Uley South groundwater model scenarios 2020

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Government
of South Australia

Department for
Environment and Water

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Foreword

The Department for Environment and Water (DEW) is responsible for the management of the State's natural resources, ranging from policy leadership to on-ground delivery in consultation with government, industry and communities.

High-quality science and effective monitoring provides the foundation for the successful management of our environment and natural resources. This is achieved through undertaking appropriate research, investigations, assessments, monitoring and evaluation.

DEW's strong partnerships with educational and research institutions, industries, government agencies, regional Boards and the community ensures that there is continual capacity building across the sector, and that the best skills and expertise are used to inform decision making.

John Schutz
CHIEF EXECUTIVE
DEPARTMENT FOR ENVIRONMENT AND WATER

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Summary

This document summarises two model scenarios run with the Uley South groundwater model (DEW, 2020). The scenarios were requested by SA Water and assess the impact of future pumping and recharge on groundwater level and seawater intrusion in the Uley South Basin. Groundwater from the Uley South Basin is the main source of municipal water supply on the Eyre Peninsula, with current extraction of ~5 GL/y. Low rainfall and recharge conditions and declining groundwater levels have raised the risk profile for groundwater resources in Uley South in recent years, and SA Water has announced plans for a desalination plant to secure future water supply. This will reduce the reliance on groundwater resources in the basin, lowering the risk profile.

The scenarios use the Uley South groundwater model, developed by DEW (2020). The model was developed in MODFLOW and the position and movement of the seawater interface is simulated with the SWI2 package. The model was recalibrated as part of this exercise following recommendations in the original model report, however for consistency scenarios are run using both the original and recalibrated models. The scenarios assume low rainfall/recharge conditions observed from 2015–19 persist into the future, with the five years of recharge rates repeated on a cycle to 2040. Scenario 1 simulates a pumping rate of 3.5 GL/y from town water supply (TWS) wells, while scenario 2 simulates a pumping rate of 6.8 GL/y.

Results show in scenario 1 an ongoing slight decline in groundwater level, however groundwater levels do not decline to historic lows observed in the late 1990s. Accompanying the minor long-term decline in groundwater level is a projected long term increase in the movement of the seawater interface inland, by a maximum of ~300m by 2040. In scenario 2, groundwater levels decline close to and in some cases below the historic lows observed in the late 1990s, when an increase in salinity was observed in the adjacent town water supply well. Scenario 2 results in further inland movement of the seawater interface by up to 600m.

1 Introduction

1.1 Background

Groundwater is a critical source of water for the Eyre Peninsula, making up the majority of water sourced for municipal supply (EPNRMB, 2016). Groundwater from the Quaternary Limestone (QL) aquifer in the Uley South Basin provides most of this supply, with average annual extraction of approximately 5 GL (Figure 1.1). In 2018 SA Water contracted the Department for Environment and Water (DEW) to develop a groundwater flow model for the Uley South Basin. The model was used to assess the impact of various groundwater extraction and rainfall/recharge scenarios on groundwater levels in the basin. The model also simulated the position and movement of the seawater interface using the SWI2 package (Bakker et al. 2013).

The model was calibrated to groundwater level measurements from 1961 to 2017, and scenarios run from 2018 to 2040. Since modelling was completed, low rainfall and recharge conditions have persisted, and groundwater levels have continued to decline. A desalination plant is planned for the Eyre Peninsula, however groundwater resources in the Uley South Basin remain the main source of supply for the region until a plant is operational.

1.2 Objectives

The objective of this report is to document two additional model scenarios requested by SA Water, to assess the impact of pumping under continued low recharge conditions on groundwater level and seawater intrusion. Scenarios assess the impact of pumping 3.5 GL/y - assuming supply is augmented by a desalination plant - and 6.8 GL/y - assuming pumping increases.

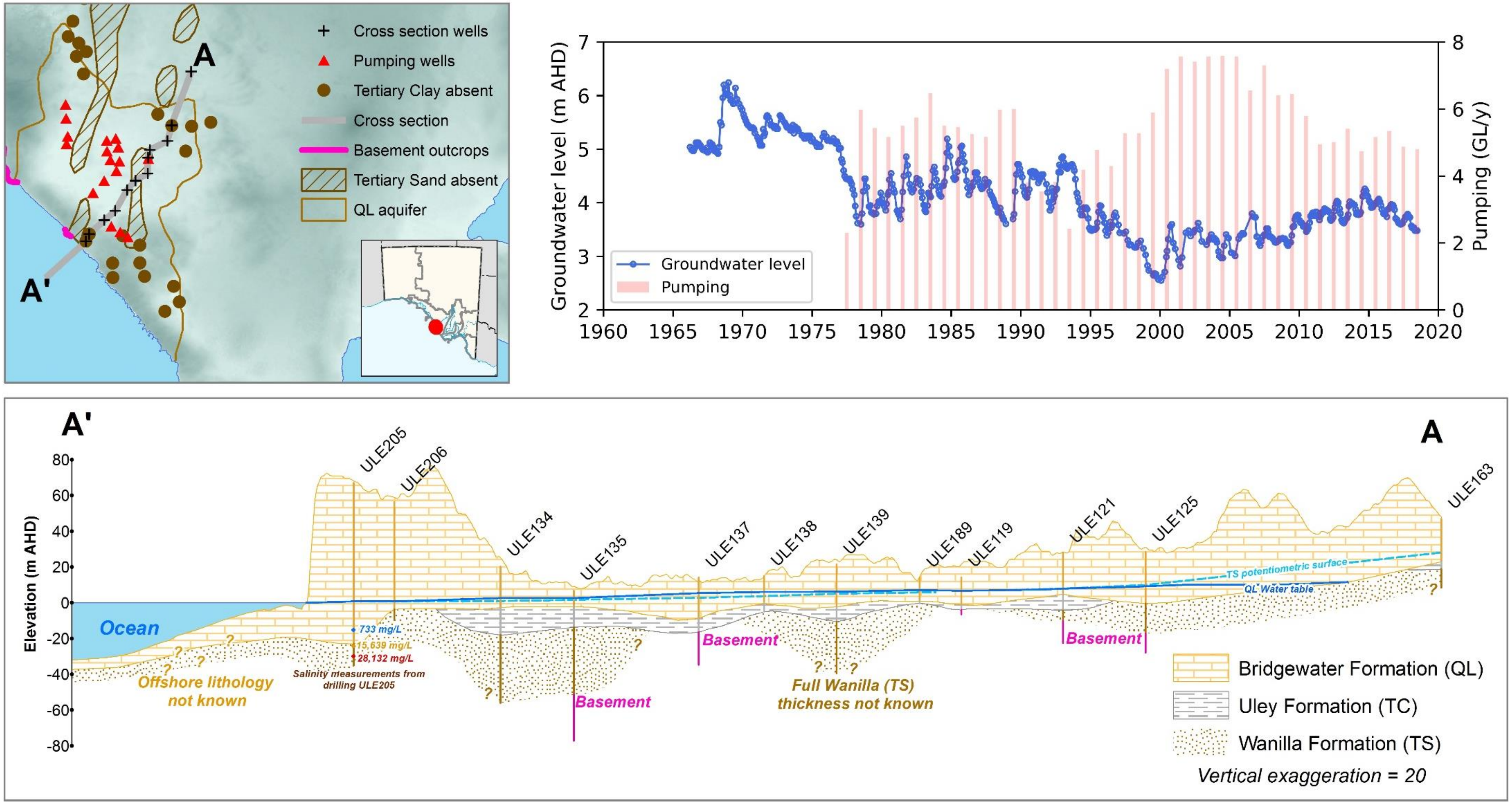


Figure 1.1. **The Uley South Basin**

2 Method

2.1 Recalibration

The Uley South groundwater model (DEW, 2020) was developed and calibrated to the best available information at the time. Based on the work undertaken, several recommendations for future work on the model were made. One of these recommendations related to aquifer parameters in the Tertiary Sand (TS aquifer). Specific storage values for the TS aquifer were based on values from Morton and Steel (1968), as well as values from previous models of the area, and the broader literature (e.g. De Marsily, 1986). However during the development of the model a new study (Rau et al. 2018) showed that $1.3 \times 10^{-5}\ m^{-1}$ is likely to be a physically plausible upper bound for specific storage (S_s) values in confined aquifers, and a recommendation to revisit TS parameters in future was made.

Based on this, the model was re-calibrated with new bounds on pilot points used to derive S_s values in the TS aquifer ranging from $1x10^{-7}$ to $1.3x10^{-5}$. Although six versions of the model were originally developed to test uncertainty in the conceptual model, only one version of the model, referred to as version 1c in DEW (2020), was recalibrated.

2.2 Scenarios

Model scenarios were developed in consultation with SA Water. Scenarios run from 2018 to 2040, with recharge for 2018 and 2019 based on recharge estimates from groundwater level fluctuations for those years, see DEW (2020) for more information on recharge determination in the model. For the remainder of the scenario, recharge from 2015–19 is repeated on a cycle, assuming low recharge conditions persist into the future. Scenario 1 simulates the impact of pumping 3.5 GL/y starting in 2018, while scenario 2 simulated the impact of pumping 6.8 GL/y from 2018 onwards (Table 2.1). The spatial distribution of pumping rates between the 17 pumping wells in the basin is based on the distribution used in the original model (Figure 1.1). Likewise, the temporal distribution in the scenarios is the same as the original model, with monthly stress periods and generally higher pumping during summer months (DEW, 2020).

Table 2.1. Model scenarios

Scenario	Pumping	Recharge
1	3.5 GL/y	Recharge based on 2015-19
2	6.8 GL/y	Recharge based on 2015-19

3 Results

3.1 Recalibration

Recalibration resulted in a slight improvement in model calibration statistics, with a root mean squared error values of 0.62 m, compared to 0.66 m in the original model (DEW, 2020). The recalibrated model produces a similar simulation of the position and movement of the seawater interface over time (Figure 2.1). The recalibrated model could be said to 'fit' the data on seawater interface position slightly better, however this data is based on measurements of salinity with a YSI Sonde in a long screened well (SLE069), which straddles the QL and TS aquifers, and uncertainty regarding the position of the interface remains (Inverarity, 2019). The location of observation wells is shown in Appendix A, while measured and modelled groundwater levels at key observation wells for the recalibrated model are presented in Appendices B and C. The biggest differences between modelled groundwater levels following recalibration are in wells close to the boundary of the QL aquifer (e.g. SLE006 and ULE092, see Appendix A for location of observation wells) and in the TS aquifer, where lower storage values result in larger fluctuations and a better fit to observation data (e.g. ULE127, see Appendix B).

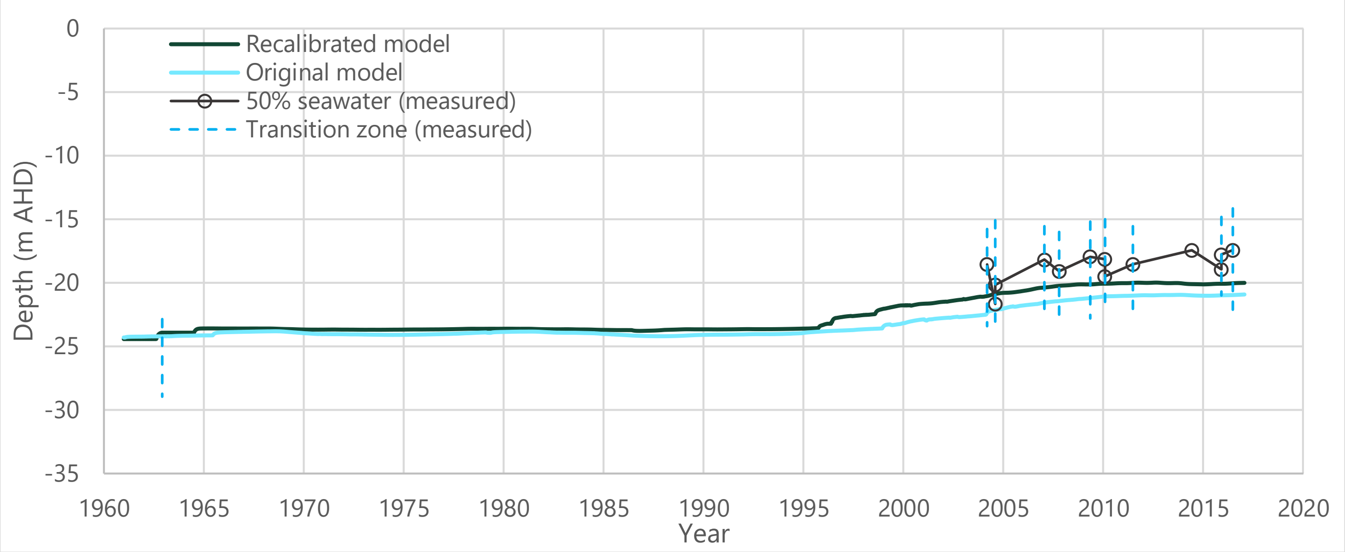


Figure 3.1. Simulated elevation of the seawater interface at SLE069 where measurements have been made

3.2 Scenarios - groundwater level

Modelled groundwater level results are presented for observation well ULE190 (Figure 3.2). This well is located adjacent to town water supply (TWS) well 3 (replaced by TWS well 20), see Appendix A for a map of observation well and pumping well locations. TWS3 showed an increase in salinity in the late 1990s as groundwater extraction increased and groundwater level decreased. This increase in salinity was attributed to increased flow from the underlying TS aquifer (DEW, 2020). Results from additional observations wells can be found in Appendix B and C.

