APPENDIX 16

Technical Memorandum

Date	06 July 2023
To	Superintendent Environment Approvals (Eastern)
From	Principal Biodiversity, Biodiversity & Rehabilitation
Subject	Orebody 32 Below Water Table Derived Proposal: Request for further information – Stygofauna supplementary information

1. Purpose

To provide further information on Subterranean Fauna (stygofauna), in response to Part 1 comments 12 to 15 in Attachment 1 of the Notice Requiring Further Information, issued pursuant to s. 38F(1) and (2) of the *Environmental Protection Act 1986* (EP Act) by the Environmental Protection Authority on 15 May 2023.

This memorandum is issued as an additional appendix (Appendix 16) of the *Newman Hub (Orebody 32 Below Water Table) Derived Proposal Request Ministerial Statement 1105* (OB32 BWT Derived Proposal document) (BHP 2022a).

2. Local context - approved proposals

As discussed in Section 2.4 of the OB32 BWT Derived Proposal document, the OB32 BWT Proposal is mostly located within the boundary of BHP's operating Eastern Ridge Mine (authorised under Ministerial Statement (MS) 1037 for the Eastern Ridge Revised Proposal) in the Newman Hub. Existing BHP projects that are approved for groundwater abstraction (and are in operations) in the Newman Hub (Section 5.3.2.3 of the OB32 BWT Derived Proposal document) are shown in **Figure 1** (reproduced from Figure 7 in the *Orebody 32 below water table: Groundwater impact assessment* (BHP 2022b); Appendix 4 of the OB32 BWT Derived Proposal document):

- dewatering at BHP mining operations at Mt Whaleback (Whaleback and Orebody 29/30/35) and Eastern Ridge (OB23, OB24 and OB25)
- abstraction at BHP water supply borefields for Newman: Ophthalmia Borefield and Homestead Borefield.

MS1037 also authorises above water table mining (AWT) at OB32.

3. Groundwater drawdown

3.1. Assessed and observed groundwater drawdown – Newman Hub

As discussed in Section 5.4.1.1 of the OB32 BWT Derived Proposal document, the impacts of drawdown have been assessed under Part IV of the EP Act and *Rights in Water and Irrigation Act 1914* (RiWI) for the approved projects.

Previous assessments for mines at Eastern Ridge predicted vertical drawdown of up to 150 m, at OB25 Pit 3 (RPS Aquaterra, 2013). As discussed in the *Orebody 32 below water table: Groundwater impact assessment* (Appendix 4 of the OB32 Derived Proposal document), actual drawdown in the vicinity of the Eastern Ridge pits reached a maximum of approximately 130 m at OB25 Pit 3 and 100 m at OB23. Both pits are located in the Ethel Gorge aquifer, adjacent to the Ethel Gorge Aquifer Stygobiont Community Threatened Ecological

Community (Ethel Gorge TEC). However, while there was some response to the dewatering observed in the Ethel Gorge aquifer, the groundwater level data shows that the observed vertical drawdown in the Ethel Gorge aquifer (in the Ethel Gorge TEC) between 2006 and 2012 ranged between 2 and 5 m, due to the operation of the Ophthalmia Dam Managed Aquifer Recharge system, which infiltrates water back into the Ethel Gorge aquifer. Since mining ceased at OB23, groundwater levels in the vicinity of the OB23 pit have recovered and are approaching pre-mining groundwater levels.

The lateral extent of the assessed drawdown for the approved proposals in the Newman area is represented by the 2015 Eastern Ridge 2 m Drawdown Contour and 2013 Orebody 29/30/35 1 m drawdown contour (as shown in Figure 5-4 of the Derived Proposal document, reproduced as **Figure 2**).

3.2. Predicted groundwater drawdown – OB32 BWT Proposal

As discussed in Section 5.4.1.1 of the OB32 BWT Derived Proposal document, the OB32 BWT Proposal will result in drawdown within the same aquifer compartments as those previously assessed for the approved Eastern Ridge Revised Proposal.

Referral information (2022)

As discussed in Section 5.4.1.1, page 39 of the OB32 BWT Derived Proposal document, groundwater levels in the OB32 orebody would need to be lowered by dewatering by up to 200 m for BWT mining. The extent of vertical drawdown ranges from 10 - 20 m at the western boundary to 140 m at the south-eastern boundary of the model domain and represents the unmitigated predicted drawdown for the dewatering from OB32 only (Figure 9 in the Groundwater impact assessment, reproduced as **Figure 3**).

The OB32 BWT Development Envelope is located within the assessed groundwater drawdown extent for the Eastern Ridge Revised Proposal (**Figure 2**). As discussed in Section 5.4.1.1 of the OB32 BWT Derived Proposal document, the predicted additional lateral extent of groundwater drawdown resulting from the proposed OB32 dewatering is represented by the additional areas of predicted drawdown in the southern and western extents of the cumulative Eastern Ridge groundwater drawdown extent (2022 Additional OB32 drawdown extent shown as yellow shaded areas (Areas 1-5) in **Figure 2**). The increase in lateral drawdown from OB32 dewatering represents an increase of less than 10% compared to the previously assessed Eastern Ridge drawdown extent (represented by the 2015 Eastern Ridge 2 m drawdown contour in **Figure 2**).

At the time of the preparation of the OB32 BWT Derived Proposal document (2022), groundwater levels in the western additional areas of drawdown extent (Areas 1 to 3 in **Figure 2**) were estimated to be between 20 mbgl and 55 mbgl (Section 5.6.2, page 50 of the OB32 BWT Derived Proposal document).

The predicted unmitigated vertical drawdown of up to 140 m at the model boundary to the south-east is in the area that was assessed for groundwater drawdown for the Eastern Ridge Revised Proposal (represented by the 2015 Eastern Ridge 2 m drawdown contour in **Figure 2**). However, as discussed in Section 5.4.1.1, page 40 of the OB32 BWT Derived Proposal document (and in further detail in Section 6.1 of the Groundwater impact assessment (Appendix 4)), groundwater levels in the Ethel Gorge aquifer are predicted to remain within historical levels, during dewatering of OB32, with the continued operation of the Ophthalmia Dam system. This is based on a comparison of actual data observed when OB23 and OB25 Pit 3 (located in the Ethel Gorge aquifer and adjacent the Ethel Gorge TEC) were dewatered, which demonstrated that groundwater levels in the Ethel Gorge aquifer in the vicinity of the Ethel Gorge TEC were maintained. Although the predicted drawdown at OB32 is deeper than predicted in 2015, the groundwater level change within the Ethel Gorge aquifer compartment is comparable or less than already encountered during OB23 and OB25 Pit 3 dewatering, when the net loss of groundwater flow out of the Ethel Gorge aquifer was almost double the predicted outflow during OB32 dewatering.

Updated hydrogeological understanding (2023)

Hydrogeological information obtained since the referral of the OB32 BWT Derived Proposal (*The Hydraulic Behaviour of Apache Dyke at Homestead West* (BHP 2023); **Appendix A**) indicates the presence of a dyke (Apache Dyke) within the western end of the cumulative Eastern Ridge groundwater drawdown extent (2022

Cumulative Eastern Ridge 2 m drawdown contour in **Figure 2**). Based on an analysis of groundwater levels on both sides of the dyke, BHP has concluded that groundwater drawdown associated with the OB32 BWT Proposal (and the existing Homestead Borefield) is expected to be confined to the eastern side of the Apache Dyke, reducing the lateral extent of drawdown predicted for the OB32 BWT Derived Proposal. Current groundwater levels immediately east of the Apache Dyke are consistent with what was estimated for the OB32 BWT Derived Proposal (30 mbgl to greater than 50 mbgl) (**Figure 4**).

Based on this new hydrogeological information, most of the far western area of additional drawdown (Area 2 in **Figure 2** and **Figure 4**) is unlikely to experience drawdown as a result of proposed dewatering at OB32, as this area is west of the Apache Dyke. Areas 1 and 4 of the additional drawdown areas (**Figure 2** and **Figure 4**) are unlikely to host aquifer material. This is assumed due to the geology present in these areas, which are not considered or known to host an aquifer, as well as the depth to groundwater (specifically in Area 1) which is predicted to be greater than 50 m.

The vertical drawdown in the southern area of additional drawdown (Area 5 in **Figure 2**) is likely to range between 2 m and 10 m. The aquifer in Area 5 is of variable depth and hydraulic quality and as such, forms part of the low transmissivity zone between the OB29/OB30 and Ethel Gorge aquifer systems (as shown in Figure 5-4 of the Derived Proposal document, reproduced as **Figure 1**). In the western area of the model domain (Area 3) (**Figure 2** and **Figure 4**), the drawdown is predicted to range between 10 m and 20 m and is likely to decrease outside (west of) the model domain to approximately 2 m, with no further drawdown west of the Apache Dyke. East of the dyke, current groundwater levels are estimated to be range between 20 m to greater than 50 mbgl (**Figure 4**).

BHP is undertaking further studies and groundwater modelling in association with the Homestead Borefield. This will include reviewing the predicted extent of drawdown for the proposed OB32 dewatering with the revised hydrogeological conceptualisation, including the Apache Dyke.

4. Groundwater recovery post-mining (and dewatering)

As discussed in Section 5.4.1.1, page 41 of the OB32 BWT Derived Proposal document, two closure (post-mining) scenarios were considered: backfill (i.e., above pre-development groundwater levels) and no or partial backfill. For both scenarios, groundwater levels in the Ethel Gorge aquifer are likely to be maintained within historical levels, and therefore, there will be no direct or indirect impacts due to the changes in groundwater regimes from the OB32 BWT Proposal to the Ethel Gorge TEC post-mining,

If the OB32 pit is backfilled, no permanent changes to the Ethel Gorge aquifer are expected. Groundwater will flow towards the OB32 pit area from the Ethel Gorge aquifer until pre-development groundwater levels have recovered. However, during this time, the continued operation of the Ophthalmia Dam system will maintain groundwater levels in the Ethel Gorge aquifer. Once pre-development groundwater levels have recovered, the direction of groundwater flow will reverse to the pre-development direction, towards the Ethel Gorge aquifer.

For the no or partial backfill scenario, a pit lake will form which is predicted to be a sink, where groundwater will flow from the Ethel Gorge aquifer compartment towards the OB32 pit. While the change in flow direction is likely to be permanent, the groundwater model predicts that the post-mining groundwater flow out of the Ethel Gorge aquifer will reduce after dewatering from OB32 ceases. With the continued operation of the Ophthalmia Dam system, groundwater levels in the Ethel Gorge aquifer will stabilise at levels similar to the period prior to dewatering at Eastern Ridge (i.e., within recent historical variation).

The reference to groundwater recovery taking 50-200 years (Section 5.4.1.1, page 41 of the OB32 BWT Derived Proposal document) is for groundwater levels in the Homestead East/ OB32E aquifer compartment, not groundwater levels in the Ethel Gorge aquifer compartment (see **Figure 1** for locations of the aquifer compartments).

5. Groundwater level monitoring of the Ethel Gorge aquifer

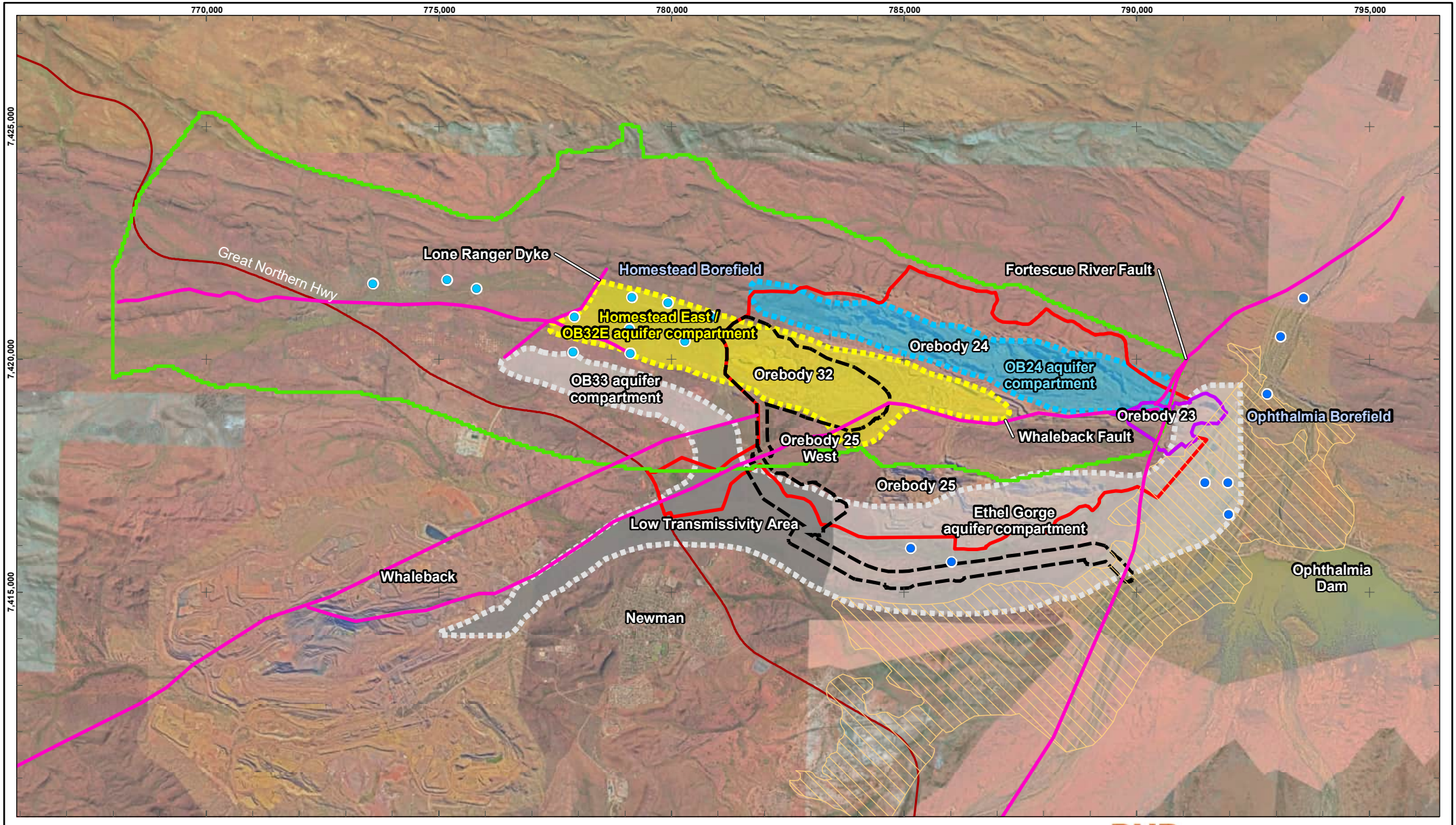
5.1. Operations

Groundwater levels in the Ethel Gorge aquifer in the Ethel Gorge TEC (i.e., at the receptor) are monitored according to the *Eastern Pilbara Water Resource Management Plan* (EPWRMP) (BHP 2022c; Appendix 7 of the OB32 BWT Derived Proposal document). Groundwater levels in the Ethel Gorge aquifer are also monitored as part of the Groundwater Operating Strategies for the RiWI abstraction licences for the Ophthalmia Borefield and Eastern Ridge operations. Groundwater levels are also monitored in the Eastern Ridge area at the source (Eastern Ridge in-pit groundwater levels and Homestead Borefield in the Homestead East/ OB32E aquifer compartment) and along the pathway to the Ethel Gorge TEC.

