

Surface water background assessment for the Quindanning and Hotham North Extended Mining Areas

FINAL REPORT

11th May 2023

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Alluvium recognises and acknowledges the unique relationship and deep connection to Country shared by Aboriginal and Torres Strait Islander people, as First Peoples and Traditional Owners of Australia. We pay our respects to their Cultures, Country and Elders past and present.

Artwork by Melissa Barton. This piece was commissioned by Alluvium and tells our story of caring for Country, through different forms of waterbodies, from creeklines to coastlines. The artwork depicts people linked by journey lines, sharing stories, understanding and learning to care for Country and the waterways within.

This report has been prepared by Alluvium Consulting Australia Pty Ltd for CDM Smith under the contract titled 'Worsley Alumina Surface Water Assessment'.

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1 Introduction

South32 Worsley Alumina (hereafter referred to as South32) are the current operators of the Worsley Bauxite – Alumina Project, located near to Boddington, Western Australia. In 2005, South32 were granted approval to expand their mining operation to an additional five mining areas. Prior to commencing mining operations, however, additional environmental studies within the extended mining areas were required.

This report provides an assessment of surface water quantity and quality at two of the five proposed mine expansion areas, namely, the Hotham North Extension and East Quindanning areas (Figure 1). In addition to the assessment of the current conditions, an impact assessment is undertaken, and future monitoring sites proposed to ensure any changes to water quantity and quality may be characterised following the commencement of mining operations in these areas.

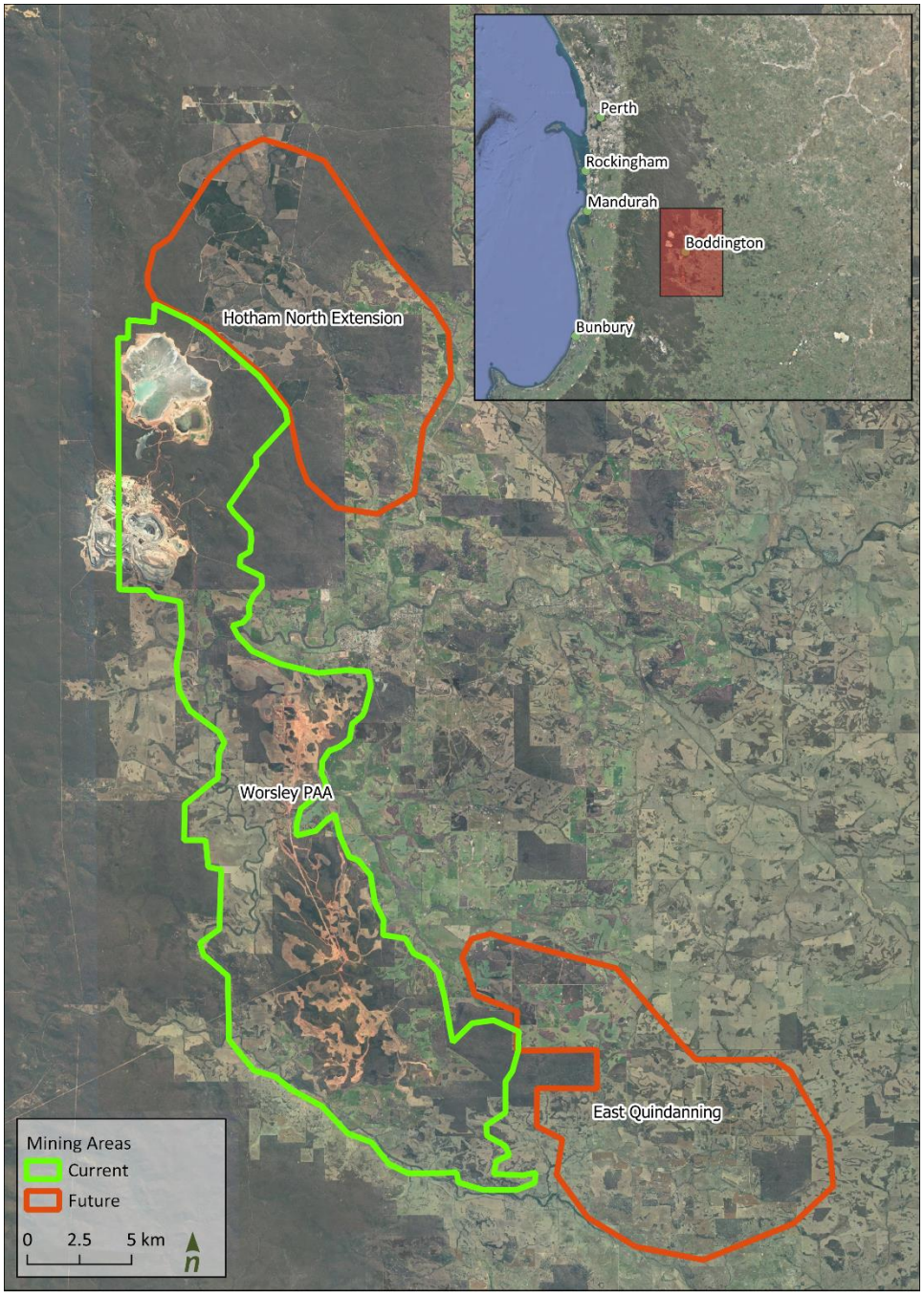


Figure 1. *Approximate location of current and extended mining areas considered in this study.*

1.1 Catchments and Streams

The current and expanded mining areas are primarily situated over catchments that drain into the greater Murray River catchment (Figure 2). A majority of the current mining area is seen to extend principally within the Hotham and Williams catchments, while a small portion is located within the South Dandalup catchment. The future East Qunindanning mining area is situated over both the Hotham and Williams catchments, whereas the Hotham North Extension lies predominantly within the Hotham catchment. Although there are small portions of this mining area that lie within the headwaters of the South Dandalup and Serpentine catchments. It must be noted that there is some uncertainty around the boundaries of the current and future mining extents as they have not been precisely delineated but have rather been provided as indicative areas.

It is also important to note that runoff from the South Dandalup and Serpentine catchments is intercepted by the South Dandalup Dam and Serpentine Dams, respectively, both of which are sources of drinking water. As such, these catchments have stringent catchment management plans and require water resource protection. Mining operations in these catchments would therefore need to comply with more stringent monitoring and regulations.