Scenario 1 shows that groundwater levels generally remain stable in ULE190, with a slight declining trend towards 2040. However, levels remain well above the historic lows they declined to in the late 1990s.

In scenario 2 groundwater levels decline as a result of the increased extraction rate (Figure 3.2). A new 'equilibrium' water level appears to be reached by 2040 with groundwater levels fluctuating with the recharge cycle. However, this groundwater level is similar to those observed in the late 1990s, when salinity was observed to increase in the adjacent town water supply well.

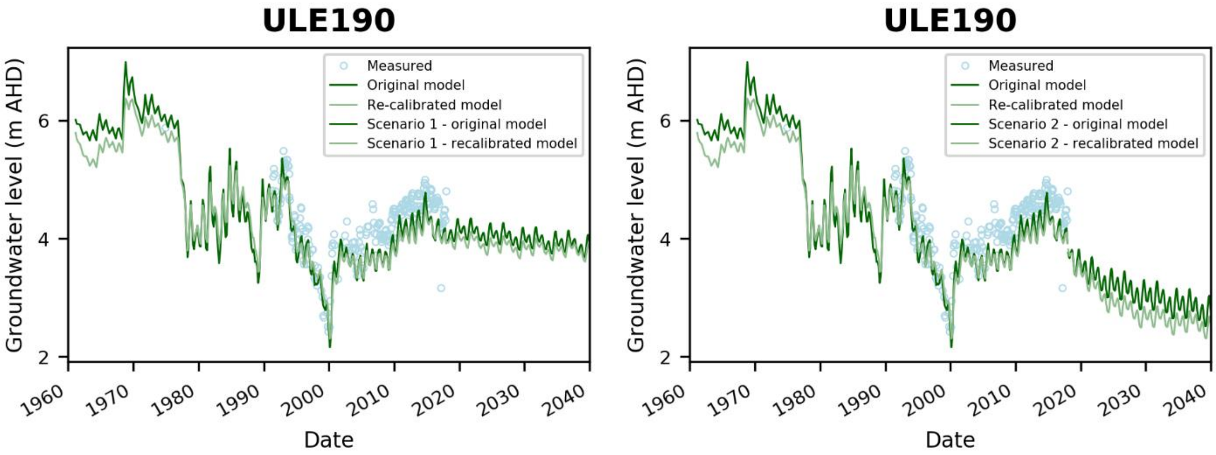


Figure 3.2. **Groundwater levels at UL190 for scenario 1 and 2**

3.3 Scenarios - seawater interface

Position and movement of the seawater interface was modelled using SWI2 (Bakker et al. 2013). Scenarios were run for both the original version of the model (v1c in DEW 2020) and the recalibrated model.

In scenario 1, where pumping reduces to 3.5 GL/y from 2018 to 2040, the interface shows an increase in elevation of 2.08 m in SLE069 (Figure 3.3). This movement can be related to the slight declining trend in groundwater level in scenario 1 (Figure 3.2).

In scenario 2 where pumping increases to 6.8 GL/y, the elevation of the interface in SLE069 increases by 4.3 m, associated with declining groundwater levels (Figure 3.4).

Figure 3.5 shows the position of the seawater interface toe – the location at which the interface intersects the base of the QL aquifer. This can be thought of as the furthest point inland that the interface extends. Results are shown for the recalibrated version of the model. In scenario 1 is seen to migrate up to 300 m further inland. In Scenario 2 the interface moves up to 600 m further inland.

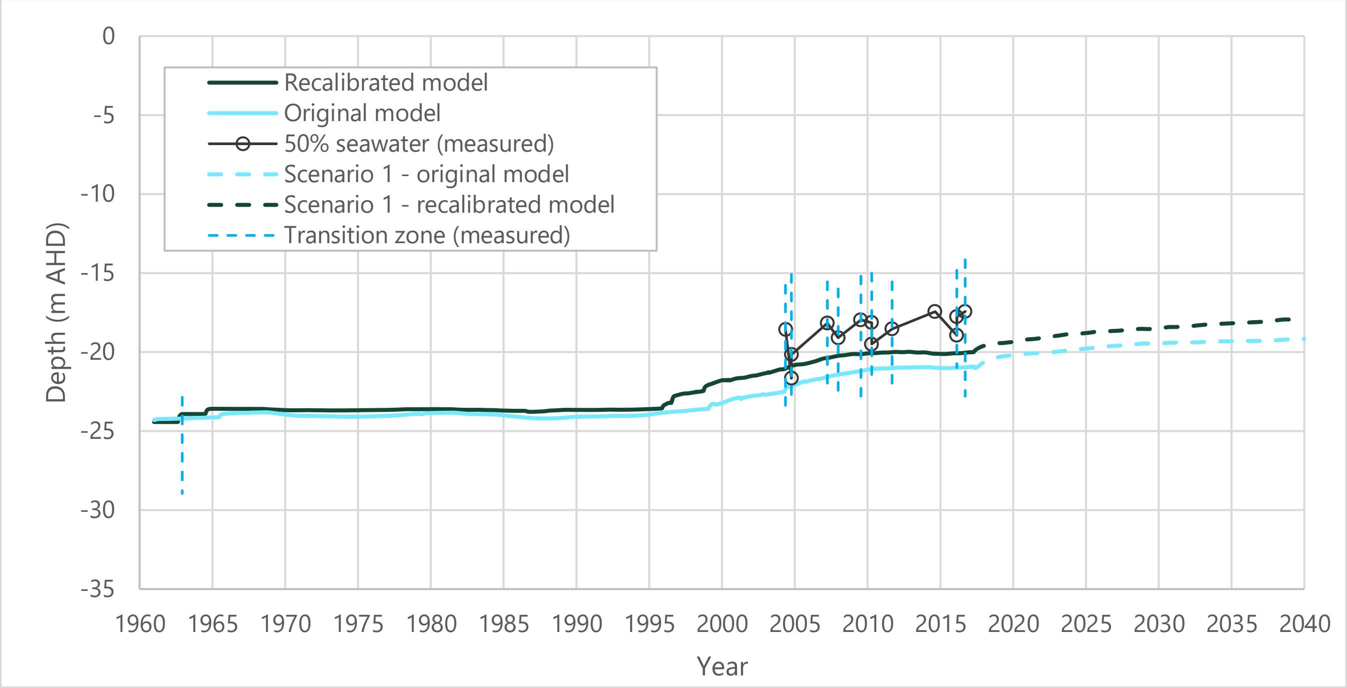


Figure 3.3. **Modelled seawater interface at SLE069 in Scenario 1, pumping 3.5 GL/y**

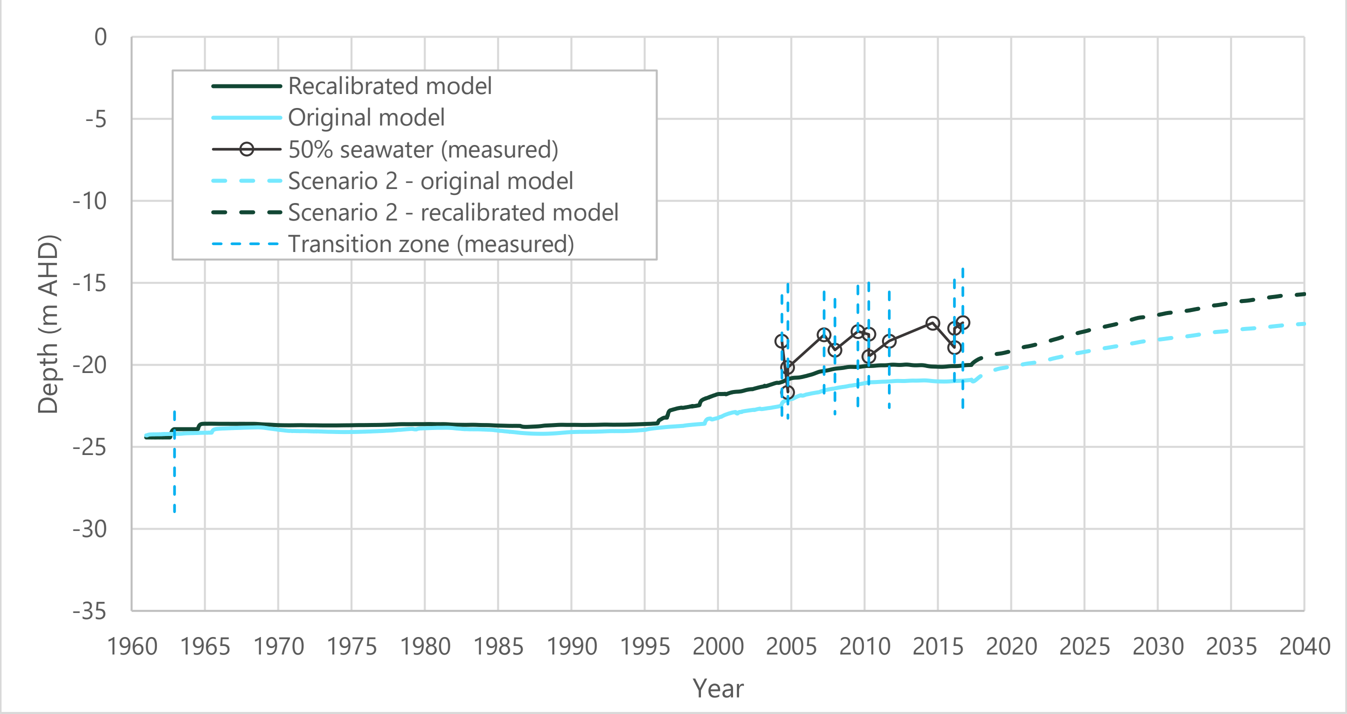


Figure 3.4. **Modelled seawater interface at SLE069 in Scenario 2, pumping 6.8 GL/y**