If the OB32 BWT Proposal is approved, BHP will undertake additional groundwater level monitoring at the source (OB32 pit) and pathway to validate the assumptions regarding the rate and connection of groundwater flow between OB32 and the Ethel Gorge aquifer. However, the current EPWRMP groundwater level controls (trigger and threshold) will maintain groundwater levels in the Ethel Gorge aquifer within historical variation during operations.

5.2. Post-mining

The *Eastern Ridge Mine Closure Plan* (ERMCP) (BHP 2022d; Appendix 9 of the OB32 BWT Derived Proposal document), includes the completion criteria for groundwater levels at key receptors including Ethel Gorge TEC (C5.3 Table 8-1). As discussed in the ERMCP, the regional groundwater monitoring network will continue to be used to support and inform closure assessments and refine completion criteria as required. The results of the operational monitoring programs will be used to refine and calibrate the conceptual and numerical groundwater levels, and to inform pit backfill strategies and frequency of monitoring post-closure to confirm predictions of pit groundwater level recovery.



- Homestead Borefield Bores
- Ophthalmia Borefield Bores
- Regional Faults and Dykes
- Proposed Development Envelope
- Model domain
- Eastern Ridge MS1037 Development Envelope
- Orebody 23 MS478 Development Envelope
- Ethel Gorge Threatened Ecological Community

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KILOMETRES

GDA 1994 MGA ZONE 50

BHP

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OREBODY 32 BELOW WATER TABLE REQUEST FOR INFORMATION RESPONSE

Conceptual groundwater system

PLANNING & STANDARDS - IRON ORE

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DATE:	4/07/2023	REQUESTOR:	ENV. APPROVALS	NO:	A1079/058B

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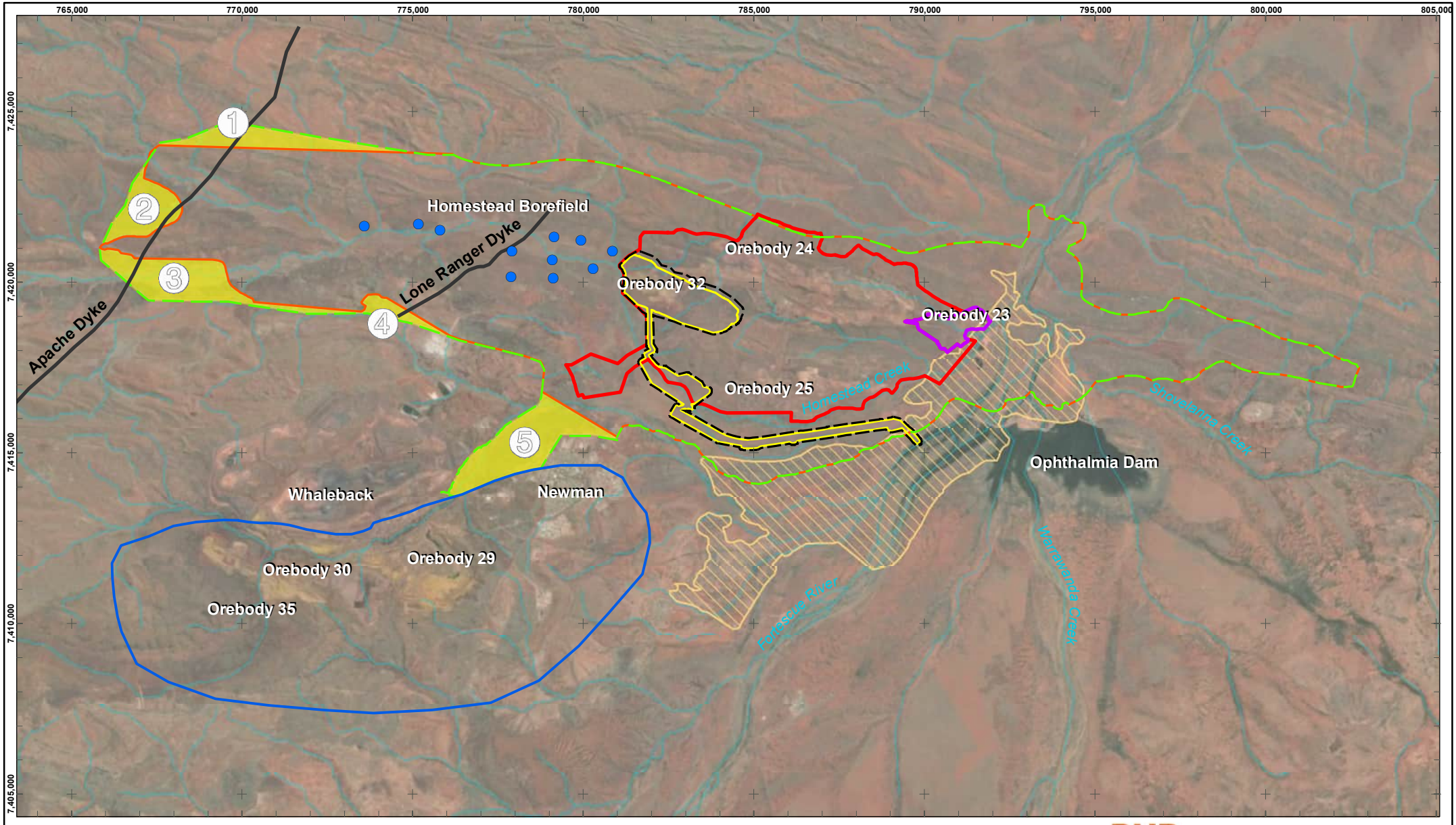

- Proposed Development Envelope
- Indicative Footprint
- 2013 Orebody 29/30/35 1m drawdown contour
- 2015 Eastern Ridge Iron Ore Revised Proposal 2m drawdown contour
- 2022 Cumulative Eastern Ridge 2m drawdown contour
- 2022 Additional OB32 drawdown extent
- Eastern Ridge MS1037 Development Envelope
- Orebody 23 MS478 Development Envelope

Threatened Ecological Communities

- Ethel Gorge aquifer stygobiont community
- Homestead Borefield bores
- Dyke
- Watercourse

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OREBODY 32 BELOW WATER TABLE REQUEST FOR INFORMATION RESPONSE

Cumulative Groundwater Drawdown Extent

PLANNING & STANDARDS - IRON ORE

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DATE:	7/06/2023	REQUESTOR:	ENV. APPROVALS	NO:	A1079/073A

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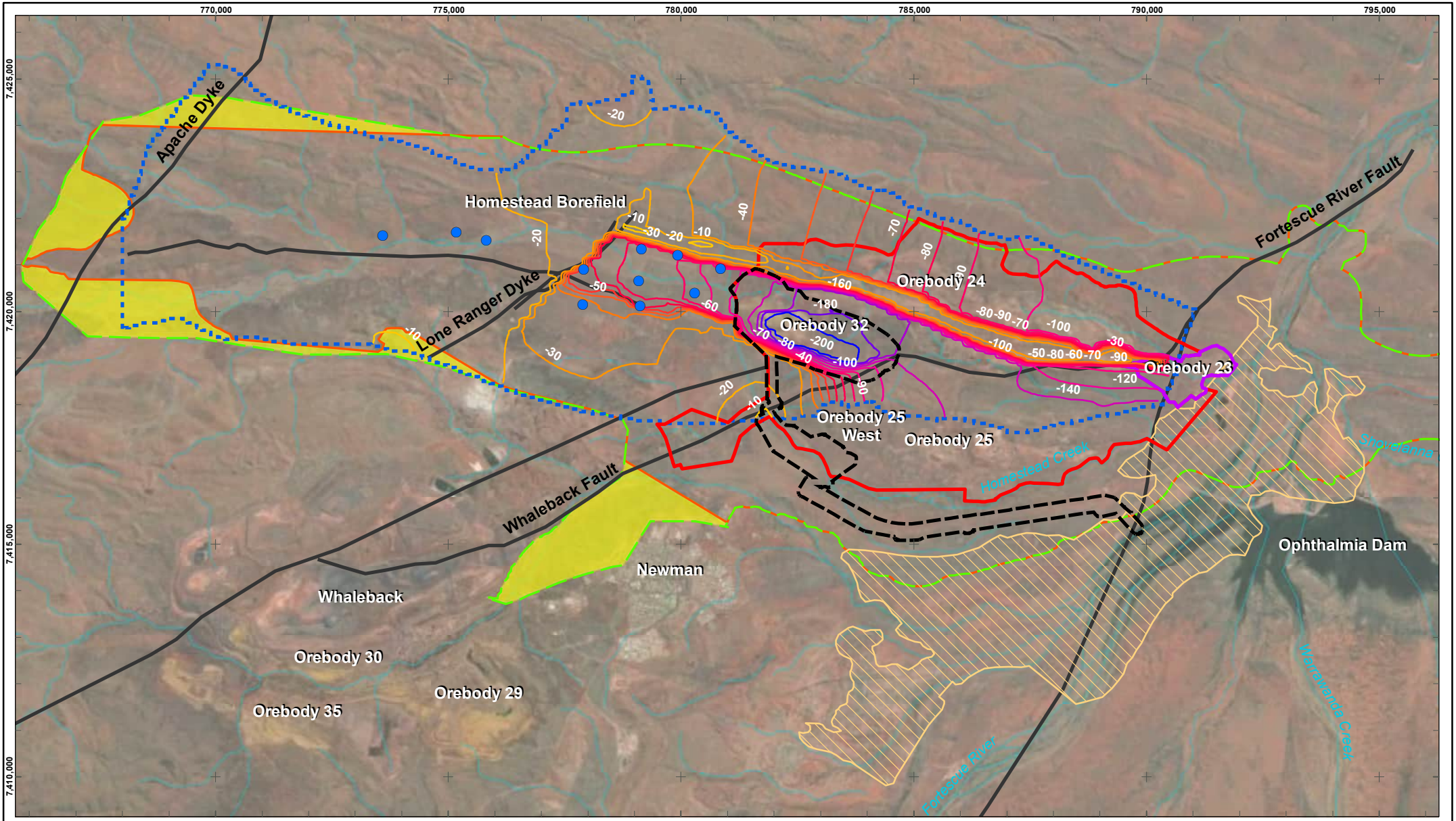

- Proposed Development Envelope
- 2015 Eastern Ridge Iron Ore Revised Proposal 2m drawdown contour
- 2022 Cumulative Eastern Ridge 2m drawdown contour
- 2022 Additional OB32 drawdown extent
- Model domain
- Eastern Ridge MS1037 Development Envelope
- Orebody 23 MS478 Development Envelope
- Ethel Gorge Threatened Ecological Community
- Homestead Borefield Bores
- Regional faults and Dykes
- Watercourse

Predicted drawdown (m)

-200	-100	-50
-180	-90	-40
-160	-80	-30
-140	-70	-20
-120	-60	-10

N

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OREBODY 32 BELOW WATER TABLE
REQUEST FOR INFORMATION RESPONSE
Predicted OB32 Groundwater Drawdown