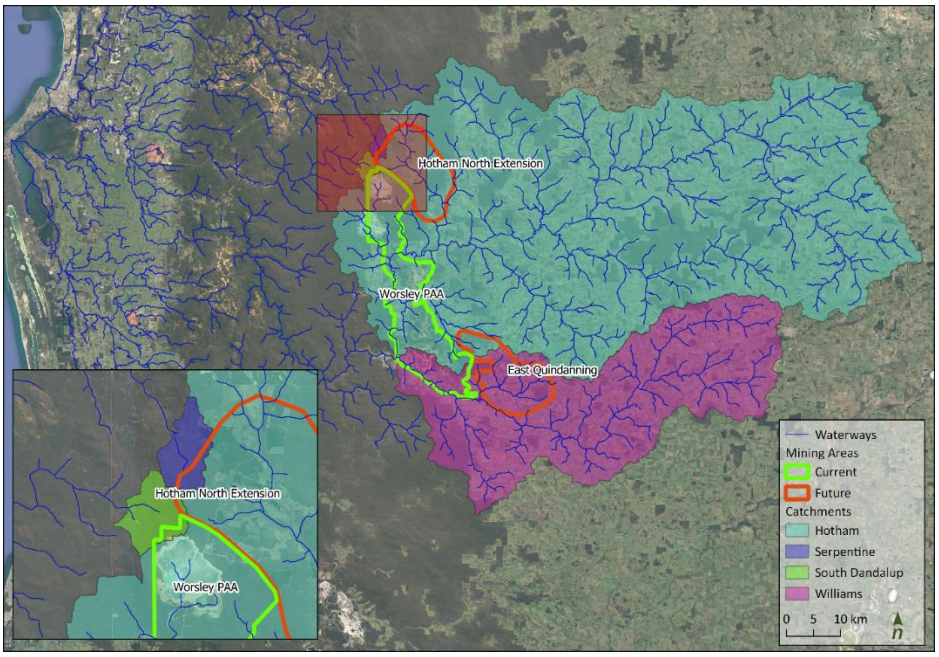


Figure 2. *Proposed mining extents areas over relevant drainage catchments.*

1.2 Legislative Context

Inland waters are covered and considered by the Environmental Protection Authority (EPA) through the *Environmental Factor Guideline: Inland Waters EPA, Western Australia (2018)*, which provides commentary on how inland waters should be considered in Environmental Impact Assessments. Clear quantitative objectives for flows and water quality within the state's waterways are not provided within the guideline.

Rather, water quality in the region should be evaluated against the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC & ARMCANZ, 2000). Trigger values are provided to protect aquatic ecosystems, for irrigation and general water use, as well as for stocking use. As the current land use over the future mining areas is predominantly made up of forest and agricultural uses (mix of stocking and cropland), it may be necessary to ensure water quality from the future mining activities in these subcatchments complies with these guideline values.

Additional regulations are in place for the drinking water catchments of South Dandalup and Serpentine Dam. These include catchment management plans for these catchments, which are intended to assist state and local government with land use planning decisions in these catchments (Department of Environment, 2005 and 2007). Drinking water within these dams should also comply with the Australian Drinking Water Guidelines (NHMRC & NRMMC, 2011).

2 Existing Monitoring and Impact Assessment

2.1 Available Monitoring Data

Daily water quantity data was sourced from the Bureau of Meteorology (BOM) (http://www.bom.gov.au/climate/data/) as rainfall, and from the Water Information Reporting (WIR) portal (https://wir.water.wa.gov.au/) as streamflow (Table 1), in the relevant catchments (Figure 3). Some rainfall gauges outside of the relevant catchments were also assessed for comparison. No site-specific monitoring data was available for the existing mining extents to be used in this analysis and as such, publicly available water quantity and quality monitoring data was relied upon.

Table 1. Stream and rainfall gauge information.

Gauge name and ID	Gauge ID	Source	Type	Length of record
Bannister	9507	BOM	Rainfall gauge	112 years
Dwelingup	9538	BOM	Rainfall gauge	88 years
Marradong	9575	BOM	Rainfall gauge	113 years
Oakland	10620	BOM	Rainfall gauge	104 years
Culford	9769	BOM	Rainfall gauge	53 years
Williams	10655	BOM	Rainfall gauge	107 years
Mooradung Brook Tributary at Tunnel Road	614011	WIR	Streamflow gauge	58 years
Williams River at Saddleback Road Bridge	614196	WIR	Streamflow gauge	58 years
Hotham River at Marradong Road Bridge	614224	WIR	Streamflow gauge	24 years

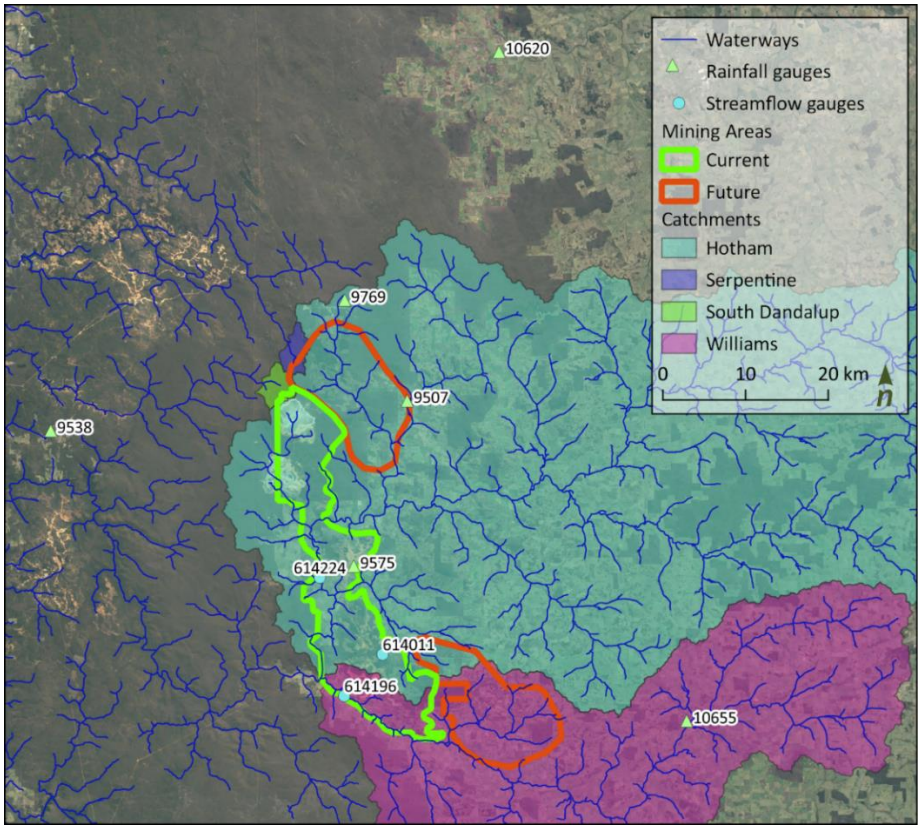


Figure 3. *Location of assessed rainfall and streamflow gauges over current and future mining areas.*

Relevant water quality information was sourced from the WIR portal (Table 2). All the gauges except for one were situated in the Hotham catchment (Figure 4). A range of water quality constituents were monitored at these sites, though there was more detailed monitoring data for the Hotham River (Gauge ID: 614224) and for the Williams River (Gauge ID: 614196) sites.

Table 3 presents a list of all water quality constituents assessed and at which gauges they were monitored. Trigger values are shown for physical and chemical indicators (nutrients, pH, and dissolved oxygen) which were retrieved from the Australian and New Zealand Guidelines (ANZG) (ANZECC & ARMCANZ, 2000) for slightly disturbed ecosystems in south-west Australia.

Table 2. Water quality gauge information.