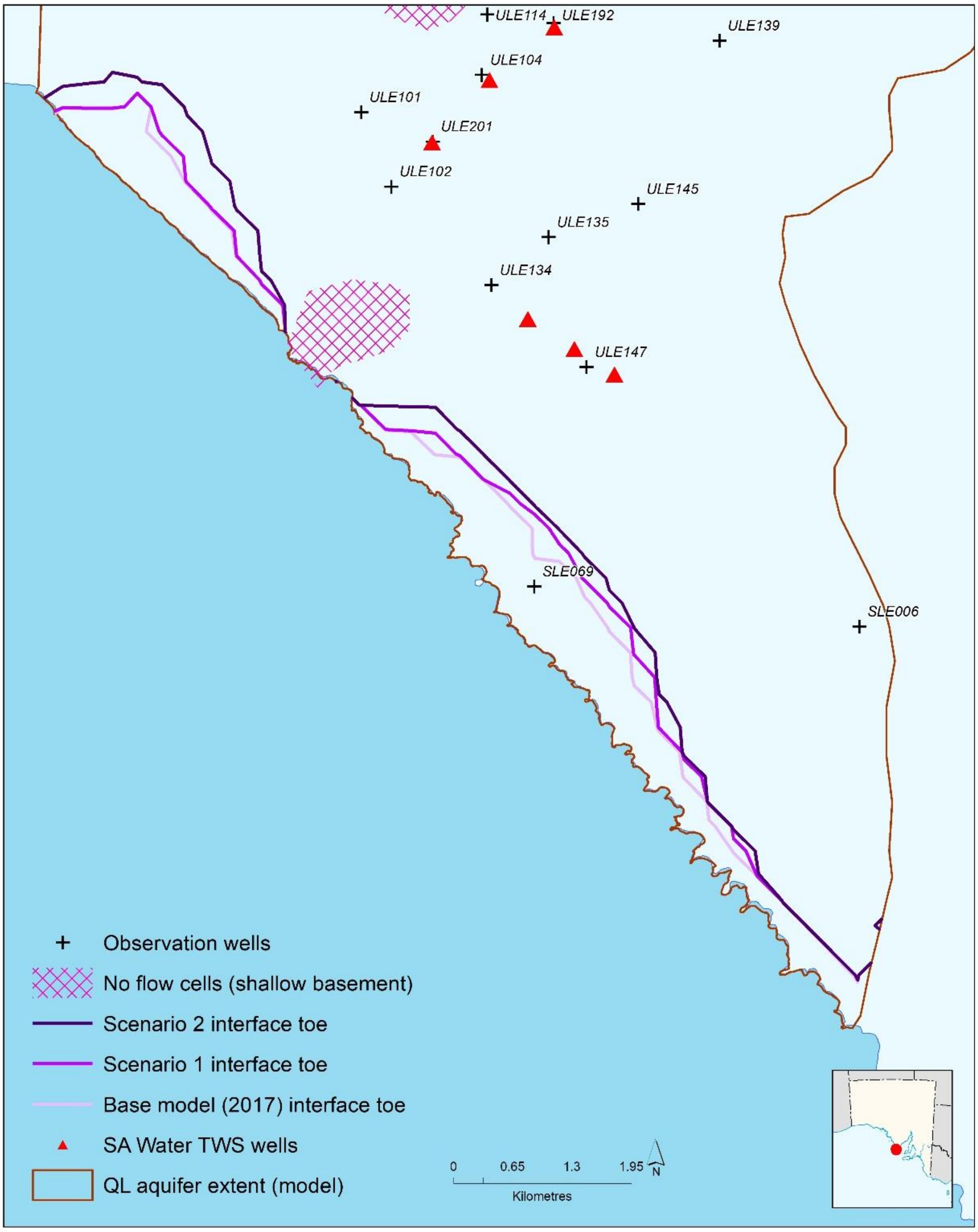


Figure 3.5. **Position of the seawater interface toe (recalibrated model)**

4 Conclusions and recommendations

4.1 Conclusions

Two scenarios were run with the Uley South groundwater model, to test the impact of future pumping and recharge on groundwater level and seawater intrusion.

Scenario 1 simulated the impact of pumping 3.5GL/y from 2018 to 2040, with low rainfall/recharge conditions from 2015–19 repeated on a cycle. The modelled seawater interface increased in elevation by 2.08 m in monitoring well SEL069, and moved up to 300 m further inland in the eastern half of the basin. Movement of the interface inland corresponds with a minor long-term decline in groundwater level, noting that levels are currently lower than historic levels in the 1960s-70s.

Scenario 2 simulated the impact of pumping 6.8 GL/y from 2018 to 2040, with low rainfall/recharge conditions from 2015–19 repeated on a cycle. The modelled seawater interface increased in elevation by ~4.3 m in monitoring well SEL069, and moved inland by up to 600 m in the eastern half of the basin. This inland movement of the interface corresponds with a decline in groundwater level due to increased pumping. Groundwater levels are also observed to decline to and in some cases below the historic lows observed in the late 1990s. This may result in more inflow from the TS aquifer with implications for salinity in TWS wells, separate from any issues related to seawater intrusion.

Therefore, continued low recharge conditions in Uley South may result in further inland movement of the seawater interface, even if groundwater pumping reduces. Increased pumping will result in groundwater level declines in some cases below historic lows observed in the late 1990s. This will result in increased seawater intrusion, and may have implications for salinity in TWS wells.

4.2 Assumptions and limitations

The Uley South groundwater model report (DEW, 2020) discusses the assumptions and limitations associated with the model in great detail. It should be reiterated here that the seawater interface is simulated using the SWI2 package in MODFLOW (Bakker et al. 2013). This package simulates a 'sharp interface', approximating the 50% seawater-freshwater isohaline, and does not simulate movement of seawater in the aquifer by diffusion or dispersion. Therefore, the results showing movement and position of the interface do not represent full dispersive mixing of seawater intruding in the aquifer, and thus results may be an underestimate of the extent of seawater intrusion for the model and scenarios considered here.

4.3 Recommendations

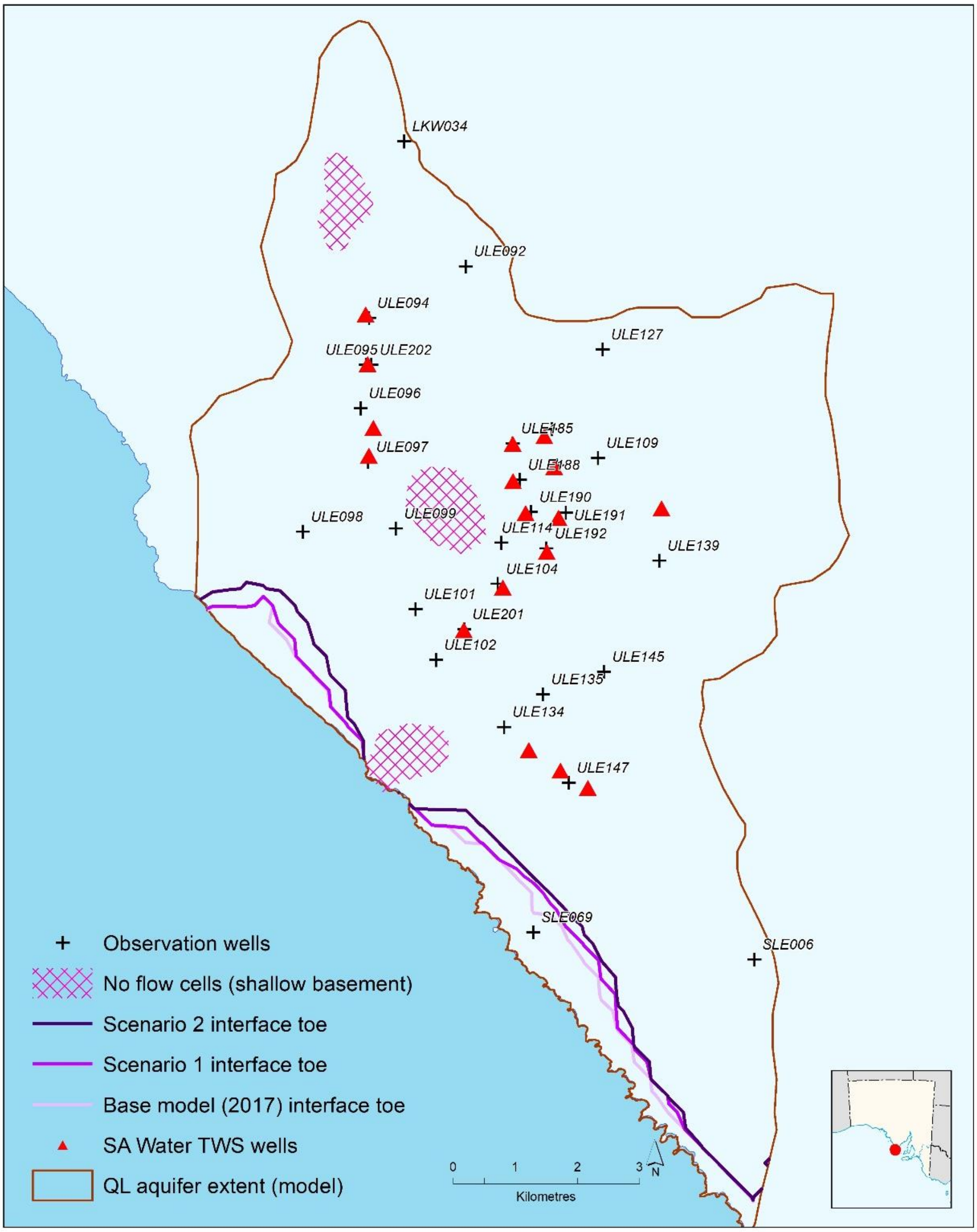
Several recommendations for additional monitoring and modelling related to the Uley South groundwater model work were made in DEW (2020). Some of these recommendations, such as consideration of different future recharge and a sudden increase in pumping rates, are carried out in this current piece of work. Additional recommendations in DEW (2020) are considered still valid and for convenience are included in Appendix D. Recommendations that relate directly to the work in this report are:

- These scenarios are based on the assumption that current low rainfall/recharge conditions persist into the future. They do not assess the potential impact of climate change projections on rainfall into the future. Previous modelling (DEW, 2020) included an analysis of climate change impacts on recharge. However, this has not been updated in this report. Further work considering climate change impacts on groundwater recharge in the Uley South Basin is recommended.

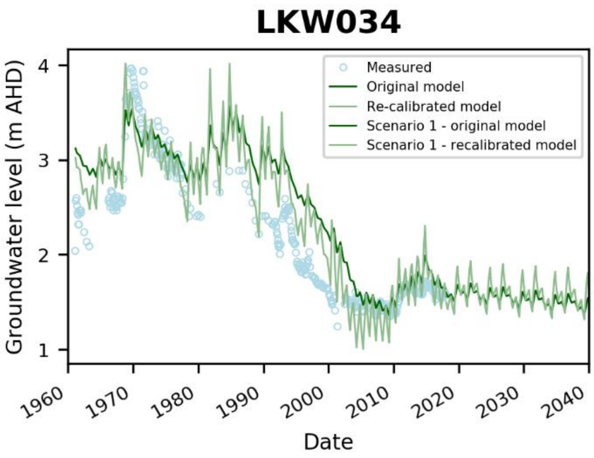
- The recalibrated version of the model performs well, and incorporates updated information on aquifer parameters. It is recommended that this version of the model be used in future work. However further work to assess parameter uncertainty associated with this new version, similar to uncertainty analysis conducted in the original model (DEW, 2020), is recommended.
- The scenarios simulate potential impacts for the given recharge assumptions up to 2040. Further movement of the seawater interface past 2040 may be expected for if low rainfall and recharge conditions persist. Consideration should be given to simulating impacts further into the future if continued extraction from Uley South Basin past 2040 is considered likely.

