Technical Memorandum

Date	July 2022
To	Eve Drain, Superintendent Environmental Approvals
From	Gareth Price, Principal Modeller Water Planning
CC	Nicole McAlinden, Principal Environment Approvals
Subject	Orebody 32 East 2022 groundwater modelling update

1. Purpose

To update the hydrogeological assessment for Orebody 32E (OB32E) undertaken in 2020 (BHP 2022a) to incorporate the revised numerical groundwater model, which was updated to support the OB24 *Rights in Water and Irrigation 1914* (RiWI) 5C licence amendment in February 2022 (BHP 2022b).

2. Background

The numerical model described in the *OB32 East and OB25 West Joffre: Detailed Hydrogeological Assessment* (BHP 2022a) was completed in November 2020 ('2020 model'). Since then, it has been updated to support the OB24 5C licence amendment in February 2022 (BHP 2022b) ('2022 model'). Major changes were made to the model to incorporate the OB24 orebody aquifer and calibrate (also referred to as history matching) the model to OB24 groundwater level data. The data shows that, to date, drawdown of up to 50 m from dewatering of the local OB24 aquifer has not propagated to the south (i.e. into the regional aquifer between OB24 and OB32E) (Figure 1).

The main change pertinent to predictions of dewatering and drawdown from OB32E dewatering was the inclusion of very low permeability Mt McRae / Sylvia Formations between the OB24 orebody aquifer and the regional dolomite to the south (which is hydraulically connected to the OB32E orebody). This resulted in the model over predicting drawdown in the OB32E / Homestead East area from operation of the Homestead borefield. This was rectified by changing the storage (increasing) and hydraulic conductivity (reducing) settings of the regional dolomite and OB32E orebody aquifer.

The changes have resulted in a model (2022 model) that represents the regional hydrogeology more adequately than the 2020 model (which allowed drawdown to propagate much more readily into the northern part of the model than was observed).

Because the changes have been so material to the structure of the model, the original predictions for OB32E dewatering rates and drawdown were reviewed. This memo describes the predictions for OB32E from the 2022 model and provides a summary of the model update and calibration. A more detailed description of the 2022 model update is in *Eastern Ridge – OB24 Hydrogeological Assessment* (BHP 2022b).

