BHP

Western Ridge: Groundwater impact assessment

December 2022

Authorisation

Version	Description of Version	Position	Date
0	Initial	Superintendent, Stewardship & Approvals	19 December 2022

Contents

Figures

1 Introduction

The purpose of this document is to provide an assessment of the impacts on water resources from the proposed groundwater abstraction for mine dewatering for the Western Ridge Proposal (BHP 2022a). The *Western Ridge: Ophthalmia Dam surplus water impact assessment update* (BHP 2022b) documents the assessment of the impacts of discharge of surplus mine dewater from the Western Ridge Proposal to Ophthalmia Dam.

2 Existing environment and environmental values

The proposed Western Ridge mine is identified as a future expansion of BHP's existing mining operations at Newman in the Pilbara Expansion Strategic Proposal (Ministerial Statement 1105). Existing mines in the Newman Hub are the Whaleback and OB29/30/35 mines to the north of Western Ridge and the Eastern Ridge mining operation to the northeast (Figure 1).

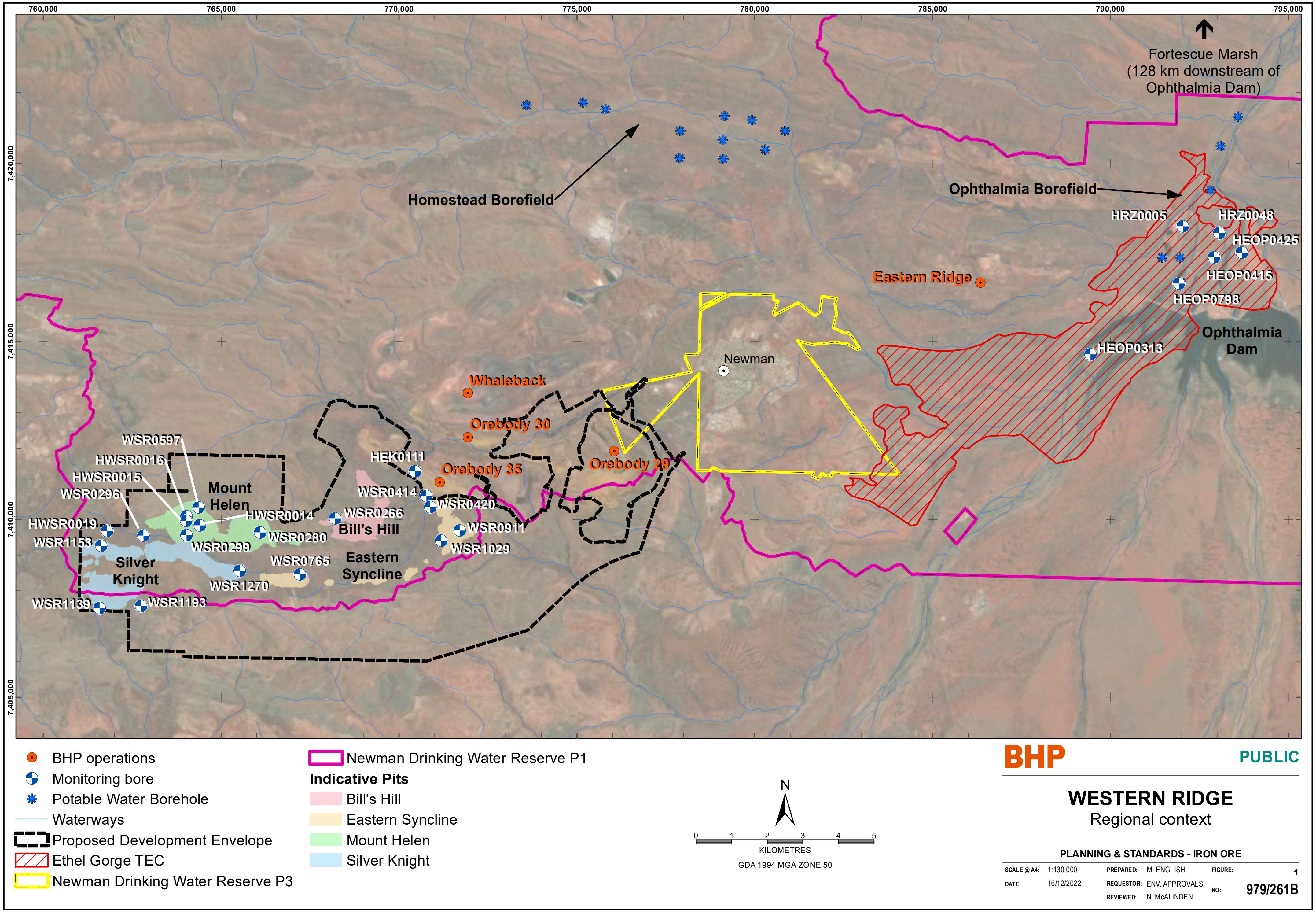
The Western Ridge Proposal is partially located within the Priority 1 Public Drinking Water Source Area of the Newman Water Reserve (Figure 1). Groundwater is abstracted from the BHP operated Ophthalmia and Homestead borefields, to provide drinking water for the Newman town water supply. The Homestead Borefield is adjacent to the Eastern Ridge mining operation (to the west) and the Ophthalmia Borefield is located to the northeast of Western Ridge, within the Ethel Gorge aquifer.

The Ophthalmia Dam system partially overlies the Ethel Gorge aquifer which supports the Ethel Gorge aquifer stygobiont community Threatened Ecological Community (Ethel Gorge TEC). Ophthalmia Dam was commissioned in 1981 as a managed aquifer recharge (MAR) scheme, to maintain groundwater levels within the Ethel Gorge aquifer and to support the Ophthalmia Borefield, which has operated since the 1970s. The Ophthalmia Dam system continues to maintain groundwater levels within the Ethel Gorge aquifer to protect the Ethel Gorge TEC and also provides a discharge location for surplus water from BHP mines including the Western Ridge Proposal (BHP 2022b).

The main water-related environmental values that may be impacted by groundwater abstraction for the Western Ridge Proposal are (Figure 1):

- local groundwater resource in the Newman Water Reserve, used for town water supply.
- Ethel Gorge aquifer (and TEC).

Fortescue Marsh is located approximately 128 km north of Ophthalmia Dam at the terminus of the Fortescue River. The aquifer system underlying Fortescue Marsh is not connected to the Western Ridge aquifer and will not be impacted by Western Ridge dewatering.