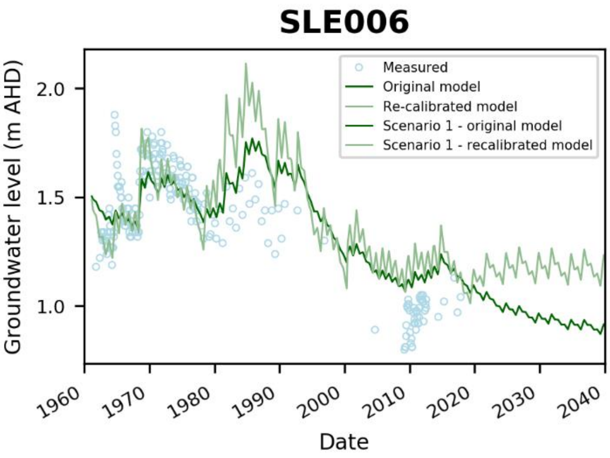
5 Appendices

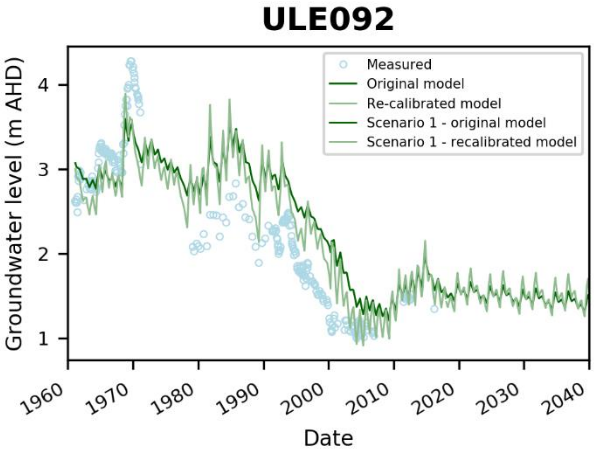
A. Observation well locations

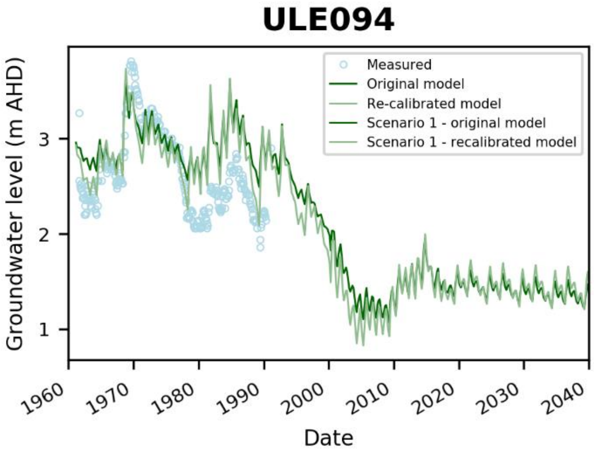


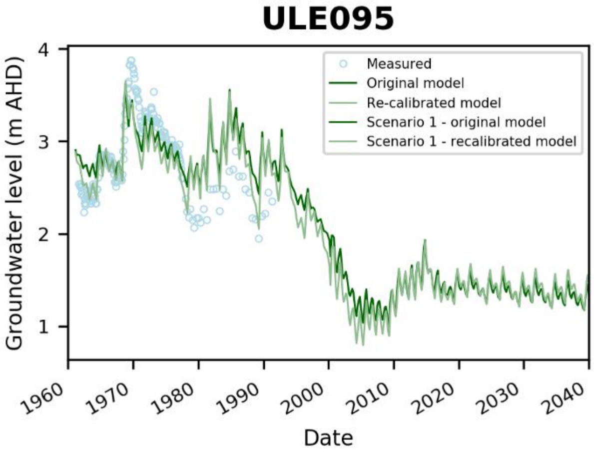
B. Scenario 1 groundwater level results

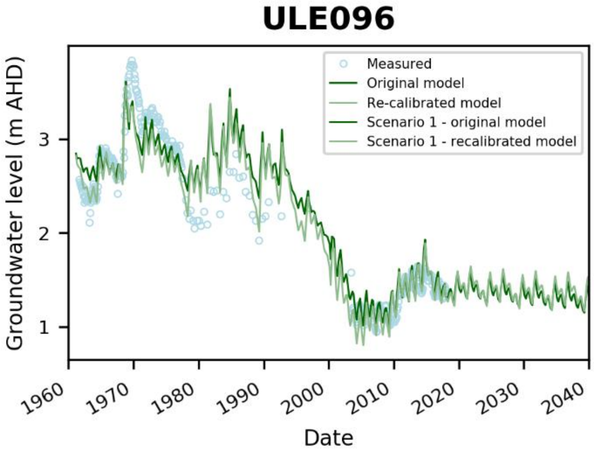


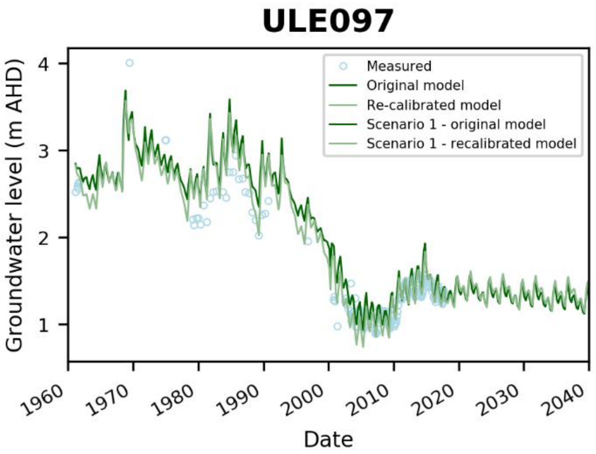








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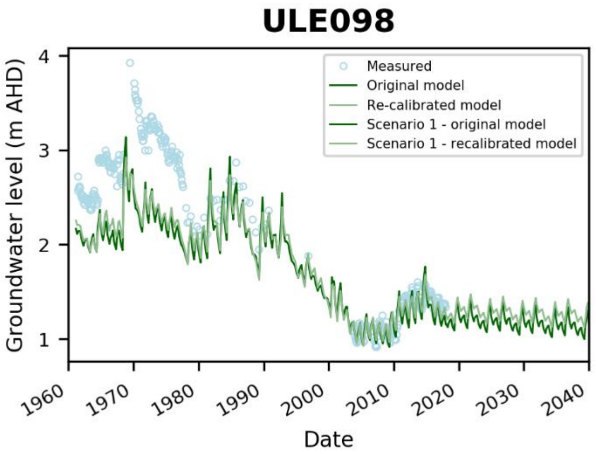
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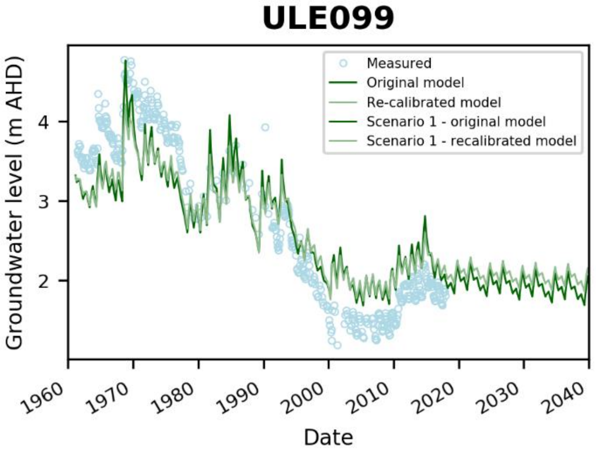
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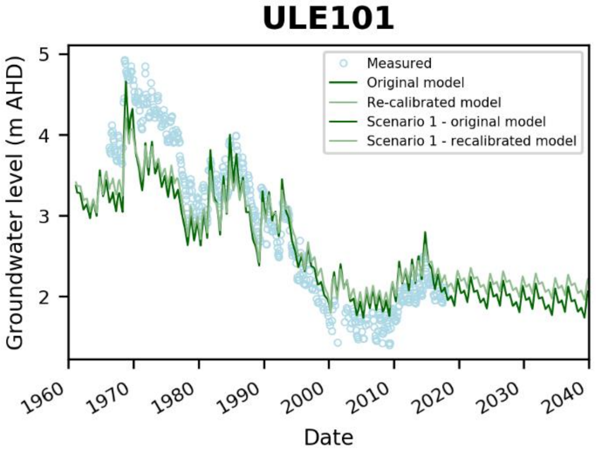
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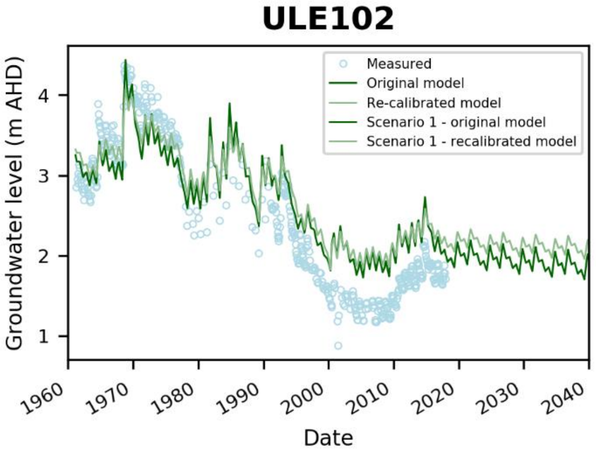
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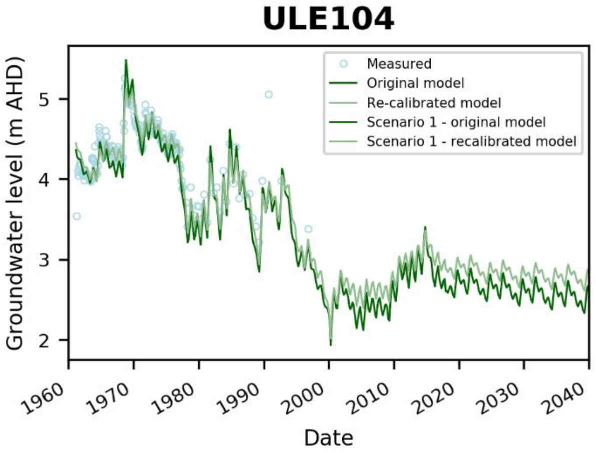
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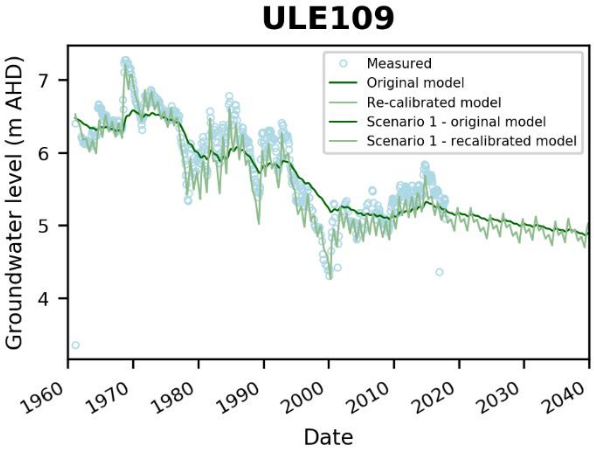

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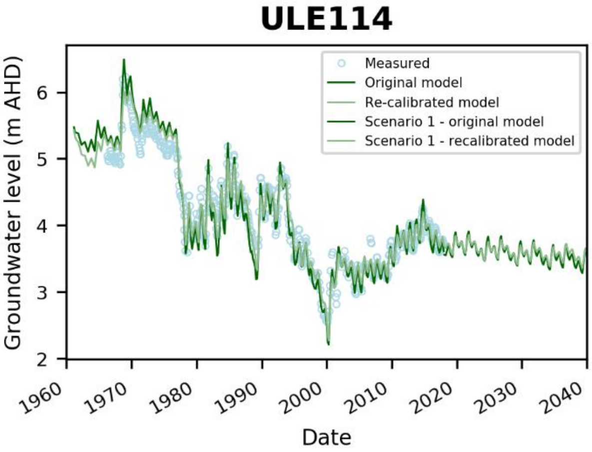

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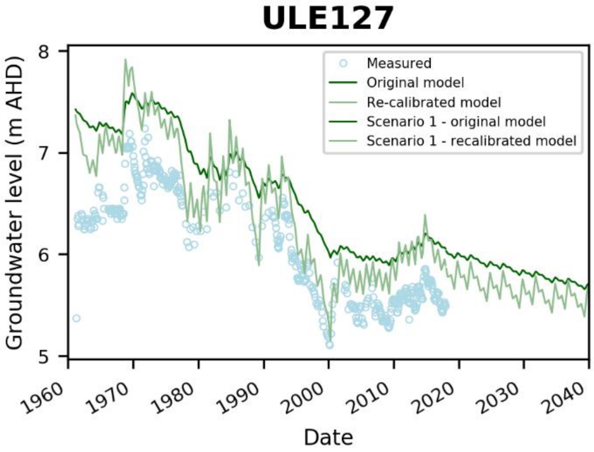

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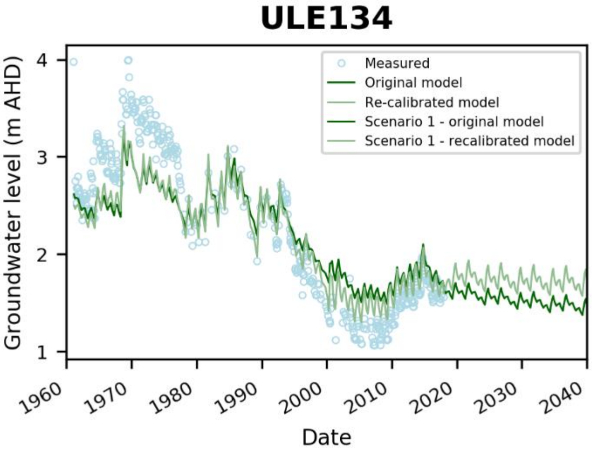

