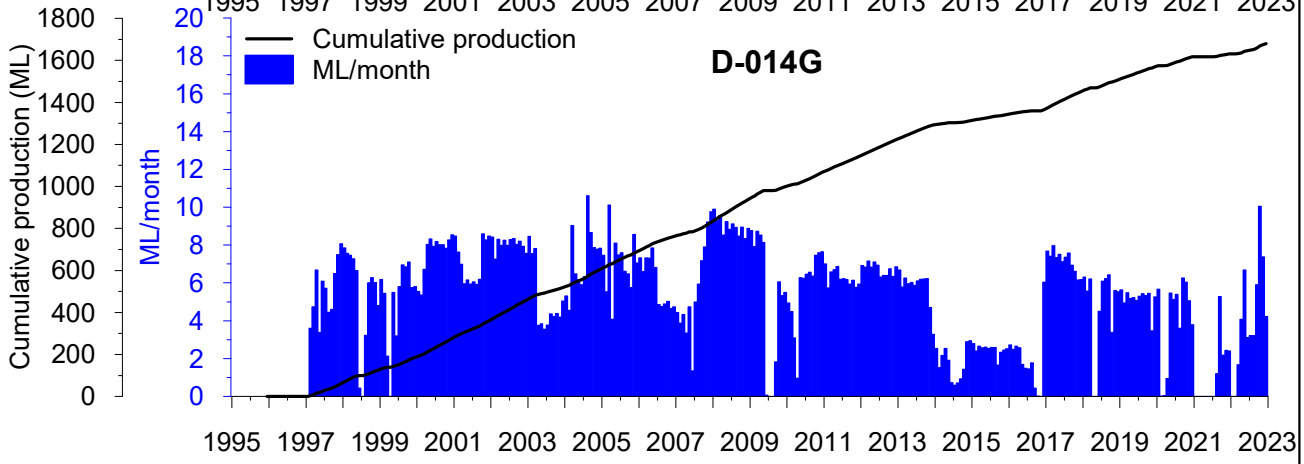
Figure 2

CLIENT: Alcoa of Australia Limited	Appendix I - Wagerup groundwater production: depressurising bores and dewatering sump
PROJECT: Wagerup and Bunbury 2020-2022 water report	
DATE: March 2023	
Dwg. No: 308-8/23/1/App. I	





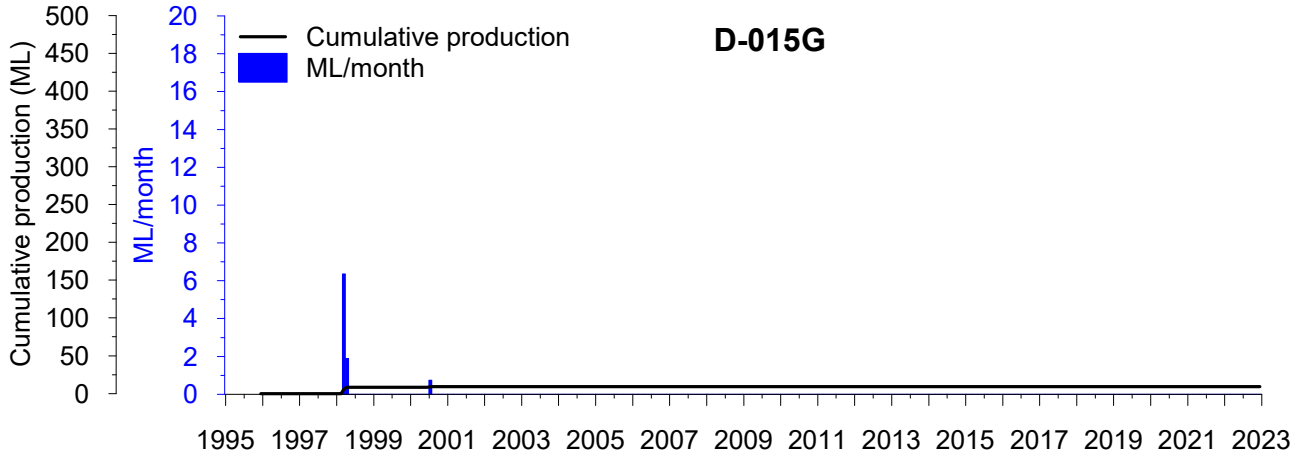


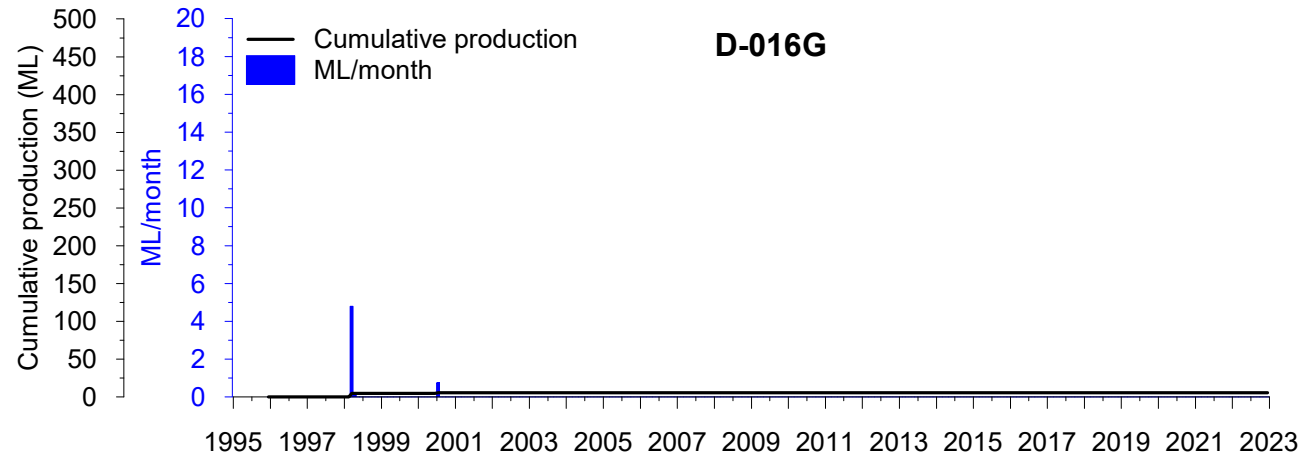


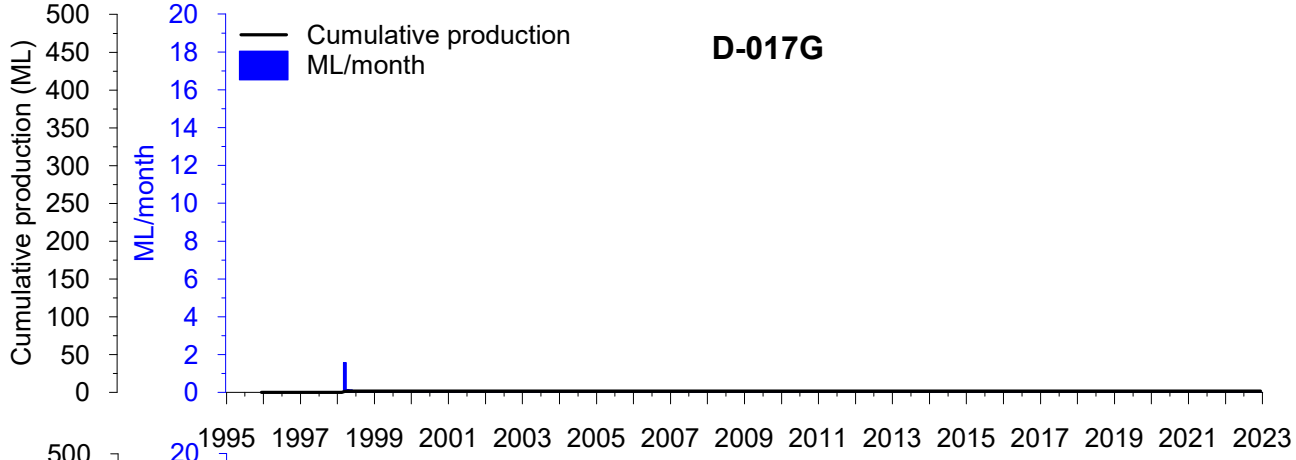
308-8/Grapher/Appendix I.grf

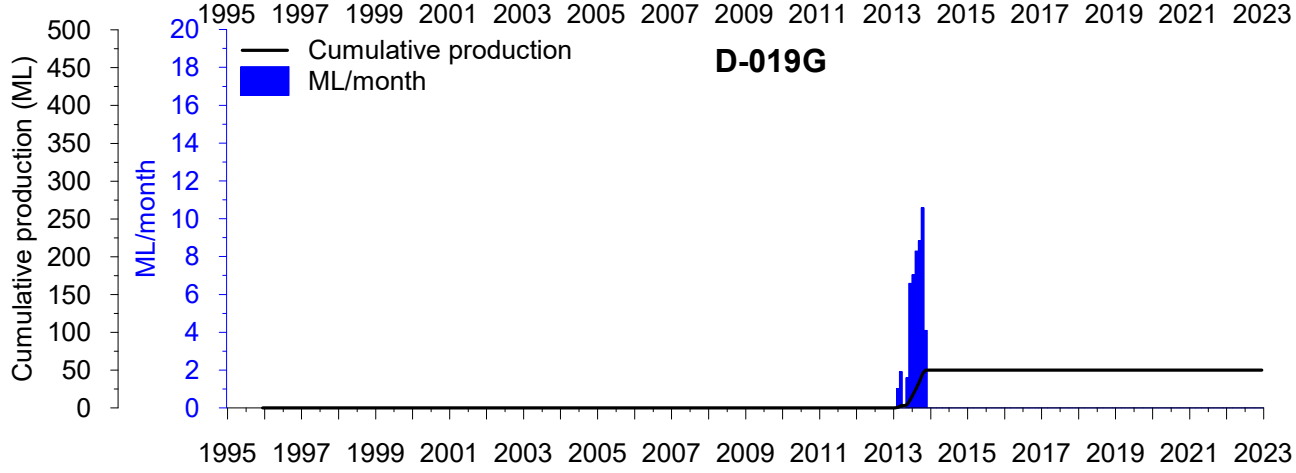
Figure 3

CLIENT: Alcoa of Australia Limited PROJECT: Wagerup and Bunbury 2020-2022 water report DATE: March 2023 Dwg. No: 308-8/23/1/App. I	Appendix I - Wagerup groundwater production: depressurising bores and dewatering sump