Gauge name	Gauge ID	Data source	Length of record
Mooradung Brook Tributary - Tunnel Road	614011	WIR	1975-1992
Mooradung Brook Tributary - Bee Farm Road	614012	WIR	1975-1992
Thirty Four Mile Brook - Boddington Gold Mine	614058	WIR	1987-1994
Thirty Four Mile Brook – Hedges	614061	WIR	1988-1996
Hotham River – Boddington	614106	WIR	2001
Crossman River – Rivendale	614125	WIR	2007-2021
Hotham River - Marradong Rd Bridge	614224	WIR	1965-2022
Williams River - Saddleback Rd Bridge	614196	WIR	1966-2022

Table 3. List of water quality constituents considered and at what sites they were assessed. Here, river gauges indicate only the two sites on the main rivers (Hotham River Gauge ID: 614224 and Williams River Gauge ID: 614196). Where relevant, trigger values are presented with the relevant source.

Constituent	Units	Gauges Assessed	Trigger value	Source
Total Alkalinity (CaCO3)	(ug/L)	All gauges	-	-
Soluble Calcium (Ca sol)	(ug/L)	All gauges	-	-
Soluble Chlorine (Cl sol)	(ug/L)	All gauges	-	-
Colour	(Hu)	All gauges	-	-
Conductivity	(uS/cm)	All gauges	-	-
Total Hardness	(ug/L)	All gauges	-	-
Total Potassium (K tot)	(ug/L)	All gauges	-	-
Soluble Magnesium (Mg sol)	(ug/L)	All gauges	-	-
Soluble Sodium (Na sol)	(ug/L)	All gauges	-	-
Total Nitrogen (TN)	(ug/L)	Rivers gauges	<450	ANZG
Total Kjeldahl Nitrogen (TKN)	(ug/L)	Rivers gauges	-	-
NH4-N	(ug/L)	Rivers gauges	<60	ANZG
NOx-N	(ug/L)	Rivers gauges	<200	ANZG
DO Saturation	(%)	Rivers gauges	>90	ANZG
DO concentration	(ug/L)	Rivers gauges	-	-
Total Phosphorus (TP)	(ug/L)	Rivers gauges	<20	ANZG
Orthophosphate (PO4-P)	(ug/L)	Rivers gauges	<10	ANZG
pH	-	All gauges	6.5 – 8.0	ANZG
Salinity	ppt	Rivers gauges	-	-
Silicon Dioxide (SiO2)	(ug/L)	All gauges	-	-
Sulfate (SO4)	(ug/L)	All gauges	-	-
Total dissolved salts (TDSalts)	(mg/L)	All gauges	-	-
Total dissolved solids (TDSolids)	(mg/L)	Rivers gauges	-	-
Temperature	(deg C)	All gauges	-	-
Turbidity	(NTU)	All gauges	-	-

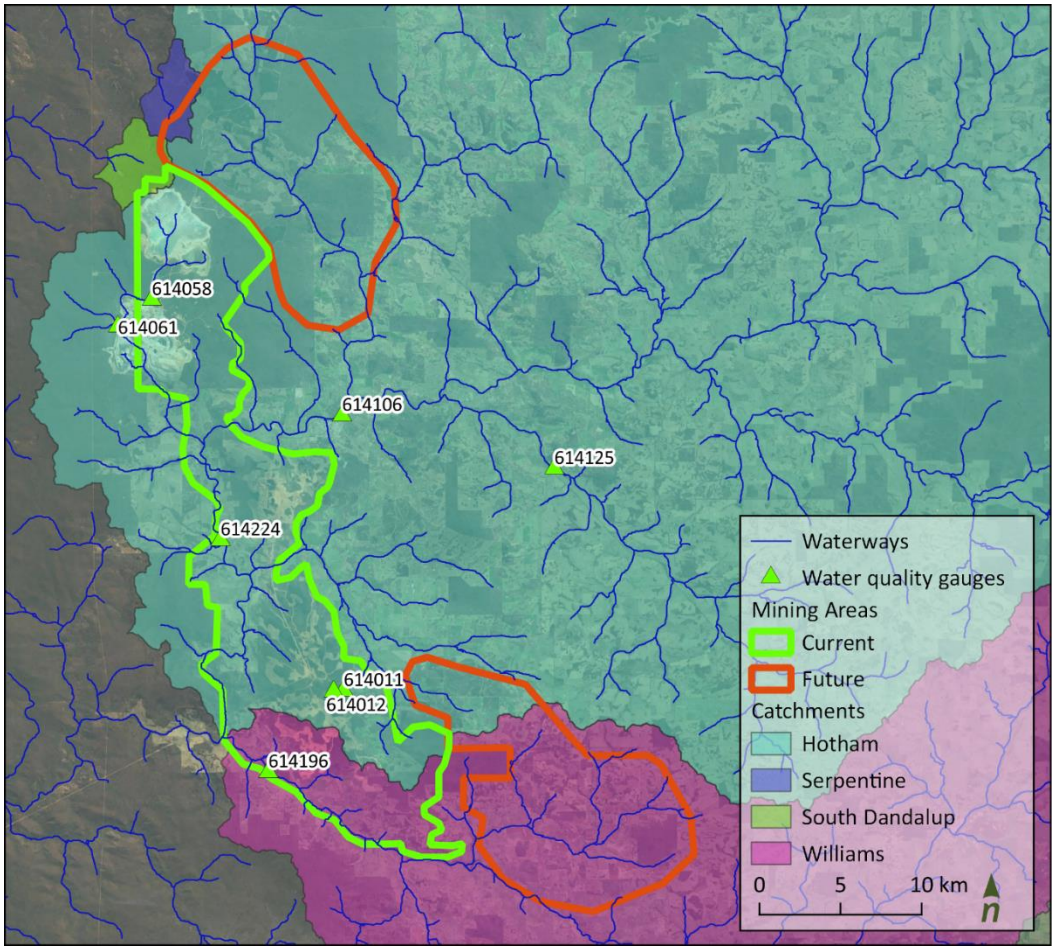


Figure 4. *Location of assessed water quality gauges over current and future mining areas.*

2.2 Water Quantity

Trend Analysis

Understanding continual changes in climate observed over the last 30 years throughout south-west Western Australia is the first step in surface water assessment for the proposed mining extension. For this purpose, we have analysed trends in rainfall, and streamflow, at relevant rainfall and streamflow gauging stations.