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Fortescue Marsh
(128 km downstream of
Ophthalmia Dam)
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Ophthalmia Borefield
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HRZ0048
HEOP0425
HEOP0415
HEOP0798
HEOP0313
Ophthalmia
Dam
Eastern Ridge
Newman
Whaleback
Orebody 30
Orebody 35
Orebody 29
HEK0111
WSR0414
WSR0420
WSR0911
WSR1029
WSR0266
Bill's Hill
Eastern
Syncline
WSR0765
WSR0597
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Mount
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WSR0299
Silver
Knight
WSR1270
WSR1139
WSR1193
BHP operations
Monitoring bore
Potable Water Borehole
Waterways
Proposed Development Envelope
Ethel Gorge TEC
Newman Drinking Water Reserve P3
Newman Drinking Water Reserve P1
Indicative Pits
Bill's Hill
Eastern Syncline
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WESTERN RIDGE
Regional context
PLANNING & STANDARDS - IRON ORE
SCALE @ A4: 1:130,000
DATE: 16/12/2022
PREPARED: M. ENGLISH
REQUESTOR: ENV. APPROVALS
REVIEWED: N. McALINDEN
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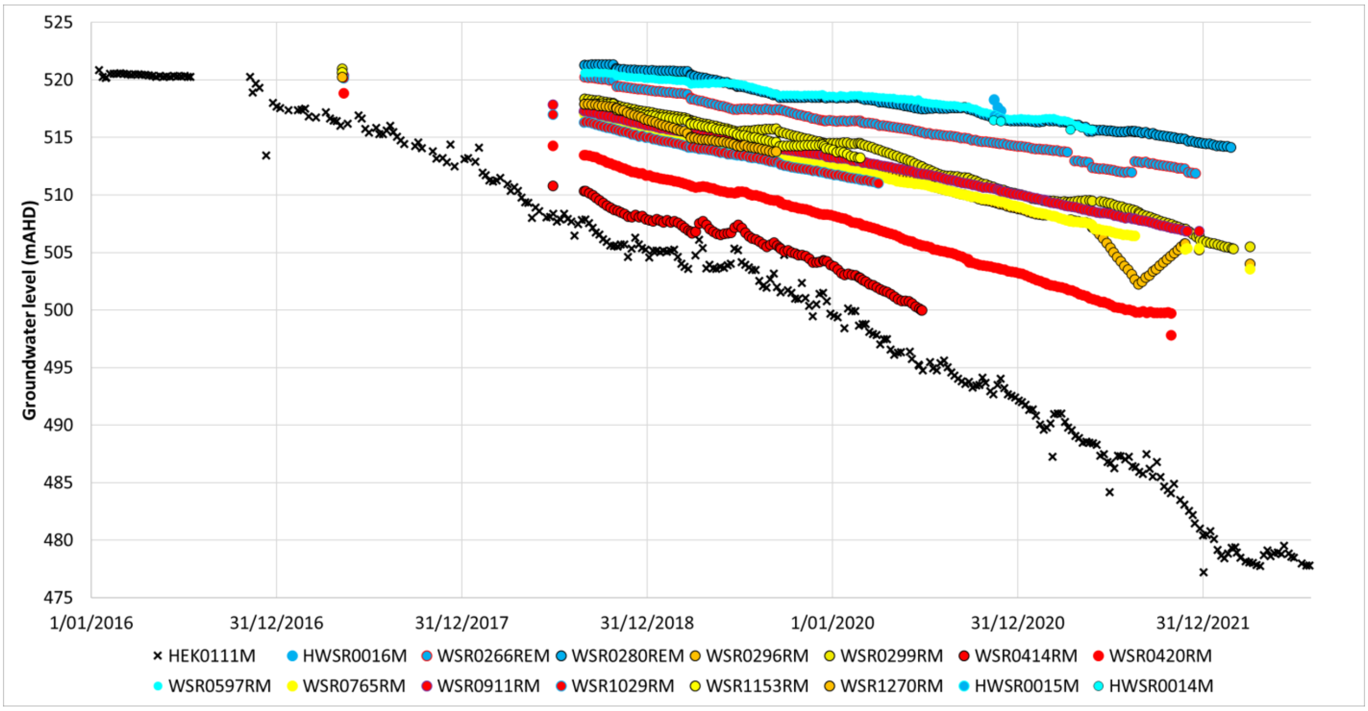
3 Historical abstraction and groundwater levels

The groundwater regime in the Newman area has been altered by groundwater abstraction for water supply for Newman since the 1970s from the Ophthalmia Borefield and since 2013 from the Homestead Borefield. Within the Newman Hub, mine dewatering has also altered the local groundwater regime since 1984 at Mt Whaleback and 2015 at OB29/30/35 (OB29 and OB35). Since the commissioning of Ophthalmia Dam in 1981, the Ethel Gorge aquifer has been recharged by the Ophthalmia Dam system. Since 2006, surplus water from BHP mines has been discharged to the Ophthalmia Dam system (BHP 2022a).

Figure 2 shows observed groundwater levels in the Western Ridge area in the vicinity of the proposed Western Ridge orebodies since May 2017. The data show that groundwater levels at Western Ridge were similar to OB35 in 2017 (bore HEK0111M is representative of OB35). Since then, groundwater level decline (drawdown) at OB35 is up to approximately 40 m due to dewatering. Water levels at the Western Ridge bores have also been drawdown by OB35 dewatering. Drawdown is higher to the east (i.e closest to OB35) and lower in the west (BHP 2022c). The current groundwater levels at Western Ridge range from approximately 495 to 505 mRL in the east (Eastern Syncline) to 505 mRL in the west (Mt Helen). The current corresponding depth to groundwater ranges from approximately 75-85 m below ground level (mbgl) at Eastern Syncline to 110 mbgl at Mt Helen and Silver Knight.



