APPENDIX 7

HYDROGEOLOGICAL AND HYDROLOGY ASSESSMENTS

7A: AQ2 2020a - HYDROGEOLOGICAL ASSESSMENT
7B: AQ2 2019a - SURFACE WATER ASSESSMENT
7C: AQ2 2020b - SITE WATER BALANCE
7D: AQ2 2019b - SURFACE WATER DISCHARGE ASSESSMENT
7E: AQ2 2020c – DRAFT GROUNDWATER OPERATING STRATEGY
APPENDIX 7A

AQ2 2020a - HYDROLOGICAL ASSESSMENT
YALYALUP MINERAL SANDS PROJECT
Hydrogeological Assessment

Prepared for
DORAL MINERAL SANDS

May 2020
# TABLE OF CONTENTS

1 INTRODUCTION ........................................................................................................... 1

2 PHYSICAL SETTING .................................................................................................... 3
   2.1 Location and Landform .......................................................................................... 3
   2.2 Climate and Rainfall ............................................................................................ 3

3 HYDROLOGY ................................................................................................................ 5
   3.1 Regional Water Courses ...................................................................................... 5
   3.2 Local Water Courses ........................................................................................... 6
   3.3 Local Surface Water Quality ............................................................................... 6

4 GEOLOGY .................................................................................................................... 9

5 COLLECTION OF SITE-SPECIFIC HYDROGEOLOGICAL DATA ................................ 11
   5.1 Mineral Exploration Drilling ............................................................................... 11
   5.2 Drilling and Bore Construction .......................................................................... 11
   5.3 Hydraulic Testing ................................................................................................ 13
   5.4 Baseline Hydrogeological Monitoring ................................................................ 15
      5.4.1 Water Levels ............................................................................................... 15
      5.4.2 Groundwater Quality .................................................................................. 16

6 CONCEPTUAL HYDROGEOLOGY ............................................................................. 18
   6.1 Groundwater Management Area ........................................................................ 18
   6.2 Study Groundwater Modelling Area .................................................................. 18
   6.3 Aquifer Units ....................................................................................................... 18
      6.3.1 Superficial Aquifer ...................................................................................... 18
      6.3.2 Leederville Aquifer ..................................................................................... 19
      6.3.3 Yarragadee Aquifer ................................................................................... 19
   6.4 Aquifer Properties ............................................................................................... 19
      6.4.1 Superficial Aquifer ...................................................................................... 20
      6.4.2 Leederville Aquifer ..................................................................................... 20
      6.4.3 Yarragadee Aquifer ................................................................................... 20
   6.5 Recharge ............................................................................................................... 21
      6.5.1 Superficial Aquifer ...................................................................................... 21
      6.5.2 Leederville Aquifer ..................................................................................... 21
      6.5.3 Yarragadee Aquifer ................................................................................... 21
   6.6 Water Levels and Groundwater Flow Direction ................................................. 22
      6.6.1 Superficial Aquifer ...................................................................................... 22
      6.6.2 Leederville Aquifer ..................................................................................... 22
      6.6.3 Yarragadee Aquifer ................................................................................... 22
   6.7 Discharge ............................................................................................................... 23
      6.7.1 Superficial Aquifer ...................................................................................... 23
      6.7.2 Leederville Aquifer ..................................................................................... 23
      6.7.3 Yarragadee Aquifer ................................................................................... 23
   6.8 Groundwater Quality ........................................................................................... 23
      6.8.1 Superficial Aquifer ...................................................................................... 23
      6.8.2 Leederville Aquifer ..................................................................................... 23
      6.8.3 Yarragadee Aquifer ................................................................................... 24

7 EXISTING GROUNDWATER USE .......................................................................... 25
   7.1 Groundwater Dependent Ecosystem ................................................................... 25
      7.1.1 Wetlands .................................................................................................... 25
      7.1.2 Vegetation .................................................................................................. 25
   7.2 Other Groundwater Users .................................................................................. 26

8 PROPOSED MINING DEVELOPMENT BACKGROUND ...................................... 28

9 GROUNDWATER MODELLING .............................................................................. 29
   9.1 Objectives ............................................................................................................ 29


9.2 Model Setup and Extent .......................................................... 29
9.3 Model Geometry ................................................................. 31
9.4 Groundwater Inflow and Outflow ........................................ 31
  9.4.1 Groundwater Throughflow ............................................ 31
  9.4.2 Recharge ................................................................. 32
  9.4.3 Evapotranspiration ...................................................... 32
  9.4.4 Groundwater Pumping ............................................... 33
9.5 Model Calibration ............................................................. 34
  9.5.1 Approach to Model Calibration ...................................... 34
  9.5.2 Initial Conditions ....................................................... 34
9.6 Transient Calibration .......................................................... 35
  9.6.1 Groundwater Levels .................................................... 35
  9.6.2 Groundwater Level Contours ........................................ 37
  9.6.3 Measured and Modelled Water Levels ............................ 37
  9.6.4 Aquifer Parameters .................................................... 38
  9.6.5 Other Calibrated Aquifer Parameters ............................. 38
  9.6.6 Model Sensitivity ........................................................ 39
    9.6.6.1 Specific Yield and Rainfall Recharge ....................... 39
    9.6.6.2 Aquifer Hydraulic Conductivity Superficial Aquifers ..... 40
    9.6.6.3 Aquifer Hydraulic Conductivity Yarragadee Aquifer ........ 40
    9.6.6.4 Vertical Hydraulic Conductivity Leederville Aquifer Vasse Member .... 40
  9.6.7 Water Balance ............................................................ 40
9.7 Other Model Details .......................................................... 40
9.8 Model Predictions ............................................................. 41
  9.8.1 Dewatering Prediction Setup ......................................... 41
  9.8.2 Water Supply Prediction Setup ....................................... 43
  9.8.3 Closure Prediction Setup ............................................... 43
  9.8.4 Prediction Model Summary .......................................... 44
9.9 Results ............................................................................... 45
  9.9.1 Operational Predictions ................................................ 45
    9.9.1.1 Yalyalup Dewatering ............................................ 45
    9.9.1.2 Yalyalup Water Supply .......................................... 46
    9.9.1.3 Water Balance ...................................................... 46
    9.9.1.4 Operational Predictions Drawdown ......................... 49
    9.9.1.5 Water Supply Predictions Drawdown ....................... 49
  9.9.2 Closure Predictions ...................................................... 50
    9.9.2.1 Yalyalup Dewatering Scenarios ............................... 50
    9.9.2.2 Yalyalup Water Supply Scenarios ......................... 50
    9.9.2.3 Water Balance Closure ......................................... 50
    9.9.2.4 Drawdown Closure ............................................... 53
9.10 Extended Irrigation Predictions ........................................ 53
9.11 Model Uncertainty .......................................................... 54
9.12 Model Limitations, Assumptions and Classifications .......... 55
10 ASSESSMENT OF POTENTIAL IMPACTS ......................................... 58
  10.1 Mine Dewatering .......................................................... 58
  10.2 Aquifers ................................................................. 58
  10.3 Existing Other Groundwater Users .................................. 59
    10.3.1 Groundwater Dependent Ecosystems and Vegetation ...... 59
    10.3.2 Vasse-Wonnerup System Ramsar Wetland .................. 60
    10.3.3 Surface Water Courses ............................................ 60
    10.3.4 Acid Sulphate Soils ............................................... 60
  10.4 Yarragadee Water Supply Abstraction ............................... 60
    10.4.1 Aquifers ............................................................ 60
    10.4.2 Existing Other Groundwater Users ............................ 61
  10.5 Additional Groundwater Model Predictions ....................... 61
11 GROUNDWATER MANAGEMENT AND MONITORING ...................... 63
12 SUMMARY AND CONCLUSIONS .................................................. 64
13 REFERENCES ................................................................................................................ 67

Tables
Table 1: Rainfall and Evaporation Statistics (Station Nos. 9515 and 9603) ............................... 4
Table 2: Details of Surface Water Monitoring Sites .................................................................. 8
Table 3: Summary of Stratigraphy and Hydrogeology in the Yalyalup Area .............................. 9
Table 4: Monitoring Bore Drilling and Construction Details ...................................................... 12
Table 5: Summary of Hydraulic Testing (Micro-Testing and Slug Tests) ................................. 14
Table 6: Summary of Superficial Aquifer Properties ................................................................. 15
Table 7: Conceptual Model – Aquifer Parameters ................................................................. 19
Table 8: Active Superficial and Leederville Aquifer Groundwater Licensees within 2 km from the Proposed Yalyalup Mine (DWER) ................................................................. 27
Table 9: Model Layer Summary .............................................................................................. 30
Table 10: Extent of Model Domain .......................................................................................... 31
Table 11: Model Predicted Water Balances .......................................................................... 40
Table 12: Summary of Model Predictions ............................................................................. 45
Table 13: Summary of Model Predictions............................................................................. 45
Table 14: Yalyalup Dewatering Dry Climate Model Predicted Water Balance .......................... 47
Table 15: Yalyalup Dewatering Wet Climate Model Predicted Water Balance .......................... 47
Table 16: Yalyalup Water Supply Only Dry Climate Model Predicted Water Balance .............. 48
Table 17: Yalyalup Water Supply Only Wet Climate Model Predicted Water Balance .............. 48
Table 18: Yalyalup Dewatering Dry Climate Model Predicted Water Balance (Closure) ........... 51
Table 19: Yalyalup Dewatering Wet Climate Model Predicted Water Balance (Closure) ........... 51
Table 20: Yalyalup Water Supply Only Dry Climate Model Predicted Water Balance (Closure) .... 52
Table 21: Yalyalup Water Supply Only Wet Climate Model Predicted Water Balance (Closure) .... 52
Table 22: Yalyalup Water Supply Only Wet Climate Model Predicted Water Balance (Closure) .... 52

Figures
Figure 1 Regional Location of the Yalyalup Mineral Sands Project
Figure 2 Busselton Rainfall and Pan Evaporation Data
Figure 3 Catchment Plan and Surface Drainage
Figure 4 Lower Sabina and Abba Rivers Stages and Flows
Figure 5 Local Surface Water Drainage and Surface Water Monitoring Sites
Figure 6 Surface Water Sites YALSW01-YALSW14 Field Chemistry (pH, EC, TDS)
Figure 7 Surface Water Sites YALSW01-YALSW14 Laboratory Chemistry (TSS, Total Acidity, Sulphate)
Figure 8 Conceptual Regional Hydrogeological Cross Section (North-South) of the Southern Perth Basin
Figure 9 Location of Doral Superficial Aquifer Monitoring Bores YA_MB01 – YA_MB12
Figure 10 Location of Superficial Aquifer Baseline Groundwater Monitoring Bores
Figure 11 Location of Leederville Aquifer Baseline Groundwater Monitoring Bores
Figure 12 Monitoring Bore Water Level Elevations m AHD (Superficial Aquifer)
Figure 13 Monitoring Bore Water Levels m AHD (Leederville Aquifer)
Figure 14 Site Groundwater Level Contours in the Superficial Aquifer for the Winter Period
Figure 15 Site Groundwater Level Contours in the Superficial Aquifer for the Summer Period
Figure 16 Site Groundwater Level Contours in the Leederville Aquifer for the Winter Period
Figure 17 Site Groundwater Level Contours in the Leederville Aquifer for the Summer Period
Figure 18 Superficial Aquifer Monitoring Bore Field Chemistry (pH, EC, TDS)
Figure 19 Superficial Aquifer Monitoring Bore Laboratory Chemistry (Total Acidity, Total Alkalinity, Sulphate)
Figure 20 Leederville Aquifer Monitoring Bore Field Chemistry (pH, EC, TDS)
Figure 21 Leederville Aquifer Monitoring Bore Laboratory Chemistry (Total Acidity, Total Alkalinity, Sulphate)
Figure 22 Piper Diagram - Superficial Aquifer Water Quality Data for May and August 2019
Figure 23 Piper Diagram - Leederville Aquifer Water Quality Data for December 20018 and March 2019
Figure 24  Selected Superficial, Leederville and Yarragadee Hydrographs
Figure 25  Average Water Table Elevation Contours in the Superficial Aquifer Across the Modelled Area
Figure 26  Average Water Table Elevation Contours in the Leederville Aquifer Across the Modelled Area
Figure 27  Current Drawpoints and Licenced Groundwater Users in the Superficial Aquifer in the Vicinity of the Yalyalup Site
Figure 28  Current Drawpoints and Licenced Groundwater Users in the Leederville Aquifer in the Vicinity of the Yalyalup Site
Figure 29  DWER WIR Database Bores (Unlicenced and Licenced Bores, DWER Monitoring Bores) in the Superficial, Leederville and Yarragadee Aquifers in the vicinity of the Yalyalup Site
Figure 30  Proposed Mine Schedule and Yarragadee Production Bore Location at the Yalyalup Site
Figure 31: Model Extent and Boundary Conditions
Figure 32: Schematic Model Section
Figure 33: Contours of Elevation of Ground Surface (Top of Layer 1) and Base of Layer 1
Figure 34: Contours of Elevation of Base of Layer 2 and Base of Layer 3
Figure 35: Contours of Elevation of Base of Layer 4 and Base of Layer 5
Figure 36: Contours of Elevation of Base of Layer 6 and Base of Layer 7
Figure 37: Modelled Aquifer Zones Layer 1 and Layer 2
Figure 38: Modelled Aquifer Zones Layer 4
Figure 39: Schematic of Evapotranspiration Setup
Figure 40: Locations of Licenced Abstraction Superficial Aquifer
Figure 41: Locations of Licenced Abstraction Leederville Aquifer
Figure 42: Locations of Licenced Abstraction Yarragadee Aquifer
Figure 43: Locations of Abstraction Bores and Existing Mining Areas for Transient Simulation
Figure 44: Locations of Bores Used for Model Calibration in Superficial Aquifer
Figure 45: Locations of Bores Used for Model Calibration in Leederville and Yarragadee Aquifers
Figure 46: Calibration Hydrographs for Superficial Aquifer near Proposal Yalyalup Mine Area
Figure 47: Calibration Hydrographs for Superficial Aquifer near Proposal Yalyalup Mine Area
Figure 48: Calibration Hydrographs for Superficial Aquifer near Proposal Yalyalup Mine Area
Figure 49: Calibration Hydrographs for Superficial Aquifer near Proposal Yalyalup Mine Area
Figure 50: Calibration Hydrographs for Superficial Aquifer near Proposal Yalyalup Mine Area
Figure 51: Calibration Hydrographs for Superficial Aquifer near Proposal Yalyalup Mine Area
Figure 52: Calibration Hydrographs for Leederville Aquifer near Proposal Yalyalup Mine Area
Figure 53: Calibration Hydrographs for Leederville Aquifer near Proposal Yalyalup Mine Area
Figure 54: Calibration Hydrographs for Leederville Aquifer near Proposal Yalyalup Mine Area
Figure 55: Calibration Hydrographs for Leederville Aquifer near Proposal Yalyalup Mine Area and Superficial Aquifer in the Coastal Area
Figure 56: Calibration Hydrographs for Superficial Aquifer in the Coastal Area
Figure 57: Calibration Hydrographs for Leederville Aquifer in the Coastal Area
Figure 58: Calibration Hydrographs for Leederville Aquifer in the Coastal Area
Figure 59: Calibration Hydrographs for Superficial Aquifer in the Agricultural Area
Figure 60: Calibration Hydrographs for Superficial Aquifer in the Agricultural Area
Figure 61: Calibration Hydrographs for Superficial Aquifer in the Agricultural Area
Figure 62: Calibration Hydrographs for Superficial Aquifer in the Agricultural Area
Figure 63: Calibration Hydrographs for Leederville Aquifer in the Agricultural Area
Figure 64: Calibration Hydrographs for Leederville Aquifer in the Agricultural Area
Figure 65: Calibration Hydrographs for Leederville Aquifer in the Agricultural Area
Figure 66: Contours of February 2018 (Dry Season) Water Levels and Measured Water Levels in Superficial Aquifer
Figure 67: Contours of August 2018 (Wet Season) Water Levels in Superficial Aquifer
Figure 68: Measured versus Modelled Water Levels August 2018
Figure 69: Measured versus Modelled Water Levels February 2018
Figure 70: Proposed Mining Area, Doral Abstraction Bore and Tracking Points
Figure 71: Yalyalup Dewatering Scenarios Selected Hydrographs for Water Level and Mining Floor
Figure 72: Yalyalup Dewatering Scenarios Selected Hydrographs for Water Level and Mining Floor
Figure 73: Yalyalup Dewatering Scenarios Selected Hydrographs for Water Level and Mining Floor
Figure 74: Predicted Monthly Groundwater Inflows for Wet and Dry Climatic Conditions
Figure 75: Water Supply Scenario Selected Hydrographs for Water Level and Mining Floor
Figure 76: Water Supply Scenario Selected Hydrographs for Water Level and Mining Floor
Figure 77: Water Supply Scenario Selected Hydrographs for Water Level and Mining Floor
Figure 78: Q3 – 2021 – Contours of Predicted Drawdown in Superficial Aquifer in Dry Conditions
Figure 79: Q4 – 2021 – Contours of Predicted Drawdown in Superficial Aquifer in Dry Conditions
Figure 80: Q1 – 2022 – Contours of Predicted Drawdown in Superficial Aquifer in Dry Conditions
Figure 81: Q2 – 2022 – Contours of Predicted Drawdown in Superficial Aquifer in Dry Conditions
Figure 82: Q3 – 2022 – Contours of Predicted Drawdown in Superficial Aquifer in Dry Conditions
Figure 83: Q4 – 2022 – Contours of Predicted Drawdown in Superficial Aquifer in Dry Conditions
Figure 84: Q1 – 2023 – Contours of Predicted Drawdown in Superficial Aquifer in Dry Conditions
Figure 85: Q2 – 2023 – Contours of Predicted Drawdown in Superficial Aquifer in Dry Conditions
Figure 86: Q3 – 2023 – Contours of Predicted Drawdown in Superficial Aquifer in Dry Conditions
Figure 87: Q4 – 2023 – Contours of Predicted Drawdown in Superficial Aquifer in Dry Conditions
Figure 88: Q1 – 2024 – Contours of Predicted Drawdown in Superficial Aquifer in Dry Conditions
Figure 89: Q2 – 2024 – Contours of Predicted Drawdown in Superficial Aquifer in Dry Conditions
Figure 90: Q3 – 2024 – Contours of Predicted Drawdown in Superficial Aquifer in Dry Conditions
Figure 91: Q4 – 2024 – Contours of Predicted Drawdown in Superficial Aquifer in Dry Conditions
Figure 92: Q3 – 2021 – Contours of Predicted Drawdown in Superficial Aquifer in Wet Conditions
Figure 93: Q4 – 2021 – Contours of Predicted Drawdown in Superficial Aquifer in Wet Conditions
Figure 94: Q1 – 2022 – Contours of Predicted Drawdown in Superficial Aquifer in Wet Conditions
Figure 95: Q2 – 2022 – Contours of Predicted Drawdown in Superficial Aquifer in Wet Conditions
Figure 96: Q3 – 2022 – Contours of Predicted Drawdown in Superficial Aquifer in Wet Conditions
Figure 97: Q4 – 2022 – Contours of Predicted Drawdown in Superficial Aquifer in Wet Conditions
Figure 98: Q1 – 2023 – Contours of Predicted Drawdown in Superficial Aquifer in Wet Conditions
Figure 99: Q2 – 2023 – Contours of Predicted Drawdown in Superficial Aquifer in Wet Conditions
Figure 100: Q3 – 2023 – Contours of Predicted Drawdown in Superficial Aquifer in Wet Conditions
Figure 101: Q4 – 2023 – Contours of Predicted Drawdown in Superficial Aquifer in Wet Conditions
Figure 102: Q1 – 2024 – Contours of Predicted Drawdown in Superficial Aquifer in Wet Conditions
Figure 103: Q2 – 2024 – Contours of Predicted Drawdown in Superficial Aquifer in Wet Conditions
Figure 104: Q3 – 2024 – Contours of Predicted Drawdown in Superficial Aquifer in Wet Conditions
Figure 105: Q4 – 2024 – Contours of Predicted Drawdown in Superficial Aquifer in Wet Conditions
Figure 106: September 2023 Contours of Predicted Drawdown in Leederville Aquifer Dry Conditions
Figure 107: September 2023 Contours of Predicted Drawdown in Leederville Aquifer Wet Conditions
Figure 108: Predicted Contours of Drawdown in Leederville Aquifer at End of Mining for Dry Conditions in Water Supply Only
Figure 109: Predicted Contours of Drawdown in Yarragadee Aquifer at End of Mining for Dry Conditions in Water Supply Only
Figure 110: Predicted Contours of Drawdown in Leederville Aquifer at End of Mining for Wet Conditions in Water Supply Only
Figure 111: Predicted Contours of Drawdown in Yarragadee Aquifer at End of Mining for Wet Conditions in Water Supply Only
Figure 112: July 2026 - Predicted Contours of Drawdown in Superficial Aquifer at Closure for Dewatering Scenarios for Dry Conditions
Figure 113: July 2026 - Predicted Contours of Drawdown in Superficial Aquifer at Closure for Dewatering Scenarios for Wet Conditions
Figure 114: Q2 - 2022 Contours of Predicted Drawdown in Superficial Aquifer Dry Conditions and Other Groundwater Users
Figure 115: Q2 - 2022 Contours of Predicted Drawdown in Leederville Aquifer Dry Conditions and Other Groundwater Users
Figure 116: Predicted Contours of Drawdown in Yarragadee Aquifer at End of Mining for Dry Conditions in Water Supply Only and Other Groundwater Users
Figure 117: Predicted Contours of Drawdown in Leederville Aquifer at End of Mining for Dry Conditions in Water Supply Only and Other Groundwater Users

Appendices

Appendix A: Borelogs
Appendix B: Results of Hydraulic Tests
Appendix C: Details of Private Landowner Bores
Appendix D: Details of Groundwater Licences
Appendix E: Details of Model Predictions with Extended Irrigation
Appendix F: Details of Uncertainty Calibration and Model Predictions
1 INTRODUCTION

Doral Mineral Sands Pty Ltd (Doral) proposes to develop the Yalyalup mineral sands mine, located approximately 11 km south-east of Busselton, Western Australia (Figure 1). The Yalyalup mineral sands deposit is located halfway between Iluka’s Tutunup South Mine (closed in 2018) and Tronox’s (Tronox) Wonnerup Mine (operating and northern extension).

The expected Yalyalup mine life is scheduled for six years, with three and a half years of the mining phase and the remainder being startup and closure. To enable optimal resource recovery, the mining will occur below the groundwater level and as a result, dewatering of the open-cut pits will be required to provide dry mining conditions.

Water supplies are required for mineral ore processing and are planned to be sourced from recycled water from hydraulically returned tailings, rainfall runoff, pit dewatering water and supplemented by pumping from the external production bore in the Yarragadee aquifer.

AQ2 was engaged by Doral to undertake groundwater and surface water assessments at the Yalyalup project. The work was required to fulfil the Department of Water and Environmental Regulation’s (DWER, former Environmental Protection Agency (EPA)) objectives for the project’s key environmental factors related to the water regime and to support Doral’s Environmental Review Document (ERD) submission to the DWER. The key environmental factors are outlined in the Environmental Scoping Document (ESD) and listed below, as:

- To maintain the hydrological regimes of groundwater and surface water, so that environmental values are protected (Hydrological Processes); and
- To maintain the quality of groundwater and surface water, so that environmental values are protected (Inland Waters Environmental Quality).

This hydrogeological assessment report presents the findings of:

- A desktop literature review of all available geological and hydrogeological data and previous work, including the Initial Hydrogeological Desktop Assessment report (Hydrosolutions, 2017);
- Field programmes, including the establishment of a site groundwater monitoring network, groundwater and surface water monitoring and hydraulic testing;
- The development of a conceptual hydrogeological model; and
- The development of a calibrated numerical groundwater model of the mine site and surrounding area.

This calibrated numerical groundwater model was used to:

- Determine the life of mine dewatering requirements associated with the proposed mine plan;
- Assess the predicted groundwater drawdown associated with mining and closure at Yalyalup;
- Assess the predicted drawdown associated with process water supply abstraction from the Yarragadee aquifer during operations and after mine closure;
- Assess potential drawdown impacts associated with the mine pit dewatering and the Yarragadee water supply pumping on the environment and other users (i.e. aquifers, water availability to nearby bore users, potential GDE’s, surface water features and the Vasse-Wonnerup Ramsar wetland); and
• Predict pre-and post-mining groundwater catchment water balances.