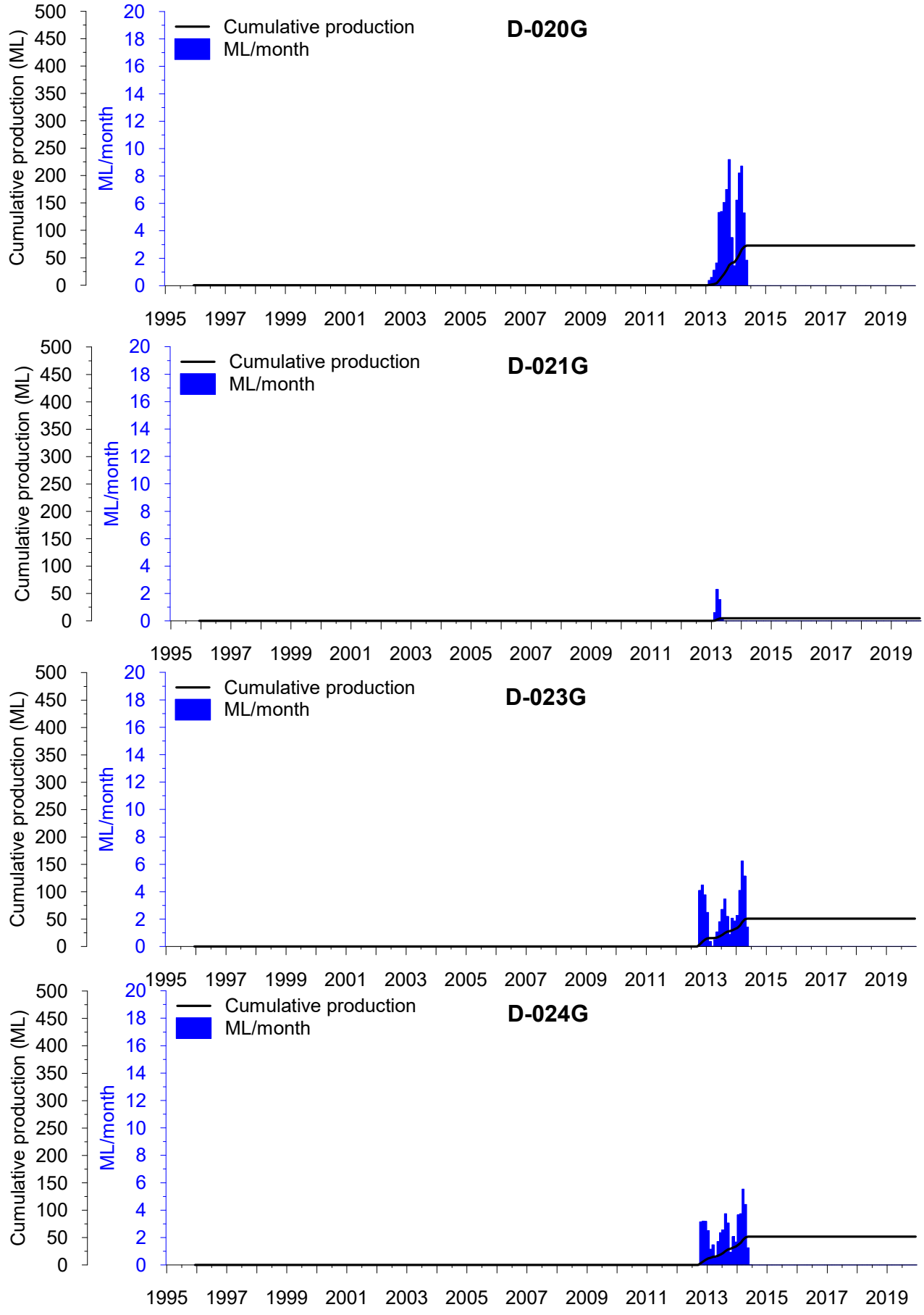




308-8/Grapher/Appendix I.grf

Figure 4

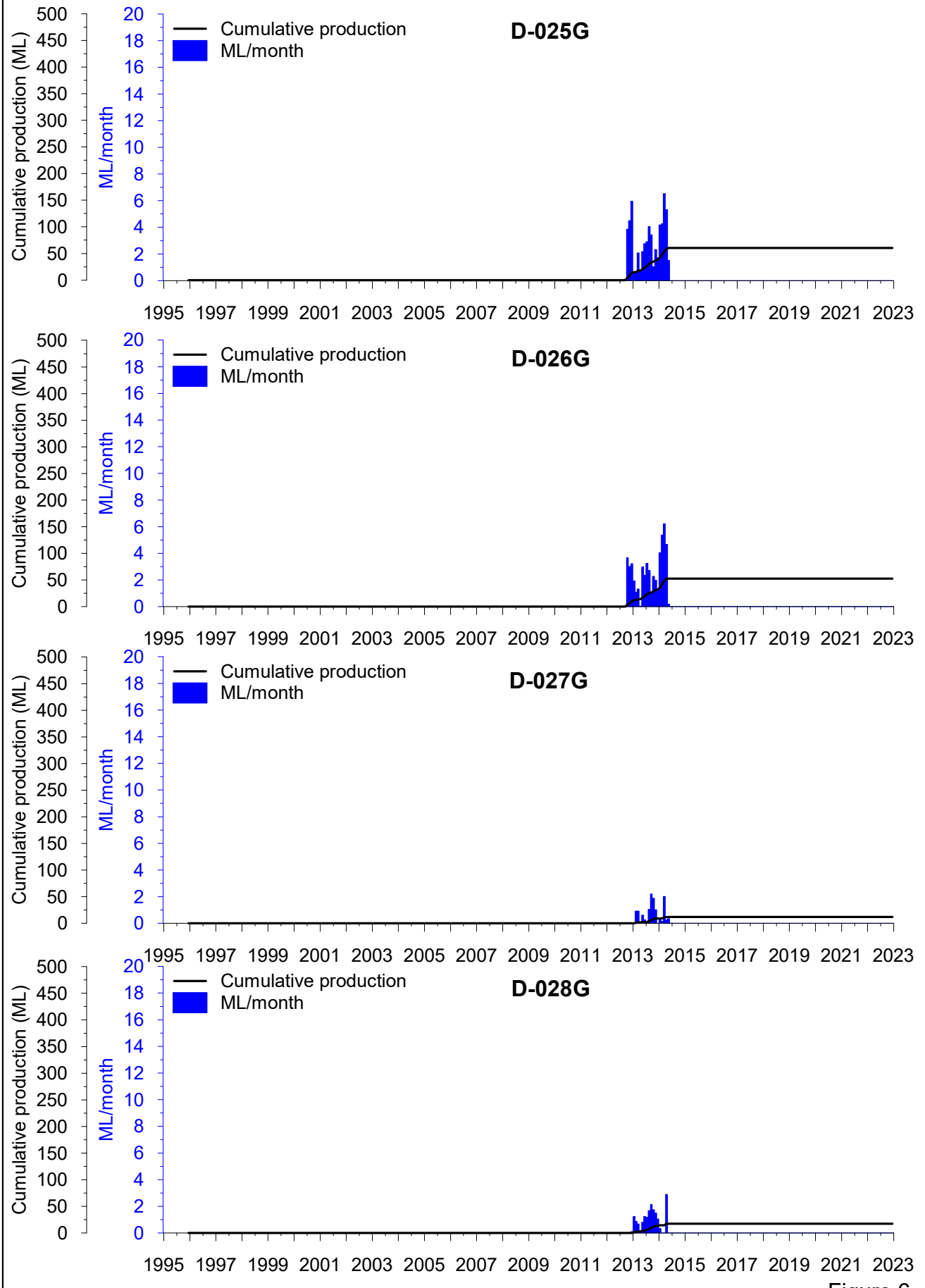
CLIENT: Alcoa of Australia Limited PROJECT: Wagerup and Bunbury 2020-2023 water report DATE: March 2023 Dwg. No: 308-8/23/1/App. I	Appendix I - Wagerup groundwater production: depressurising bores and dewatering sump



308-8/Grapher/Appendix I.grf

Figure 5

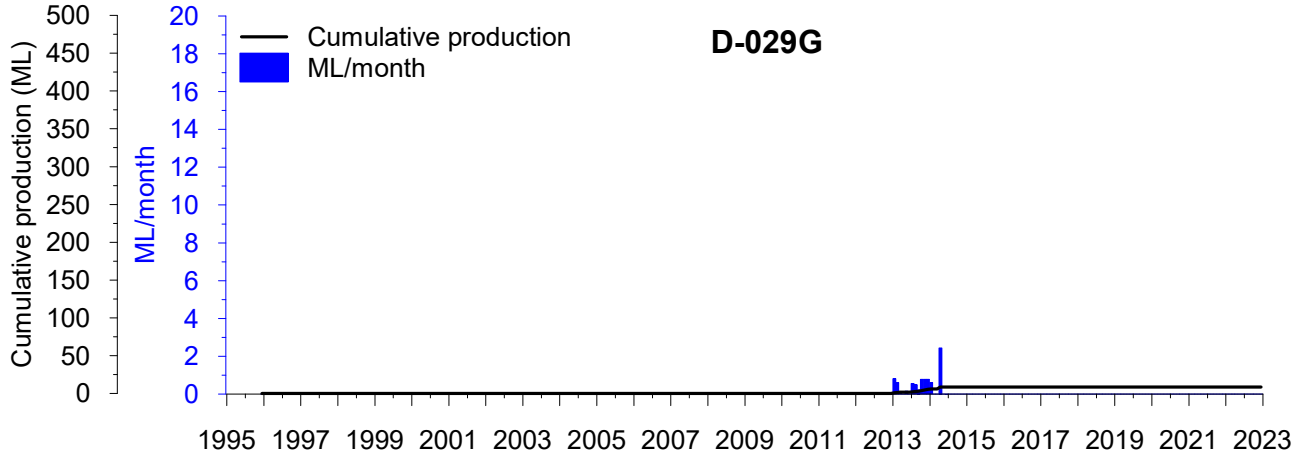
CLIENT: Alcoa of Australia Limited PROJECT: Wagerup and Bunbury 2020-2022 water report DATE: March 2023 Dwg. No: 308-8/23/1/App. I	Appendix I - Wagerup groundwater production: depressurising bores and dewatering sump

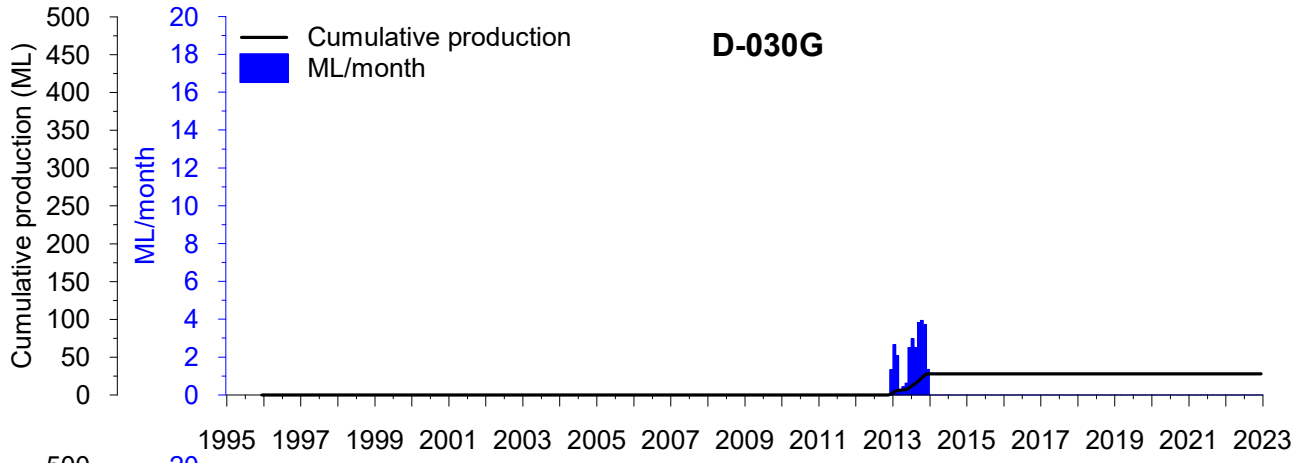


308-8/Grapher/Appendix I.grf

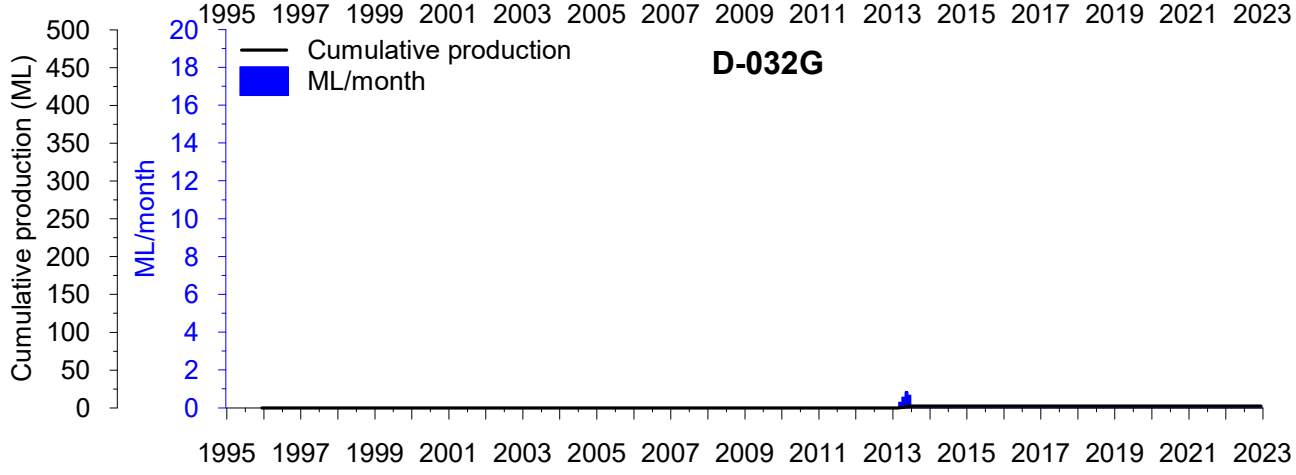
Figure 6

CLIENT: Alcoa of Australia Limited PROJECT: Wagerup and Bunbury 2020-2023 water report DATE: March 2023 Dwg. No: 308-8/23/1/App. I	Appendix I - Wagerup groundwater production: depressurising bores and dewatering sump