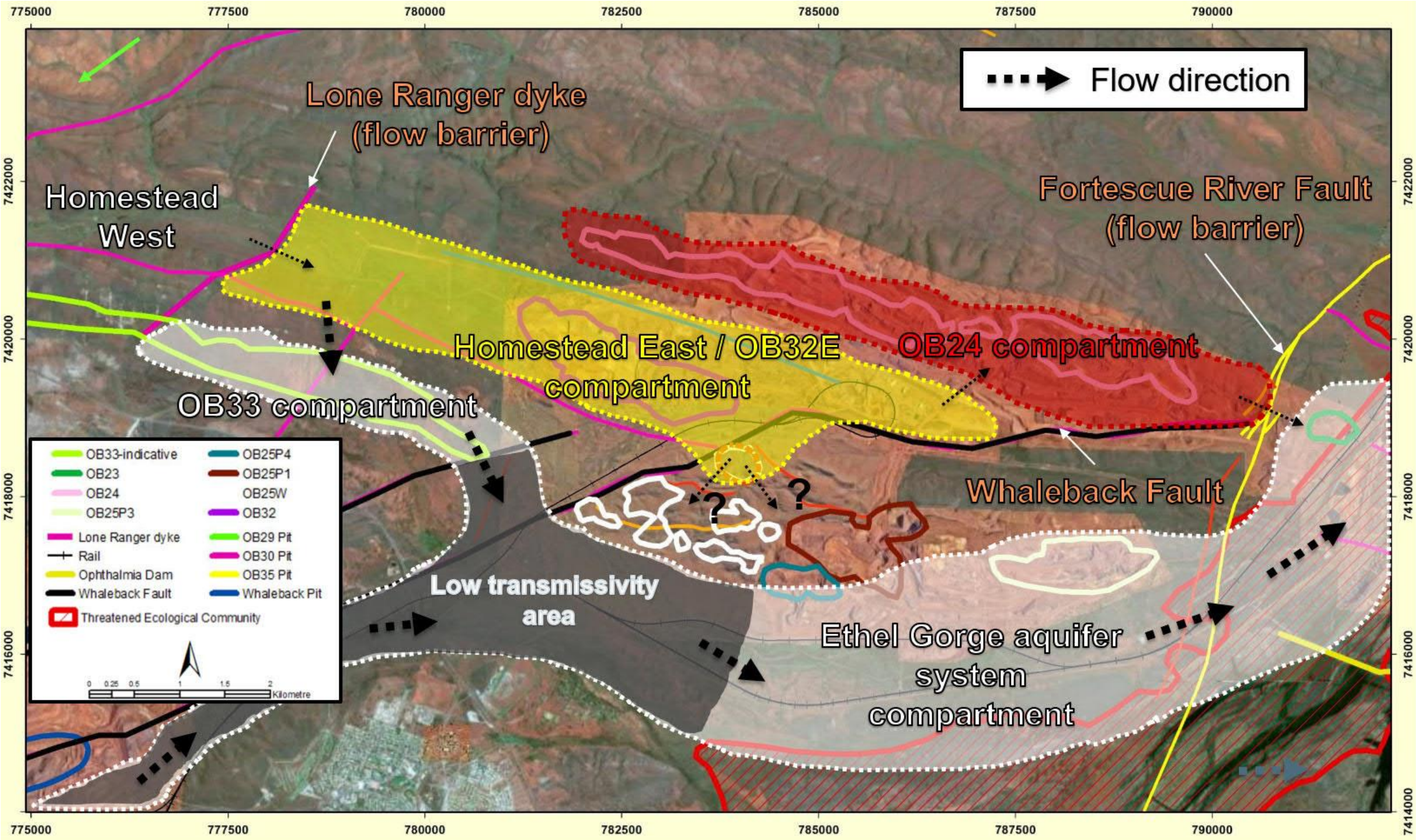

Figure 1 Pre-development conceptual model

3. 2022 model update

The following changes were made to the numerical model to accommodate the OB24 data:

- The model was extended to the east (Figure 2) to incorporate the full aquifer compartment associated with OB24 (Figure 1)
- The hydrostratigraphic zones were updated in the area of OB24 based on the latest mining geological and resource models (this included delineation of the Mt McRae / Sylvia Formations south of OB24)
- The low permeability Lone Ranger dyke was extended to the north east and south west
- The simulation time was extended up to October 2021
- Homestead Borefield abstraction was extended to October 2021 and abstraction for OB24 dewatering was included (Figure 3).

These changes resulted in significant over prediction of observed drawdown in the OB32 / Homestead East area. The following changes were made to the model to improve the calibration in this area, specifically:

- Specific Yield:
  - Dolomite north of OB32E (south of OB24) increased from 10% to 15%
  - Dolomite north of OB33 increased from 6% to 15%
  - OB32 mineralised orebody increased from 6% to 12%
  - OB32 sub-mineralised orebody increased from 2% to 6%
- Hydraulic conductivity:
  - Dolomite north of OB32E (south of OB24) decreased from 20 m/d to 2 m/d
  - Lone ranger dyke:
    - northern extent decreased from 0.0007 m/d to 0.0001 m/d
    - southern extent increased from 0.0001 m/d to 0.0025 m/d.

The changes to parameters follow a clear pattern; storage (Specific Yield) has been increased and hydraulic conductivity decreased. This is in response to the fact that the addition of the low hydraulic conductivity Mt McRae / Sylvia Formations between OB24 and OB32E reduced the area that could contribute groundwater to the Homestead East production bores. The adjustments described above therefore provided far more available water close to the borefield than in the 2020 model and reduced the drawdown footprint from Homestead East abstraction (as per the observed drawdown).