In addition to this hydrogeological assessment, AQ2 has also completed a surface water assessment (AQ2, 2019a), a conceptual water balance (AQ2, 2019b) and surface water discharge assessment (AQ2, 2019c) for the project.
2 PHYSICAL SETTING

2.1 Location and Landform

The Yalyalup project is located approximately 11 km south-east of Busselton (Figure 1) and situated close to:

- RAMSAR listed Vasse-Wonnerup System Wetland (~4.6 km north-north west);
- Tronox’s Wonnerup Mineral Sands Mine (~4 km north-north west);
- Iluka Resources’ Tutunup South Mineral Sands Mine (~2.5 km south east);
- Doral’s Yoongarillup Mineral Sands Mine (~6 km southwest).

The project area is generally comprised of farmland, which is zoned under City of Busselton planning as agricultural. It lies within the Swan Coastal Plain, which in the area slopes gently to the north west from maximum elevations of approximately 50 mAHĐ at the base of the Whicher Scarp, to minimum elevations at or close to the sea level (i.e. 0 mAHĐ; the Vasse-Wonnerup wetlands system and the coastline). The elevations across the site generally range between 22 mAHĐ in the north west and 30 mAHĐ in the south-east, sloping towards the north-west.

2.2 Climate and Rainfall

The Yalyalup project area has a Mediterranean type climate, characterised by hot dry summers and cold wet winters. The nearest Bureau of Meteorology (BoM) weather station with long-term data averages is Busselton Aero (Station No. 9603) and Busselton Shire (Station No. 9515), approximately 5 and 10 km, respectively to the north-east of the study area.

At the Yalyalup area, the long-term average annual rainfall (1877-2019) is 810 mm, while the more recent, short-term average annual rainfall (1998-2019) is 685 mm, which is 85% of the long-term average, indicating a general decline in rainfall in the study area.

Rainfall is greatest during the winter months (May to September) and peaks in July. Conversely, monthly annual pan evaporation data obtained from the BoM’s Jarrahwood station (Station No. 9842), shows that evaporation is lowest during the months of May to August and highest during the dry summer months, with a mean pan evaporation of about 1,220 mm.

Long-term rainfall and pan evaporation data are shown in Figure 2 and summarised in Table 1.
Table 1: Rainfall and Evaporation Statistics (Station Nos. 9515 and 9603)

<table>
<thead>
<tr>
<th></th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Annual</th>
</tr>
</thead>
<tbody>
<tr>
<td>Long-term Average Rainfall Busselton Shire (mm) (1877-2019)</td>
<td>10.4</td>
<td>10.1</td>
<td>20.7</td>
<td>40.8</td>
<td>114.5</td>
<td>166.0</td>
<td>162.2</td>
<td>115.5</td>
<td>74.6</td>
<td>49.1</td>
<td>24.4</td>
<td>13.0</td>
<td>810.4</td>
</tr>
<tr>
<td>Short-term Average Rainfall Busselton Aero (mm) (1998-2019)</td>
<td>15.3</td>
<td>4.2</td>
<td>19.4</td>
<td>32.9</td>
<td>100.3</td>
<td>126.8</td>
<td>133.4</td>
<td>108.4</td>
<td>75.1</td>
<td>30.3</td>
<td>22.1</td>
<td>10.8</td>
<td>684.8</td>
</tr>
<tr>
<td>Long-term Average Pan Evaporation Busselton (mm)*</td>
<td>192</td>
<td>157</td>
<td>135</td>
<td>78</td>
<td>60</td>
<td>42</td>
<td>50</td>
<td>53</td>
<td>70</td>
<td>91</td>
<td>130</td>
<td>181</td>
<td>1,239</td>
</tr>
<tr>
<td>Long-term Average Pan Evaporation Jarrahwood (mm) (1975-2015)</td>
<td>189</td>
<td>160</td>
<td>133</td>
<td>78</td>
<td>53</td>
<td>42</td>
<td>47</td>
<td>56</td>
<td>69</td>
<td>99</td>
<td>129</td>
<td>164</td>
<td>1,219</td>
</tr>
</tbody>
</table>

From: Evaporation Data for Western Australia (1987), Dept. of Agriculture
3 HYDROLOGY

3.1 Regional Water Courses

The proposed Yalyalup mine site is located within the Wonnerup (Busselton Coast) Surface Water Management subarea (Figure 3) and is not located within a proclaimed area for surface water management (DoW, 2009).

The project is situated within the Lower Sabina River subcatchment area. The Lower Sabina River flows from below the Sabina Diversion Weir to the RAMSAR listed Vasse-Wonnerup Wetlands. The Lower Sabina, Lower Vasse, Abba and Ludlow rivers drain into the Vasse-Wonnerup Wetlands, before discharging through the Wonnerup Inlet into Geographe Bay (Figure 3).

The Vasse-Wonnerup Wetlands is an environmentally sensitive surface water receptor. Most of the Lower Sabina catchment has either been cleared for agricultural uses or other mining operation (i.e. Tronox’s Wonnerup Mineral Sands Mine in the northern portion). The Sabina River and Vasse River, both tributaries to the Vasse-Wonnerup Wetlands, have been historically modified with diversions to reduce flooding risk of Busselton.

The Sabina Diversion Weir was constructed to allow overflow during extreme rainfall events from the Upper Sabina to the Lower Sabina, with regular flows through the Sabina Diversion Drain. The weir was over designed and the Upper Sabina catchment (78 km²) no longer contributes any flow directly to the Lower Sabina river, although some minor sub-drains in the upper catchment may spill in large events (Marillier, 2018). The flow upgradient of the Sabina diversion weir is directed through the Sabina Diversion Drain to the Vasse Diversion Drain system and out to the Geographe Bay, rather than to Vasse-Wonnerup Wetlands.

The Vasse-Wonnerup Wetlands catchment area is 473 km², excluding the diverted subcatchments (DWER, 2019). The Lower Sabina River catchment area of 45.5 km² is less than 10% of the Vasse-Wonnerup Wetland Catchment. The Abba River is one of the other major tributaries to the Vasse-Wonnerup Wetland and has a catchment area of 137 km² which is 29% of the Vasse-Wonnerup Wetlands catchment.

There are no stream gauges in the Lower Sabina catchment. The closest stream gauges are on the Upper Sabina at the Sabina Diversion (site 610025), and on the Abba River (site 610062). Marillier (2018) analysed gauge information and estimated average annual flows (2001–2014) in the major ungauged rivers flowing to the Vasse Estuary Wetland. Marillier (2018) estimated the Lower Sabina discharge as 5.7 GL/year, less than half the Abba River volumes (12.5 GL/year). In contrast, 4 GL/year is diverted away from Vasse-Wonnerup Wetlands along the Sabina Diversion Drain, and 24 GL/year is diverted via the Vasse Diversion Drain. The Ludlow River discharges the second highest volumes to the Vasse-Wonnerup Wetlands an annual average of 11.4 GL/year based on DWER gauging station summary statistics (DWER, 2019).

The Whicher Area Surface Water Management Plan (DoW, 2009) does not list the Sabina or Abba Rivers as connected to the groundwater system. However, the shallow depth of unconfined groundwater at the Yalyalup could suggest the possibility of groundwater discharge occurring as baseflow in these rivers. Notwithstanding, hydrographs for both rivers (Figure 4) clearly indicate a cessation of the river flow.
during summer periods, with limited rainfall recharge. Therefore, there is limited or no groundwater connection with the surface water, resulting in minimal or no groundwater contribution to the river’s baseflow. The surface water flow regime is therefore likely to be dominated by high-rainfall periods generating surface water runoff, rather than any substantial groundwater flow component.

3.2 Local Water Courses

Several roads and man-made drains installed in the 20th century have modified the natural drainage patterns. The project’s mine development is situated along Princefield roadside drain and other first order drainage lines which contributed to a tributary of the Lower Sabina River (downstream of the Sabina Diversion Weir). The local drains and waterways in the vicinity of the project are shown on Figure 5.

The current project areas lie completely within the Lower Sabina subcatchment. Potential north eastern extensions of the project might overlap the modified channels of the Abba River. Surface water flows from the south of the project are diverted around the project area via the Woddidup diversion, Sabina diversion and Vasse diversion drains (into Geographe Bay, not the Vasse-Wonnerup wetlands).

3.3 Local Surface Water Quality

A network of surface water monitoring sites has been identified adjacent to of the Yalyalup project area since July 2017. Fourteen surface water monitoring sites (YALSW01 to YALSW14) are shown on Figure 5, and site details are summarised in Table 2. Monitoring of surface water levels and quality when flowing at these locations allows recording of any unseasonal increases in water levels, seasonal fluctuations and any changes in basic water chemistry pre-mining and during the period of the mine operations.

Since monitoring commenced in July 2017, data for all surface monitoring sites has been collected on a monthly basis, except for the site YALSW09, owing to the site access limitation (i.e. a lack of the landowner access approval).

The monitoring results to date indicate that surface water flows around the site are limited to winter and spring seasons (i.e. June/July to October/November), as recorded in most of Doral’s surface water monitoring sites. The only exceptions were two sites YALSW04 and YALSW07, as they have recorded water every month since July 2017, due to both dams being fed by groundwater seepage.

The field and laboratory surface water results since July 2017 are presented in Figures 6 and 7, and summarised below:

- Field pH was in the range of 6 (YALSW03) to 8.5 (YALSW07); slightly acidic to slightly alkaline, but generally neutral (i.e. pH between 6.5 and 7).
- Field EC was generally between 100 and 3,000 μS/cm for all surface water sites, except for site YALSW07, where higher EC readings were recorded (between 3,600 and 5,300 μS/cm). These increased EC values could be related to this dam having limited seepage connection with the groundwater, possibly due to clayey layers surrounding the wall of this dam, causing increase in EC concentrations owing to evaporation. Additionally, at this site EC concentrations are the
lowest during wet season where rainfall peaks and the highest during dry seasons where rainfall is low.

- Field TDS concentrations ranged between 40 and 1,500 mg/L for all surface water sites, indicating water being fresh becoming slightly brackish. The only exception is site YALSW07 where TDS concentrations range from 1,800 to 2,600 mg/L, being brackish, likely due to this dam having limited seepage and high evaporation.

- TSS values were mostly below 10 mg/L for the majority of surface water sites, except for July 2018 sampling event, where high TSS concentrations were recorded at all sites.

- Sulphate concentrations were generally below 150 mg/L, except for YALSW07 (i.e. 250 to 490 mg/L).

- Total Acidity (as CaCO₃) was below 15 mg/L in all monitoring sites.

- There have been seasonal increasing trends of EC, TDS and sulphate in all surface water sites (except for YALSW07). These rising trends generally commence in June/July (i.e. at the start of the surface water flow) to October/November (i.e. when the flows diminish) and are likely related to sulphate leaching out from free draining soils up-slope of the Lower Sabina catchment during high rainfall or irrigation periods.
<table>
<thead>
<tr>
<th>Site Name</th>
<th>Approximate Location (GPS surveyed)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>YALSW01</td>
<td>355307 6269882 23</td>
<td>Original Sabina River channel. Limited area surface flows ~1km downstream from Sabina Diversion weir.</td>
</tr>
<tr>
<td>YALSW02</td>
<td>356614 6269990 24</td>
<td>Artificial drainage flows from paddocks within Lot 421</td>
</tr>
<tr>
<td>YALSW03</td>
<td>357034 6270001 26</td>
<td>Woddidup Creek flows, semi regional, ~3.0km x 2.0km catchment</td>
</tr>
<tr>
<td>YALSW04</td>
<td>357848 6270038 23</td>
<td>Ag dam Lot 758. Seepage from Bassendean Sands in close proximity to proposed mining</td>
</tr>
<tr>
<td>YALSW05</td>
<td>359214 6270070 29</td>
<td>Un-named Creek, catchment estimated 2.0km x 2.0km</td>
</tr>
<tr>
<td>YALSW06</td>
<td>356099 6270231 21</td>
<td>Optional, alternate site if YALSW02 access is poor</td>
</tr>
<tr>
<td>YALSW07</td>
<td>356887 6270304 20</td>
<td>Farm dam</td>
</tr>
<tr>
<td>YALSW08</td>
<td>356081 6270852 20</td>
<td>Optional, alternate site if YALSW02+06 access is poor</td>
</tr>
<tr>
<td>YALSW09</td>
<td>357805 6270840 22</td>
<td>Un-named Creek/Artificial drains in centre of project</td>
</tr>
<tr>
<td>YALSW10</td>
<td>355520 6271611 18</td>
<td>Downslope sampling site for western margins of project.</td>
</tr>
<tr>
<td>YALSW11</td>
<td>356540 6271665 18</td>
<td>Woddidup Creek flows, downslope flows from central west of project area. No Mixing with Princefield Drain</td>
</tr>
<tr>
<td>YALSW12</td>
<td>356866 6271676 18</td>
<td>Un-named Creek/Artificial drains in centre of project. No Mixing with Princefield Drain</td>
</tr>
<tr>
<td>YALSW13</td>
<td>356997 6271686 18</td>
<td>Roadside drain downslope flows from north east of project area.</td>
</tr>
<tr>
<td>YALSW14</td>
<td>358604 6271766 21</td>
<td>Roadside drain downslope flows from north east of project area.</td>
</tr>
</tbody>
</table>
The Yalyalup project is located within the southern part of the Perth Basin, an elongate north–south rift trough with a series of sub-basins, shelves, troughs and ridges. The study area is wholly contained within the Bunbury Trough, a sub-basin containing a Permian–Cretaceous succession up to 11 km thick. The sub-basin is wedged between the Vasse Shelf and the Yilgarn Craton, bounded to the east by the Darling Fault and to the west by the Busselton Fault. Detailed descriptions of the local geology and groundwater system are given by Iasky (1993), Crostella and Backhouse (2000), and Baddock (2005).

Yalyalup geology and the groundwater occurrence in the upper 900 m of the Perth Basin at the Yalyalup area, is summarised in Table 3. A conceptual regional hydrogeological cross section (north-south) of the Southern Perth Basin is shown in Figure 8.

Table 3: Summary of Stratigraphy and Hydrogeology in the Yalyalup Area

<table>
<thead>
<tr>
<th>Age</th>
<th>Formation</th>
<th>Stratigraphy</th>
<th>Thickness (m)</th>
<th>Lithology</th>
<th>Hydrogeology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quaternary-late Tertiary</td>
<td>Superficial</td>
<td>Bassendean Sand</td>
<td>0.5-3</td>
<td>Fine to medium sub-rounded quartz sand</td>
<td>Superficial aquifer</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Guildford Formation</td>
<td>2-5</td>
<td>Clay and sandy clay with occasional discontinuous sand lenses</td>
<td>Local aquiclude</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Yoganup Formation</td>
<td>2-5</td>
<td>Leached and ferruginized beach sand conglomerate and clay. Local laterite.</td>
<td>Superficial aquifer</td>
</tr>
<tr>
<td>Cretaceous</td>
<td>Leederville</td>
<td>Mowen Member</td>
<td>1-10</td>
<td>Clay and silty clay, with thin interbedded silt, clayey sand and fine grained sand</td>
<td>Regional aquitard; local Leederville aquifer (when significant sand is present)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Vasse Member</td>
<td>50-100</td>
<td>Fine to medium grained quartz sandstone and interbedded shale.</td>
<td>Leederville aquifer</td>
</tr>
<tr>
<td>Mid-late Jurassic</td>
<td>Yarragadee</td>
<td>Unit 1</td>
<td>0-50</td>
<td>Medium to coarse grained, weakly consolidated sandstone, minor siltstone and shales</td>
<td>Yarragadee aquifer</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Unit 2</td>
<td>0-250</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Unit 3</td>
<td>200-500</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Unit 4</td>
<td>0-100</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The upper geology sequence comprises the Quaternary-late Tertiary aged Superficial Formation, which are represented at the Yalyalup site by the Bassendean Sand towards the top, the Guildford Formation and the Yoganup Formation towards the base. The Bassendean Sand forms a thin bed of fine to medium grained aeolian sand. The Guildford Formation consists predominantly of silty to sandy clay of fluvial origin. The Yoganup Formation comprises leached and ferruginous coarse grained beach sand, with localised concentrations of heavy minerals and some sandy silt and clay layers. The superficial deposits commonly contain ironstone caprock, colloquially known as Coffee Rock, in the zone of water table.
fluctuation. At the site, the Coffee Rock is generally 2 to 3 m thick and is exposed at the surface in the western side of the project, near and along the McGibbon Track. The thickness of the Superficial Formation is irregular, reaching a maximum of 12 m at the site, but generally 7 to 8 m thick.

Outside of the project area, closer to the coast, the Bassendean Sand is interfingered by Tamala Limestone (i.e. limestone, calcarenite and sand), which can be up to 15 m thick. Tamala Limestone is overlain by Estuarine and swamp deposits at the Vasse-Wonnerup Wetland, consisting of fine sand, silt and clay and by Safety Bay Sand at the coast area. Thin layer of the Guildford Formation underlain Tamala Limestone, with the basal sand of the Guildford Formation being equivalent to the Yoganup Formation.

The Superficial Formation is unconformably underlain by Cretaceous age, riverine and deltaic sediments of the Leederville Formation, comprising discontinuous interbedded weakly consolidated sandstone, clayey sand, silt and shale. Three member units of the Leederville Formation are identified: Vasse Member, Mowen Member, and Quindalup Member, with only Vasse and Mowen Members, present in the Yalyalup area. The lower Vasse Member is highly stratified, containing sand beds interbedded with clay aquitards. Sand beds are generally up to 10 m thick with overall unit thickness of 100 m at the project site. The upper Mowen Member is dominated by clay and silt with some thin interbedded silty to medium grained sand, with a thickness of up to 10 m. The Mowen Member is likely to be very thin or has a greater sand content, especially on the eastern side of the project area.

The Yarragadee Formation (the aquifer being targeted for the mine water supply) underlies the Leederville Formation, comprising predominantly weakly consolidated, medium to very coarse grained quartz sandstone, with minor siltstone and shale beds. Based on lithology and age, this formation has been divided into four sub-units (sequentially, Unit 1 to Unit 4; Baddock, 2005). Unit 1 occurs at the top of the formation and Unit 4 at the base, with all units likely to be present in the project area (a total thickness of approximately 900 m).

The Bunbury Basalt occurs discontinuously between the Yarragadee and Leederville Formations and the top of the basalt is typically highly weathered. The Bunbury Basalt is unlikely to be present at the study area, based on the literature (i.e. DWER drilling information records (DWER, 2019) and the Water Corporation Magnetic data survey (Baddock, 2005)).
5 COLLECTION OF SITE-SPECIFIC HYDROGEOLOGICAL DATA

To augment the available regional data available, some fieldwork was undertaken on the proposed Yalyalup mine site, to collect local scale information on the prevailing geological and hydrogeological conditions.

5.1 Mineral Exploration Drilling

A number of vertical aircore exploration holes have been drilled across the Yalyalup site (~1,100m of drilling) during 2012 to mid-2015 and late-2017 to early-2018 to depths of between 3 to 15 m (average 9 m). All of these holes have been re-habilitated and no longer exist. Doral has used this mineral drilling data to interpret and contour the base elevation of the Superficial Formation within the mining area, including the contours of the base elevations of each Superficial Formation unit (i.e. Bassendean Sand, Guildford Formation and Yoganup Formation). These base elevation unit contours have been used in the groundwater model for the mine site (refer to Section 9.2).

Additionally, lithological and assays data provided by Doral on the grain size of the material drilled (i.e. content of silt and clay (<0.063 mm), sand (<0.063-2 mm>) and gravel (>2 mm) fractions) was used to support the assessment of permeabilities for each Superficial unit present at the site (i.e. Bassendean Sand, Guildford Formation and Yoganup Formation). On average:

- the Bassendean Sand contains approximately 83% of sand fraction, 12% of silt and clay fraction and 5% of gravel fraction; which is dominated by fine to medium grained sand, slightly clayey and slightly gravelly;
- the Guildford Formation contains approximately 54% of silt and clay fraction, 44% of sand fraction and 2% of gravel fraction; which is dominated by sandy silt and clay, with sand being fine to medium grained;
- the Yoganup Formation contains approximately 80% of sand fraction, 18% of silt and clay fraction and 2% of gravel fraction; which is dominated by medium to coarse grained sand, slightly clayey.

Many of mineral holes were drilled up to 12 m depth and were drilled through the base of the Superficial Formation (i.e. base of the Yoganup Formation unit), a couple of meters into the Leederville Formation. The presence of mica, pyrite, organic clays and changes in the grain size evident in these drill holes is typical for sediments of the Leederville Formation. The lithological and assays data show that the clayey Mowen Member of the Leederville Formation is present in the western portion of the proposed mine site (present up to the total drill depth), with the Mowen Member being either thin or with greater sand content in the eastern part.

5.2 Drilling and Bore Construction

Doral has drilled and installed 12 monitoring bores (i.e. YA_MB01S to YA_MB12S) across the proposed Yalyalup site, with 6 bores being installed in December 2017 and the remaining 6 bores in June 2019. All these monitoring bores were drilled to the base of the Superficial Formation (i.e. Yoganup Formation) and screened across the all Superficial Formation units. Bore locations are shown in Figure 9. Bore construction details are summarized in Table 4 and the bore logs are presented in Appendix A.
Table 4: Monitoring Bore Drilling and Construction Details

<table>
<thead>
<tr>
<th>Bore ID</th>
<th>Coordinates (MGA, Zone 50)</th>
<th>Ground Elevation#</th>
<th>Cased Depth</th>
<th>Current Cased Total Deptha</th>
<th>Top of Casing (TOC)</th>
<th>TOC Elevation</th>
<th>PVC Casing Diameter</th>
<th>Screened/Slotted Intervals</th>
<th>Static Water Level (SWL) May and June 2019</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Easting (m)</td>
<td>Northing (m)</td>
<td>(mRL)</td>
<td>(m)</td>
<td>(mbgl)</td>
<td>(magl)</td>
<td>(mRL)</td>
<td>(mm)</td>
<td>(mbgl)</td>
</tr>
<tr>
<td>YA_MB01S</td>
<td>357253</td>
<td>6270021</td>
<td>23.46</td>
<td>7.0</td>
<td>5.01</td>
<td>24.18</td>
<td>0.72</td>
<td>50</td>
<td>1-7</td>
</tr>
<tr>
<td>YA_MB02S</td>
<td>356760</td>
<td>6270882</td>
<td>20.23</td>
<td>9.0</td>
<td>7.16</td>
<td>21.17</td>
<td>0.94</td>
<td>50</td>
<td>3-9</td>
</tr>
<tr>
<td>YA_MB03S</td>
<td>356989</td>
<td>6271678</td>
<td>18.76</td>
<td>7.8</td>
<td>8.66</td>
<td>19.22</td>
<td>0.46</td>
<td>100</td>
<td>1.8-7.8</td>
</tr>
<tr>
<td>YA_MB04S</td>
<td>357789</td>
<td>6270637</td>
<td>22.86</td>
<td>9.0</td>
<td>7.56</td>
<td>23.57</td>
<td>0.71</td>
<td>50</td>
<td>3-9</td>
</tr>
<tr>
<td>YA_MB05S</td>
<td>357787</td>
<td>6270960</td>
<td>21.8</td>
<td>7.5</td>
<td>7.64</td>
<td>22.28</td>
<td>0.48</td>
<td>100</td>
<td>1.5-7.5</td>
</tr>
<tr>
<td>YA_MB06S</td>
<td>357960</td>
<td>6271720</td>
<td>20.52</td>
<td>7.3</td>
<td>7.43</td>
<td>20.95</td>
<td>0.43</td>
<td>100</td>
<td>1.3-7.3</td>
</tr>
<tr>
<td>YA_MB07S</td>
<td>358606</td>
<td>6270858</td>
<td>25.04</td>
<td>8.0</td>
<td>7.26</td>
<td>25.83</td>
<td>0.79</td>
<td>50</td>
<td>2-8</td>
</tr>
<tr>
<td>YA_MB08S</td>
<td>358589</td>
<td>6271310</td>
<td>23.24</td>
<td>9.3</td>
<td>9.42</td>
<td>23.65</td>
<td>0.41</td>
<td>100</td>
<td>3.3-9.3</td>
</tr>
<tr>
<td>YA_MB09S</td>
<td>359401</td>
<td>6270501</td>
<td>30.58</td>
<td>8.0</td>
<td>7.65</td>
<td>31.2</td>
<td>0.62</td>
<td>50</td>
<td>2-8</td>
</tr>
<tr>
<td>YA_MB10S</td>
<td>359305</td>
<td>6270896</td>
<td>28.51</td>
<td>7.0</td>
<td>4.65</td>
<td>29.26</td>
<td>0.75</td>
<td>50</td>
<td>1-7</td>
</tr>
<tr>
<td>YA_MB11S</td>
<td>359295</td>
<td>6271545</td>
<td>24.69</td>
<td>7.8</td>
<td>8.22</td>
<td>25.14</td>
<td>0.45</td>
<td>100</td>
<td>1.8-7.8</td>
</tr>
<tr>
<td>YA_MB12S</td>
<td>359159</td>
<td>6271808</td>
<td>22.79</td>
<td>8.5</td>
<td>8.51</td>
<td>23.24</td>
<td>0.45</td>
<td>100</td>
<td>2.5-8.5</td>
</tr>
</tbody>
</table>

magl = metres above ground level
mbgl = metres below ground level
mbtoc = metres below top of casing

# Total depth of the bore was measured during May & June 2019 site visits
It should be noted that bores YA_MB01S, YA_MB02S, YA_MB04S, YA_MB07S, YA_MB09S and YA_MB10S have been equipped with 50 mm Class 18 PVC casing, with the remaining bores being equipped with 100 mm Class 18 PVC casing. At each bore, the bore annulus was packed with gravel to approximately 1 m below the ground (mbgl), above which a bentonite/cement seal was emplaced to surface. After gravel pack installation, the bores were developed by airlifting.