PLANNING & STANDARDS - IRON ORE

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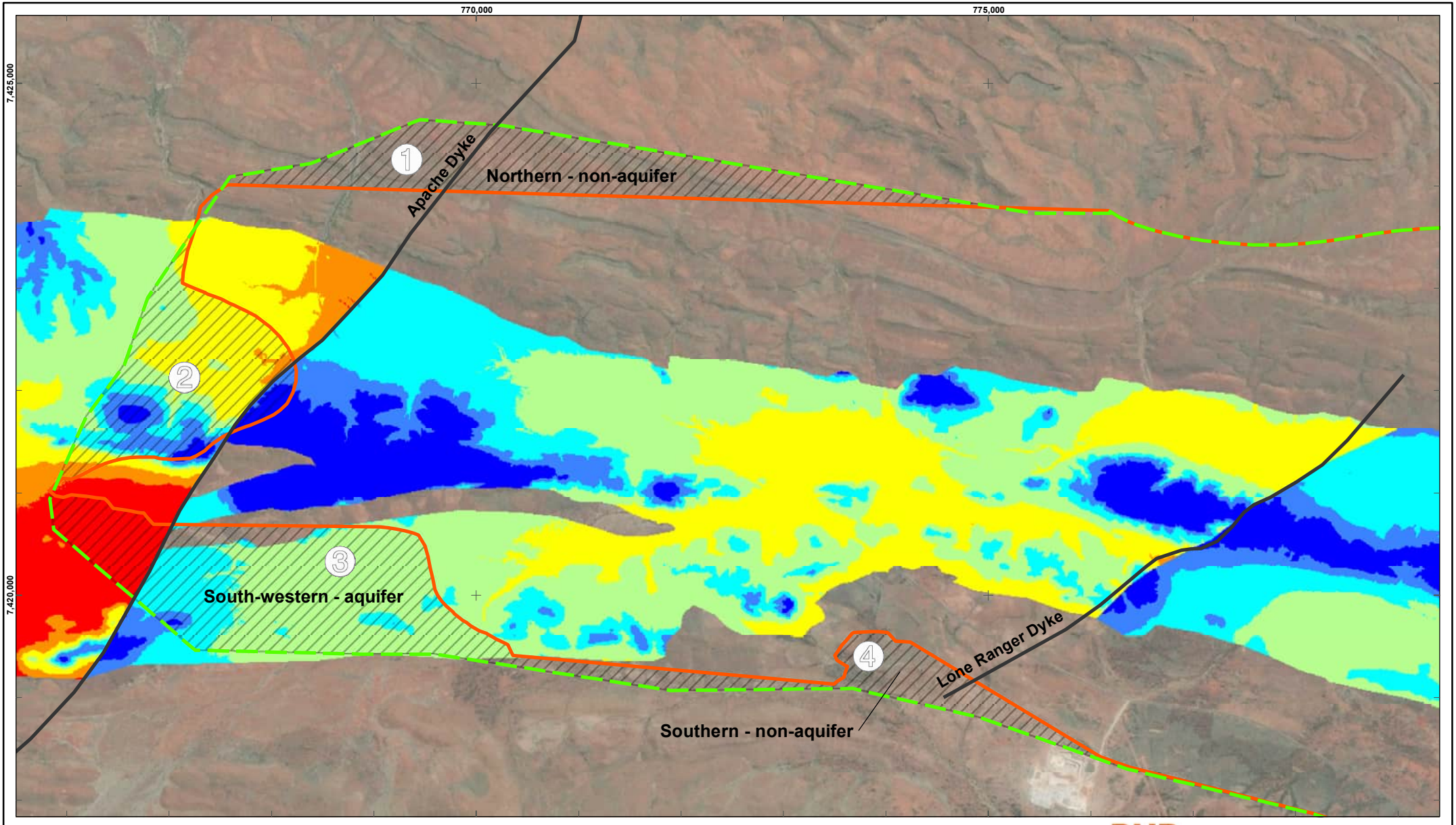

Dyke

2015 Eastern Ridge Iron Ore Revised Proposal 2m Drawdown Contour

2022 Cumulative Eastern Ridge 2m Drawdown Contour

2022 Additional OB32 Drawdown Extent

Depth of water (m)

- <5
- 5 - 10
- 10 - 20
- 20 - 30
- 30 - 40
- 40 - 50
- >50

N

0 1 2 3

KILOMETRES

GDA 1994 MGA ZONE 50

BHP

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OREBODY 32 BELOW WATER TABLE
REQUEST FOR INFORMATION RESPONSE

Regional Groundwater Levels (2022)

PLANNING & STANDARDS - IRON ORE

SCALE @ A4:	1:50,000	PREPARED:	M. ENGLISH	FIGURE:	4
DATE:	7/06/2023	REQUESTOR:	ENV. APPROVALS	NO:	A1079/077A

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6. Stygofauna survey in the Newman Hub area

All sampling and monitoring locations in the Newman Hub area, including within and in the vicinity of the predicted 2022 Cumulative Eastern Ridge drawdown extent (represented by the 2022 Cumulative Eastern Ridge 2 m drawdown contour in **Figure 2**), and within the OB32 BWT Development Envelope, are shown in **Figure 5**.

All stygofauna records known from within, and in the vicinity of, the 2022 Cumulative Eastern Ridge drawdown extent, including within the OB32 BWT Development Envelope are shown in **Figure 6**.

6.1. 2015 Eastern Ridge Revised Proposal sampling

The Eastern Ridge Revised Proposal assessment was informed by stygofauna surveys undertaken in the predicted 2015 Eastern Ridge drawdown extent (represented by the 2015 Eastern Ridge 2 m drawdown contour in **Figure 2**) and associated reference areas, which were conducted in accordance with the relevant EPA guidance at the time of sampling. A total of 178 stygofauna samples were collected from within the predicted 2015 Eastern Ridge drawdown extent and 615 stygofauna samples from the reference areas (Bennelongia 2015).

6.2. 2020 - 2023 sampling

As discussed in Section 7.3.1 of the OB32 BWT Derived Proposal document, targeted surveying in the predicted additional areas of groundwater drawdown from OB32 dewatering (represented by the 2022 Additional OB32 drawdown extent yellow shaded areas in **Figure 2**) was not undertaken. This was due to the relatively small areas of additional groundwater drawdown predicted for the OB32 BWT Proposal, and that previous sampling within the predicted 2015 Eastern Ridge drawdown extent concluded that the stygofauna community is widespread and species within the drawdown extent are not restricted (Bennelongia 2015).

Since the Eastern Ridge Revised Proposal assessment, additional subterranean fauna sampling (and Ethel Gorge TEC monitoring) has been undertaken within the 2022 Cumulative Eastern Ridge drawdown extent (**Figure 2**). Stygofauna species were collected from 52 drill holes in 2020 and 2021 as bycatch from troglofauna sampling (*Orebody 32 West, OB28 and Orebody 33 Troglofauna Survey and Desktop Review*, Bennelongia 2023a *in prep*.). An additional five holes were sampled for stygofauna during phase 1 surveying for a programme in early 2023 in the additional area of groundwater drawdown to the north of Newman township (Area 5 in **Figure 2**). Preliminary data from this sampling indicates that four species were collected from this additional area (Area 5).

Stygofauna sampling in the East Ophthalmia area (north of Ophthalmia Dam, partly within the north-eastern area of the Ethel Gorge TEC buffer) also was conducted in 2020 and 2021 (*East Ophthalmia Subterranean Fauna Survey and Desktop Review*, Bennelongia 2023b *in prep*.). Sampling locations included drill holes within and outside of the 2022 Cumulative Eastern Ridge drawdown extent. Additionally, the Ethel Gorge TEC monitoring programme has recorded stygofauna in 22 drill holes that are located within and outside the 2022 Cumulative Eastern Ridge groundwater drawdown extent since 2015.

7. Assessment of impacts to stygofauna

7.1. Assessed impacts – Eastern Ridge Revised Proposal

Stygofauna community

In the *Eastern Ridge Revised Proposal: Stygofauna Assessment*, Bennelongia (2015) reported 49 stygofauna species from within the predicted 2015 Eastern Ridge drawdown extent, of which 44 are known from outside the predicted drawdown extent (occurring more broadly in the region) and the remaining five were considered likely to have ranges extending beyond the predicted groundwater extent. Bennelongia (2015) discusses the extent and habitat connectivity of the alluvial aquifers of the Tertiary Detrital valley-fill successions in the tributaries associated with the Upper Fortescue River, which allows the dispersal of stygofauna species between the areas of predicted groundwater drawdown and surrounding aquifers. This assessment also

determined that suitable habitat extended outside of the 2015 Eastern Ridge drawdown extent (represented by the orange 2015 Eastern Ridge 2 m drawdown contour in **Figure 5** and **Figure 6**), allowing stygofauna to disperse.

Stygofauna habitat – vertical extent

Vertical habitat extent is dependent on aquifer characteristics (including presence of aquifer, depth to groundwater and aquifer thickness). BHP takes a conservative or precautionary approach when assessing potential impacts to stygofauna habitat, within the modelled lateral groundwater drawdown extent. During the Eastern Ridge Revised Proposal assessment, it was assumed that the total vertical extent of potential stygofauna habitat was lost, regardless of the predicted depth of groundwater drawdown (unless specifically stated with regards to the edge of the drawdown where impacts are predicted to be lower (i.e. typically 1-2 m)). Table 7 of the *Eastern Ridge Revised Proposal Environmental Referral Document* (BHP Billiton 2016a) lists the five stygofauna species that may have ranges restricted to the Groundwater Assessment Area. In Table 7, the Groundwater Assessment Area is described as the area where the cumulative modelled drawdown is greater than or equal to 2 m over and above the natural climatic fluctuations (represented by the 2015 Eastern Ridge drawdown extent). The assessment considered impacts to these species where drawdown is greater than 2 m regardless of the predicted depth of drawdown.

This approach was based on the assessment in *Eastern Ridge Revised Proposal: Stygofauna Assessment* (Bennelongia 2015). On page 5 (Section 2.1.2) of this assessment, Bennelongia states that 'Identifying the amount of drawdown required to threaten the persistence of a stygofauna species is potentially a complex process', and 'in most stygofauna assessments in the Pilbara the threshold has been set more or less independently of the depth of the aquifer and its characteristics'. It continues that 'modelled groundwater drawdowns interpreted as likely to cause impact in the Pilbara have mostly been from greater than 1 m to greater than 5 m over and above natural groundwater fluctuations'. In the Eastern Ridge Revised Proposal assessment, the threshold of potential impacts was set at greater than 2 m (Section 2.5.3, page 9), with the Groundwater Assessment Area representing the spatial extent of cumulative groundwater drawdown greater than 2 m. It was assumed that regardless of the depth of drawdown, the stygofauna species within the Groundwater Assessment Area were potentially impacted. The Groundwater Assessment Area is reproduced as 2015 Eastern Ridge drawdown extent (orange contour line) in **Figure 5** and **Figure 6**.

Considering the above, BHP has already assessed the full loss of potential vertical habitat within the 2015 Eastern Ridge drawdown extent, as part of the approved Eastern Ridge Revised Proposal.

7.2. Validation of impacts – OB32 BWT Proposal

As discussed in Section 3.2 of this memorandum, the predicted additional lateral extent of groundwater drawdown resulting from the proposed OB32 dewatering represents an increase of less than 10% compared to the previously assessed drawdown extent for the approved Eastern Ridge Revised Proposal. Rather than focusing on these small additional areas of drawdown in isolation, BHP considered the stygofauna community and the cumulative Eastern Ridge groundwater drawdown extent for the validation of the OB32 BWT Proposal.

As discussed in Section 7.3.2.2 of the OB32 BWT Derived Proposal document, the potential impacts to stygofauna from the OB32 BWT Proposal were assessed based on the stygofauna community known from the 2022 Cumulative Eastern Ridge drawdown extent. Most (91.2%) of this lateral cumulative drawdown extent was assessed as part of the Eastern Ridge Revised Proposal.

Stygofauna community

The sampling undertaken by Bennelongia (2023a *in prep*.) which yielded stygofauna bycatch, recorded at least 12 species of stygofauna within the 2022 Cumulative Eastern Ridge drawdown extent. Of the 12 species, nine were previously recorded and have distributions beyond the 2022 Cumulative Eastern Ridge drawdown extent (including one from the Ethel Gorge TEC). The remaining three genera are indeterminate to the species level but have the potential to represent known species from the Ethel Gorge TEC and beyond the 2022 Cumulative Eastern Ridge drawdown extent. The East Ophthalmia sampling (Bennelongia 2023b *in prep*) recorded at least 26 species of stygofauna and 25 of these were recorded within the 2022 Cumulative Eastern Ridge drawdown

extent. Of the 25 species, two new species were collected; one which was found within and outside of the 2022 Cumulative Eastern Ridge drawdown extent and the other which is only known from one location within the Ethel Gorge TEC. The remaining 23 species have been collected on previous surveys and/or during Ethel Gorge TEC monitoring and are also known to occur beyond the 2022 Cumulative Eastern Ridge drawdown extent.

At least 36 stygofauna species have been recorded during the Ethel Gorge TEC monitoring from 2016 to 2022. Thirty (30) of the 36 species are known from outside of the 2022 Cumulative Eastern Ridge drawdown extent, four species are only known from the Ethel Gorge TEC and two are known from Eastern Ridge and the Ethel Gorge TEC.

Preliminary data from the sampling programme undertaken in early 2023 within the additional area of groundwater drawdown to the north of Newman township (Area 5), indicates that the four species collected are all known to occur more broadly and have ranges extending outside of the 2022 Cumulative Eastern Ridge drawdown extent.

Geological barriers

The presence of the Apache Dyke (**Figure 5** and **Figure 6**) is likely to restrict stygofauna distribution and dispersal from the east to the west of the dyke. This may result in some difference between the stygofauna communities present on either side of the dyke. However, as discussed above, sampling within the cumulative drawdown extent demonstrates that the majority of stygofauna present have been recorded outside of the 2022 Cumulative Eastern Ridge drawdown extent, including at the Ethel Gorge TEC, or are expected to occur elsewhere. In addition (as discussed in Section 3.2 of this memorandum), the lateral extent of drawdown resulting from OB32 dewatering is now considered unlikely to extend west of the Apache Dyke, limiting the potential impacts to stygofauna species and their habitat to the areas east of the dyke.