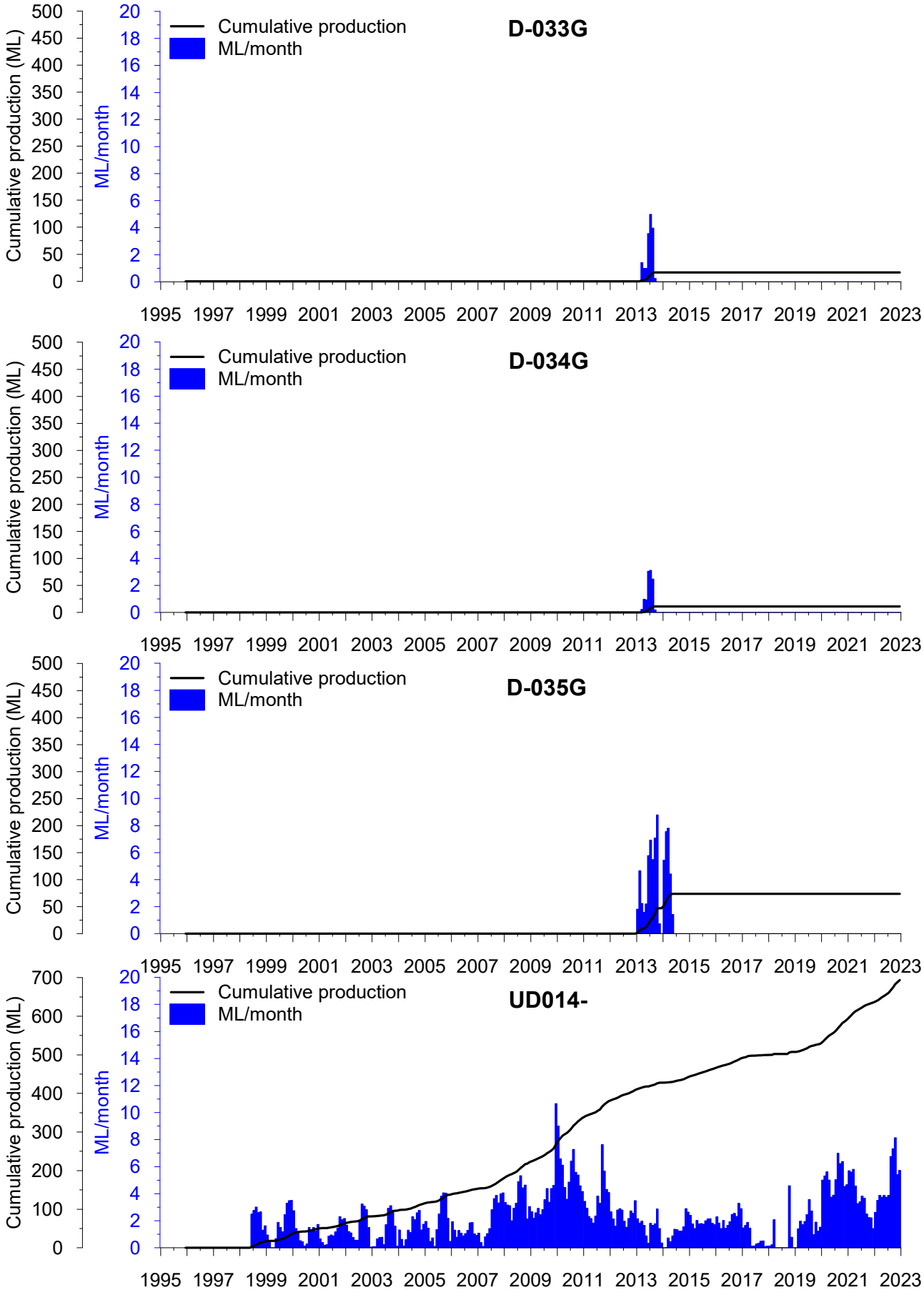




308-8/Grapher/Appendix I.grf

Figure 7

CLIENT: Alcoa of Australia Limited PROJECT: Wagerup and Bunbury 2020-2023 water report DATE: March 2023 Dwg. No: 308-8/23/1/App. I	Appendix I - Wagerup groundwater production: depressurising bores and dewatering sump



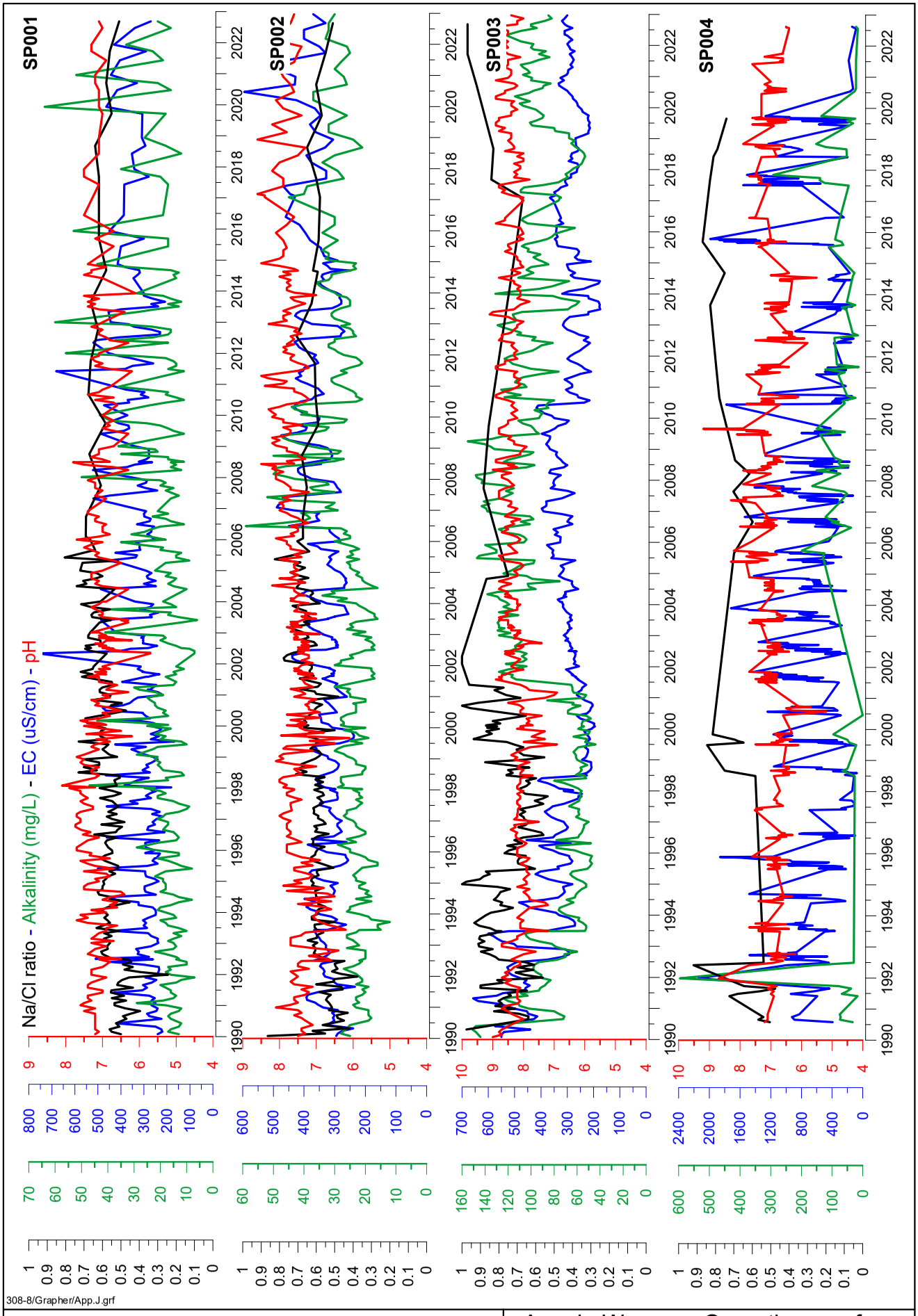
308-8/Grapher/Appendix I.grf

Figure 8

CLIENT: Alcoa of Australia Limited PROJECT: Wagerup and Bunbury 2020-2022 water report DATE: March 2023 Dwg. No: 308-8/23/1/App. I	Appendix I - Wagerup groundwater production: depressurising bores and dewatering sump

APPENDIX J

Wagerup Operations surface water hydrochemistry graphs

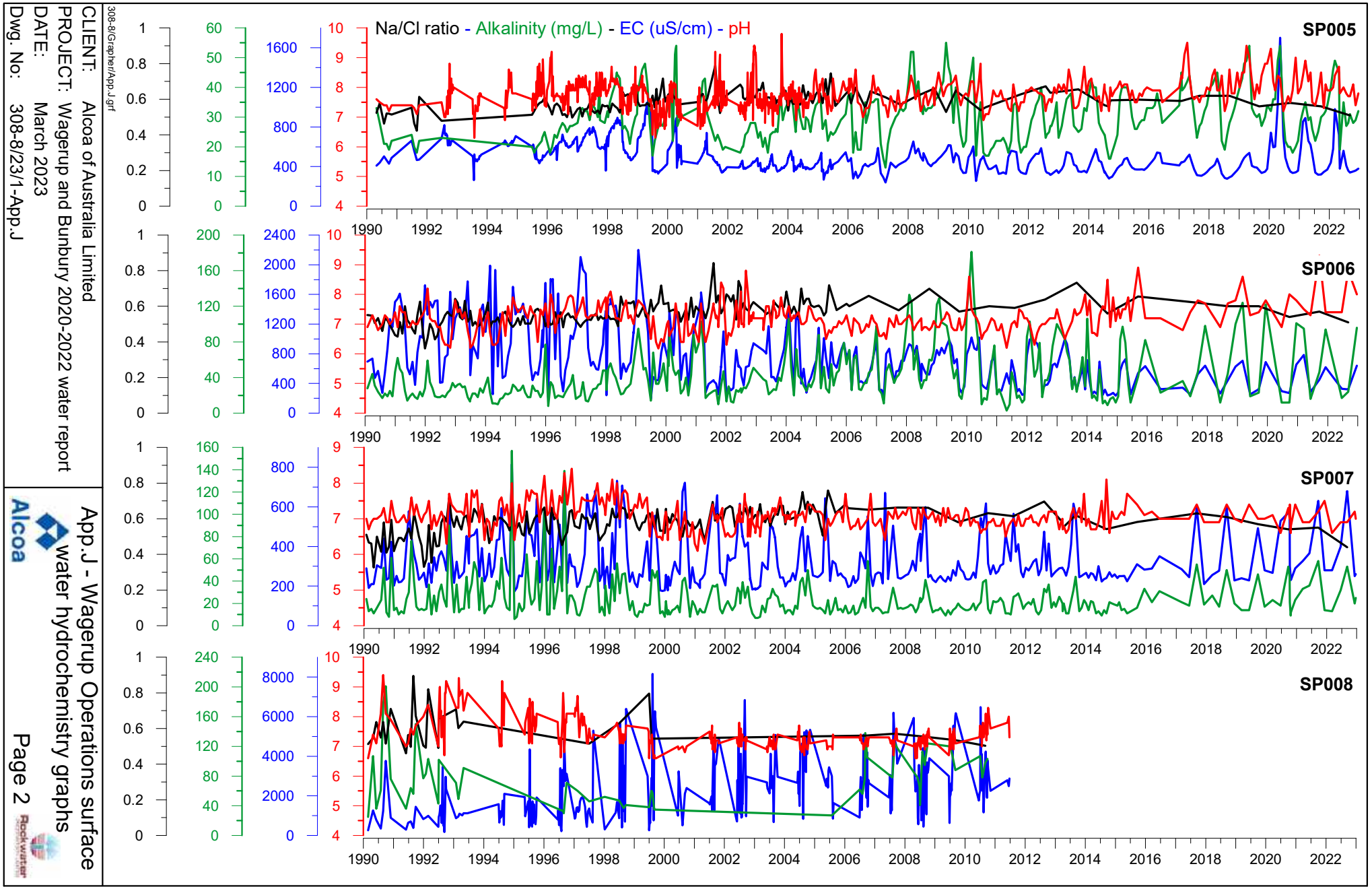


CLIENT:	Alcoa of Australia Limited
PROJECT:	Wagerup and Bunbury 2020-2022 water report
DATE:	March 2023
Dwg. No:	308-8/23/1-App.J