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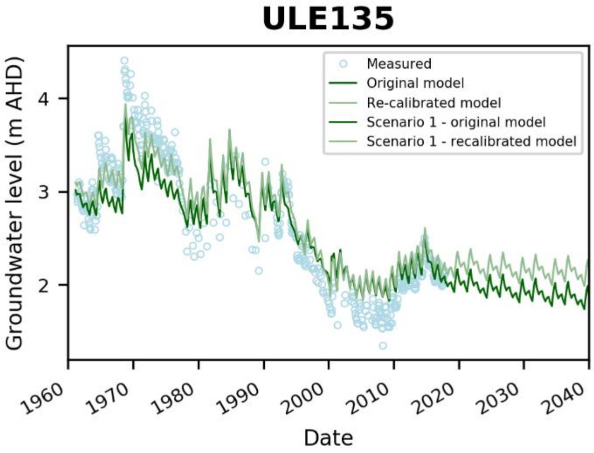

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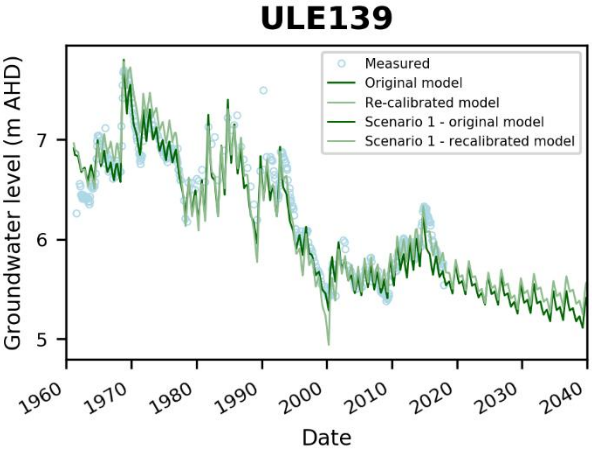

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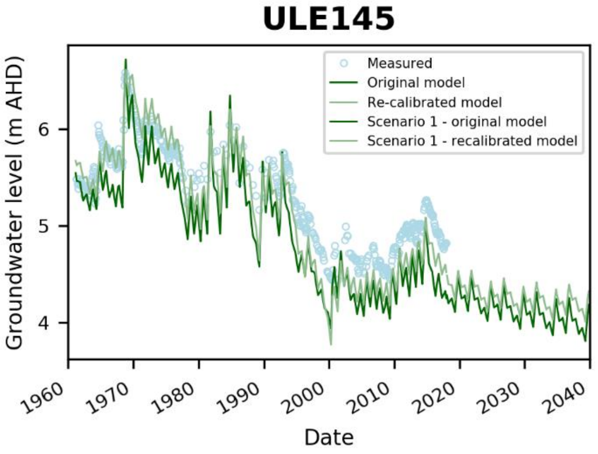
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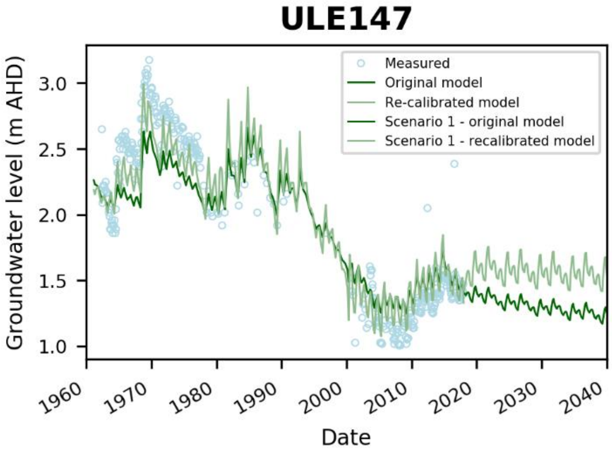
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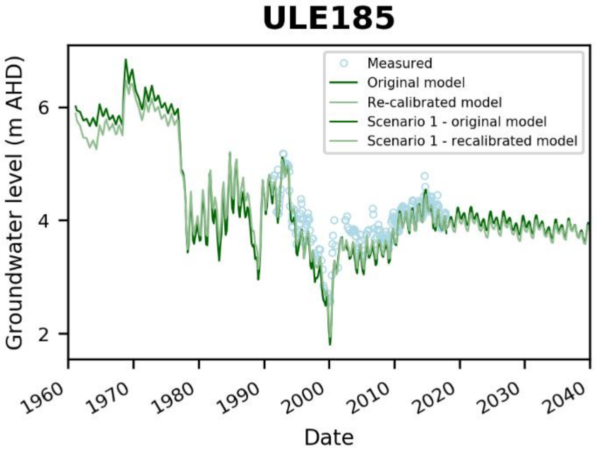
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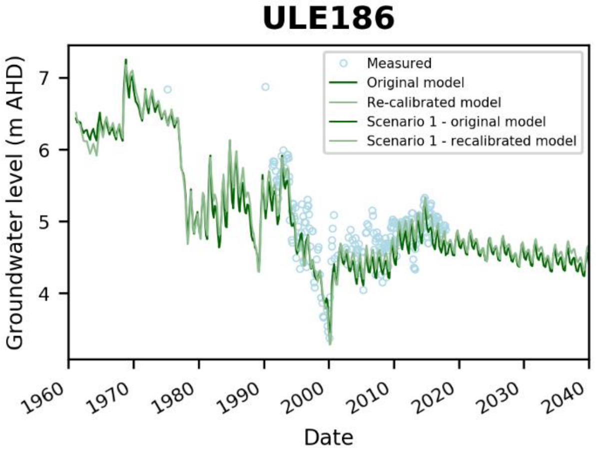
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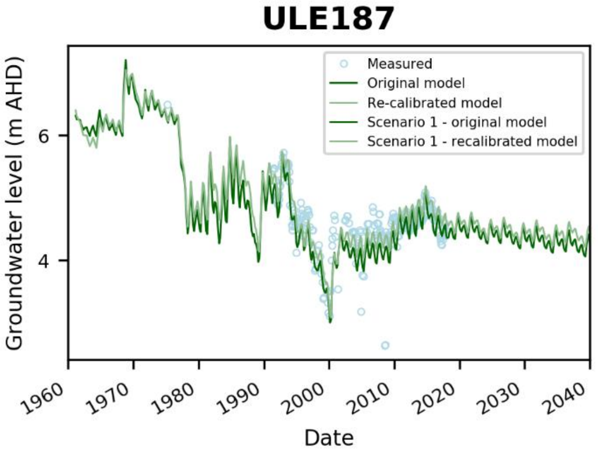
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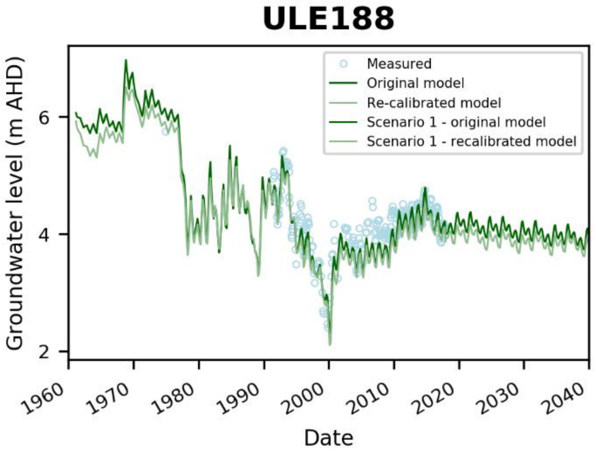
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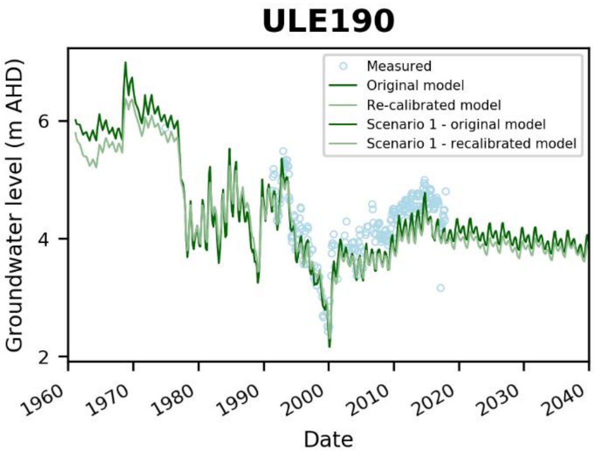
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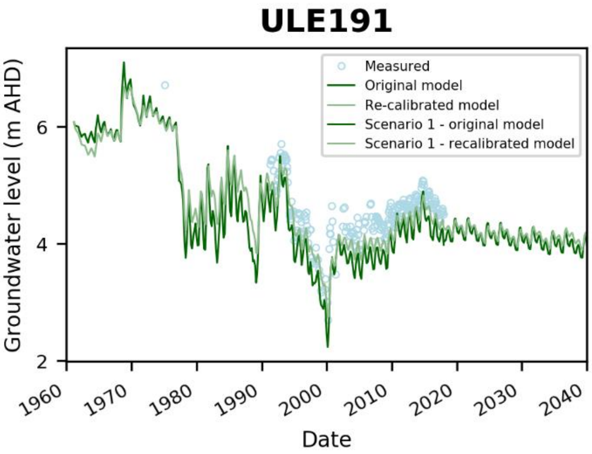
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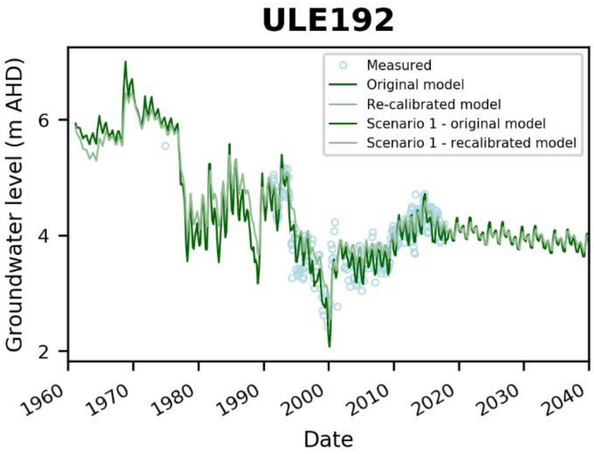
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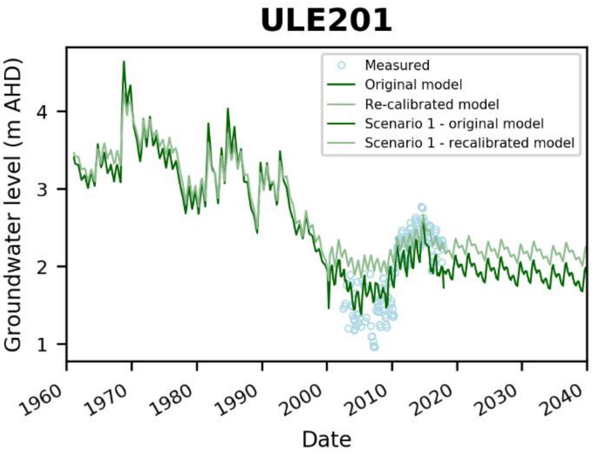
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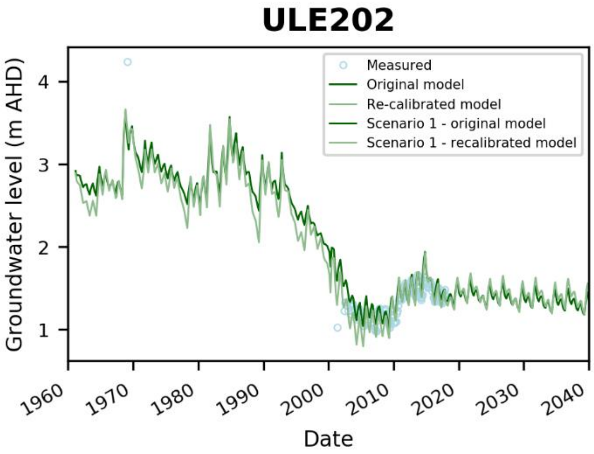
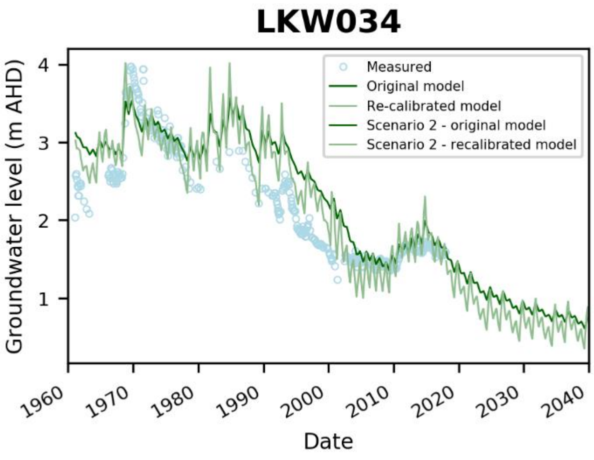
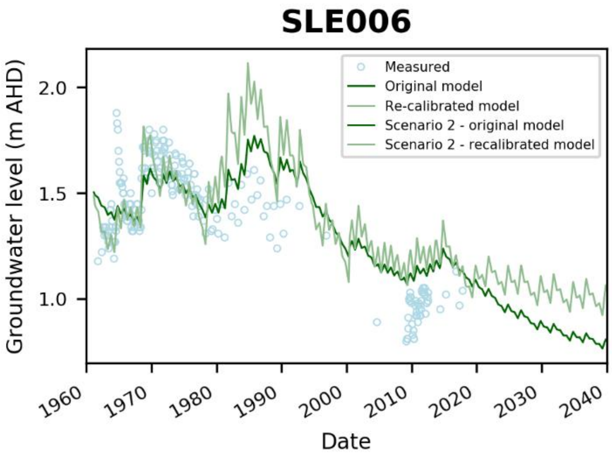
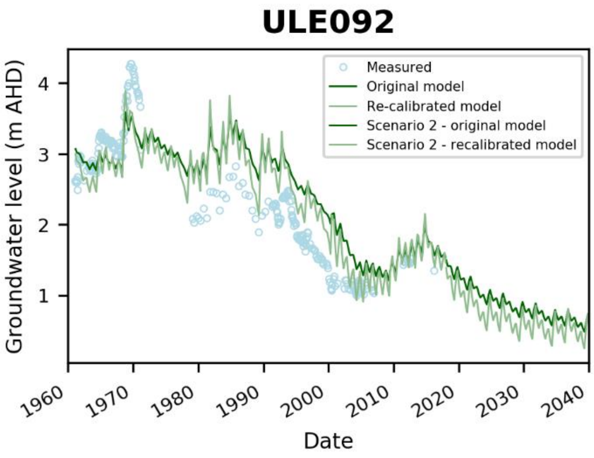
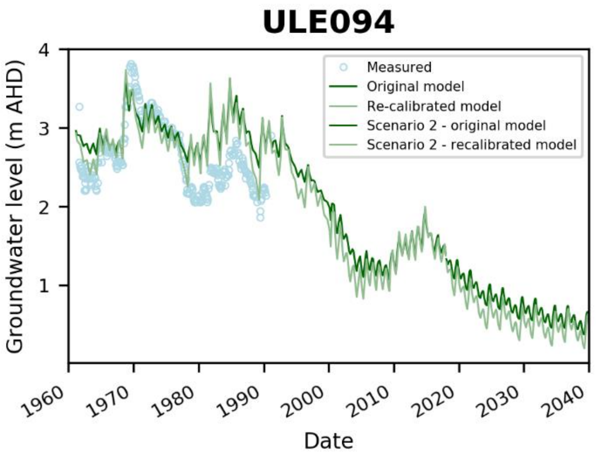