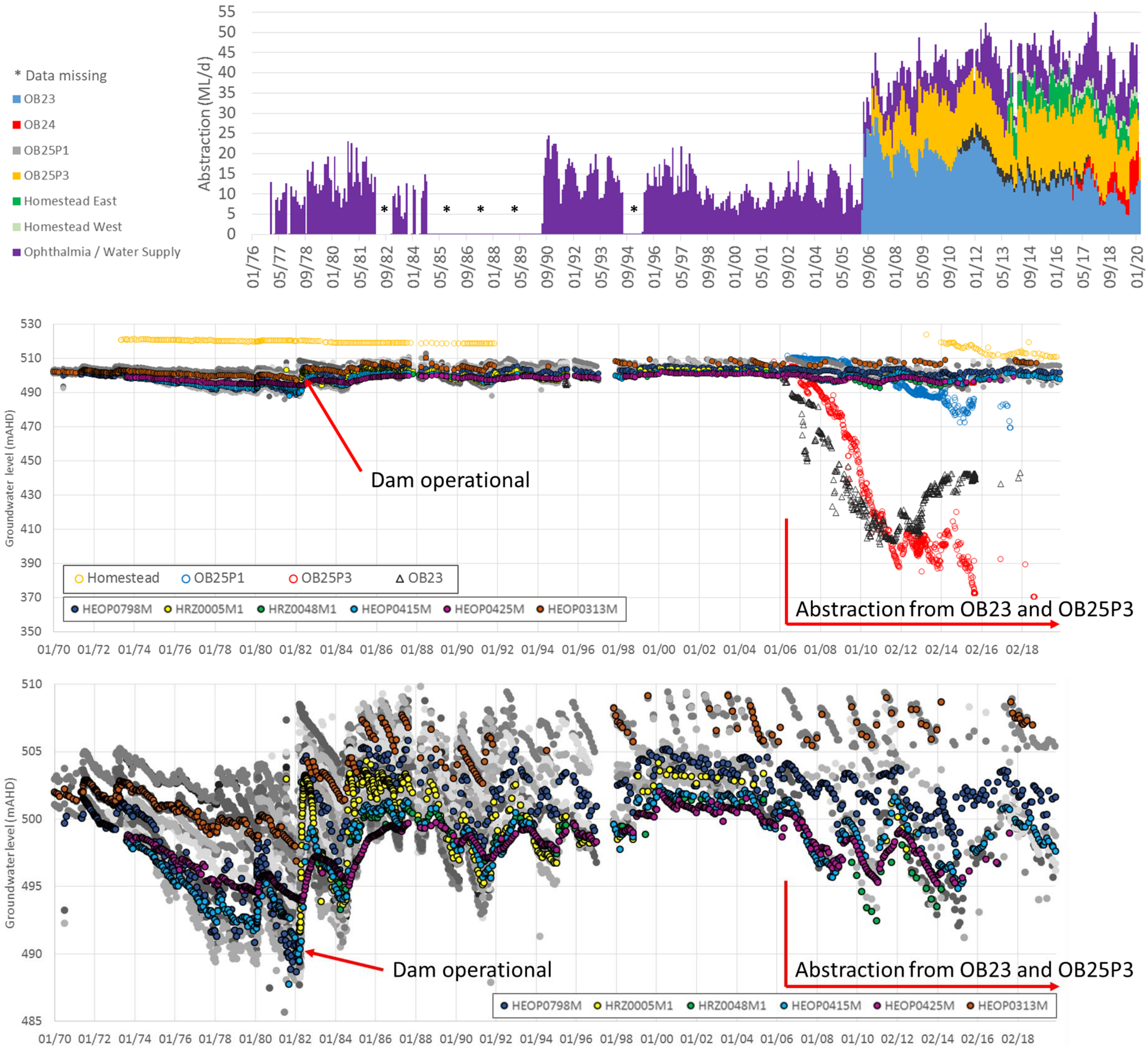
See Figure 1 for bore locations

Figure 2: Observed groundwater levels in the Western Ridge area

Figure 3 shows observed groundwater levels in the Ethel Gorge aquifer since the 1970s when abstraction from the Ophthalmia Borefield started. The data for the Ethel Gorge aquifer shows the decline in groundwater levels (drawdown) during the 1970s due to abstraction from the Ophthalmia Borefield for the Newman town water supply (as discussed in Section 2) and the rapid groundwater level response following the commissioning of Ophthalmia Dam in 1981. Observed groundwater levels in the Ethel Gorge aquifer are generally higher since Ophthalmia Dam was commissioned.

As shown in Figure 3, the drawdown in the vicinity of the Eastern Ridge pits adjacent to the Ethel Gorge TEC reached a maximum of approximately 130 m at OB25 Pit 3 and 100 m at OB23. However, while there was some response to the dewatering in the Ethel Gorge aquifer, the groundwater level data shows that the observed drawdown in the Ethel Gorge aquifer between 2006 and 2012 was limited to a maximum of 5 m. This occurred downstream of Ophthalmia

Dam and adjacent to OB23 (i.e. HEOP0425M, HEOP0415M, HRZ0048M and HRZ0005M) and reduced to less than 2 m upstream of the dam (HEOP0313M) (see Figure 1 for bore locations). Groundwater levels in the vicinity of the OB23 pit have recovered and are approaching the pre-mining groundwater levels (BHP 2021). Since 2006, when abstraction at Eastern Ridge (and the discharge of surplus water from Eastern Ridge to the dam) started, groundwater levels in the Ethel Gorge aquifer have remained within the range of groundwater levels since Ophthalmia Dam was commissioned.



See Figure 1 for pit and bore locations

Figure 3: Dewatering rates and observed groundwater levels in the Ethel Gorge aquifer

4 Groundwater modelling

4.1 Detailed hydrogeological assessment

BHP undertook the *Western Ridge and OB29/30/35 Detailed Hydrogeological Assessment* (Appendix A; BHP 2022c) to assess the potential impacts from groundwater abstraction from the Western Ridge Proposal, to support *Rights in Water and Irrigation 1914* (RiWI) 5C licence and *Environmental Protection Act 1986* Part IV approval processes.

The detailed hydrogeological assessment (BHP 2022c) describes the hydrogeology and conceptualisation of the Western Ridge area in detail. Figure 4 shows the conceptual groundwater system in the Western Ridge area. The Western Ridge area is characterised by hydraulically connected regional (weathered dolomite and some tertiary detritals) and Marra Mamba orebody aquifers. The connection of the regional aquifer to the Marra Mamba orebodies (OB29, OB30, OB35 deposits and the Eastern Syncline and Silver Knight deposits at Western Ridge) is either through mineralisation or absence of the West Angela Shale. The regional dolomite aquifer over much of the area is likely to have both high storage (most likely karstic) and high hydraulic conductivity (BHP 2022c).

The Marra Mamba orebody aquifers and the regional dolomite aquifer are bounded by the low permeability Mt Sylvia Formation and Mt McRae Shale to the north (isolating this system from Whaleback orebody aquifer) and the low permeability Jeerinah Formation to the south. There is no evidence of any significant connection between the Whaleback orebody aquifer and the regional aquifers. The Mt Sylvia Formation and Mt McRae Shale appear to be less of a barrier to flow in the west however, allowing some flow between the regional aquifer and the Brockman orebody aquifers (Bills Hill and Mt Helen) (BHP 2022c).

The regional aquifer system associated with Western Ridge appears to be continuous between the Whaleback Fault in the west and a leaky flow barrier between OB35 and OB30. From here the regional aquifer continues unbroken to the east of OB29 where there is another leaky flow barrier. The western side of the Whaleback Fault consists of the Jeerinah Formation which is considered very low permeability and presents a no flow boundary. The exact nature of the regional flow barriers (between OB35 and OB30 and to the east of OB29) is unknown and some flow does appear to occur across them (hence “leaky” flow barriers). However, the barrier between OB35 and OB30 may provide increasing disconnection between the dewatering in the east (OB29 and OB30) and the west (OB35 and Western Ridge) as groundwater levels decline further (BHP 2022c). Between the leaky flow barrier east of OB29 and the main Ethel Gorge aquifer compartment (Figure 4) there is evidence of a reduced regional aquifer transmissivity resulting in constrained groundwater flow. There is also evidence for another leaky flow barrier through the Ethel Gorge aquifer just southwest of OB25 Pit 4.

The depth to groundwater (between 30 and 90 m for the aquifers) throughout the area suggests that groundwater/surface water interaction and evapotranspiration do not occur in this area (BHP 2022c).