App.J - Wagerup Operations surface water hydrochemistry graphs

Alcoa

Rockwater



CLIENT: Alcoa of Australia Limited

PROJECT: Wagerup and Bunbury 2020-2022 water report

DATE: March 2023

Dwg. No: 308-8/23/1-App.J

App.J - Wagerup Operations surface water hydrochemistry graphs

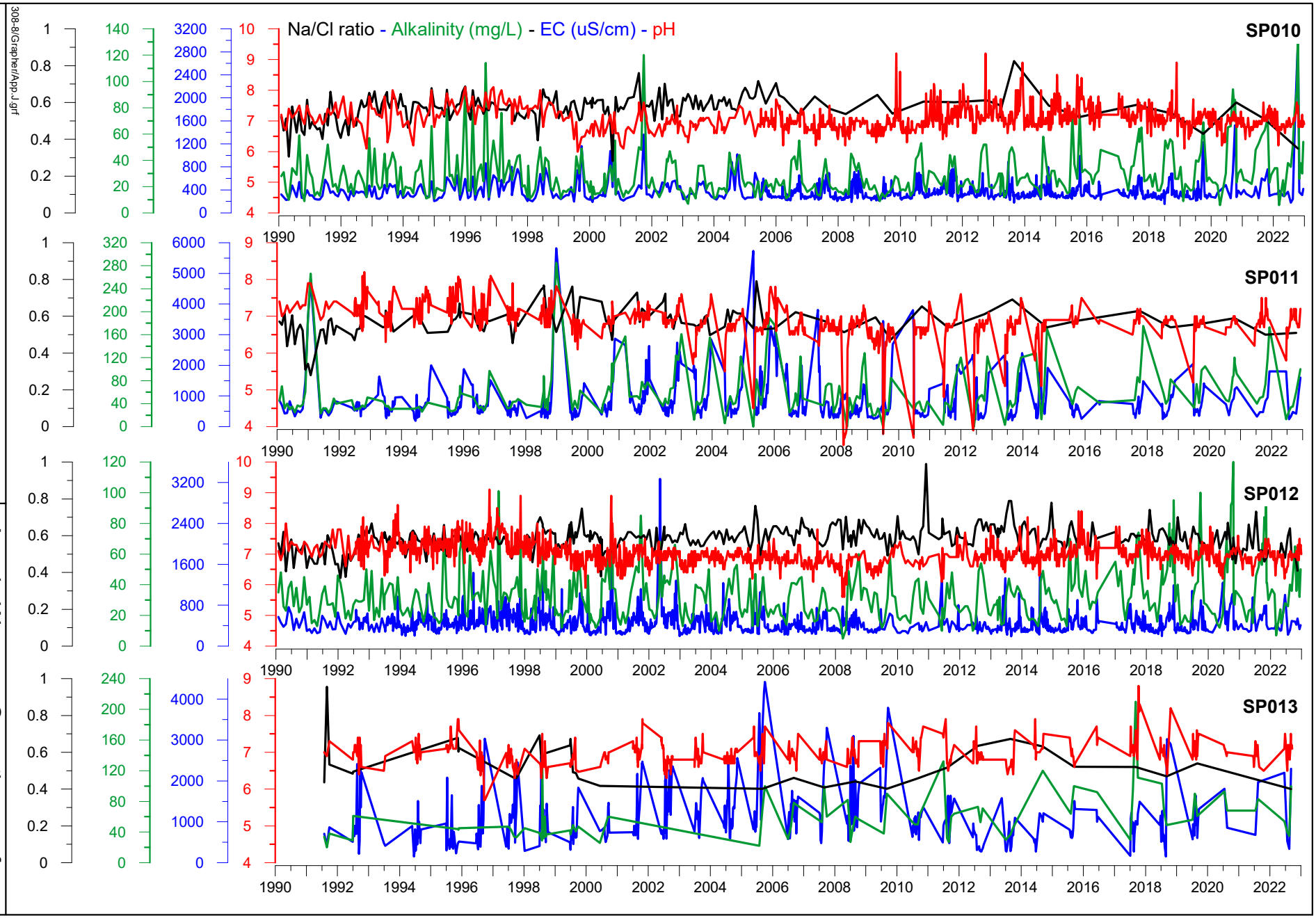
CLIENT: Alcoa of Australia Limited

PROJECT: Wagerup and Bunbury 2020-2022 water report

DATE: March 2023

Dwg. No: 308-8/23/1-App.J

308-8/Grapher/App.J.grf



App.J - Wagerup Operations surface water hydrochemistry graphs

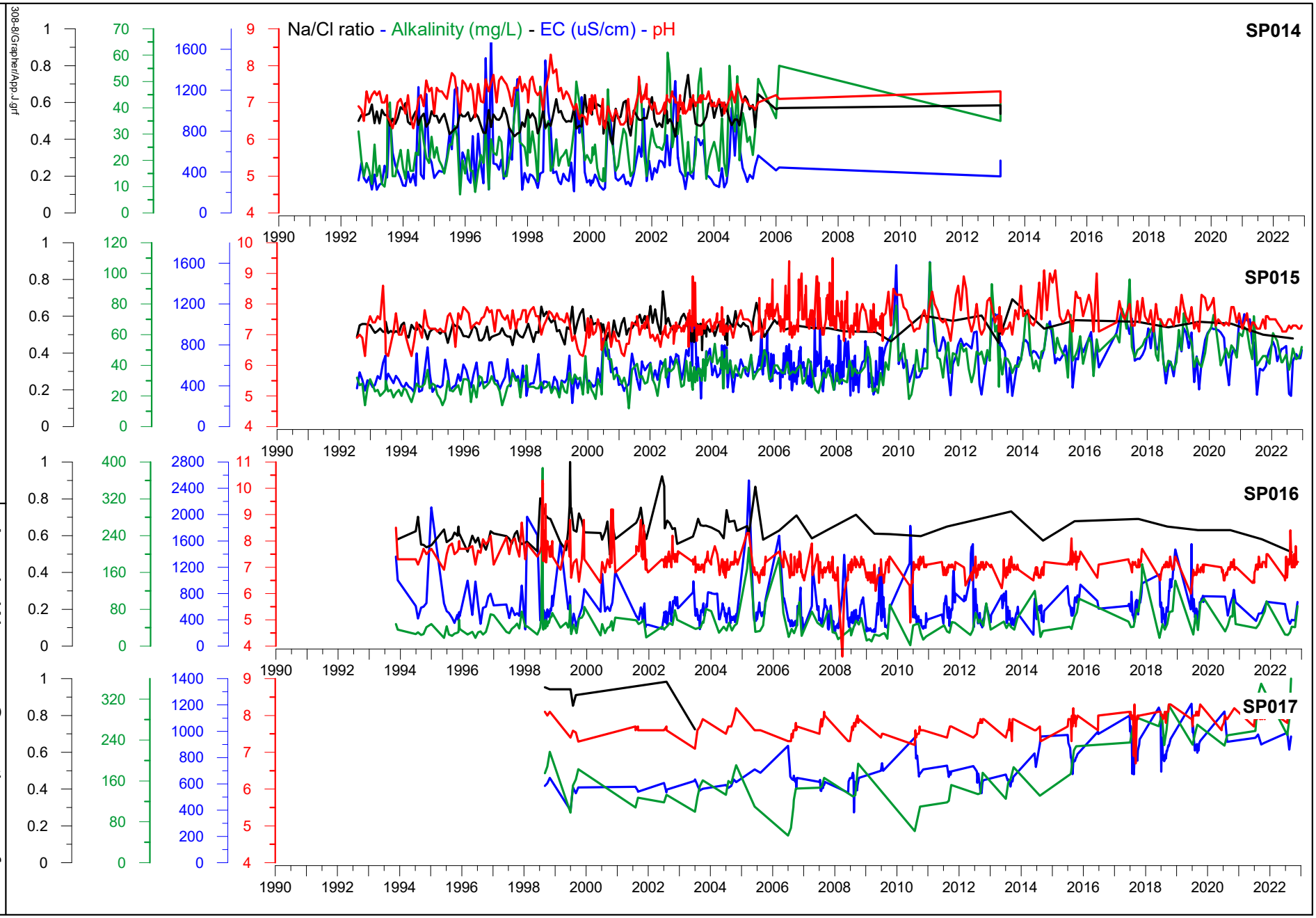
CLIENT: Alcoa of Australia Limited

PROJECT: Wagerup and Bunbury 2020-2022 water report

DATE: March 2023

Dwg. No: 308-8/23/1-App.J

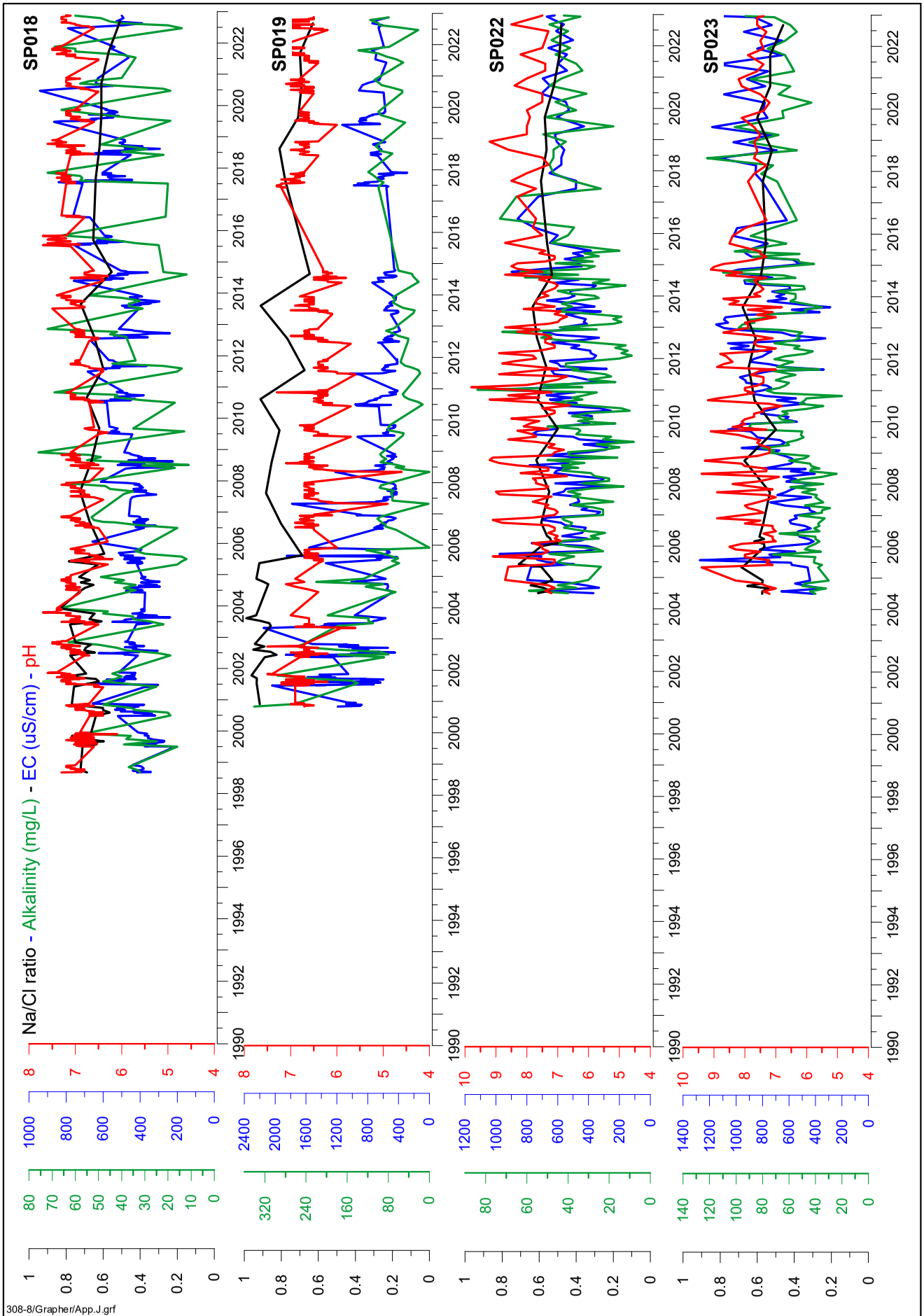
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Alcoa