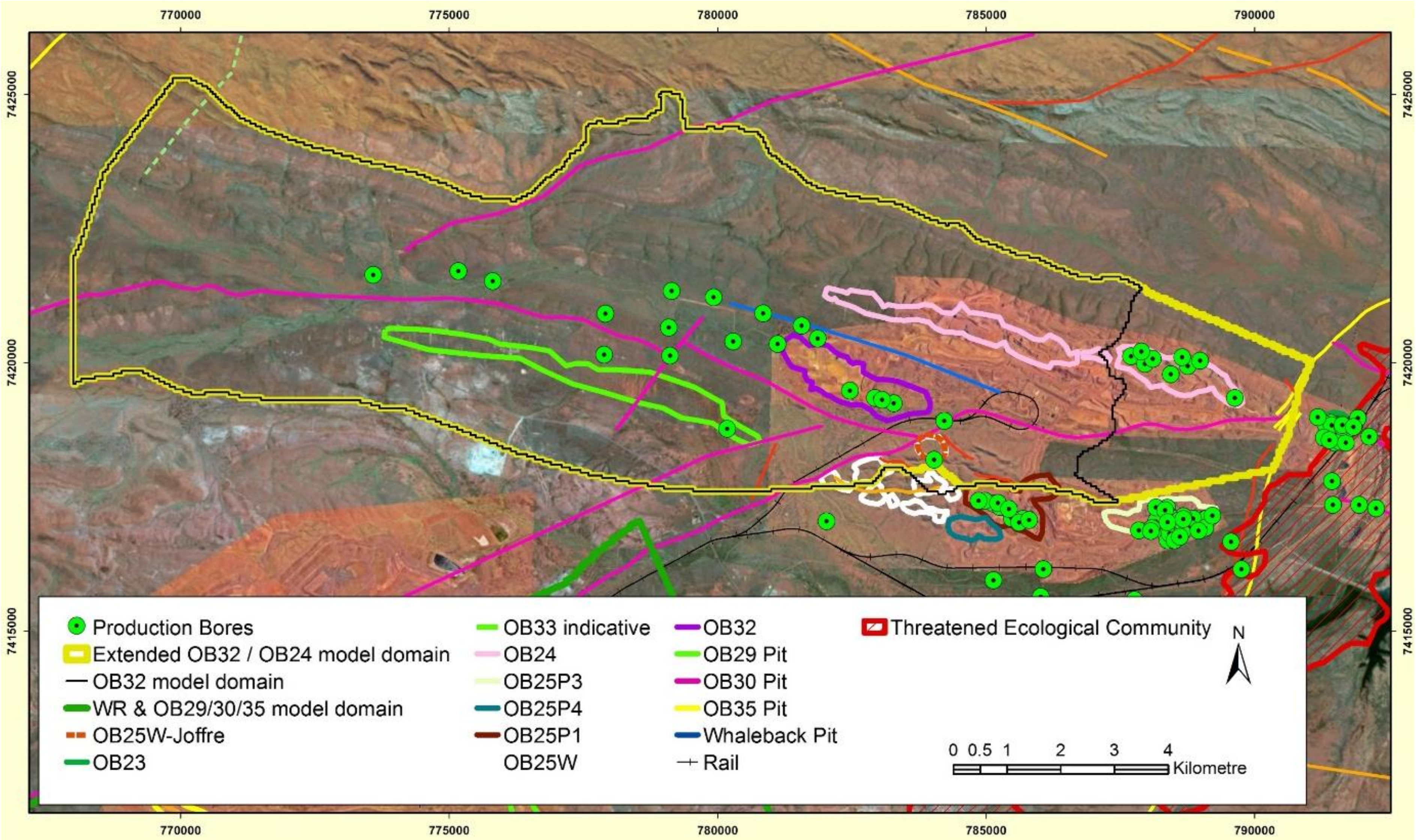

Figure 2 2020 and 2022 model domains

Figure 3 Calibration data – abstraction

4. 2022 model calibration

The calibration performance is shown as hydrographs in Figure 4 and Figure 5. These data are compared against the 2020 model calibration (in the area of OB32E).

A single predictive uncertainty run was undertaken with the 2022 model (included in Figure 4 and Figure 5). In this model the Specific Yield of the regional dolomite north of OB32E was increased to 30% (from 15%). This run was intended to provide an upper limit on dewatering, much like the high dewatering cases run with the 2020 model. The calibration performance of the 2022 uncertainty model was assessed to see whether this higher storage would invalidate the calibration and therefore whether dewatering predictions from this run should be considered feasible.

The results for the 2022 model calibration in the OB32E area (Figure 4) compared to the 2020 model calibration (BHP 2022a) show the following:

- The 2022 model calibration is quite similar to the 2020 model calibration in many locations. The main differences are down to the “smoothness” of the simulated water level decline in the 2022 model, versus the actual, which shows more variation (as did the 2020 model calibration).
- The 2022 calibration is much closer to the observed than the 2020 calibration at one of the dolomite bores (HST0397RM).
- The 2022 calibration produces initial heads that are approximately 1 m lower than the 2020 calibration.

The stress periods used in the 2020 and 2022 models are roughly the same (yearly) for most of the simulation. Therefore, the smoothness of the predicted drawdown in the 2022 model is most likely a function of the lower hydraulic conductivity and higher storage rather than any other reason. With higher hydraulic conductivity and lower storage, the 2020 model simulates the observed variations well, particularly in the OB32E orebody aquifer. This suggests that whilst the 2022 model has appropriate parameter values for the primary hydraulic conductivity (i.e. that associated with the rock itself), there may be significant fracture flow (i.e. secondary hydraulic conductivity) that is not represented in the model. This will become more apparent when OB32E dewatering commences.