ULE202

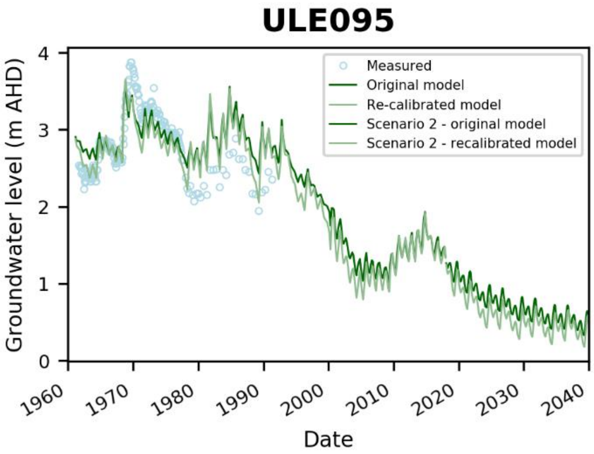
C. Scenario 2 groundwater level results

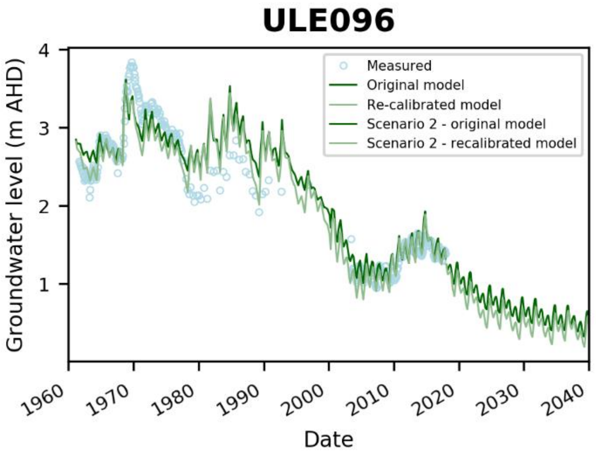


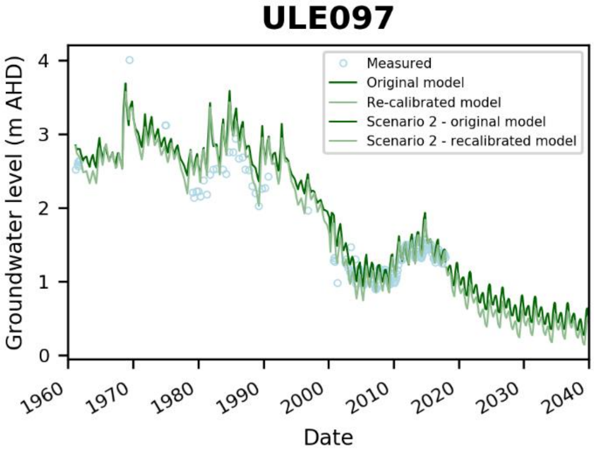












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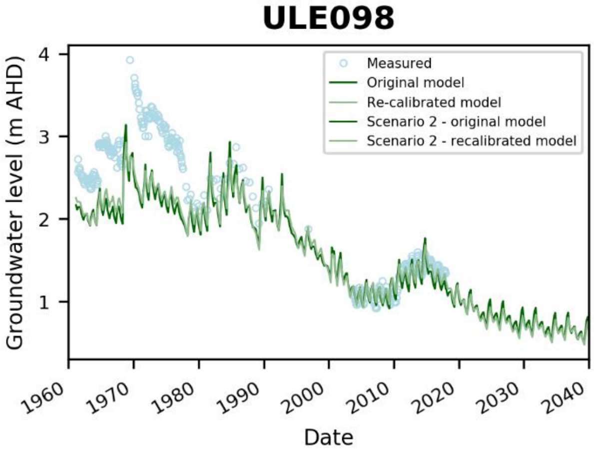

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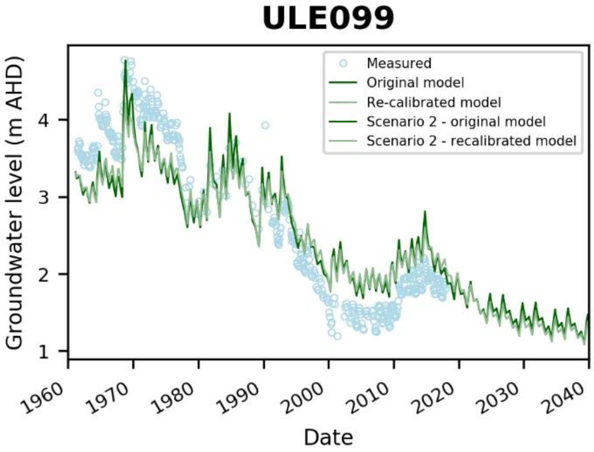

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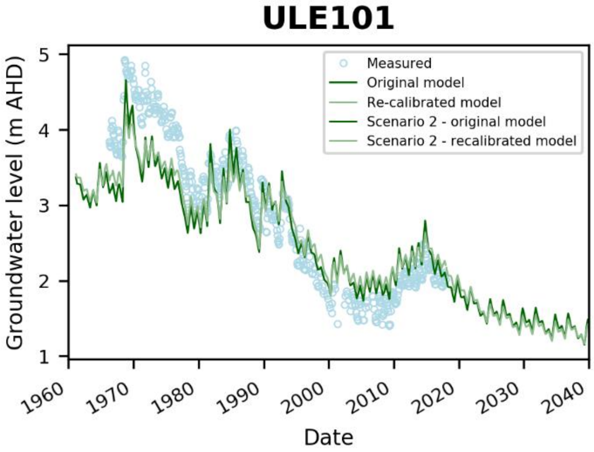

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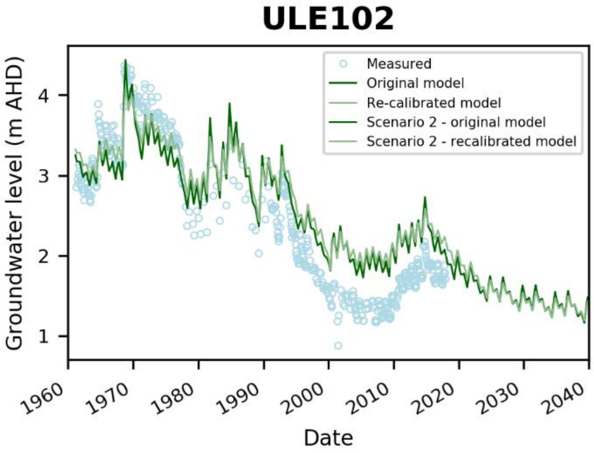

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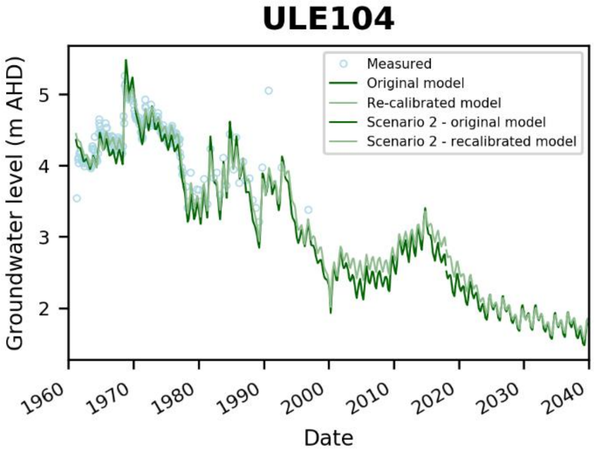