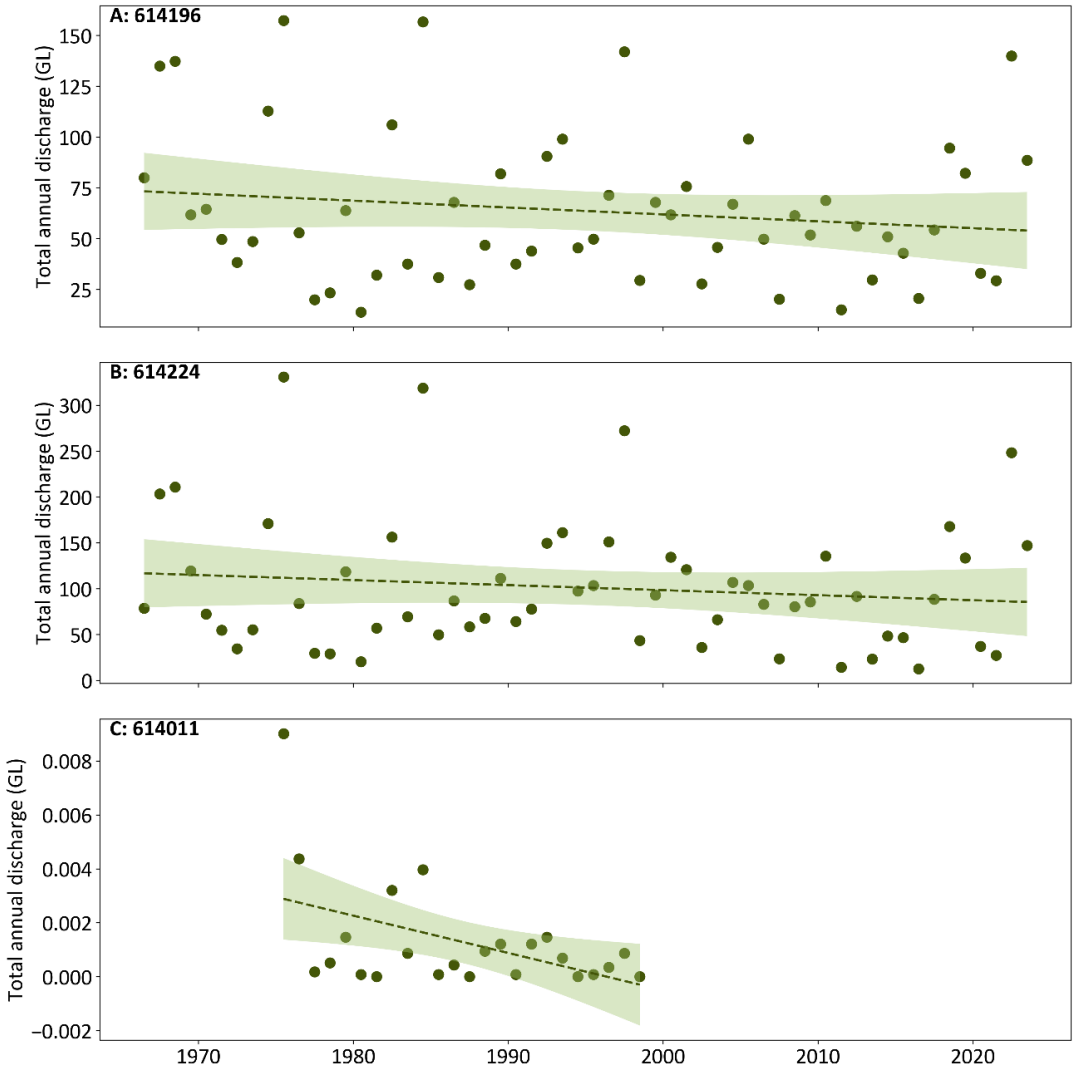
Daily rainfall data collected at stations in the Hotham catchment (Bannister (112 years), Marradong (113 years), Oakland (104 years), Culford (53 years)), and the Williams catchment (Williams (107 years)) were aggregated to yearly data (Figure 6). Additionally, the Dwellingup gauge (88 years) was considered in the analysis. Any years in the record with less than 200 days of monitoring data were removed from the analysis to avoid introducing skewed data, and thus potential outliers.

All gauges except for the Culford gauge show a clear downward trend in rainfall over the historic record. The downward trend is especially noticeable after 1970 (Figure 6 (Marradong, Dwelingup)). The downward trend is statistically significant for all rainfall gauges ($p < 5\%$), except for the Culford and Williams gauge, which indicates that rainfall may be stationary at the Culford and Williams gauges. However, the amount of data recorded at the Culford rainfall gauge was much less than the other gauges, with recording starting in 1967 when a decrease in rainfall was observed in all other gauges.

The observed decrease in rainfall across the region has led to decreased streamflow at various streams in the Hotham and Williams catchments (Figure 5). The decrease in streamflow is more pronounced than that seen for rainfall, indicating a non-linear response. This relates to the step change in the catchment's response to rainfall as a result of the catchment drying out. The drier catchment leads to more rainfall percolating into the ground and being lost to evapotranspiration, causing less runoff even for the same levels of rainfall previously observed.

A similar response has been observed in Victorian catchments following the Millennium drought (Peterson et al., 2021).

It is important to note that while there have been decreases in annual rainfall and streamflow, the intensity of extreme rainfall events has been increasing, with potential consequences for load event load pollutant delivery. Additionally, the seasonality of rainfall has a shift towards higher rainfall during the summer dry season and lower rainfall during the winter wet season (Raut et al., 2014).



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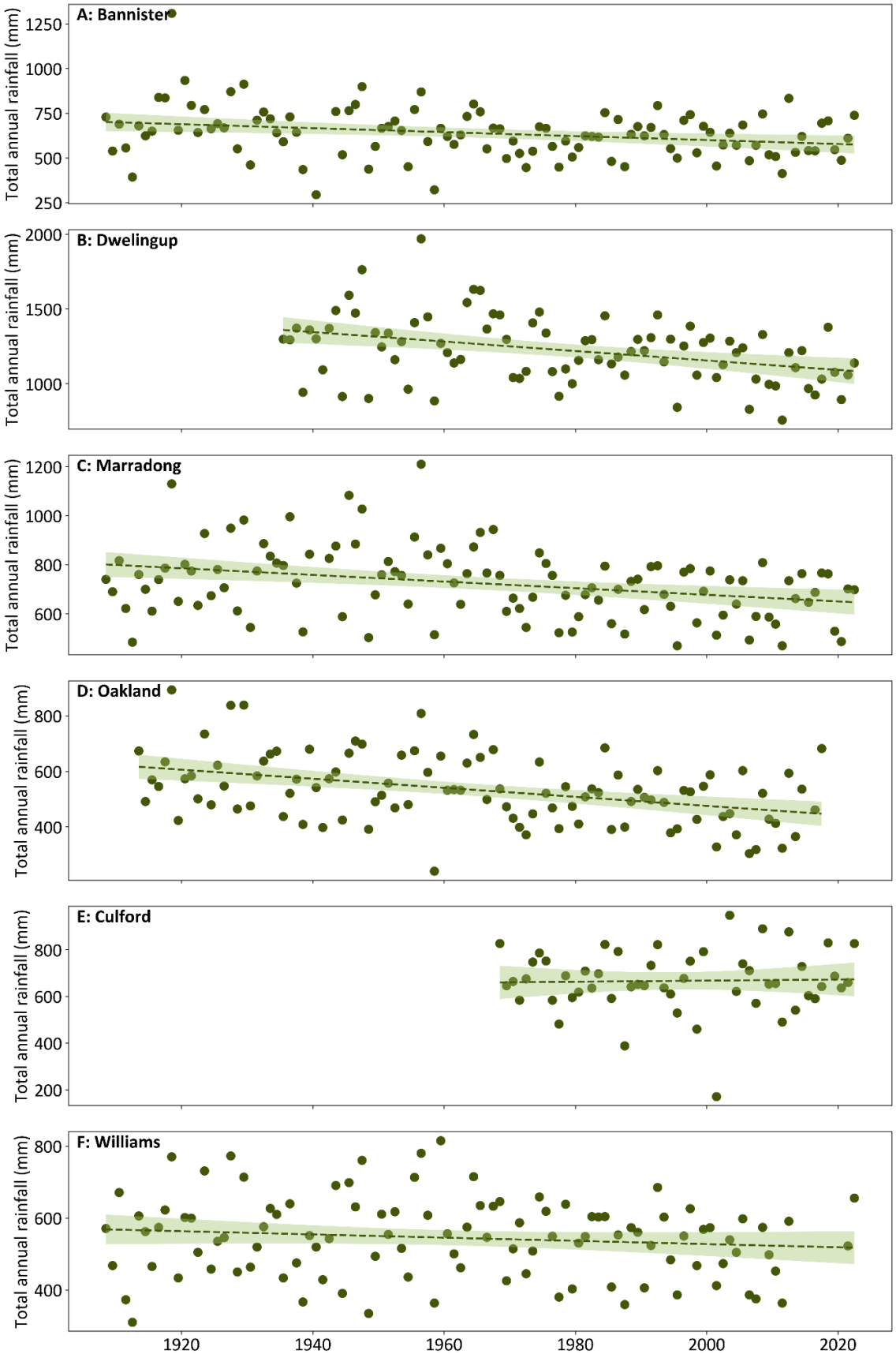