In the Homestead East and OB33 areas (Figure 5):

- The 2022 calibration is equivalent to the 2020 calibration.
- The 2022 calibration reproduces the observed variations in drawdown / recovery much more closely than those in the OB32E area.

The predicted hydrographs from the 2022 uncertainty run are very similar to the 2022 calibrated model in the Homestead East and OB33 areas. In the OB32E area the 2022 uncertainty run simulates less drawdown than the calibrated 2022 model, but still produces a relatively good fit in many of the bores. This suggests that the 2022 uncertainty case represents a feasible upper bound for the dewatering predictions.

According to the *Australian groundwater modelling guidelines* (Barnett et al 2012), the Scaled Root Mean Square (SRMS) provides an appropriate statistical indication of the goodness of fit between simulated and observed groundwater levels. The SRMS for each of these models is:

- 2020 calibrated model: 2.8%
- 2020 uncertainty model (run 3): 2.5%
- 2022 calibrated model: 3.8%
- 2022 uncertainty model: 4.1%.

This shows that the 2022 model does not perform as well as the 2020 model in this measure, but the goodness of fit is still acceptable according to the guidelines.

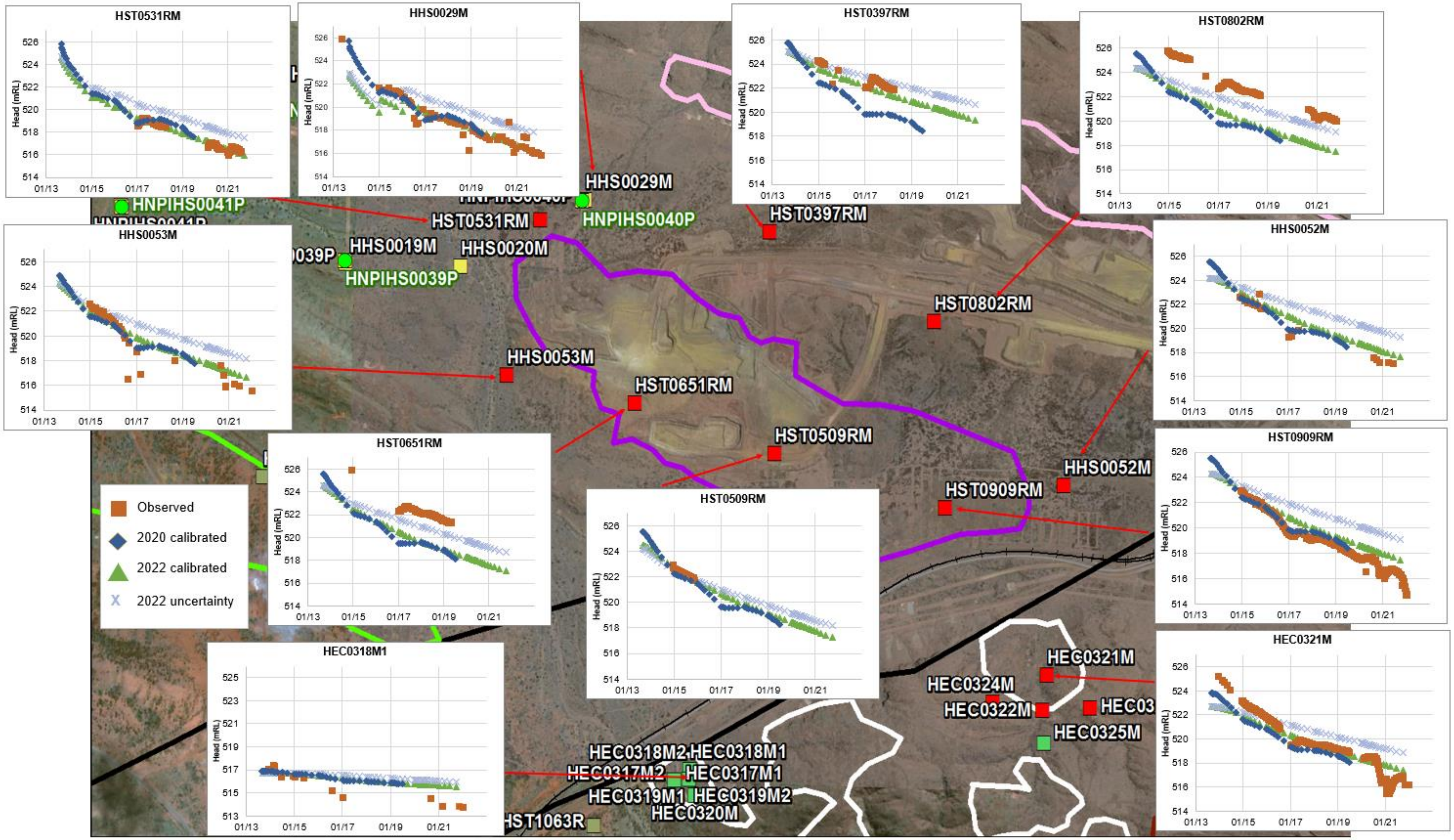

Figure 4 Calibration performance in the OB32E area

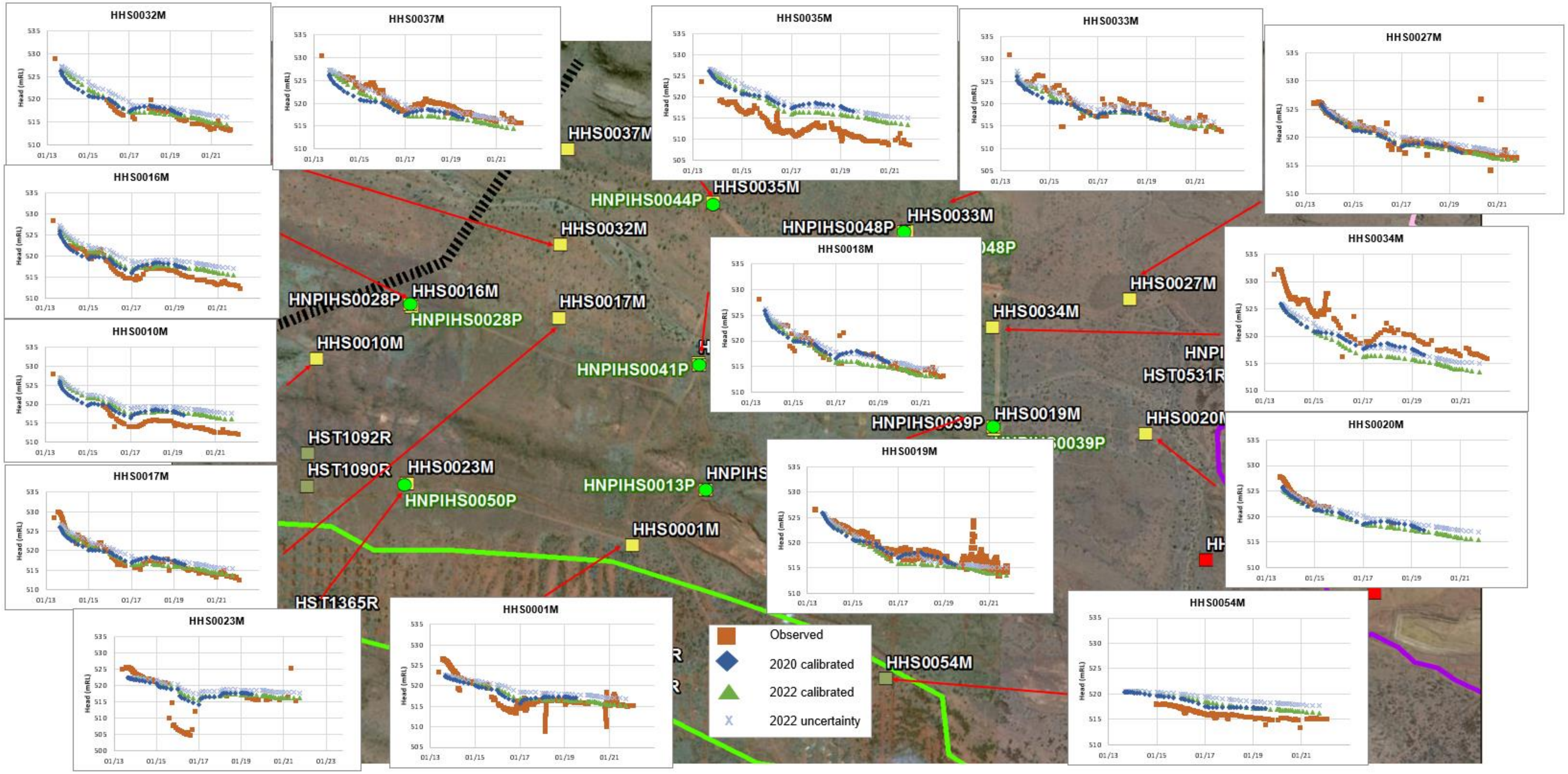

Figure 5 Calibration performance in the Homestead East / OB33 areas

5. Dewatering predictions

The 2022 model was run for 27 years from Financial Year (FY) 22 to FY49. The predicted dewatering rates from the 2020 and 2022 models are shown in Figure 6. This includes Run 1 and Run 3 of the 2020 model (corresponding to the calibrated and highest (uncertainty) dewatering rate runs respectively) and the 2022 model calibrated and uncertainty runs.

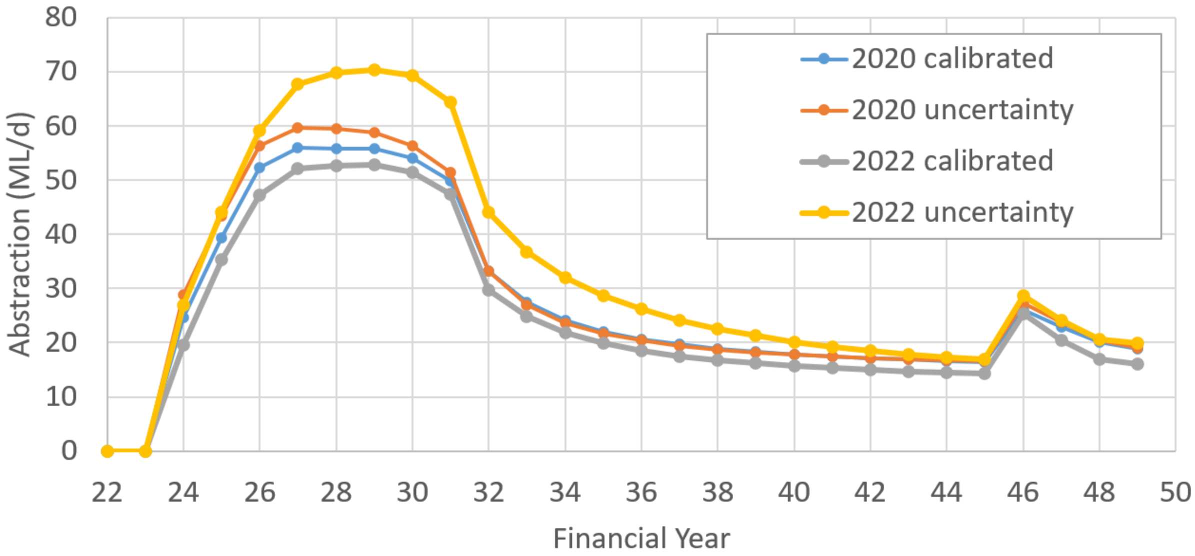

Figure 6 Dewatering predictions

Figure 6 shows that:

- The 2022 calibrated model produces a slightly lower maximum dewatering rate than the 2020 calibrated model.
- The 2022 uncertainty model produces a maximum dewatering rate of 70 ML/d compared to the maximum of 60 ML/d in the 2020 uncertainty model.
- The overall trend with time is similar for the 2020 and 2022 models.

Predicted drawdown in FY49 from the 2020 calibrated model and the 2022 uncertainty model is shown in Figure 7 and Figure 8.

The 2020 calibrated model (Run 1) is shown as this produced more regional drawdown than the 2020 uncertainty model (Run 3). However, as described in *OB32 East and OB25 West Joffre: Detailed Hydrogeological Assessment* (BHP 2022a), the main uncertainty associated with drawdown in the south (in the OB33 area and along the flow path to Ethel Gorge) comes from the boundary condition in that area. This uncertainty, and the findings from the 2020 model are the same for the 2022 model, as there has been no change to the boundary condition and no significant changes to the parameters in the OB33 area.

Figure 7 and Figure 8 show that the 2022 model predicts much less regional drawdown than the 2020 model, particularly in the north and west. This is due to three factors:

- the lower hydraulic conductivity in the regional dolomite aquifer
- the low hydraulic conductivity Mt McRae / Sylvia Formations between the regional dolomite aquifer and OB24.
- the extension of the Lone Ranger dyke to the south west and north east.