5.3 Hydraulic Testing

Hydraulic testing (micro-test pumping and/or slug tests) was undertaken on all 12 monitoring bores (YA_MB01S-YA_MB12S) across the Yalyalup site by AQ2 hydrogeologist during two site visits; 30 April to 1 May 2019 and 18 to 19 June 2019. The purpose of the hydraulic testing was to obtain local hydrogeological data to assess the near-bore aquifer permeability (= hydraulic conductivity).

Micro aquifer tests (micro-testing) was undertaken in all bores and involved the installation of a small, low-yielding pump into the bores, together with a pressure transducer to monitor the water level response to pumping.

All bores were pumped for 1 hour. Monitoring of water levels was carried out throughout the test and for 1 hour after the test (or until water levels had recovered to 90% of the initial drawdown). All test data collected during pumping and recovery were analysed using standard curve-fitting analysis methods to ascertain aquifer properties.

In addition to the micro-tests, all monitoring bores were subject to slug tests (as an alternative method to obtain near-bore aquifer parameters). Each slug test consisted of measuring the static water level in the hole / bore, then introducing a near instantaneous change of water level by adding a solid (cylinder slug) into the bore and measuring the change in water level (i.e. rise and fall) over time, until the water level returned to its near original static water level. A pressure transducer was used to measure the water level changes over time, at 1-second intervals. The declining water levels were used for analysis of the permeability, utilising the Bower-Rice method.

The results of the hydraulic tests are summarised in Table 5 and presented in Appendix B.
Table 5: Summary of Hydraulic Testing (Micro-Testing and Slug Tests)

<table>
<thead>
<tr>
<th>Bore ID</th>
<th>Total Depth (m btoc)</th>
<th>Aquifer tested</th>
<th>SWL (m btoc) During tests</th>
<th>Aquifer thickness (m)</th>
<th>Bulk Transmissivity (m²/d) Range</th>
<th>Bulk Transmissivity (m²/d) Average</th>
<th>Bulk Permeability (m/d) Range</th>
<th>Bulk Permeability (m/d) Average</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>YA_MB01S</td>
<td>5.73</td>
<td>Superficial</td>
<td>3.6</td>
<td>2.13</td>
<td>7.4-17.8</td>
<td>12.6</td>
<td>3.5-8.4</td>
<td>5.9</td>
<td>Sandy</td>
</tr>
<tr>
<td>YA_MB02S</td>
<td>8.1</td>
<td>Superficial</td>
<td>2.98</td>
<td>5.12</td>
<td>0.9-3.1</td>
<td>1.7</td>
<td>0.2-0.6</td>
<td>0.3</td>
<td>Clayey</td>
</tr>
<tr>
<td>YA_MB03S</td>
<td>9.12</td>
<td>Superficial</td>
<td>1.07</td>
<td>8.05</td>
<td>20.4-54.7</td>
<td>36.4</td>
<td>2.5-6.8</td>
<td>4.5</td>
<td>Sandy</td>
</tr>
<tr>
<td>YA_MB04S</td>
<td>8.27</td>
<td>Superficial</td>
<td>2.5</td>
<td>5.77</td>
<td>16.8-47.4</td>
<td>28.4</td>
<td>2.9-8.2</td>
<td>4.9</td>
<td>Sandy</td>
</tr>
<tr>
<td>YA_MB05S</td>
<td>8.12</td>
<td>Superficial</td>
<td>1.09</td>
<td>7.03</td>
<td>12.9-31.6</td>
<td>20.9</td>
<td>1.8-4.5</td>
<td>3.0</td>
<td>Sandy</td>
</tr>
<tr>
<td>YA_MB06S</td>
<td>7.86</td>
<td>Superficial</td>
<td>2.08</td>
<td>5.78</td>
<td>0.6-3.4</td>
<td>1.3</td>
<td>0.1-0.6</td>
<td>0.2</td>
<td>Clayey</td>
</tr>
<tr>
<td>YA_MB07S</td>
<td>8.05</td>
<td>Superficial</td>
<td>3.84</td>
<td>4.21</td>
<td>38.6</td>
<td>38.6</td>
<td>9.2</td>
<td>9.2</td>
<td>Very sandy</td>
</tr>
<tr>
<td>YA_MB08S</td>
<td>9.83</td>
<td>Superficial</td>
<td>1.68</td>
<td>8.15</td>
<td>58.7-82.3</td>
<td>67.0</td>
<td>7.2-10.1</td>
<td>8.2</td>
<td>Very Sandy</td>
</tr>
<tr>
<td>YA_MB09S</td>
<td>8.27</td>
<td>Superficial</td>
<td>4.04</td>
<td>4.23</td>
<td>0.5-2.5</td>
<td>1.7</td>
<td>0.1-0.6</td>
<td>0.4</td>
<td>Clayey</td>
</tr>
<tr>
<td>YA_MB10S</td>
<td>5.4</td>
<td>Superficial</td>
<td>2.55</td>
<td>2.85</td>
<td>0.4-2.3</td>
<td>0.9</td>
<td>0.1-0.8</td>
<td>0.3</td>
<td>Clayey</td>
</tr>
<tr>
<td>YA_MB11S</td>
<td>8.67</td>
<td>Superficial</td>
<td>1.13</td>
<td>7.54</td>
<td>10.3-18.5</td>
<td>14.1</td>
<td>1.4-2.5</td>
<td>1.9</td>
<td>Sandy</td>
</tr>
<tr>
<td>YA_MB12S</td>
<td>8.96</td>
<td>Superficial</td>
<td>-0.45</td>
<td>7.96</td>
<td>12.7-19.1</td>
<td>15.9</td>
<td>1.6-2.4</td>
<td>2.0</td>
<td>Sandy</td>
</tr>
</tbody>
</table>
The summary of the Superficial aquifer permeabilities are presented in Table 6.

**Table 6: Summary of Superficial Aquifer Properties**

<table>
<thead>
<tr>
<th>Tested Sediment</th>
<th>Bulk Permeability (m/d)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Range (from-to)</td>
</tr>
<tr>
<td></td>
<td>Average</td>
</tr>
<tr>
<td>Clay/Clayey sand/ Sandy clay</td>
<td>0.1-0.8</td>
</tr>
<tr>
<td>Slightly clayey/gravelly sand</td>
<td>1.4-10.1</td>
</tr>
<tr>
<td>Average Superficial sediments (mix of clay/sand/gravel)</td>
<td>0.1-10.1</td>
</tr>
</tbody>
</table>

The salient points are as follows:

- The calculated permeability values are bulk values for all of the sediment tested; none of the values apply to individual units of the Superficial Formation;
- The bulk average permeability of the Superficial aquifer varies and ranges between 0.1 and 10 m/d, averaging 3.5 m/d;
- The variability in permeability values indicate a highly heterogeneous aquifer, which reflects the variation in lithology;
- Based on the lithological characteristics of the dominated sediment tested at each bore, lower bulk permeability (i.e. average of 0.3 m/d) was calculated for more clayey sediments and higher bulk permeability (i.e. average of 5.4 m/d) was estimated for sandy sediments;
- These estimated values are consistent with the published data of the permeability (Freeze and Cherry, 1979).

**5.4 Baseline Hydrogeological Monitoring**

Since monitoring commenced in July 2017, six monitoring bores (YA_MB01S, YA_MB02S, YA_MB04S, YA_MB07S, YA_MB09S and YA_MB10S) and several private landowner bores have been monitored for water level and water quality of the Superficial and Leederville aquifers on the monthly basis. Locations of bores selected for the baseline groundwater monitoring are shown in Figures 10 and 11. Details of Doral’s monitoring bores are presented in Table 4, whereas for the private landowner bores in Appendix C.

It should be noted that bores (YA_MB03S, YA_MB05S, YA_MB06S, YA_MB08S, YA_MB11S and YA_M12S) have not been monitored since these bores were constructed in May 2019 due to the site access limitation (i.e. a lack of the landowner access approval), except during the hydraulic testing in October 2019, where water levels reading and water samples were collected. Monthly baseline groundwater monitoring in these bores will commence from October 2019 onwards.

**5.4.1 Water Levels**

The results from monthly water levels monitoring in the Superficial and Leederville aquifers from Doral’s monitoring bores and several private bores have been plotted, as hydrographs in Figures 12 and 13.
The groundwater level hydrographs in Figure 12, representing monitoring bores screened in the Superficial Formation, indicate the following:

- Pre-mining groundwater levels in the Superficial aquifer across the proposed mining area ranged between 15.6 and 34.8 mAHD (i.e. 0 to 4.7 mbgl);
- Highest water level elevations were recorded in August or September and lowest in May or June;
- Seasonal cycles of water table variations associated with the winter-dominated rainfall recharge to the aquifer are evident. The seasonal water level variations for these bores were between 1.7 and 2.6 m, averaging of 2 m;
- Variations in water levels can usually be correlated with variations in rainfall.

The Superficial water levels across the site slope in north-western direction under a low hydraulic gradient, which closely reflect the site topography. The site’s groundwater flow direction is consistent with the regional flow direction, generally towards the coast. Site groundwater level contours in the Superficial aquifer for the winter and summer period are shown in Figures 14 and 15.

The groundwater level hydrographs for monitoring bores screened in the shallow depths of the Leederville Formation (Figure 13), indicate the following:

- Long-term groundwater elevations (since 2000) recorded in the DWER monitoring bores, 61030085 (BN28I) and 61030088 (BN29I), located nearby to Yalyalup site, ranged between 18.2 to 20.3 mAHD and 33 to 35.8 mAHD, respectively with the seasonal water level fluctuations of between 2 to 2.5 m;
- Bores Lot668_Bore2 and 23073124 recorded water level variation of up to 6 m as a response to pumping in these bores.

Groundwater levels (m below surface) in the Leederville aquifer tend to decrease towards the north-west, which is consistent with the regional groundwater flow direction generally towards the coast. Site groundwater level contours in the Leederville aquifer for the winter and summer period are shown in Figures 16 and 17.

5.4.2 Groundwater Quality

The field water quality measurements (i.e. pH, EC and TDS) were taken from selected bores screened in the Superficial and Leederville aquifers on monthly basis since December 2017 and the results are presented in Figures 18 to 21.

The chemistry data from the monitoring bores have been plotted on Piper diagrams (Figures 22 and 23) and is discussed further below.

The field and laboratory water chemistry results for the Superficial aquifer since December 2017 are presented in Figures 18 and 19, and summarised below:

- Field pH is in the range of 5.2 (YA_MB07S) to 6.5 (20005166); acidic to slightly acidic, but generally pH was between 5.4 and 6. Lower values of pH were normally recorded in summer periods and higher values in winter periods;
• Field TDS concentrations ranged between 190 mg/L (YA_MB07S) and 1,900 mg/L (SCPD28A), generally below 1,200 mg/L, indicating water being generally fresh to marginal. The only exception is site SCPD28A, where TDS concentrations range from 1,400 and 1,900 mg/L, i.e. being brackish;

• Total Acidity (as CaCO₃) ranged from 14 to 170 mg/L, relatively consistent;

• Total Alkalinity (as CaCO₃) ranged from 11 to 130 mg/L, generally below 70 mg/L, relatively consistent;

• Sulphate concentrations ranged between 24 to 230 mg/L, generally below 150 mg/L;

• Concentrations of dissolved metals were mostly below or just above the limit of reporting, except for the iron concentrations that were recorded to be slightly elevated (below between 0.4 to 23 mg/L) in all Doral monitoring bores.

The Piper Plot (Figure 22) indicates that all of the groundwater samples collected from Superficial aquifer monitoring bores during summer and winter periods have a similar chemical composition and are dominated by sodium and chloride.

The field and laboratory water chemistry results for the Leederville aquifer since December 2017 are presented in Figures 20 and 21, and summarised below:

• Field pH was in the range of 5.2 (20005356) 6.6 (Lot758_Bore); acidic to slightly acidic, but generally pH was between 5.6 and 6.2;

• Field TDS concentrations ranged between 350 mg/L (Lot552_Bore) and 1,050 mg/L (20005356), generally below 800 mg/L, indicating water being fresh to marginal;

• Total Acidity (as CaCO₃) ranged from 50 to 200 mg/L, relatively consistent;

• Total Alkalinity (as CaCO₃) ranged from 20 to 90 mg/L, relatively consistent;

• Sulphate concentrations are generally below 40 mg/L, except for 20005356 (60 to 140 mg/L);

• Concentrations of dissolved metals were generally low, except for the iron concentrations that were recorded to be elevated (below between 20 and 35 mg/L).

The Piper Plot (Figure 23) indicates that all of the groundwater samples collected from Leederville monitoring bores during summer and winter periods have a similar chemical composition and are dominated by sodium and chloride.
6 CONCEPTUAL HYDROGEOLOGY

The hydrogeology of the Yalyalup project area has previously been documented by Hydrosolutions (2017). The current understanding of the site hydrogeological conditions has been based on the review of all available literature in the South West region (Wharton, 1982, Hirschberg, 1989, Deeney, 2005 and Baddock, 2005), mineral exploration drilling data for the site, together with the assessment of the hydrogeological data collected during the recent fieldwork undertaken by Doral and AQ2 (refer to Section 5).

6.1 Groundwater Management Area

The Yalyalup project is wholly located within the Busselton-Capel Groundwater Area for the Superficial and Leederville aquifers and within the Busselton-Yarragadee Groundwater Area for the Yarragadee aquifer. All these groundwater areas are covered by the South West Groundwater Areas Allocation Plan produced by the DWER (DWER, 2009).

6.2 Study Groundwater Modelling Area

The study area that is covered by the numerical groundwater model comprises the proposed Yalyalup mine area, which was investigated during the drilling and testing programmes, and the wider area that covers the Vasse-Wonnerup Wetland, Abba and Sabina Rivers and Whicher Scarp (Figure 3).

6.3 Aquifer Units

Three major aquifers have been identified within the Yalyalup project (ordered from shallow to deep), namely:

- Superficial;
- Leederville; and
- Yarragadee.

A conceptual hydrogeological cross section in the Yalyalup area is presented in Figure 8.

6.3.1 Superficial Aquifer

The Bassendean Sand, Guildford Formation and Yoganup Formation form an unconfined Superficial aquifer, with a maximum saturated thickness of 9 m in the study area. The permeability of the superficial aquifer is variable and depends on sediment type, with saturated sands having higher permeability than clays. At the project, the Yoganup Formation forms the main portion of the aquifer, while the Bassendean Sand is generally saturated when water levels rise in the wet season. The Guildford Formation is of lower permeability, owing to its more clayey nature. The high sand content in all the superficial units at the site mean they are in hydraulic connection and behave as a single aquifer unit. There is no evidence of any perched aquifer at the site.

Outside of the proposed mine area, within the modelling study area and closer to the coast, the Bassendean Sands are interfingered by Tamala Limestone and Safety Bay Sand, which form a significant aquifer zone along the coastal margin. The basal sand of the Guildford Formation close to the coast also forms local aquifer, which may be equivalent to the Yoganup Formation, that is likely to be absent at
this location. The estuarine and swamp deposits at the Vasse-Wonnerup Wetland act as a low permeability aquiclude, owing to its clayey nature.

6.3.2 Leederville Aquifer

The Leederville Formation forms a multi-layered confined aquifer system, comprising discontinuous interbedded sequences of sand, clayey sand, silt and shale. It underlies the Superficial deposits across the study area, coming to surface only to the south-east of the study area, where it forms the Whicher Scarp.

At the study area, the Leederville aquifer generally comprises the Vasse Member of the Leederville Formation. The Mowen Member of the Leederville Formation, which overlies the Vasse Member is commonly considered as an aquitard due to its clayey nature. At the eastern portion of the modelled study area, the Mowen Member is likely to be very thin or has a greater sand content.

6.3.3 Yarragadee Aquifer

The Yarragadee Formation forms a confined Yarragadee aquifer below the Leederville aquifer. There are four sub-units within the Yarragadee Formation with distinct lithological properties. The Yarragadee aquifer is confined by the Leederville Formation. The Bunbury Basalt is discontinuously thin aquitard and it is believed not to be present at the modelled study area.

6.4 Aquifer Properties

Proposed aquifer properties for use in the numerical modelling for the Superficial, Leederville and Yarragadee Aquifers are provided in Table 7. These are based on a combination of field observations from the site investigation, review of geology data from resource drilling (i.e. lithology and assays) and a literature review (especially values used in the SWAMS model).

Table 7: Conceptual Model – Aquifer Parameters

<table>
<thead>
<tr>
<th>Aquifer</th>
<th>Aquifer Units</th>
<th>Horizontal Hydraulic Conductivity, Kh (m/d)</th>
<th>Vertical Hydraulic Conductivity, Kv (m/d)</th>
<th>S</th>
<th>Sy (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Superficial</td>
<td>Alluvium, Estuarine Deposits &amp; Sand derived from Tamala Limestone</td>
<td>5</td>
<td>0.5</td>
<td>NA</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Alluvium and Estuarine Mud</td>
<td>0.01</td>
<td>0.0001</td>
<td>NA</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Safety Bay Sand</td>
<td>15</td>
<td>0.15</td>
<td>NA</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>Tamala Limestone</td>
<td>50</td>
<td>5</td>
<td>0.0001</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>Bassendean Sand</td>
<td>10</td>
<td>1</td>
<td>NA</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>Guildford Formation</td>
<td>0.3</td>
<td>0.03</td>
<td>0.0001</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Yoganup Formation</td>
<td>5</td>
<td>0.5</td>
<td>0.0001</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>Mowen Member</td>
<td>0.01</td>
<td>0.0001</td>
<td>0.0001</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Vasse Member</td>
<td>1</td>
<td>0.0001 (north coastal margin) and 0.001 (remaining study area)</td>
<td>0.0001</td>
<td>10</td>
</tr>
<tr>
<td>Yarragadee</td>
<td>Yarragadee (Units 1,2,3,4)</td>
<td>7</td>
<td>0.07</td>
<td>0.0001</td>
<td>10</td>
</tr>
</tbody>
</table>

Vertical permeabilities of the Superficial, Leederville and Yarragadee aquifers are lower than horizontal permeabilities by a factor of between 10 and 1000. Generally, this is due to stratification and variation
in lithology (i.e. higher factor reflects higher clayey content, which restrict vertical flow) and vertical permeabilities vary considerably through the units.

6.4.1 **Superficial Aquifer**

The Superficial Formation is variable across the region and permeabilities are site specific. However, in general, permeabilities have been estimated to be up to 50 m/d (Davidson, 1995; Hirschberg, 1989), dependent on the percentage of the sand content.

It should be noted that a lower permeability (10 m/d) for the Bassendean Sand was used, due to a slightly greater clay content, according to the site’s assays and lithology. This permeability value is consistent with the value for fine to medium grained sand (Freeze and Cherry, 1979).

The Guildford Formation consists of low permeability sediments (i.e. clay and silt), however at the site it is sandy in places, thus the assigned permeability of 0.3 m/d is slightly higher than the average permeability for this unit (i.e. <0.1 m/d). This permeability value is consistent with the value obtained from the hydraulic testing at the site for the clayey sediment.

The permeability value of 5 m/d assigned to the Yoganup Formation is slightly reduced from the average value of 8 to 10 m/d, owing to being slightly clayey in places. This permeability value is consistent with the value obtained from the hydraulic testing at the site for the sandy sediment.

The estuarine and swamp deposits at the Vasse-Wonnerup Wetland act as an aquiclude, with a low permeability of 0.001 m/d assigned to the horizon.

6.4.2 **Leederville Aquifer**

The hydraulic permeability of the Leederville aquifer is highly variable, dependent on the portion of clay and sand beds, and the clay matrix content within the sand beds. Bulk horizontal permeability is estimated to be in the range of 0.1 to 5 m/d, with the horizontal permeability of generally 1 to 3 m/d in the sand beds (Baddock, 2005). Pumping test data conducted in the Busselton area (Baddock, 2005) show the horizontal permeability of approximately 1 m/d, which indicate a higher clay content. The Mowen Member acts as an aquiclude, with a low permeability of 0.001 m/d.

6.4.3 **Yarragadee Aquifer**

The permeabilities of the Yarragadee aquifer vary between each of the aquifer units. High permeability sands are present within Yarragadee Formation Units 1, 2 and 3, although they are most extensive within Unit 3. At the Yalyalup site, the Yarragadee Formation is likely to encounter all four units up to 900 m thick. The bulk permeability is estimated to be in the range between 1 and 30 m/d, with the average permeability of 14 m/d, however, isotopic dating of groundwater indicates an average hydraulic conductivity of 8 m/day (Baddock et al., 2005). Based on the literature pumping data in the Busselton region (Baddock, 2005) and the experience from the Tronox’s Wonnerup mine and Doral’s Yoongarilup mine permeability is typically 2 to 8 m/d.

It is likely that the water supply bore will be drilled in the Unit 3, which is reported to be the most transmissive unit, due to its low clay content. Thus, a bulk permeability of 7 m/d has been assigned in the numerical model.
6.5 Recharge

6.5.1 Superficial Aquifer

Recharge of groundwater to the Superficial aquifer is mostly from direct infiltration of rainfall, with some recharge occurring by upward leakage from the underlying Leederville aquifer mostly across the seaward section and from down-slope surface drainage from the Whicher Scarp (Hirschberg 1989). In the climate of South West of WA, most of the rain that falls is lost again through various forms of evapotranspiration. Any precipitation in excess of soil moisture deficit and evapotranspiration will become runoff or infiltrate downward to the water table. The downward flow of water may or may not reach the water table depending on the soil properties in the soil profile. The rate of groundwater recharge is controlled by climate, land use, vegetation type and density, soil hydraulic properties, geology and topography; and is in a range between 5 and 40% of the rainfall, averaging 10%. Much of the Swan Coastal Plain is cleared of native vegetation for pasture, which results in relatively high recharge rates even up to 50% of the rainfall (Baddock 2005). Rainfall recharge values assigned in the groundwater model and its logic is described in more detail in Sections 9.4.2 and 9.6.4.

6.5.2 Leederville Aquifer

The Leederville aquifer is recharged mostly on the Blackwood Plateau by direct recharge where the aquifer is present at surface, with lower rates by downward leakage through the Mowen aquitard. Chloride mass balance calculations suggest that recharge rates are around 7% of rainfall and locally significantly higher, while leakage recharge through the Mowen aquitard may be equivalent to only 1 to 2% of rainfall. (Baddock 2005).

Hirschberg (1989), reports that upward leakage occurs into the Superficial aquifer from the confined aquifers in the vicinity of the Yalyalup site, although later studies suggest that downward flows have also been occurring since that time, potentially due to ongoing regional abstraction from the Leederville aquifer (Schafer et al, 2008). Based on the measured groundwater levels for the two aquifers shown on Figure 24, there is generally a 1 m or greater difference in equipotential heads between the Superficial and Leederville aquifers, with lower elevations recorded within the Leederville aquifer. However, water levels recorded in bores screened in the deeper section of the Leederville aquifer show the upward hydraulic heads (Figure 24). The potential for recharge on the coastal plains is restricted by the upward potentiometric head gradients or small downward gradients that exist between the Leederville and Superficial aquifers.