Figure 6. *Rainfall trends at the Bannister (A), Marradong (C), Oakland (D), and Culford (E) rain gauges in the Hotham catchment. In the Williams catchment, the Williams rainfall gauge (F) was analysed, and the Dwelingup gauge (B) was added for comparison.*

Climate Change

Assessment of climate change projections over the mid- and long-term show that the decreasing trend observed in the hydrologic records in the Hotham and Williams catchments is likely to continue in the future under a changing climate (Department of Water, 2015). Predicted percentage changes to rainfall and potential-evapotranspiration (PET) across south-west Western Australia are presented in Table 4 across four future time periods. Scenarios representing 'dry', median, and 'wet' modelling results are presented. Rainfall is seen to decrease regardless of the scenario selected across all future time periods. The largest decreases are reported by the end of the century under the dry scenario. At the same time, PET is seen to increase across all scenarios and time periods.

A non-linear response between rainfall and streamflow was noted in the historical trend analysis, with a more pronounced decreasing trend for streamflow shown. Under climate change, the combination of decreased rainfall and increased PET will act synergistically to amplify the decreases to streamflow, further decreasing surface water flows. This will increase the number of no flow days for the region's ephemeral streams (Barron et al., 2012). On the other hand, the intensity of extreme rainfall events may increase in the future which potentially increases the risk of inundation and risk of exceeding water quality targets after extreme rainfall events.

Table 4. Percentage change in rainfall and potential-evapotranspiration (Department of Water, 2015) in four future time periods compared to a baseline period (1961-1990).

	Median percentage change to rainfall (%)			Median percentage change to potential-evapotranspiration (%)		
year	Dry	Median	Wet	Dry	Median	Wet
2030	-14%	-5%	-2%	3%	2%	3%
2050	-25%	-9%	-4%	5%	3%	5%
2070	-36%	-13%	-5%	8%	5%	6%
2100	-47%	-17%	-7%	10%	6%	9%

2.3 Water Quality

Water quality monitoring sites situated within subcatchments impacted by mining (Gauge IDs: 614058, 614061, 614012, and 614011) are shown in Figure 7, Figure 8, and Figure 9. These sites appear to have lower pollutant concentrations for most of the assessed water quality constituents when compared to riverine monitoring site (Gauge IDs: 614224 and 614196) except for turbidity, which was higher at the mining impacted sites compared to the riverine. Notably, riverine water quality was considerably more saline, with higher electrical conductivity and total dissolved salt values recorded. River sites were also subject to considerably higher concentrations of major cations and anions (Sulphate, chloride, carbonate, calcium, magnesium, and potassium), while the physical indicators assessed (pH and temperature) were generally very similar between all sites.

It is important to note that the length of the monitoring record varied between the gauges assessed (Table 2), with a much longer period of monitoring recorded for the riverine sites compared to the local subcatchments. There was often limited data available for many of the gauges as seen with the number of samples taken (Figure 7 to Figure 9).

There was no monitoring data available for nutrients, heavy metals, metalloids, and dissolved oxygen at the mining impacted sites. Nutrient and dissolved oxygen concentrations were available at the riverine sites as presented in Figure 10, but heavy metals and metalloid concentrations were still lacking from the publicly available monitoring data.

The Hotham and Williams River are shown to have very similar concentrations of nutrients, dissolved oxygen, and salinity (Figure 10). TN and TP at these sites often exceeded the trigger values for slightly disturbed ecosystems in south-west Australia.