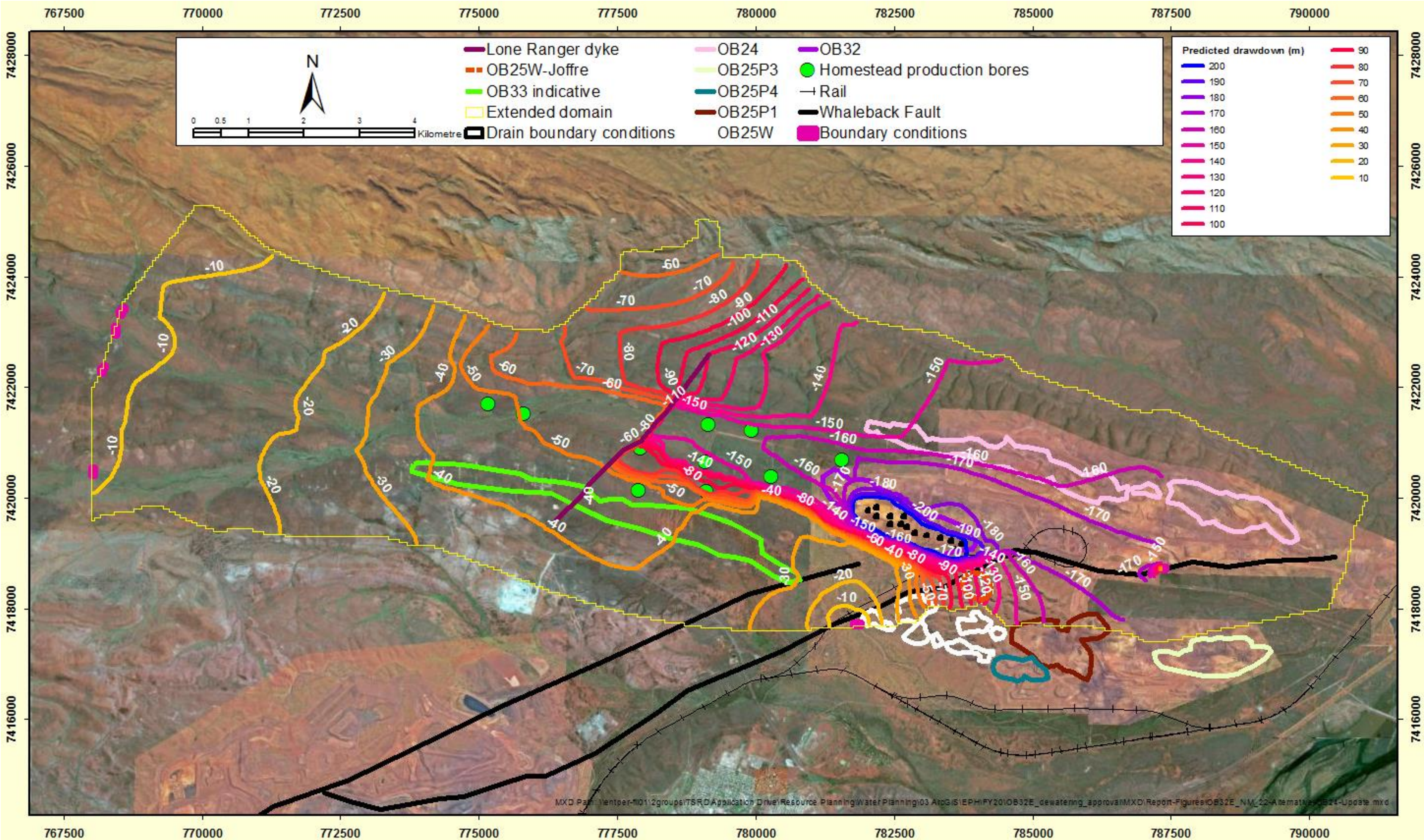

Figure 7 Predicted drawdown at FY49 - 2020 calibrated model (Run 1)