6.5.3 Yarragadee Aquifer

The Yarragadee aquifer receives recharge by downward leakage from the Leederville Formation (Hirschberg 1989), especially in the inland areas around the Whicher Scarp where downward heads prevail. As well as downward leakage from the Leederville Aquifer, recharge to the aquifer is likely to occur mostly from the south and south east where the formation outcrops.
6.6 Water Levels and Groundwater Flow Direction

6.6.1 Superficial Aquifer

The water table elevation slopes gently from the Whicher Scarp (i.e. ~40 mAH) to the coast (i.e. 0 mAH), closely parallels to the topography in north-western direction under a low hydraulic gradient. Groundwater levels, as measured in the Superficial monitoring bores (both Doral’s monitoring bores, other private users and DWER monitoring bores), are close to surface, at depths of 0 to 4.7 mbgl (i.e. 15.6 and 34.8 mAH). At the project low-lying areas are often waterlogged during winter period (i.e. with the water table rising to ground surface). The seasonal water table fluctuation is less than 0.4 m close to the coast, approximately 1 to 2 m across the central part of the Swan Coastal Plain (including the mine site) and up to 2 to 4 m close to the Whicher Scarp. Hydrographs for superficial deposits on the Coastal Plain show that variations in water level are usually correlated with variations in rainfall. Peaks in the groundwater hydrographs generally occur 1 to 3 months after peaks in the rainfall and the length of the time lag increases with increasing depth to the water. The average water table elevation contours in the Superficial aquifer across the modelled area are shown in Figure 25. Although annual rainfall indicates a drying climate (Section 2.2), rainfall and subsequently aquifer recharge experienced in recent years is still sufficient to fill the Superficial aquifer and a long-term trend of decline in water levels due to change in climate is therefore not observed in the modelled study area (Figure 24).

6.6.2 Leederville Aquifer

Generally, the Leederville Formation receives recharge towards the Whicher Scarp and discharges towards the coast. Groundwater level elevations in the Leederville aquifer reduce from an average of approximately 35 mAH at the foot of the Whicher Scarp (61030067) to approximately 2 mAH close to the coast (61030028). The seasonal water level fluctuations are generally between 2 to 3 m. Additionally, a gradual small declining trend associated with ongoing pumping activity in the area is evident since 2003, especially in the bores screened deeper in the Leederville aquifer (Figure 24). The average water table elevation contours in the Leederville aquifer across the modelled area are shown in Figure 26.

6.6.3 Yarragadee Aquifer

Groundwater flow through the upper part of the Yarragadee aquifer is south to southwest toward the coast. Groundwater level elevations in the Yarragadee aquifer reduce from an average of approximately 25 to 35 mAH at the foot of the Whicher Scarp to approximately 5 mAH close to the coast.

There is generally 4 to 5 m of the average seasonal water level fluctuation evident at the study area. The hydrograph for DWER’s monitoring bore 61000125 (Figure 24), located 2.5 km north of the proposed mine site water supply production bore indicates, apart from seasonal fluctuations (peaks in March and lows in September), a gradual small declining trend associated with ongoing pumping activity in the area.
6.7 Discharge

6.7.1 Superficial Aquifer

Groundwater is discharged from the Superficial aquifer to the ocean and the coastal swamps, to surface drainage including rivers, streams and an extensive network of constructed drains. It is also discharged via direct evaporation from swamps and evapotranspiration from vegetation where the water table is shallow. There is also discharge of groundwater downward into the Leederville and Yarragadee aquifers where the hydraulic head gradient is downward, especially where the superficial lithology is sandy (Baddock, 2005). Owing to the very shallow water table, the loss of groundwater to the atmosphere through evapotranspiration is likely to be high (Hirschberg 1989).

6.7.2 Leederville Aquifer

Groundwater discharge from the Leederville aquifer into the underlying Yarragadee aquifer occur through the majority of the study area. However, clay layers within the Leederville Formation and shale layers of the upper unit of the Yarragadee Formation are believed to restrict vertical flow. Groundwater head gradients are upward in the north of the study area, where groundwater is discharged into the overlying Superficial Formation near the coast and offshore.

6.7.3 Yarragadee Aquifer

A major volume of groundwater discharge from the Yarragadee aquifer is offshore adjacent to Bunbury, where the aquifer subcrops beneath the Superficial aquifer below the sea floor. Groundwater is also discharged to the overlying Superficial and Leederville Formations adjacent to the coast.

6.8 Groundwater Quality

6.8.1 Superficial Aquifer

Groundwater within the study area is fresh (<500 mg/L TDS) to brackish (up to 3,000 mg/L TDS), with a general trend of increasing salinity toward the coast from the Whicher Scarp. High salinity groundwater occurs in areas of poorly drained clay soils and swampy areas, exceeding 2,000 mg/L in some areas. Elevated groundwater salinity occurs near the coast resulting from coastal saline swamps and groundwater mixing with the sea-water interface (Baddock, 2005).

Groundwater chemistry within the Superficial aquifer is normally a sodium-chloride type.

6.8.2 Leederville Aquifer

Groundwater within the study area is fresh to transitional, with the average salinity of between 300 and 400 mg/L TDS. The areas of high salinity groundwater generally correspond to discharge areas of the Leederville aquifer where there is an upward potentiometric head gradient with the overlying Superficial aquifer or affected by downward leakage of higher salinity groundwater from the overlying Superficial aquifer (Baddock, 2005).
Groundwater chemistry within the Leederville aquifer is normally a sodium-chloride type, but the elevated bicarbonate is evident around Busselton area likely associated with the infiltration from the Superficial aquifer containing Tamala Limestone.

Locally the aquifer can contain high concentrations of iron.

6.8.3 Yarragadee Aquifer

Groundwater within the study area is fresh with the average salinity of groundwater within Yarragadee units 1 to 3 is 360 mg/L TDS, while in unit 4 it is 440 mg/L TDS. Groundwater salinity is lowest within the main recharge areas to the aquifer, where the salinity is mostly less than 200 mg/L TDS. Higher groundwater salinity within the Yarragadee aquifer beneath the Swan Coastal Plain in the area of Busselton correspond to elevated groundwater salinity within the overlying Leederville and Superficial aquifers (Baddock, 2005).

Groundwater chemistry within the Yarragadee aquifer is normally a sodium-chloride type, but becomes sodium-bicarbonate type in the deeper portions of the aquifer. An increased proportion of sodium and bicarbonate generally distinguishes older groundwater in the Yarragadee aquifer, possibly as the result of weathering of feldspars (Baddock, 2005). The relative proportions of major ions are similar to those in the Leederville Formation, suggesting a close relationship between the two aquifers in the project area.
7 EXISTING GROUNDWATER USE

7.1 Groundwater Dependent Ecosystem

7.1.1 Wetlands

Approximately 90% of the proposed Yalyalup mine site is mapped as a wetland in the Department of Biodiversity, Conservation and Attractions (DBCA) Geomorphic Wetlands of the Swan Coastal Plain dataset (DEC, 2008), all of which has been assessed as being in the ‘Multiple Use’ management category, which is described as wetlands with few ecological attributes and functions remaining. The majority of the wetland area within the project area (77%) is mapped as Palusplain (i.e. seasonally waterlogged flat), with small areas of Sumpland (i.e. seasonally inundated basin, 3%) and floodplain (seasonally inundated flats, 17%).

There are no wetlands of environmental significance present within the proposed mine site location. The Vasse-Wonnerup wetland is located approximately 4.6 km to the northwest of the project area (Figure 1). This wetland is listed under the RAMSAR convention as a wetland of international significance and is an extensive, shallow, nutrient-enriched, wetland system with widely varying salinities. Water levels in it have two principal components, the Vasse and Wonnerup lagoons (former estuaries), are managed through the use of weirs (flood gates) with the aim of minimising flooding of adjoining lands and of keeping sea water out. When the water level in the estuaries rises above sea level, hydrostatic pressure opens the floodgates and allows water to flow out to Wonnerup Inlet and the sea. When the level drops, the gates close, thereby preventing ingress of sea water (Hydrosolutions, 2017).

Three reserve areas in the Busselton-Capel groundwater subarea are under ecological monitoring due to the presence of high sensitivity GDE’s (DWER, 2009, Figure 3). These GDE’s have management triggers and responses attached to them by DWER (Del Borello, 2008). These are labelled ‘conservation’ Sumpland and Floodplain, but are located approximately 6 km the northeast and southwest of the proposed Yalyalup mine site.

7.1.2 Vegetation

A search of the BOM GDEs database by HydroSolutions (2017) over a 5km radius from the Site indicated that no stygofaunal GDEs were present in the vicinity of the project, but that the surrounding area contains marri, jarrah, wandoo, river gum and casuarina vegetation, identified in the database as “medium woodland” with moderate to high potential GDE status. The majority of these stands of vegetation are proximal to the Sabina River.

A detailed Groundwater Dependent Ecosystem (GDE) survey at the site has been undertaken by Ecoedge in 2019, as a supplementation to the initial vegetation survey conducted in 2016 (Ecoedge, 2019a). The detailed GDE survey concluded that portions of both the McGibbon Track and Princefield Road within the study area contain vegetation that is understood to be high conservation value GDE. The impact assessment on the GDEs due to dewatering at the Yalyalup have been investigated by Ecoedge and reported in a separate document (Ecoedge, 2019b).
7.2 Other Groundwater Users

According to the DWER Water Register Database, there are currently 23 licenced groundwater users within the vicinity of the Yalyalup site (i.e. within a 2 km radius), of which 2 abstract from the Superficial aquifer, 21 from the Leederville aquifer and none from the Yarragadee aquifer.

A total of 503 licenced groundwater users are currently abstracting water within the groundwater modelled area (refer to Section 9.4.4); 43 of them are abstracting from the Superficial aquifer (a total of 4.1 GL/year), 435 from the Leederville aquifer (a total of 6.8 GL/year), and 25 from the Yarragadee aquifer (a total of 32.3 GL/year).

Current drawpoints and licenced groundwater users in the vicinity of the Yalyalup area are shown in Figures 27 and 28 and details are summarised in Appendix D. More details on the other users’ pumping regime and the logic used in the numerical groundwater model are provided in Section 9.4.4 and shown in Figures 40 to 42.

The majority of groundwater abstracted from the Superficial aquifer is stated to be used for livestock and domestic/household purposes, although there are two major, high volume abstraction licenses. These abstractions are located to the north and down gradient of the Yalyalup site, are owned by the Cable Sands (WA) Pty Ltd (GWL173523 0.6 GL/year and GWL202089 1.4 GL/year) and are associated with the Wonnerup mine (existing mine) and Wonnerup North (proposed mine), respectively. Iluka’s Tutunup South mine site, located 2.5 km south east and up gradient of the Yalyalup site, used to abstract 1.04 GL/year (GWL167315), however this mine was closed in 2018.

There are two licences that abstract water from the Superficial aquifer in close proximity to the project; GWL 180363 is allowed to abstract 50,000 kL/year, while GWL182032 is allowed to abstract 30,000 kL/year.

All identified groundwater licences within the proposed mine area abstract from the Leederville Aquifer (5 licenses). The licenced abstraction volumes are minor, ranging between 1,500 to 14,500 kL/year and are used for livestock and domestic/household purposes. There is one Leederville licence (GWL180362), located immediately south west of the project, that is allowed to abstract 100,000 kL/year. Details of these licences are summarized in Table 8.

The closest licenced Yarragadee abstraction bore to the Doral’s proposed Yarragadee production bore (YA_PB01) is bore under GWL156423 (Turf Farm), located approximately 3.7 km away. Additionally, there are three major, high volume abstraction Yarragadee aquifer licenses within the groundwater modelled area: Cable Sands (WA) Pty Ltd (GWL16184 - 3.9 GL/year), Doral Mineral Sands Pty Ltd (AGR18381291) under GWL6658815 -1.6 GL/year) and The Trust Company Ltd (GWL151407-6.66 GL/year). Cable Sands and Doral licences are associated with the Wonnerup North mine and Yoongarillup mine, respectively. Two avocado farms are covered under one GWL151407, with first farm being located north of the Wonnerup North mine and second farm to the northeast of the Yoongarillup mine.

In addition to the DWER Water Register Database, DWER Water Information Reporting (WIR) database provides information regarding the bores drilled (including licenced and unlicenced bores) and shows that there are also 26 current and legacy landholder bores within the project development which are
screened within the Superficial Aquifer, but not licenced. Licencing of Superficial Aquifer abstractions are not always mandated by the DWER. These bores are listed in Appendix C and shown in Figure 29.

DWER WIR Database also shows that there are several DWER bores within the modelled project area that are screened in the Superficial, Leederville and Yarragadee aquifers and are used as regional monitoring bores. All DWER monitoring bores are listed in Appendix C and shown in Figure 29.

Table 8: Active Superficial and Leederville Aquifer Groundwater Licensees within 2 km from the Proposed Yalyalup Mine (DWER)

<table>
<thead>
<tr>
<th>WRI Licence Number</th>
<th>Issue Date</th>
<th>Expiry Date</th>
<th>Licence Allocation (kL/year)</th>
<th>Aquifer</th>
</tr>
</thead>
<tbody>
<tr>
<td>180363</td>
<td>24/03/2016</td>
<td>31/03/2026</td>
<td>50,000</td>
<td>Superficial</td>
</tr>
<tr>
<td>182032</td>
<td>11/12/2015</td>
<td>10/12/2025</td>
<td>30,000</td>
<td></td>
</tr>
<tr>
<td>107623</td>
<td>30/04/2012</td>
<td>13/03/2022</td>
<td>2,850</td>
<td></td>
</tr>
<tr>
<td>110289</td>
<td>24/02/2017</td>
<td>23/02/2027</td>
<td>1,500</td>
<td></td>
</tr>
<tr>
<td>156606</td>
<td>19/03/2015</td>
<td>18/03/2025</td>
<td>2,220</td>
<td></td>
</tr>
<tr>
<td>165828</td>
<td>20/11/2009</td>
<td>9/11/2019</td>
<td>10,000</td>
<td></td>
</tr>
<tr>
<td>168831</td>
<td>30/05/2017</td>
<td>31/05/2027</td>
<td>63,700</td>
<td></td>
</tr>
<tr>
<td>169309</td>
<td>19/06/2019</td>
<td>18/06/2029</td>
<td>32,000</td>
<td></td>
</tr>
<tr>
<td>174021</td>
<td>4/08/2011</td>
<td>4/08/2021</td>
<td>1,000</td>
<td></td>
</tr>
<tr>
<td>174905</td>
<td>6/01/2012</td>
<td>6/01/2022</td>
<td>1,800</td>
<td></td>
</tr>
<tr>
<td>175045</td>
<td>21/02/2012</td>
<td>20/02/2022</td>
<td>1,500</td>
<td></td>
</tr>
<tr>
<td>177828</td>
<td>16/01/2019</td>
<td>11/01/2026</td>
<td>10,500</td>
<td></td>
</tr>
<tr>
<td>178017</td>
<td>2/09/2013</td>
<td>1/09/2023</td>
<td>1,500</td>
<td></td>
</tr>
<tr>
<td>179889</td>
<td>16/09/2014</td>
<td>15/09/2024</td>
<td>1,500</td>
<td></td>
</tr>
<tr>
<td>180362</td>
<td>1/06/2017</td>
<td>31/05/2027</td>
<td>100,000</td>
<td></td>
</tr>
<tr>
<td>181194</td>
<td>17/08/2015</td>
<td>18/08/2025</td>
<td>18,400</td>
<td></td>
</tr>
<tr>
<td>183817</td>
<td>10/01/2017</td>
<td>10/01/2027</td>
<td>60,000</td>
<td></td>
</tr>
<tr>
<td>202488</td>
<td>22/02/2019</td>
<td>21/02/2029</td>
<td>1,500</td>
<td></td>
</tr>
<tr>
<td>49902</td>
<td>19/06/2019</td>
<td>18/06/2029</td>
<td>27,000</td>
<td></td>
</tr>
<tr>
<td>50966</td>
<td>15/06/2015</td>
<td>14/06/2025</td>
<td>14,500</td>
<td></td>
</tr>
<tr>
<td>58886</td>
<td>19/02/2013</td>
<td>19/02/2023</td>
<td>2,500</td>
<td></td>
</tr>
<tr>
<td>67672</td>
<td>1/05/2015</td>
<td>30/04/2025</td>
<td>9,500</td>
<td></td>
</tr>
<tr>
<td>95377</td>
<td>23/05/2012</td>
<td>30/06/2022</td>
<td>3,000</td>
<td></td>
</tr>
</tbody>
</table>
8 PROPOSED MINING DEVELOPMENT BACKGROUND

The Yalyalup Project is proposed to operate for 6 years, from startup to closure, with 3.5 years of the mining phase, starting mining in the third quarter (Q3) of 2021 (i.e. July 2021) and finish in Q4 of 2024 (i.e. December 2024). The total extent of mining and dewatering, including the staged mining zones, is shown on Figure 30.

Ore from the deposit will be mined progressively via a series of open-cut pits using dry mining techniques. Mining will be staged in order to minimise the area of disturbance, with the aim of achieving focused and effective management of the environmental factors at each pit location, prior to moving onto the next pit location. Each mining zone would be mined over a period of approximately three months. Doral is planning to extract mineral sands from the Bassendean Sand and Yoganup Formation. The removed topsoil and overburden will be stockpiled. Ore will be mined in a series of cuts, to an approximate maximum depth of 10.5 mbgl. Pits will be mined on a slight incline from the deepest point and then mined moving up-gradient in order to retain pit water within drainage channels to a sump at the deepest point on the pit floor. This form of dewatering is referred to as ‘passive’, as no dewatering apparatus (e.g. spears) are used to actively abstract water and groundwater drawdown below the base of the pit. The groundwater drawdown of any given pit will be related to the pit depth (i.e. up to 10.5 m).

Processing of ore will commence in-pit mining to the feed preparation plant, where after the slurry will be pumped to the wet concentration plant for further processing. Waste clay and sand materials from processing of this ore will be combined and backfilled into the mine voids using co-flotation (co-disposal system) as a priority where possible. Thus the majority of clay tailing resulting from the primary mineral separation will be co-disposed to the pit void with the remaining surplus volume temporarily placed in a Tailing Storage Facility, herein referred to as Solar Evaporation Ponds (SEPs) to allow drying of the clay prior to harvesting and returning to the pit void. The mined area will be rehabilitated back to pasture and/or native vegetation, depending on pre-mining conditions, consistent with the post-mine land use requirements.

Abstracted water during mining (i.e. dewatering) will be conserved in the mining process as much as possible, the majority being used in processing or included in reinstatement material. Water returns from the process may have a low (i.e. acidic) pH and will be treated as needed, prior to backfilling.

Water supplies are required for mineral ore processing and are planned to be sourced from recycled water from hydraulically returned tailings (i.e. sand and clay fines pumped to the mine void and solar evaporation ponds), rainfall runoff, pit dewatering water and supplemented by pumping from the external production bore in the Yarragadee aquifer (only during periods of water shortfall).

The proposed Yarragadee production bore location is shown in Figure 30.
9 GROUNDWATER MODELLING

9.1 Objectives

A groundwater model was developed for the Yalyalup mine and the surrounding groundwater catchment to predict:

- Dewatering requirements for the proposed Yalyalup mining operation.
- Drawdown impacts across the modelled catchment from mine dewatering at Yalyalup and water supply pumping from the Yarragadee aquifer during mining and after mine closure.
- Drawdown impacts of Doral’s proposed groundwater abstraction on:
  - Other groundwater users in the modelled catchment.
  - The Vasse-Wonnerup Ramsar Wetland system.
  - Other potentially sensitive areas in the catchment (Groundwater Dependent Ecosystems (GDEs)).
- The impact of groundwater pumping on the modelled catchment water balance.

The modelling study was completed consistent with the Australian Groundwater Modelling Guidelines (Barnett et al, 2012). Key features of the groundwater model are described in detail in the following sections and summarised below. The model includes:

- The Superficial Formation and the underlying Leederville and Yarragadee aquifers.
- Recharge to the aquifer system from rainfall recharge.
- Groundwater inflow from upstream and groundwater outflow to downstream.
- Dewatering of the proposed Yalyalup mine area and dewatering at Tronox’s nearby operational mine.
- Water supply pumping from the Superficial, Leederville and Yarragadee aquifers.
- Evapotranspiration from the shallow water table across the modelled catchment and the areas of the Vasse-Wonnerup Wetlands System that lie within the model domain, north west of the Yalyalup mine area.

9.2 Model Setup and Extent

A Leapfrog (Seequent, 2019) geological model was constructed for the regional aquifer system in the Yalyalup mine area and across the surrounding groundwater catchment using the following information:

- Ground surface in the immediate mine area was assigned consistent with data provided by Doral (yal_topo_2010_1m_cont2019.dxf). Across the remainder of the modelled catchment, ground surface was set consistent with the Department of Primary Industries and Regional Development (DPIRD) Land Monitor Project (2m and 10m contours, Busselton Special Sheet, DPIRD, 1999).
- The geometry of units of the Superficial Formation in the mine area was based on information provided by Doral (base of Bassendean Sand -yal_bsa_2010_1m_cont_2019.dxf; base of Guildford Formation - yal_bclay_2010_1m_cont_2019.dxf; and base of Yoganup Formation - yal_base_2010_1m_cont_2019.dxf).
- Away from the mine area, the thickness of hydrogeological units was derived from the DWER WIR Database (DWER 2019 b).
• The thickness of the Mowen and Vasse Members of the Leederville Formation and the Yarragadee Formation was based on base elevation contours developed for the South West Aquifer Modelling System (SWAMS) groundwater model and reported by Baddock (2005). The SWAMS groundwater model was developed jointly by the DWER and the Water Corporation in 2005 and incorporated all the major aquifers of the Southern Perth Basin.

The Leapfrog model allowed the generation of a seven-layer groundwater model to represent the aquifers and aquitards present in the groundwater catchment. These layers are summarised in Table 9.

Using the layer geometry of the Leapfrog model, groundwater model layer geometry and aquifer parameter zones were applied to a seven-layer groundwater flow model grid, described in the following sections.

It should be noted that based on Baddock (2005), the total thickness of the Units 1-4 of the Yarragadee Formation in the current model study area, is between 200 and 900 m. In the current model set up, the Yarragadee Formation is assigned a thickness of 200 m.

**Table 9: Model Layer Summary**

<table>
<thead>
<tr>
<th>Layer</th>
<th>Aquifer Units</th>
<th>Layer Geometry</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Alluvium, Estuarine Deposits &amp; Sand derived from Tamala Limestone Alluvium and Estuarine Mud Safety Bay Sand</td>
<td>Thickness of 2 to 6 m Thickness of 1.5 to 2 m Thickness of 1 to 4 m</td>
</tr>
<tr>
<td>2</td>
<td>Bassendean Sand Tamala Limestone</td>
<td>Thickness of 1 to 6 m Thickness of 2 to 8 m</td>
</tr>
<tr>
<td>3</td>
<td>Guildford Formation</td>
<td>Thickness of 1 to 10 m</td>
</tr>
<tr>
<td>4</td>
<td>Yoganup Formation</td>
<td>Thickness of 1 to 10 m</td>
</tr>
<tr>
<td>5</td>
<td>Leederville Formation Mowen Member</td>
<td>Thickness of 1 to 27 m</td>
</tr>
<tr>
<td>6</td>
<td>Leederville Formation Vasse Member (North Coastal Margin) Leerderville Formation Vasse Member (Central)</td>
<td>Thickness of 70 to 200 m Thickness of 20 to 200 m</td>
</tr>
<tr>
<td>7</td>
<td>Yarragadee Formations (Units 1 to 4)</td>
<td>Thickness of 200 m</td>
</tr>
</tbody>
</table>

The groundwater model was developed using the numerical groundwater flow modelling package Modflow Surfact (Version 4.0, Hydrogeological Inc. 1996), operating under the Groundwater Vistas graphical user interface (Version 7, Environmental Simulations Inc, 1996 to 2019).

The extent of the model domain and the location of model boundaries are shown in Figure 31 and summarised in Table 10. The model grid is rotated 34 degrees, to align it with the inferred groundwater flow direction in the shallow aquifers (towards the coastline). The model and all associated data are specified using the GDA (Zone 50) coordinate system. The active model domain covers a maximum distance of 18.5 km (approximately south east to north west) and 15 km approximately north west to south east.
Table 10: Extent of Model Domain

<table>
<thead>
<tr>
<th></th>
<th>Easting (m)*</th>
<th>Northing (m)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>North West</td>
<td>344,040</td>
<td>6,276,890</td>
</tr>
<tr>
<td>North East</td>
<td>360,730</td>
<td>6,288,140</td>
</tr>
<tr>
<td>South West</td>
<td>355,300</td>
<td>6,260,200</td>
</tr>
<tr>
<td>South East</td>
<td>371,980</td>
<td>6,271,450</td>
</tr>
</tbody>
</table>

*GDA Zone 50

The model uses a minimum cell size of 20 m in the mine area (refer Figure 31) to simulate the groundwater gradients that will develop as mining progresses. A maximum cell size of 100 m is assigned away from the mine area and close to model boundaries. The model grid includes 338 rows and 348 columns over 7 model layers resulting in a total of 823,368 model cells with 557,431 active model cells.