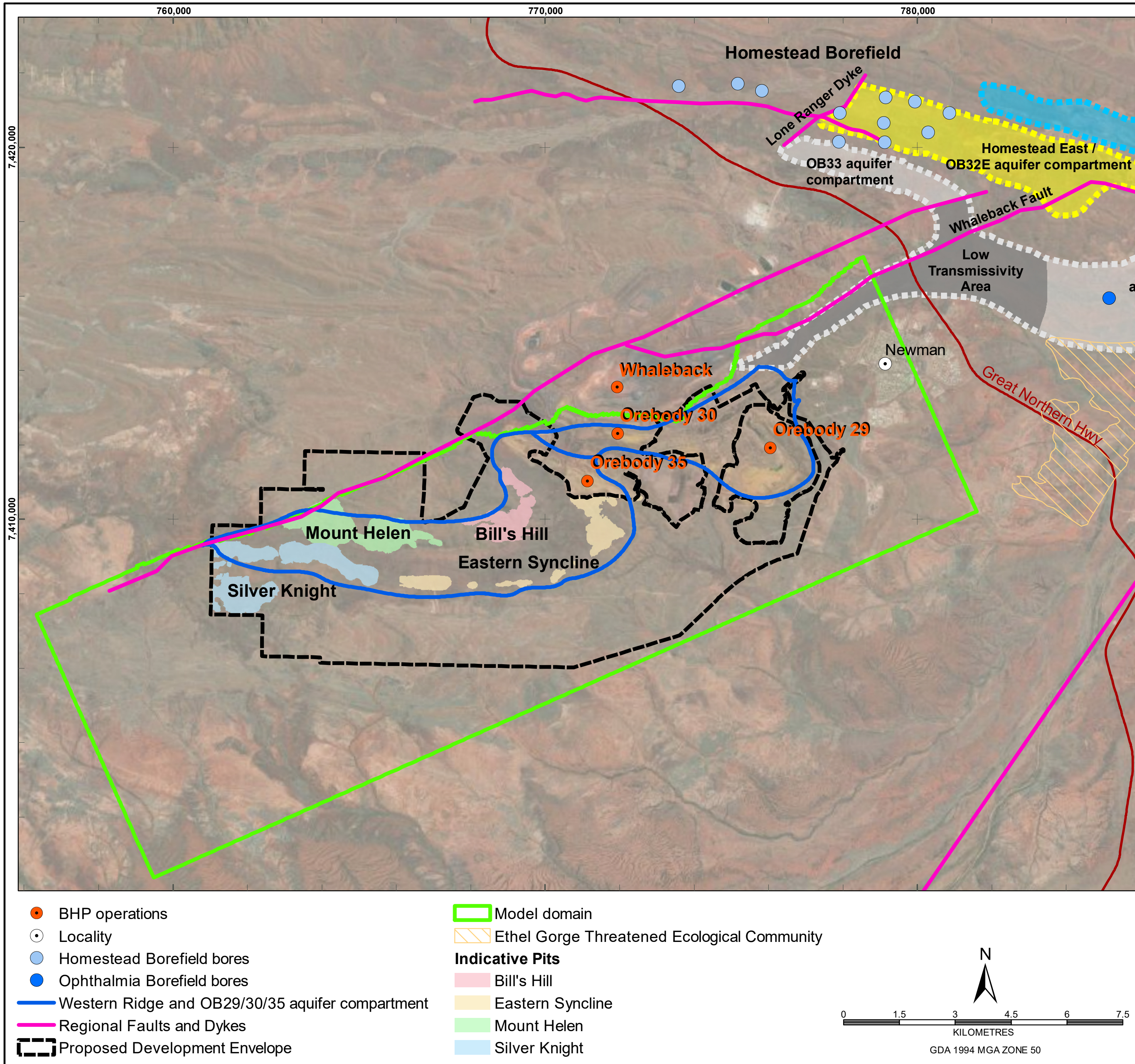
The numerical model includes planned dewatering at the existing OB29/30/35 BWT mine (to allow for future deeper mining), as it is adjacent to Western Ridge and the OB29, OB30, OB35 deposits are hosted in the same aquifer (Marra Mamba Formation) as some of the Western Ridge deposits (Eastern Syncline and Silver Knight). The predictive dewatering version of the model was run for 30 years from 2020 to 2050 to:

- predict the likely dewatering rates required to achieve the Western Ridge target groundwater levels (lowering groundwater levels by up to approximately 155 m from current groundwater levels (down to 352 mRL at Eastern Syncline) (Figure 5), to allow dry mining
- predict the vertical and lateral extent of drawdown as a result of the dewatering.

The predictive closure version of the model was run for 600 years from 2050 to 2650 to provide a high level understanding of potential groundwater level recovery times post mining.

As the Ethel Gorge aquifer and Ophthalmia Dam are outside of the model domain, the groundwater modelling did not consider ongoing recharge from the Ophthalmia Dam system. Changes to groundwater levels from the

Ophthalmia Dam MAR scheme were modelled separately as part of the Eastern Pilbara Hub water balance model review (EMM 2020) and Western Ridge water balance modelling assessment (EMM 2021, BHP 2022b). However, the groundwater model was used to predict the changes to groundwater flow between the Western Ridge and OB29/30/35 aquifer compartment and the Ethel Gorge aquifer compartment during Western Ridge dewatering and after dewatering ceases (post-mining), to estimate the groundwater level change in the Ethel Gorge aquifer (see Section 5).



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WESTERN RIDGE
Conceptual groundwater system

PLANNING & STANDARDS - IRON ORE

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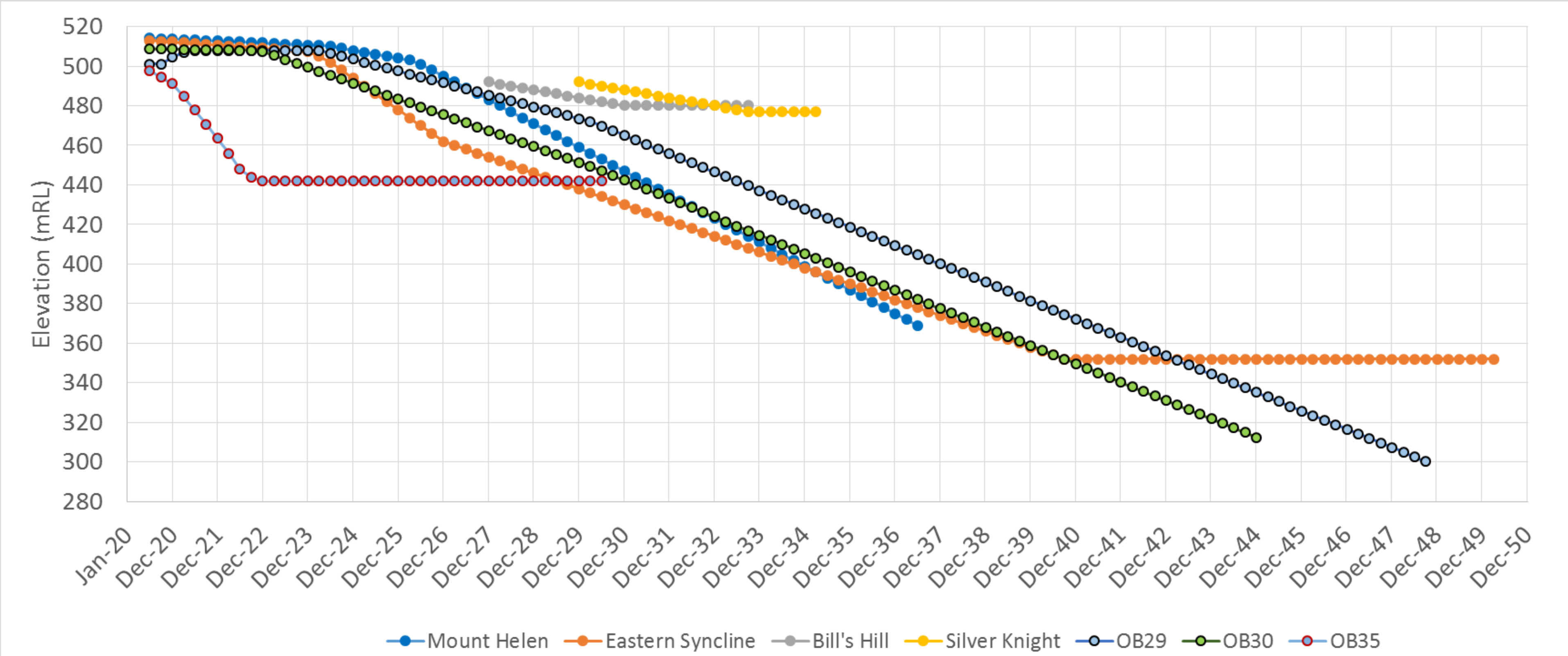


Figure 5: Target pit groundwater levels

4.2 Sensitivity analysis and predictive uncertainty

A sensitivity analysis was undertaken with the calibrated model (the basecase) to determine whether model outputs were sensitive to changes in key parameter values (specific yield and hydraulic conductivity) and whether the changes in key parameter values should be considered in the future predictive runs (i.e. dewatering predictions).