While other geological barriers within the area (e.g. the Lone Ranger Dyke, Whaleback Fault shown in **Figure 3**) may reduce the migration of groundwater drawdown, they appear unlikely to be barriers to stygofauna dispersal. This is supported by results of sampling undertaken in the 2022 Cumulative Eastern Ridge drawdown extent (in which the Lone Ranger Dyke is located), which indicate that the stygofauna community is not restricted by this geological feature. Recent sampling undertaken during 2020 and 2021 (as discussed above in Section 7.2 of this memorandum), collected the same species on either side of the Lone Ranger Dyke (as demonstrated by the distribution of Paramelitidae gen. nov. 1 `AMP001` shown in **Figure 7**). The stygofauna community present in the 2022 Cumulative Eastern Ridge drawdown extent reflects the wider community, with the vast majority (~96%) of the species having also been collected from outside the predicted drawdown extent (Bennelongia and BHP data; stygofauna records shown in **Figure 6**). Therefore, the widespread occurrence of the community demonstrates that the barriers that reduce groundwater flow are considered unlikely to restrict the stygofauna distribution and dispersal in the wider area (with the exception of the Apache Dyke).

Since the 2015 assessment, these further collections and taxonomic revisions have resulted in the extension of the known ranges of some of the species (i.e., species have been demonstrated to occur more widely) (Bennelongia data). This information supports the validation that the stygofauna community occurring in the 2022 Cumulative Eastern Ridge drawdown extent is not restricted.

Stygofauna habitat – vertical extent

As discussed in Section 7.1 of this memorandum, BHP has already assessed the full loss of potential vertical habitat within the 2015 Eastern Ridge drawdown extent (orange contour line in **Figure 5** and **Figure 6**), as part of the approved Eastern Ridge Revised Proposal. This includes the loss of stygofauna habitat in the OB32 orebody area. BHP applied the same conservative or precautionary approach (assuming the total vertical extent of potential stygofauna habitat was lost within the 2022 Additional OB32 drawdown extent) to validate potential impacts to stygofauna habitat from the OB32 BWT Proposal.

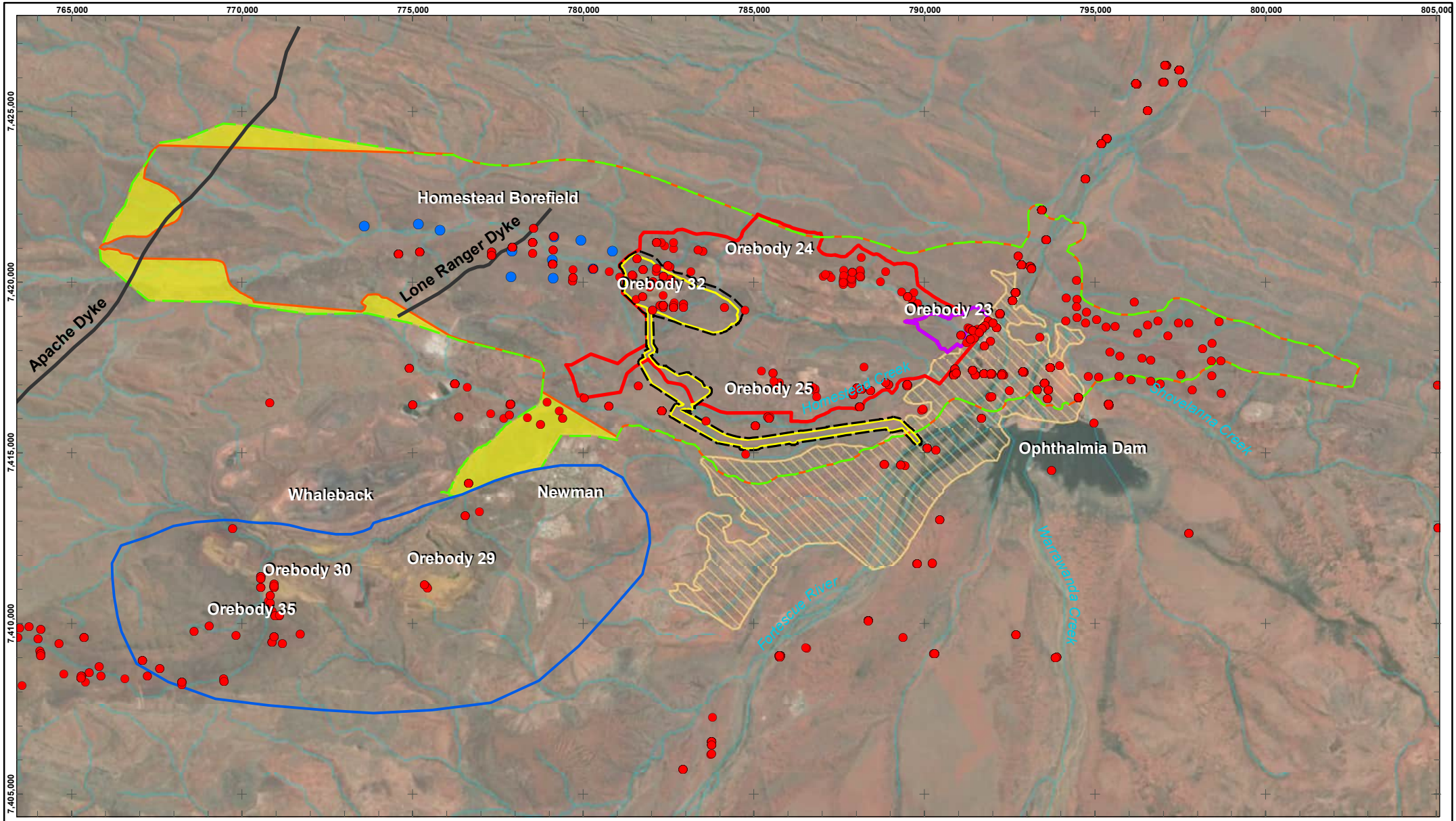
While BHP has estimated the current groundwater levels and modelled the predicted groundwater drawdown from OB32 dewatering, due to the highly variable aquifer thickness or insufficient drilling in areas, the vertical extent of the aquifer (and potential stygofauna habitat) in the additional areas of drawdown (2022 Additional

OB32 drawdown extent represented by the yellow shaded areas (Areas 1-5) in **Figure 2**) cannot be quantified (or represented as a 3-dimensional output). Furthermore, the additional areas of drawdown have unique hydrogeological characteristics and therefore different likelihoods of providing suitable habitat for stygofauna species, based on presence of aquifer, depth to groundwater etc. (as discussed in Section 3.2 of this memorandum).

As discussed in Section 7.3.1.2, page 89 of the OB32 BWT Derived Proposal document, information presented in the *Pilbara Public Environmental Review Strategic Proposal* (BHP Billiton 2016a; Section 8.1.5.1) indicated that low numbers of stygofauna occur where depth to groundwater is greater than 30 mbgl, and areas where the depth to groundwater was less than 40 m (to be conservative) are considered likely to be prospective for stygofauna. Based on this, BHP applied a precautionary approach and assumed that all the predicted additional areas of groundwater drawdown were potential stygofauna habitat, and therefore, the loss of potential stygofauna habitat was identified as a potential impact for the OB32 BWT Derived Proposal (Section 7.4.1.2, page 89 of the OB32 BWT Derived Proposal document).

Based on the hydrogeological information presented in the OB32 BWT Derived Proposal document and the updated hydrogeological information (see Section 3.2 of this memorandum), BHP has concluded the following regarding potential impacts to stygofauna habitat from OB32 dewatering in the 2022 Additional OB32 drawdown extent shown in **Figure 2**:

- Areas 1 and 4 of the 2022 Additional OB32 drawdown extent are considered unlikely to provide stygofauna habitat, as they are unlikely to host aquifer material and the depth to groundwater in Area 1 is predicted to be greater than 50 m (which is considered unlikely to be prospective stygofauna habitat as the depth is greater than 40 m).
- Most of Area 2 is unlikely to experience drawdown, as it is west of the Apache Dyke. In the small portion of Area 2 east of the dyke, the depth to groundwater exceeds 50 m and is considered unlikely to be prospective stygofauna habitat.
- In Area 3 within the model domain (shown in **Figure 3**), the vertical drawdown is predicted to range between 10 m and 20 m, and is likely to decrease outside (west of) the model domain to approximately 2 m, with no drawdown west the Apache Dyke. Immediately east of the dyke, current groundwater levels are estimated to be greater than 30 mbgl (where low numbers of stygofauna are likely to occur). Due to the varying aquifer depth in this area it is not possible to quantify the extent of vertical stygofauna habitat.
- The vertical drawdown in Area 5 is likely to range between 2 m and 10 m. The aquifer in Area 5 is part of the low transmissivity zone (shown in **Figure 1**). Due to the varying aquifer depth in this area it is not possible to quantify the extent of vertical stygofauna habitat.



- Proposed Development Envelope
- Indicative Footprint
- 2013 Orebody 29/30/35 1m drawdown contour
- 2015 Eastern Ridge Iron Ore Revised Proposal 2m drawdown contour
- 2022 Cumulative Eastern Ridge 2m drawdown contour
- 2022 Additional OB32 drawdown extent
- Eastern Ridge MS1037 Development Envelope
- Orebody 23 MS478 Development Envelope

Threatened Ecological Communities

- Ethel Gorge aquifer stygobiont community
- Stygofauna sample
- Homestead Borefield bores
- Dyke
- Watercourse

N

0 2 4 6

KILOMETRES

GDA 1994 MGA ZONE 50

BHP

PUBLIC

OREBODY 32 BELOW WATER TABLE
REQUEST FOR INFORMATION RESPONSE
Stygofauna Sampling

PLANNING & STANDARDS - IRON ORE

SCALE @ A4:	1:150,000	PREPARED:	M. ENGLISH	FIGURE:	5
DATE:	5/07/2023	REQUESTOR:	ENV. APPROVALS	NO:	A1079/074A

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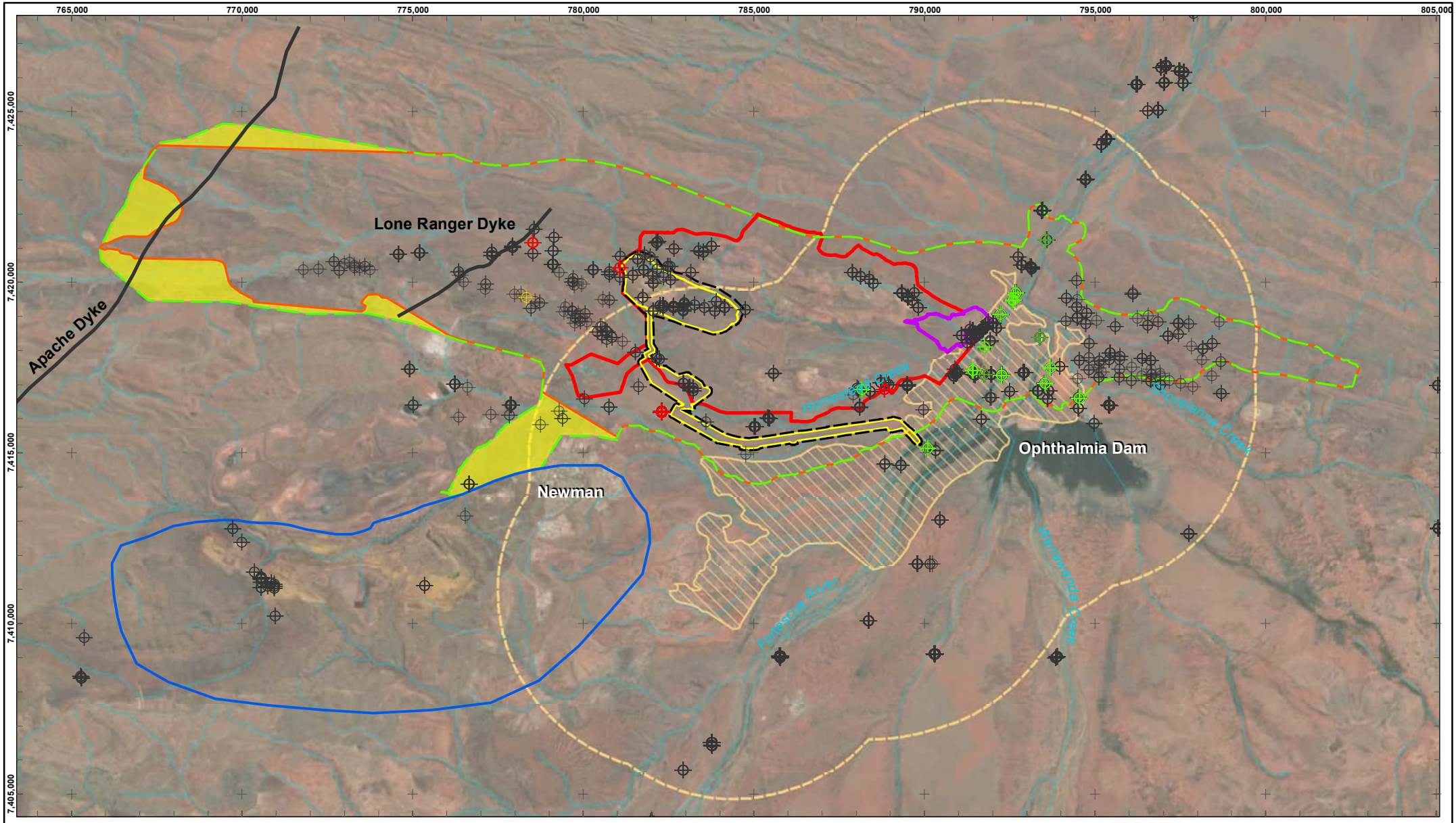