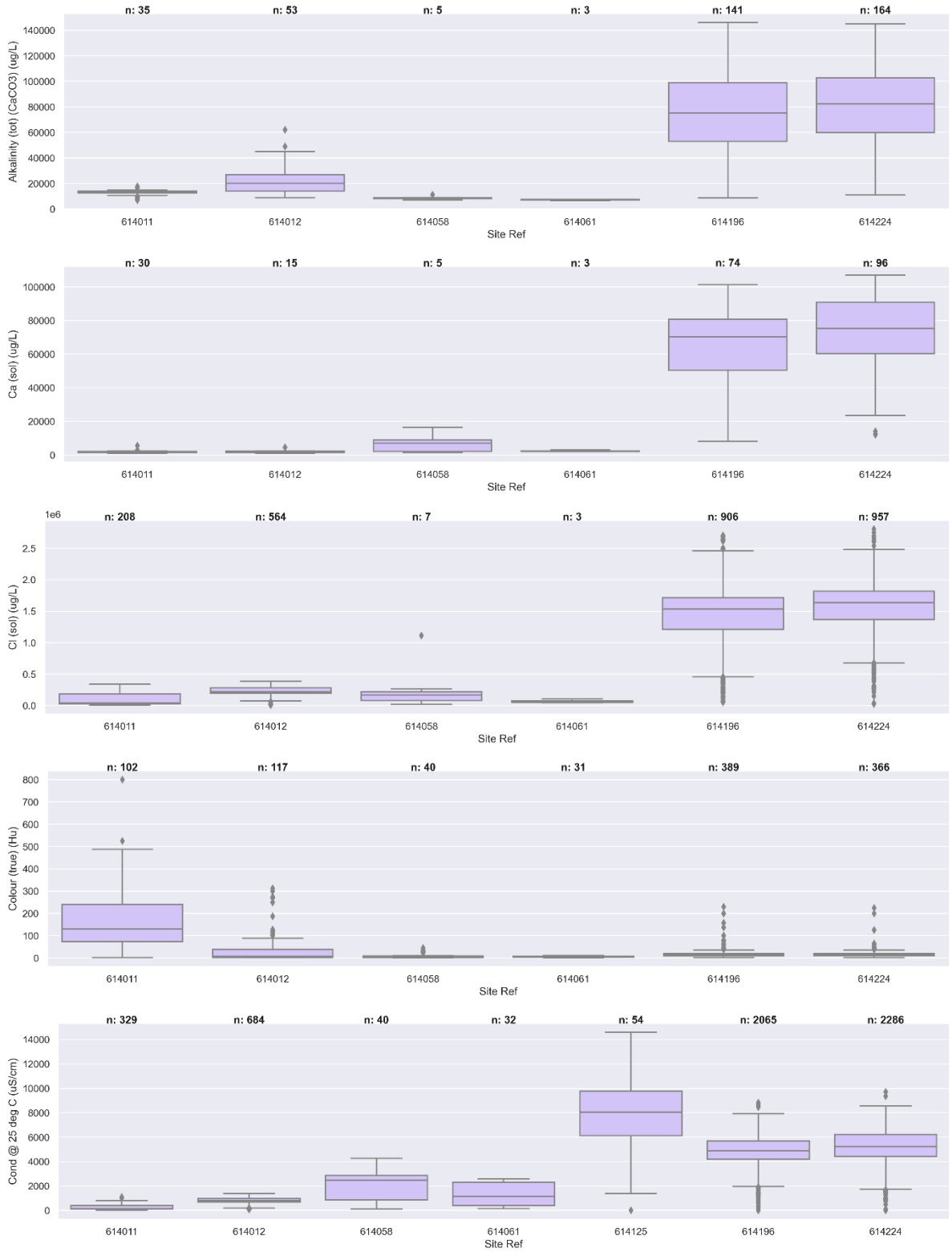

Figure 7. *Observed water quality values (with number of observations) for total alkalinity, soluble calcium, soluble chlorine, Colour, and conductivity at all gauges assessed.*

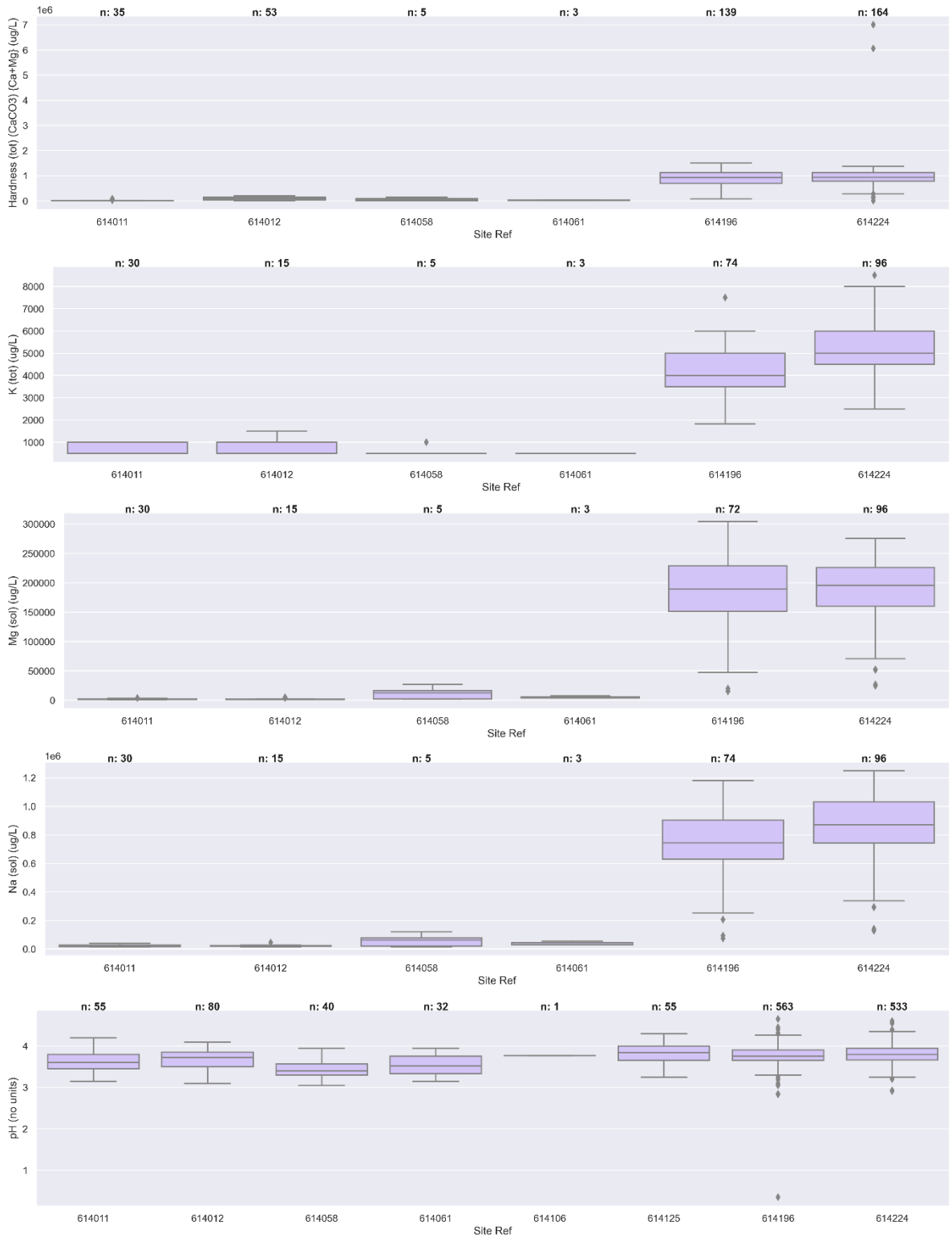

Figure 8. *Observed water quality values (with number of observations) for total hardness, total potassium, soluble magnesium, soluble sodium, and pH at all gauges assessed.*