App.J - Wagerup Operations surface water hydrochemistry graphs

Rockwater

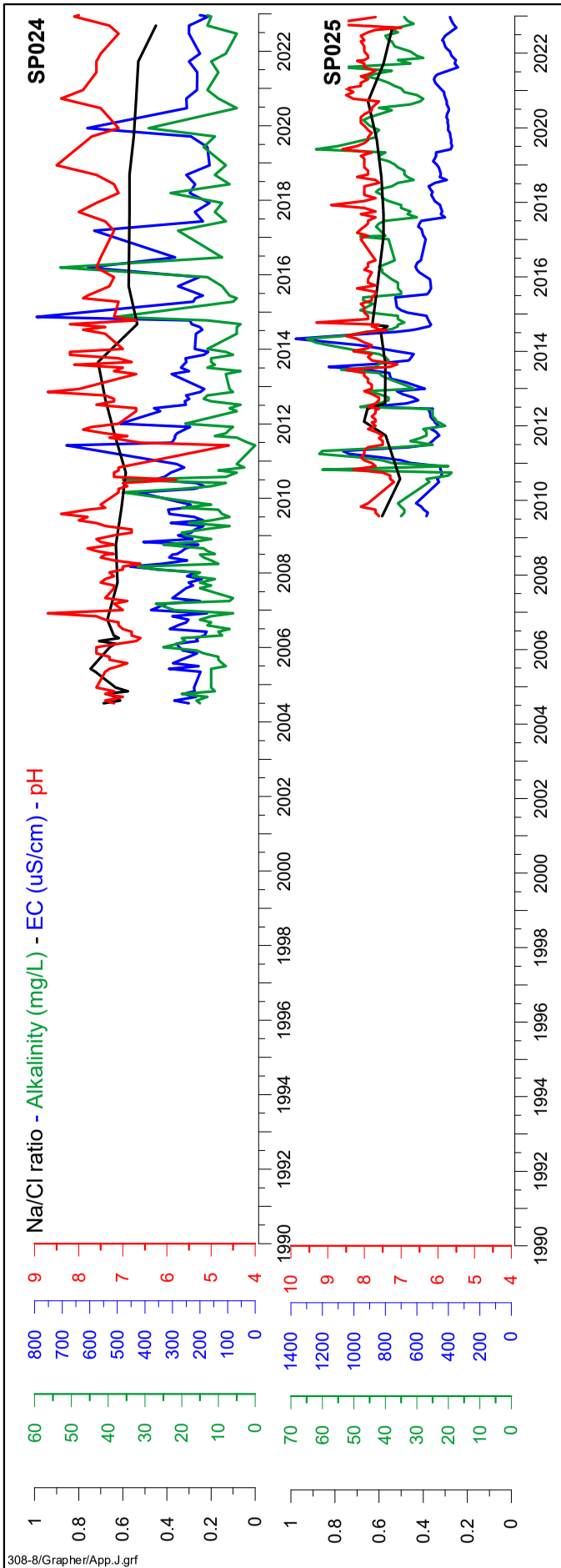


CLIENT: Alcoa of Australia Limited
PROJECT: Wagerup and Bunbury 2020-2022 water report
DATE: March 2023
Dwg. No: 308-8/23/1-App.J

App.J - Wagerup Operations surface water hydrochemistry graphs

Alcoa

Rockwater



CLIENT:	Alcoa of Australia Limited
PROJECT:	Wagerup and Bunbury 2020-2022 water report
DATE:	March 2023
Dwg. No:	308-8/23/1-App.J

App.J - Wagerup Operations surface water hydrochemistry graphs

Alcoa

Rockwater

APPENDIX K

Bunbury Operations time series groundwater levels

CLIENT: Alcoa of Australia Limited

PROJECT: Wagerup and Bunbury 2020-2022 water report

DATE: March 2023

Dwg. No: 308-8/23/1-App. K

308-8/Graphs/Appendix K.grf

Alcoa

Rockwater

Appendix K - Bunbury Operations time series groundwater levels

Graph colour nomenclature (screened aquifer depth): Upper, Middle, Lower

CLIENT: Alcoa of Australia Limited
PROJECT: Wagerup and Bunbury 2020-2022 water report
DATE: March 2023
Dwg. No: 308-8/23/1-App. K

308-8/Graphs/Appendix K.grf

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Appendix K - Bunbury Operations time series groundwater levels

Rockwater

Graph colour nomenclature (screened aquifer depth): **Upper**, **Middle**, **Lower**

CLIENT: Alcoa of Australia Limited

PROJECT: Wagerup and Bunbury 2020-2022 water report

DATE: March 2023

Dwg. No: 308-8/23/1-App. K

308-8/Graphs/Appendix K.grf

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Rockwater

Appendix K - Bunbury Operations time series groundwater levels

Graph colour nomenclature (screened aquifer depth): **Upper**, **Middle**, **Lower**

APPENDIX L

Time-series groundwater quality, Bunbury

CLIENT: Alcoa of Australia Limited
PROJECT: Wagerup and Bunbury 2020-2022 water report
DATE: March 2023
Dwg. No: 308-8/23/1-App. L

Alcoa

Appendix L Page 1
Time-series groundwater quality data

Rockwater

CLIENT: Alcoa of Australia Limited
PROJECT: Wagerup and Bunbury 2020-2022 water report
DATE: March 2023
Dwg. No: 308-8/23/1-App. L

308-8/Graphs/Appendix G.grf

Alcoa

Rockwater

Appendix L Page 2
Time-series groundwater quality data

CLIENT: Alcoa of Australia Limited
PROJECT: Wagerup and Bunbury 2020-2022 water report
DATE: March 2023
Dwg. No: 308-8/23/1-App. L

308-8/Graphs/Appendix G.grf

Alcoa

Appendix L Page 3
Time-series groundwater quality data

Rockwater

CLIENT: Alcoa of Australia Limited
PROJECT: Wagerup and Bunbury 2020-2022 water report
DATE: March 2023
Dwg. No: 308-8/23/1-App. L

308-8\Graphs\Appendix G.grf

Alcoa

Appendix L Page 4
Time-series groundwater quality data

Rockwater

CLIENT: Alcoa of Australia Limited
PROJECT: Wagerup and Bunbury 2020-2022 water report
DATE: March 2023
Dwg. No: 308-8/23/1-App. L

308-8/Graphs/Appendix G.grf

Alcoa

Appendix L
Time-series groundwater quality data

Rockwater

CLIENT: Alcoa of Australia Limited
PROJECT: Wagerup and Bunbury 2020-2022 water report
DATE: March 2023
Dwg. No: 308-8/23/1-App. L

308-8/Graphs/Appendix G.grf

Alcoa

Appendix L Page 6
Time-series groundwater quality data

Rockwater

CLIENT: Alcoa of Australia Limited
PROJECT: Wagerup and Bunbury 2020-2022 water report
DATE: March 2023
Dwg. No: 308-8/23/1-App. L

308-8/Graphs/Appendix G.grf

Alcoa

Appendix L
Time-series groundwater quality data

Rockwater

CLIENT: Alcoa of Australia Limited
PROJECT: Wagerup and Bunbury 2020-2022 water report
DATE: March 2023
Dwg. No: 308-8/23/1-App. L

Alcoa

Appendix L
Time-series surface water quality data

Rockwater

APPENDIX M

Bore installation logs

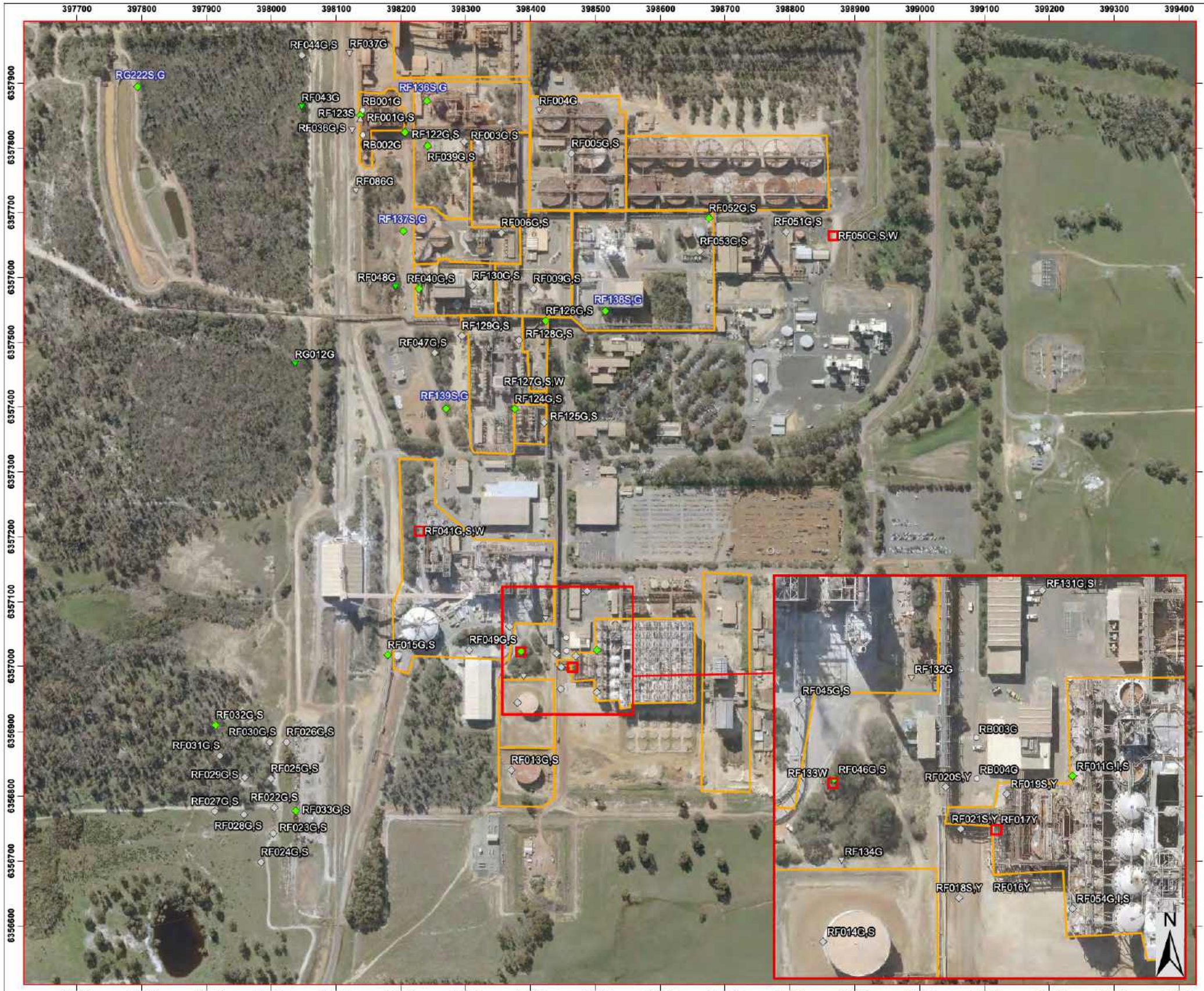
Summary construction and development data for monitor bores constructed in 2020