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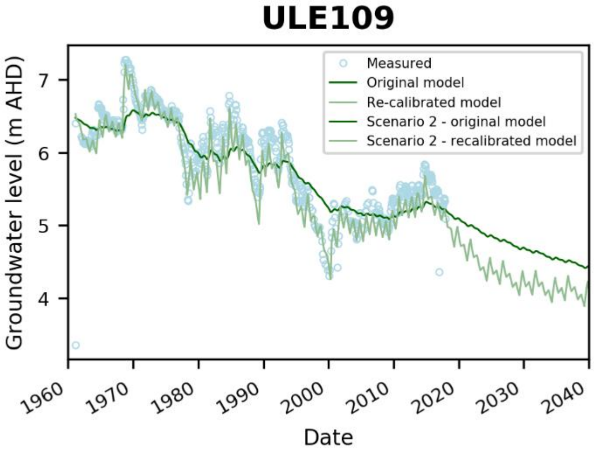
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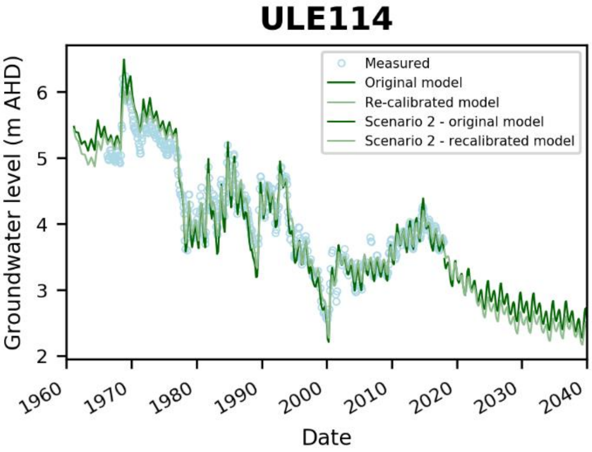
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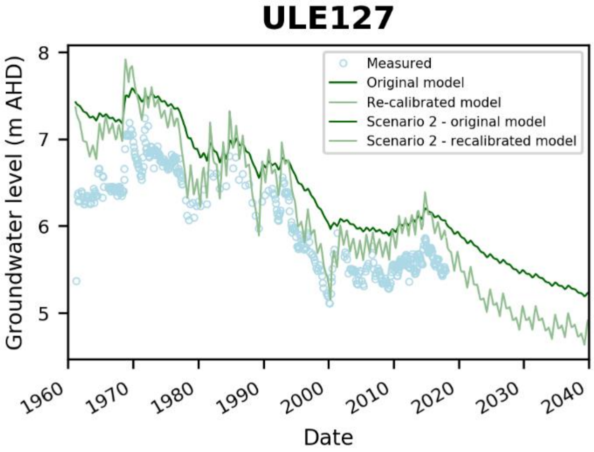
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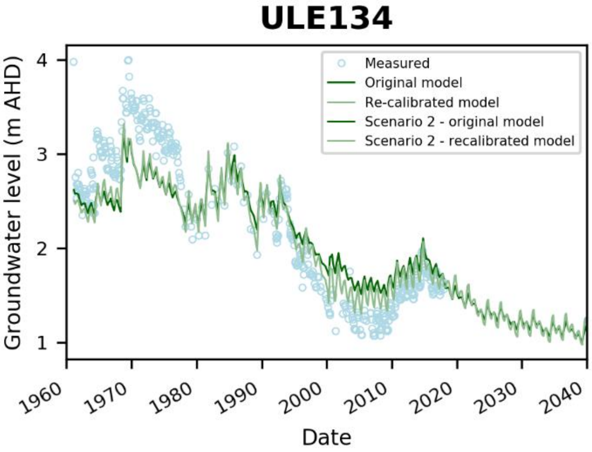
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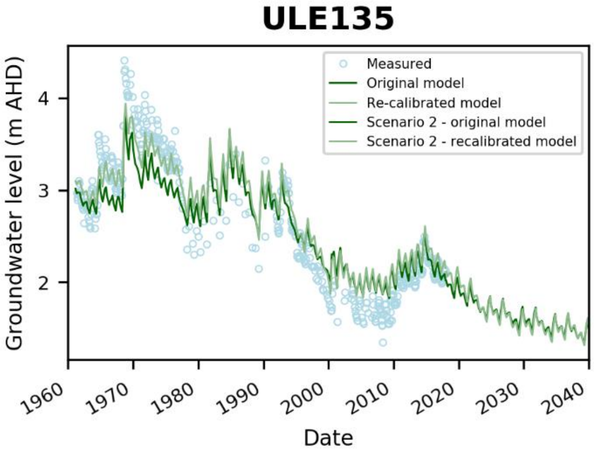
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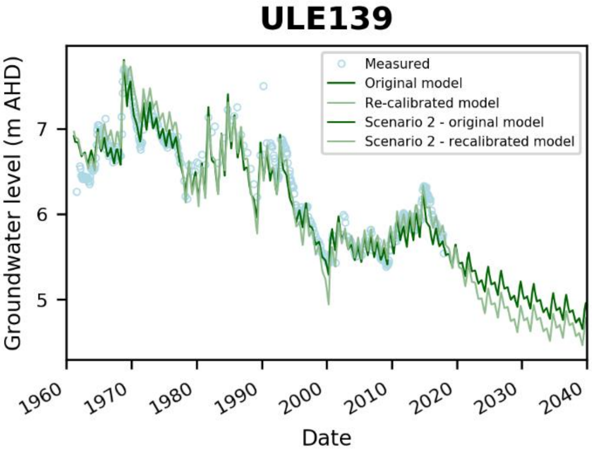
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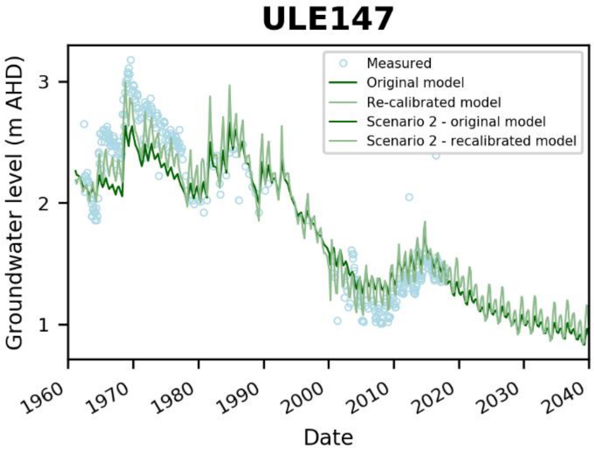
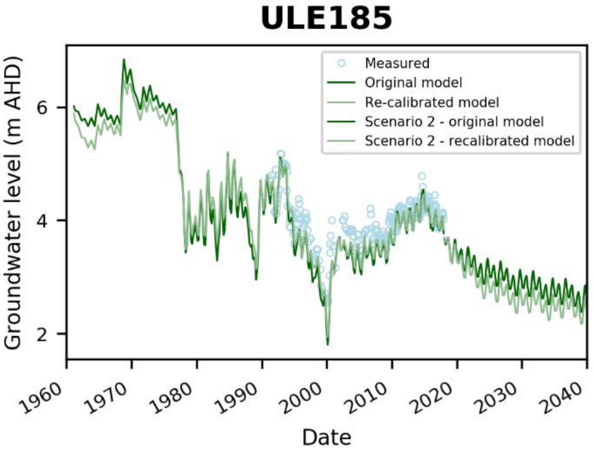
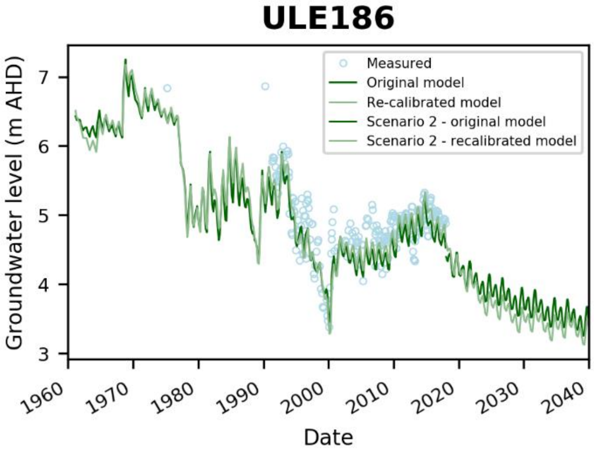
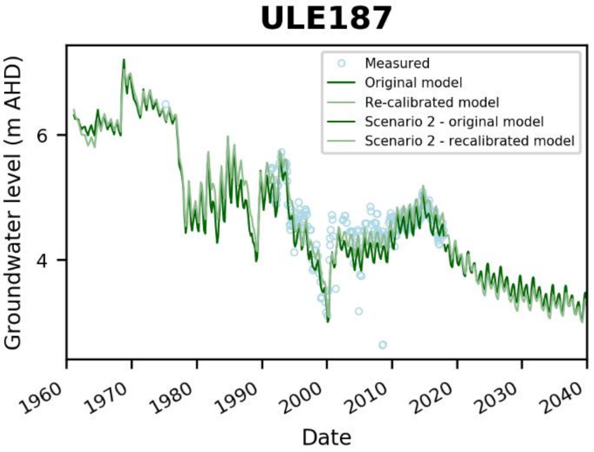
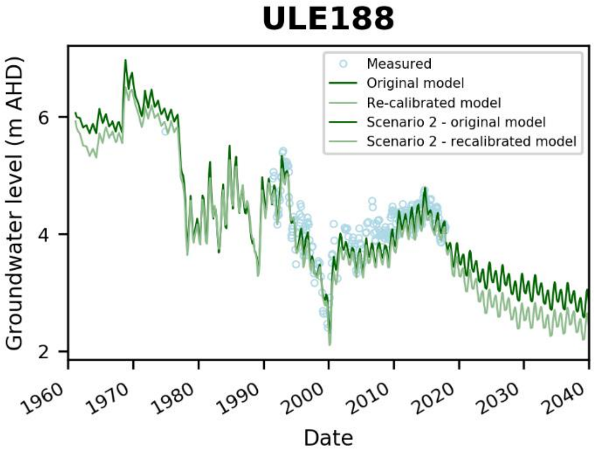
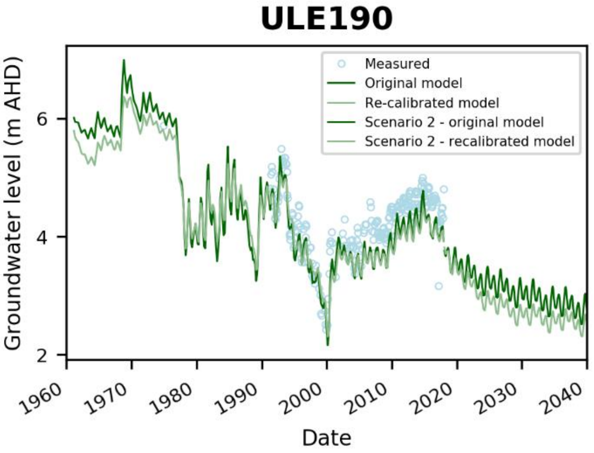

ULE147
Measured
Original model
Re-calibrated model
Scenario 2 - original model
Scenario 2 - recalibrated model
Groundwater level (m AHD)
1
2
3
1960
1970
1980
1990
2000
2010
2020
2030
2040
Date

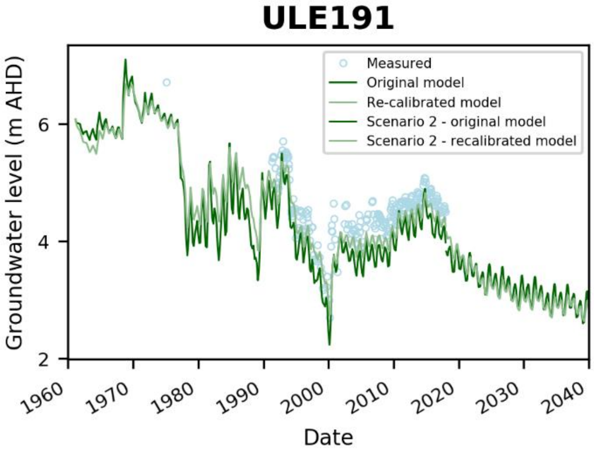

ULE185
Measured
Original model
Re-calibrated model
Scenario 2 - original model
Scenario 2 - recalibrated model
Groundwater level (m AHD)
2
4
6
1960
1970
1980
1990
2000
2010
2020
2030
2040
Date

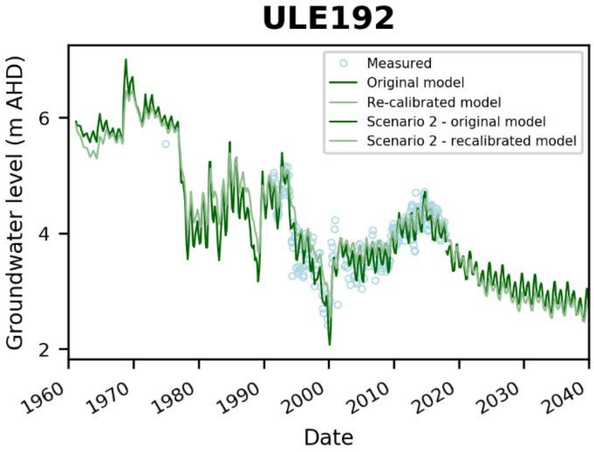

ULE186
Measured
Original model
Re-calibrated model
Scenario 2 - original model
Scenario 2 - recalibrated model
Groundwater level (m AHD)
3
4
5
6
7
1960
1970
1980
1990
2000
2010
2020
2030
2040
Date