The analysis showed that the simulated water level response (in the Western Ridge area) to abstraction at OB29 and OB35 is sensitive to changes in most of the key parameters. However, given the limited time and spatial distribution of monitoring bores in the Western Ridge area, none of these parameter settings should be considered unacceptable. Whilst the basecase model does represent the best fit to the observed data, these data limitations mean that the parameter variations tested in the sensitivity analysis were used in the predictive dewatering model to assess uncertainty in both drawdown and dewatering rates. The confidence in the predictions from these is lower than the basecase, but still possible (i.e. their predictions cannot be discounted) (BHP 2022c).

Climate variability is unlikely to affect the predictions of either dewatering or drawdown during the operational phase of mining (i.e. up to 2050). Dewatering rates are expected to be much greater than recharge rates from rainfall and runoff, and consequently, variation in rainfall is unlikely to affect dewatering or drawdown rates. The results from a number of Global Climate Models predict a change in annual rainfall of between -7.1% and 4.9%, with a median of 0.2% for 2050, emphasising the uncertainty in future rainfall (BHP 2022d).

4.3 Predicted abstraction rates and drawdown

Figure 6 shows the predicted dewatering rates for the ten parameter runs used to test predictive uncertainty. The peak dewatering rate at Western Ridge (total for all four deposits) ranges between 15 ML/d and 34 ML/d. To be conservative, BHP has assumed that a peak dewatering rate of up to 34 ML/d (13 GL/a rounded to nearest GL) will be required and has evaluated the potential impact based on this. The selection of the run representing the highest dewatering rate (Run 9) provides a higher level of confidence that dewatering volumes from Western Ridge will be within the predicted range.

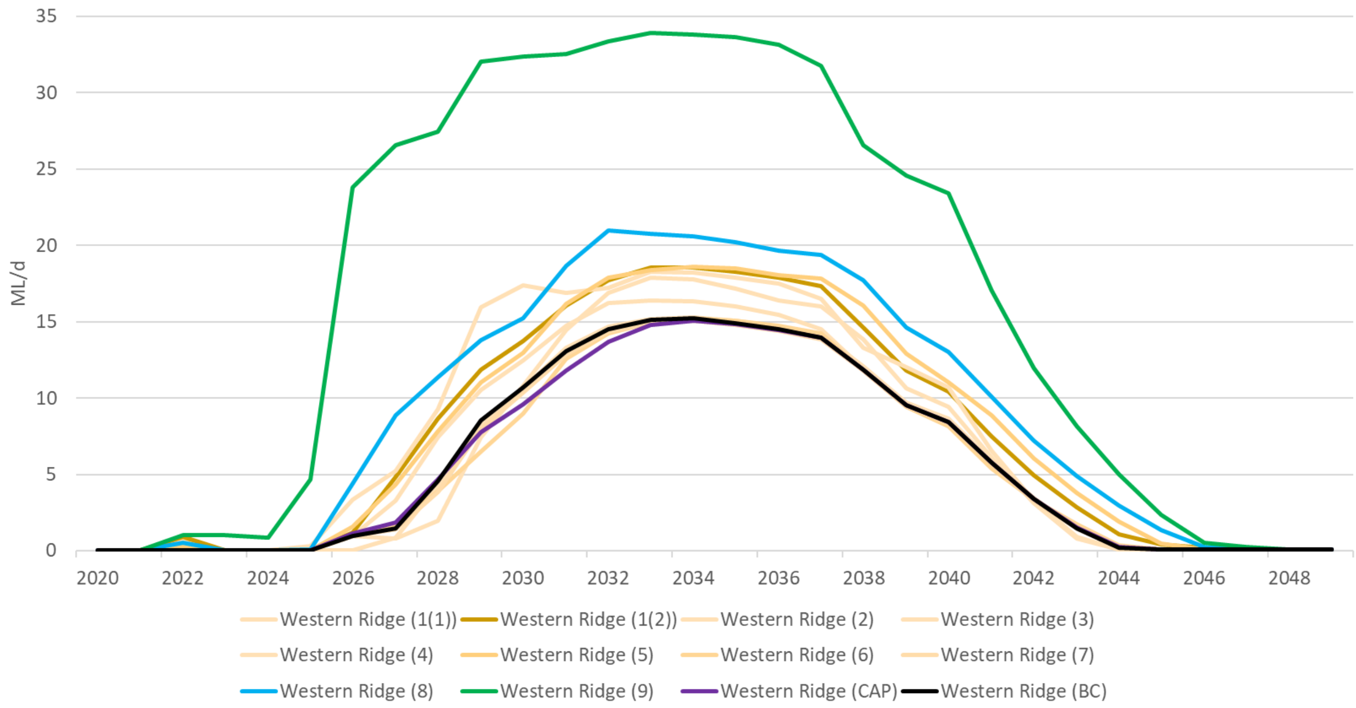
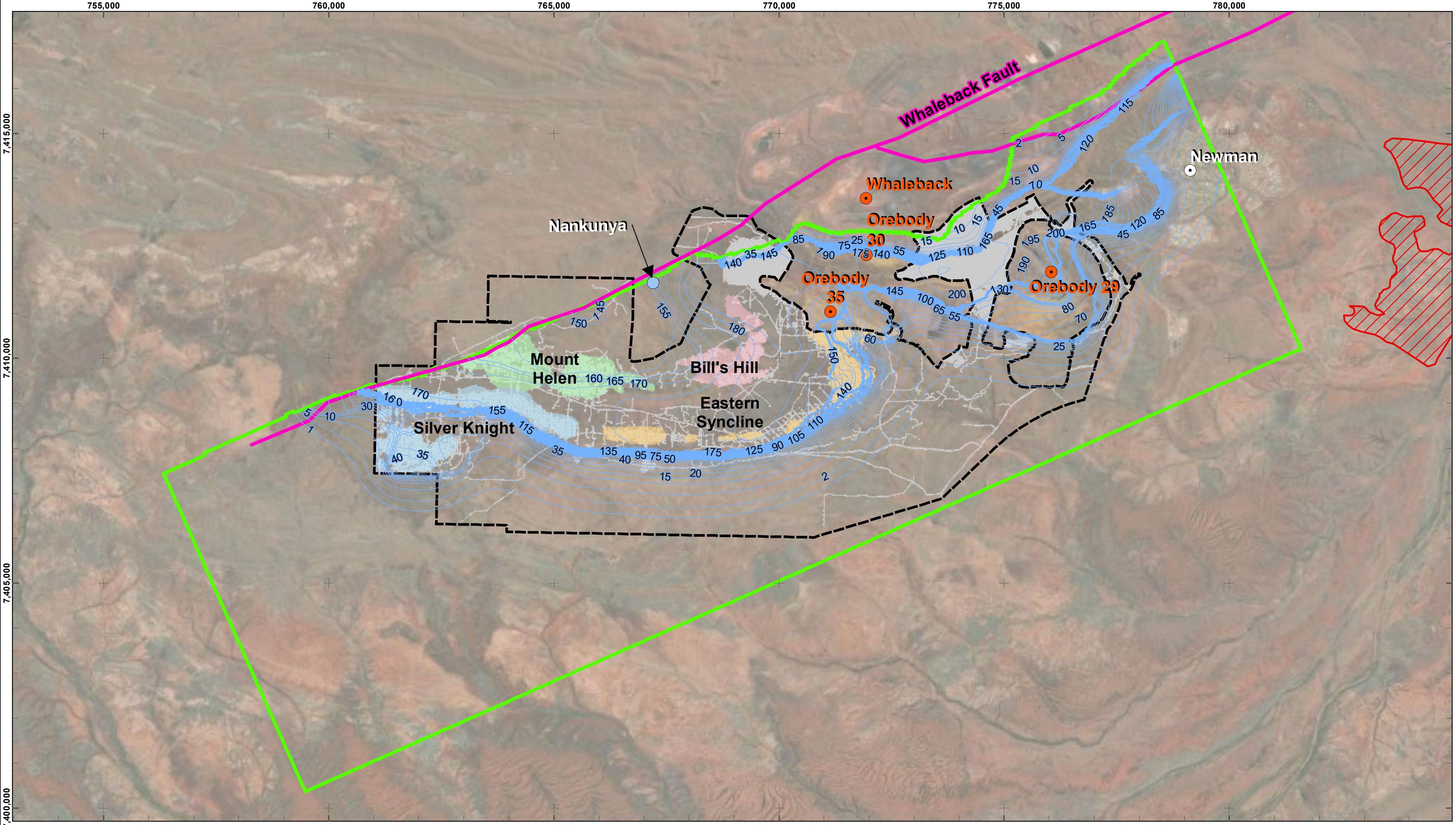