	Bore Number		RF136G	RF136S	RF137G	RF137S	RF138G	RF138S	RF139G	RF139S	RG222G	RG222S
Particulars of Well	Drilling Start		3/02/2020	3/02/2020	7/02/2020	7/02/2020	4/02/2020	4/02/2020	5/02/2020	5/02/2020	6/02/2020	6/02/2020
	Drilling Completion		3/02/2020	3/02/2020	7/02/2020	7/02/2020	4/02/2020	4/02/2020	5/02/2020	5/02/2020	6/02/2020	6/02/2020
	Drilling Method		Direct Push	Direct Push	Direct Push	Direct Push	Direct Push	Direct Push	Direct Push	Direct Push	Direct Push	Direct Push
	Final Status of Bore		Ready to Operate	Ready to Operate	Ready to Operate	Ready to Operate	Ready to Operate	Ready to Operate	Ready to Operate	Ready to Operate	Ready to Operate	Ready to Operate
	Purpose of bore		Monitoring	Monitoring	Monitoring	Monitoring	Monitoring	Monitoring	Monitoring	Monitoring	Monitoring	Monitoring
Surveyed Bore Location	Easting	MGA94	398236	398236	398205	398205	398504	398504	398264	398263	397801	397802
	Northing	MGA94	6357873	6357874	6357675	6357676	6357567	6357566	6357416	6357417	6357896	6357897
Construction Details*	Ground level	mAHD	46.391	46.395	46.422	46.413	46.533	46.54	46.316	46.296	40.431	40.424
	Top of PVC height	mAHD	46.975	47.014	46.265	46.302	47.099	47.163	46.961	46.986	41.048	41.042
	Stick up	magl	0.584	0.619	-0.157	-0.111	0.566	0.623	0.645	0.69	0.617	0.618
	Top of slots	mbgl	9.5	3	12	5	8.5	3.5	10	3	8	3.5
	Bottom of slots	mbgl	12.5	6	15	8	11.5	6.5	13	6	11	6.5
	Total depth drilled	mbgl	12.5	6.01	15	8	11.5	6.5	13	6.69	11	6.5
Well Development and Field Samples	Date		3/02/2020	24/08/2020	7/03/2020	28/08/2020	4/03/2020	25/08/2020	5/03/2020	24/08/2020	29/05/2020	28/08/2020
	Method		Pumping	Pumping	Pumping	Pumping	Pumping	Pumping	Pumping	Pumping	Pumping	Pumping
	Approximate purging duration	hr	0.75	1.5	1	1	1	1.75	1	1.333	0.25	1.5
	Approximate purging rate	L/min	3.5	low flow	1.3	low flow	2.6	low flow	3	low flow	1.5	low flow
	Final pH		6.04	7.5	6.06	6.4	12.36	6.4	10.62	6.6	6.57	7.1
	Final EC (temperature compensated)	µS/cm	419.5	1,215	504	451	15843	470	4002	805	1103	4750
Water Levels	Date		5/11/2020	5/11/2020	4/11/2020	4/11/2020	5/11/2020	5/11/2020	5/11/2020	5/11/2020	4/11/2020	4/11/2020
	Depth to Water	mbgl	5.89	5.85	6.04	5.96	4.26	4.24	5.76	5.75	2.96	2.83
	SWL	mAHD	40.505	40.544	40.385	40.452	42.269	42.203	40.561	40.546	37.468	37.592

* additional details on bore construction logs provided

Driller [redacted]

Drilling Supervisc 360 Environmental



Legend

- Refinery Buildings

Sampling Locations

- Upper Superfical, not monitored
- Lower Superfical
- not monitored
- Multiple Superfical
- not monitored
- Multiple Superfical + Leederville + Cattamarra
- not monitored
- Recovery Bore, not monitored
- RF138S,G New Groundwater Monitoring Wells

- LOCALITY MAP SOURCED FROM LANDGATE 2017
- AERIAL PHOTOGRAPHY SOURCED LANDGATE 2018
(© Western Australian Land Information Authority 2018)

SLIP ENABLER

ALCOA

- NOTE THAT POSITION ERRORS CAN BE >5M IN SOME AREAS

360 environmental
a 10 Bermondsey St, West Leederville, 6007 WA
t (08) 9388 8360
f (08) 9381 2360
w www.360environmental.com.au

0 100 200
Meters
1:5,500 @ A3

LOCALITY MAP



PROJECT NO	DATE
3218	20/01/2020

HORIZONTAL DATUM AND PROJECTION
AGD 1984 AMG Zone 50

CREATED	CHECKED	APPROVED	REVISION
VM	EL	JP	0

ALCOA of Australia
Wagerup Refinery and Residue Storage Area

Groundwater Wells Installation

Figure 1

Groundwater Wells Location

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GROUNDWATER MONITORING WELL

PROJECT: Alcoa WGP Well Install 2020 | **Bore Identification:** *RF136G* | **Sheet:** *1 of 2*

PROJECT #: *3218* | **AOPC:** *Building B25A* | **Date Logged:** *03/02/2020*

Project Manager: *JP* | **PROJECT Location:** *Alcoa Wagerup Refinery*

Client: *Alcoa of Australia* | **Zone:** *50* | **Easting:** *398235.566* | **Northing:** *6357873.406*

Drilled by: *DPP* | **Inner Diameter (mm):** *50* | **Elevation (mAHD):** *46.391*

Drill Type: *Geoprobe* | **Drilling Method:** *Direct Push*

SOIL DESCRIPTION	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	WELL CONSTRUCTION	MOISTURE	pH (pH Units)	COMMENTS
Ground Surface	0.0			Riser Cover			
Limestone crushed LIMESTONE, pale yellow/grey						10.8	
SAND Orange, fine to medium grained, poorly graded, subangular/subrounded	1.0		CL	Concrete		9.8	
Sandy Gravelly Clay Brown with red mottles, lateritic gravels, stiff, high plasticity						9.2	
Clayey Sand Brown, fine to medium grained, poorly graded, subangular/subrounded	2.0			Bentonite Granules	Dry	8.4	
Sandy Gravelly CLAY Brown with red mottles, lateritic gravels, stiff, high plasticity			SC			8.7	
Clayey SAND Brown, fine to medium grained, subangular/subrounded	3.0		SC			8.4	
Gravelly Clayey SAND Brown with red mottles, fine to medium grained, poorly graded, subangular/subrounded	4.0		SC	Class 18 50 mm PVC Blank		8.4	
Clayey SAND Brown, fine to medium grained, poorly graded, subangular/subrounded	5.0				Moist	8.2	
Clayey SAND Pale grey, fine to medium grained, poorly graded, subangular/subrounded	6.0		SC			7.5	
	7.0					7.6	
SAND Dark grey/black, fine to medium grained, poorly graded, subangular/subrounded			SP			7.4	
Clayey SAND Pale grey, fine to medium grained, poorly graded, subangular/subrounded	8.0		SP			7.6	
						7.5	
						7.1	
						7.5	
						8.0	

Elevation reported as ground level in mAHD

Logged by: *EL*
Checked by: *VM*

GROUNDWATER MONITORING WELL

PROJECT: Alcoa WGP Well Install 2020 | **Bore Identification:** *RF136G* | **Sheet:** *2 of 2*

PROJECT #: *3218* | **AOPC:** *Building B25A* | **Date Logged:** *03/02/2020*

Project Manager: *JP* | **PROJECT Location:** *Alcoa Wagerup Refinery*

Client: *Alcoa of Australia* | **Zone:** *50* | **Easting:** *398235.566* | **Northing:** *6357873.406*

Drilled by: *DPP* | **Inner Diameter (mm):** *50* | **Elevation (mAHD):** *46.391*

Drill Type: *Geoprobe* | **Drilling Method:** *Direct Push*

SOIL DESCRIPTION	DEPTH (m)	CLASSIFICATION SYMBOL	MOISTURE	pH (pH Units)
SAND Brown, fine to medium grained, poorly graded, subangular/subrounded	9.0	SC	Wet	8.4
SAND Brown, fine to medium grained, poorly graded, subangular/subrounded		SP		9.1
Clayey SAND Pale grey, fine to medium grained, poorly graded, subangular/subrounded	10.0	SC		8.9
	11.0			8.7
Sandy CLAY Pale grey, soft, high plasticity	12.0	CL		8.6
Clayey SAND Pale grey/white, fine to coarse grained, well graded, subangular		SC		8.1
Clayey SAND Pale grey, fine to medium grained, poorly graded, subangular/subrounded	13.0	CL		8.0
CLAY Grey, stiff, high plasticity		CL		7.4
CLAY Brown with red mottles, very stiff, very high plasticity	14.0	CL		7.9
CLAY Grey with red and dark grey mottles, stiff, very high plasticity	15.0			7.9
End of Log	16.0			6.5
	17.0			

WELL CONSTRUCTION: 0.8-1.2 mm clean graded gravel pack; Bentonite Plug; Class 18 threaded 50 mm machine-slotted PVC Screen

Elevation reported as ground level in mAHD

Logged by: *EL*
Checked by: *VM*

GROUNDWATER MONITORING WELL

PROJECT: Alcoa WGP Well Install 2020
PROJECT #: 3218
Project Manager: JP
Client: Alcoa of Australia
Drilled by: DPP
Drill Type: Geoprobe

Bore Identification: RF136S
AOPC: Building 25A
PROJECT Location: Alcoa Wagerup Refinery
Zone: 50 **Easting:** 398235.667
Inner Diameter (mm): 50
Drilling Method: Direct Push

Sheet: 1 of 1
Date Logged: 03/02/2020
Northing: 6357874.332
Elevation (mAHD): 46.395

SOIL DESCRIPTION	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	WELL CONSTRUCTION	MOISTURE	pH (pH Units)	COMMENTS
Ground Surface	0.0						
Limestone crushed LIMESTONE, pale yellow/grey						10.2	
Gravelly CLAY Brown with red mottles, lateritic gravels, stiff, high plasticity	1.0		CL			9.4	
Clayey SAND Brown/grey, fine to medium grained, poorly graded, subangular/subrounded	2.0					9.0	
Sandy Gravelly Clay Brown with red mottles, lateritic gravels, stiff, high plasticity						8.9	
Clayey Sand Brown, fine to medium grained, poorly graded, subangular/subrounded	3.0		SC		Dry	8.9	
Sandy Gravelly CLAY Brown with red mottles, lateritic gravels, stiff, high plasticity						8.7	
Clayey SAND Brown, fine to medium grained, subangular/subrounded	4.0		SC			8.7	
Gravelly Clayey SAND Brown with red mottles, fine to medium grained, poorly graded, subangular/subrounded	5.0					8.9	
Clayey SAND Brown, fine to medium grained, poorly graded, subangular/subrounded	6.0		SC		Moist	9.1	
Clayey SAND Pale grey, fine to medium grained, poorly graded, subangular/subrounded						8.9	
SAND Dark grey/black, fine to medium grained, poorly graded, subangular/subrounded	7.0				Wet	8.8	
	8.0					8.9	
End of Log	9.0					8.9	
						8.6	

Riser Cover
Bentonite Granules
18.50 mm PVC Blank Concrete
Class
0.8-1.2 mm clean graded gravel pack
Class 18 threaded 50 mm machine-slotted PVC Screen
Bentonite Plug

Elevation reported as ground level in mAHD

Logged by: EL
Checked by: VM

GROUNDWATER MONITORING WELL

PROJECT: Alcoa WGP Well Install 2020 | **Bore Identification:** *RF137G* | **Sheet:** *1 of 2*

PROJECT #: *3218* | **AOPC:** *Building 30A* | **Date Logged:** *07/02/2020*

Project Manager: *JP* | **PROJECT Location:** *Alcoa Wagerup Refinery*

Client: *Alcoa of Australia* | **Zone:** *50* | **Easting:** *398204.894* | **Northing:** *6357675.473*

Drilled by: *DPP* | **Inner Diameter (mm):** *50* | **Elevation (mAHD):** *46.422*