9.3 Model Geometry

A schematic model section from south east to north west across the model domain is shown in Figure 32 and shows the following model layers:

- Layer 1 – Alluvium, Estuarine Mud, Estuarine Deposits, Sand derived from Tamala Limestone and Safety Bay Sand
- Layer 2 – Bassendean Sand and Tamala Limestone
- Layer 3 – Guildford Formation
- Layer 4 – Yoganup Formation
- Layer 5 – Leederville Formation Mowen Member
- Layer 6 – Leederville Formation Vasse Member
- Layer 7 – Yarragadee Formation

The thickness of model layers was assigned consistent with the modelled thicknesses of the Leapfrog model. Contours of elevation of the top of layer 1 (topographic surface) and the base of layer 1 are shown in Figure 33. Similarly, contours of the base of layers 2 to 7 are shown in Figures 34 to 36.

Aquifer property zones assigned to model layers 1, 2 and 6 are shown in Figures 37 to 38 (model layers 3, 4, 5 and 7 simulate the same aquifer conditions and are assigned uniform properties). Layer 1 is used to simulate the areas where the surface aquifer is not the Bassendean Sand and is only active in the areas where the surface aquifers are as shown in Figure 37 (the shallow coastal margin of the model domain represents alluvium, estuarine mud, estuarine deposits, sand derived from Tamala Limestone and Safety Bay Sand).

9.4 Groundwater Inflow and Outflow

9.4.1 Groundwater Throughflow

The locations of all model boundaries are shown in Figure 31. The general direction of groundwater flow in the model domain is from the Whicher Scarp to the coast in the Superficial aquifer (or from the south...
east to the north west). In the deeper aquifers (the Leederville (Vasse Members) and the Yarragadee), flow directions are inferred to be similar to the Superficial aquifers. Measured water levels in the lower aquifers suggest there is a downward gradient from the Superficial aquifer to the lower aquifers.

Groundwater inflow, that simulates recharge to outcropping area of the Leederville (Vasse Member) aquifer is simulated using a General Head Boundary (GHB) on the south eastern model boundary. This boundary is set at an elevation of 50 mAHHD in areas of layers 2 to 4, where these layers are saturated (i.e. the base of the layers is above 50 mAHHD). In layers 6 and 7, an inflow boundary is also simulated using the GHB package, however the elevation at this boundary varies along the length the boundary consistent with estimated potentiometric heads (Baddock, 2005). No inflow boundary is assigned in layer 5 (the Leederville Mowen Member aquitard).

Groundwater outflow at the coastal boundary is also simulated using the GHB package. This boundary is set at an elevation of 0 mAHHD in model layers 1 to 4 and 6 to 7 (no outflow is simulated in layer 5, the Leederville Mowen Member). The conductance values of the GHB conditions assigned in the calibrated model are discussed in Section 9.6.4.

All other model boundaries are aligned perpendicular to the inferred groundwater flow direction and are set as no flow boundaries, as shown in Figure 31.

Surface water flows, in the nearby Sabina and Abba Rivers are not simulated in the model. Flows in these rivers result from surface water runoff during periods of high rainfall and are not supported by groundwater discharge. Groundwater discharge to low lying areas is simulated using the evapotranspiration flux described in Section 9.4.3 below.

9.4.2 Recharge

In addition to groundwater inflows from upstream, the groundwater system is also recharged by incident rainfall. Rainfall recharge is assigned at the same rates (i.e. a single recharge zone) across the modelled catchment. Recharge rates are calculated assuming that recharge to groundwater only occurs once the soil column above the water table has been raised to a moisture content close to field capacity. This has been simulated by assuming that no recharge occurs until cumulative annual rainfall exceeds a set amount (based on rainfall data collected at BOM Busselton Shire Rainfall Station, 9515). The threshold and the percentage of monthly rainfall assigned as recharge was varied during model calibration and is discussed in Section 9.6.4.

9.4.3 Evapotranspiration

Evapotranspiration (ET) from the water table, the Vasse Wonnerup wetland area and short drainage paths in areas of lower topographic elevation (for example through river beds) is simulated in the model using the Evapotranspiration (EVT) package in Modflow Surfact. The EVT package uses a depth dependent relationship such that if predicted aquifer water levels are at or above a specified elevation (represented by the ET surface), ET occurs at the maximum specified rate. If predicted aquifer water levels decrease to below the specified ET surface, the ET rate decreases linearly to zero as the predicted water level approaches an elevation equal to the ET surface, minus a specified extinction depth. This relationship is shown schematically in Figure 39.
ET losses are included over the modelled catchment at a rate of approximately 90% of pan evaporation
data sourced from the SILO enhanced climate database service for the Busselton Aero meteorological
station. The assigned ET rate is varied throughout the year to account for seasonal variations in ET
rate. The assigned monthly ET rate is presented in Table 11. The ET surface was set equal to the
modelled ground surface. The ET depth was set equal to 2 m.

Table 11: Modelled Evapotranspiration Rates

<table>
<thead>
<tr>
<th>Month</th>
<th>Rate (m/d)</th>
<th>Month</th>
<th>Rate (m/d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>6.19 x 10⁻³</td>
<td>July</td>
<td>1.61 x 10⁻³</td>
</tr>
<tr>
<td>February</td>
<td>5.61 x 10⁻³</td>
<td>August</td>
<td>1.71 x 10⁻³</td>
</tr>
<tr>
<td>March</td>
<td>4.35 x 10⁻³</td>
<td>September</td>
<td>2.33 x 10⁻³</td>
</tr>
<tr>
<td>April</td>
<td>2.60 x 10⁻³</td>
<td>October</td>
<td>2.94 x 10⁻³</td>
</tr>
<tr>
<td>May</td>
<td>1.94 x 10⁻³</td>
<td>November</td>
<td>4.33 x 10⁻³</td>
</tr>
<tr>
<td>June</td>
<td>1.40 x 10⁻³</td>
<td>December</td>
<td>5.84 x 10⁻³</td>
</tr>
</tbody>
</table>

9.4.4 Groundwater Pumping

Data from the DWER Water Register database is available for 305 licenced bores across the modelled
catchment. This information provides a Groundwater Well Licence (GWL) location (as draw point
location(s) and aquifer and associated property boundary) and an annual groundwater allocation. The
data base does not include any information on the usage of individual bores or historical abstraction and
only current licence details are available. GWL details and inspection of areal imagery suggests that
within the modelled catchment, groundwater is abstracted for mining and for irrigation (i.e. for farming
and agricultural activities).

Based on the available GWL information, groundwater abstraction across the modelled catchment was
estimated. It is widely believed that the usage of many licenses is below the approved allocation rates
as approved in the licences. Groundwater pumping is included in the model as follows:

- The total allocation for each GWL was included in the model calibration data set at the following
  rates:
  - 40% of the total allocation was included between 1987 to 2002,
  - 60% of the total allocation was included in 2003,
  - 80% of the total allocation was included from 2004 to 2019 (and as part of model
    predictions, as discussed in Section 9.8).
- Groundwater abstraction associated with agricultural activities / irrigation, are included over the
  warmer months only (August to April).
- Groundwater abstraction associated with mining related water supply and all other non-
  agricultural activities is included throughout the year.

The locations of DWER licenced abstractions in the Superficial, Leederville and Yarragadee aquifers are
shown in Figures 40, 41 and 42 respectively. The Modflow SURFACT Well (WEL) package was used to
simulate abstraction from these bores as part of model calibration and model predictions. The proposed water supply pumping (for ore processing) at the Yalyalup site is also simulated in model predictions using this approach.

Existing GWL allocations associated with mine dewatering are also simulated. Dewatering at the nearby Tronox mining operation (shown in Figure 43) is simulated using the Modflow SURFACT Drain (DRN) package, assuming that water levels are reduced to 5 m below ground surface. Two stages of dewatering are included as shown in Figure 43. Stage 1 dewatering is included from January 2012 onwards (Wonnerup Mine), while Stage 2 dewatering is included from October 2018 onwards (Wonnerup North mining extension). Stage 2 dewatering is also included in model predictions. This approach to simulate dewatering at the nearby Tronox mining operations was adopted as data on operational dewatering was not available to Doral.

Dewatering from Doral’s Yoongarillup mine and Iluka’s Tutunup South mine were not included in the model as these operations are located on or near the current model boundaries.

9.5 Model Calibration

9.5.1 Approach to Model Calibration

Model calibration is the process by which the parameters of a numerical model are adjusted, within realistic limits, to provide the best match to measured data. This process involves testing and refining the aquifer properties and boundary conditions of the model to improve the match between observed data and simulated values.

The groundwater level data available for model calibration for the Superficial, Leederville and Yarragadee aquifers was from a number of the sources, including:

- Historical groundwater level monitoring, from the DWER data base. Monitoring data from some bores is available from 1987 to the present. In general, data from these bores is available for periods of 10 to 20 years, however at some locations data is available over the period January 1987 to September 2019.
- Groundwater level monitoring from the Yalyalup site, extending from 2017 to 2019.
- Groundwater level monitoring from Doral’s Yoongarillup operation (AQ2, 2016 to 2019).

The locations of groundwater monitoring bores used for model calibration are shown in Figure 44 and 45. The calibration period of the model is from January 1987 to the end of August 2019 consistent with the longest period of active water level monitoring. The groundwater model was calibrated using a manual or trial and error approach, using 392 monthly time increments or stress periods (periods over which all modelled stresses were held constant).

9.5.2 Initial Conditions

Available groundwater monitoring, that extends as far back as 1987 at some monitoring locations, shows an annual fluctuation in groundwater levels due to rainfall recharge, of at least 2 m. As a result, groundwater levels in the modelled catchment are not readily described by a long-term average or
steady state water level calibration. To accommodate this, water level conditions for the catchment were simulated using a dynamic calibration process. This process involved running the model for a period of 32 years (or 384 monthly time periods) using the rainfall recharge, groundwater throughflow and ET conditions described in the preceding sections. The data set was run for successive 32 year periods, with predicted water levels from the end of one simulation used as initial conditions for the next simulation. This process was repeated to predict a set of water level conditions that were appropriate for the start of the model calibration (January 1987). This process was repeated each time a change was made to model parameters or boundary conditions.

9.6 Transient Calibration

9.6.1 Groundwater Levels

The locations of monitoring bores screened in the Superficial aquifer and used for model calibration, are shown in Figure 44. The locations of monitoring bores screened in the Leederville and Yarragadee aquifers and used for model calibration, are shown in Figure 45. Model calibration performance is described by general location in the sections below.

Proposed Yalyalup Mine Area

Measured and modelled water levels for the Superficial aquifer in the mine area are presented in Figures 46 to 51. In this area, the longest water level monitoring data set extends from 1987 to 2019 (bore 61030060 in Figure 46 and bore 61030084 in Figure 47). At most Superficial aquifer monitoring locations in the mine area used for model calibration, data is available for a period of up to five years. Measured water levels in the mine area are observed to respond to winter rainfall recharge, with a groundwater recession in the following months. While the peak measured water level varies from year to year at individual monitoring locations, the minimum measured water levels are relatively consistent from year to year. Across the mine area, the magnitude of the measured water levels is well matched in the calibration, with a maximum difference between measured and modelled water levels of up to 1 m. At most locations in the immediate mine area, the seasonal water level trend is also well matched.

Measured and modelled water levels for the Leederville aquifer are presented in Figures 52 to 55. In the mine area, the longest water level monitoring data set extends from 1987 to 2019 (bore 61030062 in Figure 52 and 61030086 in Figure 53). At most Leederville monitoring locations in the mine area used for model calibration, data is available for periods of two to twenty years. Overall, in the mine area there is less data available for the Leederville aquifer compared to the Superficial aquifer. The monitoring data that is available shows an overall decline in measured water levels until 2019 (Bore 61030062 in Figure 52 and 61030086 in Figure 53).

The magnitude of the Leederville aquifer measured water levels is generally matched, with a maximum difference between measured and modelled water levels of up to 6 m. The seasonal water level trend in the Leederville aquifer is also replicated by the model, however, the long term decrease in water levels does not appear to be matched in the mine area. This could be related to changes in abstraction from the Leederville aquifer that are not replicated in the current model set up (i.e. due to the approximations made to simulate the abstraction of GWLs in the modelled catchment).
**Downstream of Yalyalup (Coastal Area)**

Measured and modelled water levels for the Superficial aquifer in the coastal area downstream of the proposed Yalyalup mine are presented in Figures 55 to 57. In this area, the longest groundwater level monitoring data set extends from 1987 to 2019 (61030026 in Figure 55). At most Superficial aquifer monitoring locations used for the model calibration, monitoring data is available for periods of up to five years. Similar to the other Superficial aquifer monitoring locations, measured water levels are observed to respond to mid year winter rainfall recharge, with a groundwater recession in the months later in the calendar year.

The available monitoring data in this area suggests that water levels in the Superficial aquifer have increased over the monitoring interval (61000049 in Figure 56, 61000074 in Figure 57 and 61000075 in Figure 57). The seasonal peaks and recessions in measured water levels are matched by the model (including the magnitude of the seasonal responses), with measured and modelled water levels in general agreement. The maximum difference in measured and modelled water levels in this area is up to 2m.

Measured and modelled water levels for the Leederville aquifer in the coastal area downstream of the proposed Yalyalup mine are presented in Figures 57 and 58. In this area, the longest groundwater level monitoring data set extends from 1987 to 2019 (61030028 in Figure 57 and 61030059 in Figure 58). At most Leederville aquifer monitoring locations used for model calibration, data is available for periods of between four and twenty years. Some of the available data for the Leederville aquifer in this area show a decrease in measured water level over the monitoring period (up to 2019). The measured decrease in water level over this period is up to 3m (610300028 in Figure 57 and 61030059 in Figure 58). The measured water level response at 61019056 (Figure 58) is well matched by the model, however data at this location is only available for a four year period until early 2015. The model does not however, simulate the measured water level decrease in the Leederville aquifer until 2019, although the model does replicate the seasonal trend in measured water levels.

**Agricultural Areas**

Other monitoring bores across the modelled catchment are in agricultural or farm areas. Measured and modelled water levels from the Superficial aquifer in farm areas are presented in Figures 59 to 62. In this area, the longest groundwater level monitoring data set extends from 1987 to 2019 (61030066 in Figure 59, 61030063 in Figure 61 and 61030087 in Figure 62). At most Superficial aquifer monitoring locations used for model calibration, data is available for periods of between five and ten years. These data generally show no overall increase or decrease in measured water levels over the monitoring period.

Measured water levels at Superficial aquifer bores in agricultural areas are well matched by the model, with both the seasonal trends and water level elevations well matched. There are a few locations (61000121 in Figure 59 and 61000020 in Figure 61) where the water level is less well matched and the difference between measured and modelled water levels is at times up to 2m. At 6100128 (Figure 62) water levels fluctuate up to 3 m in response to rainfall recharge, however at this location the modelled response to rainfall recharge is 1 to 1.5m. As outlined in Section 9.4.2, the model uses a uniform distribution of recharge and ET across the modelled catchment and these distributions have not been zoned or divided further to replicate the measured water level response at specific locations.
Measured and modelled water levels from the Leederville and Yarragadee aquifer in agricultural areas are presented in Figures 63 to 65. In this area, the longest groundwater level monitoring data set extends from 1987 to 2019 (61030065 in Figure 64 and 61030089 in Figure 65). At most Leederville aquifer monitoring locations used for model calibration, data is available for periods of between three and twenty years.

The seasonal water level response is generally well matched at most monitoring locations. However, at some locations there is a difference between measured and modelled water levels of up to 5m. At some monitoring locations, the measured water level responses are much greater than those modelled (610300067 in Figure 63 and 610000125 in Figure 65). It is possible that these bores reflect the water level changes associated with groundwater pumping that are not reflected in the modelled approximation of abstraction rates.

9.6.2 Groundwater Level Contours

Contours of predicted water table elevation for February and August 2018 are presented in Figures 66 and 67. Also shown are available measured water levels for the two periods. The general groundwater flow direction toward the coast and the water table elevation is matched by the model. Modelled water levels are generally within 1m of measured values in the mine area. The greatest difference between measured and modelled water levels is 2.5m at bores 20005101 and 61000121.

9.6.3 Measured and Modelled Water Levels

Measured and modelled water levels for February and August 2018 are shown in Figures 68 to 69. Predicted water levels are shown for the end of summer and winter. Measured and modelled water levels are shown for the Superficial and Leederville aquifers.

For the February 2018 measured water levels, the difference between measured and modelled water levels is generally less than 5m. In some areas, the difference between measured and modelled water levels is up to 8m (23073124 and Lot668 Bore 2 in the Leederville aquifer). The majority of these bores with larger differences between measured and modelled water levels are screened in the Leederville aquifer, where there are uncertainties associated with the pumping associated with GWLs. These uncertainties are related to the amount of pumping that is associated with each GWL and the seasonal distribution, dating back to the start of the calibration period. This may explain why there is a mismatch between measured and modelled water levels measured in the Leederville aquifer at the end of summer. There is however, no systematic over or under prediction of measured water levels. The Scaled Root Mean Squared (SRMS) error as a percentage of the range of measured heads for the February 2018 measured and modelled water levels is 7.8%.

For the August 2018 measured water levels, the difference between measured and modelled water levels is at most locations, between 1 and 2m in both the Superficial and Leederville aquifers. In some areas, the difference between measured and modelled water levels is up to 4m (23073124 and Lot668 Bore 2 in the Leederville aquifer i.e. at the same locations where water levels were over predicted in February 2018, outlined above). During winter there is likely to be less abstraction for irrigation and hence there is a better match to measured water levels in the Leederville aquifer. Similar to the February
2018 data, there is also no systematic over or under prediction of measured water levels. The Scaled Root Mean Squared (SRMS) error as a percentage of the range of measured heads for the August 2018 measured and modelled water levels is 6.7%.

The modelling guidelines (Barnett et al, 2012) do not specify SRMS criteria for this measure of model performance. These criteria should be considered with other model performance criteria including the simulation of seasonal water level trends and the use of realistic aquifer parameters. As outlined above, aquifers parameters have been assigned to replicate the majority of measured water levels and local scale features have not been added to achieve a better model calibration in local areas and in turn improve the SRMS error. There are other uncertainties in the model set up which may also contribute to the differences to measured and modelled water levels, including the amount of dewatering completed at Tronox’s nearby mining operation and the total abstraction and the seasonal distribution of abstraction associated with GWLs in the modelled catchment.

9.6.4 Aquifer Parameters

Aquifer parameters assigned to the calibrated model are summarised in Table 12. The modelled aquifer zone distributions for model layers 1, 2, and 6 are shown in Figures 37 and 38 (as model layers 3, 4, 5 and 7 are used to represent a single hydrogeological unit). Aquifer parameter values are consistent with published and tested ranges.

Table 12: Calibrated Aquifer Parameters

<table>
<thead>
<tr>
<th>Layer</th>
<th>Aquifer Units</th>
<th>Horizontal Hydraulic Conductivity, Kh (m/d)</th>
<th>Vertical Hydraulic Conductivity, Kv (m/d)</th>
<th>S</th>
<th>Sy (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Alluvium, Estuarine Deposits, &amp; Sand derived from Tamala Limestone</td>
<td>5</td>
<td>0.5</td>
<td>NA</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Alluvium and Estuarine Mud</td>
<td>0.01</td>
<td>0.0001</td>
<td>NA</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Safety Bay Sand</td>
<td>15</td>
<td>0.15</td>
<td>NA</td>
<td>20</td>
</tr>
<tr>
<td>2</td>
<td>Bassendean Sand</td>
<td>10</td>
<td>1</td>
<td>NA</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>Tamala Limestone</td>
<td>50</td>
<td>5</td>
<td>0.0001</td>
<td>20</td>
</tr>
<tr>
<td>3</td>
<td>Guildford Formation</td>
<td>0.3</td>
<td>0.03</td>
<td>0.0001</td>
<td>10</td>
</tr>
<tr>
<td>4</td>
<td>Yoganup Formation</td>
<td>5</td>
<td>0.5</td>
<td>0.0001</td>
<td>20</td>
</tr>
<tr>
<td>5</td>
<td>Leederville Formation Mowen Member</td>
<td>0.01</td>
<td>0.0001</td>
<td>0.0001</td>
<td>5</td>
</tr>
<tr>
<td>6</td>
<td>Leederville Formation Vasse Member North</td>
<td>1</td>
<td>0.0001</td>
<td>0.0001</td>
<td>10</td>
</tr>
<tr>
<td>6</td>
<td>Leederville Formation Vasse Member South</td>
<td>1</td>
<td>0.001</td>
<td>0.0001</td>
<td>10</td>
</tr>
<tr>
<td>7</td>
<td>Yarragadee Formation</td>
<td>7</td>
<td>0.07</td>
<td>0.0001</td>
<td>10</td>
</tr>
</tbody>
</table>

9.6.5 Other Calibrated Aquifer Parameters

The threshold of cumulative rainfall that is required for recharge to groundwater was assigned at 200 mm in the calibrated model. This threshold value was adjusted as part of the model calibration process. Once this rainfall total is recorded during a calendar year (i.e. from January of any year) recharge was assigned in the calibrated model as follows:
• When annual rainfall is less than 850 mm, recharge to groundwater is assigned at 60% of monthly rainfall (in excess of the 200 mm annual threshold).
• When annual rainfall exceeds 850 mm, recharge to groundwater is assigned to 40% of monthly rainfall (in excess of the 200 mm annual threshold).

Over the model calibration period (1987 to 2019) these recharge rates result in calculated annual recharge to groundwater of between 23% and 48% of recorded annual rainfall. The average recharge to groundwater over the calibration period is 35% of annual recorded rainfall, with the median recharge of 40% of annual recorded rainfall. These recharge rates are within a range of recharge values for the South West Swan Coast Plain that were obtained from two recharge studies undertaken in the WA South West to provide input to the SWAMS groundwater model. Much of the Swan Coastal Plain (and most of the modelled catchment, especially around the mine site) is cleared of native vegetation for pasture. This results in recharge rates up to 50% of rainfall (Baddock, 2005).

The conductance values assigned to the upstream and downstream GHBs was assigned consistent with the aquifer properties, saturated thickness, model cell width and distance to the modelled boundary of each GHB cell. Conductance values assigned in the calibrated model varied between 3.6 and 100 m²/d.

As outlined in Section 9.4.4, dewatering from Tronox’s mining operations is included in the model calibration data set. Tronox dewatering was set at an annual average rate of 1,680 kL/day over the model calibration period (2012 to 2018). This is less than the GWL licence allocation associated with the mining operation, which permits a total groundwater draw of 5,580 kL/day (or 2,000,000 kL/year¹).

9.6.6 Model Sensitivity

As outlined in Section 9.5.1, the model was calibrated using a trial and error approach. As part of this process, model parameters and some boundary conditions were adjusted through realistic ranges to produce the best match between measured and modelled water levels. The model calibration performance was observed to be sensitive to the changes in model parameters / boundary conditions outlined below.

9.6.6.1 Specific Yield and Rainfall Recharge

The combination of specific yield and rainfall recharge assigned to the Superficial or unconfined aquifers across the model domain was observed to impact the performance of the model. For lower values of specified yield (up to 50% of the calibrated specific yield values in Table 12) the model was found to calibrate or provide a similar match to measured water levels trends when a reduced rate of recharge was applied. The variable specific yield values assigned to the water table aquifers across the model domain resulted in up to a 50% reduction in the amount of recharge assigned on an annual basis as a percentage of total rainfall. Specific yield values at the higher end of the range were adopted for the Base Case calibrated model, with lower values of specific yield (and rainfall recharge) investigated as part of the Uncertainty Analysis outlined in Section 9.10.

¹ Includes GWL numbers 173523 (600,000 kL/year) and 202089 (1,400,000 kL/year)
9.6.6.2 Aquifer Hydraulic Conductivity Superficial Aquifers

Reducing the assigned aquifer hydraulic conductivity values (both horizontal and vertical hydraulic conductivity) assigned to the Superficial aquifers (Bassendean Sand, Guildford Formation and Yoganup Formation) by a half of the values outlined in Table 12 was not observed to significantly impact the model calibration performance. The calibrated aquifer parameters adopted are at the lower end of the measured range and were investigated further as part of the Uncertainty Analysis outlined in Section 9.10.