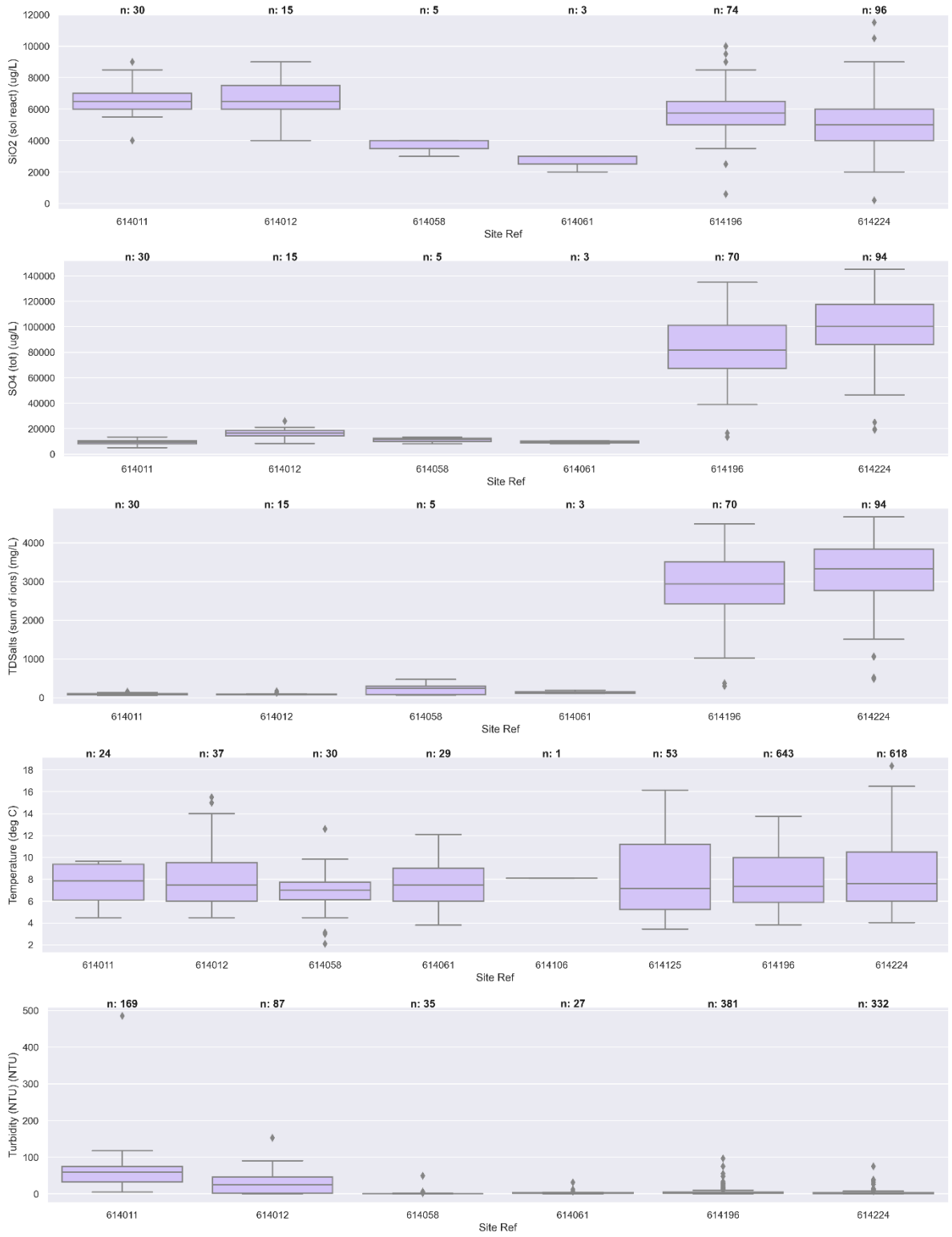

Figure 9. *Observed water quality values (with number of observations) for silicon dioxide, sulphur, total dissolved salts, temperature, and turbidity at all gauges assessed.*

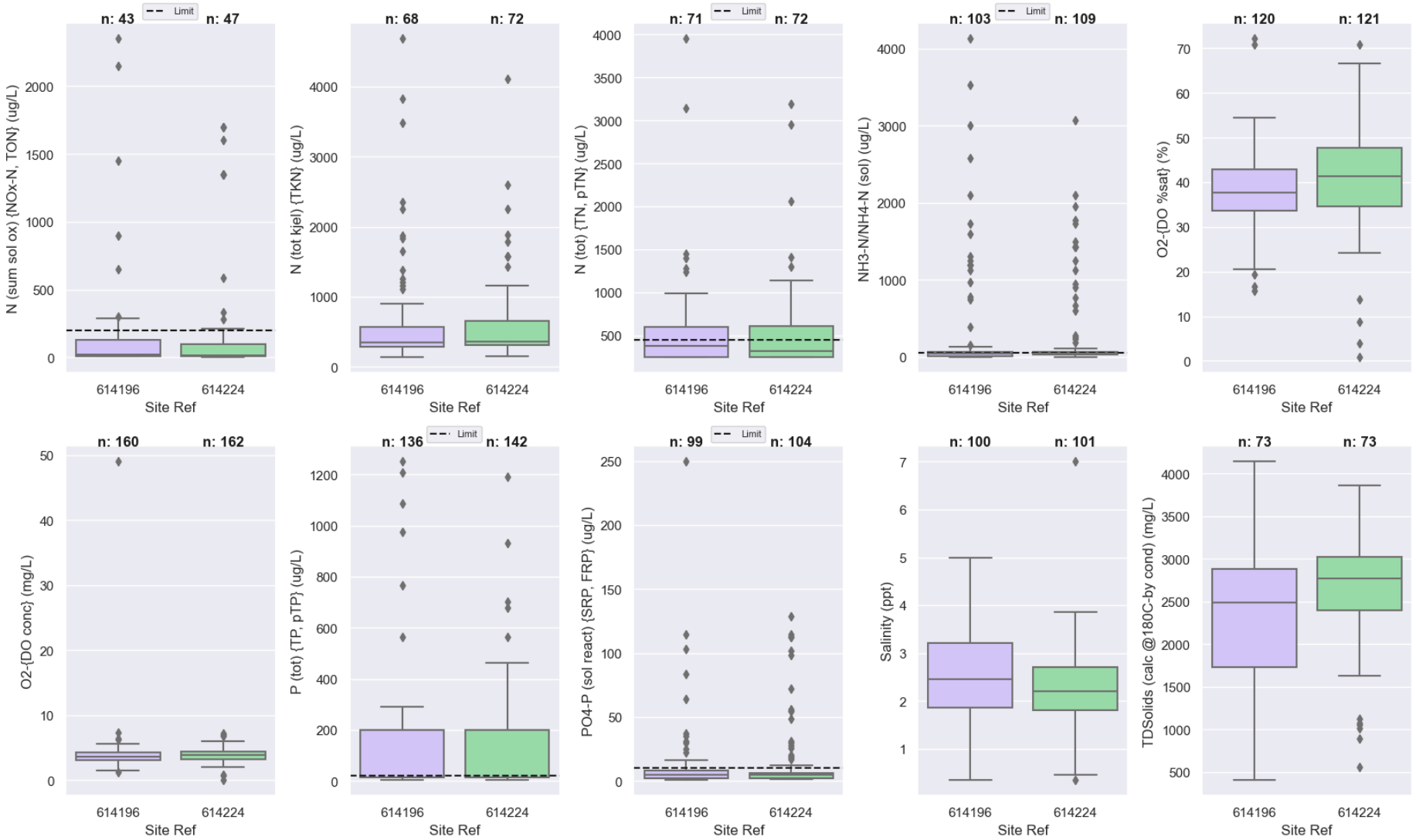

Figure 10. *Observed water quality values (with number of observations) for oxidised nitrogen, total Kjeldahl nitrogen, total nitrogen, ammonia, oxygen (saturation and concentration), total phosphorus, orthophosphate, salinity, and total dissolved solids at the riverine gauges assessed. Black dotted lines show the trigger values (ANZECC & ARMCANZ, 2000).*

2.4 Impact assessment

The available monitoring data has been used to develop an understanding of the historic climatic, streamflow, and water quality conditions within the existing and future mining sites. Available monitoring from mining impacted subcatchments suggests that water is of a better quality for all constituents assessed except for turbidity (sediments) compared to the receiving water at the Hotham and Williams River sites.