Figure 6: Predicted dewatering rates

As discussed in Section 4.1, BHP estimates that groundwater levels would need to be lowered by up to 155 m (from current groundwater levels) at Western Ridge. Figure 7 shows the predicted maximum drawdown in 2050 to achieve the target pit groundwater levels shown in Figure 5 and with the highest dewatering rate. The model predicts that Western Ridge dewatering results in a maximum vertical drawdown of up to approximately 150 m at the northern boundary of the model domain, 100 m at the eastern boundary and less than 1 m at the southern and western boundaries.

Drawdown is expected to extend through the regional and local (orebody) aquifers in the area. The modelled groundwater drawdown is predicted to extend 7 km to the northeast of OB29. However, migration of drawdown will be contained within the orebody and regional aquifers due to the low permeability Mt McRae and Mt Sylvia Formations to the north and the low permeability Jeerinah Formation to the south. The Whaleback fault is predicted to limit drawdown to the west (BHP 2022c). Changes to groundwater levels to the east, including in the Ethel Gorge aquifer compartment, are discussed in Section 5.



- BHP operations
- Predicted drawdown (m)
- Model domain
- Ethel Gorge TEC
- Proposed Development Envelope

Indicative Pits

- Bill's Hill
- Eastern Syncline
- Mount Helen
- Silver Knight
- Indicative Cleared Area as at FY2021

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Predicted Western Ridge and OB29/30/35 drawdown

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4.4 Post-mining groundwater level recovery

As it is possible that residual voids will remain post-mining, the recovery of post-mining groundwater levels was modelled for both backfill (to at least the pre-development groundwater level) and no-backfill scenarios, using the predictive closure version of the model.

4.4.1 Backfill above pre-development water level

For the backfill scenario, the model predicted that there is very little variation in the speed of recovery of groundwater levels throughout the Western Ridge area after dewatering ceases. Groundwater levels are predicted to recover to 50% of pre-development levels after approximately 50 years and 100% of pre-development levels after approximately 350 years. The backfill scenario is not expected to result in any permanent changes in groundwater levels at Western Ridge or in the Ethel Gorge aquifer (BHP 2022c).

4.4.2 No backfill

For the no-backfill scenario, the model predicted that after dewatering ceases, pit lakes are expected to form in all voids. Equilibrium of the pit lake level is reached within approximately 150 years after dewatering ceases and most of the recovery happens in the first 50 years. The lowest equilibrium levels are found in the Brockman deposits. The regional groundwater system recovers to approximately 100 m lower than the pre-development groundwater levels at Western Ridge and up to 50 m lower at the eastern boundary of the model at Newman. The level at which the pit lake would reach equilibrium is predicted to be lower than the surrounding groundwater level. Because the final water level in the pit is predicted to be lower than the surrounding groundwater level, the Western Ridge pit voids would be sinks and groundwater will therefore flow from the east towards Western Ridge (Figure 8).

The model predicts that the post-mining groundwater flow out of the low transmissivity area of the Ethel Gorge aquifer compartment will be less than the groundwater flow out of the Ethel Gorge aquifer compartment during abstraction from the Ophthalmia Borefield (prior to dewatering at Eastern Ridge) (BHP 2022c). While the no-backfill scenario is predicted to result in groundwater levels lower than pre-development levels within the groundwater model domain, no permanent changes are expected at the Ethel Gorge TEC, given the Ophthalmia Dam system maintains groundwater levels in the Ethel Gorge aquifer.

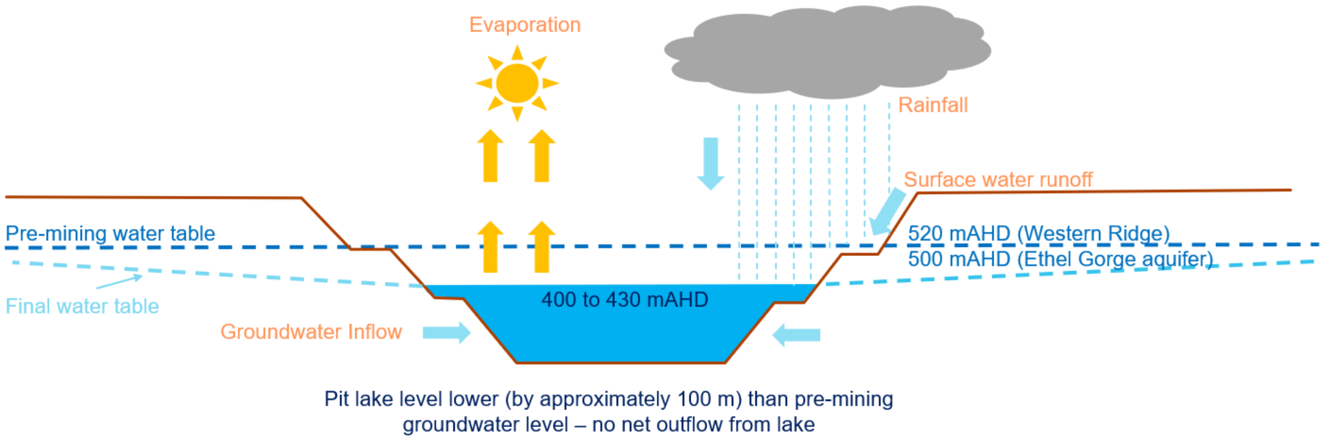


Figure 8: Conceptual pit lake diagram – sink

5 Change assessment

The results from the numerical modelling, the conceptual model of the groundwater system and observed data were used to assess the change in groundwater flows and groundwater levels in the Ethel Gorge aquifer. To understand the cumulative drawdown extent, BHP considered the predicted drawdown from Western Ridge (see Section 4.3) in the context of other approved activities in the Newman Hub.

5.1 Change in groundwater flows and groundwater levels

The Ethel Gorge aquifer compartment is outside of the numerical model domain. The groundwater model does however, predict the change in flow that will occur from the east into the model domain in response to Western Ridge dewatering during operations and post-mining (no backfill scenario) after dewatering ceases. This information was used with historical groundwater level observations of the response of the Ethel Gorge aquifer compartment to water supply abstraction (Ophthalmia Borefield) and dewatering (OB23 and OB25 Pit 3) to estimate the effects that the predicted changes in flow will have on groundwater levels in the Ethel Gorge aquifer compartment.