9.6.6.3 Aquifer Hydraulic Conductivity Yarragadee Aquifer

Reducing the aquifer hydraulic conductivity value (both horizontal and vertical hydraulic conductivity) assigned to the Yarragadee Formation by a half (of the values outlined in Table 12) was not observed to significantly impact the model calibration performance.

9.6.6.4 Vertical Hydraulic Conductivity Leederville Aquifer Vasse Member

Increasing the vertical hydraulic conductivity value assigned to the Vasse Member (of the Leederville Formation) by a factor of 5 (of the values outlined in Table 12) was not observed to significantly impact the model calibration performance.

9.6.7 Water Balance

Predicted water balances for the calibrated model for February 2018 and August 2018 are presented in Table 13.

Table 13: Model Predicted Water Balances

<table>
<thead>
<tr>
<th>Water Budget Component</th>
<th>August 2018</th>
<th>February 2018</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>In (kL/d)</td>
<td>Out (kL/d)</td>
</tr>
<tr>
<td>Storage</td>
<td>0</td>
<td>399,670</td>
</tr>
<tr>
<td>Recharge</td>
<td>646,410</td>
<td>0</td>
</tr>
<tr>
<td>Catchment Inflow</td>
<td>42,520</td>
<td>0</td>
</tr>
<tr>
<td>Catchment Outflow</td>
<td>0</td>
<td>52,920</td>
</tr>
<tr>
<td>Tronox Dewatering</td>
<td>0</td>
<td>2,630</td>
</tr>
<tr>
<td>Licensed Abstraction</td>
<td>0</td>
<td>6,040</td>
</tr>
<tr>
<td>ET</td>
<td>0</td>
<td>227,670</td>
</tr>
<tr>
<td>Total</td>
<td>688,930</td>
<td>688,930</td>
</tr>
</tbody>
</table>

The model predicted water balances show that rainfall recharge (and the associated increase in groundwater storage) and ET losses from the water table, represent the greatest components of the modelled water balance.

9.7 Other Model Details

Other details of model setup are outlined below:

- Over both the model calibration and prediction periods, stress periods were set at a monthly time increment.
• The Modflow SURFACT Automatic Time Stepping (ATO) package was used for model calibration and predictions with the following parameters:
  o An initial time step length of 5 days was used.
  o A minimum time step of $1 \times 10^{-8}$ and a maximum time step of 31 days.
  o A time multiplier of 1.2 and a reduction factor of 2.0.

• The model was run with the Modflow SURFACT Block Centred Flow 4 (BCF4) package using the Variably Saturated Flow Option (Pseudo Soil Relations) to accommodate re-saturation.

• The model was run with the Pre-Conjugated Gradient 5 (PCG5) solver along with the following parameters:
  o Number of outer iterations = 50
  o Number of inner iterations = 20
  o Maximum orthoganalisations = 10
  o Head change criterion = 0.01
  o Relative Convergence Criterion = 0
  o Newton Raphson Linearalisation (Backtracking Factor) = 0.9
  o Newton Raphson Linearalisation (Residual Reduction Factor) = 1

9.8 Model Predictions

The calibrated groundwater flow model was used to predict:

• The impact of dewatering of the proposed Yalyalup mine on groundwater levels and the regional groundwater balance.

• The impact of Yarragadee aquifer water supply pumping only at Yalyalup from the Yarragadee aquifer on groundwater levels and the regional groundwater balance.

• The behaviour of the Yalyalup mine area and the surrounding groundwater catchment after the end of mining and water supply pumping, including the time taken for groundwater recovery to final equilibrium levels and any associated impacts on groundwater levels and the regional groundwater balance.

Details of the setup of model predictions and prediction results are discussed in the following sections.

9.8.1 Dewatering Prediction Setup

Predictions of groundwater inflow to the proposed Yalyalup mine were completed for the mine plan provided by Doral in May 2019, which included quarterly pit progressions for a period of 3.5 years (a_q3_2021.dxf, b_q4_2021.dxf, c_q1_2022.dxf, e_q3_2022.dxf, f_q4_2022.dxf, g_q1_2023.dxf, h_q2_2023.dxf, i_q3_2023.dxf, j_q4_2023.dxf, k_q1_2024.dxf, l_q2_2024.dxf, m_q3_2024.dxf, n_q4_2024.dxf and o_q1_2025.dxf). These plans show mining starting in Quarter 3 (July) 2021 and finishing in Quarter 4 (December) 2024. Mining will progress to a depth of between 0.35 m and 10.5 m below ground surface and will cover a total mined area of up to 260 ha. The extent of the mining area is shown in Figure 70.
Other details of model predictions are outlined below:

- Operational model predictions were completed for the period 1 July 2021 to December 2024, using a monthly time increment or stress period, with initial water level conditions for model predictions taken from the calibration model (water levels predicted for the end of June 2019).
- Groundwater inflows into the open pits were simulated consistent with the mining schedule provided assuming that water levels were drawn down to the floor elevation of each mining area for a period of three months. The reduction in water levels is simulated using the Drain (DRN) package in Modflow Surfact. Drain elevations and extents were set consistent with the mining schedule provided.
- The dewatering approach simulates water level reduction consistent with the mine plan and no advanced dewatering is predicted ahead of mining.
- Once mining at a particular location was completed, the area was assumed to be backfilled and groundwater levels were allowed to recover. Thus, depending on mining progress, different areas of the mine could be undeveloped, actively dewatered or backfilled.
- Backfill placed into the mined out areas was assumed to form a final landform consistent with the original ground surface, and that there was no change to recharge and ET processes in the mine area or the rest of the modelled catchment. The backfill material was assumed to have the same hydraulic parameters as the original aquifer material.
- Operational prediction models were run for a set of wet and dry climatic conditions. Based on the rainfall data sets used for model calibration, a set of “wet” rainfall and associated recharge conditions was included in model predictions using the measured monthly rainfall from July 1997 to December 2000. The same rainfall threshold and proportions were used to calculate recharge to groundwater as outlined in Section 9.6.4. Similarly, a set of “dry” rainfall and associated recharge conditions was included in model predictions based on measured rainfall from July 2003 to December 2006.
- Groundwater inflows and outflows and evaporative losses were included in model predictions consistent with the model calibration.
- Water supply pumping from other users in the catchment was included consistent with the groundwater pumping estimates included in the model calibration data set for agricultural and non-agricultural users (i.e. 80 % of the GWL allocation was modelled with a seasonal variation in water abstraction for agricultural users and constant monthly water demand across the year for non-agricultural users).
- Water supply pumping from other users in the catchment was included in model predictions assuming that agricultural and non-agricultural users used 100% of their GWL allocation. This abstraction was assumed to extend from August to May of each year. This represents an increase from the 80% of the licenced allocation included from 2004 to 2019 in the model calibration and Base Case predictions. Details of these predictions are presented in Appendix E.
- Dewatering from Tronox’s mining operation was included consistent with the post 2018 approximation for Stage 1 and 2 mine dewatering (refer Figure 43).
- A Yalyalup No Development Scenario was also run to allow calculation of drawdown and comparison of model predicted water balances. The Yalyalup No Development Scenario
contained the same conditions as outlined above, except that proposed dewatering at Yalyalup was excluded.

9.8.2 Water Supply Prediction Setup

Predictions were completed to assess the impact of Doral’s proposed water supply pumping only. It is anticipated that this water will be used for ore-processing. The location of the proposed water supply bore (YA_PB01, refer Figure 70) was provided by Doral. Pumping from this bore was simulated from the Yarragadee aquifer at a rate of 4,383 kL/d (50L/s or 1.6 GL/year) for a period of 3.5 years (i.e. the length of the mine life at the maximum ore processing demand if no dewatering discharge was available for ore processing). Other details of the water supply predictions are outlined below:

- Water supply predictions were completed for the period 1 July 2021 to December 2024, using a monthly time increment or stress period, with initial water level conditions for model predictions taken from the calibration model (water levels predicted for the end of June 2019).
- Water supply predictions were run for a set of wet and dry climatic conditions. Based on the rainfall data sets used for model calibration, a set of “wet” rainfall and associated recharge conditions was included in model predictions based on the measured rainfall from July 1997 to December 2000. The same rainfall threshold and proportions were used to calculate recharge to groundwater as outlined in Section 9.6.4.5. Similarly, a set of “dry” rainfall and associated recharge conditions was included in model predictions based on measured rainfall from July 2003 to December 2006.
- Groundwater inflows and outflows and evaporative losses were included in model predictions consistent with the model calibration.
- Water supply pumping from other users in the catchment was included consistent with the groundwater pumping estimates included in the model calibration data set for agricultural and non-agricultural users (i.e. 80% of the GWL allocation was modelled with a seasonal variation in water abstraction for agricultural users and constant monthly water demand across the year for non-agricultural users).
- Water supply pumping from other users in the catchment was included in model predictions assuming that agricultural and non-agricultural users used 100% of their GWL allocation. This abstraction was assumed to extend from August to May of each year. This represents an increase from the 80% of the licenced allocation included from 2004 to 2019 in the model calibration and preliminary predictions. Details of these predictions are presented in Appendix E.
- Dewatering from Tronox’s mining operation was included consistent with the post 2018 approximation for Stage 1 and 2 mine dewatering (refer Figure 43).

9.8.3 Closure Prediction Setup

The mine path will be incrementally developed and infilled over the 3.5 year mine life. After 3.5 year of mining, the mined out areas will be backfilled and groundwater levels will be allowed to recover (i.e. the last dewatering conditions will be removed). Groundwater levels across the mine path in the superficial aquifer will recover to final equilibrium levels until a balance is reached between groundwater inflows (upstream inflow and recharge) and outflows (ET from the water table and outflow to
downstream). No ET is expected from the mined out areas, in addition to water table ET losses as the final mine path will be infilled and rehabilitated to levels similar to the pre-development groundwater level.

After 3.5 years, Doral’s proposed water supply pumping from the Yarragadee aquifer will also no longer be required for production purposes however a far lesser volume will be required as a supply of water for water carts to manage fugitive dust, and possibly for irrigation of the McGibbon track vegetation. Following the rehabilitation works, this abstraction will cease, and water levels in the Yarragadee aquifer will also recover.

Closure predictions were run for the Yalyalup Dewatering and Yalyalup Water Supply Scenarios for a period of 10 years (1 January 2025 to 31 December 2034). Closure predictions were assumed to commence immediately after the end of mining (31 December 2024) with details of the closure predictions are summarised below:

- For the Yalyalup Dewatering Scenarios, final backfilling was assumed to be complete by March 2025 with all dewatering ceasing 3 months earlier (end of December 2024).
- For the Yalyalup Water Supply Scenarios, all pumping from the Yarragadee aquifer for production purpose will cease at the end of December 2024.
- For the wet climatic conditions, rainfall recharge was calculated using recorded rainfall data from January 2001 to December 2010 and included in closure predictions. For the dry climatic conditions, rainfall recharge was calculated using recorded rainfall data from January 2007 to December 2016 and included in closure predictions.
- Closure period predictions were also completed for the Yalyalup No Development Scenario to allow calculation of drawdown and comparison of model predicted water balances for the groundwater catchment.
- Closure predictions were run using a monthly time increment.

### 9.8.4 Prediction Model Summary

A summary of model predictions completed is presented in Table 14.
Table 14: Summary of Model Predictions

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Operational Period (July 2021 to December 2024)</th>
<th>Closure Period (January 2025 to December 2034)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yalyalup Dewatering Scenario 1</td>
<td>Initial conditions from calibrated model Abstraction from other users Dewatering at Yalyalup Dry Climatic Conditions (July 2003 to December 2006)</td>
<td>No further mining at Yalyalup No further water supply pumping for Yalyalup Abstraction from other users Climatic conditions from 1 January 2007 to 31 December 2016</td>
</tr>
<tr>
<td>Yalyalup Dewatering Scenario 2</td>
<td>Initial conditions from calibrated model Abstraction from other users Dewatering at Yalyalup Wet Climatic Conditions (July 1997 to December 2000)</td>
<td>No further mining at Yalyalup No further water supply pumping for Yalyalup Abstraction from other users Climatic conditions from 1 January 2001 to 31 December 2010</td>
</tr>
<tr>
<td>Yalyalup Water Supply Scenario 1</td>
<td>Initial conditions from calibrated model Abstraction from other users Yalyalup Yarragadee Water Supply Dry Climatic Conditions (July 2003 to December 2006)</td>
<td>Abstraction from other users No further water supply pumping for Yalyalup Climatic conditions from 1 January 2007 to 31 December 2016</td>
</tr>
<tr>
<td>Yalyalup Water Supply Scenario 2</td>
<td>Initial conditions from calibrated model Abstraction from other users Yalyalup Yarragadee Water Supply Wet Climatic Conditions (July 1997 to December 2000)</td>
<td>Abstraction from other users No further water supply pumping for Yalyalup Climatic conditions from 1 January 2001 to 31 December 2010</td>
</tr>
<tr>
<td>No Yalyalup Development Scenario 1</td>
<td>Initial conditions from calibrated model Abstraction from other users Dry Climatic Conditions (July 2003 to December 2006)</td>
<td>Abstraction from other users Climatic conditions from 1 January 2007 to 31 December 2016</td>
</tr>
<tr>
<td>No Yalyalup Development Scenario 2</td>
<td>Initial conditions from calibrated model Abstraction from other users Wet Climatic Conditions (July 1997 to December 2000)</td>
<td>Abstraction from other users Climatic conditions from 1 January 2001 to 31 December 2010</td>
</tr>
</tbody>
</table>

9.9 Results

9.9.1 Operational Predictions

9.9.1.1 Yalyalup Dewatering

Predicted water levels for selected shallow (Superficial aquifer) observation locations across and just outside of the mine path over the calibration period (1987 to 2019) and the subsequent operational period (2021 to 2024) for the Yalyalup Dewatering Scenarios are shown in Figures 71 to 73. For observation locations within the mine path, the corresponding pit floor elevations are also shown. For locations of observation locations refer to Figure 70.

At locations within the mine path, water levels are predicted to decrease consistent with mine progression. At in-pit locations, water levels are drawn down to the base of mining, as no advanced dewatering is included in model predictions. Model predicted drawdown that is lower than the mining depth, is related to dewatering at nearby, deeper locations. This is seen as predicted reductions in water level at TP O (Figure 73) on two occasions prior to and just after June 2023. In September 2024 however, water levels at TP O are predicted to decrease to the mining elevation (~15.5mAHD).

At observation locations outside of the mine path, reductions in water levels are predicted at the same time as the water level reduction associated with mining, however the reduction in water level is significantly less. For a reduction in water level within the mine path of close to 10m at TP H, the corresponding water level reduction at bore 61000055, located outside of the mine path is less than 2 m at the same time and for a similar, but longer period than the adjacent mining. A reduction in
water level is also predicted at 61000055 during mid-2023 and mid-2024 as mining progresses at different locations across the mine path.

Predicted monthly groundwater inflows for the wet and dry climatic conditions are shown in Figure 74. Groundwater inflows are predicted to vary with depth of mining and season. For the dry conditions, dewatering is predicted to peak at 2,420 kL/d in March 2023, with a corresponding peak in dewatering when wet conditions are included of 4,090 kL/d, in May 2023.

Predicted cumulative annual abstraction from the Superficial aquifer ranged from approximately 0.13 to 0.53 GL/year (average of 0.32 GL/year) for the dry climatic scenario and from 0.21 to 0.68 GL/year (average of 0.47 GL/year) for the wet climatic scenario.

9.9.1.2 Yalyalup Water Supply

Predicted water levels for selected observation locations across and just outside of the mine path over the calibration period and the subsequent operational period (2021 to 2024) for the Yalyalup Water Supply Scenarios are shown in Figures 75 to 77. The locations of observation locations are shown in Figure 70.

At all locations presented, the water level impact of Doral’s proposed water supply pumping from the Yarragadee is predicted to be minimal. Water levels for the wet and dry climatic scenarios, with and without Doral’s water supply pumping are predicted to be similar, suggesting that pumping from the Yarragadee aquifer has very little impact on shallow (Superficial aquifer) water levels.

9.9.1.3 Water Balance

The model predicted water balances for August 2023 and February 2024 are shown in Tables 15 to 18. Water balances are shown for wet and dry climatic inputs for the Yalyalup Dewatering and Yalyalup Water Supply Scenarios. Also shown in brackets and italics are the predicted water balance components for the corresponding No Yalyalup Development Scenario.

The model predicted water balances for the Yalyalup Dewatering and Yalyalup Water Supply Scenarios, when compared to the No Yalyalup Development Scenarios show:

- Overall, model predicted water balances are similar with and without groundwater development associated with the Yalyalup mine.
- There is a predicted increase in catchment inflow when Yalyalup groundwater development is included. This is a maximum of 2,000 kL/d which is a very small component of the predicted catchment water balance. The predicted increases in groundwater inflow are less than 5% of the total predicted inflow.
- There is also a predicted decrease in catchment outflow when Yalyalup groundwater development is included. This is a maximum of 1,000 kL/d which is a very small component of the predicted catchment water balances. The predicted increases in groundwater outflows are less than 10% of the predicted outflow.
- The Yalyalup dewatering and water supply pumping are very small components of the total predicted water balances (less than 10% of the total predicted water balance predicted at the end of summer).
### Table 15: Yalyalup Dewatering Dry Climate Model Predicted Water Balance

<table>
<thead>
<tr>
<th>Water Budget Component</th>
<th>Wet Season (August 2023)</th>
<th>Dry Season (February 2024)</th>
<th>Wet Season (August 2023)</th>
<th>Dry Season (February 2024)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>In (kL/d)</td>
<td>Out (kL/d)</td>
<td>In (kL/d)</td>
<td>Out (kL/d)</td>
</tr>
<tr>
<td>Storage</td>
<td>1,260</td>
<td>237,800</td>
<td>84,360</td>
<td>280</td>
</tr>
<tr>
<td></td>
<td>(1,260)</td>
<td>(237,960)</td>
<td>(84,600)</td>
<td>(20)</td>
</tr>
<tr>
<td>Recharge</td>
<td>486,620</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>(486,620)</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Catchment Inflow</td>
<td>66,540</td>
<td>0</td>
<td>77,910</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>(66,300)</td>
<td>(0)</td>
<td>(77,890)</td>
<td>(0)</td>
</tr>
<tr>
<td>Catchment Outflow</td>
<td>0</td>
<td>27,850</td>
<td>0</td>
<td>18,800</td>
</tr>
<tr>
<td></td>
<td>(0)</td>
<td>(27,950)</td>
<td>(0)</td>
<td>(18,810)</td>
</tr>
<tr>
<td>Estimated Tronox Dewatering*</td>
<td>0</td>
<td>5,830</td>
<td>0</td>
<td>2,410</td>
</tr>
<tr>
<td></td>
<td>(0)</td>
<td>(5,830)</td>
<td>(0)</td>
<td>(2,410)</td>
</tr>
<tr>
<td>Doral Dewatering</td>
<td>0</td>
<td>2,320</td>
<td>0</td>
<td>350</td>
</tr>
<tr>
<td></td>
<td>(0)</td>
<td>(0)</td>
<td>(0)</td>
<td>(0)</td>
</tr>
<tr>
<td>Doral Water Supply</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>(0)</td>
<td>(0)</td>
<td>(0)</td>
<td>(0)</td>
</tr>
<tr>
<td>Licensed Abstraction</td>
<td>0</td>
<td>58,030</td>
<td>0</td>
<td>58,030</td>
</tr>
<tr>
<td></td>
<td>(0)</td>
<td>(58,030)</td>
<td>(0)</td>
<td>(58,030)</td>
</tr>
<tr>
<td>ET</td>
<td>0</td>
<td>222,590</td>
<td>0</td>
<td>82,400</td>
</tr>
<tr>
<td></td>
<td>(0)</td>
<td>(224,410)</td>
<td>(0)</td>
<td>(83,220)</td>
</tr>
<tr>
<td>Total</td>
<td>554,420</td>
<td>554,420</td>
<td>162,270</td>
<td>162,270</td>
</tr>
</tbody>
</table>

Water balance components for no Yalyalup Development Scenario shown in brackets and italics

### Table 16: Yalyalup Dewatering Wet Climate Model Predicted Water Balance

<table>
<thead>
<tr>
<th>Water Budget Component</th>
<th>Wet Season (August 2023)</th>
<th>Dry Season (February 2024)</th>
<th>Wet Season (August 2023)</th>
<th>Dry Season (February 2024)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>In (kL/d)</td>
<td>Out (kL/d)</td>
<td>In (kL/d)</td>
<td>Out (kL/d)</td>
</tr>
<tr>
<td>Storage</td>
<td>45,710</td>
<td>20,440</td>
<td>90,090</td>
<td>250</td>
</tr>
<tr>
<td></td>
<td>(46,000)</td>
<td>(19,090)</td>
<td>(90,180)</td>
<td>(0)</td>
</tr>
<tr>
<td>Recharge</td>
<td>348,620</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>(348,620)</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Catchment Inflow</td>
<td>64,270</td>
<td>0</td>
<td>77,550</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>(64,030)</td>
<td>(0)</td>
<td>(77,540)</td>
<td>(0)</td>
</tr>
<tr>
<td>Catchment Outflow</td>
<td>0</td>
<td>32,460</td>
<td>0</td>
<td>18,830</td>
</tr>
<tr>
<td></td>
<td>(0)</td>
<td>(32,560)</td>
<td>(0)</td>
<td>(18,830)</td>
</tr>
<tr>
<td>Estimated Tronox Dewatering*</td>
<td>0</td>
<td>7,060</td>
<td>0</td>
<td>2,510</td>
</tr>
<tr>
<td></td>
<td>(0)</td>
<td>(7,060)</td>
<td>(0)</td>
<td>(2,510)</td>
</tr>
<tr>
<td>Doral Dewatering</td>
<td>0</td>
<td>1,070</td>
<td>0</td>
<td>360</td>
</tr>
<tr>
<td></td>
<td>(0)</td>
<td>(0)</td>
<td>(0)</td>
<td>(0)</td>
</tr>
<tr>
<td>Doral Water Supply</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>(0)</td>
<td>(0)</td>
<td>(0)</td>
<td>(0)</td>
</tr>
<tr>
<td>Licensed Abstraction</td>
<td>0</td>
<td>58,030</td>
<td>0</td>
<td>58,030</td>
</tr>
<tr>
<td></td>
<td>(0)</td>
<td>(58,030)</td>
<td>(0)</td>
<td>(58,030)</td>
</tr>
<tr>
<td>ET</td>
<td>0</td>
<td>339,540</td>
<td>0</td>
<td>87,660</td>
</tr>
<tr>
<td></td>
<td>(0)</td>
<td>(341,910)</td>
<td>(0)</td>
<td>(88,350)</td>
</tr>
<tr>
<td>Total</td>
<td>458,600</td>
<td>458,600</td>
<td>167,640</td>
<td>167,640</td>
</tr>
</tbody>
</table>

Water balance components for no Yalyalup Development Scenario shown in brackets and italics
### Table 17: Yalyalup Water Supply Only Dry Climate Model Predicted Water Balance

<table>
<thead>
<tr>
<th>Water Budget Component</th>
<th>Wet Season (August 2023)</th>
<th>Dry Season (February 2024)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>In (kL/d)</td>
<td>Out (kL/d)</td>
</tr>
<tr>
<td>Storage</td>
<td>1,280</td>
<td>238,040</td>
</tr>
<tr>
<td></td>
<td>(1,260)</td>
<td>(237,960)</td>
</tr>
<tr>
<td>Recharge</td>
<td>486,620</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>(486,620)</td>
<td>(0)</td>
</tr>
<tr>
<td>Catchment Inflow</td>
<td>68,870</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>(66,300)</td>
<td>(0)</td>
</tr>
<tr>
<td>Catchment Outflow</td>
<td>0</td>
<td>27,020</td>
</tr>
<tr>
<td></td>
<td>(0)</td>
<td>(27,950)</td>
</tr>
<tr>
<td>Estimated Tronox Dewatering*</td>
<td>0</td>
<td>5,800</td>
</tr>
<tr>
<td></td>
<td>(0)</td>
<td>(5,830)</td>
</tr>
<tr>
<td>Doral Dewatering</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>(0)</td>
<td>(0)</td>
</tr>
<tr>
<td>Doral Water Supply</td>
<td>0</td>
<td>4,380</td>
</tr>
<tr>
<td></td>
<td>(0)</td>
<td>(0)</td>
</tr>
<tr>
<td>Licensed Abstraction</td>
<td>0</td>
<td>58,030</td>
</tr>
<tr>
<td></td>
<td>(0)</td>
<td>(58,030)</td>
</tr>
<tr>
<td>ET</td>
<td>0</td>
<td>223,500</td>
</tr>
<tr>
<td></td>
<td>(0)</td>
<td>(224,410)</td>
</tr>
<tr>
<td>Total</td>
<td>556,770</td>
<td>556,770</td>
</tr>
<tr>
<td></td>
<td>(554,180)</td>
<td>(554,180)</td>
</tr>
</tbody>
</table>

Water balance components for no Yalyalup Development Scenario shown in brackets and italics

### Table 18: Yalyalup Water Supply Only Wet Climate Model Predicted Water Balance

<table>
<thead>
<tr>
<th>Water Budget Component</th>
<th>Wet Season (August 2023)</th>
<th>Dry Season (February 2024)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>In (kL/d)</td>
<td>Out (kL/d)</td>
</tr>
<tr>
<td>Storage</td>
<td>46,160</td>
<td>19,020</td>
</tr>
<tr>
<td></td>
<td>(46,000)</td>
<td>(19,090)</td>
</tr>
<tr>
<td>Recharge</td>
<td>348,620</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>(348,620)</td>
<td>(0)</td>
</tr>
<tr>
<td>Catchment Inflow</td>
<td>66,640</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>(64,030)</td>
<td>(0)</td>
</tr>
<tr>
<td>Catchment Outflow</td>
<td>0</td>
<td>31,600</td>
</tr>
<tr>
<td></td>
<td>(0)</td>
<td>(32,560)</td>
</tr>
<tr>
<td>Estimated Tronox Dewatering*</td>
<td>0</td>
<td>7,060</td>
</tr>
<tr>
<td></td>
<td>(0)</td>
<td>(7,060)</td>
</tr>
<tr>
<td>Doral Dewatering</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>(0)</td>
<td>(0)</td>
</tr>
<tr>
<td>Doral Water Supply</td>
<td>0</td>
<td>4,380</td>
</tr>
<tr>
<td></td>
<td>(0)</td>
<td>(0)</td>
</tr>
<tr>
<td>Licensed Abstraction</td>
<td>0</td>
<td>58,030</td>
</tr>
<tr>
<td></td>
<td>(0)</td>
<td>(58,030)</td>
</tr>
<tr>
<td>ET</td>
<td>0</td>
<td>341,330</td>
</tr>
<tr>
<td></td>
<td>(0)</td>
<td>(341,910)</td>
</tr>
<tr>
<td>Total</td>
<td>461,420</td>
<td>461,420</td>
</tr>
<tr>
<td></td>
<td>(458,650)</td>
<td>(458,650)</td>
</tr>
</tbody>
</table>

Water balance components for the No Yalyalup Development Scenario shown in brackets and italics
9.9.1.4 Operational Predictions Drawdown

Contours of predicted water table drawdown at quarterly intervals, over the mine life, for the Yalyalup Dewatering Scenarios are shown in Figures 78 to 91 for the dry climatic conditions, and Figures 92 to 105 for the wet climatic conditions.