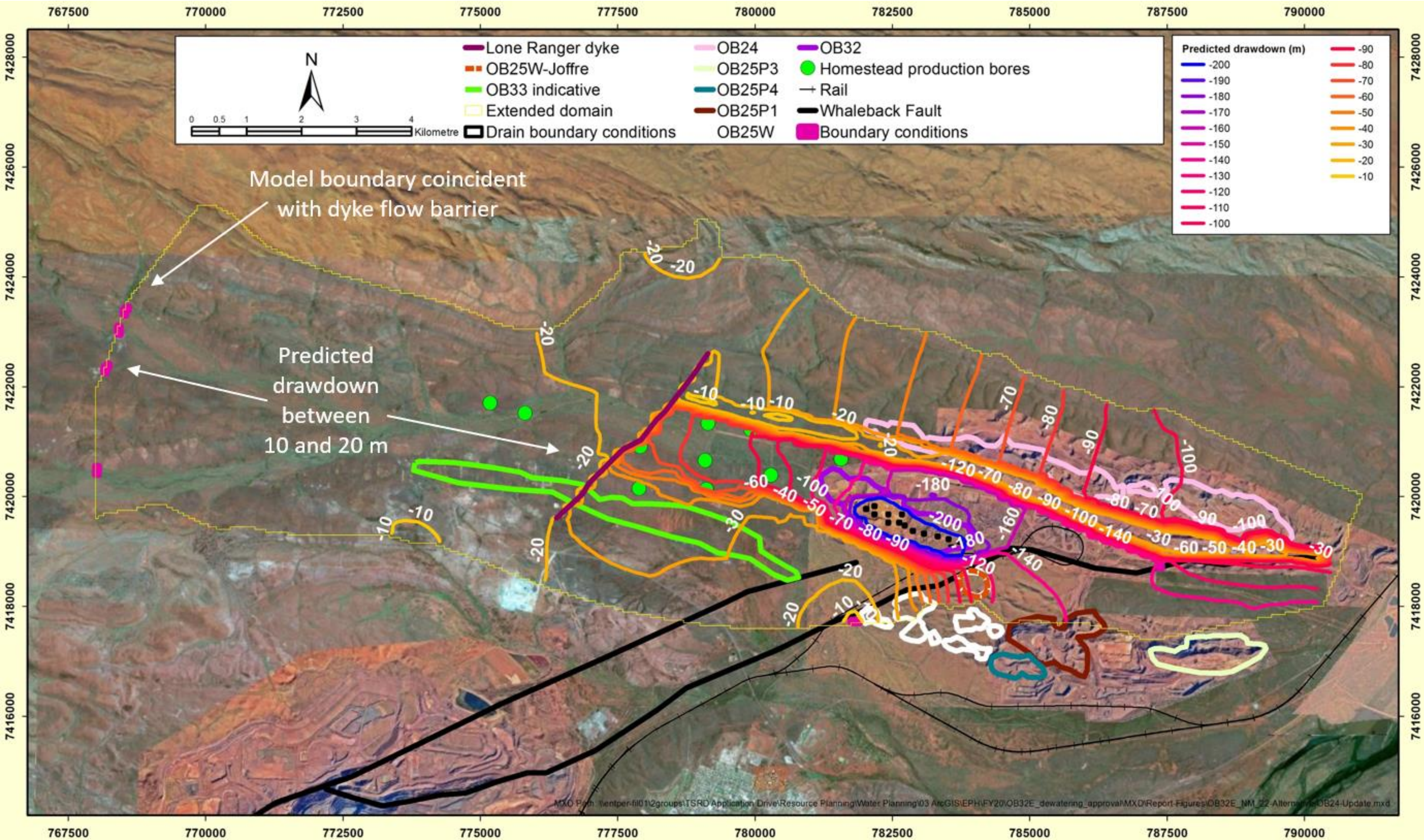

Figure 8 Predicted drawdown at FY2049 - 2022 uncertainty model

6. Groundwater level recovery

Several closure scenarios were run with the 2020 model. These showed that the OB32E groundwater system would take from 50 to 200 years to fully recover if the void is backfilled. The main uncertainties were rainfall recharge over that period and the amount of inflow that could enter the system from the Ethel Gorge aquifer compartment. Therefore the closure predictions would be very similar with the 2022 model as these settings were not changed.

7. Conclusion

Given what is now known about the OB24 orebody, all of these updates to the numerical groundwater model (the 2022 model) are considered to represent the OB32E / Homestead East and OB24 hydrogeological system more accurately than the 2020 model.

However, this update does not fundamentally change the outcomes and conclusions from the 2020 modelling. It does however extend the highest (uncertainty) dewatering rate from 60 ML/d to 70 ML/d, with comparable drawdown to the south and less drawdown everywhere else.

8. References

Barnett et al (2012) *Australian groundwater modelling guidelines*, Waterlines report, National Water Commission, Canberra.

BHP (2022a) *OB32 East and OB25 West Joffre: Detailed Hydrogeological Assessment*. January 2022.

BHP (2022b) *Eastern Ridge - OB24 Hydrogeological Assessment*. February 2022.