Pre-development (pre Western Ridge)

Prior to dewatering at OB29 and OB35, groundwater flow was from Western Ridge towards the Ethel Gorge aquifer compartment in the east. Dewatering at OB29 and OB35 has reversed the groundwater flow direction locally within a few kilometres, however beyond this distance, east of OB29, the flow direction is still towards the Ethel Gorge aquifer compartment.

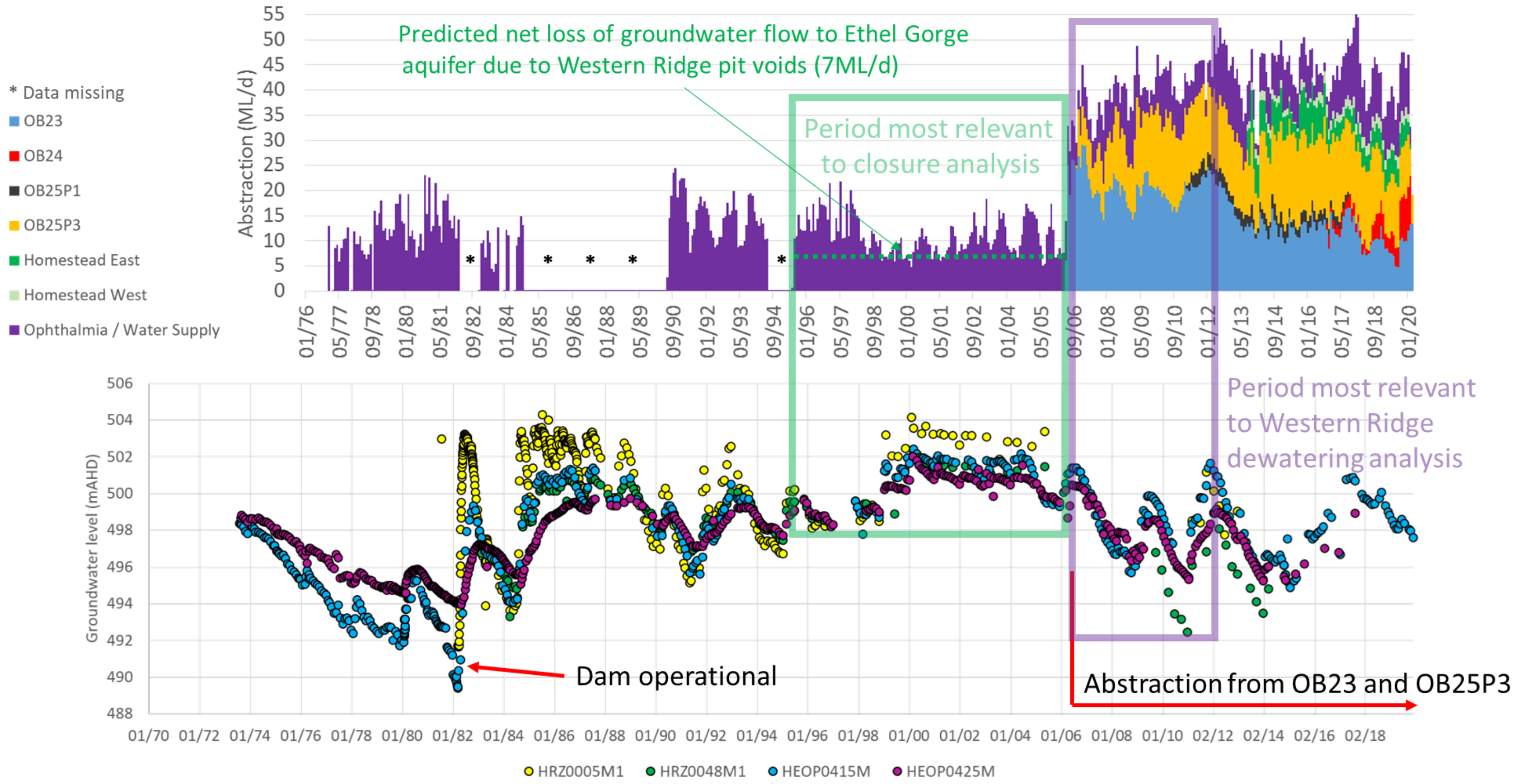
Proposed Western Ridge dewatering

The numerical groundwater model predicts that the proposed dewatering at Western Ridge (including dewatering at OB29/30/35) will increase the amount of groundwater flowing from the east into the model (away from the Ethel Gorge aquifer compartment) from approximately 1 ML/d in 2022 to 8.5 ML/d by 2050. This assumes that flow into the model domain from the east has no upper limit. This prediction is therefore conservative because it does not consider the poorer hydraulic conditions east of the numerical model boundary (BHP 2022c) or any leaky flow barriers between the boundary of the model and the Ethel Gorge aquifer, both of which will limit flows.

At its peak during dewatering, the groundwater flow out of the Ethel Gorge aquifer compartment is predicted to be 8.5 ML/d due to Western Ridge and OB29/30/35 dewatering. As discussed in the Orebody 32 BWT: Groundwater impact assessment (BHP 2022e), the estimated groundwater flow out of the Ethel Gorge aquifer compartment between 2006 and 2012 (from OB23, OB25 Pit 3 and Ophthalmia Borefield) was 32 ML/d, which is almost four times greater than the estimated groundwater flow out of the Ethel Gorge aquifer compartment from Western Ridge and OB29/30/35 dewatering. Therefore, with the continued operation of Ophthalmia Dam, groundwater levels in the Ethel Gorge aquifer are predicted to remain within historical levels during dewatering of Western Ridge.

Post-mining: Western Ridge pit lakes

As discussed in Section 4.4.2, post-mining of Western Ridge, pit lakes are predicted to form if the pits remain as voids and the pit lakes will be sinks (i.e. groundwater will flow into the pit lake). The voids at OB29 and OB30 were included in the pit lakes analysis. The post-mining analysis indicates that once the system reached equilibrium, approximately 7 ML/d of groundwater will flow from the Ethel Gorge aquifer compartment to the Western Ridge, OB29 and OB30 voids in response to evapo-transpiration from the pit lakes. Most of the flow out of the Ethel Gorge aquifer compartment will be a result of the OB29 and OB30 pit voids, as they have a greater surface area than the Western Ridge pit voids and are closer to the Ethel Gorge aquifer. As discussed in BHP 2022e, the historical abstraction from the Ophthalmia Borefield between 1996 and 2006 was greater that this (11 ML/d). Therefore, with the continued operation of the Ophthalmia Dam system, this indicates that groundwater levels in the Ethel Gorge aquifer will stabilise to levels between 1996 and 2006 (see Figure 9), within the upper part of the range of 498 to 504 mAHD.