These drawdowns are the difference between the water levels predicted at each selected time interval for the Yalyalup Dewatering Scenario and the corresponding No Yalyalup Development Scenario. These drawdowns were provided to Doral in electronic format at these time increments, to allow assessment of the potential drawdown impact on vulnerable areas. The following general observations are made regarding predicted drawdown:

- As would be expected, maximum drawdown is predicted in the immediate mine area. The total maximum drawdown predicted over the life of the mine varies with mining depth.
- Maximum drawdown is predicted in the immediate mining area and is similar for both climatic cases.
- The extent of predicted drawdown shown (0.1 m contour) is generally limited to the Potential Disturbance Envelope.
- The maximum distance that drawdown of 0.1 m extends outside of the perimeter of the mine area is 700 m to the north, 250 m to the south, 300 m to the east and 450 m to the west, at various times during the mine life for the dry climate scenario.
- For the wet climate scenario, the maximum distance that drawdown of 0.1 m extends outside of the perimeter of mine area is 600 m to the north, 200 m to the south, 300 m to the east and 400 m to the west, at various times during the mine life for the wet climate scenario.

Contours of maximum predicted drawdown in the Leederville aquifer from dewatering of the Yalyalup mine (Yalyalup Dewatering Scenario) are shown in Figures 106 and 107 for dry and wet climatic conditions. This maximum drawdown is predicted in September 2023 and is calculated by subtracting predicted water levels for the Leederville aquifer for the Yalyalup Dewatering Scenario from the No Yalyalup Development Scenario. A similar drawdown profile is predicted for the dry and wet climate scenarios. The extent of predicted drawdown in the Leederville Aquifer shown (0.1 m) is generally limited to the Potential Disturbance Envelope. The maximum distance that drawdown of 0.1 m extends outside of the perimeter of mine area is 700 m to the north, 50 m to the south, 300 m to the east and 300 m to the west.

9.9.1.5 Water Supply Predictions Drawdown

For the Yalyalup Water Supply Scenarios that include dry climatic conditions, contours of predicted water level drawdown for the Leederville and Yarragadee aquifers at the end of 2024 for dry climatic conditions are shown in Figures 108 and 109. Predicted drawdown for the Leederville and Yarragadee aquifers at the end of 2024 for wet climatic conditions are shown in Figure 110 and 111. Similar to the predicted water table drawdown contours, these contours are calculated as the difference between predicted water levels for the Leederville and Yarragadee aquifers for the Yalyalup Water Supply Scenario and the Yalyalup No Development Scenario.
Drawdown from water supply pumping is predicted at a maximum value of close to 2 m in the Yarragadee aquifer, and less than 1 m in the overlying Leederville aquifer, for both wet and dry climatic conditions. It is noted that these predicted drawdowns are not water table drawdowns, but pressure changes. As shown in Figures 75 to 77 (refer Section 9.9.1.2) pumping from the Yarragadee aquifer is not predicted to have any impact on the shallow (superficial) water table.

9.9.2 Closure Predictions

9.9.2.1 Yalyalup Dewatering Scenarios

Predicted water levels for selected observation locations across and just outside of the mine path over the calibration period (1987 to 2019), the operational period (2021 to 2024) and the closure period (2025 to 2034) for the Yalyalup Dewatering Scenarios are shown in Figure 71 to 73. The locations of observation points are shown in Figure 70.

At locations within the mine path, water levels are predicted to recover rapidly after the cessation of dewatering. At the location in the mine area that is anticipated to progress to the greatest depth and represent one of the latest stages of mining, water levels (at TP O, refer Figure 70) are predicted to have recovered to No Yalyalup Development Scenario levels by June 2026, or close to 1.5 years after the end of mining for the dry climate conditions. By July 2026, all water levels are predicted to have recovered to No Yalyalup Development Scenario levels. For wet climate conditions, water levels are predicted to have recovered to Yalyalup Dewatering Scenario levels by July 2026, or 1.5 years after the end of mining.

9.9.2.2 Yalyalup Water Supply Scenarios

Predicted water levels for selected superficial observation locations across and just outside of the mine path over the calibration period (1987 to 2019), the operational period (2021 to 2024) and the closure period (2025 to 2034) for the Yalyalup Water Supply Scenarios are shown in Figures 75 to 77. The locations of observation points are shown in Figure 70.

At all locations presented, the water level impact of Doral’s proposed water supply pumping from the Yarragadee aquifer is predicted to be minimal and predicted shallow water levels for the wet and dry climatic scenarios, with and without Doral’s water supply pumping, are predicted to be similar over the closure period.

9.9.2.3 Water Balance Closure

The model predicted water balances for August 2033 and February 2034, ten years after dewatering and water supply pumping has ceased are shown in Tables 19 to 22. Water balances are shown for wet and dry climatic inputs for the Yalyalup Dewatering and Yalyalup Water Supply Only Scenarios. Also shown in brackets and italics are the predicted water balance components for the corresponding No Yalyalup Development Scenario.

The model predicted water balances for the Yalyalup Dewatering and Yalyalup Water Supply Scenarios, when compared to the No Yalyalup Development Scenarios show that by August 2033, the predicted water balances for the two development scenarios are identical to the corresponding No Yalyalup Development Scenarios. These results suggest that the regional groundwater system has recovered after the modelled development scenarios. There is no residual water table or aquifer drawdown predicted by February 2034 (i.e. 10 months prior to the end of the simulated closure period).
Table 19: Yalyalup Dewatering Dry Climate Model Predicted Water Balance (Closure)

<table>
<thead>
<tr>
<th>Water Budget Component</th>
<th>Wet Season (August 2033)</th>
<th>Dry Season (February 2034)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>In (kL/d)</td>
<td>Out (kL/d)</td>
</tr>
<tr>
<td>Storage</td>
<td>1,330</td>
<td>180,930</td>
</tr>
<tr>
<td></td>
<td>(1,330)</td>
<td>(180,930)</td>
</tr>
<tr>
<td>Recharge</td>
<td>440,620</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>(440,620)</td>
<td>(0)</td>
</tr>
<tr>
<td>Catchment Inflow</td>
<td>65,940</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>(65,940)</td>
<td>(0)</td>
</tr>
<tr>
<td>Catchment Outflow</td>
<td>0</td>
<td>28,290</td>
</tr>
<tr>
<td></td>
<td>(0)</td>
<td>(28,290)</td>
</tr>
<tr>
<td>Estimated Tronox Dewatering*</td>
<td>0</td>
<td>5,940</td>
</tr>
<tr>
<td></td>
<td>(0)</td>
<td>(5,940)</td>
</tr>
<tr>
<td>Doral Dewatering</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>(0)</td>
<td>(0)</td>
</tr>
<tr>
<td>Doral Water Supply</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>(0)</td>
<td>(0)</td>
</tr>
<tr>
<td>Licensed Abstraction</td>
<td>0</td>
<td>58,030</td>
</tr>
<tr>
<td></td>
<td>(0)</td>
<td>(58,030)</td>
</tr>
<tr>
<td>ET</td>
<td>0</td>
<td>234,700</td>
</tr>
<tr>
<td></td>
<td>(0)</td>
<td>(234,700)</td>
</tr>
<tr>
<td>Total</td>
<td>507,890</td>
<td>507,890</td>
</tr>
<tr>
<td></td>
<td>(507,890)</td>
<td>(507,890)</td>
</tr>
</tbody>
</table>

Water balance components for the No Yalyalup Development Scenario shown in brackets and italics

Table 20: Yalyalup Dewatering Wet Climate Model Predicted Water Balance (Closure)

<table>
<thead>
<tr>
<th>Water Budget Component</th>
<th>Wet Season (August 2033)</th>
<th>Dry Season (February 2034)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>In (kL/d)</td>
<td>Out (kL/d)</td>
</tr>
<tr>
<td>Storage</td>
<td>0</td>
<td>412,000</td>
</tr>
<tr>
<td></td>
<td>(0)</td>
<td>(412,000)</td>
</tr>
<tr>
<td>Recharge</td>
<td>627,040</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>(627,040)</td>
<td>(0)</td>
</tr>
<tr>
<td>Catchment Inflow</td>
<td>47,480</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>(47,480)</td>
<td>(0)</td>
</tr>
<tr>
<td>Catchment Outflow</td>
<td>0</td>
<td>48,290</td>
</tr>
<tr>
<td></td>
<td>(0)</td>
<td>(48,290)</td>
</tr>
<tr>
<td>Estimated Tronox Dewatering*</td>
<td>0</td>
<td>6,170</td>
</tr>
<tr>
<td></td>
<td>(0)</td>
<td>(6,170)</td>
</tr>
<tr>
<td>Doral Dewatering</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>(0)</td>
<td>(0)</td>
</tr>
<tr>
<td>Doral Water Supply</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>(0)</td>
<td>(0)</td>
</tr>
<tr>
<td>Licensed Abstraction</td>
<td>0</td>
<td>6,230</td>
</tr>
<tr>
<td></td>
<td>(0)</td>
<td>(6,230)</td>
</tr>
<tr>
<td>ET</td>
<td>0</td>
<td>201,830</td>
</tr>
<tr>
<td></td>
<td>(0)</td>
<td>(201,830)</td>
</tr>
<tr>
<td>Total</td>
<td>674,520</td>
<td>674,520</td>
</tr>
<tr>
<td></td>
<td>(674,520)</td>
<td>(674,520)</td>
</tr>
</tbody>
</table>

Water balance components for the No Yalyalup Development Scenario shown in brackets and italics
Table 21: Yalyalup Water Supply Only Dry Climate Model Predicted Water Balance (Closure)

<table>
<thead>
<tr>
<th>Water Budget Component</th>
<th>Wet Season (August 2033)</th>
<th>Dry Season (February 2034)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>In (kL/d)</td>
<td>Out (kL/d)</td>
</tr>
<tr>
<td>Storage</td>
<td>1,330</td>
<td>180,950</td>
</tr>
<tr>
<td></td>
<td>(1,330)</td>
<td>(180,930)</td>
</tr>
<tr>
<td>Recharge</td>
<td>440,620</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>(440,620)</td>
<td>(0)</td>
</tr>
<tr>
<td>Catchment Inflow</td>
<td>65,940</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>(65,940)</td>
<td>(0)</td>
</tr>
<tr>
<td>Catchment Outflow</td>
<td>0</td>
<td>28,280</td>
</tr>
<tr>
<td></td>
<td>(0)</td>
<td>(28,290)</td>
</tr>
<tr>
<td>Estimated Tronox Dewatering*</td>
<td>0</td>
<td>5,940</td>
</tr>
<tr>
<td></td>
<td>(0)</td>
<td>(5,940)</td>
</tr>
<tr>
<td>Doral Dewatering</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>(0)</td>
<td>(0)</td>
</tr>
<tr>
<td>Doral Water Supply</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>(0)</td>
<td>(0)</td>
</tr>
<tr>
<td>Licensed Abstraction</td>
<td>0</td>
<td>58,030</td>
</tr>
<tr>
<td></td>
<td>(0)</td>
<td>(58,030)</td>
</tr>
<tr>
<td>ET</td>
<td>0</td>
<td>234,690</td>
</tr>
<tr>
<td></td>
<td>(0)</td>
<td>(234,700)</td>
</tr>
<tr>
<td>Total</td>
<td>507,890</td>
<td>507,890</td>
</tr>
<tr>
<td></td>
<td>(507,890)</td>
<td>(507,890)</td>
</tr>
</tbody>
</table>

Water balance components for the No Yalyalup Development Scenario shown in brackets and italics

Table 22: Yalyalup Water Supply Only Wet Climate Model Predicted Water Balance (Closure)

<table>
<thead>
<tr>
<th>Water Budget Component</th>
<th>Wet Season (August 2033)</th>
<th>Dry Season (February 2034)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>In (kL/d)</td>
<td>Out (kL/d)</td>
</tr>
<tr>
<td>Storage</td>
<td>1,020</td>
<td>228,740</td>
</tr>
<tr>
<td></td>
<td>(1,020)</td>
<td>(228,740)</td>
</tr>
<tr>
<td>Recharge</td>
<td>530,200</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>(530,200)</td>
<td>(0)</td>
</tr>
<tr>
<td>Catchment Inflow</td>
<td>67,200</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>(67,200)</td>
<td>(0)</td>
</tr>
<tr>
<td>Catchment Outflow</td>
<td>0</td>
<td>27,240</td>
</tr>
<tr>
<td></td>
<td>(0)</td>
<td>(27,240)</td>
</tr>
<tr>
<td>Estimated Tronox Dewatering*</td>
<td>0</td>
<td>6,020</td>
</tr>
<tr>
<td></td>
<td>(0)</td>
<td>(6,020)</td>
</tr>
<tr>
<td>Doral Dewatering</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>(0)</td>
<td>(0)</td>
</tr>
<tr>
<td>Doral Water Supply</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>(0)</td>
<td>(0)</td>
</tr>
<tr>
<td>Licensed Abstraction</td>
<td>0</td>
<td>58,030</td>
</tr>
<tr>
<td></td>
<td>(0)</td>
<td>(58,030)</td>
</tr>
<tr>
<td>ET</td>
<td>0</td>
<td>278,390</td>
</tr>
<tr>
<td></td>
<td>(0)</td>
<td>(278,390)</td>
</tr>
<tr>
<td>Total</td>
<td>598,420</td>
<td>598,420</td>
</tr>
<tr>
<td></td>
<td>(598,420)</td>
<td>(598,420)</td>
</tr>
</tbody>
</table>

Water balance components for the No Yalyalup Development Scenario shown in brackets and italics
9.9.2.4 Drawdown Closure

Contours of predicted water table drawdown throughout the simulated closure period were provided to Doral in electronic format at selected times to allow assessment of the potential drawdown impact on vulnerable areas. These drawdowns are the difference between the water table predicted at each time interval for the Yalyalup Dewatering Scenario and the corresponding No Yalyalup Development Scenario.

Contours of predicted water table drawdown for June 2026 for dry and wet climate conditions, for the Yalyalup Dewatering Scenario are shown in Figures 112 and 113. Drawdown of 0.1m is predicted for both climate scenarios. This drawdown is limited to the mine area and a small area to the east. Drawdown of 0.1m is predicted to extend a maximum distance of 200m east of the mine perimeter for both the wet and dry climatic conditions. From July 2026, there is no residual drawdown predicted.

9.10 Extended Irrigation Predictions

Model predictions described in Section 9.8 and 9.9 of the main report include groundwater pumping from other users in the modelled catchment. Abstraction is included for all Groundwater Well Licences (GWLS), including non-agricultural and agricultural users. Abstraction is included for agricultural users at 80% of the licences allocation over the summer months (August to April). Abstraction for non-agricultural users is included at 80% of the licenced allocation, with distributed equally throughout the year.

It has been identified that water use may increase in the south west of Western Australia in the future. To address this, model predictions were re-run assuming that groundwater pumping from all other users in the catchment was increased to 100% of the current licenced allocations and was extended for a month. Model predictions were run to assess the impact of the extended and increased pumping periods on model predicted drawdown from Doral’s proposed groundwater development.

The distribution of abstraction throughout the year included in model predictions is outlined below:

- For agricultural users, 100% of the licenced allocations was assumed to be abstracted from August to May of each year. This represents an increase in the pumping period of one month compared to the model predictions described in Section 9.8 and 9.9.
- For non-agricultural users, 100% of the licenced allocation was assumed to be abstracted throughout the year.

Details of the model predictions completed and an assessment of key model results are presented in Appendix E. When the Base Case predictions are compared to the Extended and Increase GWL allocation predictions, model results suggest that the impacts of increased and extended GWL abstraction are limited and outlined below:

- There is very little impact of extended and increased GWL licence abstraction predicted in the Superficial aquifer over the life of the mine (2021 to 2024) and during the simulated mine closure period (2025 to 2034) for both the Yalyalup Dewatering and Yalyalup Water Supply Scenarios (refer Figures E1 to E6, Appendix E).
- There is some impact of extended and increased GWL abstraction predicted in the Leederville aquifer. Reduced water levels are predicted for an additional month each year, however the
additional drawdown predicted is generally less than 0.5m at selected monitoring points across the modelled catchment (Figures E3 to E4 and E7 to E8, Appendix E)

- By the end of 2024, when production water supply pumping at Yalyalup ceases, predicted drawdown for the Base and Increased and Extended Irrigation Cases are similar for the Leederville and Yarragadee aquifers (refer Figures E13 and E14).

9.11 Model Uncertainty

The groundwater model used for the predictions described in Sections 9.8 and 9.9 was calibrated to groundwater level responses across the modelled catchment. To assess the potential for different prediction outcomes, an alternate or uncertainty prediction was also completed. This calibration was developed to assess the model sensitivity described in Section 9.6.6. For this model calibration the following changes were adopted:

- The horizontal and vertical hydraulic conductivity values assigned to the Bassendean Sand, Guildford Formation and Yoganup Formation were halved.
- The unconfined storage values assigned to all of the Superficial Formation was also assigned at 50% of the value assigned to the Base Case.
- The modelled aquifer recharge was assigned as follows:
  - When annual rainfall is less than 850 mm, recharge to groundwater is assigned at 30% of monthly rainfall (in excess of the 150 mm annual threshold).
  - When annual rainfall exceeds 850 mm, recharge to groundwater is assigned at 20% of monthly rainfall (in excess of the 150 mm annual threshold).

Over the model calibration period (1987 to 2019) these recharge rates result in calculated annual recharge to groundwater of between 13% and 26% of recorded annual rainfall. The average recharge to groundwater over the calibration period is 20% of annual recorded rainfall, with the median recharge of 21% of annual recorded rainfall. These recharge rates are approximately 50% of the values assigned to the calibrated model. These reduced recharge rates are at the lower end of the range of recharge values for the South West Swan Coast Plain el (Baddock, 2005).

Details of the Uncertainty Calibration, including the adopted aquifer parameters, the modelled catchment water balances and calibration hydrographs are provided in Appendix F.

The calibrated uncertainty model was used to complete the Yalyalup Dewatering, Yalyalup Water Supply and No Development Scenarios, as outlined in Table 14 and Appendix F (Table F1). These predictions included the same conditions as used for the Base Case models (described in Section 9.8). The model predicted contours of predicted drawdown suggest that the predicted drawdown impacts of mine dewatering and water supply for the Yalyalup mine are similar for the Uncertainty Case and the Base Case. As would be expected from a model that is calibrated using lower values of aquifer storage and rainfall recharge, the Uncertainty model predicts lower groundwater inflows to the proposed Yalyalup mine, a lower modelled catchment water balance and less drawdown impact in the water table aquifers.
9.12 Model Limitations, Assumptions and Class

The groundwater model was developed consistent with the available data and includes the results of hydrogeological investigations to date. As with all models, there are limitations associated with data availability, conceptualisation and representation of hydrogeological processes. The model includes the known features of the system and is calibrated to available data. However, the predictions are simulations based on the mine plan provided and the estimated maximum water supply demand (for ore processing).

The following is a list of model limitations:

- The model was set up to predict the regional impacts of the proposed Yalyalup mine, including dewatering of the open pit and the water supply pumping from the Yarragadee aquifer and simulated the aquifer scale responses to groundwater stresses. The parameters assigned to each aquifer unit have been assigned uniformly across each hydrogeological unit. For example, the Bassendean Sand is assigned the same hydraulic property values across the model. The model does not include detailed or local scale features which may influence short term behaviour (for example lenses of clay or other lower permeability features in the mine area).
- The model includes single layer aquifers to simulate both the Leederville and Yarragadee aquifers and does not include detailed or local scale features which may influence short term behaviour.
- While the model is calibrated to long term water level monitoring data from the Superficial and Leederville aquifers, no model calibration has been completed for the Yarragadee aquifer.
- The ground surface elevations used to define the thickness of aquifer units and also assigned as the ET surface is based on detailed survey data (provided by Doral) in the immediate mine area and Land Monitor data for the remainder of the modelled catchment.
- The model uses a variable cell size to predict the aquifer response to groundwater stresses. The minimum model cell size of 20 m by 20 m is not designed to replicate water levels that develop close to groundwater abstraction bores across the modelled catchment.

A number of assumptions have been included in the model set up and prediction scenarios as outlined below:

- Recharge and ET have been assigned in the model. The current model set up does not include variations in these parameters across different land use type (e.g. urban areas versus farm areas). Additionally, no change in land use type has been included over the calibration period (e.g. land clearing or the establishment of urban areas close to the coast).
- Model boundaries were assigned, upstream and downstream of the proposed Yalyalup development to limit the impact of these boundaries. The rate of groundwater flow across these boundaries is controlled by the head and conductance parameters assigned to the south east and north west general head boundaries. These values were adjusted during model calibration to limit the predicted change in groundwater flow across these boundaries.
- Assumptions have been included in the model for groundwater abstraction in other parts of the modelled catchment including:
The location and proportion of licenced abstractions included in the model (calibration and predictions).

The depth and timing of mine develop at the nearby Tronox mining operation.

A consistent approach is used in predictions of Yalyalup groundwater development and the corresponding no development scenarios so that any drawdown impact predicted is from the Yalyalup development.

- The model includes a simplified approximation for groundwater recharge from rainfall based on a threshold or total amount of rainfall that must occur prior to the onset of recharge to groundwater. This approximation was derived for the current depth to water across the catchment. During model predictions, these recharge estimates were not updated to account for the temporary increase in depth to water, or depth of the soil column above the water table, that will occur as a result of dewatering of the mine area.