Available water quality monitoring data from the mining impacted subcatchments is, however, limited having occurred between 1975 and 1996. The scale of mining during this period over the region is not known and it would be preferential if further monitoring data could be collected from these sites to better ascertain current conditions. While it seems apparent that water quality from these subcatchments (at least prior to 1996) was better than that from the rivers, it is not known whether it has degraded compared to similar non-impacted subcatchments. Comparisons between impacted subcatchments and riverine monitoring sites are difficult as the riverine site is subject to the influence from the whole upper catchment, which primarily consists of agricultural land use and masks the influence from the tributary streams, while the mining sites appear to be mostly forested (at least prior to mining). Forested catchments have much improved water quality compared to agricultural catchments. Future monitoring regimes of mining activities ought to account for this by implementing an impact and control monitoring regime to allow for the changes as a result of mining activities to be better characterised.

To date most of the existing mining activities have occurred in forested catchments, however, future mining activities will occur over agricultural areas as well, especially in the Quindanning East area. Water quality in these areas should be maintained to a similar standard such that it may still be used for agriculture and stock. Most of the trigger values for stock relate to heavy metals and metalloids, which have not been measured as part of the historic monitoring regime, making it impossible to discern if mining activities have had any impact on these constituents. Future monitoring regimes need to take this into consideration and monitor these constituents in order to determine the impacts.

Portions of the Hotham North Expansion mining area overlap with the headwaters of the Serpentine and South Dandalup drinking water catchments. Any mining activities in these catchments could impact on these drinking water dams and would therefore need to comply with regulations to ensure water resource protection. If possible, it would be recommended that mining in these areas be avoided.

3 Proposed Monitoring Regime

Given the constraints of the current monitoring data, we propose a water quantity and quality monitoring regime be set up, which focuses on the future mining areas. A control-impact approach is proposed, which will allow for comparisons between sites that are impacted by mining activities and those that are not. Both sites will be subject to similar climatic conditions and land use prior to mining, allowing for the impacts of the mining activities to be discerned through comparison. The monitoring regime should begin prior to the commencement of the mining activities such that the pre-existing baseline conditions of the subcatchment (prior to mining) can be established. Collection of monitoring data before and after mining, and from a control and impact site will allow for implementation of statistical analyses to quantify the changes as a result of mining (e.g. Before After Control Impact (BACI) design). A list of the proposed variables to be monitored is provided in Table 5. Importantly, the list of constituents to be monitored includes both heavy metals and metalloids, which have not been monitored in the existing data.

Table 5. Recommended parameters to be monitored for at the proposed monitoring sites.

Type	Variables to monitor
Water quantity	Streamflow
Nutrients	Total nitrogen and total phosphorus
Sediments	Turbidity and total suspended solids
Heavy metal	Cadmium, chromium, copper, nickel, lead, and zinc
Metals and metalloids	Aluminium, iron, and manganese
Physical	Total dissolved solids, temperature, dissolved oxygen, and pH
Major cations and anions	Sulphate, chloride, carbonate, calcium, magnesium, and potassium

The location of the proposed monitoring sites are presented in Figure 11 and are tabulated in Table 6. The selected sites have been positioned near to main roads (where possible) to ensure that they are easily accessible. Further monitoring of the existing mine sites is also recommended (Gauge IDs: 614058 and 614011) to better ascertain the current conditions, though not required.

There exists a small portion of the current and future mining extents that overlaps with the drinking water catchments of the Serpentine and South Dandalup Dams. Although there is some uncertainty regarding these extents given the rough delineation between these areas. Should mining activities take place within these catchments there would need to be a similar monitoring regime set up for these catchments with additional monitoring sites required.

Table 6. Details of the proposed monitoring sites.

Name	Site type	Mining Area	Latitude	Longitude
Warrening Brook at Punjarra Williams Rd	Impact	East Qunindanning	-33.033	116.564
Unnamed Creek near to Chalk Brook Rd	Impact	Hotham North Extension	-32.697	116.466
Mungarra Creek at Norwood Rd	Control	East Qunindanning	-33.078	116.532
Bannister River at Albany Highway	Control	Hotham North Extension	-32.678	116.519

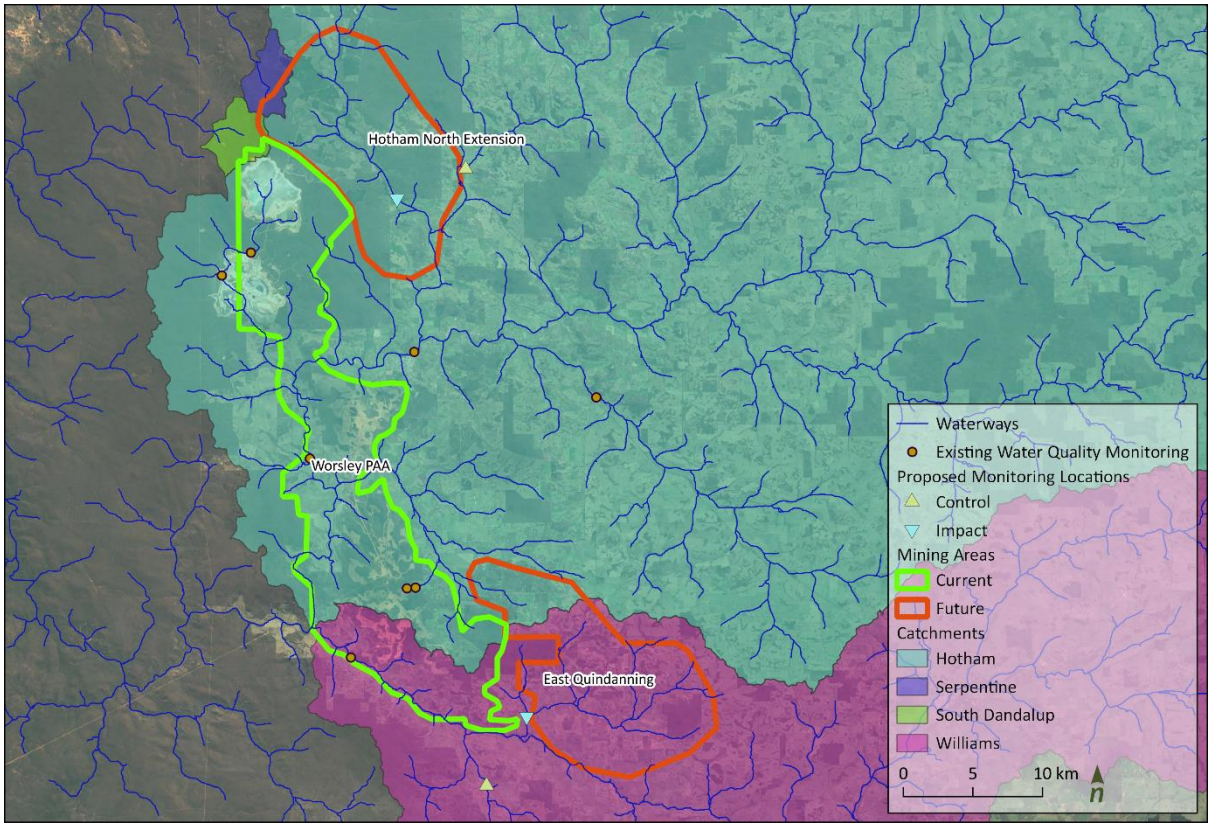

Figure 11. *Proposed location of future water quality monitoring gauges.*

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