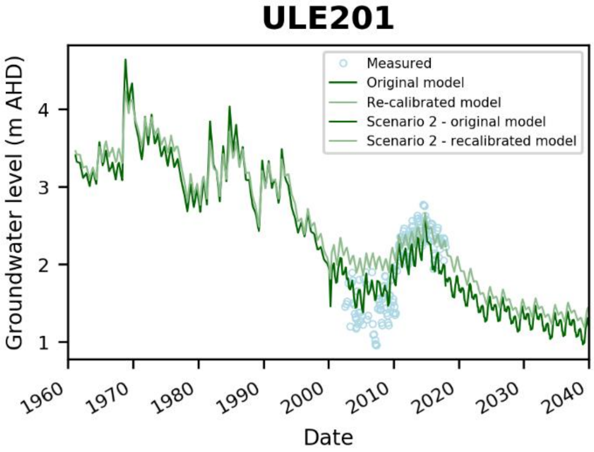

ULE187
Measured
Original model
Re-calibrated model
Scenario 2 - original model
Scenario 2 - recalibrated model
Groundwater level (m AHD)
4
6
1960
1970
1980
1990
2000
2010
2020
2030
2040
Date

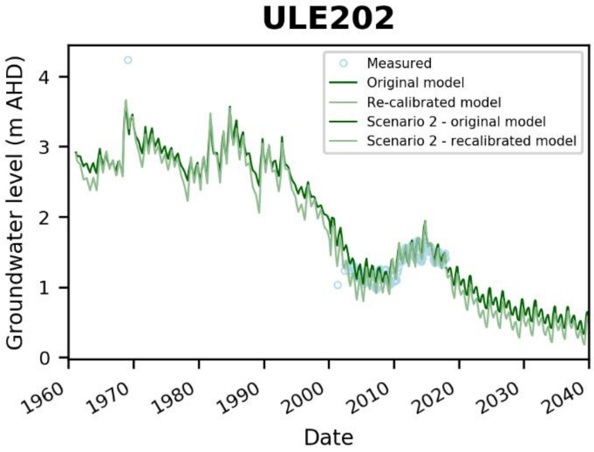

ULE188
Measured
Original model
Re-calibrated model
Scenario 2 - original model
Scenario 2 - recalibrated model
Groundwater level (m AHD)
2
4
6
1960
1970
1980
1990
2000
2010
2020
2030
2040
Date


ULE190
Measured
Original model
Re-calibrated model
Scenario 2 - original model
Scenario 2 - recalibrated model
Groundwater level (m AHD)
2
4
6
1960
1970
1980
1990
2000
2010
2020
2030
2040
Date


ULE191
Groundwater level (m AHD)
2
4
6
1960
1970
1980
1990
2000
2010
2020
2030
2040
Date
Measured
Original model
Re-calibrated model
Scenario 2 - original model
Scenario 2 - recalibrated model


ULE192
Groundwater level (m AHD)
2
4
6
1960
1970
1980
1990
2000
2010
2020
2030
2040
Date
Measured
Original model
Re-calibrated model
Scenario 2 - original model
Scenario 2 - recalibrated model


ULE201
Groundwater level (m AHD)
1
2
3
4
1960
1970
1980
1990
2000
2010
2020
2030
2040
Date
Measured
Original model
Re-calibrated model
Scenario 2 - original model
Scenario 2 - recalibrated model


ULE202
Groundwater level (m AHD)
0
1
2
3
4
1960
1970
1980
1990
2000
2010
2020
2030
2040
Date
Measured
Original model
Re-calibrated model
Scenario 2 - original model
Scenario 2 - recalibrated model

D. Existing model recommendations

The following list of recommendations are based on those given in DEW (2020), with minor revisions based on data and information that has become available since the recommendations were originally made, and the work carried out in this report.

Recommendations for data collection and conceptualisation:

1. Replacement of long-screened coastal wells (e.g. SLE069 and ULE205) with short-screened wells constructed with PVC: Salinity profiles with depth in long-screened wells may give an inaccurate measure of the seawater interface elevation (Shalev et al., 2009), and another method such as geophysical logging on PVC wells with short screens (Kamps et al., 2016), or installation and sampling of nested wells with short screens may be more appropriate. Following the review by Inverarity (2019), ambient flow profiling of these wells long-screened coastal wells is recommended to determine whether active inflow zones can be identified.
2. Re-interpretation of AEM data (Fitzpatrick et al., 2009): This may offer more insight into the position of the freshwater-seawater interface, which could be used to better constrain the SWI2 simulations. Supplementary data collection may be required close to the coast, where AEM data is missing (based around the location of the wind farm). This could also improve constraints on basement elevation, to give a better understanding of the TS thickness across the basin (particularly in coastal areas).
3. Elevation surveys where required: Accurate elevation surveys on all wells should be carried out, as discrepancies in water table elevation like those at sites ULE130 andULE175 (see Section 5.3) may be due to inaccurate survey elevation data.

Recommendations for modelling:

1. Assessing the impact of scenario uncertainty on model predictions: Further work is recommended to consider the impact of other rainfall scenarios on groundwater resources e.g. successive years of below average rainfall.

2. Improved understanding of the connection between the TS and QL aquifer: Current understanding and assumptions regarding TS flow into QL are conceptual, based on comparisons in ion chemistry in both aquifers, and changes in salinity that have been observed in the TWS wells over time. A better understanding of the connection between the two formations is needed. The development of a solute transport model (e.g. based on this flow model) may be one such way to test the conceptual model for interaction between the TS and QL aquifers.

3. Further work on climate change scenarios: Climate change scenarios modelled only consider changes in mean annual rainfall. However, Charles and Fu (2015a) show the seasonality of rainfall is likely to change in the Eyre Peninsula, with larger declines in spring rainfall compared with other seasons. Further work will be required to determine the impact of changing seasonal rainfall on recharge and groundwater processes in the Uley South Basin.

4. Incorporation of metered pumping data: Monthly pumping data from each SA Water town water supply well should be included in the model as it becomes available, and the model re-run with updated data to test model performance.

5. Assessing the impact of parameter uncertainty on SWI2 simulations: This has not been assessed, due to large file sizes and processing time required for SWI2 simulations. However, further work could be done with preferred model version 1c to derive parameter sets which represent the 5th, 50th and 95th percentiles of the modelled distributions (e.g. modelled distributions in Figure 7.10) and run SWI2 simulations on this subset of models.

6. Further work on parameter uncertainty: The approach taken to assessing parameter uncertainty in DEW (2020) was limited in scope compared with a full null space Monte Carlo analysis, in that models were not recalibrated due to time constraints (model non-linearity resulted in a large number of models with an objective function (phi) significantly higher than the calibrated model). Further work could be done to recalibrate all realisations, and possibly use a technique such as polynomial chaos expansion (which provides progressive estimates of the reduction in confidence limits) to assess the number of realisations that should be used for scenario analysis (Miller et al., 2018).

7. Further work on modelling TS to QL interlayer flow in the northern part of the basin: Conversion to MODFLOW-USG would help appropriately handle flow between layers, as MODFLOW-USG allows layers to ‘pinch-out’ and horizontal flow to occur between layers.

8. Further work on seawater intrusion modelling: Conversion of the MODFLOW/SWI2 model to a SEAWAT model or MODFLOW-USG, to better understand impact of dispersive mixing on coastal groundwater salinity. However, improved measurement and monitoring of the seawater interface may be required before modelling seawater-freshwater mixing in a more detailed way.

9. Assessing the potential impact of sea level rise on seawater intrusion: The scenarios do not include the potential impact of sea level rise, which should be assessed as it may impact the simulated extent of intrusion (i.e. current scenario results may underestimate seawater intrusion).

10. Sensitivity analysis of SWI2 results: Particular attention should be paid to the sensitivity of seawater intrusion scenarios to coastal hydraulic conductivity. Despite variation in recharge and pumping, the simulated position of the interface will also depend upon the hydraulic conductivity of cells close to the coast, for which there is limited data. Improved conceptualisation of hydraulic conductivity in the coastal region will improve confidence in simulations of the interface position. Geophysical techniques such as NMR may provide improved understanding of the spatial variability of aquifer properties in the coastal zone.

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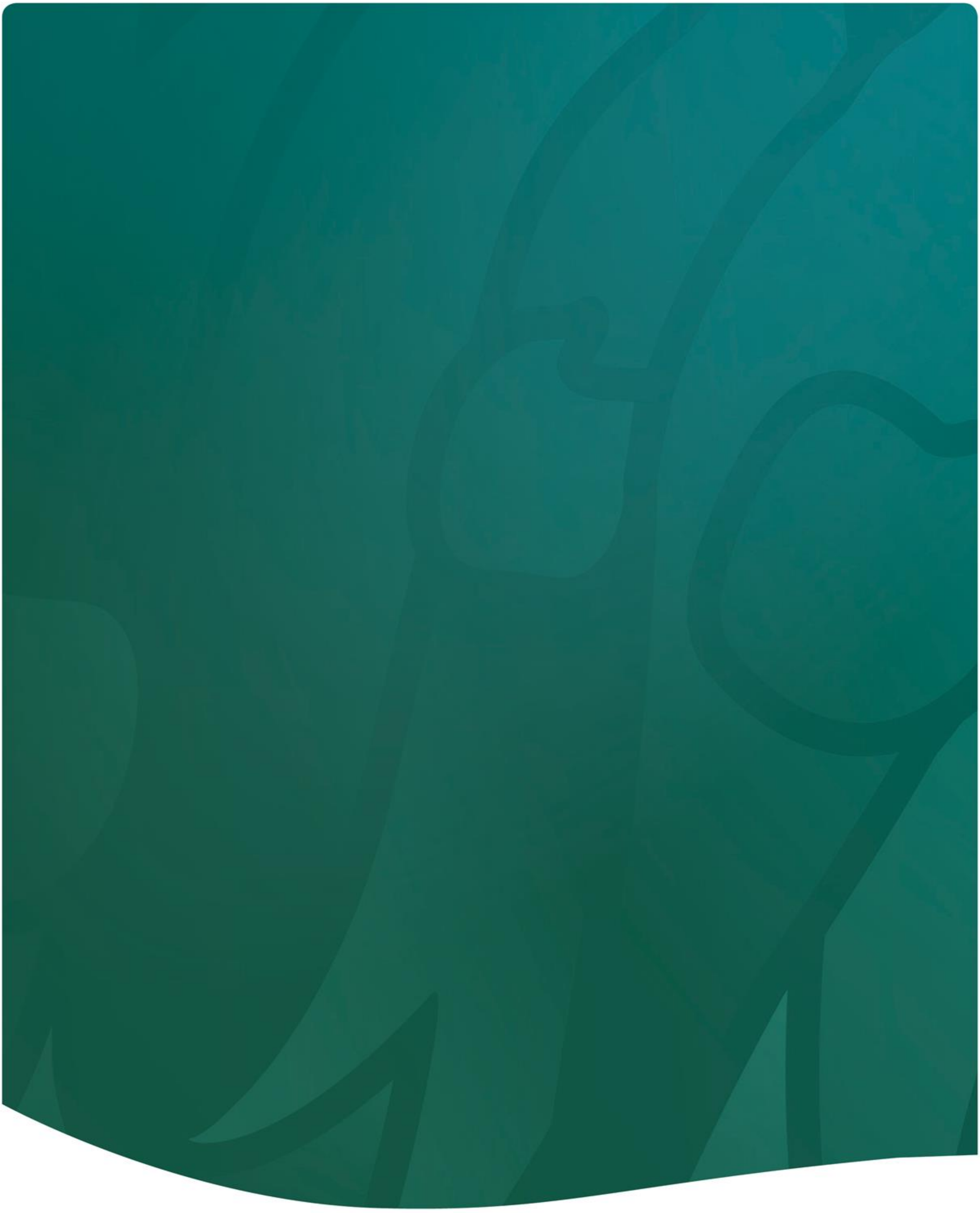

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