- Proposed Development Envelope
- Indicative Footprint
- Species known from outside of the cumulative drawdown extent
- Species only known from TEC and cumulative drawdown extent
- Species only known from cumulative drawdown extent
- Species distribution uncertain (potential to occur outside the cumulative drawdown extent)
- 2013 Orebody 29/30/35 1 m Drawdown Contour
- 2015 Eastern Ridge Iron Ore Revised Proposal 2m drawdown contour
- 2022 Cumulative Eastern Ridge 2m drawdown contour
- 2022 Additional OB32 drawdown extent
- Eastern Ridge MS1037 Development Envelope
- Orebody 23 MS478 Development Envelope

Threatened Ecological Communities

- Ethel Gorge aquifer stygobiont community
- Ethel Gorge aquifer stygobiont community - Buffer
- Dyke
- Watercourse

N

0 2 4 6

KILOMETRES

GDA 1994 MGA ZONE 50

BHP

PUBLIC

OREBODY 32 BELOW WATER TABLE REQUEST FOR INFORMATION RESPONSE

Stygofauna Species

PLANNING & STANDARDS - IRON ORE

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DATE:	7/06/2023	REQUESTOR:	ENV. APPROVALS	NO:	A1079/075A

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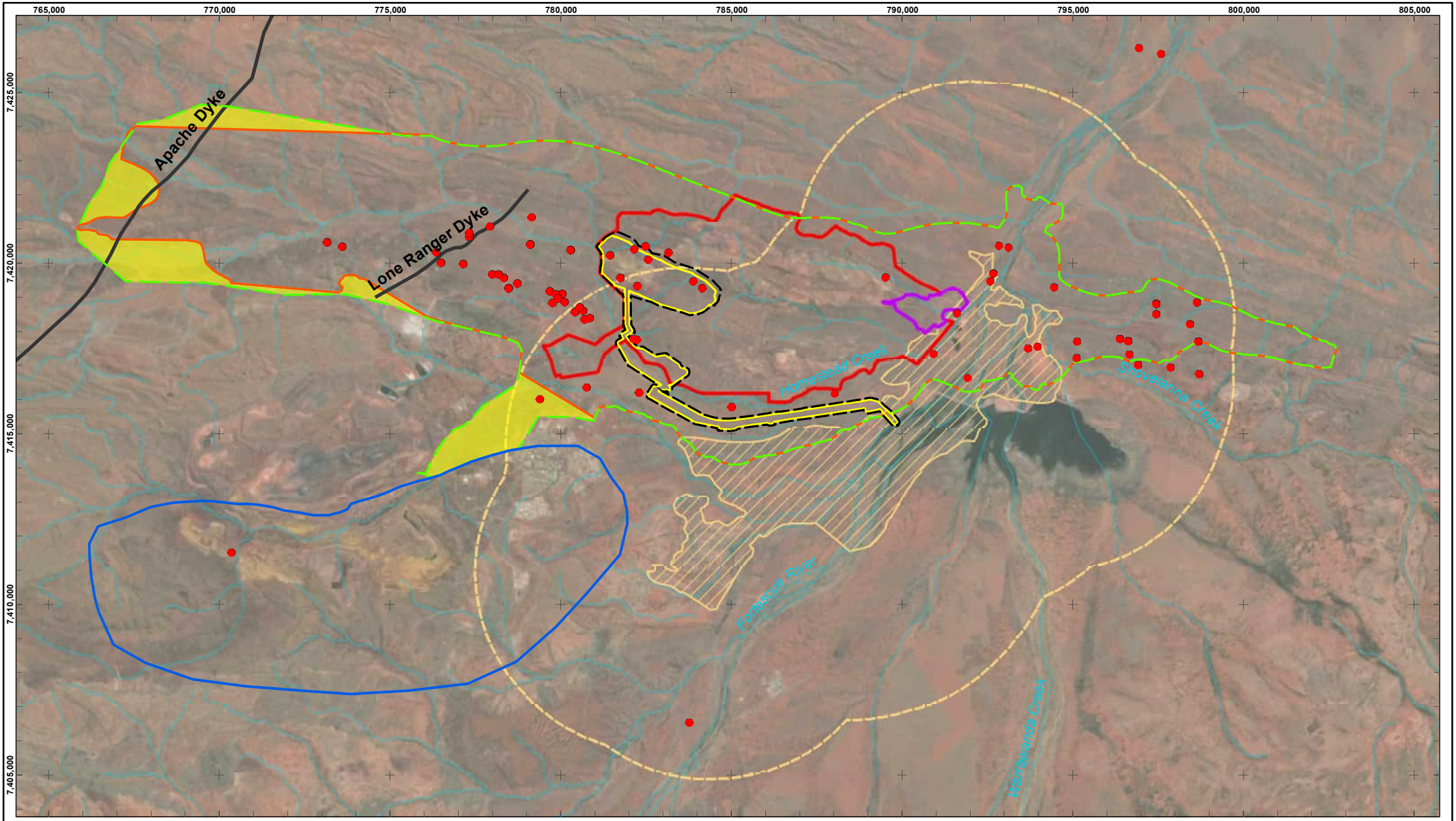

- Proposed Development Envelope
- Indicative Footprint
- Paramelitidae gen. nov. 1 `AMP001`
- 2022 Cumulative Eastern Ridge 2m drawdown contour
- 2013 Orebody 29/30/35 1m drawdown contour
- 2015 Eastern Ridge Iron Ore Revised Proposal 2m drawdown contour
- 2022 additional OB32 drawdown extent
- Eastern Ridge MS1037 Development Envelope
- Orebody 23 MS478 Development Envelope

Threatened Ecological Communities

- Ethel Gorge TEC boundary
- Ethel Gorge TEC buffer
- Dyke
- Watercourse

N

0 2 4 6

KILOMETRES

GDA 1994 MGA ZONE 50

BHP

PUBLIC

OREBODY 32 BELOW WATER TABLE
REQUEST FOR INFORMATION RESPONSE
Distribution of Paramelitidae gen. nov. 1 `AMP001`

PLANNING & STANDARDS - IRON ORE

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Document Path: Y:\Jobs\A1001_A1500\A1079\3Project\A1079_072_OB32_BWT_DP_RFI_DistributionOfParamelitidae_RevA.mxd

8. References

Bennelongia (2015) *Eastern Ridge Revised Proposal: Stygofauna Assessment*.

Bennelongia (2023a) *Orebody 32 West, OB28 and Orebody 33 Troglofauna Survey and Desktop Review*. In prep.

Bennelongia (2023b) *East Ophthalmia Subterranean Fauna Survey and Desktop Review*. In prep.

BHP Billiton (2016a) *Eastern Ridge Revised Proposal Environmental Referral Document*. May 2016.

BHP Billiton (2016b) *Pilbara Public Environmental Review Strategic Proposal*. BHP, Perth, WA.

BHP (2022a) *Newman Hub (Orebody 32 Below Water Table) Derived Proposal Request Ministerial Statement 1105*. October 2022.

BHP (2022b) *Orebody 32 Below Water Table: Groundwater impact assessment.* August 2022. Appendix 4 of the OB32 BWT Derived Proposal document.

BHP (2022c) *Eastern Pilbara Water Resource Management Plan*, Version 6.2, April 2022.

BHP (2022d) *Eastern Ridge Mine Closure Plan*. Version 3.0, July 2022.

BHP (2023) *The Hydraulic Behaviour of Apache Dyke at Homestead West.* Internal BHP technical memo.

RPS Aquaterra (2013) *RE: Orebody 25 Modelling*. Report prepared for BHP Billiton Iron Ore Pty Ltd.

9. Appendices

Appendix A: *The Hydraulic Behaviour of Apache Dyke at Homestead West*

Appendix A

Date	2 June 2023
To	WAIO Environment Approvals
From	Water Planning
Subject	The Hydraulic Behaviour of Apache Dyke at Homestead West

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Purpose

The purpose of this memo is to communicate Water Planning's understanding of how the Apache Dyke affects groundwater levels and flow within the Homestead West aquifer system.

Location and Setting

The Homestead West area is located approximately 6 km north-northwest of Newman, topographically west of Newman East (Eastern Ridge) between the Ophthalmia Range to the north and the Whaleback mining area in the south. It is defined as the area west of the Lone Ranger Dyke, extending over 9 km west to the Apache Dyke and includes the western portions of OB28, 32 & 33 and OB26 and 36 (Figure 1). The Mudd deposit in Cathedral Gorge is also partly within Homestead West.

The catchment area above the Lone Ranger Dyke is roughly 255 km^2 and includes Homestead Creek and the Homestead South tributary which joins Homestead Creek at the western end of OB33. Homestead Creek drains surface runoff from the southern Ophthalmia Range to the north, extending about 17 km to the west-northwest of the Lone Ranger Dyke, while Homestead South extends approximately 27 km to the west, draining the southern flanks of the Ophthalmia Range. Streamflow is ephemeral, triggered by heavy rainfall events, occurring primarily during the wet season (December to March).

The Homestead Potable Borefield is primarily located on the eastern side of the Lone Ranger Dyke, with two operational and one unequipped bore located to the west of the dyke. The Great Northern Highway traverses the area, passing over OB26, OB28, OB33 and OB36 before exiting the area to the north through Cathedral Gorge.

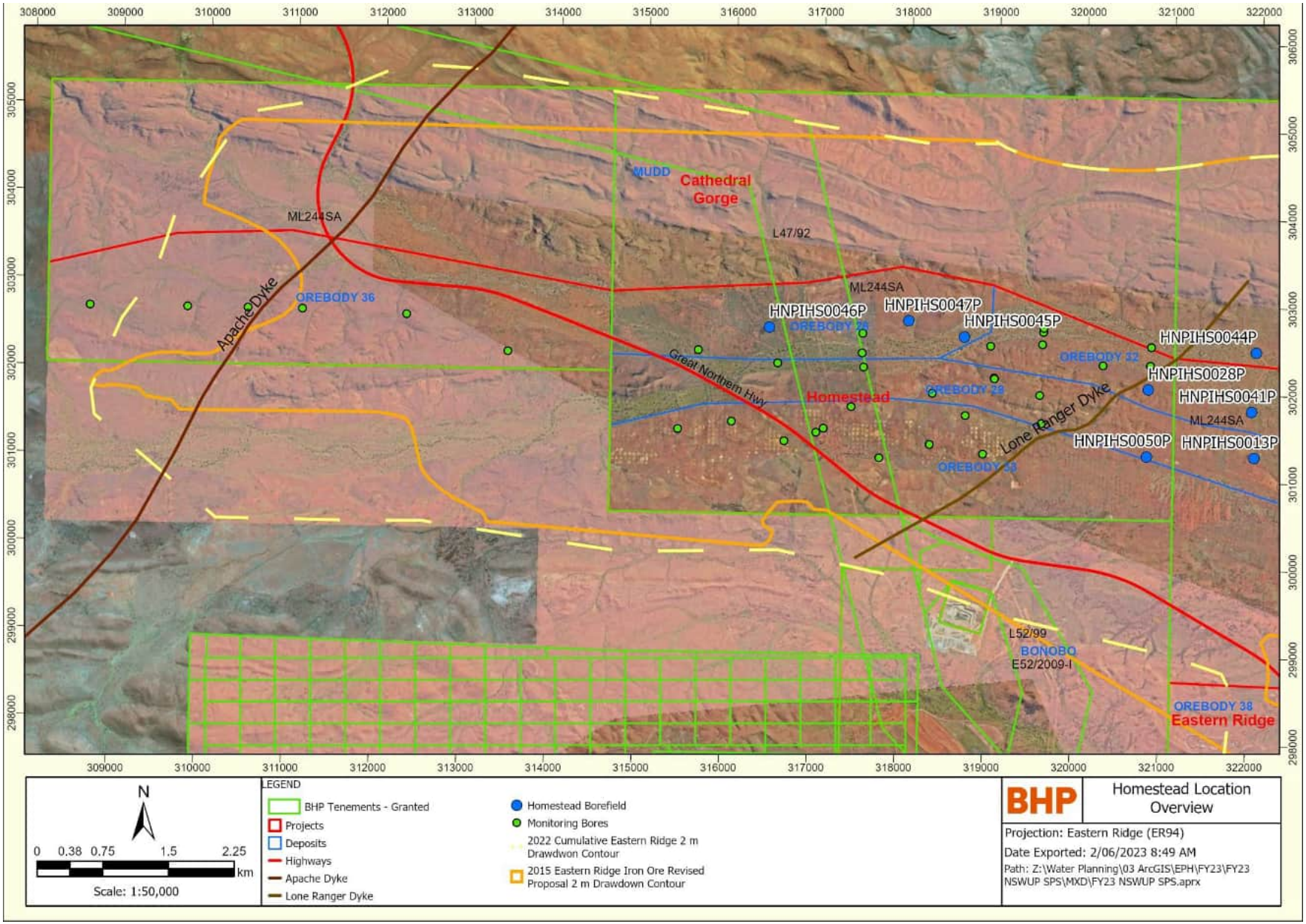

Figure 1: Overview map of the Homestead West area.

Geology

The Homestead West area is made up of a stratigraphic sequence extending from the Jeerinah Formation of the Fortescue Group up to the Brockman Iron Formation Joffre Member of the Hamersley Group. The distribution of these units is presented in the BHPIO surface geology mapping 1:100k (Figure 2). The Marra Mamba Iron Formation and Brockman Iron Formation form two east-west ridges separated by an alluvium and colluvium filled valley which is host to Homestead Creek. The Wittenoom Formation underlies much of the alluvium/colluvium beneath the Homestead Creek valley and is composed of BIF, interbedded shale, and dolomite of the Bee Gorge Member, with massive dolomite of the Paraburdoo Member and shale-rich West Angela Member.