See Figure 1 for pit and bore locations

Figure 9: Historical groundwater level analysis

5.2 Cumulative drawdown

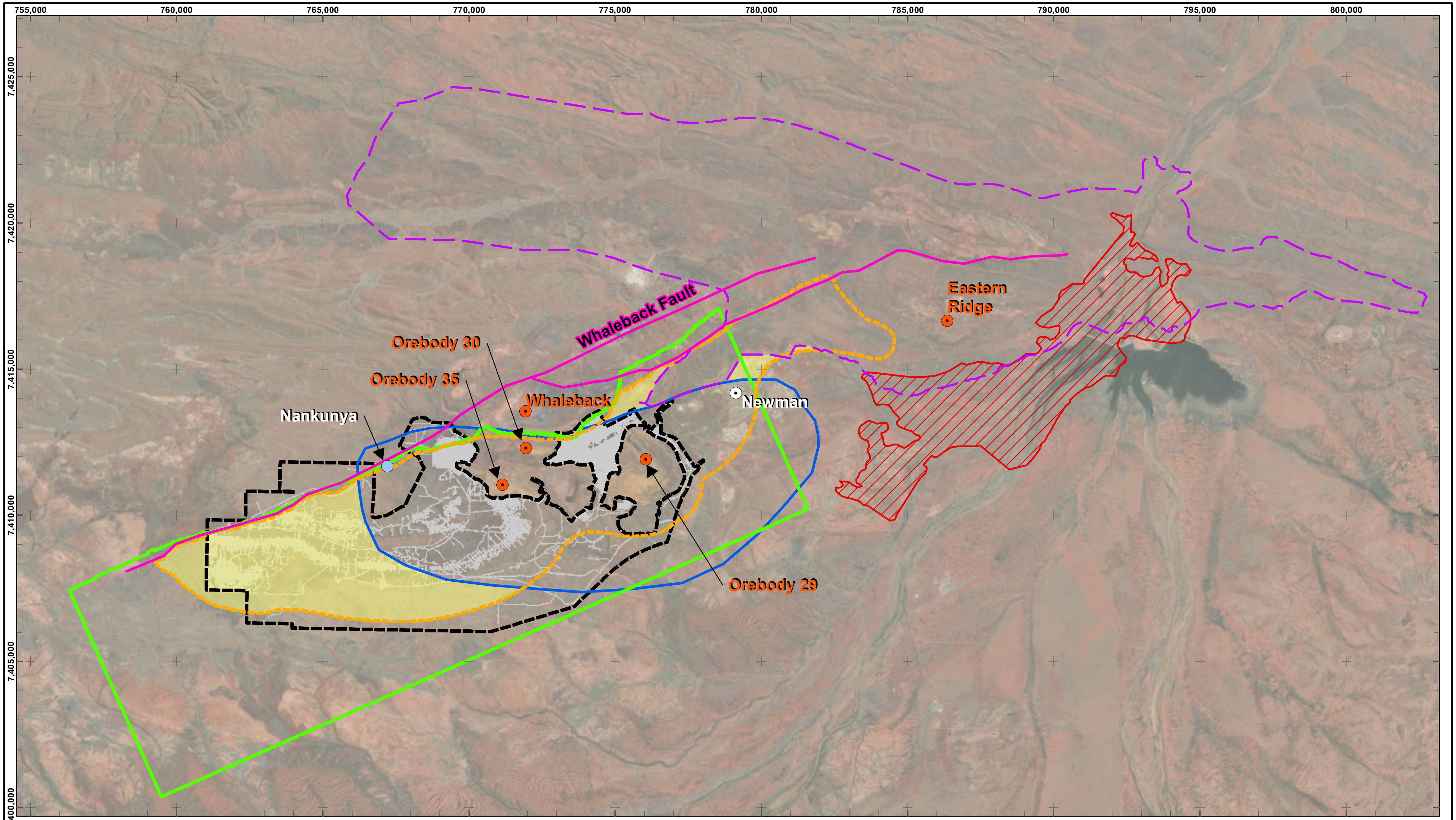
As discussed in Section 2, Western Ridge is located in the Newman Hub where there are existing approved groundwater abstraction activities (for water supply from the Ophthalmia and Homestead borefields and for mine dewatering at Mt Whaleback, OB29/30/35 and Eastern Ridge). and the Ophthalmia Dam MAR system. The conceptual hydrological model and monitoring data indicates that there is no direct connection between OB29/30/35 and Western Ridge, and the other operations (Mt Whaleback, Eastern Ridge and Ophthalmia and Homestead borefields) (BHP 2022m). However, the drawdown from Eastern Ridge (including from OB32) and Western Ridge and OB29/30/35 is predicted to merge in the lower transmissivity area (Figure 4). Therefore, BHP has considered the predicted drawdown from Western Ridge and OB29/30/35 in the context of approved drawdown at OB29/30/35 and Eastern Ridge, and proposed drawdown at OB32. Figure 10 shows the following:

- 2013 OB29/30/35 1 m drawdown contour: represents the assessed and approved drawdown extent for the existing OB29/30/35 BWT mine
- 2022 Western Ridge and OB29/30/35 1 m drawdown contour: represents the estimated maximum lateral extent of the predicted drawdown from the proposed Western Ridge dewatering and planned OB29/30/35 dewatering
- 2022 Cumulative Eastern Ridge 2 m drawdown contour: represents the estimated maximum lateral extent of the cumulative effect of assessed and approved drawdown from Eastern Ridge and predicted drawdown from the proposed OB32 dewatering
- 2022 Western Ridge and additional OB29/30/35 drawdown extent: represents the predicted drawdown extent in addition to the assessed and approved drawdown from OB29/30/35 and Eastern Ridge and the predicted drawdown from OB32.

The modelled drawdown and boundary flow results were used with the conceptual model to estimate the total area of potential impact (2022 Western Ridge and OB29/30/35 1 m drawdown contour), as shown in Figure 10. Within the model domain the area of impact is as predicted by the model. Outside of the model domain the area of impact is estimated using a combination of the predicted flow into the OB29/30/35 and Western Ridge area through the boundary just to the east of OB29 and the hydrogeological conceptualisation from this point to the east (up to and including the Ethel Gorge TEC).

The additional lateral drawdown extent from the proposed Western Ridge dewatering and planned OB29/30/35 dewatering compared to the assessed and approved drawdown (2022 Western Ridge and additional OB29/30/35 drawdown extent, shown on Figure 10) is mostly to the west of the drawdown extent modelled for the OB29/30/35 dewatering in 2013 (2013 OB29/30/35 1 m drawdown contour). This is expected as the groundwater model includes dewatering of deposits west of the 2013 OB29/30/35 1 m drawdown contour, i.e Mount Helen and Silver Knight.

Drawdown from Western Ridge and OB29/30/35 is not expected to reach the Ethel Gorge aquifer in the vicinity of the Ethel Gorge TEC, located approximately 15 km northeast of the OB29/30/35 aquifer system, or to increase the drawdown footprint associated with Eastern Ridge. The groundwater flow from the orebody aquifers to the regional aquifers to the east is constrained due to a leaky flow barrier north-east of OB29 which reduces groundwater flow, as well as likely poorer aquifer quality between OB29 and the Ethel Gorge aquifer compartment. This is supported by groundwater monitoring data between OB29/30/35 and at Ethel Gorge. Any drawdown impact to the regional aquifer north-east of OB29 is anticipated to be mitigated by the current Eastern mines surplus schemes and/or Ophthalmia dam (BHP 2022c).



- BHP operations
- Proposed Development Envelope
- Ethel Gorge TEC
- Indicative Cleared Area as at FY2021
- Model domain
- 2022 Cumulative Eastern Ridge 2 m Drawdown Contour
- 2022 Western Ridge and OB29/30/35 1m drawdown contour
- 2013 Orebody 29/30/35 1m drawdown contour
- 2022 Western Ridge and additional OB29/30/35 drawdown extent

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KILOMETRES

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WESTERN RIDGE

Cumulative groundwater drawdown extent

PLANNING & STANDARDS - IRON ORE

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BHP (2022c) *Western Ridge and OB29/30/35 Detailed Hydrogeological Assessment*. November 2022.

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Appendices

Appendix A Western Ridge and OB29/30/35 Detailed Hydrogeological Assessment