Drill Type: *Geoprobe* | **Drilling Method:** *Direct Push*

SOIL DESCRIPTION	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	WELL CONSTRUCTION	MOISTURE	pH (pH Units)	COMMENTS
Ground Surface	0.0						
Sandy Gravelly Clay Brown with red mottles, lateritic gravels, stiff, high plasticity	1.0		CL	Stainless Steel Gatic Cover; Concrete	Dry	9.7, 9.6, 9.6, 9.4, 9.2, 8.8, 8.8	
Clayey Sand Brown, fine to medium grained, poorly graded, subangular/subrounded	4.0		SC	Bentonite Granules	Moist	8.3, 8.3, 8.2	
Sandy CLAY Pale grey, soft, high plasticity	6.0		CL			8.2, 8.1, 7.9	
Clayey SAND Pale grey, fine to medium grained, poorly graded, subangular/subrounded	7.0		SC			7.4, 7.5	
SAND Pale grey, fine to medium grained, poorly graded, subangular/subrounded	8.0		SP	Class 18 50 mm PVC Blank		7.6, 7.1, 7.2, 6.9	
	9.0						

Logged by: *EL*
Checked by: *VM*

GROUNDWATER MONITORING WELL

PROJECT: Alcoa WGP Well Install 2020	**Bore Identification:** *RF137G*	**Sheet:** *2 of 2*
PROJECT #: *3218*	**AOPC:** *Building 30A*	**Date Logged:** *07/02/2020*
Project Manager: *JP*	**PROJECT Location:** *Alcoa Wagerup Refinery*	
Client: *Alcoa of Australia*	**Zone:** *50* **Easting:** *398204.894*	**Northing:** *6357675.473*
Drilled by: *DPP*	**Inner Diameter (mm):** *50*	**Elevation (mAHD):** *46.422*
Drill Type: *Geoprobe*	**Drilling Method:** *Direct Push*	

SOIL DESCRIPTION	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	WELL CONSTRUCTION	MOISTURE	pH (pH Units)	COMMENTS
Clayey SAND Pale grey, fine to medium grained, poorly graded, subangular/subrounded	10.0		SC	0.8-1.2 mm clean graded gravel pack	Wet	7.0	
						7.0	
SAND Pale grey, fine to medium grained, poorly graded, subangular/subrounded	11.0		SP			6.8	
						6.9	
Clayey SAND Pale grey, fine to medium grained, poorly graded, subangular/subrounded	12.0		CS			7.3	
			SP			7.2	
SAND Pale grey, fine to medium grained, poorly graded, subangular/subrounded	13.0		CL	Class 18 threaded 50 mm machine-slotted PVC Screen		7.2	
						7.5	
CLAY Pale grey, stiff, very high plasticity						7.5	
Sandy CLAY Pale grey, stiff, very high plasticity	14.0		CL			7.4	
	15.0					7.7	
End of Log	16.0						
	17.0						
	18.0						
	19.0						

Elevation reported as ground level in mAHD

Logged by: *EL*
Checked by: *VM*

GROUNDWATER MONITORING WELL

PROJECT: Alcoa WGP Well Install 2020	**Bore Identification:** *RF137S*	**Sheet:** *1 of 1*
PROJECT #: *3218*	**AOPC:** *Building 30A*	**Date Logged:** *07/02/2020*
Project Manager: *JP*	**PROJECT Location:** *Alcoa Wagerup Refinery*	
Client: *Alcoa of Australia*	**Zone:** *50* **Easting:** *398204.901*	**Northing:** *6357676.382*
Drilled by: *DPP*	**Inner Diameter (mm):** *50*	**Elevation (mAHD):** *46.413*
Drill Type: *Geoprobe*	**Drilling Method:** *Direct Push*	

SOIL DESCRIPTION	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	WELL CONSTRUCTION	MOISTURE	pH (pH Units)	COMMENTS
Ground Surface	0.0						
Sandy Gravelly Clay Brown with red mottles, lateritic gravels, stiff, high plasticity	1.0 – 3.0		CL	Stainless Steel Gatic Cover; Concrete; Bentonite Granules; Class 18 50 mm PVC Blank	Dry	7.1, 8.5, 8.8, 8.8, 7.0, 6.7, 6.6	
Clayey Sand Brown, fine to medium grained, poorly graded, subangular/subrounded	4.0 – 6.0		SC	0.8-1.2 mm clean graded gravel pack	Moist	6.4, 6.6, 6.5	
Sandy CLAY Pale grey, soft, high plasticity	6.0 – 7.0		CL		Wet	6.6, 6.5, 6.6, 6.3, 6.3, 6.6	
Clayey SAND Pale grey, fine to medium grained, poorly graded, subangular/subrounded	7.0 – 8.0		SC	Class 18 threaded 50 mm machine-slotted PVC Screen			
End of Log	9.0						

Elevation reported as ground level in mAHD

Logged by: *EL*
Checked by: *VM*

GROUNDWATER MONITORING WELL

PROJECT: Alcoa WGP Well Install 2020 | **Bore Identification:** *RF138G* | **Sheet:** *1 of 2*

PROJECT #: *3218* | **AOPC:** *Building 35* | **Date Logged:** *04/02/2020*

Project Manager: *JP* | **PROJECT Location:** *Alcoa Wagerup Refinery*

Client: *Alcoa of Australia* | **Zone:** *50* | **Easting:** *398503.556* | **Northing:** *6357566.620*

Drilled by: *DPP* | **Inner Diameter (mm):** *50* | **Elevation (mAHD):** *46.533*

Drill Type: *Geoprobe* | **Drilling Method:** *Direct Push*

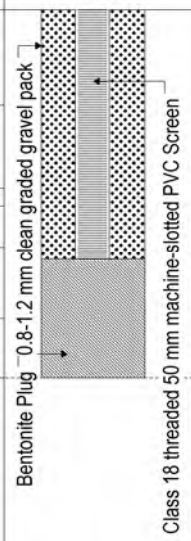
SOIL DESCRIPTION	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	WELL CONSTRUCTION	MOISTURE	pH (pH Units)	COMMENTS
Ground Surface	0.0			Riser Cover			
Sandy Gravelly CLAY Brown with red mottles, lateritic gravels, stiff, high plasticity			SC	Concrete		9.7	
Clayey SAND Brown, fine to medium grained, poorly graded, subangular/subrounded	1.0					9.7	
Sandy Gravelly CLAY Brown with red mottles, lateritic gravels, stiff, high plasticity	2.0		CL		Dry	9.5	
						9.4	
	3.0					8.8	
Clayey SAND Brown, fine to medium grained, poorly graded, subangular/subrounded			SC	Class 18 50 mm PVC Blank		8.8	
	4.0					8.6	
Clayey SAND Pale grey, fine to medium grained, poorly graded, subangular/subrounded						8.8	
	5.0		SC	Bentonite Granules	Moist	8.9	
						8.8	
SAND Pale grey, fine to medium grained, poorly graded, subangular/subrounded	6.0					8.6	
						8.3	
Clayey SAND Pale grey, fine to medium grained, poorly graded, subangular/subrounded	7.0		SC			8.8	
						8.9	
	8.0					8.7	
						8.9	
SAND Pale grey, fine to medium grained, poorly graded, subangular	9.0		SP		Wet	8.7	
						8.7	

Logged by: *EL*
Checked by: *VM*

GROUNDWATER MONITORING WELL

PROJECT: Alcoa WGP Well Install 2020
Bore Identification: *RF138G*
Sheet: *2 of 2*
PROJECT #: *3218*
AOPC: *Building 35*
Date Logged: *04/02/2020*
Project Manager: *JP*
PROJECT Location: *Alcoa Wagerup Refinery*
Client: *Alcoa of Australia*
Zone: *50* **Easting:** *398503.556*
Northing: *6357566.620*
Drilled by: *DPP*
Inner Diameter (mm): *50*
Elevation (mAHD): *46.533*
Drill Type: *Geoprobe*
Drilling Method: *Direct Push*

SOIL DESCRIPTION	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	WELL CONSTRUCTION	MOISTURE	pH (pH Units)	COMMENTS
	10.0					8.9	
Clayey SAND Pale grey, fine to medium grained, poorly graded, subangular/subrounded			SC			8.8	
SAND Pale grey, fine to coarse grained, well graded, subangular	11.0		CL			11.9	
CLAY Grey, very high plasticity, stiff			CL			11.5	
CLAY Grey with red mottles, very high plasticity, stiff	12.0		CL			9.4	
Sandy CLAY Red, very high plasticity, stiff						9.3	
End of Log	13.0						
	14.0						
	15.0						
	16.0						
	17.0						
	18.0						
	19.0						



Elevation reported as ground level in mAHD

Logged by: *EL*
Checked by: *VM*

GROUNDWATER MONITORING WELL

PROJECT: Alcoa WGP Well Install 2020	**Bore Identification:** *RF138S*	**Sheet:** *1 of 1*
PROJECT #: *3218*	**AOPC:** *Building 35*	**Date Logged:** *04/02/2020*
Project Manager: *JP*	**PROJECT Location:** *Alcoa Wagerup Refinery*	
Client: *Alcoa of Australia*	**Zone:** *50* **Easting:** *398503.537*	**Northing:** *6357565.963*
Drilled by: *DPP*	**Inner Diameter (mm):** *50*	**Elevation (mAHD):** *46.540*
Drill Type: *Geoprobe*	**Drilling Method:** *Direct Push*	

SOIL DESCRIPTION	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	WELL CONSTRUCTION	MOISTURE	pH (pH Units)	COMMENTS
Ground Surface	0.0			Riser Cover			
Sandy Gravelly CLAY Brown with red mottles, lateritic gravels, stiff, high plasticity				Concrete		10.1	
Clayey SAND Brown, fine to medium grained, poorly graded, subangular/subrounded	1.0					9.9	
Sandy Gravelly CLAY Brown with red mottles, lateritic gravels, stiff, high plasticity	2.0		CL	Bentonite Granules	Dry	9.2	
				Class 18 50 mm PVC Blank		9.1	
						8.9	
						8.7	
Clayey SAND Brown, fine to medium grained, poorly graded, subangular/subrounded	3.0		SC			8.8	
	4.0					8.6	
Clayey SAND Pale grey, fine to medium grained, poorly graded, subangular/subrounded			SC	0.8-1.2 mm clean graded gravel pack	Moist	8.5	
	5.0			Class 18 threaded 50 mm machine-slotted PVC Screen		8.7	
						8.4	
	6.0					8.3	
SAND Pale grey, fine to medium grained, poorly graded, subangular/subrounded			SP			8.5	
Clayey SAND Pale grey, fine to medium grained, poorly graded, subangular/subrounded	7.0		SC	Bentonite Plug	Wet	8.6	
						8.5	
End of Log	8.0						
	9.0						

Elevation reported as ground level in mAHD

Logged by: *EL*
Checked by: *VM*

GROUNDWATER MONITORING WELL

PROJECT: Alcoa WGP Well Install 2020 | **Bore Identification:** *RF139G* | **Sheet:** *1 of 2*

PROJECT #: *3218* | **AOPC:** *Building 40* | **Date Logged:** *05/02/2020*

Project Manager: *JP* | **PROJECT Location:** *Alcoa Wagerup Refinery*

Client: *Alcoa of Australia* | **Zone:** *50* | **Easting:** *398263.587* | **Northing:** *6357416.161*

Drilled by: *DPP* | **Inner Diameter (mm):** *50* | **Elevation (mAHD):** *46.316*

Drill Type: *Geoprobe* | **Drilling Method:** *Direct Push*

SOIL DESCRIPTION	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	WELL CONSTRUCTION	MOISTURE	pH (pH Units)	COMMENTS
Ground Surface	0.0			Riser Cover			
Sandy Gravelly CLAY Brown with red mottles, lateritic gravels, stiff, high plasticity	1.0		CL	Concrete	Dry	9.3, 9.7, 9.6, 9.0, 9.1	
	2.0			Bentonite Granules		8.9	
Clayey Sand Brown, fine to medium grained, poorly graded, subangular/subrounded	3.0		SC			8.6, 8.6, 8.7	
Sandy Gravelly CLAY Brown with red mottles, lateritic gravels, stiff, high plasticity	4.0		CL			8.7	
Clayey SAND Pale grey, fine to medium grained, poorly graded, subangular/subrounded	5.0		SC		Moist	8.7, 8.6, 8.6, 8.5, 8.6, 8.6, 8.7, 8.7, 8.8, 8.6	
Gravelly SAND Dark brown/black, fine to coarse grained, well graded, subangular/subrounded	6.0		SW				
Clayey SAND Pale grey, fine to medium grained, poorly graded, subangular/subrounded	7.0		SC	Class 18 50 mm PVC Blank			
	8.0						
	9.0						