The stratigraphy at the western end of the Homestead West area is crosscut by the Apache dyke, which is a steeply dipping, late-stage intrusive structure composed of fine-grained dolerite and clay in the weathered zone. The structure outcrops in the Marra Mamba Formation with a thickness of up to 3 metres, forming a gap in the ridge known as Apache Pass (C. Crowe, 2011). The structure is observed in the Brockman Formation in the Cathedral Gorge project area to the north as an eroded gap in the ridge (Figure 3).

Historic exploration drilling on the western side of the dyke intersected detrital deposits and weathered profile over bedrock (which can be similar to the detrital deposits). Depths of these deposits range from 3 m to 27 m, with the thickest occurrences being associated with surface drainage features. Drilling on the eastern side of the dyke is limited to resource drilling in OB36. There is currently no drilling data for the eastern side of the dyke that provides information on the depth of the detrital channel fill deposits. The limited number of drill holes outside of the mineralised areas combined with detritals not being a unit of interest for resource drill hole logging means that there is uncertainty in the depth and distribution of the tertiary detritals on both sides of the dyke.

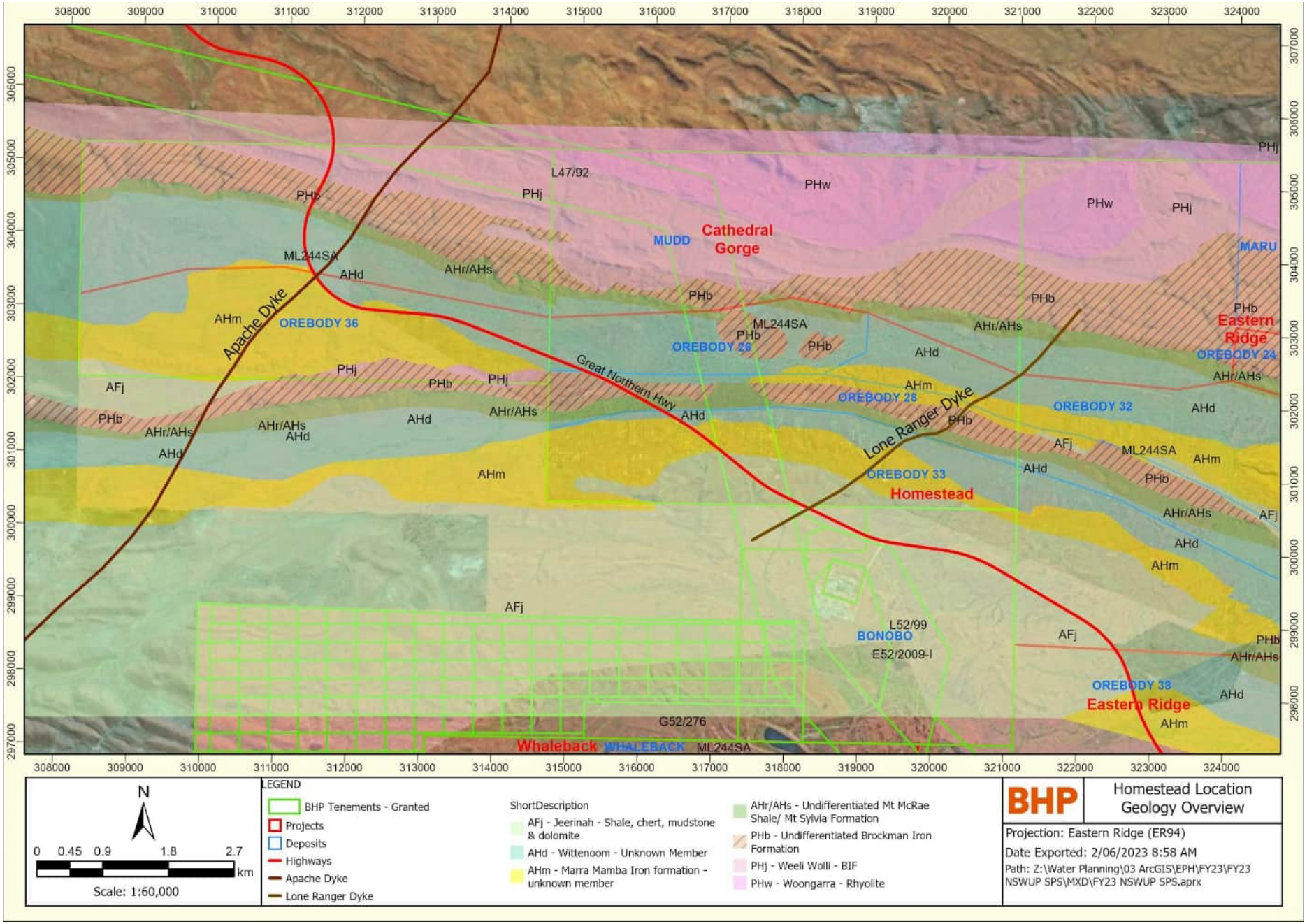

Figure 2: Homestead West BHPIO 1:100,000 geological mapping with major intrusive dyke structures

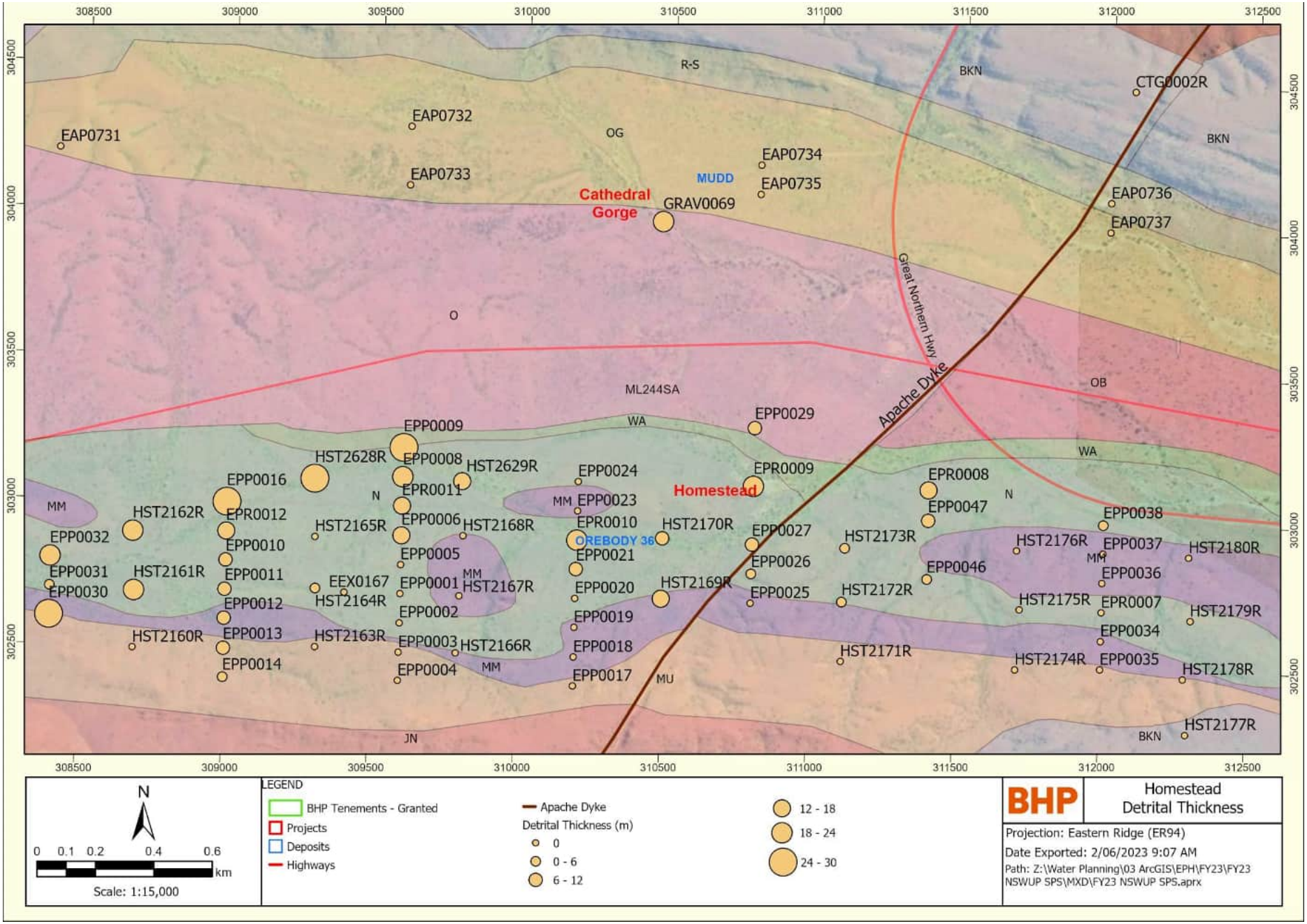

Figure 3: Map of exploration drill holes in the vicinity of Apache Dyke classified based on intercepted detrital thickness (m) overlain on modelled geology at the water table.

Hydrogeology

Aquifers

The major aquifer units in the Homestead Valley are mineralised and fractured Marra Mamba and Brockman Iron Formation, and the Wittenoom Formation (Paraburdoo Member) dolomite, where it is weathered and karstic. Where the alluvium and detritals along the axis of the Homestead Valley are saturated, these also form aquifers. In the Homestead project area, the aquifers within mineralised Brockman Iron Formation are understood to be effectively isolated from the dolomite aquifer by shales of the Mount McRae and Mount Sylvia Members. The Marra Mamba, dolomite and (where present) detrital aquifers are hydraulically connected and form a significant aquifer system, which is the target of the Homestead Potable Borefield.

The Lone Ranger Dyke and Apache Dyke divide the Homestead Valley into three aquifer compartments (Figure 4). These intrusive structures are largely impermeable when compared to the surrounding formations, and the late-stage emplacement means that they act as a barrier to groundwater flow within the stratigraphic units of the Fortescue and Hamersley Groups. Subsequent surface erosion associated with Homestead Creek has incised a channel across these dykes, resulting in a localised subsurface low point within the valley host to alluvial channel fill deposits.

The extents of the Homestead West aquifer compartments have been mapped based on Leapfrog models for the area and BHPIO surface geology mapping (1:20k and 1:100k). Interpretation of airborne magnetic survey data has been used to extrapolate the likely geology in areas with no mapping available.

The central compartment is bound by:

- The Apache Dyke to the west,
- Lone Ranger Dyke to the East,
- Mt McRae Shale and Mt Sylvia Formation to the north, and
- Jeerinah Formation to the south

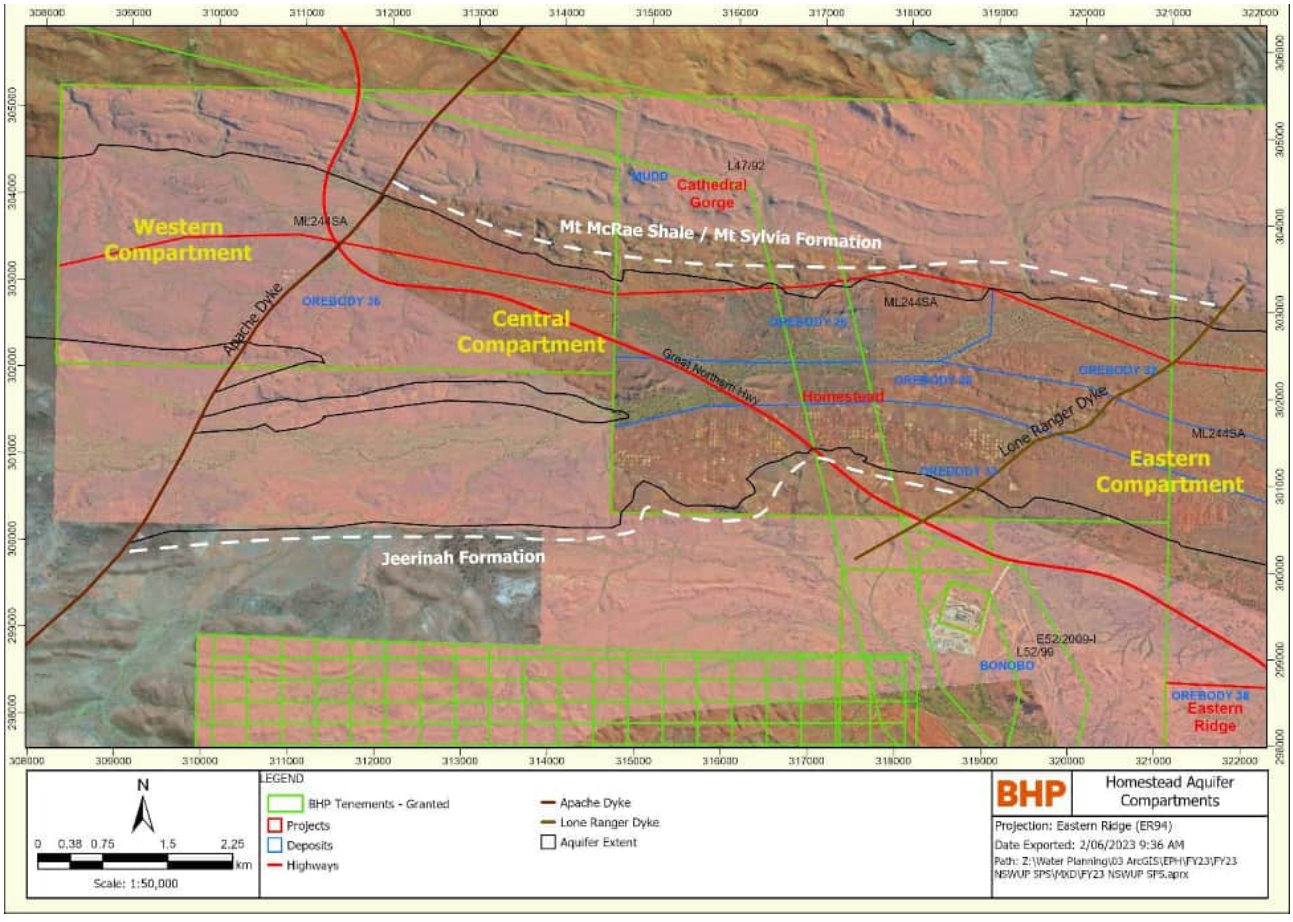

Figure 4: Homestead aquifer compartments.