- The assessment of the potential drawdown impacts associated with the Yarragadee aquifer water supply abstraction is based on aquifer parameters derived from a desktop study assessment (ie the model set up is not based on site specific data).

Fieldwork to drill and construct a Yarragadee production bore and undertake aquifer tests is scheduled after the environmental approvals for the Yalyalup mine site are received from DWER. The groundwater flow model will need to be updated for H3 level reporting to support a DWER 5C groundwater licence application.

- Model predictions include a wet and dry rainfall sequence, which is used to calculate recharge to groundwater. Predictions do not however account for changes in ET and recharge to groundwater related to future climate change.

The groundwater model developed for the Yalyalup mine and surrounding groundwater catchment was completed consistent with the Australian Groundwater Modelling Guidelines (Barnett et al, 2012).

Based on the Australian Groundwater modelling guidelines (2012), specifically Table 2-1 (Model confidence level classification – characteristics and indicators), the model satisfies some of the requirements of a Class 3 confidence level (the highest level) for the Superficial aquifer in the Yalyalup mine area as:

- The model is calibrated to long term data;

- The prediction period (3.5 years of mining and 10 years of post-mining) is shorter than the length of the calibration data set at some locations (close to thirty years).

Areas where the model does not satisfy the Class 3 confidence level are outlined below:

- Over the model calibration period, changes in water levels are associated with seasonal variations. The model is calibrated to replicate these seasonal water level changes. The water level changes included in predictions and associated with dewatering, are much greater than the seasonal variations. As a result the model is not calibrated to the magnitude of water level changes or drawdown expected during mine development. This type of data, that includes a
significant change or stress on the aquifer, is only available once mining and dewatering commences.

- There is no data available for model calibration for the Yarragadee aquifer (long term monitoring data or similar aquifer stresses). The Yarragadee aquifer is the target water supply aquifer included in model predictions.

- There is uncertainty around the amount and location of groundwater abstraction that has occurred historically and into the future across the modelled catchment (dewatering and bore pumping). The future impacts of pumping at 100% of GWL allocation, for an extra month each year was investigated. Model results suggested that increased abstraction has minimal impact on superficial water levels and a seasonal impact of 0.5m on Leederville water levels.

Overall, the model confidence classification level could be considered Class 2. This classification means that the model is suitable for the purposes of:

- Providing estimates of dewatering requirements for the proposed mine area and associated impacts.
- Prediction of impacts of water supply pumping on surrounding aquifers.
10 ASSESSMENT OF POTENTIAL IMPACTS

Potential impacts from the proposed Yalyalup project on hydrological processes are:

- Short-term dewatering of mine pits and associated changes to water levels (i.e. drawdowns), which may affect:
  - Water availability at surrounding groundwater users of the Superficial aquifer and the underlying Leederville aquifer;
  - Potential GDE's and vegetation;
  - Vasse-Wonnerup System Ramsar Wetland;
  - Surface water courses;
  - Acid Sulfate Soils.

- Short-term groundwater abstraction from the Yarragadee aquifer, which may affect other groundwater users of the Yarragadee aquifer and the overlying Leederville Aquifer.

10.1 Mine Dewatering

10.2 Aquifers

Groundwater drawdowns (i.e. decrease in water levels) in the Superficial aquifer and the underlying Leederville aquifer due to the open pit dewatering have been predicted by the numerical model and the results are discussed in Section 9.9.1.1 (i.e. Base Case Model Predictions).

To sum up, water level drawdowns in the Superficial aquifer are predicted to be localised in the immediate area of the active mining (pits), temporary in duration and relatively small, with a maximum drawdown of 10.5 m is predicted at the end of mining in Q2 of 2023. The cone of depression of 0.1 m generally lies within the proposed mining disturbance envelop and only marginally extends past this area (up to 700 m for the dry scenario and 600 m for the wet scenario).

Additionally, some small drawdowns (up to 0.4 m) are predicted in the Leederville aquifer due to dewatering of the overlying Superficial aquifer. The Mowen Member of the Leederville Formation is generally considered as an aquitard, however at the Yalyalup site the Mowen Member is thin resulting in small indirect upward leakage of water from the Leederville aquifer from below the pit floor. Based on the results of groundwater modelling, the drawdowns in the Leederville aquifer are predicted to be local and likely to extend laterally, but not vertically (owing to clayey layers within the sand). The drawdown of 0.1 m is estimated to extend no more than 1.2 km for both wet and dry scenario (i.e. Q3 of 2023) from the active mining area and only marginally extending past the proposed mining disturbance envelop boundaries (i.e. up to 700 m).

Therefore, it is unlikely that short-term dewatering at the proposed Yalyalup mine will have any adverse impacts on the water supply potentials of the Superficial and Leederville aquifer systems.

Long-term post mining effects on water levels are expected to be minimal. The recovery of water levels will commence immediately once mining of each active mine pit is completed, owing to backfilling of mined-out pits. Groundwater inflows to the mined-out pits are driven by water level gradients between the mine voids and the surrounding areas. It should be noted that during the mining phase, water recovery in mined-out areas may be interfered with by dewatering of subsequent mining areas, thus the rate of water level recovery can be slow. Once all mining areas are completed, dewatering will cease,
and water levels will continue to rise until a steady state or equilibrium water level is resumed. The numerical model shows that water levels are predicted to return to pre-mining levels within 18 months of mine closure (i.e. by July 2026).

### 10.3 Existing Other Groundwater Users

The modelling only identified one licenced bore under GWL180363 which abstracts water from the Superficial aquifer, that is located within the modelled drawdown extent of between 0.1 to 0.25 m due to dewatering (occurring during Q4 of 2021 and Q3 of 2022 for the wet scenario and from Q4 of 2021 to Q1 of 2023 for the dry scenario). The maximum drawdown of 0.3 m is predicted to occur during Q2 of 2022 (Figure 114). The remaining Superficial aquifer licenced bores are located outside of the predicted 0.1 m drawdown contour and are unlikely to be impacted by the Yalyalup dewatering operations.

Additionally, there are several unlicenced bores which are screened in the Superficial aquifer that are within the modelled extent of the 0.1 to 0.25 m drawdown contours. Most of them have either been decommissioned or used by DWER for monitoring purposes. There are only five unlicenced bores (20005101, 20005166, 20005168, 20005169 and Lot421_Bore2) that have been reported by Doral being in use and three of them (20005101, 20005166 and 20005169) fall within the modelled zone of between 0.1 to 0.25 m due to mining dewatering – this limit drop in water level is unlikely to influence their supply potential.

The numerical model also indicated that small drawdowns (up to 0.4 m) are predicted in the Leederville aquifer due to dewatering of the overlying Superficial aquifer. There are three Leederville aquifer licences (GWL67672, GWL94291 and GWL178017) that have bores located within the drawdown extent of between 0.1 to 0.25 m and could be affected by mining related dewatering (Figure 115). However, these drawdowns are predicted to be temporary in duration and relatively minor.

It is therefore unlikely that short-term dewatering at the proposed Yalyalup mine will have any long-term adverse impacts on the water supply potentials of other users in the Superficial and Leederville aquifers.

Regular monitoring of groundwater levels in the Superficial and Leederville bores and the clear communication with the nearby groundwater users during the mining operation, will provide information on the actual induced drawdowns and impacts on the other users. If any of the Superficial and Leederville bores are affected by Doral’s mining operations, then Doral will implement the mitigation measures.

#### 10.3.1 Groundwater Dependent Ecosystems and Vegetation

No groundwater drawdown in the Superficial aquifer is predicted to extend beyond 700 m from the edge of the mining area at the Yalyalup, therefore it is unlikely that any of three high value wetland GDEs, located approximately 6 km to either the northeast and southwest of the site, will be impacted by the proposed Yalyalup development.

The impact assessment on the local GDEs due to dewatering at the Yalyalup has been undertaken by Ecoedge (2019b) and the results are reported separately in a GDE report (i.e. not included in this report).
10.3.2 Vasse-Wonnerup System Ramsar Wetland

The numerical model shows that there will be no drawdown in the Superficial aquifer predicted to extend to the Vasse-Wonnerup System Ramsar Wetland (~4.6 km to the north) due to dewatering at the Yalyalup site (i.e., the maximum extent of 0.1 m drawdown may extend up to 700 m from the mining disturbance area). Therefore, it is highly unlikely that the Vasse-Wonnerup wetland will be impacted by the proposed Yalyalup mining development.

10.3.3 Surface Water Courses

The numerical model indicates that no drawdown from dewatering at the Yalyalup mine extend to the Lower Sabina River (~1.6 km to the west) or to the Abba River (~1 km to the east) (Figure 114). Additionally, as it was commented in Section 3.1, there is limited or no groundwater connection with these surface water bodies, resulting in minimal or no groundwater contribution to the river’s baseflow. Therefore, the existing surface water flow regime is unlikely to be impacted by the dewatering operations at the Yalyalup, as it is likely to be dominated by high-rainfall periods generating surface water runoff, rather than any substantial groundwater flow component.

Additionally, flows in the local surface water drains around the mining area similar to the Lower Sabina or Abba Rivers and rely mainly on surface water runoff after heavy rainfall events, with no or limited groundwater contribution to surface water flow in these local drains. The initial surface water assessment (AQ2, 2019a) outlined that all runoff from Lower Sabina catchment areas upstream of the mine envelope, will be diverted around mining operations and discharged to a downstream water course. Runoff from areas within the mine envelope will be either used in mining operations (generated by rainfall) or discharged through a designated location (i.e., following large event, or if water surplus exists). The surface water discharge assessment (AQ2, 2019c) outlined that if a site water surplus is required to be discharged off-site, it is unlikely the discharges will have adverse impacts to the downstream surface water regime, as the discharge from the disturbed areas will be returning to its original downstream catchment below where the mine has been developed.

To sum up, any dewatering operations at the site are unlikely to impact on the immediate surface water flow regime.

10.3.4 Acid Sulphate Soils

The impact assessment relating to the ASS potential on the groundwater due to dewatering at the Yalyalup mine has been undertaken by ABEC Environmental Consulting (2019) and the results are separately reported in the ASS report.

10.4 Yarragadee Water Supply Abstraction

10.4.1 Aquifers

The proposed extraction of 1.6 GL/year from the Yarragadee aquifer at the Yalyalup project is unlikely to have any adverse impacts on the water supply potentials of the aquifer systems, as the extraction will result in a piezometric level reduction in this aquifer on the local scale only. A maximum drawdown of 3.8 m is predicted adjacent to the production bore after 3.5 years of pumping, with the 1 m drawdown
cone extending up to 1.2 km from the production bore. Generally, the 1 m drawdown lies within the proposed mining disturbance envelope.

At the site, the Yarragadee aquifer is a confined aquifer with limited downward leakage from overlying aquifers, due to the presence of low permeable confining layers within the aquifers. However, there may be some small drawdowns recorded in the Leederville aquifer (Vasse Member) during the 3.5 years of pumping from YA_PB01 and the drawdown may extend in the vicinity of YA_PB01 (i.e. a maximum drawdown of 0.6 m with the 0.5 m drawdown estimated to extend no more than 1.3 km from the production bore).

It should be noted that Doral plans to pump from YA_PB01 only when required (i.e. when there is a shortage of water from rainfall runoff and pit dewatering); therefore the actual drawdowns in the Yarragadee and Leederville aquifers will be smaller than predicted, due to the recovery periods between the extractions.

Regular monitoring of groundwater levels in all aquifers during the mining operation will provide information on the actual induced drawdowns and impacts on these aquifers.

### 10.4.2 Existing Other Groundwater Users

There are no known bores that abstract water from the Yarragadee aquifer that are located within the modelled extent of the 0.5 m and 1 m drawdown cones developed around the production bore (i.e. within 1.2 and 3.7 km from the YA_PB01, respectively). The closest Yarragadee aquifer production bore is located at 4.5 km from the site (i.e. GWL156423, Turf Farm) and small drawdowns (between 0.25 and 0.5 m) are predicted at this location due to extraction from YA_PB01 (Figure 116).

There are four licenced bores that abstract water from the Leederville aquifer that are located within the modelled extent of the 0.5 m drawdown cone in the Leederville aquifer (i.e. under 1.3 km from the production bore YA_PB01) (Figure 117).

However, given the short duration of the abstraction from YA_PB01, the impacts to other Yarragadee and Leederville aquifer users is not expected to be significant. It should be noted that continuously pumping from YA_PB01 has been modelled, while it is planned that YA_PB01 will be used only when required, most likely during summer periods when there is a shortfall of water supplied from rainfall runoff and pit dewatering. Therefore, during the winter periods when minimal to no pumping from YA_PB01 occurs, water levels will recover and the actual drawdowns in the Yarragadee and Leederville aquifers will be smaller than predicted.

Regular monitoring of groundwater levels in the Yarragadee and deep Vasse Member of the Leederville bores and the clear communication with the nearby groundwater users during the mining operation will provide information on the actual induced drawdowns and impacts on the other users.

### 10.5 Additional Groundwater Model Predictions

Additional groundwater model predictions were completed to assess the impact of additional and extended GWL allocation pumping on the groundwater impacts from Doral's proposed groundwater development (refer Appendix E). An additional Uncertainty Calibration was also used to completed model predictions for wet and dry climatic conditions (refer Appendix F). The results of the additional
modelling showed very little change to the overall modelled outcomes (i.e. predicted water levels, drawdowns and water balances) compared to the Base Case model predictions (Sections 9.8 and 9.9). Therefore, the potential impacts from the proposed Yalyalup project on hydrological processes (i.e. aquifers, other users, GDEs) from the additional model predictions are predicted to be comparable to the Base Case model predictions for both dry and wet climatic scenarios (Sections 10.1 to 10.2).
11 GROUNDWATER MANAGEMENT AND MONITORING

The groundwater system will need to be carefully managed at the Yalyalup mine in order to avoid or minimise impacts to hydrological processes (i.e. groundwater and surface water), due to mining operations. A detailed Groundwater Operating Strategy (GWOS) will be developed and submitted to DWER when applying for the 5C groundwater licences, both for the groundwater abstraction from the Superficial aquifer (during mine dewatering) and the Yarragadee aquifer (for water supply). The GWOS will include a groundwater and surface water monitoring programme (i.e. abstraction, discharge, water levels and water quality) and will be designed to assess aquifer performance, the potential impacts of groundwater abstraction proposed upon commencement of mining operations and specify operational requirements. Trigger levels and contingency actions will be developed to mitigate potential impacts caused by the Yalyalup mining operations and also to ensure the actual impacts are not greater than predicted. The GWOS will be prepared in accordance with the DWER operational policy 5.08 for reporting associated with operating strategies (DWER, 2011) and the DWER guidelines for the preparation of Operating Strategies for mineral sand mine dewatering licences in the South West Region (DWER, 2015).

Additional monitoring bores may need to be installed talking into consideration sensitive local areas (i.e. GDEs) and to supplement the existing monitoring bore network (i.e. adjacent to SEPs to monitor any seepage).

Moreover, clear communication with the nearby groundwater users during the mining operation will provide information on the actual induced drawdowns and impacts on the other users.

In addition to the GWOS Doral will prepare and implement plans and procedures relevant to the management of groundwater and surface water, which will include (but not limited to):

- GDE Management Plan;
- Surface Water Management Plan;
- Emergency Discharge – Pre-release of Discharge Procedure;
- Emergency Discharge –Discharge Monitoring Procedure;
- Groundwater Monitoring Procedure;
- SEP Construction and Operation Procedure;
- Hydrocarbon Management Procedure;
- Spill Management Procedure.
12 SUMMARY AND CONCLUSIONS

Dewatering of the open-cut pits at the Yalyalup mineral sands mine will be necessary to provide dry mining conditions. Additionally, water supplies of 1.6 GL/year are required for mineral ore processing and are to be sourced from recycled water from hydraulically returned tailings, rainfall runoff, pit dewatering water and supplemented by pumping from the external production bore in the Yarragadee aquifer.

A numerical groundwater model was developed and dewatering predictions of groundwater inflow to the proposed Yalyalup mine were completed for the current mine plan, together with predictions related to pumping of the Yarragadee bore. The prediction models were run for a set of wet and dry climatic conditions based on the “wet” and “dry” real rainfall data sets used for model calibration, with the following results:

- Monthly groundwater inflows for the wet and dry climatic conditions vary with depth of mining and season. For the dry conditions, dewatering is predicted to peak at 2,420 kL/d in March 2023, with a corresponding peak in dewatering when wet conditions are included of 4,090 kL/d, in May 2023. Generally, groundwater inflows throughout the mine life are less than 2,000 kL/d.

- Predicted cumulative annual abstraction from the Superficial aquifer ranged from approximately 0.13 to 0.53 GL/year (average of 0.32 GL/year) for the dry climatic scenario and from 0.21 to 0.68 GL/year (average of 0.47 GL/year) for the wet climatic scenario.

- Dewatering due to mining at the Yalyalup is likely to result in negligible regional scale groundwater drawdowns in the Superficial and Leederville aquifers. Drawdowns in the Superficial and Leederville aquifers are predicted to be localised in the immediate area of the active mining (pits), temporary in duration and relatively small. A maximum drawdown of 10.5 m predicted after mining Q2 of 2023, with the 0.1 m drawdown contour falling only marginally outside of the proposed mining disturbance envelop (up to 700 m for the dry scenario and 600 m for the wet scenario). Additionally, small drawdowns of up to 0.4 m are predicted in the Leederville aquifer due to dewatering of the overlying Superficial aquifer. The drawdowns in the Leederville aquifer are predicted to be local and likely to extend laterally, but not vertically (owing to clayey layers within the sand). The drawdown of 0.1 m is estimated to extend no more 700 m from the proposed mining disturbance envelop boundaries for both dry and wet scenarios.

- Long-term post mining effects on water levels are expected to be minimal. The recovery of water levels will commence immediately once mining of each active mine pit is completed, owing to backfilling of mined-out pits. Once all mining areas are completed, dewatering will cease, and water levels will continue to rise until a steady state or equilibrium water level is resumed. The numerical model shows that water levels are predicted to return to pre-mining levels within 18 months of mine closure for both dry and wet climatic scenarios.

- Drawdown impacts on adjacent licenced bores will be limited and unlikely to influence their supply potential. The maximum drawdowns of between 0.1 to 0.25 m due to mining related dewatering were predicted in one Superficial aquifer licenced bore (GWL180363), seven Superficial unlicenced bores and three Leederville aquifer licences (GWL67672, GWL94291 and GWL178017).
• The impact assessment on the local GDE’s due to dewatering has been undertaken by Ecoedge (2019) and the results are reported separately in a GDE report.
• The existing surface water flow regime is unlikely to be impacted by the dewatering operations at the Yalyalup, as it is likely to be dominated by high-rainfall periods generating surface water runoff, rather than any substantial groundwater flow component. Additionally, no drawdowns from dewatering at the Yalyalup were predicted to extend to the nearby Lower Sabi or Abba Rivers. Moreover, during mining any surface water flows from the local surface water drains will be either diverted around mining operations and discharged downstream (project’s upstream areas), or used in mining operations or discharged off-site downstream (within project’s mine development envelop).
• The proposed extraction of 1.6 GL/year from the Yarragadee aquifer is unlikely to have any adverse impacts on the water supply potentials of the aquifer systems, as the extraction will result in a piezometric level reduction in the Yarragadee aquifer and overlying Leederville aquifer on the local scale only. A maximum drawdown of 3.8 m in the Yarragadee aquifer and 0.6 m in the Leederville aquifer are predicted after 3.5 years of pumping from the Yarragadee bore. The 1 m drawdown cone in the Yarragadee aquifer is estimated to extend up to 1.2 km from the production bore, while the 0.5 m drawdown in the Leederville aquifer is estimated to extend no more than 1.3 km from the production bore.
• It is unlikely that the proposed extraction of 1.6 GL/year from the Yarragadee aquifer will have any adverse impacts on the nearby groundwater users. There are no known bores that abstract water from the Yarragadee aquifer that are located within the extent of the 0.5 m and 1 m drawdown cones developed around the production bore (i.e. within 3.7 km radius). The closest Yarragadee aquifer production bore is located at 4.5 km from the site (i.e. GWL156423, Turf Farm) and only small drawdowns (between 0.25 and 0.5 m) are predicted at this location due to pumping at the Yalyalup. Additionally, there are four licenced bores that abstract water from the overlying Leederville aquifer that are located within the modelled extent of the 0.5 m drawdown cone in the Leederville aquifer (i.e. 1.3 km radius). Moreover, the actual drawdowns in the Yarragadee and Leederville aquifers are likely to be smaller than predicted, owing to the planned discontinuous pumping regime (on demand, mostly during summer periods) that results in the water level recovery between the extraction periods.
• A detailed Groundwater Operating Strategy will be developed and submitted to DWER when applying for the 5C groundwater licences, both for the groundwater abstraction from the Superficial aquifer (during mine dewatering) and the Yarragadee aquifer (for water supply). The GWOS will include a groundwater and surface water monitoring programme designed to assess aquifer performance, the potential impacts and operational requirements. Trigger levels and contingency actions will be developed to mitigate potential impacts caused by the Yalyalup mining operations and also to ensure the actual impacts are not greater than predicted.

A groundwater model has been developed for the Doral Yalyalup mining operation and surrounding groundwater catchment. The model has been developed and calibrated using all available data. This includes data from a range of sources including long term water level monitoring and detailed geological information and site-specific hydraulic testing data. The model currently satisfies the criteria of a Class 2
model (Barnett et al, 2012) overall based on the model calibration, however some areas of the model satisfy the criteria of a Class 3 model. For the model to satisfy all the criteria of a Class 3 model would require calibration of the model to operational data of the same magnitude as the proposed Yalyalup development. It is proposed that when operational data are available, the model performance will be verified against operational data (mine progression, groundwater inflows and measured water levels).

Prior to model verification and before operational data is available and to investigate key model uncertainties, the following work has been completed:

- The Base Case calibrated model has been used to predict the groundwater inflows and the impacts (drawdown and water balance) of the Yalyalup mine (both dewatering and water sully cases) for future wet and dry climatic conditions.
- The Base Case calibrated model has also been used to predict the impact of the Yalyalup mine assuming that GWL abstraction is increased to 100% of the licenced allocation, and for an additional month each year (i.e. up to May).
- To address key model uncertainties, an alternate model calibration, that includes lower aquifer hydraulic conductivities, aquifer specific yield and reduced rainfall recharge was completed. This alternate or uncertainty model was also used to complete model predictions for wet and dry climatic conditions for both dewatering and water supply cases.

For all of the modelling work completed above, similar impacts of the Yalyalup mine on the surrounding catchment were predicted.

It is recommended that if a greater level of model confidence is required, that the model performance is verified against operational data, once that data is available. This is best done once some of the aquifer stress has been applied (i.e. mining below the water table has commenced). It is recommended that the predictive performance of the model is verified against operational data 6 months after the start of mining, including updating the rainfall recharge input to the model based on measured rainfall data. If the operational data is replicated by the model, then no further work is required. If there are mismatches between the measured data and model performance, then the model will be re-calibrated and model predictions re-run to include the updated model calibration data set and any operational / mine plan updates.
REFERENCES


Department of Environment, September 2007. Ecological Character Description, Vasse-Wonnerup RAMSAR wetlands site in south-west Western Australia.


DWER, 2009a. Operational policy no. 5.12 – Hydrogeological Reporting Associated with a Groundwater Well Licence: Department of Water Perth.


HydroSOLVE, Inc. 2006. AQTESOLVTM (software).


FIGURE 1
REGIONAL LOCATION OF THE YALYALUP MINERAL SANDS PROJECT

Proposed Yalyalup Disturbance Boundary

Scale 1:150,000

NOTES & DATA SOURCES:
Mine outline provided by Doral

GC 007
GC A
23/10/2019 JOB NO: 136
Vasse Wonnerup Wetlands Catchment 473 km²

Lower Sabina 45.51 km²

Upper Sabina 77.6 km²

NOTES & DATA SOURCES:
Lower Sabina catchment based on local drains, DWER subcatchments and Topographic 2m contours from DPIRD - Department of Primary Industries and Regional Development (1999)
LOWER SABINA AND ABBA RIVERS STAGES AND FLOWS  FIGURE 4
FIGURE 5
LOCAL SURFACE WATER DRAINAGE AND SURFACE WATER MONITORING SITES

LEGEND
- Site Boundary
- Local Surface Water Drainage
- Surface Water Monitoring Sites

Author: GC
Drawn: LDS
Date: 18/10/2019

Report No: 007
Revision: a
Job No: 136

Notes & Data Sources:
Mine outlines provided by Doral