Logged by: *EL*
Checked by: *VM*

GROUNDWATER MONITORING WELL

PROJECT: Alcoa WGP Well Install 2020 | **Bore Identification:** *RF139G* | **Sheet:** *2 of 2*

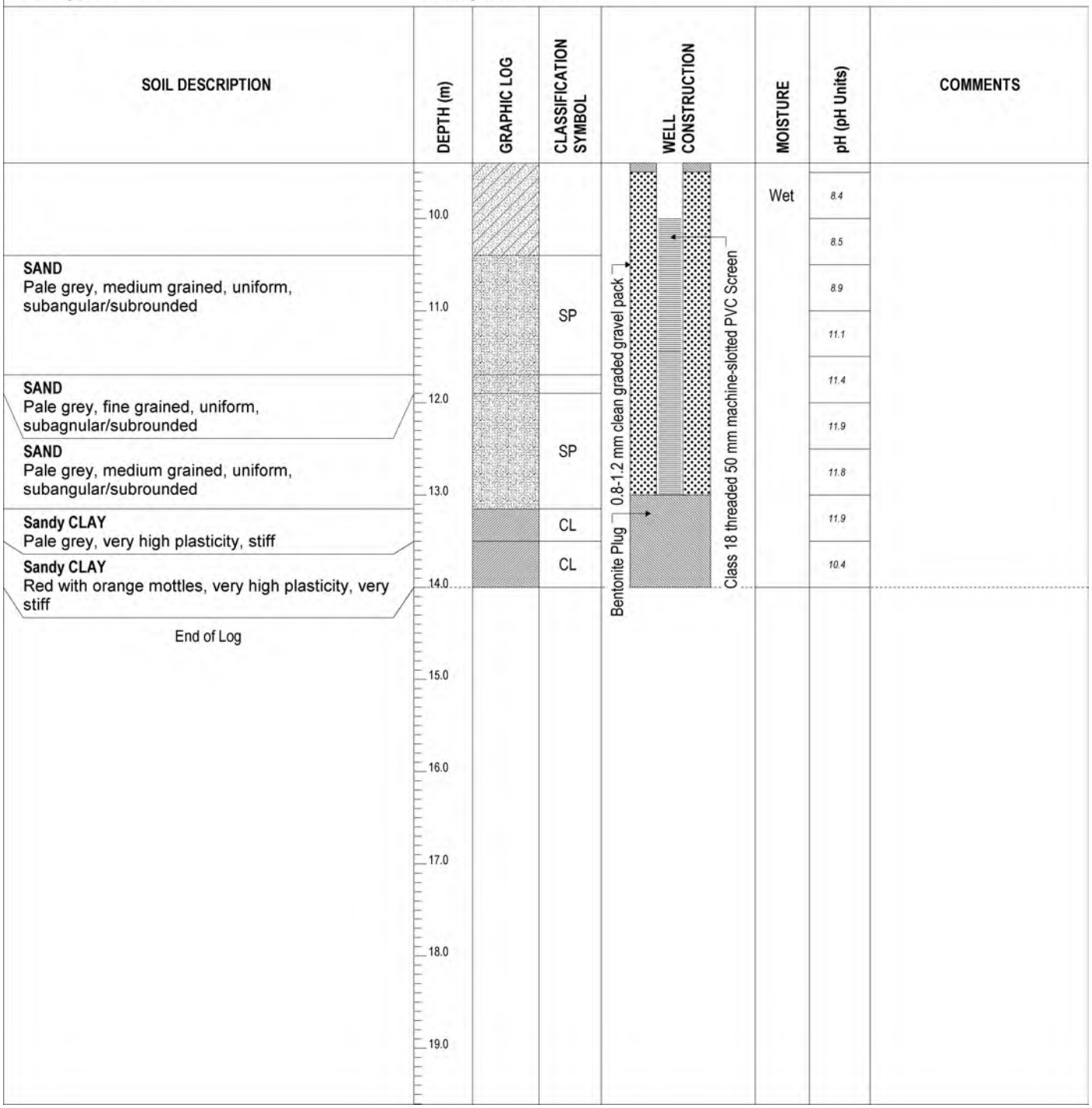
PROJECT #: *3218* | **AOPC:** *Building 40* | **Date Logged:** *05/02/2020*

Project Manager: *JP* | **PROJECT Location:** *Alcoa Wagerup Refinery*

Client: *Alcoa of Australia* | **Zone:** *50* | **Easting:** *398263.587* | **Northing:** *6357416.161*

Drilled by: *DPP* | **Inner Diameter (mm):** *50* | **Elevation (mAHD):** *46.316*

Drill Type: *Geoprobe* | **Drilling Method:** *Direct Push*



Elevation reported as ground level in mAHD

Logged by: *EL*
Checked by: *VM*

GROUNDWATER MONITORING WELL

PROJECT: Alcoa WGP Well Install 2020 | **Bore Identification:** *RF139S* | **Sheet:** *1 of 1*

PROJECT #: *3218* | **AOPC:** *Building 40* | **Date Logged:** *05/02/2020*

Project Manager: *JP* | **PROJECT Location:** *Alcoa Wagerup Refinery*

Client: *Alcoa of Australia* | **Zone:** *50* | **Easting:** *398263.374* | **Northing:** *6357417.002*

Drilled by: *DPP* | **Inner Diameter (mm):** *50* | **Elevation (mAHD):** *46.296*

Drill Type: *Geoprobe* | **Drilling Method:** *Direct Push*

SOIL DESCRIPTION	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	WELL CONSTRUCTION	MOISTURE	pH (pH Units)	COMMENTS
Ground Surface	0.0			Riser Cover			
Sandy Gravelly CLAY Brown with red mottles, lateritic gravels, stiff, high plasticity	1.0		CL	Bentonite Granules; Concrete; 18 50 mm PVC Blank	Dry	8.2	
	2.0					9.6	
	3.0					9.5	
						9.3	
						9.1	
						8.6	
						8.5	
Clayey Sand Brown, fine to medium grained, poorly graded, subangular/subrounded	4.0		SC			8.0	
					Moist	8.0	
Sandy Gravelly CLAY Brown with red mottles, lateritic gravels, stiff, high plasticity	5.0		CL			7.9	
						7.9	
Clayey SAND Pale grey, fine to medium grained, poorly graded, subangular/subrounded	6.0		SC	0.6-1.2 mm clean graded gravel pack	Wet	7.7	
	7.0					6.9	
						7.3	
	8.0			Bentonite Plug; Class 18 threaded 50 mm machine-slotted PVC Screen			
End of Log	9.0						

Elevation reported as ground level in mAHD

Logged by: *EL*
Checked by: *VM*

GROUNDWATER MONITORING WELL

PROJECT: Alcoa WGP Well Install 2020
PROJECT #: *3218*
Project Manager: *JP*
Client: *Alcoa of Australia*
Drilled by: *DPP*
Drill Type: *Geoprobe*

Bore Identification: *RF222G*
AOPC: *Storm Surge Pond*
PROJECT Location: *Alcoa Wagerup Refinery*
Zone: *50* **Easting:** *397801.571*
Inner Diameter (mm): *50*
Drilling Method: *Direct Push*

Sheet: *1 of 2*
Date Logged: *06/02/2020*
Northing: *6357896.533*
Elevation (mAHD): *40.431*

SOIL DESCRIPTION	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	WELL CONSTRUCTION	MOISTURE	pH (pH Units)	COMMENTS
Ground Surface	0.0			Riser Cover			
SAND Brown, fine to medium grained, poorly graded, subangular/subrounded			SP	Concrete	Dry	9.2	
CORE LOSS	1.0						
SAND Brown, fine to medium grained, poorly graded, subangular/subrounded			SP			9.4	
Clayey SAND Brown, fine to medium grained, poorly graded, subangular/subrounded	2.0		SC			8.3	
Sandy Gravelly CLAY Brown with red mottles, lateritic gravels, stiff, high plasticity	3.0		CL			8.0	
Sandy CLAY Pale grey, soft, high plasticity	4.0		SC			8.4	
Clayey SAND Pale grey, fine to medium grained, poorly graded, subangular/subrounded	5.0		SC	Bentonite Granules	Moist	7.6	
	6.0			Class 18 50 mm PVC Blank		6.9	
	7.0					7.3	
	8.0			0.8-1.2 mm clean graded gravel pack	Wet	7.2	
Sandy CLAY Pale grey, soft, high plasticity	9.0		CL			7.8	
						7.7	
						7.8	
						7.9	
						7.9	
						8.1	
						8.1	
						8.4	

Logged by: *EL*
Checked by: *VM*

GROUNDWATER MONITORING WELL

PROJECT: Alcoa WGP Well Install 2020
PROJECT #: *3218*
Project Manager: *JP*
Client: *Alcoa of Australia*
Drilled by: *DPP*
Drill Type: *Geoprobe*

Bore Identification: *RF222G*
AOPC: *Storm Surge Pond*
PROJECT Location: *Alcoa Wagerup Refinery*
Zone: *50* **Easting:** *397801.571*
Inner Diameter (mm): *50*
Drilling Method: *Direct Push*

Sheet: *2 of 2*
Date Logged: *06/02/2020*
Northing: *6357896.533*
Elevation (mAHD): *40.431*

SOIL DESCRIPTION	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	WELL CONSTRUCTION	MOISTURE	pH (pH Units)	COMMENTS
Sandy Gravelly CLAY Red, stiff, very high plasticity	10.0					7.2	
Sandy CLAY Pale grey, high plasticity, soft	11.0		CL			8.4	
Sandy Gravelly CLAY Red, very high plasticity, stiff			CL			8.4	
Sandy CLAY Pale grey, high plasticity, soft	12.0		CL	Bentonite Plug		8.4	
Sandy Gravelly CLAY Red, very high plasticity, stiff				Class 18 threaded 50 mm machine-slotted PVC Screen		7.5	
End of Log	13.0						
	14.0						
	15.0						
	16.0						
	17.0						
	18.0						
	19.0						

Elevation reported as ground level in mAHD

Logged by: *EL*
Checked by: *VM*

GROUNDWATER MONITORING WELL

PROJECT: Alcoa WGP Well Install 2020	**Bore Identification:** *RF222S*	**Sheet:** *1 of 1*
PROJECT #: *3218*	**AOPC:** *Storm Surge Pond*	**Date Logged:** *06/02/2020*
Project Manager: *JP*	**PROJECT Location:** *Alcoa Wagerup Refinery*	
Client: *Alcoa of Australia*	**Zone:** *50* **Easting:** *397801.194*	**Northing:** *6357895.840*
Drilled by: *DPP*	**Inner Diameter (mm):** *50*	**Elevation (mAHD):** *40.424*
Drill Type: *Geoprobe*	**Drilling Method:** *Direct Push*	

SOIL DESCRIPTION	DEPTH (m)	GRAPHIC LOG	CLASSIFICATION SYMBOL	WELL CONSTRUCTION	MOISTURE	pH (pH Units)	COMMENTS
Ground Surface	0.0			Riser Cover			
SAND Brown, fine to medium grained, poorly graded, subangular/subrounded				Bentonite Granules	Dry	8.8	
CORE LOSS	1.0			Concrete			
SAND Brown, fine to medium grained, poorly graded, subangular/subrounded			SP	Class 18 50 mm PVC Blank		9.2	
Clayey SAND Brown, fine to medium grained, poorly graded, subangular/subrounded	2.0		SC			9.0	
						7.9	
						8.1	
Sandy Gravelly CLAY Brown with red mottles, lateritic gravels, stiff, high plasticity	3.0		CL			8.0	
Sandy CLAY Pale grey, soft, high plasticity			CL	0.6-1.2 mm clean graded gravel pack		7.6	
Clayey SAND Pale grey, fine to medium grained, poorly graded, subangular/subrounded	4.0				Moist	8.1	
						8.3	
	5.0		SC			7.8	
					Wet	8.0	
	6.0					8.1	
						8.0	
	7.0			Bentonite Plug			
End of Log				Class 18 threaded 50 mm machine-slotted PVC Screen			
	8.0						
	9.0						

Elevation reported as ground level in mAHD

Logged by: *EL*
Checked by: *VM*