Groundwater Levels

Recent groundwater level monitoring is limited to the eastern portion of the Homestead West area (OB28, 32W & 33W), while historical levels are available from three out of five frontier piezometers installed in the west at OB36 into units of the Marra Mamba Formation (Figure 5). Water level measurements from frontier piezometers on either side of the Apache dyke (two west and one east) were recorded in September 2022 to characterise the current conditions in this area. The water table elevation on the western side of the Apache dyke is 586.2 mAHD (HST2169RM, Sep 2022), and 552.9 mAHD (HST2172RM, Sep 2022) on the eastern side of the Apache dyke, indicating a 33.3 m water level difference across the Apache Dyke. The depth to water on the western side of the Apache dyke in the vicinity of Homestead creek is between 5 to 13 mBGL while the depth to water on the eastern side is more than 30 mBGL (Figure 6).

A comparison between the recent 2022 levels (Figure 5) and pre-development water levels[1] in the Western extent of Homestead West (Figure 7) indicates that the water level on the immediate eastern side of the Apache dyke has decreased by 1.4 m, most likely as a result of groundwater abstraction from the Homestead Potable Borefield, while levels on the western side have remained constant.

An east-west cross section along the length of the Homestead Valley illustrates the contrasting pre-development water levels on either side of the Apache and Lone Ranger dykes, and subtle gradients that exist within each of the aquifer compartments (Figure 8). Present-day (2022) water levels (red triangles) in the central compartment show that abstraction from the two equipped NPI bores (HNPIHS0045 and HNPIHS0047) on the western side of the Lone Ranger Dyke has resulted in varying degrees of drawdown throughout the central aquifer compartment, but this does not extent west of the Apache Dyke.

[1] Pre-mining water levels derived from resistivity logs from resource RC drilling.

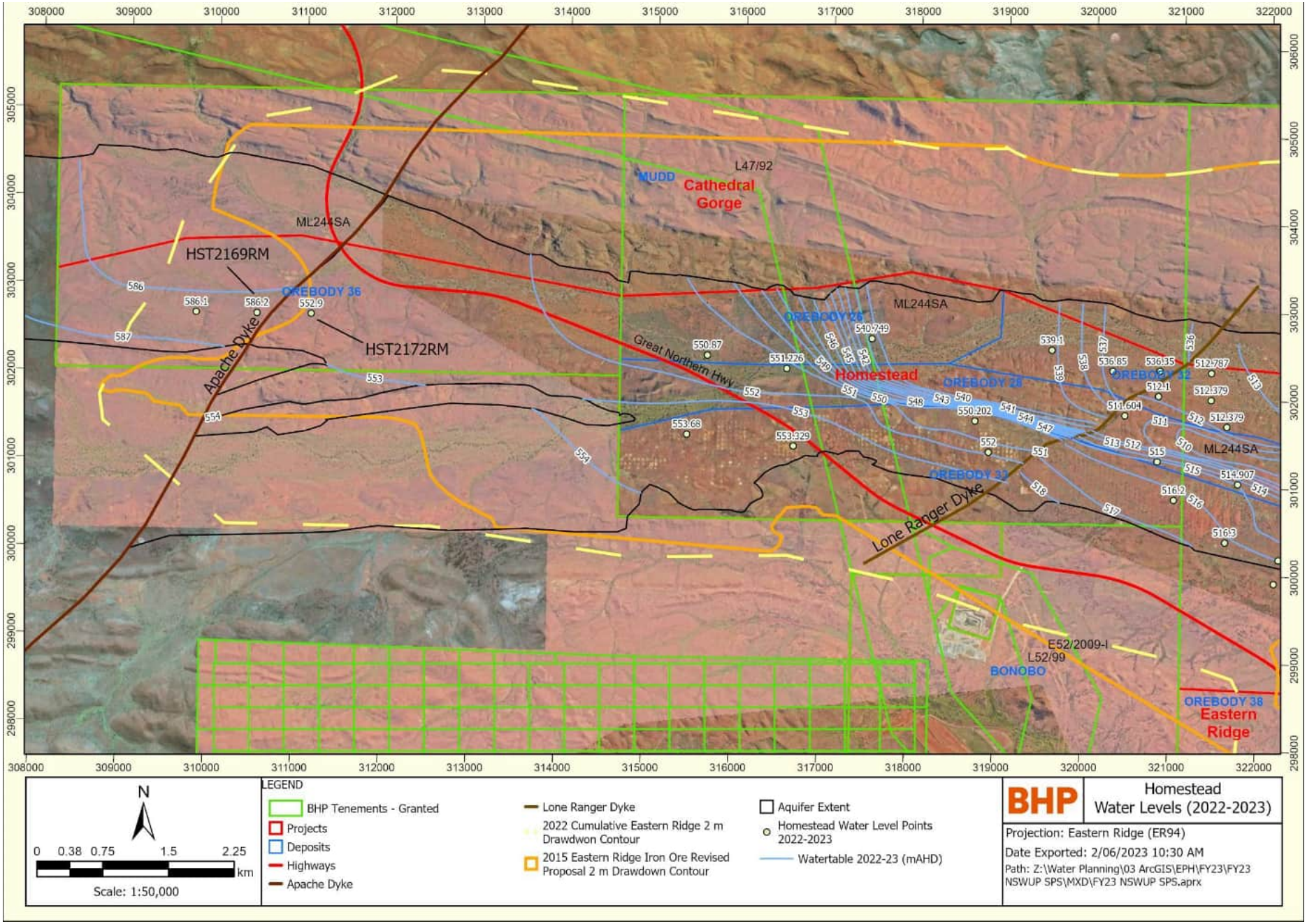

Figure 5: Homestead water levels (mAHD) (2022-2023)

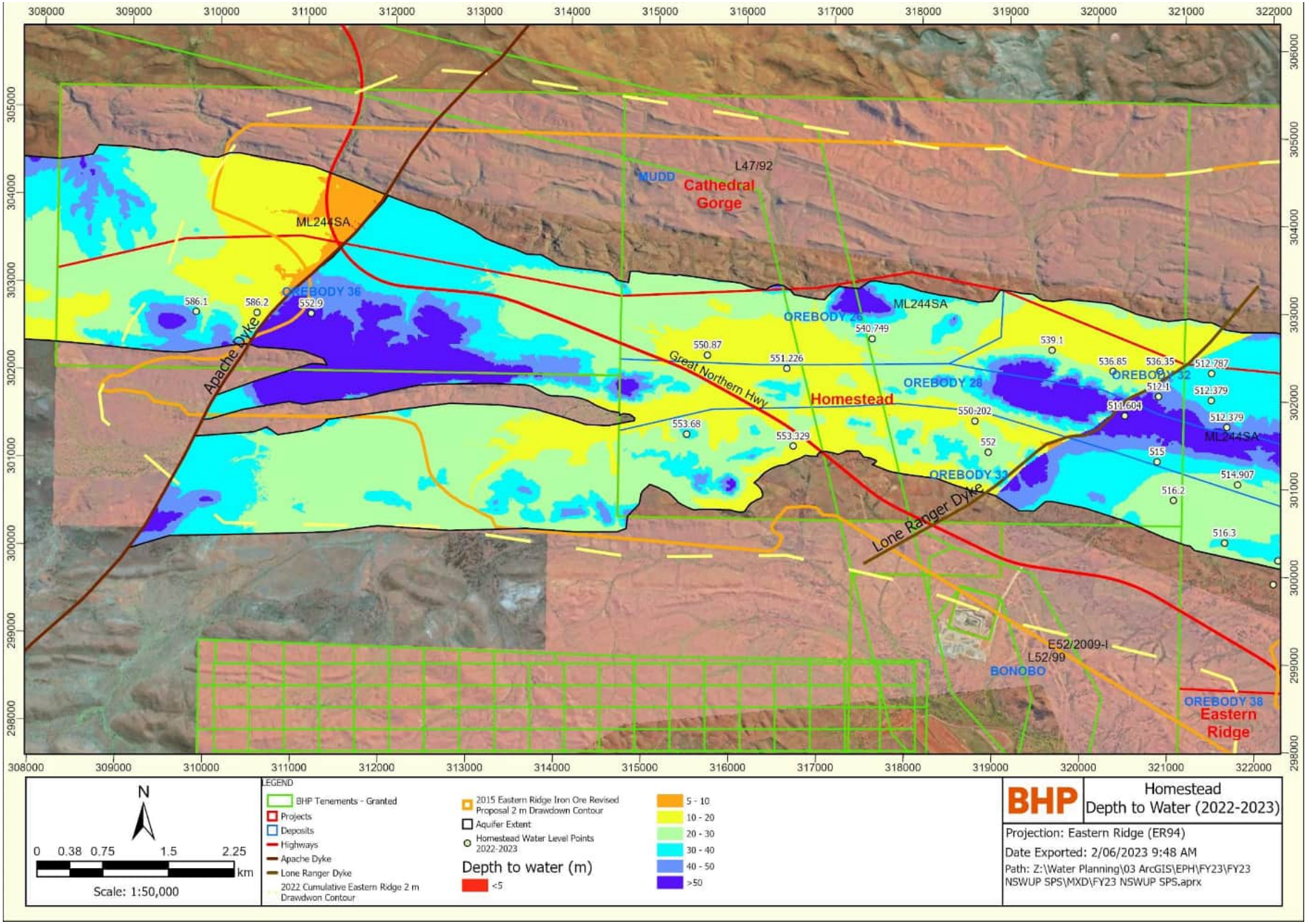

Figure 6: Depth to water (mBGL) (2022-2023)

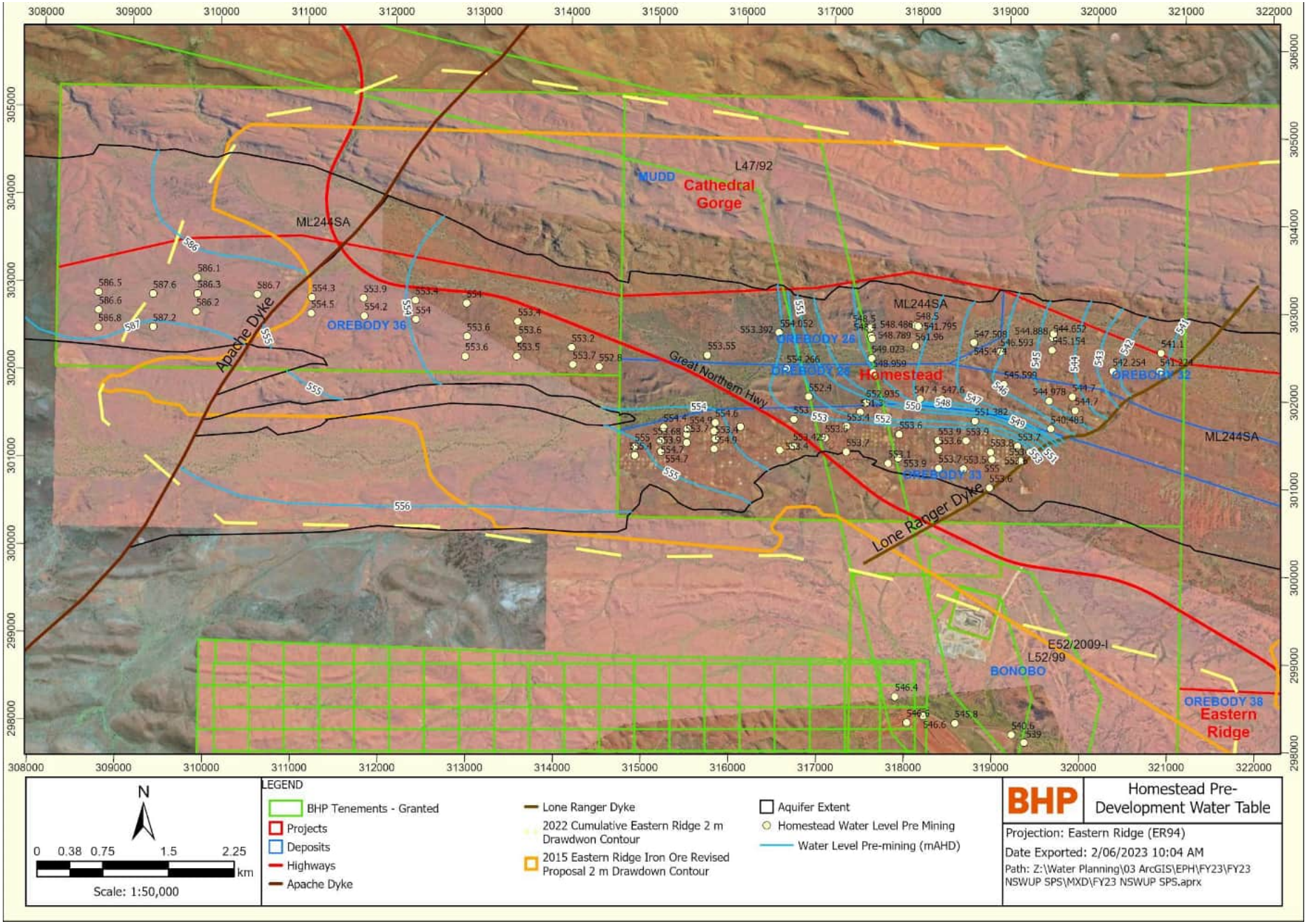

Figure 7: Pre-development water table at Homestead derived from water level and resistivity logs.

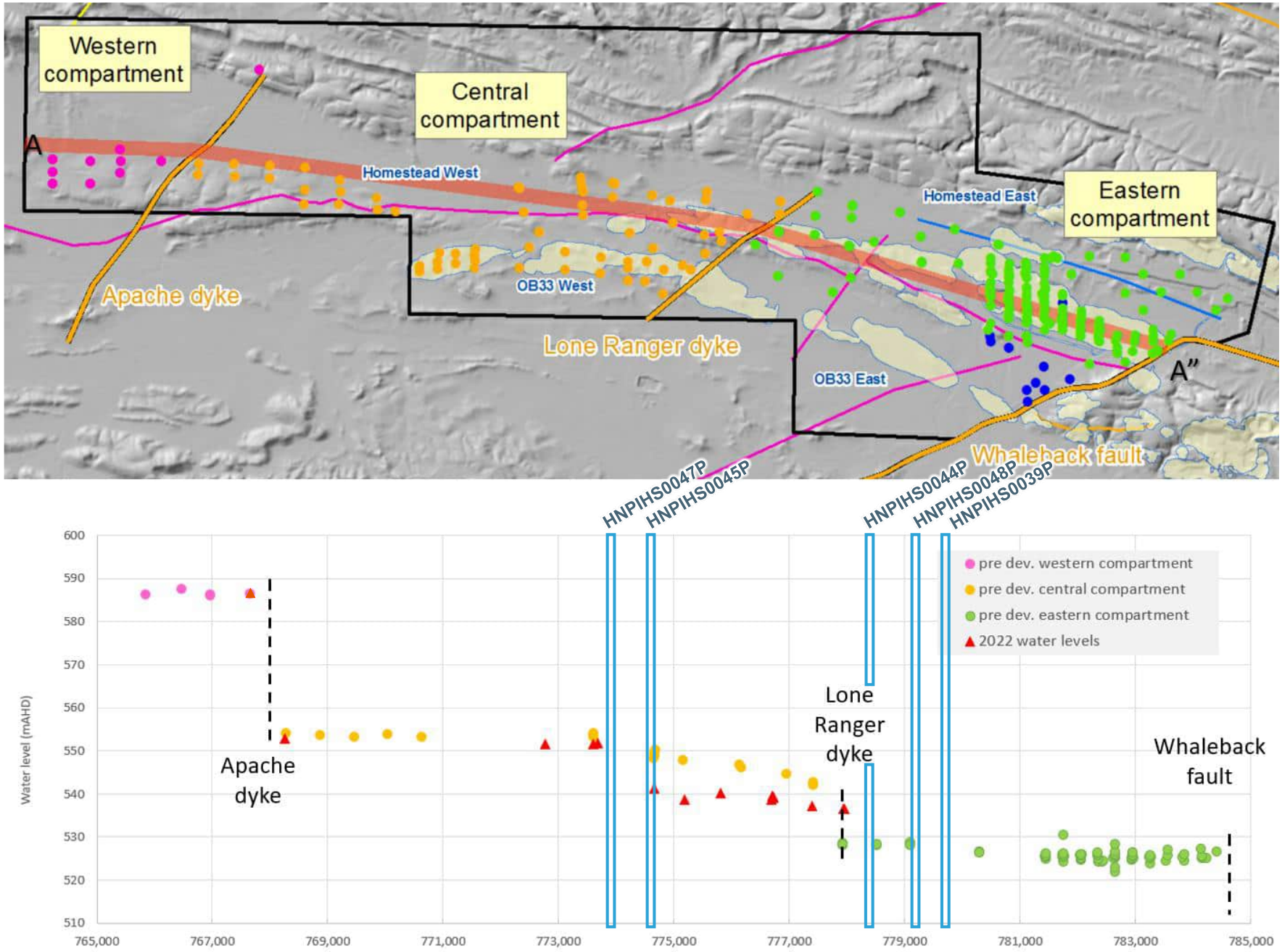

Figure 8: Cross section of Homestead West aquifer compartments with corresponding pre-development and present day (2022) water levels and major structures. Existing equipped Homestead Borefield production bores annotated. Not to scale.

Conceptual model of the Apache Dyke

The Apache Dyke is relatively impermeable when compared with the surrounding formations of the Fortescue and Hamersley Group that occur at Homestead West. As the dyke structure is perpendicular to the valley and transects all geological units except the detrital deposits, it acts as a barrier to groundwater flow, forming hydraulically separated groundwater compartments either side of the dyke. This is demonstrated by the large drop in water levels across the dyke, and the fact that the observed decline in water levels to the east of the dyke (in response to operation of the Homestead Potable Borefield) is not observed to the west.

Homestead creek is interpreted to have eroded a channel across the Apache dyke, forming a localised low point in the structure. Detrital channel fill material, alluvium and colluvium has infilled the channel to form the flat valley floor which is host to the present-day Homestead Creek. This detrital channel fill material forms a permeable pathway for groundwater to flow across (i.e. over) the dyke from west to east. The elevation of the erosional low point is interpreted as controlling the groundwater elevation on the western side of the dyke.

Exploration drill hole GRAV0069 is situated in the Homestead Creek channel on the western side of the dyke and is the closest geological data to the structure in the low-lying region of the valley (Figure 3). This hole intersected a sequence of surface scree, detritals and goethitised hard cap to a depth of 21 m (575 mAHD) (Figure 9). The channel fill material is underlain by fresh Wittenoom dolomite. The groundwater elevation on the western side of the dyke indicates that up to 11.2 m of the channel fill material is saturated.

There is insufficient data in the vicinity of the dyke, located 1100 m east of GRAV0069, to determine the detrital thickness and elevation of the base of the channel across the dyke, however it is likely that it is at or marginally below the 585 mAHD elevation of the water table. The thickness of the detritals on the eastern side of the dyke is unknown due to a lack of data but is thought to be similar to the west.

The above interpretation is presented in a simplified 3D conceptual model (Figure 10). Based on the difference in water table elevation across the dyke, coupled with the estimated elevation of the erosional low point and thickness of channel fill material across the structure, it is only possible for groundwater to flow from the western compartment to the eastern compartment. Similarly, drawdown east of the dyke cannot propagate westward.

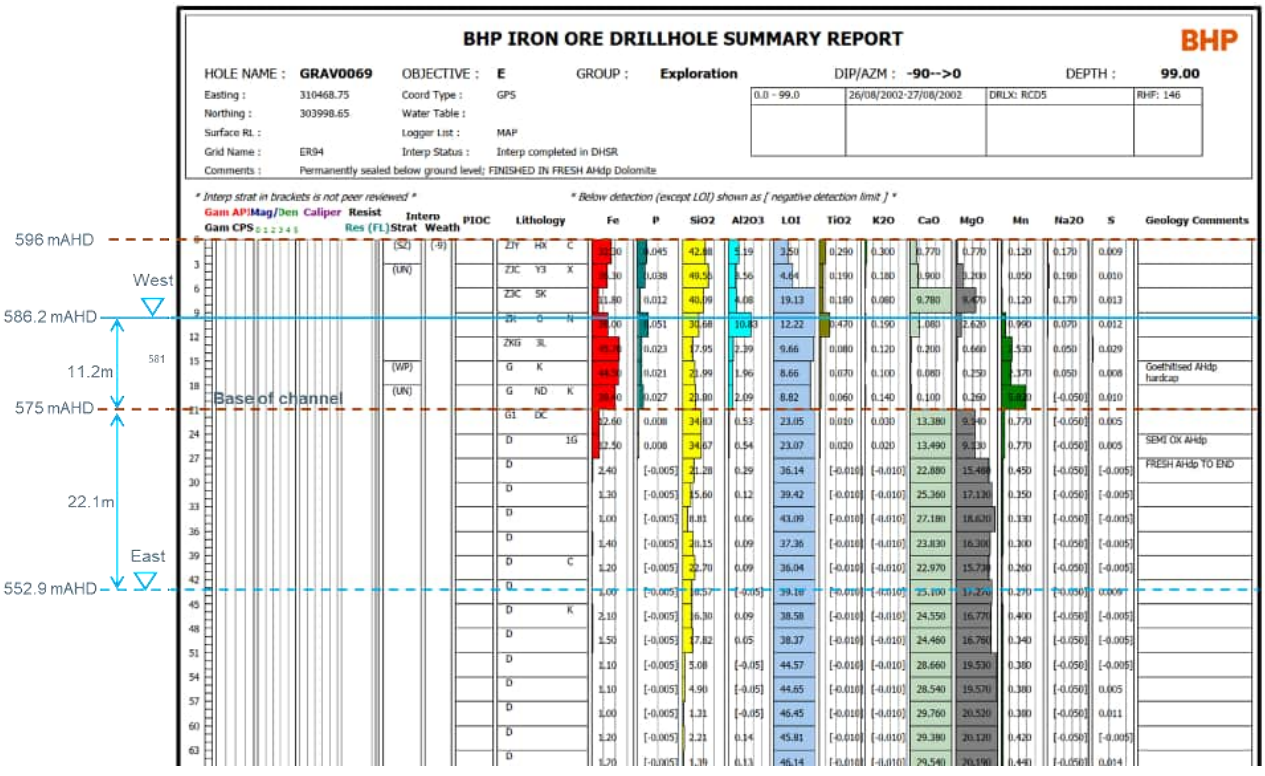

Figure 9: Drill hole GRAV0069 annotated with east and west water table elevations and interpreted base of erosional channel.

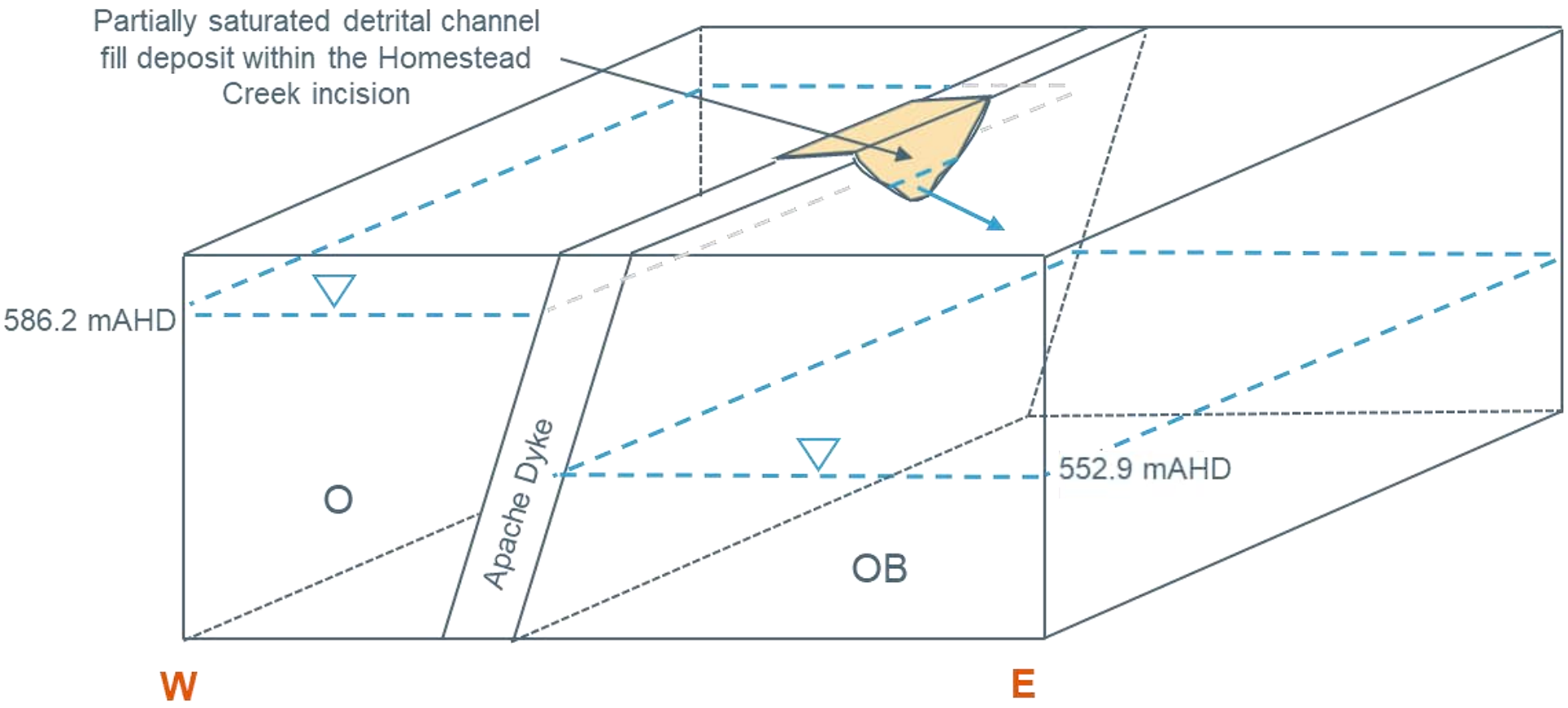

Figure 10: Simplified conceptual model illustrating the head difference and erosional channel across the Apache dyke between the east and west compartments. Not to scale.

Conclusions

Based on the above assessment and conceptualisation, the groundwater drawdown associated with the OB32BWT Proposal and Homestead Potable Borefield is expected to be confined to the eastern side of the Apache Dyke.

References

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